Final Report

of the

Kentucky Climate Action Plan Council

Submitted

to the

Secretary of the

Kentucky Energy and Environment Cabinet

November 2011

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Fellow Kentuckians,

On behalf of the Energy and Environment Cabinet, I present the final report of the Kentucky Climate Action Plan Council (KCAPC). This report is a culmination of two years of work performed by KCAPC members, staff and others who provided technical expertise. The Report presents the methods and the pros and cons of more than 70 policy options that are intended to reduce greenhouse gas emissions from all sources in the commonwealth while also encouraging energy efficiency, energy security, and economic growth. It provides the reader a greater understanding of Kentucky's opportunities and challenges to reduce these emissions.

A significant outcome of the KCAPC process was the discussion and debate among leaders from many sectors of Kentucky (the business community, environmental advocates, utilities, energy providers, government, and academia). When this process began, it seemed imminent that the U.S. Congress would impose limits on greenhouse gas emissions. While this topic is no longer at the forefront of the agenda for the U.S. Senate and House of Representatives, the need remains for Kentucky to be positioned to take action should such a requirement come about. We should also continue to develop technologies that will enable us to harness energy from cleaner sources and to reduce the emissions from fossil fuels so that we can continue using the state's affordable and abundant natural resources in an environmentally sensitive manner. This report reaffirms that energy efficiency is the most cost effective and easiest means of reducing emissions. It is also a useful resource that assembles information in one place for easy reference.

Further discussion and analysis of benefits and costs of each policy option would be needed to move forward, but this report provides a meaningful starting place. I commend those who have worked so diligently throughout the process. This is not a simple issue with simple solutions, but rather one that requires intelligent and honest discussion—the type of discussion, I expect, will continue in Kentucky.

Sincerely,
Secretary Leonard K. Peters,

Kentucky Energy and Environment Cabinet

Acknowledgments

The Kentucky Climate Action Plan Council (KCAPC) gratefully acknowledges the following individuals and organizations who contributed significantly to the successful completion of the KCAPC process and the publication of this report:

Great appreciation is due to our Chair, Kentucky Energy and Environment Cabinet Secretary Len Peters, for his leadership throughout the process. Additional thanks to the members of the Council, who provided valuable technical expertise and time during Council and Technical Work Group meetings. The KCAPC also recognizes the many individuals who participated in the sector-based Technical Work Groups, all of whom are listed in Appendix B. Although this report is intended to represent the results of the KCAPC's work, the KCAPC would be remiss if it did not recognize and express appreciation for the time and effort each Technical Work Group member spent in discussion, study, and deliberation during this process.

Many thanks to Dr. Talina Mathews, who during much of this process was the Assistant Director of the Carbon Management Division in Kentucky's Department for Energy Development and Independence and coordinated and supervised all activities associated with the KCAPC process, and to the Department staff who served as liaisons to the Technical Work Groups: Bob Amato, Millie Ellis, Greg Guess, Tim Hughes, John Lyons, and Frank Moore. Many thanks also to Donna Jones, Denise Profitt and Ashley Thomas who assisted in arranging meeting facilities, printing documents, and other meeting support logistics throughout the process.

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Members of the Kentucky Climate Action Plan Council

The Kentucky Climate Action Plan Council (KCAPC) comprises representatives from public interest groups, environmental organizations, utilities, the manufacturing sector and other key industries, universities, and state, local, and tribal governments. Members were invited to participate by Secretary Leonard Peters.

Leonard Peters, KCAPC Chair, Secretary, Kentucky Energy and Environment Cabinet
Rep. Rocky Adkins, Kentucky House of Representatives*
Rodney Andrews, Center for Applied Energy Research, University of Kentucky
David Armstrong, Chairman, Kentucky Public Service Commission
Joseph Blackburn, Office of Surface Mining
David Brown Kinloch, Lock 7 Hydro Partners
Joseph Craft, Alliance Resource Partners
William Daugherty, formerly of NGAS Resources, Inc.
Don Halcolmb, Farmer
Mike Hancock, Secretary, Kentucky Transportation Cabinet
Larry Hayes, Secretary, Cabinet for Economic Development
Sen. Tom Jensen, Kentucky State Senate*
Kelley Kline, General Electric
John Lamanna, Republic Services, Inc.
Justin Maxson, Mountain Area Community Economic Development
Jim Newberry, former Mayor, Lexington, Kentucky
Matt Powell, Century Aluminum of Kentucky
Sen. Dorsey Ridley, Kentucky State Senate*
José Sepulveda, Kentucky Division, Federal Highway Administration
Steve St. Angelo, Toyota Motor Manufacturing of Kentucky
Victor Staffieri, LG&E and KU Energy and formerly, E.ON U.S.
Mark Stallons, Owen Electric Cooperative
Sister Amelia Stenger, GREENing Western Kentucky Project
Richard Sturgill, Pine Mountain Hardwood Lumber Company
Martha Tarrant, RossTarrant Architects, Inc.
Roger Thomas, Kentucky Governor's Office of Agricultural Policy
Mickey Wilhelm, University of Louisville

* Originally named to the KCAPC but was unable to participate or vote due to scheduling conflicts with legislative duties.

Acronyms and Abbreviations

\$/kWh	dollars per kilowatt-hour
\$/MM	millions of dollars
\$/MWh	dollars per megawatt-hour
\$/t	dollars per metric ton
\$/tCO_2e	dollars per metric ton of carbon dioxide equivalent
A&E	architecture and engineering
AAA	American Automobile Association
ac	acre
ACEEE	American Council for an Energy-Efficient Economy
ADD	area development district
AEO	*Annual Energy Outlook*
AFW	Agriculture, Forestry, and Waste [Technical Work Group]
AMI	Automated Meter Infrastructure
ANL	Argonne National Laboratory [US DOE]
ANSI	American National Standards Institute
APTA	American Public Transportation Association
APU	auxiliary power unit
ARRA	American Recovery and Reinvestment Act of 2009
ARRI	Appalachian Regional Reforestation Initiative
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ATA	American Trucking Association
B-2	fuel blend of 2% biodiesel and 98% diesel.
B-10	fuel blend of 10% biodiesel and 98% diesel.
BAU	business as usual
bbl	barrel
BBtu	billion British thermal units
BCAP	Building Codes Assistance Project
bcf	billion cubic feet
BEA	Bureau of Economic Analysis [US Department of Commerce]
BRT	bus rapid transit
Btu	British thermal unit
C&D	construction and demolition
CAER	[University of Kentucky] Center for Applied Energy Research
CAFE	corporate average fuel economy
CAP	Climate Action Plan
CBD	central business district
CBMR	coal bed methane recovery
CCI	Cross-Cutting Issues [Technical Work Group]
CCS	carbon capture and storage
CCSR	carbon capture and storage or reuse

CCX	Chicago Climate Exchange
CED	[Kentucky] Cabinet for Economic Development
cf	cubic feet
CFB	circulating fluidized bed
CH_4	methane
CHFS	[Kentucky] Cabinet for Health and Family Services
CHP	combined heat and power
CMAC	Congestion Mitigation Air Quality
CMRG	Carbon Management Research Group
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CPI	Consumer Price Index
CRF	capital recovery factor
CRERES	Center for Renewable Energy. Research and Environmental Stewardship
CRP	Conservation Reserve Program [USDA]
CRS	Congressional Research Service
CSA	community-supported agriculture
CT	conventional tillage
CTG	coal to gas
CTL	coal to liquid
CVISN	Commercial Vehicle Information Systems and Networks
CY	calendar year
DEDI	[Kentucky] Department for Energy Development and Independence
DEP	[Kentucky] Department of Environmental Protection
DG	distributed generation
DHBC	[Kentucky] Department of Housing, Buildings, and Construction
DHS	[United States] Department of Homeland Security
DNR	[Kentucky] Department for Natural Resources
DOE	[United States] Department of Energy
DOT	[United States] Department of Transportation
DSM	demand-side management
DWM	[Kentucky] Division of Waste Management
E-10	fuel blend of 10% ethanol and 90% gasoline
E-85	fuel blend of 85% ethanol and 15% gasoline
EBT	Electronic Benefit Transfer
ECAP	Energy Code Ambassadors Program
EERS	energy efficiency resource standard
EIA	Energy Information Administration [US DOE]
EISA	Energy Independence and Security Act of 2007
EKPC	East Kentucky Power Cooperative
EO	Executive Order
EOR	enhanced oil recovery
EPA	[United States] Environmental Protection Agency
EPRI	Electric Power Research Institute

EPS	environmental portfolio standard
EQIP	Environmental Quality Incentives Program
ES	Energy Supply [Technical Work Group]
ESP	electrostatic precipitator
ESP	energy service provider
eTRU	electric truck refrigeration unit
FAC	[Kentucky] Finance and Administration Cabinet
FEED	front-end engineering design
FERC	Federal Energy Regulatory Commission
FGD	flue gas desulfurization
FHWA	Federal Highway Administration
FIA	Forest Inventory and Analysis [USFS]
FIT	feed-in tariff
FPC	Food Policy Council
FRA	Forestry Reclamation Approach
ft	foot
FTA	Federal Transit Administration
FWS	[United States] Fish and Wildlife Service
FY	fiscal year
gal	gallon
GHG	greenhouse gas
GJ	gigajoule
GREET	Greenhouse gases, Regulated Emissions and Energy use in Transportation [model]
GSP	gross state product
GTL	gas to liquid
GWh	gigawatt-hour [one million kilowatt-hours]
HB	House Bill
HDPE	high-density polyethylene
HDV	heavy-duty vehicle
HFC	hydrofluorocarbon
HOV	high-occupancy vehicle
HVAC	heating, ventilation, and air conditioning
I&F	Inventory and Forecast
ICC	International Code Council
ICLEI	Local Governments for Sustainability [formerly International Council for Local Environmental Initiatives]
ID	induced draft
IECC	International Energy Conservation Code
IEIA	[Kentucky] Incentives for Energy Independence Act
IESNA	Illuminating Engineering Society of North America
IGCC	integrated gasification combined cycle
IOU	investor-owned utility

IPCC	Intergovernmental Panel on Climate Change
IPP	independent power producer
IREC	Interstate Renewable Energy Council
IRP	integrated resource planning
ITS	intelligent transport system
KAPA	Kentucky Chapter of the American Planning Association
KBA	Kentucky Broadcasters Association
KCAPC	Kentucky Climate Action Plan Council
KDA	Kentucky Department of Agriculture
KDE	Kentucky Department of Education
KEEC	Kentucky Environmental Education Council
kg	kilogram
KGS	Kentucky Geological Survey
KPPC	Kentucky Pollution Prevention Center
KPTA	Kentucky Public Transit Association
KRIG	Kentucky Recycling Interest Group
KRMA	Kentucky Recycling and Marketing Assistance
KRS	Kentucky Revised Statutes
KSP	Kentucky State Police
kV	kilovolt
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
kW-yr	kilowatt-year
KYTC	Kentucky Transportation Cabinet
LandGEM	Landfill Gas Emissions Model [US EPA]
lb	pound
LCI	League Cycling Instructor
LDPE	low-density polyethylene
LDV	light-duty vehicle
LEC	levelized energy cost
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design [Green Building Rating System™]
LFG	landfill gas
LFGcost	landfill gas cost model
LFGTE	landfill gas-to-energy
LMOP	Landfill Methane Outreach Program [US EPA]
LNG	liquefied natural gas
LRC	[Kentucky] Legislative Research Commission
MACED	Mountain Association for Community Economic Development
MCY	million cubic yards
metric ton	1,000 kilograms or 22,051 pounds
MJ	megajoule
MM	million

MMBtu	millions of British thermal units
MMt	million metric tons
$MMtCO_2e$	million metric tons of carbon dioxide equivalent
mpg	miles per gallon
MPO	metropolitan planning organization
MRF	materials recycling facility
MSW	municipal solid waste
MW	megawatt [one thousand kilowatts]
MWh	megawatt-hour [one thousand kilowatt-hours]
N	nitrogen
N_2O	nitrous oxide
N/A	not applicable
NAS	National Academy of Sciences
NAS/NRC	National Academy of Sciences/National Research Council
NASS	National Agricultural Statistics Service [USDA]
NEBRA	North East Biosolids and Residuals Association
NEED	[Kentucky] National Energy Education Development Project
NETL	National Energy Technology Laboratory [US DOE]
NGCC	natural gas combined cycle
NGCT	natural gas combustion turbine
NGO	nongovernmental organization
NOAA	National Oceanic and Atmospheric Administration
NO_x	oxides of nitrogen
NPV	net present value
NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service [USDA]
NREL	National Renewable Energy Laboratory [US DOE]
NRI	National Resources Inventory [USDA]
NSR	New Source Review
NT	no till
O&M	operation and maintenance
ODS	ozone-depleting substance
OSM	Office of Surface Mining [U.S. Department of the Interior]
PACE	Property Assessment for Clean Energy
PBF	Public Benefit Fund
PET	polyethylene terephthalate
PFC	perfluororocarbon
PHEV	plug-in hybrid electric vehicle
PLTW	Project Lead The Way
PMLU	post-mining land use
PMT	person miles traveled

POD	policy option document
PRIDE	Personal Responsibility in a Desirable Environment
PSC	Public Service Commission
PV	photovoltaic
R&D	research and development
RCI	Residential, Commercial, and Industrial [Technical Work Group]
RD&D	research, development, and demonstration
REC	renewable energy certificate
RFS	renewable fuel standard
RFS2	federal renewable fuel standard 2
RPS	renewable portfolio standard
RRC	Regional Resource Center
SBC	systems benefit charge
SCADA	supervisory control and data acquisition
SF_6	sulfur hexafluoride
SO_2	sulfur dioxide
SO_x	oxides of sulfur
SOV	single-occupant vehicle
sq ft	square foot/feet
STB	Surface Transportation Board
STIP	Statewide Transportation Improvement Program
t	metric ton
T&D	transmission and distribution
TARGGET	Transit Associated Reduced Greenhouse Gas Emissions Tool
tC	metric tons of carbon
tCO_2	metric tons of carbon dioxide
tCO_2e	metric tons of carbon dioxide equivalent
tCO_2e/MWh	metric tons of carbon dioxide equivalent per megawatt-hour
TDM	transportation demand management
TIP	transportation improvement program
TLU	Transportation and Land Use [Technical Work Group]
TOD	transit-oriented development
TSM	transportation system management
TVA	Tennessee Valley Authority
TWG	Technical Work Group
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFS	United States Forest Service [USDA]
USGBC	United States Green Building Council
VHT	vehicle hours of travel
VISION	Voluntary Innovative Sector Initiatives [US DOE]

VMT	vehicle miles of travel
VOC	volatile organic compound
WARM	WAste Reduction Model [US EPA]
WIP	waste in place
WTE	waste to energy
yr	year

Executive Summary

Background

In November 2008, Governor Steven Beshear issued a report entitled *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*.[1] One of the provisions of the 7-Point Energy Strategy is to mitigate carbon dioxide (CO_2) emissions and to reduce Kentucky's carbon footprint. Development of the Climate Action Plan for Kentucky is aimed at furthering this objective to reduce Kentucky's carbon footprint. The Climate Action Plan has been built upon selected provisions of the Kentucky Energy Strategy. It also focuses attention on creating opportunities to build on Kentucky's progress to date to become more energy efficient, to reduce dependence on foreign oil, to enhance the nation's energy security, to promote new energy-related technologies, and to enhance economic opportunities in Kentucky.

The Kentucky Climate Action Plan process was convened in January 2010 by Dr. Len Peters, Secretary of the Kentucky Energy and Environment Cabinet (KEEC). Secretary Peters established the Kentucky Climate Action Plan Council (KCAPC) to assist in developing the Kentucky Climate Action Plan. The Council consists of a broad coalition of 27 members, including stakeholders from the business, academic, government, nonprofit, and environmental sectors, as well as individual citizens. Members of the Council are listed on page iii of this report.

The KCAPC was charged with producing a greenhouse gas (GHG) emissions inventory and forecast (I&F), compiling a comprehensive Climate Action Plan with recommended GHG reduction goals and potential actions to mitigate climate change and improve energy efficiency in various sectors of the economy, and advising state and local governments on measures to address climate change.

The KCAPC held six in-person meetings and one teleconference meeting leading to this draft Final Report submitted to KEEC and the Kentucky Department for Energy Development and Independence (DEDI).

To provide a broad range of technical expertise and stakeholder involvement in development of the Climate Action Plan, the Secretary and the KCPAC also formed five Technical Work Groups (TWGs) to assist in the process. The five TWGs considered information and potential options in the following sectors:

- Energy Supply (ES);
- Residential, Commercial, and Industrial (RCI);
- Transportation and Land Use (TLU);
- Agriculture, Forestry, and Waste (AFW); and
- Cross-Cutting Issues (CCI) (i.e., issues that cut across the above sectors).

[1] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008.

The Commonwealth of Kentucky hired the Center for Climate Strategies (CCS) to provide technical and facilitation support to KEEC and the KCAPC in formulating the Kentucky Climate Action Plan. CCS has extensive experience assisting states in formulating state climate action plans, preparing GHG I&Fs, and conducting numerous related technical and economic studies associated with climate change. CCS provided facilitation and technical assistance to the KCAPC and to each of the TWGs. The TWGs served as advisors to the KCAPC and consisted of KCAPC members and additional individuals with expertise in their respective sectors. Members of the public were invited to observe and provide input at all meetings of the KCAPC and TWGs. The TWGs assisted the KCAPC by generating initial Kentucky-specific policy options to be added to a catalog of existing state actions; developing priority policy options for analysis; drafting proposals on the design characteristics and quantification of the proposed policy options; reviewing specifications for analysis of draft policy options (including best available data sources, methods, and assumptions); and evaluating the other key elements of policy option proposals, including related policies and programs, key uncertainties, co-benefits and costs, feasibility issues, and potential barriers to consensus.

Key Elements and Recommendations

The KCAPC developed this Climate Action Plan, which includes, but is not limited to, the following key elements and recommendations:

- The KCAPC's proposed GHG reduction goals for Kentucky are to achieve a 20% reduction of GHGs below 1990 levels by 2030 (from about 136.7 to 109.4 million metric tons of carbon dioxide equivalent [$MMtCO_2e$]). The KCAPC also recommends that energy efficiency and energy intensity goals, targets, and metrics be developed for the major sectors of the Commonwealth's economy over the next several years. These goals were developed taking into account Governor Steven Beshear's report *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*.
- The KCAPC approved a package of 46 multi-sector policy recommendations to reduce GHG emissions and address related energy and commerce issues in Kentucky. Of the 46 policy recommendations, 33 were analyzed quantitatively to have the effect of reducing GHG emissions by about 63.7 $MMtCO_2e$ in 2020 and 128.3 $MMtCO_2e$ in 2030, and a cumulative GHG emissions reduction of 1,316 $MMtCO_2e$ over the 2011–2030 period.
- The KCAPC-approved policy recommendations are projected to have a net cost of about $11.6 billion during the period 2011–2030. The weighted-average cost-effectiveness of these policies is estimated to be approximately $8.80/$tCO_2e$.
- The KCAPC work included development of the first comprehensive, statewide GHG emissions I&F report for Kentucky for the period 1990–2030.

It is important to note that this set of recommended policies is presented to Secretary Peters for consideration. The data and costs presented in this report are based on the information and assumptions available at the time of analysis during 2010 and 2011. It is acknowledged that these recommendations may require updated data and further review and analysis prior to implementation. It is also acknowledged that many of these recommendations would require action by other entities, such as the Kentucky General Assembly and/or the Kentucky Public Service Commission.

Kentucky GHG Emissions Inventory and Reference Case Projections

CCS prepared the Kentucky I&F report for the KEEC. The report presents an assessment of Kentucky's GHG emissions and anthropogenic sinks (carbon storage) from 1990 to 2030. The final I&F report, which was approved by the KCAPC at its meeting on June 2, 2010, is summarized in Chapter 2 of this report and is available in its entirety at: http://www.kyclimatechange.us/ewebeditpro/items/O122F23537.pdf. It is important to note that the analysis was done during 2009–2010, and recent announcements by utilities and more recent actions by the U.S. Environmental Protection Agency are not included in the 2010 I&F report.

The inventory and reference case projections cover the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric—CO_2 equivalence (CO_2e)—that indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential (GWP)-weighted basis.[2]

The inventory and reference case projections revealed substantial emission growth rates and related mitigation challenges. Figure ExS-1 shows the reference case projections for Kentucky's gross GHG emissions as rising fairly steeply to 247.7 $MMtCO_2e$ by 2030, growing by 81% over 1990 levels. The figure also provides the breakdown of projected GHG emissions by sector.

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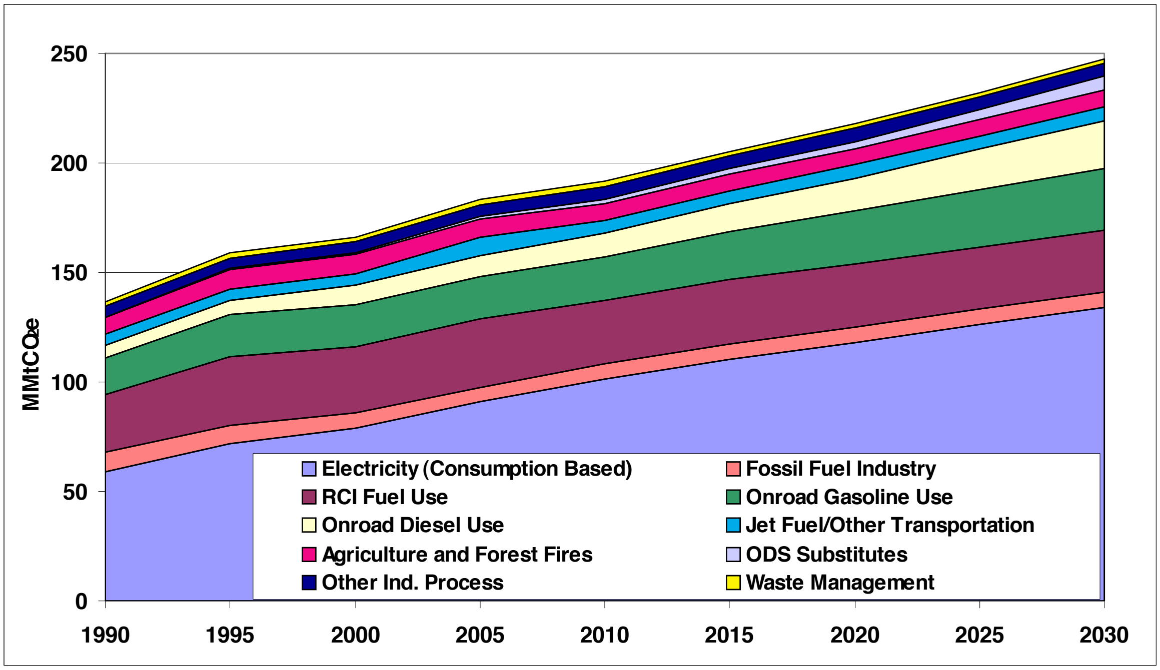
[2] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system. Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth)., See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom: Cambridge University Press. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.

Figure ExS-1. Gross GHG Emissions by Sector, 1990–2030: Historical and Projected (Consumption-Based Approach) Business-as-Usual/Base Case



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; RCI = direct fuel use in residential, commercial, and industrial sectors; ODS = ozone-depleting substance; Ind. = industrial.

The inventory and reference case projections of Kentucky's GHG emissions provided the following critical findings:

- The principal sources of Kentucky's GHG emissions are electricity consumption, transportation, and RCI fuel use, accounting for 50%, 20%, and 17% of Kentucky's gross GHG emissions in 2005, respectively.
- Estimates of carbon sinks within Kentucky's forests and soils, including urban forests, land-use changes, and agricultural soil cultivation practices, are included in this report. The current estimates indicate that about 7.6 $MMtCO_2e$ of emissions were stored in Kentucky biomass in 2005. This leads to net emissions of about 176 $MMtCO_2e$ in Kentucky in 2005, an amount equal to 2.8% of total U.S. net GHG emissions.
- The use of coal has led to low electricity rates in Kentucky compared to the rest of the country, which has allowed energy-intensive industries that provide valuable goods and services beyond the borders of Kentucky to flourish in the state, as acknowledged in Kentucky's Energy Plan.[3]

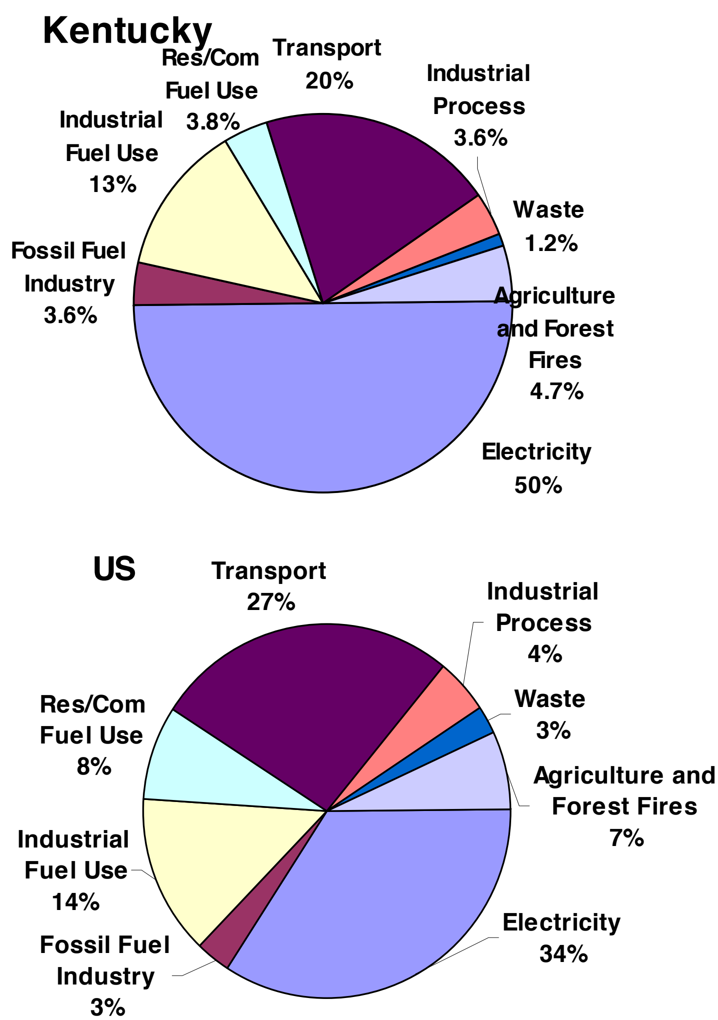
While Kentucky's estimated emissions growth rate presents challenges, it also provides major opportunities. Key choices regarding technologies and infrastructure can have a significant impact on emissions growth in Kentucky. The KCAPC's recommendations document the

[3] Governor Steven L. Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence,* November 2008.

opportunities for the state to reduce its GHG emissions, while continuing its strong economic growth by being more energy efficient, using more renewable energy sources, and increasing the use of cleaner transportation modes, technologies, and fuels.

Figure ExS-2 depicts a comparison between the sectoral components of GHG emissions in 2005 in Kentucky compared to the United States at large. Electricity supply and transportation are projected to have the highest growth.

Figure ExS-2. Gross GHG Emissions by Sector, 2005: Kentucky and U.S.



Notes: Res/Com = residential and commercial fuel use sectors; emissions for the residential, commercial, and industrial fuel use sectors are associated with the direct use of fuels (natural gas, petroleum, coal, and wood) to provide space heating, water heating, process heating, cooking, and other energy end-uses. The commercial sector accounts for emissions associated with the direct use of fuels by, for example, hospitals, schools, government buildings (local, county, and state), and other commercial establishments. The industrial processes sector accounts for emissions associated with manufacturing and excludes emissions included in the industrial fuel use sector. The transportation sector accounts for emissions associated with fuel consumption by all on-road and non-highway vehicles. Non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, railway locomotives, boats, and ships. Emissions from non-highway agricultural and construction equipment are included in the industrial sector. Electricity = electricity generation sector emissions on a consumption basis (including emissions associated with electricity imported from outside of Kentucky and excluding emissions associated with electricity exported from Kentucky to other states and regions).

Recent Actions

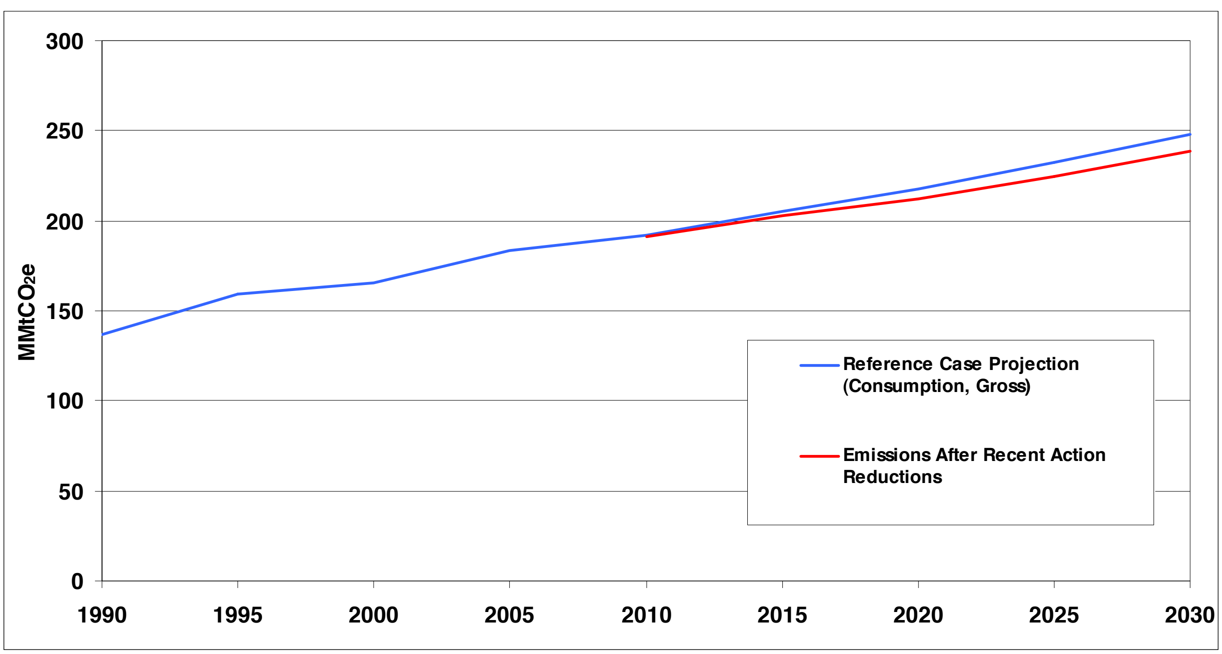
GHG Reductions Associated with Recent Federal and State Actions

The KCAPC identified recent federal and state actions undertaken in Kentucky that will reduce GHG emissions while conserving energy and promoting the development and use of renewable energy sources. The resultant emission reductions are presented below. The total GHG reductions from recent federal and state actions is projected to be about 9.4 MMtCO$_2$e in 2030, or a 3.8 % reduction from the business-as-usual (BAU) emissions in 2030 for all sectors combined. These GHG emission reductions are summarized in Figure ExS-3.

Recent Federal Actions

The federal Energy Independence and Security Act of 2007 was signed into law in December 2007. This law contains several requirements that will reduce GHG emissions as they are implemented over the next few years. During the KCAPC process, sufficient information was identified (e.g., implementation schedules) to estimate GHG emission reductions associated with implementing the federal Corporate Average Fuel Economy requirements, utility energy efficiency programs, and high-efficiency public buildings in Kentucky. The GHG emission reductions projected to be achieved by these actions are shown in Figure ExS-3. Together, these federal requirements are estimated to reduce gross GHG emissions for all sectors combined in Kentucky by about 4.02 MMtCO$_2$e (a 1.8% reduction) from the BAU emissions in 2020, and by about 6.23 MMtCO$_2$e (a 2.5% reduction) from the BAU emissions in 2030.

Figure ExS-3. Estimated Emission Reductions Associated with the Effect of Recent Federal and State Actions in Kentucky (Consumption-Basis, Gross Emissions)



MMtCO$_2$e = million metric tons of carbon dioxide equivalent.

Recent State Actions

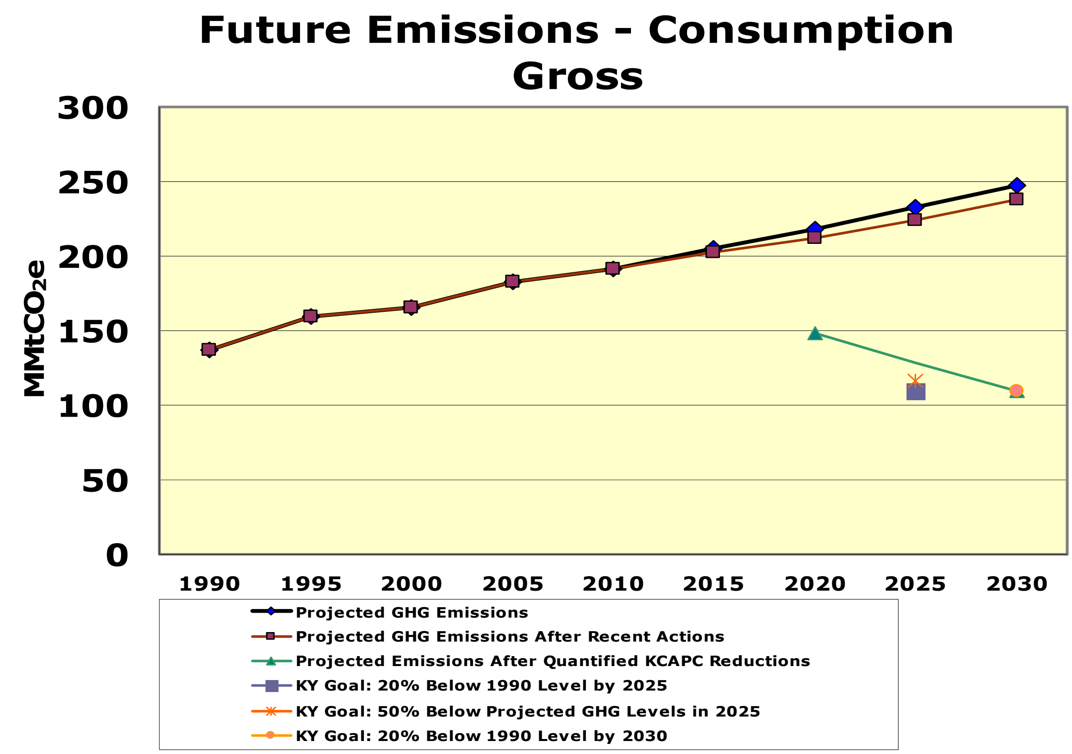
Kentucky has recently embarked on statewide energy efficiency programs in response to concerns about energy costs. Two existing state programs have also been included as recent actions. The Kentucky existing electric utility demand-side management actions are projected to yield reductions of 1.7 $MMtCO_2e$ in 2030, and the Kentucky Government Green Buildings program (House Bill 2) is projected to yield an additional 1.5 $MMtCO_2e$ of reductions in 2030.

KCAPC Policy Recommendations (Beyond Recent Actions)

The KCAPC recommended 46 policy actions. Figure ExS-4 presents a graphical summary of the potential cumulative emission reductions associated with the recent federal and state actions and the 33 policy recommendations relative to the BAU reference case projections. Table ExS-1 provides the numeric estimates underlying Figure ExS-4. In Figure ExS-4:

- The red line shows actual (for 1990, 1995, 2000, and 2005) and projected (for 2010, 2015, 2020, 2025 and 2030) levels of Kentucky' gross GHG emissions on a consumption basis. (The consumption-based approach accounts for emissions associated with the generation of electricity in Kentucky to meet the state's demand for electricity.) The red line for 2010–2030 includes projected emissions associated with recent federal and state actions that were analyzed quantitatively.
- The black line with blue diamonds portrays the reference case projections for 2010–2030 if no recent actions or additional policy options were enacted—the BAU scenario.
- The green line shows the projected GHG emission levels associated with the KCAPC's recommendation for Kentucky to adopt a statewide, economy-wide GHG reduction goal to reduce the state's gross GHG emissions by 20% below 1990 levels by 2030. Together, if the 33 quantified policy recommendations and the recent federal and state actions (or their equivalent) are successfully implemented, the 2030 emission reduction goal would be virtually achieved, based on results of analysis of KCAPC proposals conducted through the KCAPC and TWG process. (Note that other KCAPC recommendations would have the effect of reducing emissions, but those reductions were not analyzed quantitatively, so are not reflected in the green line.)

Figure ExS-4. Annual GHG Emissions: Reference Case Projections and KCAPC Recommendations (Consumption Basis, Gross Emissions)



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; GHG = greenhouse gas; KCAPC = Kentucky Climate Action Planning Council.

Table ExS-1. Annual Emissions: Reference Case Projections and Impact of KCAPC Options (Consumption Basis, Gross Emissions)

Annual Emissions ($MMtCO_2e$)	1990	1995	2000	2005	2010	2015	2020	2025	2030
Projected GHG Emissions	136.7	159.3	165.9	183.1	191.6	205.1	217.7	232.3	247.7
Reductions from Recent Actions	0.0	0.0	0.0	0.0	0.1	2.4	5.5	7.9	9.4
Projected GHG Emissions after Recent Actions	136.7	159.3	165.9	183.1	191.5	202.7	212.2	224.4	238.3
Total GHG Reductions from KCACP Recommended Policies	0.0	0.0	0.0	0.0	0.0	0.0	63.7	96.1	128.4
Projected Annual Emissions after Quantified KCAPC Reductions*							148.5	128.3	109.9
Kentucky GHG Reduction Goal: 20% below 1990 Level by 2030									109.4

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent. KCAPC = Kentucky Climate Action Planning Council;

*Projected annual emissions also include reductions from recent actions.

Table ExS-2 depicts a cumulative summary by sector of the policy recommendations and the estimated GHG reductions and costs/savings of implementing the KCAPC-recommended policies, after being adjusted for overlaps. In Table ExS-2 and throughout the Climate Action

Plan, positive cost figures ($) indicate costs; negative cost (–$) figures indicate cost savings. For example, in Table ExS-2 the TLU Cost-Effectiveness estimate of (–$126/ tCO_2e) portrays a cost savings of $126 per metric ton of CO_2e. For the policies recommended by the KCAPC to yield the levels of estimated emission reductions shown in Table ExS-3, they must be implemented in a timely, aggressive, and thorough manner.

Table ExS-2. Summary by Sector of Estimated Impacts of Implementing All of the KCAPC Recommended Options (Cumulative Reductions and Costs/Savings)

Sector	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effective-ness ($/$tCO_2e$)
	2020	2030	Total 2011–2030		
Residential, Commercial, and Industrial (RCI)	19.1	38.3	408.2	$1,220	$3
Energy Supply (ES)	37.4	75.8	755.9	$17,911	$24
Transportation and Land Use (TLU)	2.8	6.3	62.4	–$7,877	–$126
Agriculture, Forestry, and Waste Management (AFW)	4.4	7.9	89.7	$308	$3.4
Cross-Cutting Issues (CCI)	Non-quantified, enabling options				
TOTAL (includes all adjustments for overlaps)	**63.7**	**128.3**	**1,316.2**	**$11,562**	**$8.8**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

The values in this table do not include the effects of recent actions. Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings associated with the policy recommendations.

Within each sector, values have been adjusted to eliminate double counting for policies or elements of policies that overlap. In addition, values associated with policies or elements of policies within a sector that overlap with policies or elements of policies in another sector have been adjusted to eliminate double counting. Appendix F (for the ES sector), Appendix G (for the RCI sectors), Appendix E (for the AFW sectors), and Appendix H (for the TLU sectors) of this report provide documentation of how sector-level emission reductions and costs (or cost savings) were adjusted to eliminate double counting associated with overlaps between policies.

Table ExS-3, which begins below and continues through page ExS-16 summarizes the policy options analyzed and approved by the KCAPC as recommendations to be included in this report. During the final two meetings of the process, the policy options were reviewed and acted upon by the KCAPC. Of the 47 policies considered: 46 policy options were approved by a majority of the KCAPC members present and voting at the time of consideration of each of the policies. One policy option analyzed, ES-12, was not approved by the KCAPC. The sector tables below match the summary tables in each of the TWG appendices (E, F, G, H, and I). Each of the segments of the table portrays the policy recommendations, projected GHG emission reductions, the net present value costs or cost savings. and the cost-effectiveness of each policy option. The detailed narrative explaining each policy option is included in the respective appendices to this report. Note that the numbering used to denote the policy recommendation in Table ExS-3 and in other parts of this report is for reference purposes only; it does not reflect prioritization among these important recommendations.

Table ExS-3. Summary List of Policy Recommendations for All Sectors

Agriculture, Forestry, and Waste Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$) 2020	2030	Total 2011–2030	Net Present Value (Million $)	Cost-Effective-ness ($\$/tCO_2e$)
AFW-1	Forestry Management for Carbon Sequestration	0.04	0.07	0.86	$17.4	$20.3[4]
AFW-2	Expanded Use of Biomass Feed-stocks for Electricity, Heat, and Steam Production	*Costs/GHG Reductions Captured in ES-1, ES-5 and ES-7 Analysis*				
AFW-3a	On-Farm Energy Production	*GHG reductions accounted for in policies where biomass is used for Fuel (ES, RCI, & TLU)*				
AFW-3b	On-Farm Energy Efficiency Improvements	0.21	0.45	4.5	–$94	–$21
AFW-4	In-State Liquid/Gaseous Biofuels Production	*Costs/GHG Reductions Captured in TLU-10 Analysis*				
AFW-5a	Soil Carbon Management—NT/CT	0.37	0.74	7.8	$6	$1
AFW-5b	Soil Carbon Management—Winter Cover Crops	0.95	1.9	20	$141	$7
AFW-6	Increase Productivity of Abandoned, Underutilized, and Reclaimed Lands[5]	2.7	5.8	58	$50	$1
AFW-7a	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Mined Lands	0.02	0.09	0.16	–$19	–$120
AFW-7b	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Other Lands	0.55	1.0	11	$61	$5
AFW-8	Advanced MSW Reuse, Recycling, and Organic Waste Management Programs	0.84	1.3	16	$167	$10
AFW-9	Landfill Methane Energy Programs	1.4	2.4	29	$29	$1
	Sector Total After Adjusting for Overlaps	**4.4**	**7.9**	**90**	**$308**	**$3**
	Reductions From Recent Actions	**0**	**0**	**0**	**$0**	**$0**
	Sector Total Plus Recent Actions	**4.4**	**7.9**	**90**	**$308**	**$3**

$\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; ES = Energy Supply; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MSW = municipal solid waste; NT/CT = no till/conservation tillage; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use.

[4] The benefits of increased forest carbon sequestration will last far beyond the policy period. When GHG reductions and cost-effectiveness are calculated considering the lifetime of the forest (~50 years), the results are 3.3 $MMtCO_2e$ and 5.3 $\$/tCO_2e$, respectively.

[5] This policy overlaps with policies in the ES sector; the overlapping benefits and costs were removed in the overall KCAPC process results shown for total benefits and costs in the final report.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative NPV represents positive net cash flows from the policy recommendation (i.e., the costs of the policy recommendation, when levelized over their expected lifetimes, are less than expected expenditures).Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

Totals do not equal sum of individual policy recommendations due to subtraction of overlaps.

Table ExS-3 (continued). Energy Supply Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($\$/tCO_2e$)
		2020	2030	Total 2011–2030		
ES-1	Biomass Development and Efficiency Improvements at Existing Power Plants					
	Supply-side efficiency	1.6	2.1	27.4	$240	$8.8
	Biomass co-firing	4.0	4.5	65.1	$1,065	$16.34
	Total*	5.7	6.5	92.5	$1,305	$14.1
	Dedicated biomass					
	*Stoker technology**	0.4	0.4	8.2	$342	$41.5
	*Fluidized bed technology**	0.4	0.4	8.2	$242	$29.4
ES-2	Demand-Side Energy Efficiency and Management Programs	*Moved to Residential, Commercial, and Industrial Technical Work Group as policy RCI-3.*				
ES-3	Advanced Fossil Fuel Technology (IGCC, CCSR, Advanced Pulverized Coal, CFB) Incentives, Support, or Requirements					
	Scenario 1 (Supercritical without CCSR)					
	800 MW retired	0.7	0.7	7.4	$127.9	$17.2
	1,600 MW retired	1.9	1.9	21.1	$423.1	$20.1
	Scenario 2 (Conventional NGCC without CCSR)					
	600 MW retired	1.7	1.7	18.7	$307.2	$16.4
	1,200 MW retired	2.9	2.9	32.0	$544.0	$17.0
	*Scenario 3 (Supercritical with CCSR)**					
	800 MW retired	2.3	2.3	24.8	$824.8	$33.2
	1,600 MW retired	7.4	7.4	78.6	$2,729.5	$34.7
	Scenario 4 (Advanced NGCC with CCSR)					
	600 MW retired	2.4	2.4	26.8	$561.7	$21.0
	1,200 MW retired	4.2	4.2	46.3	$994.7	$21.5

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)
		2020	2030	Total 2011–2030		
ES-4	CCSR Enabling Policies, R&D, Infrastructure, and Incentives Including Enhanced Oil Recovery Using CO_2 (quantification considers CCSR demonstration project only)					
	*1 plant retrofitted**	1.8	1.8	23.5	$893.3	$37.9
	2 plants retrofitted	3.8	3.8	49.9	$1,891.7	$37.9
ES-5	Pricing Strategies to Promote Efficiency and Renewables Including Net Metering, Feed-In Tariff, Interconnection Rules, Inclined Rates, and Examination of the Standard Rate Structure (quantification considers feed-In tariff only)	1.2	5.2	43.9	$1,206	$27.5
ES-6	New Nuclear Energy Capacity	0.0	19.5	116.7	$2,481	$21.3
ES-7	Renewable Energy Incentives and Barrier Removal, Including CHP					
	*Scenario 1 (mixed renewable)**	15.1	22.2	263.6	$5,489	$20.8
	Scenario 2 (biomass)	15.1	22.3	272.2	$4,368	$16.0
	Scenario 3 (out-of-state wind)	15.1	22.3	272.2	$3,012	$11.1
	Scenario 4 (solar PV)	15.1	22.2	271.4	$8,157	$30.1
ES-8	Technology Research and Development (Not Including CCSR or Wind Potential Study) (quantification considers solar PV demonstration projects only)	0.013	0.013	0.24	$39.6	$164.9
ES-9	Policies to Support Wind Energy	*Not Quantified*				
ES-10	Shale Gas Development and Natural Gas Transportation Infrastructure and Gas-to-Liquids Technology	0.013	0.028	0.271	$22.3	$82.5
	Gas-to Liquids-Technology	0.039	0.077	0.763	$137.3	$179.1
ES-11	Smart Grid, Including Transmission and Distribution Efficiency (quantification considers smart grid only)	6.45	13.35	135.73	$3,608.4	$26.6
	Sector Total After Adjusting for Overlaps	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**
	Reductions From Recent Actions (EISA Title II requirements for new appliances and lighting)	**0.0**	**0.0**	**0.0**	**$0.0**	**$0**
	Sector Total Plus Recent Actions	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**

$/tCO_2e = dollars per metric ton of carbon dioxide equivalent; CCSR = carbon capture and storage or reuse; CFB = circulating fluidized bed; CHP = combined heat and power; CO_2 = carbon dioxide; DSM = demand-side management;

EERS = energy efficiency resource standard; EISA = Energy Independence and Security Act of 2007; EPA = U.S. Environmental Protection Agency; GHG = greenhouse gas; IGCC = integrated gasification combined cycle; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MW = megawatts; NGCC = natural gas combined cycle; N/A = not applicable; PBF = performance-based financing; PV = photovoltaics; RCI = Residential, Commercial, and Industrial; R&D = research and development; RE = renewable energy.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative net present value represents positive net cash flows from the policy (i.e., the costs of the policy, when levelized over their expected lifetimes, are less than expected expenditures). Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

*These scenarios were used in the sector totals. The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

Table ExS-3 (continued). Residential, Commercial, and Industrial Summary List of Policy Recommendations*

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effectiveness 2011–2030 ($/$tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-1	Improve Building Codes for Energy Efficiency, Coupled with Improved Energy Code Training and Enforcement	0.4	1.2	9	–$213	–$23
RCI-2	Promote, Encourage, and Provide Incentives for “Beyond-Code” Efficiency in All Building Characteristics and Systems That Impact Energy Consumption	2	5	50	–$1,376	–$27
RCI-3	Expand Utility DSM Programs for Electricity	6	19	169	–$3,340	–$20
RCI-4	Develop and Implement Comprehensive Education, Outreach, and Marketing, Including Consumer Awareness, School Curriculum, Truth-in-Advertising, Technical Information and Support (e.g., How to Do GHG Inventories, Rationales for Action, etc.)	*Not Quantified*				
RCI-5	Financing Programs and Incentives for Energy Efficiency and CHP (PBF, Revolving Loans, etc.) (ONLY CHP QUANTIFIED)	12	22	259	$538	$2
RCI-6	Financing Programs, Incentives, Policies, and Research for Conversion to Renewable Energy or Low-Carbon Energy Sources (ONLY RENEWABLE ELECTRICITY QUANTIFIED)	1.4	4.4	35	$3,372	$96
RCI-7	Government Lead by Example (GLE) in Highly Efficient State and Local Government Buildings	0.7	1.6	15	–$16	–$1
RCI-8	Training and Education for Builders, Contractors, and Building Operators	*Not Quantified*				

Policy No.	Policy Recommendation	GHG Reductions (MMtCO$_2$e)			Net Present Value 2011–2030 (Million $)	Cost-Effective-ness 2011–2030 ($/tCO$_2$e)
		2020	2030	Total 2011–2030		
RCI-9	Building Commissioning and Recommissioning, Including Energy Tracking and Benchmarking, and Implement a Building Energy Labeling Program	3	5	50	–$1,117	–$23
RCI-10	Implement Advanced Metering Technologies and Associated Policies for Greater Load Management, Customer Control, Awareness, Price Signaling, etc.	*Moved to Energy Supply Technical Work Group as policy recommendation ES-11.*				
	Sector Total After Accounting for Overlaps	**19**	**38**	**408**	**$1,220**	**$3**
	Reductions From Recent Actions (Existing DSM Programs, HB 2 for Government Buildings)	**1.5**	**3.2**	**32**		
	Sector Total Plus Recent Actions	**20**	**42**	**441**		

Negative values in the Net Present Value (NPV) and the Cost-Effectiveness columns represent net cost savings. Negative NPV represents positive net cash flows from the policy recommendation (the costs of the policy, i.e., new energy efficiency equipment (air conditioners, furnaces, etc.), when levelized over their expected lifetimes, are less than expected energy expenditures. Policy recommendations with estimated cost savings still are likely to require significant up-front capital investment for the new energy efficiency equipment.

Totals may not add up due to rounding.

$/tCO$_2$e = dollars per metric ton of carbon dioxide equivalent; CHP = combined heat and power; DSM = demand-side management; GHG = greenhouse gas; HB = House Bill; MMtCO$_2$e = million metric tons of carbon dioxide equivalent; N/A = not applicable; PBF = Public Benefit Fund.

GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five).

The cost per tCO$_2$e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMtCO$_2$e of GHG reductions (column five).

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policies.

*This analysis reflects the use of full-fuel-cycle GHG emission factors.

On October 27, 2010, the RCI Technical Work Group (TWG) discussed the issue of direct versus "full-fuel-cycle" emission factors. Full-fuel-cycle GHG emission factors include the GHG emissions associated with the production, processing, transmission, and distribution of fuels and electricity. These "upstream" emissions associated with energy supply are 5%–25% greater than direct, or end-use, emission factors that are calculated as a result of fuel combustion at the power station or building. On the October 27 call, the RCI TWG decided to present the summary table above showing GHG emissions and cost-effectiveness based on full-fuel-cycle emission factors. The work group also decided that the results for each RCI policy recommendation should show both direct and full fuel cycle emissions factors. On balance, the difference in 2011–2030 cumulative GHG reductions is about 10% between the two methodologies. The choice of emission factor does not impact the net present value calculations. However, because cumulative 2011–2030 GHG emission reductions are increased under full-fuel-cycle emission factors, the $/ton cost-effectiveness estimates will differ modestly between the two methodologies.

Table ExS-3 (continued). Transportation and Land Use Summary List of Policy Recommendations[6]

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effectiveness ($/tCO_2e$)	Energy Savings (Million gallons) 2011–2030
		2020	2030	Total 2011–2030			
TLU-1	Bicycle and Pedestrian Comprehensive Plan and Infrastructure Development	0.055	0.087	1.049	–$445	–$424	–87
TLU-2/6	Livability, Brownfield Redevelopment, Downtown Revitalization, Location-Efficient Strategies, Land Use, Building Code Reform and Connectivity	*Not Quantified*					
TLU-3A	Transportation System Management	0.32	0.38	5.32	–$1,070	–$201	–604
TLU-3B/4	Transit Management and Infrastructure	0.07	0.15	1.56	$110	$71	–143
TLU-5	Education and Outreach for Vehicle Maintenance, Idle Reduction, and Co-Driving, and Promote Alternative Modes of Travel	*Not Quantified*					
TLU-7	Parking Management and Ride Sharing	0.204	0.345	4.032	–$2,327	–$554	–335
TLU-8	Strategies to Move Freight in More GHG-Efficient Ways	0.463	1.079	10.31	–$424	–$41.16	–2,786
TLU-9	Promote Consumption of Locally Produced Goods and Services	0.31	0.55	6.36	–$769	–$120.87	–472
TLU-10	Promote the Use of Alternative Transportation Fuels	0.312	1.015	8.475	$30.7	$3.63	–1,880.9
TLU-11	Promote the Use of Clean Vehicles	1.36	3.41	31.34	–$3,581	–$114.30	–2,330
	Sector Total After Adjusting for Integration	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**–7,980**
	Reductions from Recent Actions	**0**	**0**	**0**	**$0**	**$0**	**0**
	Sector Total Plus Recent Actions	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**7,980**

$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; NQ = not quantified.

Notes: The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important recommendations.

[6] The cost analysis provides figures that represent the net of both positive up-front costs and cost savings over time. Data results that indicate the potential for net cost savings should be viewed with an understanding that in some cases, initial up-front costs may be necessary in order to achieve the net cost savings over time.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative net present value represents positive net cash flows from the policy recommendation (i.e., the costs of the policy recommendation, when levelized over their expected lifetimes, are less than expected expenditures). Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

Table ExS-3 (continued). Cross-Cutting Issues Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effectiveness ($\$/tCO_2e$)
		2020	2030	Total (2011–2030)		
CCI-1	Greenhouse Gas (GHG) Emission Inventories, Forecasts, Reporting, and Registry	*Not Quantified*				
CCI-2	Public Education and Outreach	*Not Quantified*				
CCI-3	Adaptation and Vulnerability	*Not Quantified*				
CCI-4	Statewide GHG Emission Reduction, Energy Intensity, and Energy Efficiency Goals, Targets, and Metrics	*Not Quantified*				
CCI-5	State and Local Government GHG Emission Reduction, Energy Intensity, and Energy Efficiency Activities (Lead by Example)	*Not Quantified*				
CCI-6	Local GHG Emission Reduction, Energy Intensity, and Energy Efficiency Actions	*Not Quantified*				
CCI-7	Financial Policies	*Not Quantified*				
CCI-8	Conduct an Impact Analysis of Federal GHG Constraints on Kentucky	*Not Quantified*				

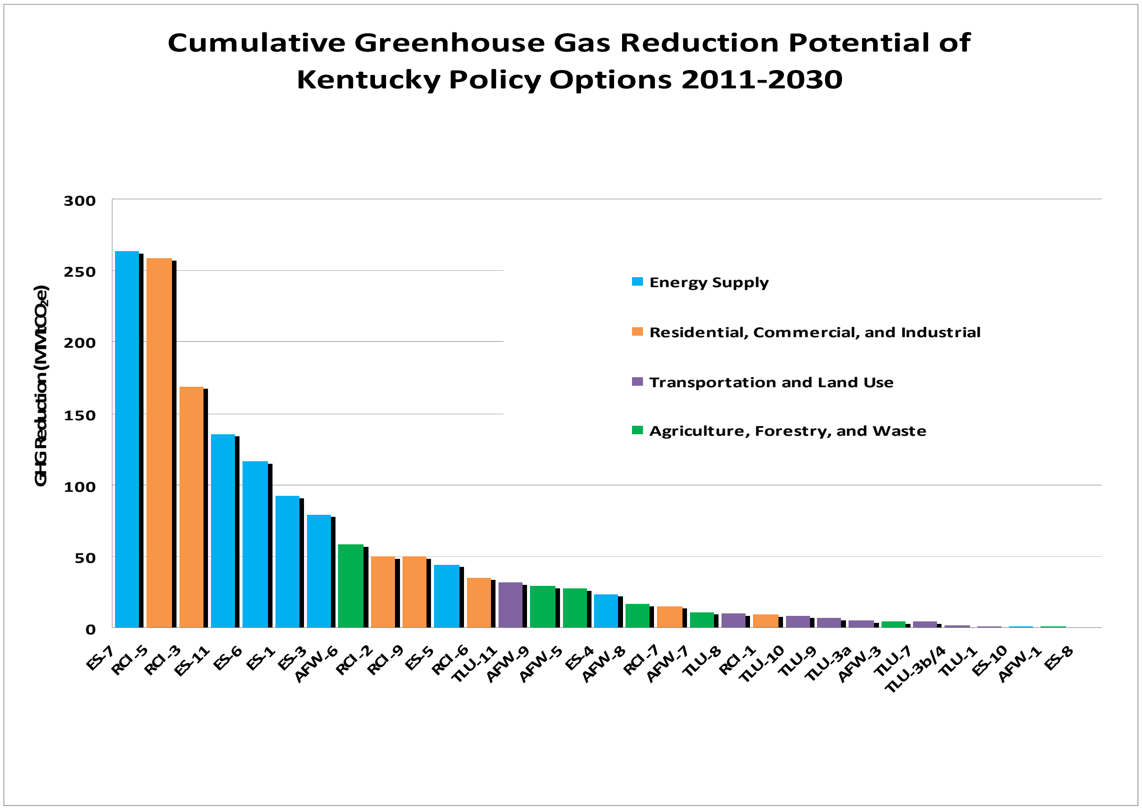
GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

Note: The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policies.

As explained previously, the KCAPC considered the estimates of the GHG reductions that could be achieved and the costs (or cost savings) for the 33 recommended policy options that were quantifiable. It is important to note that there is some level of uncertainty in projecting GHG reductions and estimating exact costs (or cost savings) per ton of reductions achieved for the time period of this analysis.

Figure ExS-5 presents the estimated tons of GHG emission reductions for each policy recommendation for which estimates were quantified, expressed as a cumulative figure for the period 2011–2030.

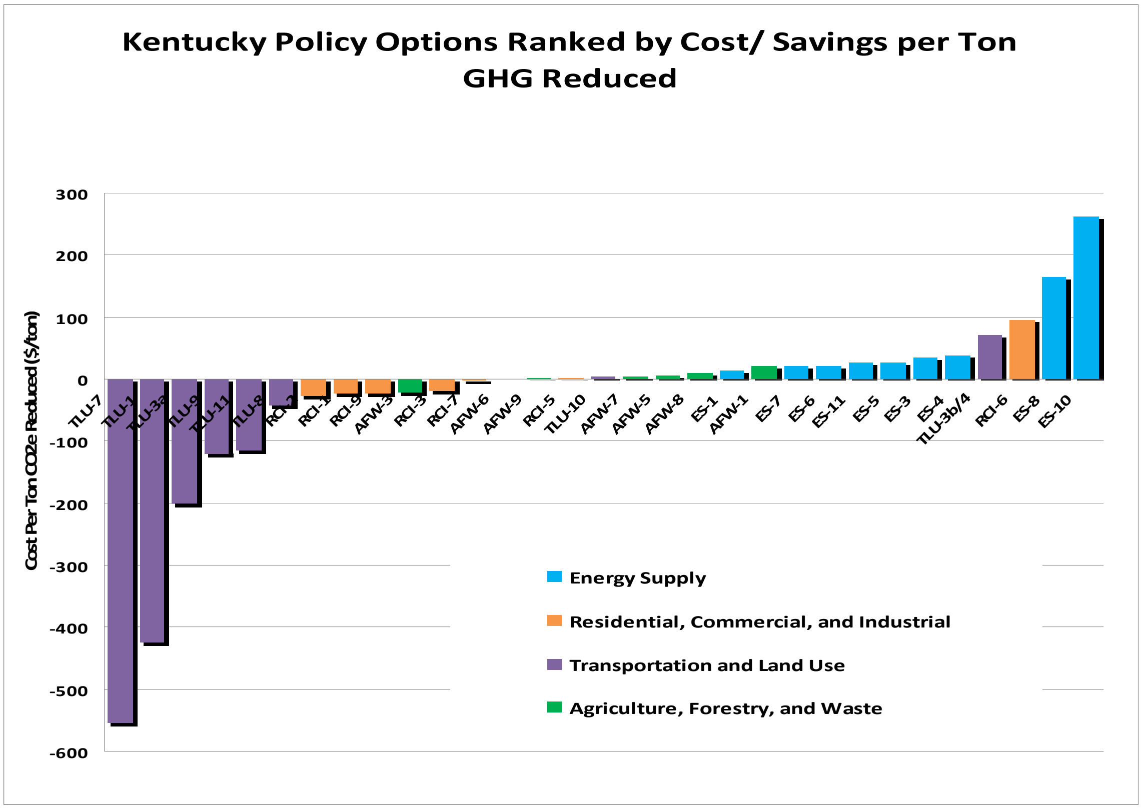
Figure ExS-5. KCAPC Policy Recommendations Ranked by Cumulative (2011–2030) GHG Reduction Potential



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; AFW = Agriculture, Forestry, and Waste Management; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply.

Figure ExS-6 presents the estimated dollars-per-ton cost (or cost savings, depicted as a negative number) for each policy recommendation for which cost estimates were quantified, expressed as a cumulative figure for the period 2011–2030. This measure is calculated by dividing the net present value of the cost of the policy recommendation by the cumulative GHG reductions, all for the period 2011–2030. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.

Figure ExS-6. KCAPC Policy Recommendations Ranked by Cumulative (2011–2030) Net Cost/Cost Savings per Ton of GHG Removed

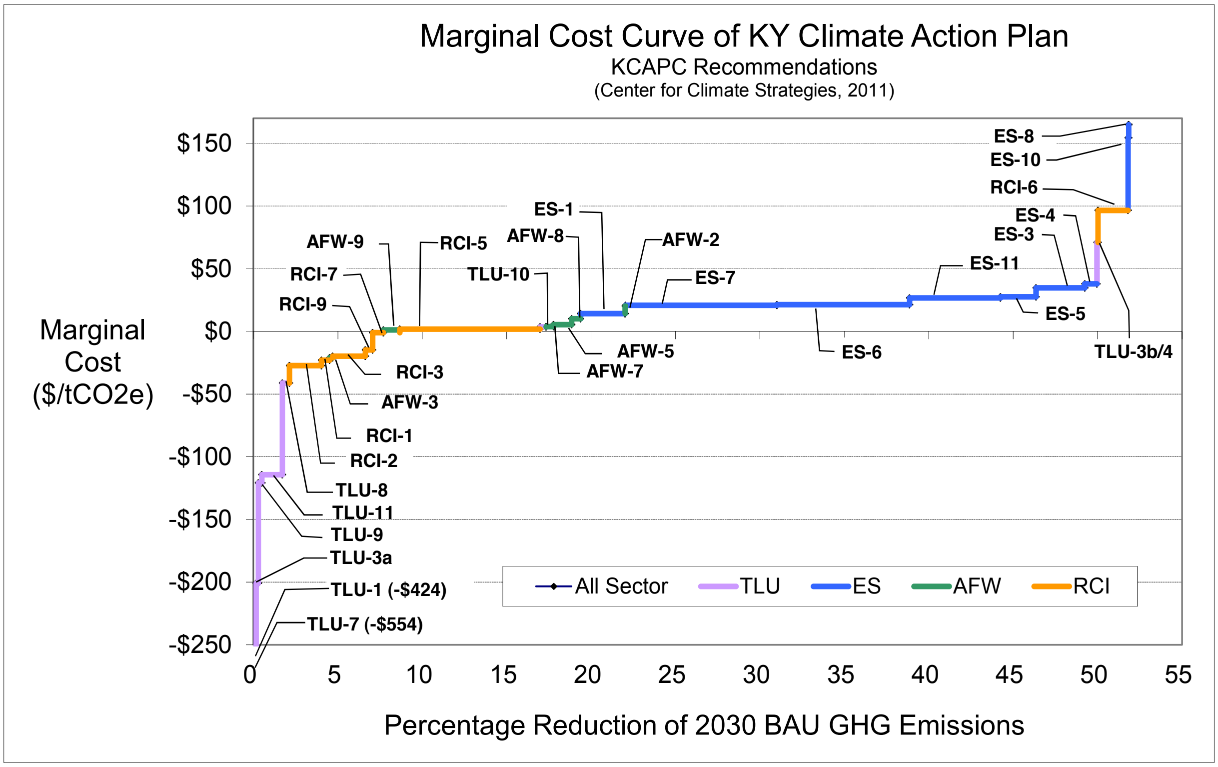


CO_2 = carbon dioxide; GHG = greenhouse gas; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply; AFW = Agriculture, Forestry, and Waste Management.

Negative values represent net cost savings, and positive values represent net costs associated with the policy recommendations.

Figure ExS-7 presents a step-wise marginal cost curve for Kentucky. The horizontal (x) axis represents the percentage of GHG emission reductions in 2030 for each policy recommendation relative to the BAU forecast. The vertical (y) axis represents the marginal cost of mitigation (expressed as the cost-effectiveness of each policy recommendation on a cumulative basis, 2011–2030). In the figure, each horizontal segment represents an individual policy. The width of the segment indicates the GHG emission reduction potential of the recommendation in percentage terms. The height of the segment relative to the vertical axis shows the average cost (or saving) of reducing 1 tCO_2e of GHG emissions with the application of the recommendation. Note that recommendation steps appearing below the “$0” line near the middle of the graph (on the vertical axis) are cost-saving measures, while the recommendations above this line have positive net direct costs. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front investments.

Figure ExS-7. Step-wise Marginal Cost Curve for Kentucky, 2030



$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; BAU = business as usual; GHG = greenhouse gas; KY = Kentucky; AFW = Agriculture, Forestry, and Waste Management; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply.

Negative values represent net cost savings, and positive values represent net costs associated with the policy recommendations. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front investments.

Note: Results have been adjusted to remove overlaps between policies.

Chapter 1
Background and Overview

Creation of the Kentucky Climate Action Plan Council

In November 2008, Governor Steven Beshear issued a report entitled *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*.[1] One of the provisions of the 7-Point Energy Strategy is to mitigate carbon dioxide (CO_2) emissions and to reduce Kentucky's carbon footprint. Development of the Climate Action Plan for Kentucky is aimed at furthering this objective to reduce Kentucky's carbon footprint. The Climate Action Plan has been built upon selected provisions of the Kentucky Energy Strategy. It also focuses attention on creating opportunities to build on Kentucky's progress to date to become more energy efficient, to reduce dependence on foreign oil, to enhance the nation's energy security, to promote new energy-related technologies, and to enhance economic opportunities in Kentucky.

The Kentucky Climate Action Plan process was convened in January 2010 by Dr. Len Peters, Secretary of the Kentucky Energy and Environment Cabinet (KEEC). Secretary Peters established the Kentucky Climate Action Plan Council (KCAPC) to assist in developing the Kentucky Climate Action Plan. The Council consists of a broad coalition of 27 members, including stakeholders from the business, academic, government, nonprofit, and environmental sectors, as well as individual citizens. Members of the Council are listed on page iii of this report.

The Commonwealth of Kentucky hired the Center for Climate Strategies (CCS) to provide technical and facilitation support to KEEC and the KCAPC in formulating the Kentucky Climate Action Plan. CCS has extensive experience assisting states in formulating state climate action plans, preparing GHG inventories and forecasts, and conducting numerous related technical and economic studies associated with climate change.

It is important to note that this set of recommended policies is presented to Secretary Peters for consideration. The data and costs presented in this report are based on the information and assumptions available at the time of analysis during 2010 and 2011. It is acknowledged that these recommendations may require updated data and further review and analysis prior to implementation. It is also acknowledged that many of these recommendations would require action by other entities, including the Kentucky General Assembly and/or the Kentucky Public Service Commission.

The KCAPC's Response

The KCAPC used an open, systematic, step-wise decision-making process to develop Kentucky's Climate Action Plan. The process is spelled out in detail in a Process Memo and Work Plan that can be found on the project Web site at www.kyclimatechange.us. As a result of the Council's work, the Climate Action Plan provides the following key recommendations and accomplishments:

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[1] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008.

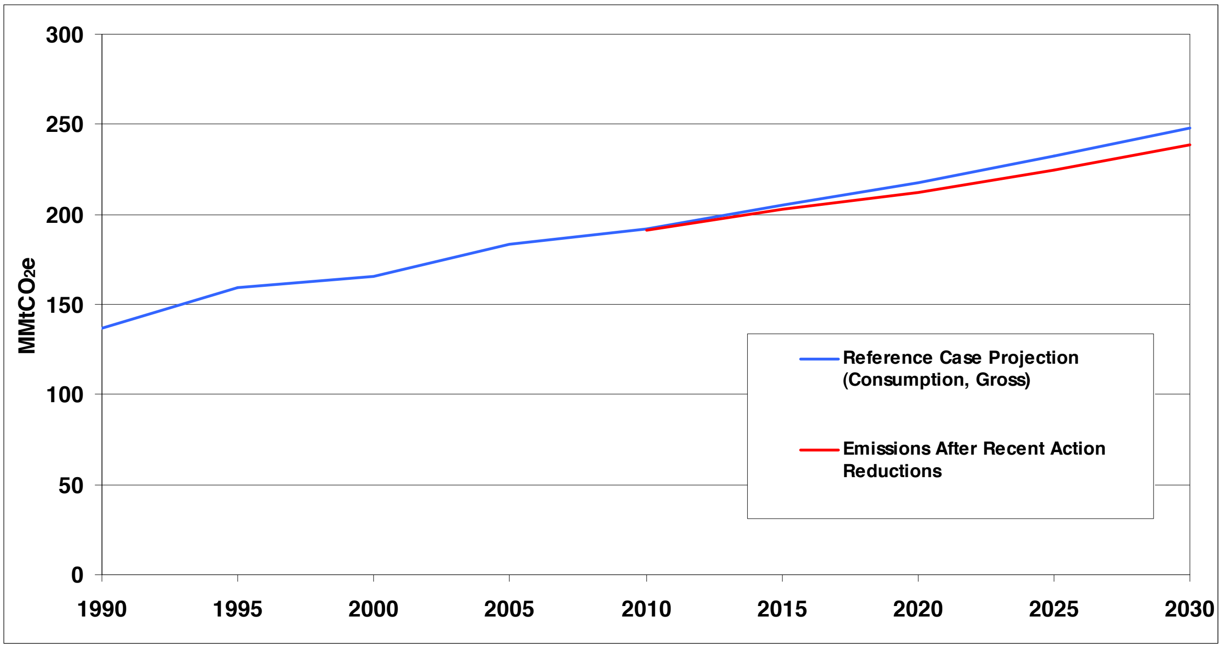
- Recommendation of a comprehensive set of 46 specific policies to reduce greenhouse gas (GHG) emissions and address climate, energy, and commerce-related issues in Kentucky. Of the 46 policy recommendations, 33 were analyzed quantitatively to have a cumulative effect of reducing GHG emissions by about 63.7 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) in 2020 and 128.3 $MMtCO_2e$ in 2030. Explanations of all policies and any objections are in Appendices E through I of this report, which contain detailed accounts of the KCAPC's recommendations.
- Recommendation that Kentucky establish a statewide, economy-wide GHG reduction goal to reduce the state's GHG emissions to 20% below 1990 levels by 2030. The KCAPC based its recommendations on its review of the potential overall emission reduction estimates (as compared to the GHG emissions inventory and forecast [I&F]) for policy options for which emission reductions were quantified, and its review of goals and targets included in Governor Steven Beshear's report *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*. This target GHG reduction level is the same as in the 7- Point Energy Strategy, but would be achieved in 2030 instead of 2025 due to some of the key policies coming to fruition to yield reductions in the last 5-year interval of the planning period (2025–2030). Together, if the 33 quantified policy recommendations and the recent federal actions (or their functional equivalent) are successfully implemented, the 2030 GHG emission reduction goal would be virtually achieved based on results of analysis of KCAPC proposals conducted through the KCAPC and Technical Work Group (TWG) process.
- Evaluation of the direct costs and direct cost savings of the policy recommendations in Kentucky. The KCAPC analyzed quantitatively the direct costs or cost savings of 33 of its 46 policy recommendations. Although the total net cost associated with the 46 policies analyzed (47 policies were analyzed; 1 was rejected) is estimated at about $11.56 billion between 2011 and 2030, the weighted-average cost-effectiveness of the 33 policies is estimated to be approximately $8.8/$tCO_2e$ reduced. Many of the policies are estimated to yield significant cost-saving opportunities for Kentucky, but may have significant initial costs. Other policies will incur net costs.
- Review, update, and approval of a comprehensive I&F of GHG emissions in Kentucky for 1990 through 2030. This is the first comprehensive, statewide GHG I&F that has been developed for Kentucky. It has benefited from the expertise of many KCAPC and TWG members, along with agency staff who provided state-specific data.

Recent Actions

GHG Reductions Associated with Recent Federal Actions

The federal Energy Independence and Security Act of 2007 (EISA) was signed into law in December 2007. This law contains several requirements that will reduce GHG emissions as they are implemented over the next few years. During the KCAPC process, sufficient information was identified (e.g., implementation schedules) to estimate GHG emission reductions associated with implementing the federal Corporate Average Fuel Economy requirements, utility energy efficiency programs as well as high efficiency public buildings in Kentucky. The GHG emission reductions projected to be achieved by these actions are shown in Figure 1-1. Table 1-1 provides the numeric estimates underlying Figure 1-1. Together, these federal requirements are estimated to reduce gross GHG emissions for all sectors combined in Kentucky by about 4.02 $MMtCO_2e$ (a 1.8% reduction) from the business-as-usual (BAU) emissions in 2020, and by about 6.23 $MMtCO_2e$ (a 2.5% reduction) from the BAU emissions in 2030.

Figure 1-1. Estimated Emission Reductions Associated with the Effect of Recent Federal Actions in Kentucky (Consumption-Basis, Gross Emissions)



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table 1-1. Estimated Emission Reductions Associated with the Effect of Recent Federal and State Actions in Kentucky (Consumption-Basis, Gross Emissions)

Sector/Recent Action	GHG Reductions ($MMtCO_2e$)		GHG Emissions ($MMtCO_2e$)	
			Business as Usual	With Recent Actions
	2020	2030	2030	2030
Transportation and Land Use				
Federal Corporate Average Fuel Economy Requirements, plus California CO_2 Vehicle Standards	4.02	6.23	56.9	50.7
RCI (Including Electricity)—Kentucky Existing Electric Utility DSM Actions	0.9	1.7	174.5	172.8
RCI—(Including Electricity)—House Bill 2 Government Green Buildings	0.6	1.5	174.5	173.0
Total (All Sectors)	**5.5**	**9.4**	**247.7**	**238.3**

CO_2 = carbon dioxide; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; RCI = residential, commercial, and industrial sectors.

Recent State Actions

Kentucky has recently embarked on statewide energy efficiency programs in response to concerns about energy costs. Two existing state programs have also been included as recent actions. The Kentucky existing electric utility demand-side management actions are projected to yield reductions of 1.7 $MMtCO_2e$ in 2030, and the Kentucky House Bill 2 Government Green Buildings program is projected to yield an additional 1.5 $MMtCO_2e$ of reductions in 2030. The total GHG reductions from recent federal and state actions is projected to be about 9.4 $MMtCO_2e$ in 2030, or a 3.8 % reduction from the BAU emissions in 2030 for all sectors combined.

The KCAPC Process

The KCAPC began its deliberative process at its first meeting on January 19, 2010, and met a total of seven times, with the final decisional meeting held via teleconference on August 25, 2011. In all, about 60 meetings and teleconferences of the KCAPC and the five supporting TWGs were held to identify and analyze various potential policy actions in advance of the KCAPC's final meeting.

The five TWGs considered information and potential recommendations in the following sectors:

- Residential, Commercial, and Industrial (RCI);
- Energy Supply (ES);
- Transportation and Land Use (TLU);
- Agriculture, Forestry, and Waste Management (AFW); and
- Cross-Cutting Issues (CCI) (i.e., issues that cut across the above sectors).

CCS provided facilitation and technical assistance to the KCAPC and each of the TWGs, based on a detailed proposal approved by KEEC. The TWGs consisted of KCAPC members plus additional technical experts. The TWG members are listed in Appendix B of this report. Members of the public were invited to observe and provide input at all meetings of the KCAPC and TWGs. The TWGs served as advisers to the KCAPC, and helped generate initial recommendations on Kentucky-specific policy options to be added to the catalog of existing states actions; priority policy recommendations for analysis; draft proposals on the design characteristics and quantification of the proposed policy recommendations; specifications and assistance for analysis of draft policy options (including best available data sources, methods, and assumptions); and other key elements of policy option proposals, including related policies and programs, key uncertainties, co-benefits and costs, feasibility issues, and potential barriers to consensus. Where members of a TWG did not fully agree on recommendations to the KCAPC, the summary of their efforts was reported to the KCAPC as a part of its consideration and actions. The KCAPC then made its decisions after reviewing the TWGs' proposals, including modifications as deemed appropriate in their judgment.

The KCAPC process employed a model of informed self-determination through a facilitated, step-wise, fact-based, and consensus-building approach. The process was based on procedures that CCS has used in a number of other state climate change planning initiatives since 2000, but was adapted specifically for Kentucky. The KCAPC process sought but did not mandate consensus. The process documented any barriers to full consensus where they existed on final consideration of proposed actions. Out of the approximately 380 potential options the KCAPC considered, the 46 policy recommendations presented in this report were developed by the KCAPC through a step-wise approach that included: (1) expanding an initial list of about 310 existing states actions to include about 70 additional actions, including Kentucky-specific actions; (2) identifying a set of about 48 priority options for further analysis and development; (3) fleshing these proposals out for full analysis by development of "straw proposals" for level of effort, timing, and parties involved in implementation; (4) developing and applying a common framework of analysis for options, including sector-specific guidance and detailed specifications for options that include data sources, methods, and key assumptions; (5) reviewing results of analysis and modifying proposals as needed to address potential barriers to consensus; (6) finalizing design and analysis of options to remove barriers to final agreement; and (7) developing other key elements of policy proposals, such as implementation mechanisms, co-benefits, and feasibility considerations.

During the final two meetings of the process, KCAPC members present and voting approved 46 policy options and rejected 1 policy option (ES-12). The TWGs' recommendations to the KCAPC were documented and presented to the KCAPC at each KCAPC meeting. All of the KCAPC and TWG meetings were open to the public, and all materials for and summaries of the KCAPC and TWG meetings are posted on the KCAPC Web site (www.kyclimatechange.us). A description of the deliberative process is included in Appendix A.

Analysis of Policy Recommendations

With CCS providing facilitation and technical analysis, the five TWGs submitted recommendations for policies for KCAPC consideration using a "policy option template" conveying the following key information:

Policy Description
Policy Design (Goals, Timing, Parties Involved)
Implementation Mechanisms
Related Policies/Programs in Place
Type(s) of GHG Reductions
Estimated GHG Reductions and Net Costs or Cost Savings
Key Uncertainties
Additional Benefits and Costs
Feasibility Issues
Status of Group Approval
Level of Group Support
Barriers to Consensus

In its deliberations, the KCAPC reviewed, modified, and reached group agreement on various policy recommendations. The final versions for each sector, conforming to the policy option templates, appear in Appendices E through I of this report, and constitute the most detailed record of decisions of the KCAPC. Appendix D describes the methods used to quantify 34 of the 47 policy options. The quantitative analysis produced estimates of the GHG emission reductions and direct net costs (or cost savings) of implementation of various policies, in terms of both a net present value from 2011 to 2030 and a dollars-per-ton cost (i.e., cost-effectiveness). The key methods are summarized below.

Estimates of GHG Reductions

Using the projection of future GHG emissions (see below) as a starting point, 34 policy options were analyzed by CCS to estimate the GHG reductions attributable to each policy in the individual years of 2020 and 2030, and the cumulative reductions over the period 2011–2030. The estimates were prepared in accordance with guidance provided by the five TWGs and the KCAPC, which later reviewed the estimates and, in some cases, directed that they be revised with respect to such elements as goals, data sources, assumptions, sensitivity analysis, and methodology. Many policies were estimated to affect the quantity or type of fossil fuel combusted; others affected methane or CO_2 sequestered. Among the many assumptions involved in this task was selection of the appropriate GHG accounting framework—namely, the choice between taking a "production-based" approach versus a "consumption-based" approach to various sectors of the economy.[2]

Estimates of Costs/Cost Savings

The analyses of 34 policy options included estimates of the direct cost of those policies, in terms of both net costs or cost savings during 2011–2030, and a dollars-per-ton cost (i.e., cost-effectiveness). The estimated costs used in these analyses of the policy options were based on data and assumptions available at the time and may need to be updated as the actions are considered for implementation in the future. One of the policy options analyzed (ES-12) was subsequently not approved by the KCACP as a policy recommendation. Following is a brief summary of the approach used to estimate the costs or cost savings associated with the policy recommendations:

- *Discounted and annualized costs or cost savings*—Standard approaches were taken here. The net present value of costs or cost savings was calculated by applying a real discount rate of 5%. Dollars-per-ton estimates were derived as an annualized cost per ton, dividing the present value cost or savings by the cumulative GHG reduction measured in tons. As was the case with GHG reductions, the period 2011–2030 was analyzed.
- *Cost savings*—Total net costs or savings were estimated by comparing monetized costs and savings of policy implementation over time, using discounting. These net costs could be positive or

[2] A production-based approach estimates GHG emissions associated with goods and services produced within the state, and a consumption-based approach estimates GHG emissions associated with goods and services consumed within the state. In some sectors of the economy, these two approaches may not result in significantly different numbers. However, the power sector is notable, in that it is responsible for large quantities of GHG emissions, and states often produce more or less electricity than they consume (with the remainder attributable to power exports or imports). Kentucky has historically been a net exporter of electricity, due in large part to the relative low cost of coal-generated power. Reference Case projections of electricity production for 2008 through 2030 indicate that Kentucky will remain a net exporter of electricity. Emissions from net electricity exports are projected to increase over the 2008–2030 period, from 4.1 $MMtCO_2e$ in 2008 to 5.7 $MMtCO_2e$ in 2030, however as a percent of total generation exports are expected to average just over 4%. Both consumption and production based emissions are presented; however, this plan will rely upon the consumption-based approach for projection and analysis of recommended policies.

negative; negative costs indicated that the policy saved money or produced "cost savings." Many policies were estimated to create net financial cost savings (typically through fuel savings and electricity savings associated with new policy actions). It is important to note that some of the policy options with an estimated cost savings are likely to require significant up-front capital investments.

- *Direct vs. indirect effects*—Estimates of costs and cost savings were based on "direct effects" (i.e., those borne by the entities implementing the policy). Implementing entities could be individuals, companies, and/or government agencies. In contrast, conventional cost-benefit analysis takes the "societal perspective," and tallies every conceivable impact on every entity in society (and quantifies these wherever possible).

Additional Costs and Benefits[3]

The KCAPC recommendations were guided by four decision criteria that included: GHG reductions, monetized costs/savings of various policies, other potential co-benefits and costs (e.g., social, economic, and environmental) and feasibility considerations. The TWGs were asked to examine co-benefits and feasibility issues in qualitative terms where deemed important, and to quantify the policy options on a case-by-case basis, as needed, depending on need and where data were readily available.

Implementation Mechanisms

The analysis for each recommendation (see Appendices E through I) of the KCAPC includes guidance on the policy instruments or "mechanisms" that were prescribed or assumed for the policy action. This includes a range of potential mechanisms, such as funding incentives, codes and standards, voluntary and negotiated agreements, market-based instruments, information and education, and reporting and disclosure. In some cases, the recommended mechanisms are precise; in others, they are more general and envision further work to develop concrete programs and steps to achieve the goals recommended by the KCAPC.

Kentucky GHG Emissions Inventory and Reference Case Projections

In January 2010, CCS completed a draft GHG emissions inventory and reference case projection to assist the KCAPC and TWGs in understanding past, current, and possible future GHG emissions in Kentucky, and thereby inform the policy development process.[4] The KCAPC and TWGs reviewed, discussed, and evaluated the draft inventory and projections methodologies, as well as alternative data and approaches for improving them. The KCAPC and TWGs were provided opportunities to review and comment on the draft emissions inventory and forecast report and did so. The inventory and reference case projections were revised to incorporate changes approved by the KCAPC, and the revised report was subsequently approved by the

[3] "Additional costs and benefits" were defined as those borne by entities other than those implementing the policy recommendation. These indirect effects were quantified on a case-by-case basis, depending on magnitude, importance, need, and availability of data.

[4] Center for Climate Strategies. *Draft Kentucky Greenhouse Gas Inventory and Reference Case Projections, 1990–2030*. Prepared for the Kentucky Climate Action Plan Council, January 2010. Available at: http://www.kyclimatechange.us/stakeholder.cfm.

KCAPC at its third meeting on June 2, 2010.[5] It is important to note that the analysis was done 2009- 2010 and recent announcements by utilities and more recent actions by the U.S. Environmental Protection Agency are not included in the 2010 I&F report.

The inventory and reference case projections included detailed coverage of all economic sectors and GHGs in Kentucky, including future emission trends and assessment issues related to energy, the economy, and population growth. These assessment issues included estimates of total statewide "gross emissions" on a production basis for all sources and on a consumption basis for the electricity sector. (See prior discussion under "Analysis of Policy Recommendations" in this chapter for an explanation of the production versus consumption approach.) The issues involved in developing the inventory and reference case projections are summarized in Chapter 2 (Inventory and Forecast of GHG Emissions) and are discussed in detail in the final report for the inventory and reference case projections.[6]

The GHG emissions inventory and reference case projections cover the six types of gases included in the U.S. Greenhouse Gas Inventory: CO_2, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Emissions of these GHGs are presented using a common metric—CO_2 equivalence (CO_2e)—that indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential-weighted basis.[7]

The inventory and reference case projections revealed substantial emission growth rates and related mitigation challenges. Figure 1-2 shows the reference case projections for Kentucky's gross GHG emissions as rising fairly steeply to 247.7 $MMtCO_2e$ by 2030, growing by 81% over 1990 levels. Figure 1-2 also provides the sectoral breakdown of projected GHG emissions.

The inventory and reference case projections of Kentucky's GHG emissions provided the following critical findings:

- The principal sources of Kentucky's GHG emissions are electricity consumption, transportation, and RCI fuel use, accounting for 50%, 20%, and 17% of Kentucky's gross GHG emissions in 2005, respectively.

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[5] Center for Climate Strategies. *Final Kentucky Greenhouse Gas Inventory and Reference Case Projections, 1990–2030*. Prepared for the Kentucky Climate Action Plan Council, June 2010. Available at: http://www.kyclimatechange.us/Inventory_Forecast_Report.cfm.

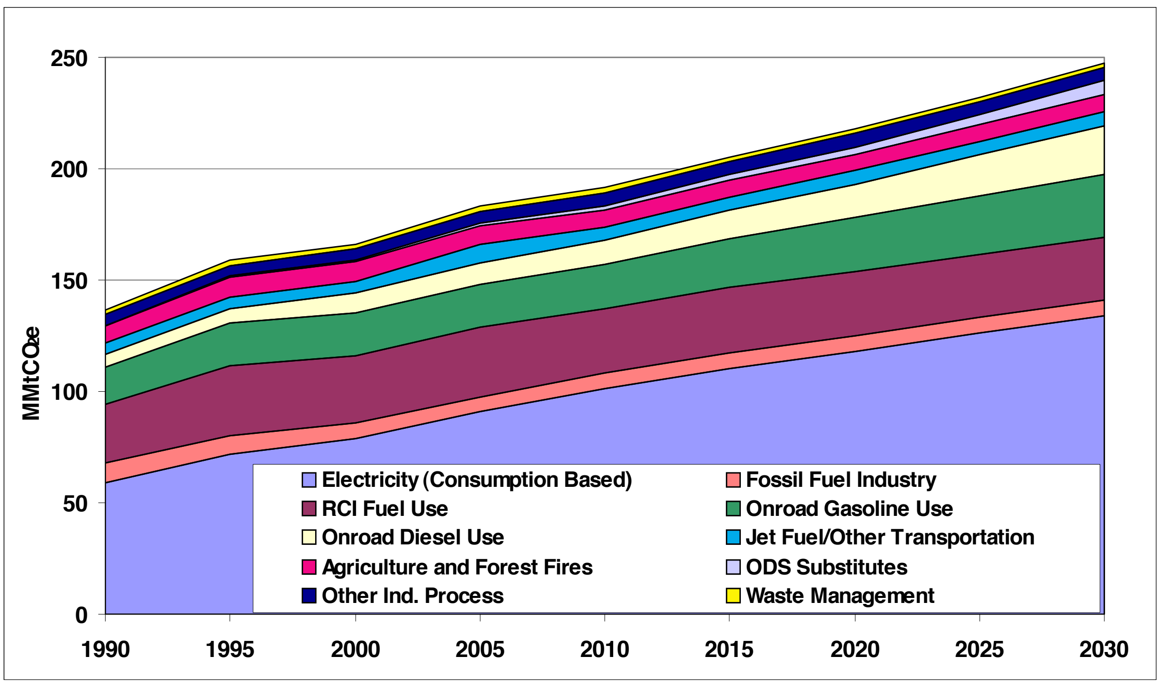
[6] Ibid.

[7] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers among the atmosphere, space, land, and oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 2001). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth). See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental Panel on Climate Change, Cambridge University Press. Cambridge, United Kingdom. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.

- Estimates of carbon sinks within Kentucky's forests and soils, including urban forests, land-use changes, and agricultural soil cultivation practices, are included in this report. The current estimates indicate that about 7.6 $MMtCO_2e$ of emissions were stored in Kentucky biomass in 2005. This leads to net emissions of about 176 $MMtCO_2e$ in Kentucky in 2005, an amount equal to 2.8% of total U.S. net GHG emissions.
- The use of coal has led to low electricity rates in Kentucky compared to the rest of the country, which has allowed energy-intensive industries, which provide valuable goods and services beyond the borders of Kentucky to flourish in the state, as acknowledged in Kentucky's Energy Plan.[8]

While Kentucky's estimated emissions growth rate presents challenges, it also provides major opportunities. Key choices regarding technologies and infrastructure can have a significant impact on emissions growth in Kentucky. The KCAPC's recommendations document the opportunities for the state to reduce its GHG emissions, while continuing its strong economic growth by being more energy efficient, using more renewable energy sources, and increasing the use of cleaner transportation modes, technologies, and fuels.

Figure 1-2. Gross GHG Emissions by Sector, 1990–2030: Historical and Projected (Consumption-Based Approach) Business-as-Usual/Base Case



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; RCI = direct fuel use in residential, commercial, and industrial sectors; ODS = ozone-depleting substance; Ind. = industrial.

Figure 1-3 depicts a comparison between the sectoral components of GHG emissions in 2005 in Kentucky compared to the United States at large. Electricity supply and transportation are projected to have the highest growth.

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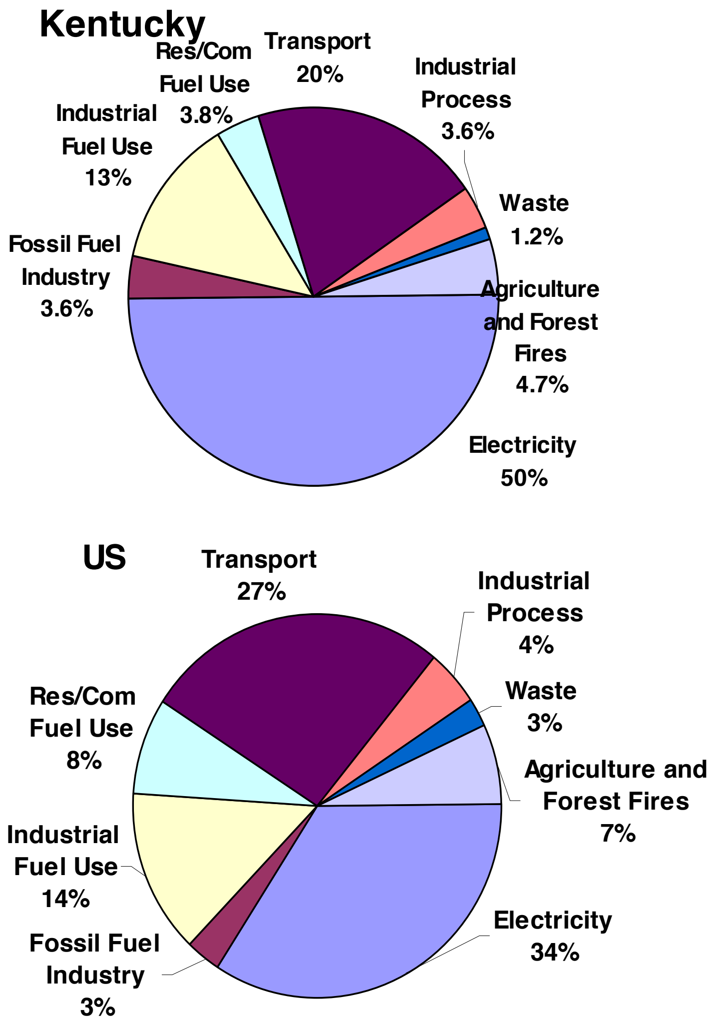
[8] Governor Steven L. Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence,* November 2008.

Figure 1-3. Gross GHG Emissions by Sector, 2005: Kentucky and U.S.



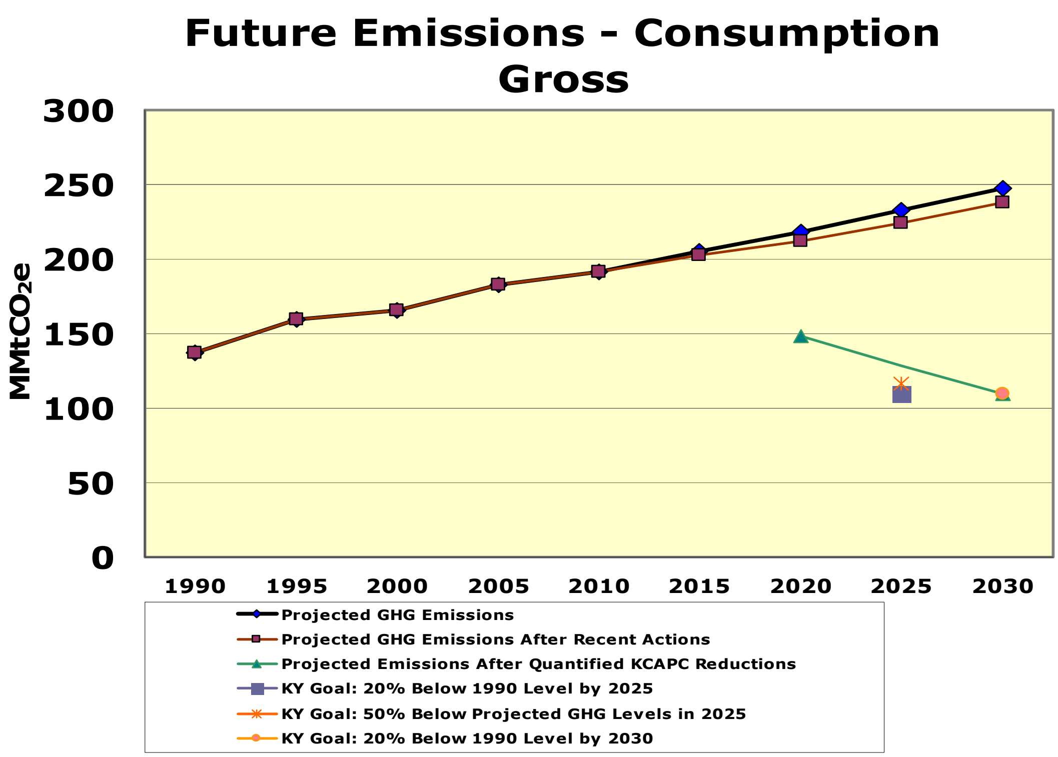
Notes: Res/Com = residential and commercial fuel use sectors; emissions for the residential, commercial, and industrial fuel use sectors are associated with the direct use of fuels (natural gas, petroleum, coal, and wood) to provide space heating, water heating, process heating, cooking, and other energy end-uses. The commercial sector accounts for emissions associated with the direct use of fuels by, for example, hospitals, schools, government buildings (local, county, and state), and other commercial establishments. The industrial processes sector accounts for emissions associated with manufacturing and excludes emissions included in the industrial fuel use sector. The transportation sector accounts for emissions associated with fuel consumption by all on-road and non-highway vehicles. Non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, railway locomotives, boats, and ships. Emissions from non-highway agricultural and construction equipment are included in the industrial sector. Electricity = electricity generation sector emissions on a consumption basis (including emissions associated with electricity imported from outside of Kentucky and excluding emissions associated with electricity exported from Kentucky to other states).

KCAPC Policy Recommendations (Beyond Recent Actions)

The KCAPC recommended 46 policy actions. Figure 1-4 presents a graphical summary of the potential cumulative emission reductions associated with the recent federal actions and the 33 policy recommendations relative to the BAU reference case projections. Table 1-2 provides the numeric estimates underlying Figure 1-4. In Figure 1-4:

- The red line shows actual (for 1990, 1995, 2000, and 2005) and projected (for 2010, 2015, 2020, 2025 and 2030) levels of Kentucky' gross GHG emissions on a consumption basis. (The consumption-based approach accounts for emissions associated with the generation of electricity in Kentucky to meet the state's demand for electricity.) The red line for 2010–2030 includes projected emissions associated with recent federal and state actions that were analyzed quantitatively.
- The black line with blue diamonds portrays the reference case projections for 2010-2030 if no recent actions or additional policy options were enacted- the Business as Usual (BAU) scenario.
- The green line shows the projected GHG emission levels associated with the KCAPC's recommendation for Kentucky to adopt a statewide, economy-wide GHG reduction goal to reduce the state's gross GHG emissions by 20% below 1990 levels by 2030. Together, if the 33 quantified policy recommendations and the recent federal and state actions (or their equivalent) are successfully implemented, the 2030 emission reduction goal would be virtually achieved, based on results of analysis of KCAPC proposals conducted through the KCAPC and TWG process. (Note that other KCAPC recommendations would have the effect of reducing emissions, but those reductions were not analyzed quantitatively, so are not reflected in the green line.)

Figure 1-4. Annual GHG Emissions: Reference Case Projections and KCACP Recommendations (Consumption-Basis, Gross Emissions)



GHG = greenhouse gas; KY = Kentucky; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table 1-2. Annual Emissions: Reference Case Projections and Impact of KCAPC Recommendations (Consumption-Basis, Gross Emissions)

Annual Emissions ($MMtCO_2e$)	1990	1995	2000	2005	2010	2015	2020	2025	2030
Projected GHG Emissions	136.7	159.3	165.9	183.1	191.6	205.1	217.7	232.3	247.7
Reductions from Recent Actions	0.0	0.0	0.0	0.0	0.1	2.4	5.5	7.9	9.4
Projected GHG Emissions after Recent Actions	136.7	159.3	165.9	183.1	191.5	202.7	212.2	224.4	238.3
Total GHG Reductions from KCACP Recommended Policies	0.0	0.0	0.0	0.0	0.0	0.0	63.7	96.1	128.4
Projected Annual Emissions after Quantified KCAPC Reductions**							148.5	128.3	109.9
Kentucky GHG Reduction Goal: 20% below 1990 Level by 2030									109.4

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

** Projected annual emissions also include reductions from recent actions.

Table 1-3 depicts a summary by sector of the estimated GHG reductions and costs/savings of implementing the KCAPC recommended policies, after being adjusted for overlaps. It is important to note that some of the policy options with an estimated cost savings are likely to require significant up-front capital investments. For the policies recommended by the KCAPC to yield the levels of estimated emission reductions shown in Table 1-3, they must be implemented in a timely, aggressive, and thorough manner.

Table 1-3. Summary by Sector of Estimated Impacts of Implementing All of the KCAPC-Approved Recommendations (Cumulative Reductions and Costs/Savings)

Sector	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effective-ness ($/tCO_2e$)
	2020	2030	Total 2011–2030		
Residential, Commercial, and Industrial (RCI)	19.1	38.3	408.2	$1,220	$3
Energy Supply (ES)	37.4	75.8	755.9	$17,911	$24
Transportation and Land Use (TLU)	2.8	6.3	62.4	–$7,877	–$126
Agriculture, Forestry, and Waste (AFW)	4.4	7.9	89.7	$308	$3.4
Cross-Cutting Issues (CCI)	Non-quantified, enabling options				
TOTAL (includes all adjustments for overlaps)	**63.7**	**128.3**	**1,316.2**	**$11,562**	**$8.8**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

The values in this table do not include the effects of recent actions. Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings associated with the policy recommendations.

Within each sector, values have been adjusted to eliminate double counting for policies or elements of policies that overlap. In addition, values associated with policies or elements of policies within a sector that overlap with policies or elements of policies in another sector have been adjusted to eliminate double counting. Appendix F (for the ES sectors), Appendix G (for the RCI sectors), Appendix E (for the AFW sectors), and Appendix H (for the TLU sectors) of this report provide documentation of how sector-level emission reductions and costs (or cost savings) were adjusted to eliminate double counting associated with overlaps between policies.

Table 1-4 on the following pages summarizes the policy options analyzed and approved by the KCAPC, with one exception (ES-12), as recommendations to be included in this report. The sector tables below match the cover pages of each of the TWG appendices (E, F, G, H, and I). Each of the segments of the table portrays the policy recommendations, projected GHG emission reductions, the net present value costs or cost savings and the cost-effectiveness of each policy option. The detailed narrative explaining each policy option is included in the respective appendices to this report.

It is acknowledged that the Kentucky Public Service Commission (KPSC) participated in discussing the policy recommendations. However, the KPSC abstained from taking a position for or against any policy recommendation that could come before it in an adjudicated proceeding. It is also acknowledged that the KPSC may need additional statutory authority to consider some of the policy recommendations.

Table 1-4. Summary List of Policy Recommendations for All Sectors

Agriculture, Forestry, and Waste Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($\$/tCO_2e$)
		2020	2030	Total 2011–2030		
AFW-1	Forestry Management for Carbon Sequestration	0.04	0.07	0.86	$17.4	$20.3[9]
AFW-2	Expanded Use of Biomass Feed-stocks for Electricity, Heat, and Steam Production	*Costs/GHG Reductions Captured in ES-1, ES-5 and ES-7 Analysis*				
AFW-3a	On-Farm Energy Production	*GHG reductions accounted for in policies where biomass is used for Fuel (ES, RCI, & TLU)*				
AFW-3b	On-Farm Energy Efficiency Improvements	0.21	0.45	4.5	–$94	–$21
AFW-4	In-State Liquid/Gaseous Biofuels Production	*Costs/GHG Reductions Captured in TLU-10 Analysis*				
AFW-5a	Soil Carbon Management—NT/CT	0.37	0.74	7.8	$6	$1
AFW-5b	Soil Carbon Management—Winter Cover Crops	0.95	1.9	20	$141	$7
AFW-6	Increase Productivity of Abandoned, Underutilized, and Reclaimed Lands[10]	2.7	5.8	58	$50	$1
AFW-7a	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Mined Lands	0.02	0.09	0.16	–$19	–$120

[9] The benefits of increased forest carbon sequestration will last far beyond the policy period. When GHG reductions and cost-effectiveness are calculated considering the lifetime of the forest (~50 years), the results are 3.3 $MMtCO_2e$ and 5.3 $\$/tCO_2e$, respectively.

[10] This policy overlaps with policies in the ES sector; the overlapping benefits and costs were removed in the overall KCAPC process results shown for total benefits and costs in the final report.

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)
		2020	2030	Total 2011–2030		
AFW-7b	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Other Lands	0.55	1.0	11	$61	$5
AFW-8	Advanced MSW Reuse, Recycling, and Organic Waste Management Programs	0.84	1.3	16	$167	$10
AFW-9	Landfill Methane Energy Programs	1.4	2.4	29	$29	$1
	Sector Total After Adjusting for Overlaps	**4.4**	**7.9**	**90**	**$308**	**$3**
	Reductions From Recent Actions	**0**	**0**	**0**	**$0**	**$0**
	Sector Total Plus Recent Actions	**4.4**	**7.9**	**90**	**$308**	**$3**

$/tCO_2e = dollars per metric ton of carbon dioxide equivalent; ES = Energy Supply; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MSW = municipal solid waste; NT/CT = no till/conservation tillage; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative NPV represents positive net cash flows from the policy recommendation (i.e., the costs of the policy recommendation, when levelized over their expected lifetimes, are less than expected expenditures). Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

Totals do not equal sum of individual policy recommendations due to subtraction of overlaps.

Table 1-4 (continued). Energy Supply Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)
		2020	2030	Total 2011–2030		
ES-1	Biomass Development and Efficiency Improvements at Existing Power Plants					
	Supply-side efficiency	1.6	2.1	27.4	$240	$8.8
	Biomass co-firing	4.0	4.5	65.1	$1,065	$16.34
	Total*	5.7	6.5	92.5	$1,305	$14.1
	Dedicated biomass					
	*Stoker technology**	0.4	0.4	8.2	$342	$41.5
	*Fluidized bed technology**	0.4	0.4	8.2	$242	$29.4
ES-2	Demand-Side Energy Efficiency and Management Programs	*Moved to Residential, Commercial, and Industrial Technical Work Group as policy RCI-3.*				

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/t$CO_2$e)
		2020	2030	Total 2011–2030		
ES-3	Advanced Fossil Fuel Technology (IGCC, CCSR, Advanced Pulverized Coal, CFB) Incentives, Support, or Requirements					
	Scenario 1 (Supercritical without CCSR)					
	800 MW retired	0.7	0.7	7.4	$127.9	$17.2
	1,600 MW retired	1.9	1.9	21.1	$423.1	$20.1
	Scenario 2 (Conventional NGCC without CCSR)					
	600 MW retired	1.7	1.7	18.7	$307.2	$16.4
	1,200 MW retired	2.9	2.9	32.0	$544.0	$17.0
	*Scenario 3 (Supercritical with CCSR)**					
	800 MW retired	2.3	2.3	24.8	$824.8	$33.2
	1,600 MW retired	7.4	7.4	78.6	$2,729.5	$34.7
	Scenario 4 (Advanced NGCC with CCSR)					
	600 MW retired	2.4	2.4	26.8	$561.7	$21.0
	1,200 MW retired	4.2	4.2	46.3	$994.7	$21.5
ES-4	CCSR Enabling Policies, R&D, Infrastructure, and Incentives Including Enhanced Oil Recovery Using CO_2 (quantification considers CCSR demonstration project only)					
	*1 plant retrofitted**	1.8	1.8	23.5	$893.3	$37.9
	2 plants retrofitted	3.8	3.8	49.9	$1,891.7	$37.9
ES-5	Pricing Strategies to Promote Efficiency and Renewables Including Net Metering, Feed-In Tariff, Interconnection Rules, Inclined Rates, and Examination of the Standard Rate Structure (quantification considers feed-In tariff only)	1.2	5.2	43.9	$1,206	$27.5
ES-6	New Nuclear Energy Capacity	0.0	19.5	116.7	$2,481	$21.3
ES-7	Renewable Energy Incentives and Barrier Removal, Including CHP					
	*Scenario 1 (mixed renewable)**	15.1	22.2	263.6	$5,489	$20.8
	Scenario 2 (biomass)	15.1	22.3	272.2	$4,368	$16.0
	Scenario 3 (out-of-state wind)	15.1	22.3	272.2	$3,012	$11.1
	Scenario 4 (solar PV)	15.1	22.2	271.4	$8,157	$30.1

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/$tCO_2e$)
		2020	2030	Total 2011–2030		
ES-8	Technology Research and Development (Not Including CCSR or Wind Potential Study) (quantification considers solar PV demonstration projects only)	0.013	0.013	0.24	$39.6	$164.9
ES-9	Policies to Support Wind Energy	*Not Quantified*				
ES-10	Shale Gas Development and Natural Gas Transportation Infrastructure and Gas-to-Liquids Technology	0.013	0.028	0.271	$22.3	$82.5
	Gas-to Liquids-Technology	0.039	0.077	0.763	$137.3	$179.1
ES-11	Smart Grid, Including Transmission and Distribution Efficiency (quantification considers smart grid only)	6.45	13.35	135.73	$3,608.4	$26.6
	Sector Total After Adjusting for Overlaps	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**
	Reductions From Recent Actions (EISA Title II requirements for new appliances and lighting)	**0.0**	**0.0**	**0.0**	**$0.0**	**$0**
	Sector Total Plus Recent Actions	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; CCSR = carbon capture and storage or reuse; CFB = circulating fluidized bed; CHP = combined heat and power; CO_2 = carbon dioxide; DSM = demand-side management; EERS = energy efficiency resource standard; EISA = Energy Independence and Security Act of 2007; EPA = U.S. Environmental Protection Agency; GHG = greenhouse gas; IGCC = integrated gasification combined cycle; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MW = megawatts; NGCC = natural gas combined cycle; N/A = not applicable; PBF = performance-based financing; PV = photovoltaics; RCI = Residential, Commercial, and Industrial; R&D = research and development; RE = renewable energy.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative net present value represents positive net cash flows from the policy (i.e., the costs of the policy, when levelized over their expected lifetimes, are less than expected expenditures). Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

*These scenarios were used in the sector totals. The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

Table 1-4 (continued). Residential, Commercial, and Industrial Summary List of Policy Recommendations*

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/$tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-1	Improve Building Codes for Energy Efficiency, Coupled with Improved Energy Code Training and Enforcement	0.4	1.2	9	–$213	–$23
RCI-2	Promote, Encourage, and Provide Incentives for "Beyond-Code" Efficiency in All Building Characteristics and Systems That Impact Energy Consumption	2	5	50	–$1,376	–$27
RCI-3	Expand Utility DSM Programs for Electricity	6	19	169	–$3,340	–$20
RCI-4	Develop and Implement Comprehensive Education, Outreach, and Marketing, Including Consumer Awareness, School Curriculum, Truth-in-Advertising, Technical Information and Support (e.g., How to Do GHG Inventories, Rationales for Action, etc.)	*Not Quantified*				
RCI-5	Financing Programs and Incentives for Energy Efficiency and CHP (PBF, Revolving Loans, etc.) (ONLY CHP QUANTIFIED)	12	22	259	$538	$2
RCI-6	Financing Programs, Incentives, Policies, and Research for Conversion to Renewable Energy or Low-Carbon Energy Sources (ONLY RENEWABLE ELECTRICITY QUANTIFIED)	1.4	4.4	35	$3,372	$96
RCI-7	Government Lead by Example (GLE) in Highly Efficient State and Local Government Buildings	0.7	1.6	15	–$16	–$1
RCI-8	Training and Education for Builders, Contractors, and Building Operators	*Not Quantified*				
RCI-9	Building Commissioning and Recommissioning, Including Energy Tracking and Benchmarking, and Implement a Building Energy Labeling Program	3	5	50	–$1,117	–$23
RCI-10	Implement Advanced Metering Technologies and Associated Policies for Greater Load Management, Customer Control, Awareness, Price Signaling, etc.	*Moved to Energy Supply Technical Work Group as policy recommendation ES-11.*				
	Sector Total After Accounting for Overlaps	**19**	**38**	**408**	**$1,220**	**$3**
	Reductions From Recent Actions (Existing DSM Programs, HB 2 for Government Buildings)	**1.5**	**3.2**	**32**		
	Sector Total Plus Recent Actions	**20**	**42**	**441**		

Negative values in the Net Present Value (NPV) and the Cost-Effectiveness columns represent net cost savings. Negative NPV represents positive net cash flows from the policy recommendation (the costs of the policy, i.e., new energy efficiency equipment (air conditioners, furnaces, etc.), when levelized over their expected lifetimes, are less than expected energy expenditures. Policy recommendations with estimated cost savings still are likely to require significant up-front capital investment for the new energy efficiency equipment.

Totals may not add up due to rounding.

\$/tCO_2e = dollars per metric ton of carbon dioxide equivalent; CHP = combined heat and power; DSM = demand-side management; GHG = greenhouse gas; HB = House Bill; MMtCO_2e = million metric tons of carbon dioxide equivalent; N/A = not applicable; PBF = Public Benefit Fund.

GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five).

The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMtCO_2e of GHG reductions (column five).

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policies.

*This analysis reflects the use of full-fuel-cycle GHG emission factors.

On October 27, 2010, the RCI Technical Work Group (TWG) discussed the issue of direct versus “full-fuel-cycle” emission factors. Full-fuel-cycle GHG emission factors include the GHG emissions associated with the production, processing, transmission, and distribution of fuels and electricity. These “upstream” emissions associated with energy supply are 5%–25% greater than direct, or end-use, emission factors that are calculated as a result of fuel combustion at the power station or building. On the October 27 call, the RCI TWG decided to present the summary table above showing GHG emissions and cost-effectiveness based on full-fuel-cycle emission factors. The work group also decided that the results for each RCI policy recommendation should show both direct and full fuel cycle emissions factors. On balance, the difference in 2011–2030 cumulative GHG reductions is about 10% between the two methodologies. The choice of emission factor does not impact the net present value calculations. However, because cumulative 2011–2030 GHG emission reductions are increased under full-fuel-cycle emission factors, the \$/ton cost-effectiveness estimates will differ modestly between the two methodologies.

Table 1-4 (continued). Transportation and Land Use Summary List of Policy Recommendations[11]

Policy No.	Policy Recommendation	GHG Reductions (MMtCO_2e)			Net Present Value (Million \$)	Cost-Effective-ness (\$/tCO_2e)	Energy Savings (Million gallons) 2011–2030
		2020	2030	Total 2011–2030			
TLU-1	Bicycle and Pedestrian Comprehensive Plan and Infrastructure Development	0.055	0.087	1.049	–\$445	–\$424	–87
TLU-2/6	Livability, Brownfield Redevelopment, Downtown Revitalization, Location-Efficient Strategies, Land Use, Building Code Reform and Connectivity	*Not Quantified*					
TLU-3A	Transportation System Management	0.32	0.38	5.32	–\$1,070	–\$201	–604
TLU-3B/4	Transit Management and Infrastructure	0.07	0.15	1.56	\$110	\$71	–143

[11] The cost analysis provides figures that represent the net of both positive up-front costs and cost savings over time. Data results that indicate the potential for net cost savings should be viewed with an understanding that in some cases, initial up-front costs may be necessary in order to achieve the net cost savings over time.

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)	Energy Savings (Million gallons) 2011–2030
		2020	2030	Total 2011–2030			
TLU-5	Education and Outreach for Vehicle Maintenance, Idle Reduction, and Co-Driving, and Promote Alternative Modes of Travel	*Not Quantified*					
TLU-7	Parking Management and Ride Sharing	0.204	0.345	4.032	–$2,327	–$554	–335
TLU-8	Strategies to Move Freight in More GHG-Efficient Ways	0.463	1.079	10.31	–$424	–$41.16	–2,786
TLU-9	Promote Consumption of Locally Produced Goods and Services	0.31	0.55	6.36	–$769	–$120.87	–472
TLU-10	Promote the Use of Alternative Transportation Fuels	0.312	1.015	8.475	$30.7	$3.63	–1,880.9
TLU-11	Promote the Use of Clean Vehicles	1.36	3.41	31.34	–$3,581	–$114.30	–2,330
	Sector Total After Adjusting for Integration	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**–7,980**
	Reductions from Recent Actions	**0**	**0**	**0**	**$0**	**$0**	**0**
	Sector Total Plus Recent Actions	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**7,980**

$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; NQ = not quantified.

Notes: The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important recommendations.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative net present value represents positive net cash flows from the policy recommendation (i.e., the costs of the policy recommendation, when levelized over their expected lifetimes, are less than expected expenditures). Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

Table 1-4 (continued). Cross-Cutting Issues Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)
		2020	2030	Total (2011–2030)		
CCI-1	Greenhouse Gas (GHG) Emission Inventories, Forecasts, Reporting, and Registry	*Not Quantified*				
CCI-2	Public Education and Outreach	*Not Quantified*				
CCI-3	Adaptation and Vulnerability	*Not Quantified*				
CCI-4	Statewide GHG Emission Reduction, Energy Intensity, and Energy Efficiency Goals, Targets, and Metrics	*Not Quantified*				
CCI-5	State and Local Government GHG Emission Reduction, Energy Intensity, and Energy Efficiency Activities (Lead by Example)	*Not Quantified*				
CCI-6	Local GHG Emission Reduction, Energy Intensity, and Energy Efficiency Actions	*Not Quantified*				
CCI-7	Financial Policies	*Not Quantified*				
CCI-8	Conduct an Impact Analysis of Federal GHG Constraints on Kentucky	*Not Quantified*				

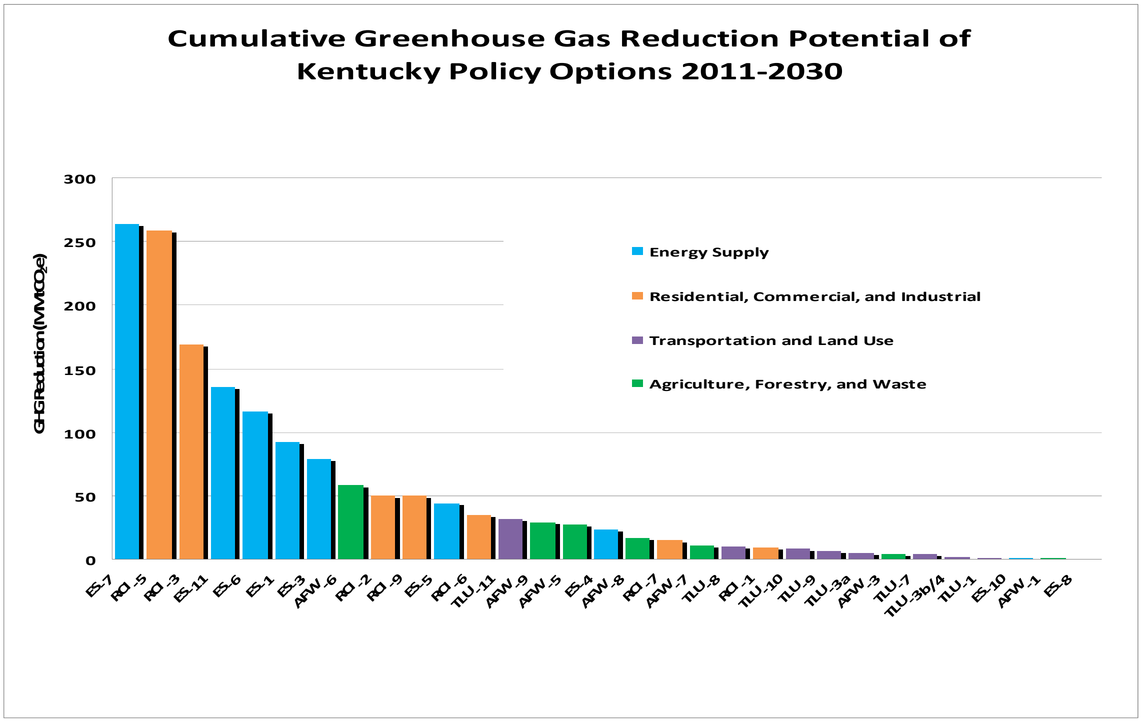
GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

Note: The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policies.

Perspectives on Policy Recommendations

As explained above, the KCAPC considered the estimates of the GHG reductions that could be achieved and the costs (or cost savings) of 33 of its recommendations. Figure 1-5 presents the estimated tons of GHG emission reductions for each policy recommendation for which estimates were quantified, expressed as a cumulative figure for the period 2011–2030 based on the assumptions and data from 2010/2011. In addition to the imprecision in GHG reductions achieved by each policy recommendation, there are uncertainties about the exact cost (or cost savings) per ton of reduction achieved.

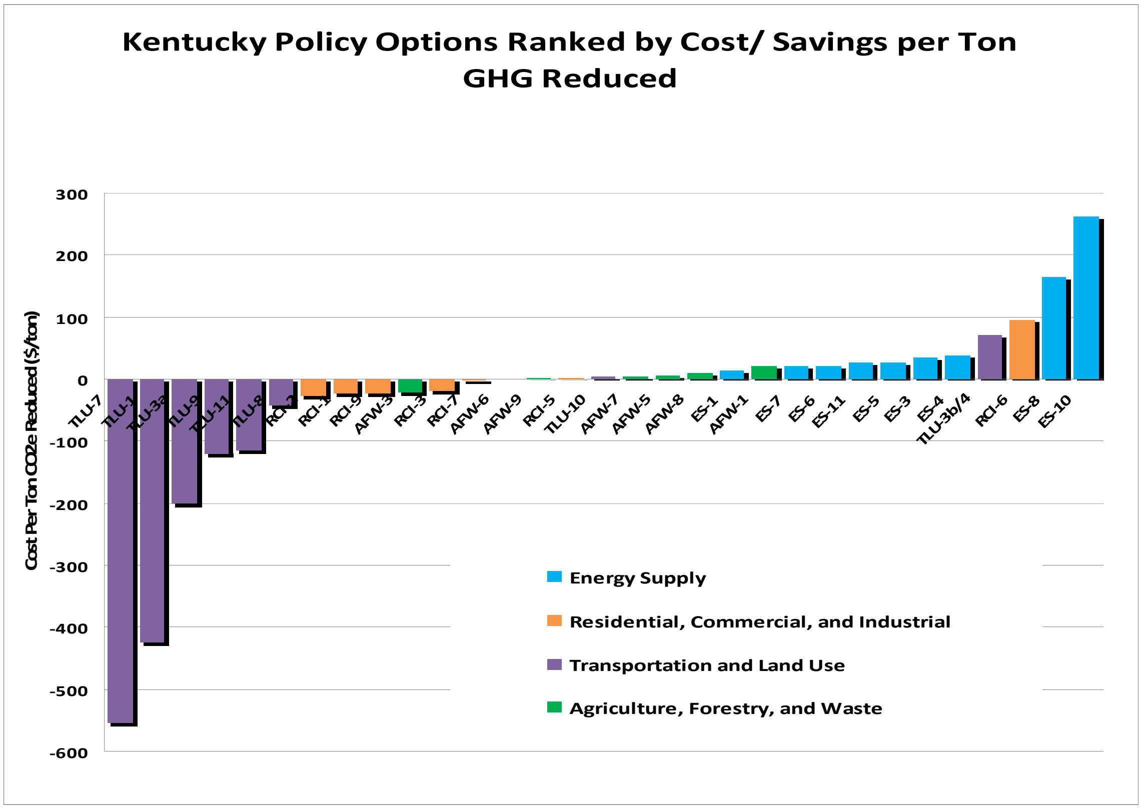
Figure 1-5. KCAPC Policy Recommendations Ranked by Cumulative (2011–2030) GHG Reduction Potential



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; AFW = Agriculture, Forestry, and Waste Management; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply.

Figure 1-6 presents the estimated dollars-per-ton cost (or cost savings, depicted as a negative number) for each policy recommendation for which cost estimates were quantified, expressed as a cumulative figure for the period 2011–2030. This measure is calculated by dividing the net present value of the cost of the policy recommendation by the cumulative GHG reductions, all for the period 2011–2030.

Figure 1-6. KCAPC Policy Recommendations Ranked by Cumulative (2011–2030) Net Cost/Cost Savings per Ton of GHG Removed

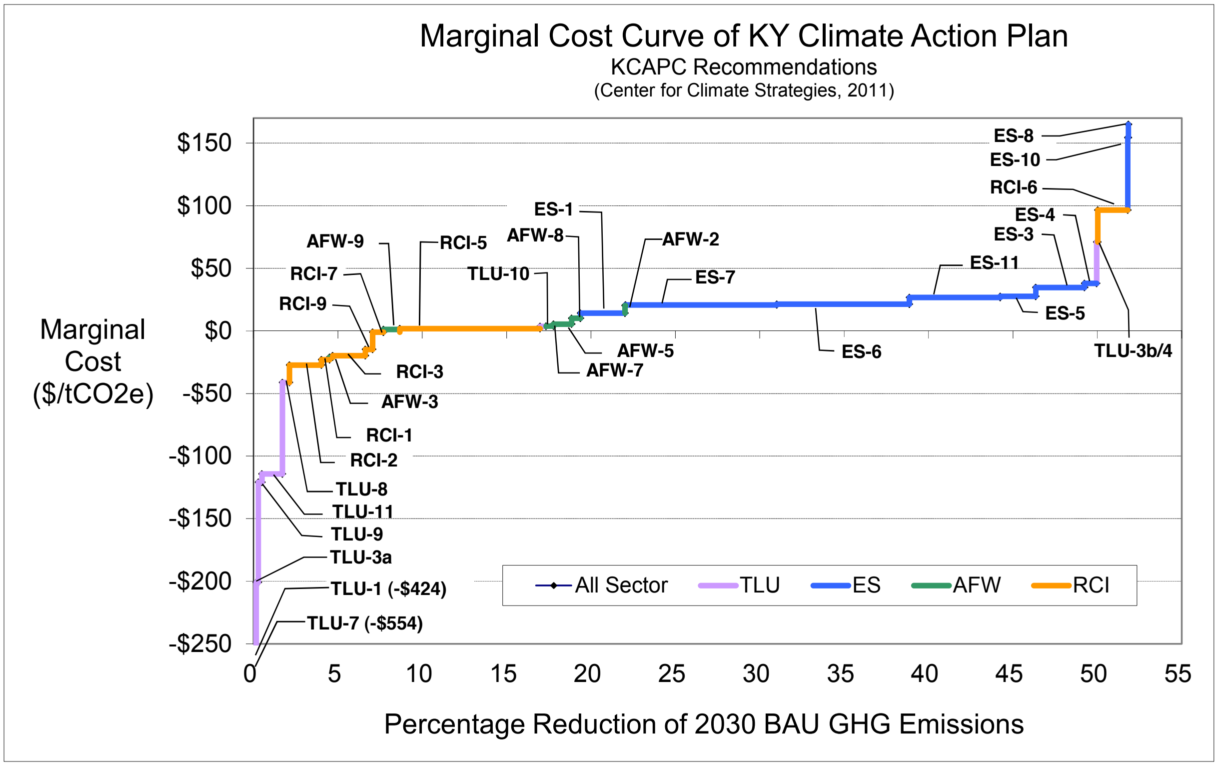


CO_2 = carbon dioxide; GHG = greenhouse gas; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply; AFW = Agriculture, Forestry, and Waste Management.

Negative values represent net cost savings, and positive values represent net costs associated with the policy recommendations. It is important to note that some of the policy options with an estimated cost savings are likely to require significant up-front capital investments.

Figure 1-7 presents a step-wise marginal cost curve for Kentucky. The horizontal (x) axis represents the percentage of GHG emission reductions in 2030 for each policy recommendation relative to the BAU forecast. The vertical axis represents the marginal cost of mitigation (expressed as the cost-effectiveness of each policy recommendation on a cumulative basis, 2011–2030). In the figure, each horizontal segment represents an individual policy. The width of the segment indicates the GHG emission reduction potential of the recommendation in percentage terms. The height of the segment relative to the vertical axis shows the average cost (or saving) of reducing one tCO_2e of GHG emissions with the application of the recommendation. Note that recommendation steps appearing below the "$0" line near the middle of the graph (on the vertical axis) are cost-saving measures, while the recommendations above this line have positive net direct costs.

Figure 1-7. Step-wise Marginal Cost Curve for Kentucky, 2030



$/tCO2e = dollars per metric ton of carbon dioxide equivalent; BAU = business as usual; GHG = greenhouse gas; KY = Kentucky; AFW = Agriculture, Forestry, and Waste Management; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply.

Negative values represent net cost savings, and positive values represent net costs associated with the policy recommendations. It is important to note that some of the policy options with an estimated cost savings are likely to require significant up-front capital investments.

Note: Results have been adjusted to remove overlaps between policies.

Chapter 2
Inventory and Projections of GHG Emissions

Introduction

This chapter summarizes Kentucky's greenhouse gas (GHG) emissions and sinks (carbon storage) from 1990 to 2030. The Center for Climate Strategies (CCS) prepared a draft of Kentucky's GHG emissions inventory and reference case projections for the Kentucky Energy and Environment Cabinet (KEEC) and the Kentucky Climate Action Plan Council (KCAPC). The draft inventory and reference case projections, completed in January 2010, provided KEEC and the KCAPC with an initial, comprehensive understanding of current and possible future GHG emissions. The draft report was provided to the KCAPC and its Technical Work Groups (TWGs) to assist them in understanding past, current, and possible future GHG emissions in Kentucky, and thereby inform the policy recommendation development process. The KCAPC and TWGs have reviewed, discussed, and evaluated the draft inventory and methodologies, as well as alternative data and approaches for improving the draft GHG inventory and forecast. The inventory and reference case forecast have since been revised to address the comments provided by the KCAPC. The information in this chapter reflects the information presented in the *Final Kentucky Greenhouse Gas Inventory and Reference Case Projections* report (hereafter referred to as the Inventory and Projections report).[1]

Historical GHG emission estimates (1990 through 2007)[2] were developed using a set of generally accepted principles and guidelines for state GHG emissions, relying to the extent possible on Kentucky-specific data and inputs when it was possible to do so. The reference case projections (2008–2030) are based on a compilation of various projections of electricity generation, fuel use, and other GHG-emitting activities for Kentucky, along with a set of simple, transparent assumptions described in the final Inventory and Projections report. It is important to note that the analysis was done in 2009–2010, and recent announcements by utilities and more recent actions by the U.S. Environmental Protection Agency (EPA) are not included.

The Inventory and Projections report covers the six types of gases included in the U.S. GHG inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric—CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential-weighted basis.[3]

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[1] Center for Climate Strategies. *Final Kentucky Greenhouse Gas Inventory and Reference Case Projections: 1990–2030*. Prepared for the Kentucky Energy and Environment Cabinet. June 2010.

[2] The last year of available historical data varies by sector, ranging from 2004 to 2008.

[3] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth–atmosphere system. Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth). See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental Panel on

It is important to note that the emission estimates reflect the *GHG emissions associated with the electricity sources used to meet Kentucky's demands*, corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the *GHG emissions produced by electricity generation facilities in the state*—a production-based method. The study covers both methods of accounting for emissions, but for consistency, all total results are reported as *consumption-based*.

Kentucky GHG Emissions: Sources and Trends

Table 2-1 provides a summary of GHG emissions estimated for Kentucky by sector for 1990, 2000, 2005, 2010, 2015, 2020, 2025, and 2030. As shown in this table, Kentucky is estimated to be a net source of GHG emissions (positive, or gross, emissions). Kentucky's forested landscape, urban forestry, land use, and the cultivation of agricultural soils serve as sinks of GHG emissions (removal of emissions, or negative emissions). Kentucky's net emissions subtract the equivalent GHG reduction from emission sinks from the gross GHG emission totals. The following sections discuss GHG emission sources and sinks, trends, projections, and uncertainties.

Table 2-1. Kentucky Historical and Reference Case GHG Emissions, by Sector: 1990–2030*

Million Metric Tons CO_2e	1990	2000	2005	2010	2015	2020	2025	2030
Energy (Consumption Based)	**121.6**	**149.5**	**165.9**	**173.8**	**187.4**	**199.2**	**212.4**	**225.8**
Electricity Use (Consumption)	**59.2**	**78.5**	**90.9**	**101.1**	**110.3**	**118.0**	**126.2**	**134.3**
Electricity Production (in-state)	68.5	89.1	98.4	105.4	115.0	123.0	131.5	140.0
Coal	*68.3*	*88.7*	*93.6*	*101.2*	*110.3*	*118.0*	*126.3*	*134.4*
Natural Gas	*0.016*	*0.31*	*1.64*	*1.89*	*2.07*	*2.23*	*2.28*	*2.39*
Oil	*0.090*	*0.13*	*3.12*	*2.32*	*2.53*	*2.70*	*2.87*	*3.07*
Biomass (CH_4 and N_2O)	*0.000*	*0.000*	*0.002*	*0.003*	*0.003*	*0.003*	*0.003*	*0.004*
MSW/Landfill Gas	*0.000*	*0.000*	*0.036*	*0.057*	*0.062*	*0.066*	*0.071*	*0.076*
Other Wastes	*0.000*	*0.000*	*0.008*	*0.007*	*0.008*	*0.009*	*0.009*	*0.010*
Net Exported Electricity	–9.27	–10.58	–7.51	–4.30	–4.69	–5.01	–5.36	–5.70
Residential/Commercial/Industrial (RCI) Fuel Use	**26.7**	**30.4**	**31.2**	**28.3**	**29.1**	**28.8**	**28.5**	**27.7**
Coal	*8.54*	*5.77*	*5.88*	*5.28*	*5.61*	*5.56*	*5.40*	*5.04*
Natural Gas	*8.72*	*11.3*	*11.2*	*10.8*	*10.8*	*10.8*	*10.8*	*10.6*
Petroleum	*9.34*	*13.3*	*14.0*	*12.2*	*12.5*	*12.4*	*12.2*	*11.9*
Wood (CH_4 and N_2O)	*0.11*	*0.06*	*0.10*	*0.10*	*0.10*	*0.11*	*0.11*	*0.11*
Transportation	**27.2**	**33.2**	**37.3**	**36.8**	**40.9**	**45.5**	**50.8**	**56.9**
On-road Gasoline	*16.4*	*19.0*	*19.2*	*20.3*	*22.2*	*24.2*	*26.3*	*28.5*
On-road Diesel	*5.77*	*8.90*	*9.59*	*10.8*	*12.7*	*15.1*	*18.2*	*22.0*
Marine Vessels	*1.17*	*1.35*	*3.63*	*1.43*	*1.50*	*1.57*	*1.64*	*1.70*
Rail, Natural Gas, LPG, Other	*1.49*	*1.28*	*1.48*	*2.12*	*2.13*	*2.13*	*2.13*	*2.13*
Jet Fuel and Aviation Gasoline	*2.32*	*2.68*	*3.35*	*2.21*	*2.39*	*2.48*	*2.56*	*2.62*
Fossil Fuel Industry	**8.51**	**7.33**	**6.50**	**7.46**	**7.05**	**6.91**	**6.91**	**6.90**

Climate Change. Cambridge, United Kingdom: Cambridge University Press. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.

Million Metric Tons CO_2e	1990	2000	2005	2010	2015	2020	2025	2030
Natural Gas Industry	*4.00*	*3.59*	*3.43*	*3.95*	*4.06*	*4.17*	*4.30*	*4.47*
Oil Industry	*0.077*	*0.058*	*0.047*	*0.052*	*0.057*	*0.062*	*0.069*	*0.076*
Coal Mining (CH_4)	*4.43*	*3.68*	*3.03*	*3.46*	*2.93*	*2.67*	*2.53*	*2.35*
Industrial Processes	**4.75**	**5.65**	**6.52**	**7.75**	**8.50**	**9.35**	**10.70**	**12.55**
Cement Manufacture (CO_2)	0.37	0.35	0.54	0.53	0.59	0.64	0.69	0.73
Lime Manufacture (CO_2)	0.46	0.48	0.72	0.77	0.83	0.88	0.94	1.01
Limestone and Dolomite Use (CO_2)	0.31	0.28	0.32	1.08	1.08	1.08	1.08	1.08
Soda Ash (CO_2)	0.040	0.038	0.036	0.034	0.033	0.031	0.029	0.029
Iron & Steel (CO_2)	2.43	2.57	2.62	2.70	2.70	2.70	2.70	2.70
Ammonia and Urea (CO_2)	0.011	0.010	0.007	0.008	0.008	0.008	0.008	0.008
ODS Substitutes (HFC, PFC)	0.005	1.02	1.48	1.90	2.56	3.32	4.59	6.35
Electric Power T&D (SF_6)	0.60	0.34	0.34	0.31	0.29	0.28	0.27	0.26
Aluminum Production (PFC)	0.53	0.57	0.46	0.42	0.41	0.40	0.40	0.39
Waste Management	**2.18**	**2.13**	**2.16**	**2.33**	**1.75**	**1.87**	**1.98**	**2.10**
Waste Combustion	0.11	0.17	0.20	0.21	0.21	0.21	0.21	0.21
Landfills	1.71	1.56	1.54	1.68	1.09	1.18	1.27	1.37
Wastewater Management	0.36	0.40	0.41	0.44	0.46	0.48	0.50	0.52
Agriculture	**7.89**	**6.96**	**7.88**	**7.05**	**6.81**	**6.65**	**6.56**	**6.59**
Enteric Fermentation	3.25	2.91	3.12	3.14	3.06	3.02	3.04	3.16
Manure Management	0.48	0.48	0.53	0.45	0.42	0.40	0.40	0.41
Agricultural Soils	3.67	3.31	4.08	3.35	3.26	3.17	3.07	2.98
Agricultural Burning	0.014	0.017	0.018	0.019	0.020	0.021	0.022	0.023
Agricultural Liming	0.48	0.24	0.13	0.088	0.057	0.037	0.024	0.016
Forest Wildfires (N_2O and CH_4)	**0.29**	**1.72**	**0.66**	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**
Total Gross Emissions (Consumption Basis)	**136.7**	**165.9**	**183.1**	**191.6**	**205.1**	**217.7**	**232.3**	**247.7**
Increase relative to 1990		*21%*	*34%*	*40%*	*50%*	*59%*	*70%*	*81%*
Emissions Sinks	**–9.94**	**–7.77**	**–7.57**	**–7.57**	**–7.57**	**–7.57**	**–7.57**	**–7.57**
Forested Landscape	–4.71	–4.71	–4.71	–4.71	–4.71	–4.71	–4.71	–4.71
Urban Forestry and Land Use	–4.09	–1.92	–1.73	–1.73	–1.73	–1.73	–1.73	–1.73
Agricultural Soils (Cultivation Practices)	–1.14	–1.14	–1.14	–1.14	–1.14	–1.14	–1.14	–1.14
Net Emissions (Consumption Basis) (including forestry and land use sinks)	**126.8**	**158.2**	**175.5**	**184.0**	**197.6**	**210.1**	**224.8**	**240.2**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; CH_4 = methane; N_2O = nitrous oxide; MSW = municipal solid waste; LPG = liquefied petroleum gas; ODS = ozone-depleting substance; HFC = hydrofluorocarbon; PFC = perfluorocarbon; SF_6 = sulfur hexafluoride; T&D = transmission and distribution.

* Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Historical Emissions

Overview

In 2005, on a gross emissions consumption basis (i.e., excluding carbon sinks), activities in Kentucky accounted for approximately 183 million metric tons (MMt) of CO_2e emissions, an amount equal to 2.6% of total U.S. gross GHG emissions. On a net emissions basis (i.e., including carbon sinks), activities in Kentucky accounted for approximately 176 $MMtCO_2e$ of emissions in 2005, an amount equal to 2.8% of total U.S. net GHG emissions.[4] Kentucky's gross GHG emissions are rising at a faster rate than those of the nation as a whole. From 1990 to 2005, Kentucky's gross GHG emissions increased by 34%, while national gross emissions rose by 16%.

On a per capita basis, Kentucky residents emitted about 37 metric tons (t) of gross CO_2e in 1990, much higher than the 1990 national per capita emissions of 25 tCO_2e. Figure 2-1 illustrates the State's emissions per capita and per unit of economic output.[5] Unlike the national per capita emissions, which remained nearly constant from 1990 to 2005, the Kentucky per capita emissions increased by 19% from 1990 to 2005. The electricity supply sector shows the greatest difference between per capita emissions in Kentucky and the nation, at 22 tCO_2e per capita in Kentucky for this sector, compared to 8 tCO_2e per capita nationally. This is because the electricity consumed in Kentucky relies on a high amount of coal in the generation fuel mix relative to the nation as a whole—about 90% for Kentucky, versus 50% for the United States in 2005. The use of coal has led to low electricity rates in Kentucky compared to the rest of the country, which has allowed energy-intensive industries to flourish in the state, as acknowledged in Kentucky's Energy Plan.[6] Like the nation as a whole, Kentucky's economic growth exceeded emissions growth throughout the 1990–2005 period (leading to declining estimates of GHG emissions per unit of state product). From 1990 to 2005, emissions per unit of gross product dropped by 11% in Kentucky and by about 26% nationally.[7]

The principal sources of Kentucky's GHG emissions in 2005 were electricity consumption; transportation; and residential, commercial, and industrial (RCI) fuel use. They accounted for 50%, 20%, and 17% of Kentucky's gross GHG emissions, respectively, as shown in Figure 2-2.

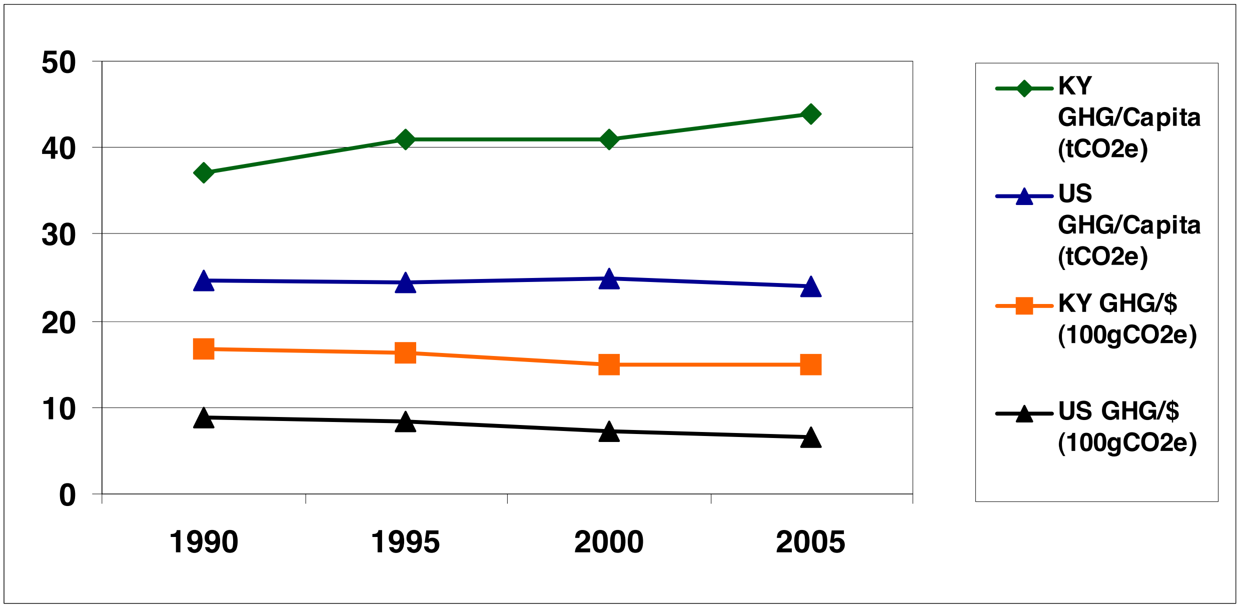
[4] The national emissions used for these comparisons are based on 2005 emissions from U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006*, April 15, 2008, EPA430-R-08-005. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[5] Historical Kentucky population statistics are compiled by Kentucky State Data Center from U.S. Census Bureau data, available at http://ksdc.louisville.edu/kpr/popest/est.htm. Kentucky population projections through 2050 are available from the same source, at http://ksdc.louisville.edu/kpr/pro/projections.htm.

[6] Governor Steven L. Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence,* November 2008.

[7] Based on real gross domestic product (millions of chained 2000 dollars) that excludes the effects of inflation, available from the U.S. Bureau of Economic Analysis (http://www.bea.gov/regional/gsp/). The national emissions used for these comparisons are based on 2005 emissions from EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006*, April 15, 2008, US EPA #430-R-08-005 (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

Figure 2-1. Kentucky and U.S. Gross GHG Emissions, Per Capita and Per Unit Gross Product, 1990–2005

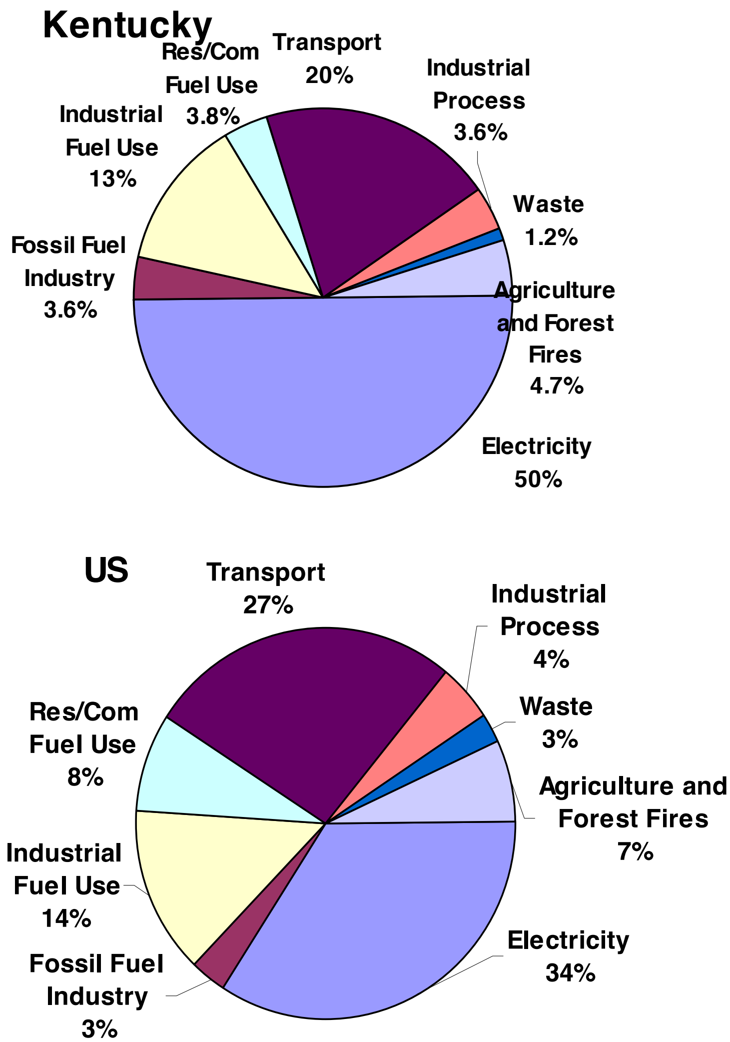


GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent; g = grams.

Figure 2-2 shows agriculture and forest fires were the next-largest contributors of gross GHG emissions in 2005, accounting for 4.7% of the 2005 gross GHG emissions in Kentucky. The agriculture sector includes emissions from enteric fermentation, manure management, agricultural soils, and agricultural burning. The fossil fuel industries and industrial processes each accounted for about 3.6% of Kentucky's gross GHG emissions in 2005. The fossil fuel industry sector includes GHG emissions associated with natural gas production, processing, transmission and distribution (T&D), and pipeline fuel use, as well as with oil production and refining and coal mining. Industrial process emissions are dominated by CO_2 releases in the production of iron and steel and the use of HFCs as substitutes for ozone-depleting chlorofluorocarbons (CFCs), which are rising rapidly through the historical and projection periods due to the increasing use of HFCs and PFCs as substitutes for ozone-depleting CFCs.[8] Other industrial sources of process CO_2 emissions include lime production, cement production, ammonia production, and the use of soda ash, limestone, dolomite, and urea. In addition, fugitive SF_6 is released during the use of electric power T&D equipment, while aluminum production is responsible for the release of PFCs. Also, the waste management sector contributed CH_4 and N_2O emissions, which accounted for 1.2% of total gross GHG emissions in Kentucky in 2005. The waste management sector is dominated by CH_4 fugitive emissions from landfills, but also includes emissions from waste combustion and wastewater management.

[8] Chlorofluorocarbons are also potent GHGs. However, they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol on Substances That Affect the Ozone Layer. See Appendix I in the final Inventory and Projections report for Kentucky (http://www.kyclimatechange.us/Inventory_Forecast_Report.cfm).

Figure 2-2. Gross GHG Emissions by Sector, 2005: Kentucky and U.S.



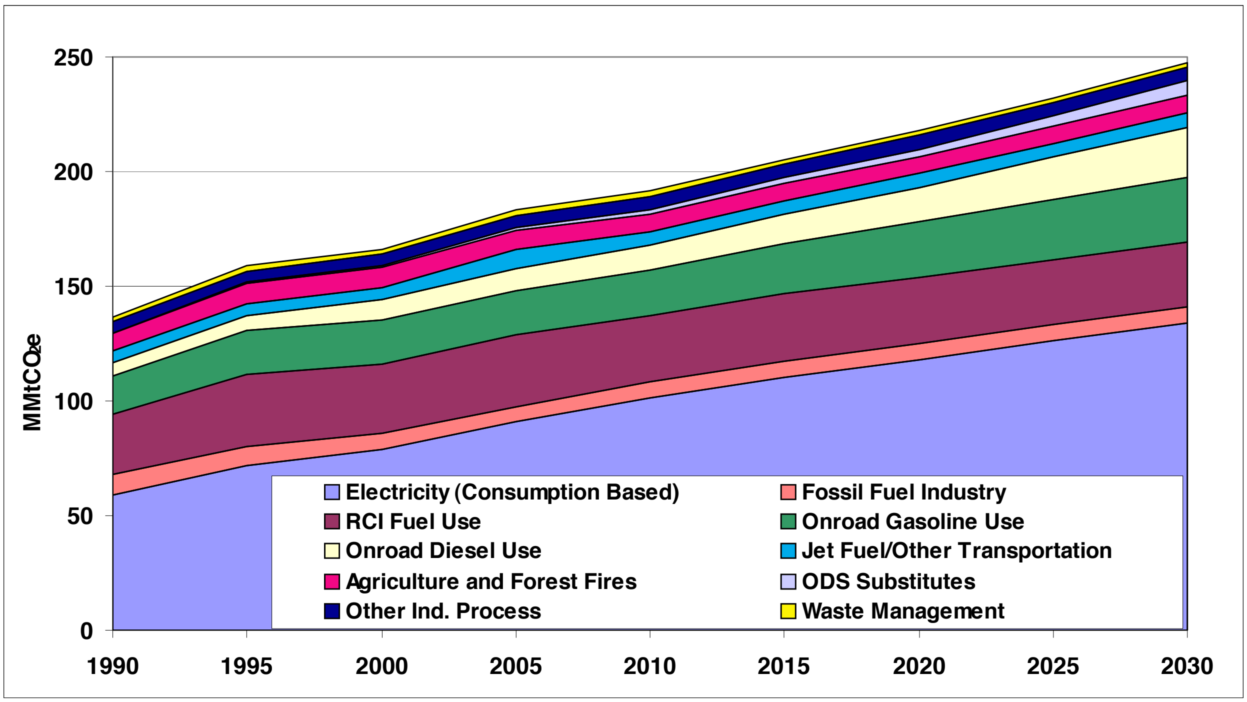
Res/Com = residential and commercial.

Estimates of carbon sinks in Kentucky include forested landscape, urban forests, land use changes, and agricultural soil cultivation practices. Note that forest wildfires and prescribed burning are sources of GHG emissions that were included with the agriculture sector in Figure 2-2. Forestry activities and agricultural soil cultivation practices in Kentucky are estimated to be net sinks of GHG emissions in all years. The current estimates indicate that about 7.6 $MMtCO_2e$ were stored in Kentucky biomass in 2005. This leads to *net* emissions of 176 $MMtCO_2e$ in Kentucky in 2005, an amount equal to 2.8% of total U.S. net GHG emissions.

Reference Case Projections (Business as Usual)

Relying on a variety of sources for projections, as noted in the Inventory and Projections report, a simple reference case projection of GHG emissions through 2030 was developed. As illustrated in Figure 2-3 and shown numerically in Table 2-1, under the reference case projections, Kentucky's gross GHG emissions continue to grow steadily, climbing to about 248 $MMtCO_2e$ by 2030, or 81% above 1990 levels. This equates to a 1.2% annual rate of growth from 2005 to 2030. Relative to 2005, the shares of emissions associated with electricity consumption, transportation, and industrial processes increase to 54%, 23%, and 5%, respectively, in 2030. The shares of emissions from the RCI fuel use, fossil fuel industries, waste management, and agriculture sectors all decrease by 2030, relative to 2005, to 11%, 3%, 0.8%, and 3%, respectively.

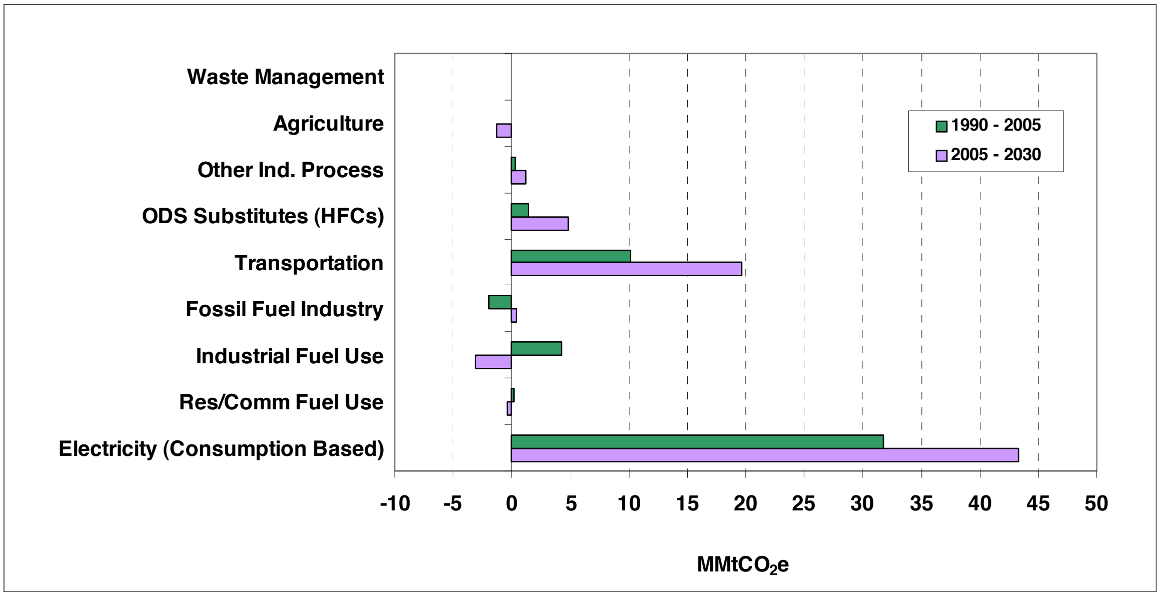
Figure 2-3. Kentucky Gross GHG Emissions by Sector, 1990–2030: Historical and Projected



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; RCI = direct fuel use in residential, commercial, and industrial sectors; ODS = ozone-depleting substance; Ind. = industrial.

Emissions associated with electricity consumption are projected to be the largest contributor to future GHG emissions growth, followed by emissions associated with the transportation sector, as shown in Figure 2-4. Other sources of emissions growth include the increasing use of HFCs and PFCs as substitutes for ozone-depleting substances in refrigeration, air conditioning, and other applications, other industrial processes, and the fossil fuel industry. Table 2-2 summarizes the growth rates that drive the growth in the Kentucky reference case projections, as well as the sources of these data.

Figure 2-4. Sector Contributions to Gross Emissions Growth in Kentucky, 1990–2025: Reference Case Projections



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; Ind. = industrial; ODS = ozone-depleting substance; HFCs = hydrofluorocarbons; Res/Comm = direct fuel use in the residential and commercial sectors.

Table 2-2. Key Annual Growth Rates for Kentucky, 1990–2030: Historical and Projected

Growth Factors	1990–2008	2009–2030	Sources
Population	0.82%	0.72%	Historical Kentucky population statistics are compiled by Kentucky State Data Center from U.S. Census Bureau data, are available at http://ksdc.louisville.edu/kpr/popest/est.htm. Kentucky population projections through 2050 are available from the same source at http://ksdc.louisville.edu/kpr/pro/projections.htm.
Electricity Sales	2.4%	1.5%	For 1990-2008, annual growth rate in total electricity sales for all sectors combined in Kentucky calculated from EIA State Electricity Profiles (Table 8) available from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls.
Vehicle Miles Traveled	1.9%	2.2%	Based on historical VMT and projected VMT growth rates provided by the Kentucky Transportation Cabinet.

EIA = Energy Information Administration; VMT = vehicle miles traveled.

A Closer Look at the Three Major Sources: Electricity Consumption, Transportation, and RCI Fuel Use

As shown in Figure 2-2, electricity use in 2005 accounted for 50% of Kentucky's gross GHG emissions (about 91$MMtCO_2e$), which was higher than the national average share of emissions from electricity generation (34%).[9] On a per capita basis, Kentucky's GHG emissions from electricity consumption are higher than the national average (in 2005, 22 tCO_2e per capita in Kentucky, versus 8 tCO_2e per capita nationally). Electricity generation in Kentucky is dominated

[9] For the United States as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the US imports only about 1% of its electricity, and exports even less.

by steam units, which are primarily fueled by coal. In 2005, 90% of Kentucky's electricity generation was provided by coal-fired units, compared to 50% for the nation. Throughout the historical and forecasted periods, Kentucky power plant generation exceeds the electricity consumed in the state. The remaining electricity generated in Kentucky is assumed to be exported to neighboring regions.

As noted above, these electricity emission estimates reflect the GHG emissions associated with the electricity sources used to meet Kentucky's demand for electricity, corresponding to a consumption-based approach to emissions accounting. In 2005, emissions associated with Kentucky's electricity consumption (91 $MMtCO_2e$) were about 7.5 $MMtCO_2e$ lower than those associated with electricity production (98 $MMtCO_2e$). The higher level for production-based emissions reflects GHG emissions associated with net exports of electricity to other states and to neighboring regions.[10] Projections of electricity sales for 2008 through 2030 indicate that Kentucky will remain a net exporter of electricity. Emissions from net electricity exports are projected to increase over the 2008–2030 period, from 4.1 $MMtCO_2e$ in 2008 to 5.7 $MMtCO_2e$ in 2030. Overall, the reference case projection indicates that production-based emissions (associated with electricity generated in-state) will increase by about 42 $MMtCO_2e$ from 2005 levels, and consumption-based emissions (associated with electricity consumed in-state) will increase by about 43 $MMtCO_2e$ from 2005 to 2030.

While estimates are provided for emissions from both electricity production and consumption, unless otherwise indicated, tables, figures, and totals in this report reflect electricity consumption emissions. The consumption-based approach can better reflect the emissions (and emission reductions) associated with activities occurring in the state, particularly with respect to electricity use (and efficiency improvements), and is particularly useful for decision making. Under this approach, emissions associated with electricity exported to other states would need to be covered in those states' inventories in order to avoid double counting or exclusions.

Like electricity emissions, GHG emissions from transportation fuel use have risen steadily from 1990 to 2005, at an average annual growth rate of 2.1%. In 2005, gasoline-powered on-road vehicles accounted for about 52% of transportation GHG emissions. On-road diesel vehicles accounted for another 26% of transportation GHG emissions, and marine vessels for roughly 10%. Air travel, rail, and other sources (natural gas- and liquefied petroleum gas-fueled vehicles used in transport applications) accounted for the remaining 13% of transportation emissions. As a result of Kentucky's population and economic growth and an increase in total vehicle miles traveled (VMT), emissions from on-road gasoline use grew by 17% from 1990 to 2005. Meanwhile, emissions from on-road diesel use rose by 66% during that period, suggesting rapid growth in freight movement within the state. Emissions from transportation fuels are projected to rise at a rate of 1.7% per year during 2005–2030, leading to an increase of 20 $MMtCO_2e$ in transportation emissions. The largest percentage increase in emissions over this 2005–2030 period is seen in on-road diesel fuel consumption, which is projected to increase by 129%, with total transportation emissions expected to reach 57 $MMtCO_2e$ by 2030.

[10] Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer demand. The current estimate reflects some very simple assumptions, as described in Appendix A of the Inventory and Projections report.

Activities in the RCI[11] sectors produce GHG emissions when fuels are combusted to provide space heating, process heating, and other applications. In 2005, combustion of oil, natural gas, coal, and wood in the RCI sectors contributed about 17% (about 31 $MMtCO_2e$) of Kentucky's gross GHG emissions, below the RCI sectors' contribution for the nation (22%). In 2005, the residential sector's share of total RCI emissions from direct fuel use was 13% (3.9 $MMtCO_2e$), the commercial sector's share was 10% (3.1 $MMtCO_2e$), and the industrial sector's share was 77% (24 $MMtCO_2e$). Overall, emissions from the RCI sectors (excluding those associated with electricity consumption) are expected to decrease by 11% between 2005 and 2030 to 28 $MMtCO_2e$. Emissions from the residential sector are projected to increase slightly by 0.8% from 2005 to 2030. In contrast, emissions from the commercial and industrial sectors are expected to decrease by 12% and 13%, respectively, from 2005 to 2030.

KCAPC Revisions

The KCAPC made the following revisions to the inventory and reference case projections, which explain the differences between the final Inventory and Projections report and the draft initial assessment completed in January 2010:

- *Electricity Supply:*
    - The electricity sales forecast was changed from relying solely on the Energy Information Administration's *Annual Energy Outlook 2009* (AEO 2009) forecast but was enhanced with recent Kentucky utility forecasts provided to the Kentucky Public Service Commission. On average, this resulted in an increase in the electricity sales growth rate from about 0.5%/year to about 1.5%/year over the 2007–2030 period. The projections do not account for utility actions to comply with new or pending EPA regulations.
    - The amount of on-site electricity use was changed from reliance on the low levels assumed in AEO 2009 to higher levels more consistent with Kentucky's experience and industry standards. On average, this resulted in an increase in parasitic load from about 0.5% of total electricity production to 7% for coal stations and 2% for natural gas-fired and oil-fired power stations.
    - There were several typos in the original report denoting "imports"; these have since been corrected to "exports."
    - The uncertainty section was revised to address the issue of Kentucky-specific versus regional assumptions.
- *RCI Fuel Use*: The changes discussed above for the electricity supply sector affecting the changes in the electricity sales forecast also have an impact on how the electricity emissions are allocated among the RCI sectors. This is reflected in Appendix B. In addition, a figure was added showing the breakout of RCI emissions by RCI sector and fuel type.
- *Transportation*: The KCAPC did not recommend any changes to the reference case transportation projections at this time. However, the KCAPC did recommend reviewing alternative VMT projections. In response to this request, Appendix C of the final Inventory

[11] The industrial sector includes emissions associated with agricultural energy use and fuel used by the fossil fuel production industry.

and Projections report presents the Kentucky transportation emissions under an alternative VMT growth scenario, in which VMT growth follows projected population growth. Transportation emissions in the front section of the Inventory and Projections report are unchanged from those reported in the draft report.

- *Waste Management*:
  - The landfill emissions were revised based on waste emplacement, flaring, and landfill gas-to-energy data from Kentucky's Solid Waste Division.
  - There is no in-state controlled waste combustion, so default emissions for that category were removed.
  - No industrial wastewater data were available for key industries, such as bourbon production, so industrial wastewater emissions remained unchanged from the draft version.

Key Uncertainties

Some data gaps exist in this inventory, and particularly in the reference case projections. Key tasks for future refinement of this inventory and forecast include review and revision of key drivers, such as the transportation, electricity demand, and RCI fuel use growth rates that will be major determinants of Kentucky's future GHG emissions (see Table 2-2 and Figure 2-4). These growth rates are driven by uncertain economic, demographic, and land use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion.

Chapter 3
Agriculture, Forestry, and Waste Sectors

Sector Overview

Overview of GHG Emissions

The agriculture, forestry, and waste (AFW) sectors are responsible for moderate amounts of Kentucky's current greenhouse gas (GHG) emissions. The total AFW contribution to carbon dioxide equivalent (CO_2e) gross emissions in 2005 was 11 million metric tons (MMt), or about 6% of the state's total. It is important to note that the AFW emissions include only non-energy sources, as described further below, and exclude combustion-related GHGs, such as diesel fuel consumption in the agriculture sector. These fuel combustion emissions are included as part of the industrial fuel combustion sector (and are covered in the Residential, Commercial, and Industrial [RCI] Sectors chapter). The AFW contribution to net emissions in 2005 is 2% of the state's total, after accounting for forestry and agricultural sinks.

Agricultural emissions include methane (CH_4) and nitrous oxide (N_2O) emissions from enteric (intestinal) fermentation,[1] storage and treatment of livestock manure (e.g., in compost piles or anaerobic treatment lagoons),[2] agricultural soils,[3] and agriculture residue burning. Figure 3-1 shows Kentucky's historic and projected GHG emissions from sources in the agriculture sector for 1990 through 2030. As shown in Figure 3-1, emissions from soil carbon losses from agricultural soils, livestock soils, manure management, enteric fermentation, and fertilizer application all make significant contributions to the sector totals. Emissions include CO_2 emissions from oxidized soil carbon, application of urea, and application of lime. Sector emissions also include N_2O emissions resulting from activities that increase nitrogen in the soil, such as fertilizer (synthetic and livestock manure) application, production of nitrogen-fixing crops (legumes), and agricultural burning activity.

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[1] Methane emissions from enteric fermentation are the result of normal digestive processes in ruminant and non-ruminant livestock. Microbes in the animal digestive system break down food and emit CH_4 as a by-product. More CH_4 is produced in ruminant livestock because of digestive activity in the large fore-stomach.

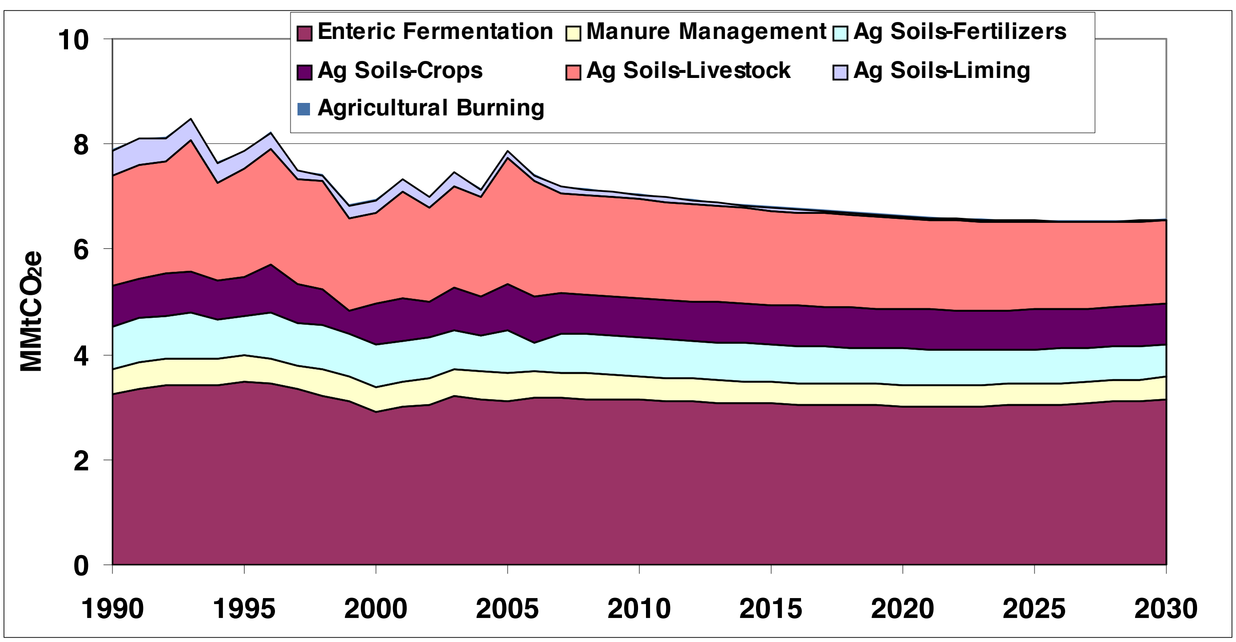
[2] Methane and N_2O emissions from the storage and treatment of livestock manure (e.g., in compost piles or anaerobic treatment lagoons) occur as a result of manure decomposition. The environmental conditions of decomposition drive the relative magnitude of emissions. In general, the more anaerobic the conditions are, the more CH_4 is produced, because decomposition is aided by CH_4-producing bacteria that thrive in oxygen-limited anaerobic conditions. Under aerobic conditions, N_2O emissions are dominant. Emission estimates from manure management are based on manure that is stored and treated in livestock operations. Emissions from manure that is applied to agricultural soils as an amendment or deposited directly to pasture and grazing land by grazing animals are accounted for in the agricultural soils emissions.

[3] The management of agricultural soils can result in N_2O emissions and net fluxes of CO_2, causing emissions or sinks. In general, soil amendments that add nitrogen to soils can also result in N_2O emissions. Nitrogen additions drive underlying soil nitrification and denitrification cycles, which produce N_2O as a by-product. Agricultural soil emissions also account for decomposition of crop residues, synthetic and organic fertilizer application, manure application, sewage sludge, nitrogen fixation, and histosols (high organic soils, such as wetlands or peatlands) cultivation. Both direct and indirect emissions of N_2O occur from the application of manure, fertilizer, and sewage sludge to agricultural soils. Direct emissions occur at the site of application, and indirect emissions occur when nitrogen leaches to groundwater or in surface water runoff and is transported off site before entering the nitrification/denitrification cycle.

Relative to other sectors, Kentucky's agriculture sector contributes relatively low amounts of GHG emissions to total statewide emissions. In 2005, the agriculture sector contributed about 7.9 $MMtCO_2e$ emissions (4%) to Kentucky's total statewide gross GHG emissions (consumption basis). Within the agriculture sector, agricultural soil management accounted for the largest source of emissions, representing 54% of gross agricultural emissions. The contributions of other agricultural sources to total agricultural emissions include livestock enteric fermentation (40%), manure management (7%), and burning of agricultural crop waste (<1%). Soil cultivation practices represent a net sink, sequestering approximately 1.1 $MMtCO_2e$.

As shown in Figure 3-1, since 2000, agriculture sector emissions have remained fairly constant through 2010, and are expected to decline slightly through 2030. Overall, emissions for the agriculture sector are expected to decrease slightly, by about 0.37 $MMtCO_2e$ (approximately 6.8%), from 2000 to 2030. In 2030, the proportional contribution of each agriculture sector to total agricultural source emissions is expected to change slightly relative to its contribution in 2000. In 2030, agricultural soil management is expected to account for 45% of gross agricultural emissions, while livestock enteric fermentation is projected to contribute 48%, manure management about 6%, and burning of agricultural crop waste less than 1% of gross agricultural emissions. Soil cultivation practices are expected to continue as a net sink, sequestering approximately 1.1 $MMtCO_2e$.

Figure 3-1. Recent and Projected GHG Emissions from the Agriculture Sector in Kentucky, 1990–2030



Note: Emissions associated with the burning of agricultural crop waste are too small to be seen in this figure.
Ag = agricultural; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Forestry and land use emissions refer to the net CO_2 flux[4] from forested lands in Kentucky. The inventory is divided into two primary subsectors: the forested landscape and urban forestry and land use. Both subsectors capture net carbon sequestered in forest biomass, urban trees, landfills, and harvested wood products. In addition, other GHG sources, such as N_2O emissions from fertilizer application in urban areas and CH_4 and N_2O emissions from prescribed burns and wildfires, are included.

On a net basis, Kentucky's forestry and land use sector is responsible for sequestering moderate amounts of carbon. In 2005, the sequestration in Kentucky from land use change and forestry was about 5.8 $MMtCO_2e$. The number of metric tons sequestered from forestry is equivalent to approximately 3% of the state's gross GHG emissions (consumption basis) from all sectors. Table 3-1 shows historical and projected GHG emissions from each subsector of the forestry and land use sector. The sector is expected to remain a net carbon sink through 2030.

Table 3-1. Recent and Projected GHG Emissions from the Forestry and Land Use Sector in Kentucky, 1990–2030 ($MMtCO_2e$)

Subsector	1990	1995	2000	2005	2015	2025	2030
Forested Landscape (excluding soil carbon)	–4.71	–4.71	–4.71	–4.71	–4.71	–4.71	–4.71
Urban Forestry and Land Use	–4.09	–2.53	–1.92	–1.73	–1.73	–1.73	–1.73
Forest Wildfires	0.29	0.87	1.72	0.66	0.68	0.68	0.68
Sector Total	**–8.51**	**–6.37**	**–4.91**	**–5.77**	**–5.75**	**–5.75**	**–5.75**

Sources: U.S. Forest Service data and U.S. Environmental Protection Agency State Inventory Tool.

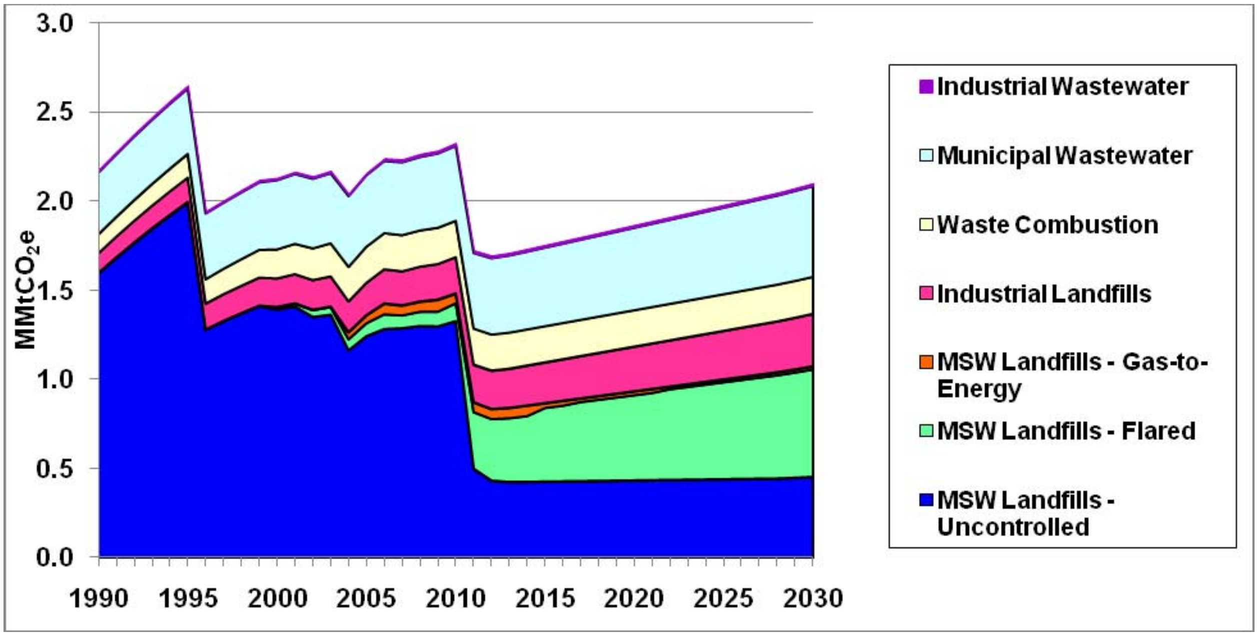
$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

In Kentucky, the waste sector produces a low amount of GHG emissions. Figure 3-2 shows historical and projected GHG emissions from sources in the waste sector. Emissions from waste management consist largely of CH_4 emitted from landfills, while emissions from wastewater treatment include both CH_4 and N_2O. Emissions are also included for MSW combustion. Note that due to data limitations, the emission estimates do not include methane emitted from about 50 landfills closed between 1992 and 1995. While some additional methane emissions are expected, given the age of the waste in place at these sites, the additional CO_2e is not expected to be significant.

Overall, the waste management sector accounted for about 2.2 $MMtCO_2e$ of GHG emissions, or about 1.2% of Kentucky's total gross emissions on a consumption basis. In 2030, gross GHG emissions for the sector are estimated to be about 2.1 $MMtCO_2e$, accounting for less than 1% of the state's total gross GHG emissions on a consumption basis. Most important, the emission estimates for managing solid waste do not capture the upstream emissions embedded in the waste materials. In the Center for Climate Change's experience, those emissions are often an order of magnitude higher than the subsequent waste management emissions. Hence, policy recommendations like AFW-8, which target MSW reuse and recycling, are needed to address those upstream emissions.

[4] "Flux" refers to both (1) emissions of CO_2 to the atmosphere and (2) removal (sequestration) of CO_2 from the atmosphere and stored in plant tissue or soils.

Figure 3-2. Kentucky GHG Emissions from Waste Management, 1990–2030



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MSW = municipal solid waste.

Key Challenges and Opportunities

Agriculture

Opportunities for GHG mitigation in the agriculture sector include measures that can reduce emissions within this sector and other sectors. Within the agriculture sector, changes in crop cultivation can reduce GHG emissions by building soil carbon (indirectly sequestering carbon from the atmosphere) or through more efficient nutrient application (reducing both direct N_2O emissions and embedded GHG emissions within those nutrients). The implementation of improved farming and harvesting techniques, as well as utilization of biomass for fuel, has the potential to reduce future emissions relative to current emissions from this sector and other sectors, such as electricity and transportation. On-farm energy expenses can also be reduced at the same time. In addition to the potential cost savings and GHG benefits from the Kentucky Climate Action Plan Council (KCAPC) recommendations discussed in the following section, the implementation of these measures may serve to sustain the viability of farming in Kentucky by preserving the quality and value of agricultural lands.

The foremost challenge facing the implementation of these policies in the agriculture sector is breaking any economic barriers that are preventing (or not properly incentivizing) farmers in Kentucky from undertaking these measures. Another challenge will be to ensure participation in new energy opportunities as commercial-scale technology matures during the policy period (e.g., cellulosic ethanol production facilities locating within the state).

Forestry

Kentucky has significant opportunity for increased carbon sequestration in the forestry sector. The principal means to reduce emissions in these areas are:

- Adopting management practices to increase carbon sequestration in forestlands;
- Increasing the area of forestland through reforestation, afforestation, and restoration of mined lands and other non-forested lands; and
- Utilizing forest biomass for energy production.

Enhanced management of the state's forests can lead to higher levels of carbon sequestration. Such enhancement can be achieved through afforestation projects and enhanced stocking in existing forests.

Actions taken within the forestry sector can also lead to GHG reductions in other sectors. The establishment of woody crops for producing biomass energy feedstocks can replace fossil fuel consumption, including transportation fuels and fuels used to produce electricity or steam in the energy supply sector.

Kentucky faces several key challenges in the forestry sector. Similar to that mentioned for agricultural biomass above, one challenge is providing incentives to produce and utilize wood energy sources, especially before additional demand is put in place (e.g., cellulosic ethanol or other biofuels derived from forest biomass). Another challenge is to encourage private forest landowners to enroll in forestry management programs (e.g., until incentives, such as carbon offset programs in other parts of the United States, provide a revenue stream). A continuing challenge in Kentucky—as in most states—is ensuring funding for new forestry programs. Kentucky also has a large number of acres that have been mined and need to be prepped and treated before forest stands can be planted.

Waste Management

Opportunities for improvements in Kentucky's waste management sector include measures that can reduce emissions from both solid and liquid wastes. Improvements could include diversion of solid waste from landfills, increased methane collection at landfills, and more efficient municipal wastewater collection and treatment. Those approaches reduce the direct emissions associated with the management of the waste. However, more significant emission reductions can be achieved by reducing the amount of waste generated or by recycling waste, since these approaches reduce the upstream emissions associated with production and transport of waste materials and packaging. Often, those reductions are achieved in other sectors and in areas outside of the state.

Kentucky's challenges in the waste management sector center on identifying funding to finance capital improvements, providing incentives to encourage private entities to make technology upgrades (e.g., composting programs), and identifying resources for municipalities and counties to increase solid waste reuse and recycling programs.

Overview of Work Plan Recommendations and Estimated Impacts

The AFW Technical Work Group (TWG) developed nine policy recommendations for the Secretary's review (see Table 3-2) that were then reviewed, revised, and ultimately approved by the KCAPC members present and voting. This set of nine policies for the AFW sectors offers the potential for major economic benefits and emission reductions. Implementing these policy recommendations could lead to emission reductions of:

- 7.9 $MMtCO_2e$ per year by 2030, and
- 90 $MMtCO_2e$ cumulative from 2011 through 2030, after adjusting for overlaps with other sectors.

The weighted-average cost-effectiveness of the recommended policies is about $3/$tCO_2e$. This average value includes policies that have both much lower and much higher likely costs per ton.

The nine policy recommendations for the AFW sectors address a diverse array of activities capturing emission reductions both within and outside of these sectors (e.g., energy consumption in the energy supply [ES] and transportation and land use [TLU] sectors). The estimated impacts of the individual policies are shown in Table 3-2. The KCAPC policy recommendations are described briefly here and in more detail in Appendix E of this report. The recommendations not only result in significant emission reductions, but also offer a host of additional benefits, including protection of biodiversity, enhanced forest aesthetics, watershed protection, reduced local air pollution, economic development, and job growth. To yield the levels of savings described here, the recommended policies need to be implemented in a timely, aggressive, and thorough manner.

The following are primary opportunities for GHG mitigation identified by the KCAPC:

- **Agricultural crop production:** Programs can be implemented with growers to utilize cultivation practices that build soil carbon and reduce nutrient consumption. By building soil carbon, CO_2 is indirectly sequestered from the atmosphere. New technologies in the area of on-farm efficiency offer opportunities to reduce on-farm fossil fuel consumption.
- **Production of biomass for energy feedstocks:** Kentucky has significant opportunities to produce biomass from AFW feedstock sources. The use of renewable fuels, such as ethanol from crop residue and forestry biomass and biodiesel from waste vegetable oils, can produce significant reductions when they are used to offset consumption of fossil fuels (e.g., gasoline and diesel in transportation and other combustion sources). This is particularly true when these fuels are produced using processes and/or feedstocks that have much lower fossil fuel inputs than those from conventional sources (sometimes referred to as "advanced" or "next-generation" biofuels). The goals to produce biomass feedstocks for energy are linked to recommendations in ES-1, ES-5, ES-7, and TLU-10.
- **Enhancement/protection of forest carbon sinks:** Through a variety of programs, enhanced levels of CO_2 sequestration can be achieved and carbon can be stored in the state's forest biomass. These include afforestation[5] projects, reforestation programs (restocking of poorly stocked forests, including previously mined lands), and forest management initiatives.
- **Changes in MSW management practices:** By promoting waste reuse, advanced MSW recycling practices, improved organics management, and increased collection and utilization of landfill methane, solid waste managers can reduce the GHG emissions associated with collecting, transporting, and managing MSW. The reuse and recycling components would also reduce the embedded GHG emissions of MSW, which tend to be much more significant than the waste management emissions themselves. The emissions reduced in this sector would come from in-state waste management practices and waste transport; as well as from upstream

[5] Afforestation refers to the establishment of forest on lands that have not historically been under forest cover.

(embedded) GHGs in the electricity supply, RCI, and transportation sectors both within and outside of the state. Current data limitations do not allow for a precise breakout of the in-state versus out-of-state reductions in embedded emissions.

Table 3-2. Summary List of AFW Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effectiveness ($/tCO_2e$)
		2020	2030	Total 2011–2030		
AFW-1	Forestry Management for Carbon Sequestration	0.04	0.07	0.86	$17.4	$20.3[6]
AFW-2	Expanded Use of Biomass Feed-stocks for Electricity, Heat, and Steam Production	*Costs/GHG Reductions Captured in ES-1, ES-5 and ES-7 Analyses*				
AFW-3a	On-Farm Energy Production	*GHG reductions accounted for in policies where biomass is used for Fuel (ES, RCI, & TLU)*				
AFW-3b	On-Farm Energy Efficiency Improvements	0.21	0.45	4.5	–$94	–$21
AFW-4	In-State Liquid/Gaseous Biofuels Production	*Costs/GHG Reductions Captured in TLU-10 Analysis*				
AFW-5a	Soil Carbon Management—NT/CT	0.37	0.74	7.8	$6	$1
AFW-5b	Soil Carbon Management—Winter Cover Crops	0.95	1.90	19.9	$141	$7
AFW-6	Increase Productivity of Abandoned, Underutilized, and Reclaimed Lands	2.7	5.8	58	$50	$1
AFW-7a	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Mined Lands	0.02	0.09	0.16	–$19	–$120
AFW-7b	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Other Lands	0.55	1.0	11	$42	$4
AFW-8	Advanced MSW Reuse, Recycling, and Organic Waste Management Programs	0.84	1.3	16	$167	$10
AFW-9	Landfill Methane Energy Programs	1.41	2.4	29	$29	$1
	Sector Total After Adjusting for Overlaps	**4.4**	**7.9**	**90**	**$308**	**$3**
	Reductions From Recent Actions	**0**	**0**	**0**	**$0**	**$0**
	Sector Total Plus Recent Actions	**4.4**	**7.9**	**90**	**$308**	**$3**

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; ES = Energy Supply; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MSW = municipal solid waste; NT/CT = no till/conservation tillage; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

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[6] The benefits of increased forest carbon sequestration will last far beyond the policy period. When GHG reductions and cost-effectiveness are calculated considering the lifetime of the forest (~50 years), the results are 3.3 $MMtCO_2e$ and $5.3/$tCO_2e$, respectively.

Totals do not equal the sum of individual policy recommendations due to subtraction of overlaps.

Overlap Discussion

The amount of GHG emissions reduced or sequestered and the costs of a policy recommendation within the AFW sectors in some cases overlap with other AFW policies or policies in other sectors. For the KCAPC recommendations in AFW, overlap occurs between AFW-8 and AFW-9 in the waste management sector. One of the policy elements of AFW-8 covers enhanced management of organic wastes in the MSW management sector. To the extent that these wastes are being diverted from landfills to other waste management facilities (e.g., composting facilities), less organic waste is available to generate landfill methane. This effect has been accounted for in the quantification of AFW-9, which quantifies production of landfill gas and the associated methane emissions; hence, the values shown for AFW-9 above assume successful implementation of AFW-8.

Overlap also occurs with some of the quantified benefits and costs of policy recommendations from other sectors. Every effort has been made to determine where those overlaps occur and to eliminate double counting of reductions. As displayed Table 3-2 above, the AFW sector totals have been adjusted accordingly, as follows:

- AFW-2 details the production of biomass feedstocks for electricity, heat, and steam production. The GHG reductions associated with utilization of these feedstocks are accounted for in the analyses of ES-1, ES-5, and ES-7.
- AFW-3a is aimed toward the goal of producing biomass feedstocks to replace a percentage of total Kentucky energy needs. The AFW Technical Work Group created an estimate of potential biomass production in the state (detailed in Appendix E of this report, Table AFW-2 Biomass Supply/Demand for Policy Recommendations), to ensure than biomass feedstocks were not being double counted for electricity production and biofuels. The GHG reductions and costs associated with actually using these feedstocks as fuels are accounted for in ES-1, ES-5, ES-7, and TLU-10.
- AFW-4 focuses on the production of biofuels from AFW feedstocks. Although the cost of production of these biofuels is calculated in AFW-4, the final costs of using the fuels as well as GHG reductions are accounted for in TLU-10.
- AFW-6 is aimed at increasing agricultural production on abandoned, underutilized, and reclaimed lands. The quantification of this policy assumes that these lands will be used to produce agricultural products that can be used as biomass feedstocks for renewable fuels. Since the use of these biomass feedstocks is accounted for in other sectors, the total GHG reductions and costs of AFW-6 are subtracted from the AFW total.

Agriculture, Forestry, and Waste Sectors Policy Descriptions

The nine AFW policies recommended by the KCAPC include emission mitigation opportunities related to the production and use of biomass energy; improved on-farm efficiency and carbon sequestration; forestry management; increased use of abandoned, underutilized, reclaimed, and previously mined lands for agricultural production and reforestation; and lower MSW emissions.

AFW-1. Forestry Management for Carbon Sequestration

This policy addresses the potential for increasing carbon stocks in forests through practices that increase the health and productivity of the forest. Forest improvements may include increasing tree density, enhancing forest growth rates, altering rotation lengths, or decreasing the chances of biomass loss from fires, pests, and disease. Increasing the transfer of biomass to long-term storage in wood products can also enhance net carbon sequestration.

Managed forests can sequester more carbon than unmanaged forests for a number of reasons. Practices may include management of rotation length, density, and ecosystem health, and sustainable use of wood products. In addition, encouraging regeneration of existing forests through stocking/planting and restoration practices (soil preparation, erosion control, etc.) can increase carbon stocks above baseline levels and ensure conditions that support forest growth, particularly after intense disturbances. Land participating in a certified management program may be eligible to generate offset credits.[7] Note that not all private landowners who enroll in forest management programs will have the goal of increased carbon sequestration. Landowner goals may include increased harvesting productivity, wildlife management, hunting, aesthetic value, or other objectives. Improvement of forest management results in side benefits, including watershed protection, improved wildlife habitat, biodiversity conservation, and enhanced aesthetics and recreation.

AFW-2. Expanded Use of Biomass Feedstocks for Electricity, Heat, and Steam Production

This policy dedicates a sustainable quantity of biomass from agricultural crops and residue, forestry products, and MSW biomass resources for efficient conversion to energy and economical production of heat, steam, or electricity. This biomass should be used in an environmentally acceptable and sustainable manner. The objective is to create concurrent reduction of CO_2 due to displacement of fossil fuels, considering life-cycle GHG emissions associated with viable collection, hauling, and energy conversion and distribution systems. The GHG reductions and costs associated with this policy are accounted for in the energy supply sector in the ES-1 analysis.

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[7] Offset credits are awarded to GHG reduction projects that achieve measurable and verifiable emission reductions through some action that is not considered business as usual practice. Offset credits (e.g., tCO_2e/yr) can be sold to entities seeking voluntary emission reductions or in some cases within mandatory systems (e.g., the California Cap & Trade Program).

AFW-3a. On-Farm Energy Production

This policy recommends increasing the productivity and conversion of crops, residues, and other farm resources to meet the ES, TLU, and RCI needs. As the feedstocks will be used by other sectors—TLU, RCI, and ES—the GHG reductions and costs/cost savings will be accounted for in the sector where the biomass is utilized. Agricultural biomass production may encompass herbaceous energy crops or woody energy crops, focusing on crops that are considered non-invasive. Underutilized agricultural land, abandoned lands, and reclaimed mine lands should be considered for production of biomass.

AFW-3b. On-Farm Energy Efficiency Improvements

This policy recommends improving energy conservation in agricultural operations. These efficiency improvements would be achieved through technology upgrades to equipment and facilities, displacement of fossil fuels with sustainable renewable fuels, improved watershed planning, and promotion of on-farm and local energy sources. GHG reductions are realized when farms reduce fossil fuel consumption. Possible on-farm energy improvements will vary, depending on the size of and type of farm and technologies used on the farm. Energy audits will be necessary to identify the improvements that would be most cost-effective.

AFW-4. In-State Liquid/Gaseous Biofuels Production

This policy promotes sustainable in-state production and consumption of transportation biofuels from agriculture, forestry, and MSW feedstocks to displace the use of gasoline and diesel. This recommendation also promotes the in-state development of feedstocks, such as cellulosic material, and production facilities to produce either liquid or gaseous biofuels with low carbon content. Production of biomass for biofuel production must be done in a sustainable manner. The objective is to create concurrent reduction of CO_2 due to displacement of fossil fuels, considering life-cycle GHG emissions associated with viable collection, hauling, and energy conversion and distribution systems. The GHG reductions and costs associated with this policy are accounted for in the transportation sector in the TLU-10 analysis.

AFW-5a. Soil Carbon Management—NT/CT

This policy aims to reduce oxidation of soil carbon compounds through reduced soil disturbance. Carbon sequestered in soil can be increased through the adoption of farming practices, such as conservation tillage (CT) and no-till (NT) cultivation that provide enhanced ground cover and minimal aeration of soil carbon. Common definitions of CT are systems that leave 50% or more of the soil covered with residue. Kentucky is one of the country's leaders in NT agriculture, due to widespread adoption of the technique in the last decade. GHG reductions in this policy are due to increased carbon accumulation, reduction in fossil fuel consumption, and reduction in commercial fertilizer use.

The implementation of NT/CT farming programs would be aided by the provision of funding, including carbon credits, federal grants, and state-level programs that provide assistance to farmers undertaking alternative farming methods that will increase the soil carbon sequestration.

AFW-5b. Soil Carbon Management—Winter Cover Crops

This policy increases carbon sequestration in the soil and can improve nitrogen levels as well. Kentucky is one of the few states where winter cover crops are viable and can improve farm revenue. Both GHG reductions and cost savings are possible from reduced nitrogen application. GHG reductions can also be attributed to reduced N_2O emissions from nitrogen runoff or leaching. Other benefits include reduced wind and water erosion and improved wildlife habitat.

AFW-6. Increase Productivity of Abandoned, Underutilized, and Reclaimed Lands

This policy promotes the productive use of lands that are otherwise not currently producing—namely, abandoned, underutilized, reclaimed mined lands, and marginal agricultural lands. These lands are available for planting of forage crops, native grasses, or energy crops, as appropriate. Implementation of this policy will need to include site preparation, as many of these lands are currently not able to support any crop production. Benefits include increased carbon sequestration, production of biomass that can be used as an energy feedstock, decreased soil erosion, improved wildlife habitat, and improved land value and aesthetics. GHG reductions are realized through increased carbon sequestration and displacement of fossil fuels by biomass energy feedstocks. Kentucky's rich mining history provides an abundant supply of previously mined lands ripe for production. This policy also promotes the improvement of crop yield on previously mined lands through application of soil amendments.

The quantification of this policy assumed that biomass produced on these lands would be used to displace in-state fossil fuel use. As this policy has complete overlap with AFW-2, Expanded Use of Biomass Feedstocks for Electricity, Heat, and Steam Production, the reductions and costs of AFW-6 were not included in the total in Table 3-2. Nevertheless, this policy represents a great opportunity for GHG reductions and other side benefits.

AFW-7a. Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Mined Lands

This policy seeks to increase carbon stored in vegetation and soils through expanding the land base associated with terrestrial carbon sequestration. Establishing new forests ("afforestation") on land not currently experiencing other uses, such as abandoned mine lands, increases the amount of carbon in biomass and soils compared to preexisting conditions. In addition to planting forest cover, this policy considers site and soil preparation, erosion control, and stand stocking to ensure conditions that support forest growth.

AFW-7b. Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Other Lands

This policy seeks to increase carbon stored in vegetation and soils through afforestation on other non-forested lands (in addition to the previously mined lands considered in AFW-7a). These lands include underutilized land not currently in agricultural production, forest, or development. This policy also recommends re-establishing stands on forest land that is currently understocked. Improvement of forest stocking and expansion of forest acres bring associated co-benefits of watershed protection, improved wildlife habitat, biodiversity conservation, and enhanced aesthetics and recreation. Key challenges to the success of this policy include identifying sufficient funding and incentives for planting.

AFW-8. Advanced MSW Reuse, Recycling, and Organic Waste Management Programs

This policy focuses on diverting MSW away from landfills through reuse, recycling, and organic waste management programs in order to reduce generation of uncontrolled methane emissions during waste management and the upstream energy and emissions associated with production and transport of waste materials and packaging. The goal of this policy is to divert 50% of all MSW by 2025. Diversion can include recycling, reusing, composting, repurposing, and converting waste to usable products.

The policy has an additional goal to improve the recycling rate of common household recyclable materials from 35% (2008) to 40% by 2025. Emissions are lowered by reducing the total amount of waste deposited at landfills and by reducing amounts of upstream energy needed to produce unnecessary products/packaging. Key challenges include identifying funding for waste programs and implementing programs in rural areas where population density is low. Additionally, methods to encourage curbside participation are difficult to quantify.

AFW-9. Landfill Methane Energy Programs

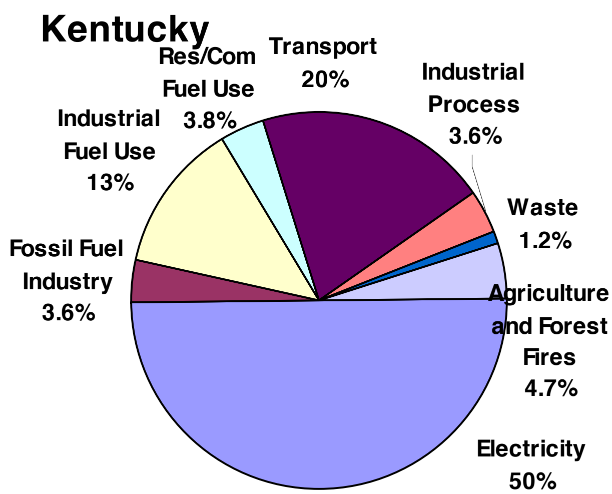
This policy aims to reduce MSW landfill emissions through installation of landfill gas collection and usage equipment. This covers both landfills that are legally required to control their emissions and those that do not meet minimum volume requirements. The renewable energy (methane) created at landfills during anaerobic degradation of wastes unable to be utilized in recycling and compost programs can be used to displace fossil fuel through the installation of methane control and collection systems. Note that Kentucky already has one bioreactor facility whose methane is piped to an industrial park and used as an energy source. The goal of this policy is by 2025 to avoid 50% of the methane emissions that would be generated under business-as-usual conditions. Key challenges to the success of this policy are identifying sufficient funds to meet the capital cost requirements of installing and running collection equipment.

Chapter 4
Energy Supply

Overview of Energy Supply Emissions

As a coal-producing state, Kentucky relies more heavily on coal as the fuel to generate electricity than any other state in the nation, except for West Virginia. According to records maintained by the U.S. Energy Information Administration (EIA), in 2009 Kentucky power producers burned coal to generate more than 84,000,000 megawatt-hours (MWh) of electricity, or about 93% of total generation. As a result, greenhouse gas (GHG) emissions from electricity consumption have consistently accounted for approximately half of Kentucky's total emissions, which are higher than the national average share of emissions (34%),[1] as shown in Figure 4-1. The use of coal has led to low electricity rates in Kentucky compared to the rest of the country, which has allowed electricity-intensive industries to flourish in the state, as acknowledged in Kentucky's Energy Plan.[2] Those energy-intensive industries provide valuable goods and services to many states beyond the borders of Kentucky.

Figure 4-1. Kentucky Gross GHG Emissions by Sector, 2005



Res/Com = residential and commercial.

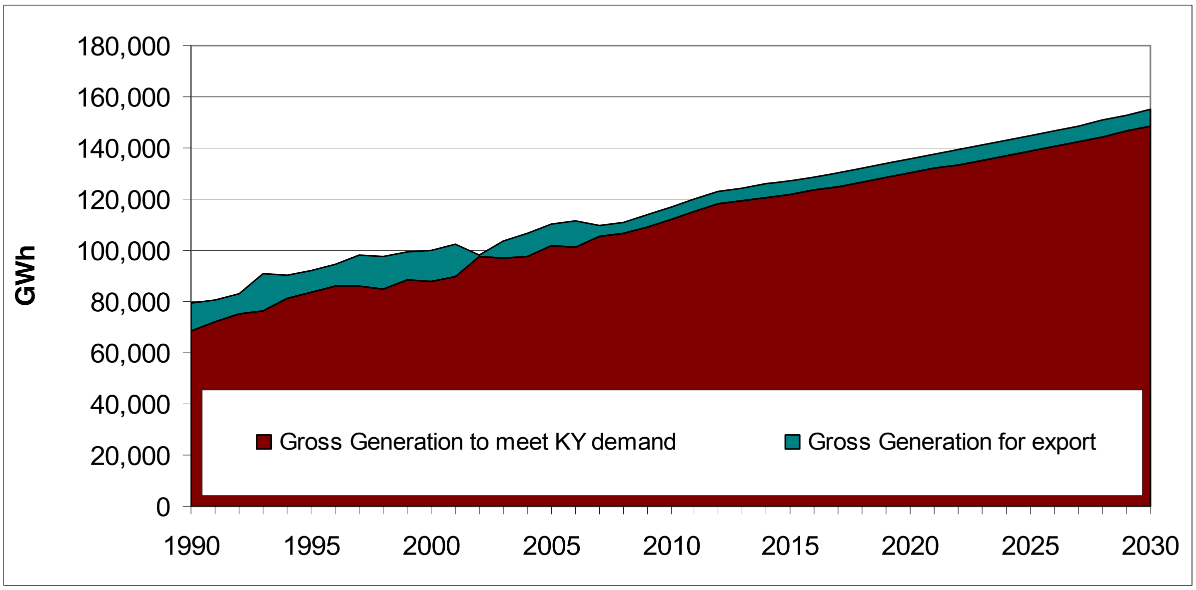
In 2005, emissions associated with Kentucky's electricity consumption (91 million metric tons of carbon dioxide equivalent [$MMtCO_2e$]) were about 7.5 $MMtCO_2e$ lower than those associated with electricity production (98 $MMtCO_2e$). The higher level for production-based emissions reflects GHG emissions associated with net exports of electricity to other states and to

[1] For the United States as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the nation imports only about 1% of its electricity, and exports even less.

[2] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence,* November 2008.

neighboring regions (see Figure 4-2).[3] Reference Case projections of electricity production for 2008 through 2030 indicate that Kentucky will remain a net exporter of electricity. Emissions from net electricity exports are projected to increase over the 2008–2030 period, from 4.1 $MMtCO_2e$ in 2008 to 5.7 $MMtCO_2e$ in 2030. Overall, the Reference Case projection indicates that production-based emissions (associated with electricity generated in-state) will increase by about 42 $MMtCO_2e$ from 2005 to 2030 (i.e., from 98 to 140 $MMtCO_2e$), and consumption-based emissions (associated with electricity consumed in-state) will increase by about 43 $MMtCO_2e$ from 2005 to 2030 (i.e., from 91 to 134 $MMtCO_2e$).

Figure 4-2. Composition of Gross Generation to Meet Kentucky's Electricity Demand



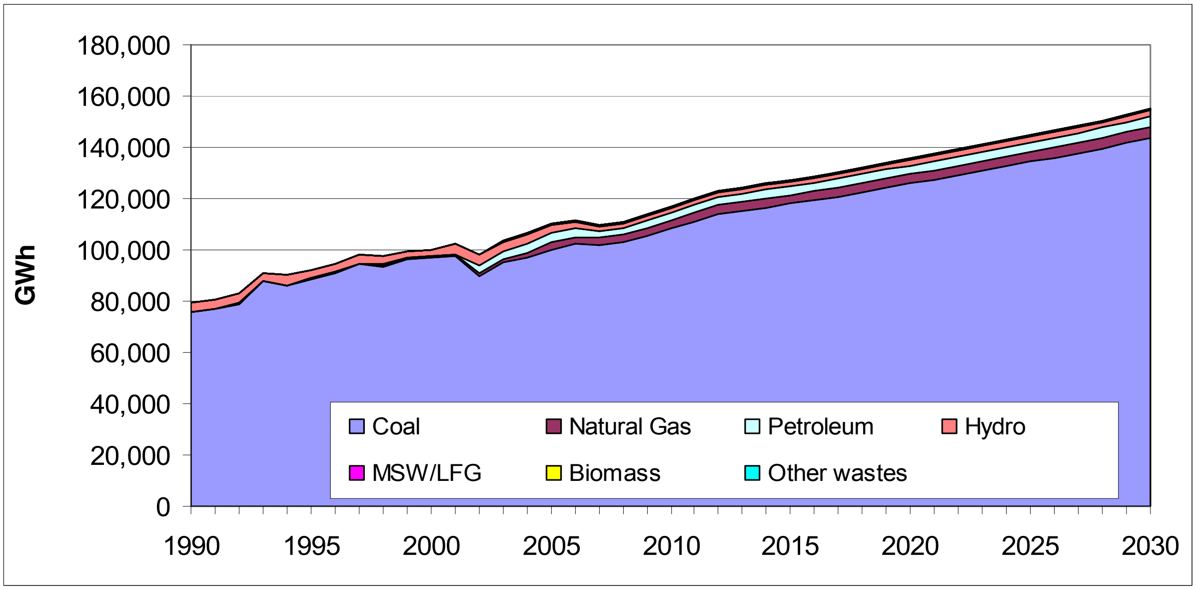
GWh = gigawatt-hours.

Exports vary from year to year based upon multiple factors, including fuel cost, fuel supply interruptions, and general market demand. Kentucky's favorable electricity prices, driven predominantly by coal-based generation, support the expectation that it will be a net exporter of electricity for the foreseeable future, with approximately 4% of annual generation projected to be exported over the 2008–2030 period.

Figure 4-3 shows recent and projected in-state generation by fuel source. The Reference Case projection indicates that while recent increases in natural gas and petroleum generation are expected to continue, coal is expected to remain the fuel of choice, accounting for 93% of electricity generation through 2030.

[3] Estimating the emissions associated with electricity use requires an understanding of the in-state and out-of-state) electricity sources used by utilities to meet consumer demand. The current estimate reflects the assumptions described in Appendix A.

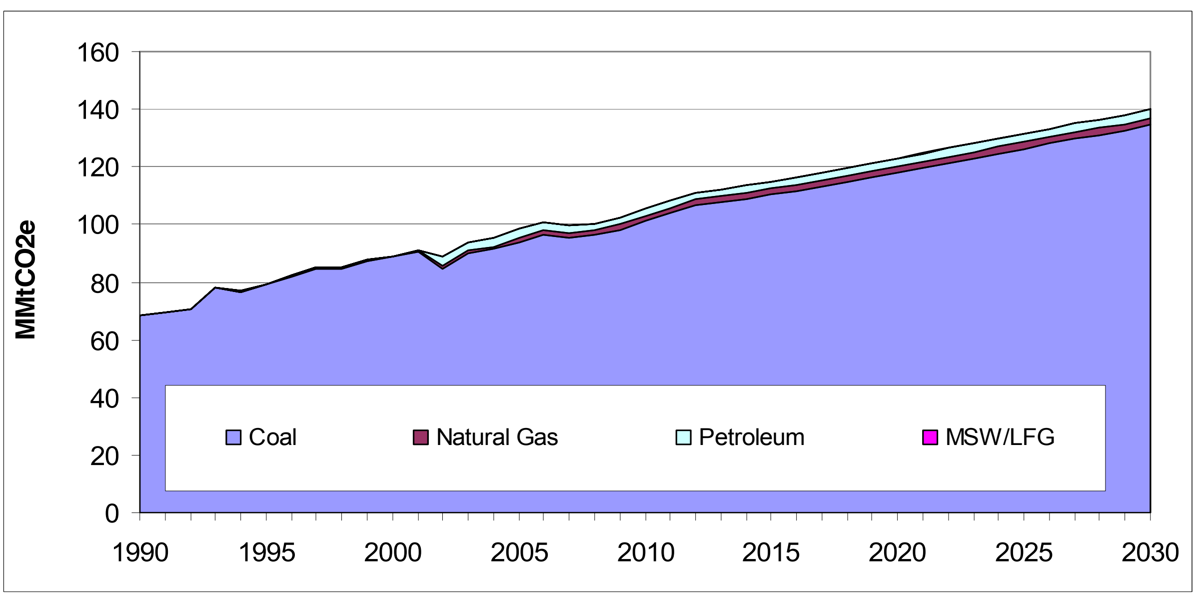
Figure 4-3. Total Gross Electricity Generation, Kentucky



GWh = gigawatt-hours; LFG = landfill gas; MSW = municipal solid waste.

Figure 4-4 gives gross GHG emissions from electricity generation in Kentucky by fuel source. As a share of total CO_2 emissions, coal accounts for about 96% of electric generation emissions through 2030, or slightly more than coal's share of electric generation due to its higher carbon intensity.

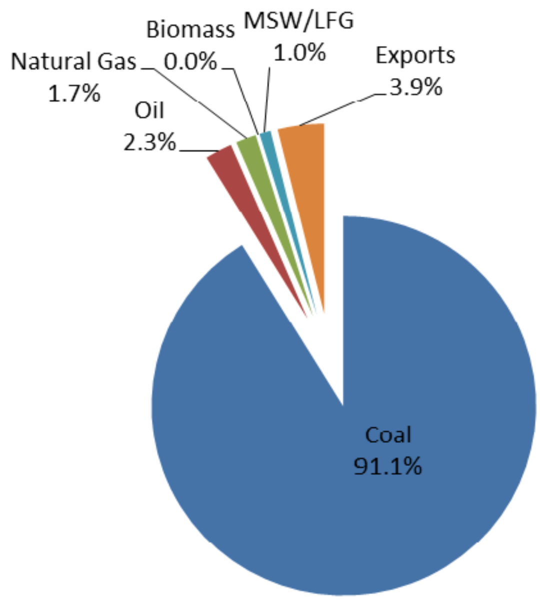
Figure 4-4. Total Gross GHG Emissions Associated with Kentucky Electricity Production by Fuel Type, All Years



LFG = landfill gas; $MMtCO_2e$ = million metric tons carbon dioxide equivalent; MSW = municipal solid waste.

The breakdown of electricity generation CO_2e emissions by fuel type is shown in Figure 4-5 for the 2007 base year. The breakdown includes utility and merchant generators, as well as combined heat and power (CHP).[4]

Figure 4-5. Total Kentucky CO_2e Emissions from Electric Generators and CHP—2007 Base Year



CHP = combined heat and power; CO_2e = carbon dioxide equivalent; LFG = landfill gas; MSW = municipal solid waste.

Table 4-1 summarizes the emissions data presented in Figures 4-4 and 4-5.

Table 4-1. Recent and Projected GHG Emissions from Electricity Generation in Kentucky, Consumption and Production, 1990–2030

Million Metric Tons CO_2e	1990	2000	2005	2010	2015	2020	2025	2030
Electricity Use (Consumption)	**59.2**	**78.5**	**90.9**	**101.1**	**110.3**	**118.0**	**126.2**	**134.3**
Electricity Production (in state)	68.5	89.1	98.4	105.4	115.0	123.0	131.5	140.0
Coal	*68.3*	*88.7*	*93.6*	*101.2*	*110.3*	*118.0*	*126.3*	*134.4*
Natural Gas	*0.016*	*0.31*	*1.64*	*1.89*	*2.07*	*2.23*	*2.28*	*2.39*
Oil	*0.090*	*0.13*	*3.12*	*2.32*	*2.53*	*2.70*	*2.87*	*3.07*
Biomass (CH_4 and N_2O)	*0.000*	*0.000*	*0.002*	*0.003*	*0.003*	*0.003*	*0.003*	*0.004*
MSW/Landfill Gas	*0.000*	*0.000*	*0.036*	*0.057*	*0.062*	*0.066*	*0.071*	*0.076*
Other Wastes	*0.000*	*0.000*	*0.008*	*0.007*	*0.008*	*0.009*	*0.009*	*0.010*
Net Exported Electricity	9.27	10.58	7.51	4.30	4.69	5.01	5.36	5.70

CH_4 = methane; CO_2e = carbon dioxide equivalent; MSW = municipal solid waste; N_2O = nitrous oxide.

[4] These percentages are slightly different from those contained in Appendix C, *Greenhouse Gas Emissions Inventory and Reference Case Projections*, reflecting minor TWG adjustments to the inventory subsequent to the completion of the June, 2010 Reference Case report upon which Appendix C is based.

Key Challenges and Opportunities

Looking forward, Kentucky's reliance on coal as the primary fuel for the generation of electricity presents both challenges and opportunities for emission reductions. Opportunities arise to reduce emissions in both the demand for and the supply of electricity to Kentuckians. Historically low prices have limited the economic need for demand-side efficiency measures, leaving significant opportunities for additional efficiencies on the customer side of the meter. These are largely identified in Chapter 5, covering recommendations in the residential, commercial, and industrial sectors; however, two polices that partially address demand-side opportunities are included here and discussed below under Overview of Policy Recommendations and Estimated Impacts.

Substantial emission reductions are also possible through changes in the generation, transmission, and distribution of electricity in Kentucky. Generation-based reductions are possible through improvements in the combustion efficiency of existing coal plants; through the replacement of inefficient coal plants with ones utilizing the newest combustion technologies; through the use of replacement fuels, such as biomass or natural gas; and through the use of carbon capture and storage or reuse (CCSR) technologies. Transmission and distribution (T&D) efficiencies can be found through the use of more efficient equipment, such as new conductors and transformers, and through the installation of smart grid technology. These types of changes would entail up-front costs, but will result in cost savings over time.

Measures aimed at improving the emissions associated with the generation of electricity dominate the recommendations and offer the majority of potential reductions. However, for some of these measures to be adopted, certain challenges must be overcome. For example, the average coal-fired power plant in Kentucky is more than 35 years old. There have been significant advances in power generation technology during the lives of Kentucky's power plants. However, uncertainties in the Clean Air Act's New Source Review (NSR) Program pose a significant disincentive, not only to power plant efficiency improvements but also to biomass co-firing, because in some cases such a project may be deemed a "major modification" that results in additional emissions, triggering additional pollution control requirements that can cost hundreds of millions of dollars. Refinements in the regulatory program are needed to fully achieve the potential benefits of biomass co-firing and efficiency improvements at existing power plants.[5]

Another opportunity lies in the future use of nuclear generation. Nuclear energy is controversial everywhere, and in some respects even more so in Kentucky. Nevertheless, nuclear energy provides reliable baseload power with dramatically lower GHG emissions than the existing generation mix. Before nuclear energy can become part of Kentucky's energy future, public support sufficient to effect the repeal of the statutory ban will need to be demonstrated.

Renewable energy generation is another opportunity. The availability of adequate wind and solar resources, as well as the current cost-effectiveness of these generation technologies in Kentucky,

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[5] The analysis performed for this report considered 13 retrofit technologies not including biomass co-firing, and estimated that Kentucky coal units have only implemented half of the potential retrofits, limiting their application to those that do not trigger NSR. Implementing efficiency improvements at existing power plants has the potential to decrease CO_2 and other emissions on a pound per million British thermal unit basis, while at the same time reducing fuel costs.

is uncertain. The cost-effectiveness will likely improve over time with technological and fabrication advances and if the presumed increased costs for fossil fuel-generated electricity due to recent U.S. Environmental Protection Agency actions are realized. Studying and testing how and where these technologies might be best applied will help ensure that renewable energy opportunities are not missed. Incentives and mandates could also help foster development of these technologies, but will require legislation.

Biofuels represent both immediate and long-term opportunities for Kentucky. Kentucky's forests and agricultural lands offer a substantial and largely untapped resource for a variety of applications.[6] Biomass can be co-fired with coal in some existing boilers, can be the primary fuel source for new dedicated biomass generators, and can be converted into liquid fuels for use in transportation, electricity generation, and heat. However, the lack of a biomass supply chain is a major impediment to the use of biomass in Kentucky. Biomass development will require creation of the infrastructure necessary to support the procurement, transport, and utilization of biomass. Utilities interested in developing or purchasing biomass generation must have the confidence that the fuel will be available at competitive prices for the expected life of the plant, and that biomass investments will qualify for cost recovery.

Overview of Policy Recommendations and Estimated Impacts

The Energy Supply (ES) Technical Work Group (TWG) developed recommendations for 12 policies (see Table 4-2), 10 of which were then reviewed, revised, and ultimately approved by the Kentucky Climate Action Plan Council (KCAPC) members present and voting. The KCAPC rejected one policy (ES-12) and transferred ES-2 to the Residential, Commercial, and Industrial (RCI) TWG. The KCAPC is recommending for the Secretary's consideration multiple policies and sub-policies for the ES sector that offer the potential for significant GHG emission reductions. The policies analyzed are summarized in Table 4-2. The numbering used to denote these policies is for reference purposes only; it does not reflect prioritization among the recommended policies. An asterisk indicates that only that sub-policy is used for the sector total.

It is acknowledged that the Kentucky Public Service Commission (KPSC) participated in discussing the policy recommendations in this chapter. However, the KPSC abstained from taking a position for or against any policy recommendation that could come before it in an adjudicated proceeding. It is also acknowledged that the KPSC may need additional statutory authority to consider some of the policy recommendations.

[6] Discussed in detail in Chapter 3.

Table 4-2. Summary Results for Energy Supply Policy Recommendations and Existing Actions

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$) 2020	2030	Total 2011–2030	Net Present Value (Million $)	Cost-Effectiveness ($\$/tCO_2e$)
ES-1	Biomass Development and Efficiency Improvements at Existing Power Plants					
	Supply-side efficiency	1.6	2.1	27.4	$240	$8.8
	Biomass co-firing	4.0	4.5	65.1	$1,065	$16.34
	Total*	5.7	6.5	92.5	$1,305	$14.1
	Dedicated biomass					
	*Stoker technology**	0.4	0.4	8.2	$342	$41.5
	*Fluidized bed technology**	0.4	0.4	8.2	$242	$29.4
ES-2	Demand-Side Energy Efficiency and Management Programs	*Moved to Residential, Commercial, and Industrial Technical Work Group as policy RCI-3.*				
ES-3	Advanced Fossil Fuel Technology (IGCC, CCSR, Advanced Pulverized Coal, CFB) Incentives, Support, or Requirements					
	Scenario 1 (Supercritical without CCSR)					
	800 MW retired	0.7	0.7	7.4	$127.9	$17.2
	1,600 MW retired	1.9	1.9	21.1	$423.1	$20.1
	Scenario 2 (Conventional NGCC without CCSR)					
	600 MW retired	1.7	1.7	18.7	$307.2	$16.4
	1,200 MW retired	2.9	2.9	32.0	$544.0	$17.0
	*Scenario 3 (Supercritical with CCSR)**					
	800 MW retired	2.3	2.3	24.8	$824.8	$33.2
	1,600 MW retired	7.4	7.4	78.6	$2,729.5	$34.7
	Scenario 4 (Advanced NGCC with CCSR)					
	600 MW retired	2.4	2.4	26.8	$561.7	$21.0
	1,200 MW retired	4.2	4.2	46.3	$994.7	$21.5
ES-4	CCSR Enabling Policies, R&D, Infrastructure, and Incentives Including Enhanced Oil Recovery Using CO_2 (quantification considers CCSR demonstration project only)					
	*1 plant retrofitted**	1.8	1.8	23.5	$893.3	$37.9
	2 plants retrofitted	3.8	3.8	49.9	$1,891.7	$37.9

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)
		2020	2030	Total 2011–2030		
ES-5	Pricing Strategies to Promote Efficiency and Renewables Including Net Metering, Feed-In Tariff, Interconnection Rules, Inclined Rates, and Examination of the Standard Rate Structure (quantification considers feed-In tariff only)	1.2	5.2	43.9	$1,206	$27.5
ES-6	New Nuclear Energy Capacity	0.0	19.5	116.7	$2,481	$21.3
ES-7	Renewable Energy Incentives and Barrier Removal, Including CHP					
	*Scenario 1 (mixed renewable)**	15.1	22.2	263.6	$5,489	$20.8
	Scenario 2 (biomass)	15.1	22.3	272.2	$4,368	$16.0
	Scenario 3 (out-of-state wind)	15.1	22.3	272.2	$3,012	$11.1
	Scenario 4 (solar PV)	15.1	22.2	271.4	$8,157	$30.1
ES-8	Technology Research and Development (Not Including CCSR or Wind Potential Study) (quantification considers solar PV demonstration projects only)	0.013	0.013	0.24	$39.6	$164.9
ES-9	Policies to Support Wind Energy	*Not Quantified*				
ES-10	Shale Gas Development and Natural Gas Transportation Infrastructure and Gas-to-Liquids Technology	0.013	0.028	0.271	$22.3	$82.5
	Gas-to Liquids-Technology	0.039	0.077	0.763	$137.3	$179.1
ES-11	Smart Grid, Including Transmission and Distribution Efficiency (quantification considers smart grid only)	6.45	13.35	135.73	$3,608.4	$26.6
	Sector Total After Adjusting for Overlaps	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**
	Reductions From Recent Actions (EISA Title II requirements for new appliances and lighting)	**0.0**	**0.0**	**0.0**	**$0**	**$0**
	Sector Total Plus Recent Actions	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**

$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; CCSR = carbon capture and storage or reuse; CFB = circulating fluidized bed; CHP = combined heat and power; CO_2 = carbon dioxide; DSM = demand-side management; EERS = energy efficiency resource standard; EISA = Energy Independence and Security Act of 2007; EPA = U.S. Environmental Protection Agency; GHG = greenhouse gas; IGCC = integrated gasification combined cycle; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MW = megawatts; NGCC = natural gas combined cycle; N/A = not applicable; PBF = performance-based financing; PV = photovoltaics; RCI = Residential, Commercial, and Industrial; R&D = research and development; RE = renewable energy.

*These scenarios were used in the sector totals. The numbering used to denote the above policies is for reference purposes only; it does not reflect prioritization among the recommended policies.

The KCAPC approved 10 policy options, totaling nearly 756 $MMtCO_2e$ in cumulative GHG emission reductions between 2011 and 2030. These reductions are the largest of all four sector groups, and nearly double the reductions of the next-largest group (RCI). In spite of this, not all recommended ES policies were quantitatively analyzed. Some lacked data upon which to reasonably base analysis, while others were enabling policies that allow subsequent policies to operate but do not offer measurable reductions on their own.

The expected cost to the Kentucky economy per ton of emissions reduced from this set of ES recommendations is $24. Individual policy cost-effectiveness ranged from a low of $8.80 per tCO_2e (ES-1, Biomass Development and Efficiency Improvements at Existing Power Plants, Supply-Side Efficiency) to a high of $179 per tCO_2e (ES-10, Gas-to Liquids-Technology). None of the ES recommendations offered negative cost (cost savings) performance.

Descriptions of specific recommendations are given below. The KCAPC recommendations covered the following:

- Biomass used as a supplemental fuel at coal power plants, and as a primary fuel at dedicated plants.
- Efficiency improvements at existing coal-generating plants.
- Use of new technologies at fossil fueled generators, including integrated gasification combined cycle, CCSR, advanced pulverized coal, and circulating fluidized bed; faster development of CCSR and enhanced oil recovery technologies; and advanced natural gas combined cycle.
- Pricing strategies to promote the use of renewables and greater customer-side efficiency.
- Development of nuclear generation in Kentucky.
- Projects to explore the potential for wind and solar generation.
- Development of smart grid and efficiency improvement in T&D systems.
- Development of additional shale gas, including demand-pull recommendations for increased use of natural gas and its derivatives as transportation fuels.

Additional details regarding the application of these recommendations to Kentucky and their analysis (targets, implementation mechanisms, parties involved, modeling approach, etc.) are provided in Appendix F.

Energy Supply Sector Policy Descriptions

The ES sector has multiple opportunities for mitigating GHG emissions from electricity generation, transmission, and distribution, whether generated through the combustion of fossil fuels, nuclear, biomass, or other renewable energy sources through centralized power stations feeding the grid or distributed generation facilities. See Appendix F for detail on each recommendation.

ES-1. Biomass Development and Efficiency Improvements at Existing Power Plants

This policy recommendation is intended to promote the use of biomass at both new and repowered existing stand-alone plants, as well as co-firing biomass at fossil-fuel electric generating units. The biomass goal of this recommendation is to generate 4,182,000 MWh of electricity from biomass by 2025. This policy will also include energy efficiency improvements at existing fossil-fuel electric generating units. Current technologies could achieve efficiency improvements in the range of 3%–5% for the current generating fleet. Implementing efficiency improvements at existing power plants has the potential to decrease CO_2 and other emissions on a pound per million British thermal unit basis, while at the same time reducing fuel costs.

ES-3. Advanced Fossil Fuel Technology (IGCC, CCSR, Advanced Pulverized Coal, CFB) Incentives, Support, or Requirements

Advanced fossil technologies for electric generation include more efficient—and thus lower-emitting—generation technologies. Advanced fossil technologies combined with CCSR may have the potential to significantly lower CO_2 emissions associated with fossil fuel-based electricity generation. The goal of this policy is to facilitate the development of at least one advanced fossil fuel electric generating project utilizing coal and one utilizing natural gas by 2020.

ES-4. CCSR Enabling Policies, R&D, Infrastructure, and Incentives, Including Enhanced Oil Recovery Using CO_2

For fossil fuels to operate in a GHG-constrained world, the capture of CO_2 from natural gas- and coal-fueled power plants, and the successful storage or utilization (in a manner permanently preventing its entry into the atmosphere or oceans) of that carbon are necessary. Kentucky needs to further characterize the capacity of its geology to successfully store carbon after capture. The legal and regulatory issues involved around carbon capture and storage (CCS) also have to be addressed. This recommendation states that by 2012, Kentucky should work with the Carbon Management Research Group to address the intrastate and interstate legal and regulatory issues, including pore space ownership and long-term environmental stewardship and risk management, and by 2018, site a commercial-size demonstration project for CCS or utilization in the Commonwealth.

ES-5. Pricing Strategies to Promote Efficiency and Renewables, Including Net Metering, Feed-In Tariff, Interconnection Rules, Inclined Rates, and Examination of the Standard Rate Structure

Pricing strategies can be used to encourage energy efficiency, conservation, and demand response. Some pricing mechanisms encourage utilities to facilitate their customers' reduction in consumption, while others encourage customers to reduce consumption directly. Three pricing strategies were analyzed. With time-of-use pricing customers are charged a different rate for electricity during different time blocks during the day corresponding to the utility's cost to produce electricity during that time. Customers would have the flexibility to modify consumption patterns, reducing both their cost and their contribution to system peaks. This pricing structure can be advantageous for all types of customers in aligning price with cost, sending the appropriate signal to the customer, and modifying consumption patterns to maximize system efficiency and conservation.

Interconnection rules and net metering policies can facilitate the cost-effective interconnection of renewable or distributed energy resources onto the power grid. The goal of this policy is to establish effective net metering and interconnection rules to facilitate the connection of renewable or distributed energy resources to the grid.

A feed-in tariff (FIT) establishes rates for renewable power and mandates electric utilities to purchase that renewable power under long-term contracts. A Kentucky FIT[7] should apply to the following renewable energy technologies: solar, wind, low-impact biomass/biogas, and hydroelectric. Utilities would be mandated to purchase power from any renewable energy generator within the state who meets the technical requirements. Residential and small commercial systems would all be eligible to participate.

ES-6. New Nuclear Energy Capacity

Nuclear power has historically been a low-GHG source of electricity. However, no new commercial reactor has come on line in the United Sates since 1996, due to high capital costs, the absence of a repository or technology for permanent disposal of nuclear waste, and pubic concerns for safety. Steps to encourage nuclear power options in the state would have to begin with the removal of the statutory ban against constructing a nuclear plant in Kentucky (KRS 278-605 and 610). Steps could also include providing a streamlined siting review and streamlined appeals process and enacting policies to reduce the risk to capital. The recommendation goal is to install 2,000 MW of nuclear generation in Kentucky by 2025.

ES-7. Renewable Energy Incentives and Barrier Removal, Including Combined Heat and Power (CHP)

Renewable portfolio standards require utilities to meet a portion of their electricity demand with electricity generated with renewable resources. The recommended standard would incorporate efficiency and renewable electricity resources and require load-serving entities to obtain gradually increasing percentages of renewable energy resources or energy efficiency demand

[7] It is not required that both FIT and a renewable portfolio standard function together. They can be independent.

reductions ranging from 3% of sales in 2013 to 15% beginning in 2021. The recommendation also states that new hydro capacity and improvements to existing hydro plants that result in added capacity should qualify as a renewable energy resource under a state portfolio standard; that third-party partnership distributed renewable energy systems allow the host entity to purchase power from the on-site system; and that a well-funded, long-term statewide education program be developed to educate the general population and decision makers about energy fundamentals and renewable energy. The recommendation was analyzed assuming four alternate renewable/efficiency resource mixes emphasizing (1) mixed renewables, (2) biomass, (3) imported out-of-state wind generation, and (4) solar photovoltaics (PV).

ES-8. Technology Research and Development

This policy develops a roadmap for expanding traditional research for fossil fuels into renewable energy sources, energy efficiency technologies, distributed/grid-scale storage, carbon-free fuel generation, and pyrolysis of municipal solid waste, and will provide for large-scale demonstrations, as well as smaller deployments in residential or commercial applications. The recommendation also seeks to establish a pilot project to demonstrate the construction, operation, and grid integration of utility-scale PV power plants, specifically calling for the installation of five utility-scale PV power plants of at least 1 MW each, with one of the plants being at least 5 MW. Each of the major utilities in Kentucky should be targeted as partners in installing these plants. Subsidies need to be supplied to bring the cost of these pilot plants down to the point where they are cost competitive for the participating utilities.

ES-9. Policies to Support Wind Energy

Even though Kentucky has low wind resources relative to midwestern states, Kentucky could see wind farm development in the future. The Commonwealth has good transmission system lines (69 kilovolts and up) across the state that might serve a distributed network of wind farms. If Kentucky is to develop wind capacity, it needs to better understand the resource. While the wind maps and calculations by the National Renewable Energy Laboratory are helpful in understanding U.S. wind resources, they lead to additional questions and the need for more data. The state should collect wind data to further validate or identify bias within the wind maps. The data should be published and may be used when crafting policies. The recommendation calls for the creation of a working group tasked to identify 10 potential wind sites around Kentucky for placement of meteorological towers, and in 2013–2014 to install equipment and collect and process data. Towers would collect wind speed data at an elevation appropriate to extrapolate information about wind speeds at 100 and 120 meters.

ES-10. Shale Gas Development and Natural Gas Transportation Infrastructure and Natural Gas Liquids Technology

The Shale Gas policy is intended to help stimulate increased shale gas production and development in Kentucky. Increased Kentucky production will provide more natural gas supply as an alternative fuel to help reduce overall GHG emissions. The goal for the Shale Gas policy is to provide for increased development of natural gas from shale formations, with an increase from the current annual production level of approximately 100 billion cubic feet per year (bcf/yr) to an annual level of 150 bcf/yr by 2020, through increased drilling as well as enhanced drilling methods. Shale gas development should be encouraged by state action to ease the regulatory, permitting, and lag time for new well development and completion.

The goal for the Natural Gas Transportation Infrastructure policy is to provide for the development of a statewide network of compressed natural gas (CNG) filling stations, in order to (1) have natural gas filling stations in all cities with populations greater than 10,000 by 2020, and (2) facilitate the increased use of natural gas as a vehicle fuel, to support the deployment of 11,700 CNG vehicles by 2020.

The goal for the Natural Gas Liquids policy is to provide for the development of liquid fuel from natural gas, so that the fuel could be used in 2,000 heavy vehicles by 2016, instead of oil-based fuels such as gasoline or diesel fuel. Also, a secondary goal is to provide liquids removal capacity to accommodate the 50% additional shale production goal by 2020.

ES-11. Smart Grid, Including Transmission and Distribution Efficiency

Smart grid can be divided into two functional areas: customer load and use management, and T&D monitoring and control. Application of each can result in increased electrical efficiency, utilization, operational efficiency, reliability, or electricity load management. This recommendation calls for actions to achieve 25% coverage for advanced metering infrastructure (AMI) by 2015, 50% by 2020, and 100% by 2025.

This recommendation also proposes to replace transmission infrastructure (transformers and conductors) with higher-efficiency equipment as projects are implemented to achieve a10% reduction in transmission losses by 2030. Similarly, it is recommended that Kentucky replace distribution infrastructure (transformers and conductors) with higher-efficiency equipment as projects are implemented to reduce distribution losses by 10% by 2030. Transmission and distribution losses are typically around 5%, so a 10% reduction in the losses would be 0.5% reduction of the net generation.

Finally, the use of a prepaid meter program should be studied to determine whether and the extent to which conservation and efficiency gains associated with prepaid meter programs are greater than those of AMI with in-home display.

Chapter 5
Residential, Commercial, and Industrial Sectors

Overview of Sectoral Greenhouse Gas Emissions

The residential, commercial, and industrial (RCI) sectors were directly responsible for slightly more than 20% of Kentucky's gross greenhouse gas (GHG) emissions as of 2005—a total of just over 37 million metric tons of carbon dioxide equivalent ($MMtCO_2e$). Direct emissions from these sectors result principally from the on-site combustion of natural gas, oil, and coal, as well as the release of CO_2 and fluorinated gases (hydrofluorocarbons [HFCs] and perfluorocarbons) during industrial processes; from the leakage of HFCs from refrigeration and related equipment; and to a smaller degree, from the use of sulfur hexafluoride in the utility industry. Direct emissions in the RCI sectors produce GHG emissions when fuels are combusted to provide space heating, process heating, and other applications.

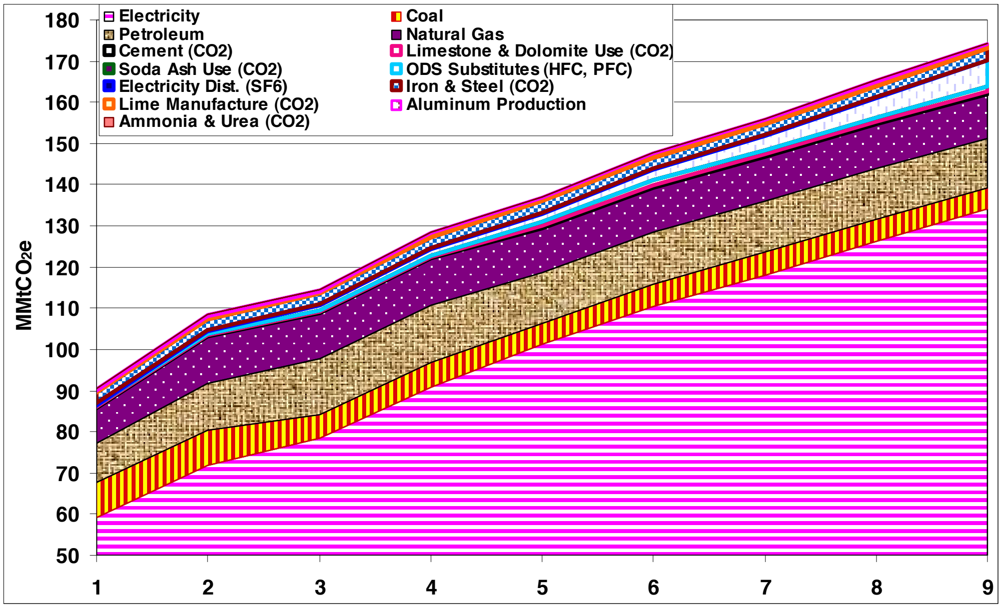
In addition to direct emissions from combustion of fuels and industrial processes in the RCI sectors, nearly all of the electricity sold in Kentucky is consumed as the result of RCI activity. Emissions associated with producing the electricity consumed in Kentucky were nearly 50% (90.9 $MMtCO_2e$) of the state's gross GHG emissions in 2005.[1] Combining fuel use, industrial process emissions, and electricity accounts for 70% of the state's total gross GHG emissions. Kentucky's future GHG emissions, therefore, will depend significantly on future trends in the consumption of electricity and other fuels in the RCI sectors.

Historical and projected GHG emissions for the RCI sectors by fuel and source are provided in Figure 5-1 for the Reference Case forecast scenario. This figure illustrates that RCI emissions associated with electricity use are expected to comprise about 77% of RCI emissions by 2030. Industrial gases and petroleum each contributes about 7% of 2030 emissions, with the balance attributable to natural gas (6%) and coal (3%). The projections do not account for utility actions to comply with new or pending U.S. Environmental Protection Agency regulations.

RCI emissions are forecasted to increase by approximately 1.2% annually between 2005 and 2030, but this overall estimate masks large changes within emission sources based on the assumptions and data from 2010 and 2011. Electricity and industrial process emissions are projected to account for all of the sector's growth in gross GHG emissions during this period. GHG emissions from the electricity sector grow at about 1.6% annually, which is faster than electricity demand growth (1.4% per year), because the assumed Reference Case electricity generation resources are GHG intensive. Emissions associated with industrial process emissions are expected to rise annually by about 2.6% between 2005 and 2030. Emissions from fuels (coal, petroleum, wood, and natural gas) are expected to decrease by about 10% over the 2005–2030 period.

[1] Gross emissions here denote GHG emissions from activities in Kentucky, adjusted for exports of electricity, oil, and gas, but not including consideration of estimated "sinks" of GHGs in the forestry and land-use sectors.

Figure 5-1. Historical and Projected Residential, Commercial, and Industrial GHG Emissions in $MMtCO_2e$, 1990–2030

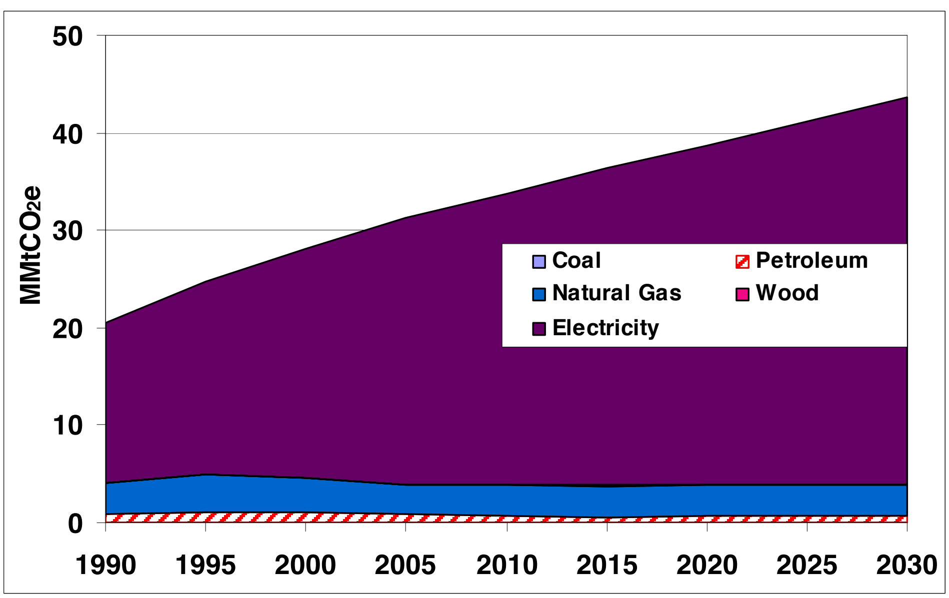


Note: Net GHG emissions from wood not shown.

CO_2 = carbon dioxide; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; HFCs = hydrofluorocarbons; ODS = ozone-depleting substance; PFCs = perfluorocarbons; SF_6 = sulfur hexafluoride.

Figure 5-2 shows that GHG emissions from the residential sector are dominated by electricity-related GHG emissions. Residential electricity emissions are forecasted to grow at 1.5% over the 2005–2030 period in the Reference Case. Natural gas is the only other significant source of GHGs for the residential sector in the Reference Case.

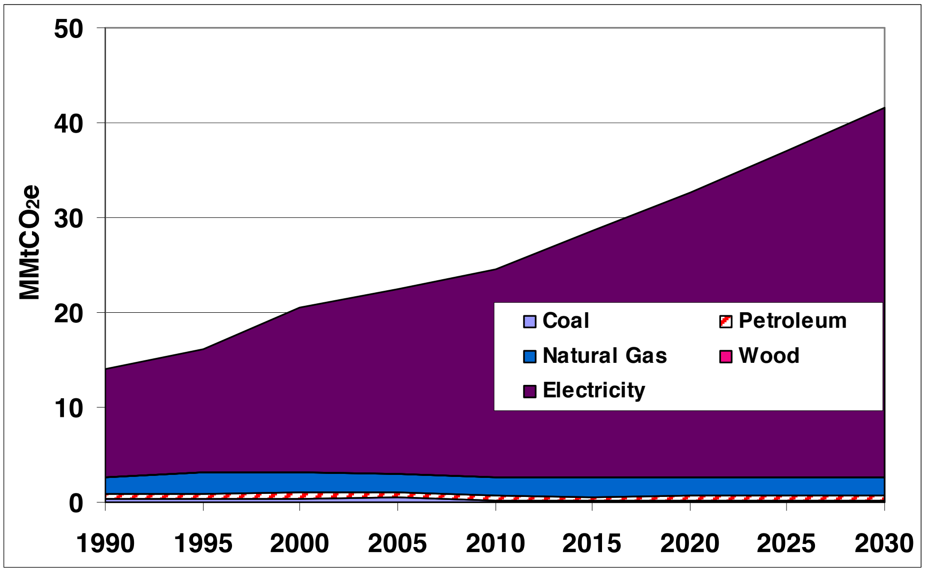
Figure 5-2. Historical and Projected Residential GHG Emissions, 1990–2030



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Figure 5-3 shows that GHG emissions from the commercial sector are also dominated by electricity-related GHG emissions. Natural gas is the only other significant source of GHGs for the commercial sector in the Reference Case as well. At 2.5%, annual commercial sector GHG emissions growth is nearly twice as high as residential sector growth (1.3%) over the 2005–2030 period.

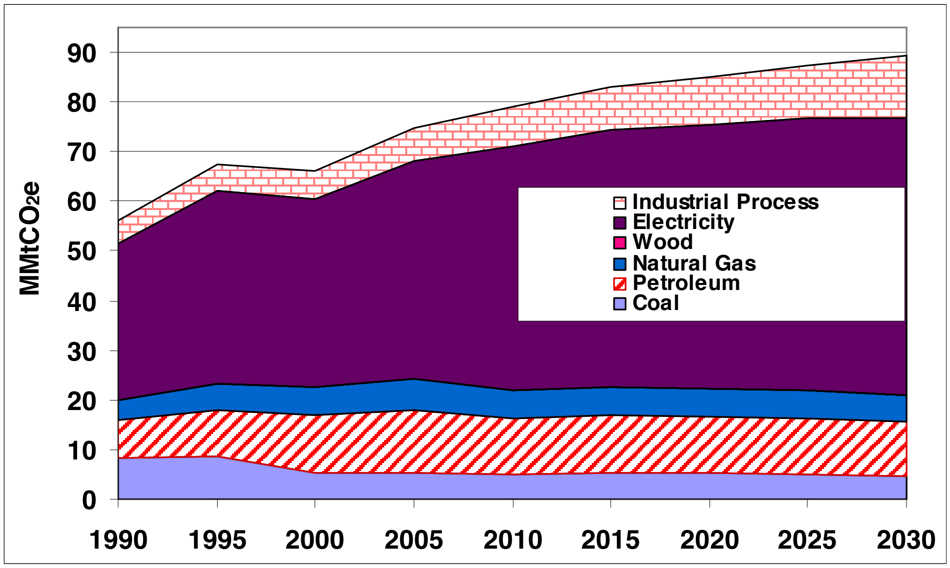
Figure 5-3. Historical and Projected Commercial GHG Emissions, 1990–2030



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Figure 5-4 shows the importance of the industrial sector to Kentucky's energy and climate policy planning. GHG emissions from the industrial sector are also dominated by electricity-related GHG emissions. But petroleum joins natural gas and coal as significant sources of GHGs for this sector. While industrial emissions are forecasted to grow at 0.5% per year from 2005 to 2030, all the emissions growth occurs from increases in electricity demand (0.9% per year). Coal, petroleum, and natural gas emissions are expected to decrease by approximately 0.5% per year from 2005 to 2030.

Figure 5-4. Historical and Projected Industrial GHG Emissions, 1990–2030



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Key Challenges and Opportunities

The principal means to reduce RCI emissions in Kentucky include improving energy efficiency, substituting electricity and natural gas with lower-emission energy resources (such as biomass and wind), and various strategies to decrease the emissions associated with electricity production (see Chapter 4, Energy Supply Sector). The state's limited pursuit of energy efficiency until recent years offers opportunities to reduce emissions through programs and initiatives to improve the efficiency of buildings, appliances, and industrial practices. The advantages of having "low-hanging fruit" in the form of low-cost energy efficiency opportunities in the RCI sectors are countered by an underdeveloped private sector that will likely be responsible for scoping, implementing, and evaluating energy efficiency projects. These jobs require special training and equipment that will take time for firms within the state to acquire.

Kentucky's large industrial sector presents opportunities for cost-effective demand reductions. Industrial energy efficiency is typically relatively cheap compared to new sources of energy supply, and energy efficiency can increase the competitiveness of firms in the state. Similarly, industrial process GHGs can typically be mitigated cost-effectively. However, with the exception of the industrial combined heat and power policy described below, Kentucky has few existing policies or planned actions specifically designed to reduce GHGs from the industrial sector.

Kentucky's utilities have been pursuing limited residential demand-side management (DSM) programs. House Bill (HB) 240 (2010) allows the Kentucky Public Service Commission to create requirements for DSM programs and allows utilities cost recovery for DSM activities. We assume that existing residential electric DSM programs are equal to 0.25% of load over the 2010–2030 period and are not in the Reference Case GHG forecast. HB 2 (2009) requires state and local government-owned (and leased) public buildings to meet high-performance building targets. Table 5-1 presents the estimated effects of residential DSM and public-sector high-performance buildings.

Table 5-1. Recent Action Results Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)		
		2020	2030	Total 2011–2030
RCI-7	Government Lead by Example	0.6	1.5	14
RCI-3	Expand Utility DSM Programs for Electricity	0.9	1.7	18

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; DSM = demand-side management; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five).

Overview of Policy Recommendations and Estimated Impacts

The Kentucky Climate Action Plan Council (KCAPC) has identified significant opportunities for reducing GHG emissions growth attributable to the RCI sectors in Kentucky. These include expanding or launching energy efficiency programs for electricity, promoting high-performance buildings in the private sector, regularly updating building codes, requiring state and local governments to implement beyond-code building practices and green power purchase/generation, labeling and benchmarking buildings, as well as actively promoting adoption of combined heat and power in the state. The KCAPC has also identified significant opportunities to reduce GHG emissions through policies addressing electricity production (detailed in Chapter 4).

The RCI Technical Work Group (TWG) developed recommendations for nine policies (see Table 5-2.[2]) that were then reviewed, revised, and ultimately approved by the KCAPC members present and voting. One additional policy option (RCI-10) was assigned to the Energy Supply (ES) TWG for analysis. The KCAPC recommends for the Secretary's consideration a set of nine policy options for the RCI sectors, as detailed in Table 5-2.[3] The GHG emission reductions and costs per ton of GHG reductions for seven of these policies were quantified. The quantified policy recommendations could lead to emission savings from Reference Case projections of:

- 38 $MMtCO_2e$ per year by 2030, and a cumulative savings of over 400 $MMtCO_2e$ from 2011 to 2030.
- Net cost of approximately $1.2 billion through 2030 on a net present value basis. The weighted-average cost of these policies is about $3/$tCO_2e$.

It is acknowledged that the Kentucky Public Service Commission (KPSC) participated in discussing the policy recommendations in this chapter. However, the KPSC abstained from taking a position for or against any policy recommendation that could come before it in an adjudicated proceeding. It is also acknowledged that the KPSC may need additional statutory authority to consider some of the policy recommendations.

[2] The net cost savings are based on fuel expenditures, operations, maintenance, and administrative costs, and on amortized, incremental equipment costs. All net present value (NPV) values shown here are calculated using a 5% per year real discount rate.

[3] The net cost savings are based on fuel expenditures, operations, maintenance, and administrative costs, and on amortized, incremental equipment costs. All net present value (NPV) values shown here are calculated using a 5% per year real discount rate.

Table 5-2. Recommended Policy Options and Results for the Residential, Commercial, and Industrial Sectors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effectiveness ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-1	Improve Building Codes for Energy Efficiency, Coupled with Improved Energy Code Training and Enforcement	0.4	1.2	9	–$213	–$23
RCI-2	Promote, Encourage, and Provide Incentives for “Beyond-Code” Efficiency in All Building Characteristics and Systems That Impact Energy Consumption	2	5	50	–$1,376	–$27
RCI-3	Expand Utility DSM Programs for Electricity	6	19	169	–$3,340	–$20
RCI-4	Develop and Implement Comprehensive Education, Outreach, and Marketing, Including Consumer Awareness, School Curriculum, Truth-in-Advertising, Technical Information and Support (e.g., How to Do GHG Inventories, Rationales for Action, etc.)	*Not Quantified*				
RCI-5	Financing Programs and Incentives for Energy Efficiency and CHP (PBF, Revolving Loans, etc.) (ONLY CHP QUANTIFIED)	12	22	259	$538	$2
RCI-6	Financing Programs, Incentives, Policies, and Research for Conversion to Renewable Energy or Low-Carbon Energy Sources (ONLY RENEWABLE ELECTRICITY QUANTIFIED)	1.4	4.4	35	$3,372	$96
RCI-7	Government Lead by Example (GLE) in Highly Efficient State and Local Government Buildings	0.7	1.6	15	–$16	–$1
RCI-8	Training and Education for Builders, Contractors, and Building Operators	*Not Quantified*				
RCI-9	Building Commissioning and Recommissioning, Including Energy Tracking and Benchmarking, and Implement a Building Energy Labeling Program	3	5	50	–$1,117	–$23
RCI-10	Implement Advanced Metering Technologies and Associated Policies for Greater Load Management, Customer Control, Awareness, Price Signaling, etc.	*Moved to Energy Supply Technical Work Group as policy recommendation ES-11.*				
	Sector Total After Accounting for Overlaps	**19**	**38**	**408**	**$1,220**	**$3**
	Reductions From Recent Actions (Existing DSM Programs, HB 2 for Government Buildings)	**1.5**	**3.2**	**32**		
	Sector Total Plus Recent Actions	**20**	**42**	**441**		

GHG = greenhouse gases; $MMtCO_2e$ = million metric tons of CO_2 equivalent; UC = unanimous consent; NA = not applicable; TWG = technical work group

Negative cost effectiveness values reflect economic savings. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.

Overlaps within RCI

To assess the cumulative emission reductions for the policies in the RCI sectors, it is necessary to consider any overlaps among the policies that affect similar types of energy use. Specifically, some policies (such as RCI-2) are defined by their goals for reducing energy use, while others (such as RCI-3, RCI-5, and RCI-6) are defined by addressing a specific type of energy use or supply. Policies were compared in terms of the type of energy use they target and the energy reduction measures each is expected to implement. Overlaps were identified and quantified by sector (RCI or government), type of energy use targeted (water heating, space heating, etc.), and measure (e.g., high-efficiency air conditioning).

- RCI-3 (Expand Electric Utility DSM Programs) overlaps are estimated at the measure level. RCI-3 and RCI-2 are both policies that offer incentives to end users to purchase more efficient equipment. RCI-3 provides incentives for electricity measures, such as ENERGY STAR appliances, weatherization, and building heating, ventilating, and air conditioning measures. We estimate that these measures and targeted markets (end users) are similar to those expected to be provided incentives under RCI-2. Because of the similarity in measures and targets, the GHG reductions and associated costs or benefits from electric efficiency under this policy are reduced by 75% to account for overlaps with RCI-2. This estimate is conservative, to ensure that GHG reductions under RCI-3 are not double counted with RCI-2.
- RCI-5 (Financing for Combined Heat and Power [CHP]) is a supply-side policy recommendation that is quantified according to the expected demand for thermal resources in the commercial and industrial sectors. More efficient use of hot water from improved commercial building heating and cooling or domestic use of hot water under RCI-2 could reduce the supply of commercial CHP. Commercial GHG reductions and associated costs or benefits from electric efficiency under this policy are reduced by 20% to account for potential overlaps with RCI-2. The KCAPC did not develop an RCI policy specifically to improve industrial energy efficiency that could reduce the supply of industrial CHP. Therefore, industrial GHG reductions and associated costs or benefits from the CHP policy are not reduced to account for overlaps with other policies.
- RCI-9 (Building Commissioning, Benchmarking, and Labeling) is composed of two main elements: commissioning and building audits that are the basis for benchmarking and labeling. Commissioning new buildings is assumed to be a part of the "above code" or green building portion of RCI-2. Similarly, recommissioning existing buildings is a cost-effective program to reduce energy consumption that is assumed to fall under the retrofit element of RCI-2. Therefore, the GHG reductions and associated costs or benefits from the commissioning and recommissioning elements of the policy are reduced by 100% to account for overlaps with RCI-2. The net effect of the overlap reductions is to reduce GHG mitigation from the policy by 85% by 2030, as most of the reductions from the policy are estimated to result from commissioning and recommissioning. While building audits are part of most residential energy efficiency programs, their penetration without the home sales element of this policy would be limited. A similar argument can be made for the limited penetration of

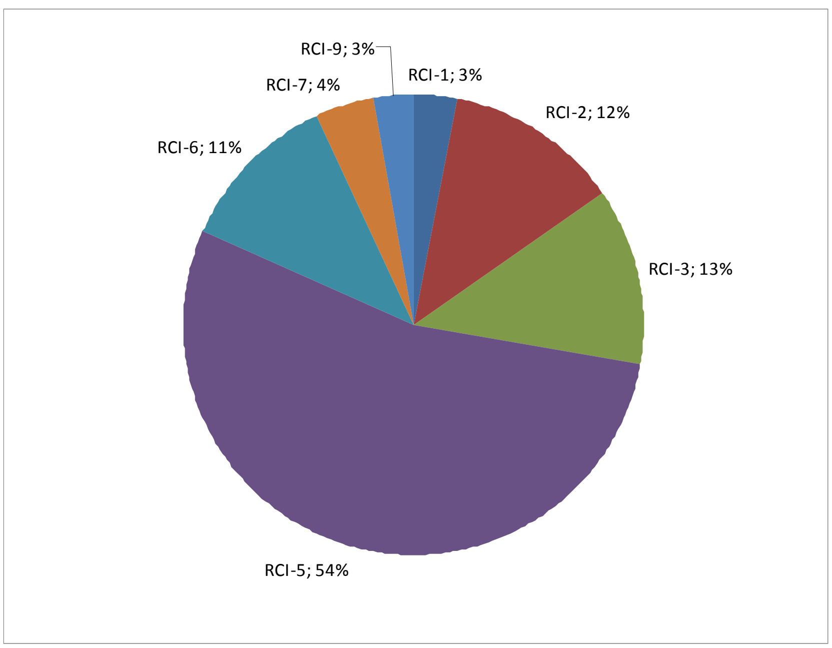
Overlaps Between Other Sectors

There are several potential overlaps between RCI and other sectors. These potential overlaps are discussed qualitatively here. The first is that electricity energy efficiency investments from the suite of RCI policy recommendations reduce electricity demand. Reducing future electricity sales makes it easier for regulated entities to meet a target for renewable electricity sales as a percentage of total sales. Such a renewable electricity target is being developed under ES-7, and the demand reductions from RCI would likely make compliance with the target more cost-effective and easier to attain.

An additional feedback is that certain Energy Supply policies will have the effect of reducing the GHG emissions associated with electricity generation. In this case, RCI policies that target electricity use will have a correspondingly reduced ability to deliver GHG emission reductions. The RCI analysis assumes that current and future electricity generation is largely coal-fired. If considerable fuel switching occurs from coal to cleaner sources of electricity, then the electricity-related GHG reductions from the RCI policies would be reduced. This impact has not been reflected in the analysis.

Figure 5-5 shows the breakdown for the KCAPC policy recommendations from the RCI sectors by their contribution to GHG reductions.

Figure 5-5. 2030 Annual RCI Greenhouse Gas Reductions by Policy Recommendation (after overlaps)



The policy recommendations described briefly below, and in more detail in Appendix G, not only result in significant emission reductions and costs savings, but offer a host of additional benefits as well. These benefits include savings to consumers and businesses on energy bills, which can result in the reduction in spending on energy by low-income households; reduced peak demand, electricity system capital and operating costs, risk of power shortages, energy price increases, and price volatility; improved public health as a result of reduced pollutant and particulate emissions by power plants; reduced dependence on imported fuel sources; employment expansion; and enhanced economic development opportunities.

For the RCI policies recommended by the KCAPC to yield the levels of savings described here, they must be implemented in a timely, aggressive, and thorough manner. This means, for example, not only putting the policies themselves in place, but also attending to the development of "supporting policies" that are needed to help make the recommended policies effective. While the adoption of the recommended policies can result in considerable benefits to Kentucky's environment, security of energy supply and the state's consumers, the state needs to ensure careful, comprehensive, and detailed planning and implementation, as well as consistent support, of these policies in order for these benefits to be achieved.

Residential, Commercial, and Industrial (RCI) Policy Descriptions

RCI-1. Improve Building Codes for Energy Efficiency, Coupled with Improved Energy Code Training and Enforcement

The KCAPC recommends upgrading and enforcing Kentucky's building energy codes that specify minimum energy efficiency requirements for new buildings or for existing buildings undergoing a major renovation. Given the lifetime of buildings, amending state building codes to include minimum energy efficiency requirements and periodically updating energy efficiency codes could provide long-term GHG savings. Kentucky can improve energy codes to include energy efficiency gains, lighting design, building envelope design, and integrated building design strategies. The recommendation expands enforcement of building energy codes, requires Kentucky to regularly adopt national codes with amendments as appropriate, and achieve targeted improvements in energy efficiency through educational programs for building inspectors and code enforcement officials to ensure that the existing codes are implemented and enforced.

RCI-2. Promote, Encourage, and Provide Incentives for "Beyond-Code" Efficiency in All Building Characteristics and Systems That Impact Energy Consumption

The KCAPC recommends providing incentives and targets to induce the owners and developers of new buildings to improve the efficiency of the use of energy and other resources in those buildings, along with provisions for raising target levels periodically and providing resources to building industry professionals to help achieve the desired building performance. Improving the energy efficiency design of buildings will have an immediate and ongoing impact on reducing GHG emissions.

The policy provides tiered incentives for energy efficiency in new buildings that achieve a reduction in energy use relative to U.S. Department of Energy (DOE) Executive Order 430.2B regarding energy standards for commercial buildings, as well as the 2009 International Energy Conservation Code (IECC) for residential buildings. Building performance is to be certified by a design professional or a nationally recognized third-party-verified green building certification system for commercial or residential buildings (e.g., Leadership in Energy and Environmental Design (LEED), American Society of Heating, Refrigeration, and Air-Conditioning Engineers [ASHRAE]/U.S. Green Building Council (USGBC)/Illuminating Engineering Society of North America [IESNA] Standard 189, or Green Globes New Construction). Additionally, the policy can reward projects where minimum energy efficiency exceeds American National Standards Institute/ASHRAE/IESNA Standard 90.1-2004 benchmark levels. Incentives could include low-cost loans for investments in energy efficiency, tax credits, expedited plan review permits, and feebates for design professionals.

RCI-3. Expand Utility DSM Programs for Electricity

The KCAPC recommends DSM programs, including energy efficiency education, programs, or goals for reduced electricity consumption, and calls for actions that influence the quantity and/or patterns of use of energy consumed by end users. This policy recommendation focuses on increasing investment in electricity DSM/energy efficiency through innovative actions developed and implemented by utilities, community partners, and customers. The ultimate goal is to provide tools, information, assistance, and knowledge that will help customers manage their energy consumption more efficiently and reduce their consumption. The GHG emission reductions assume that DSM and education programs begin in 2012 and reach full implementation by 2015, when they achieve incremental annual load reductions of 1% of the forecasted load. Load reductions occur for all RCI sectors at the same implementation rate through 2030.

RCI-4. Develop and Implement Comprehensive Education, Outreach, and Marketing, Including Consumer Awareness, School Curriculum, Truth-in-Advertising, Technical Information and Support (e.g., How to Do GHG Inventories, Rationales for Action, etc.)

The KCAPC recommends the development of consumer education courses and outreach programs for GHG emission reductions. The policy will provide information and education to present and future consumers in all levels of education—elementary, secondary, college, university, and community colleges—and will develop guidelines to ensure that factual and accurate information regarding GHG emission implications is provided to consumers through a truth-in-advertising campaign targeting advertising of energy-consuming products. Additionally, the policy will develop consumer product programs that may include education, incentives, retailer training, marketing, and promotion, and will utilize tools, such as Web-based calculators, to assist residents, businesses, and communities with developing GHG inventories and to evaluate and act upon their GHG inventory results. The policy requires that by 2012, the education awareness programs are in place, outreach programs are begun, and school curriculum areas are evaluated to make sure they include GHG awareness.

RCI-5. Financing Programs and Incentives for Energy Efficiency and CHP (PBF, Revolving Loans, etc.)

The KCAPC recommends financing programs designed to eliminate a major barrier to private investment in energy efficiency, conservation, or combined heat and power (CHP) measures installed on buildings: the large up-front investment. By removing this barrier, building owners are more likely to pursue building-scale energy efficiency retrofits and/or CHP installations.

A number of programs and incentives that have been successful in other jurisdictions could be designed and implemented in Kentucky as part of this policy recommendation. Green mortgages roll the costs of energy efficiency or CHP measures into new or refinanced mortgages and allow the amortization of the costs of the efficient equipment to better match future utility bill savings from the equipment. Public benefit funds (PBFs) provide a source of financing for all types of sales rebate programs to “buy down” the incremental costs of CHP and/or energy-efficient equipment. State income tax credits and property tax credits can also provide a source of funding to households and firms to purchase energy-efficient equipment and/or CHP. Energy loan programs, financed by state-issued bonds, provide low-interest loans and can also reduce the large up-front investments associated with energy-efficient equipment and/or CHP. Finally, Property Assessed Clean Energy (PACE) financing programs work through the creation of a public loan fund at the municipal level that is directed solely to financing energy efficiency and/or CHP installations. The repayment of the funds takes place annually along with the building owner's property tax bill, giving PACE payments the same treatment as taxes for lien priority purposes.

This policy pairs with RCI-6, which provides for similar financing mechanisms to encourage investments in renewable energy by building owners.

RCI-6. Financing Programs, Incentives, Policies, and Research for Conversion to Renewable Energy or Low-Carbon Energy Sources

The KCAPC recommends financing programs designed to address the significant opportunity in Kentucky for increased investments in renewable energy by building owners. Numerous ways exist to encourage adoption of renewable energy options, including rebates funded through PBFs or other mechanisms, low-cost loans provided through revolving loan funds, providing greater security to lenders through loan-loss reserve funds, etc. Funding may also be available through U.S. DOE programs. Market penetration will depend on funding levels and decisions concerning what kinds of improvements qualify for funding. For the purposes of quantification, renewable energy projects in Kentucky are assumed to be financed by a wide range of mechanisms that reduce market barriers to their deployment and result in the renewable energy policy goals being achieved.

RCI-7. Government Lead by Example (GLE) in Highly Efficient State and Local Government Buildings

The KCAPC recommends a policy to provide energy efficiency targets for new construction of state and local government buildings and renovation of existing state and local government buildings whose energy consumption is much higher than code standards. The Kentucky state government is a significant consumer of energy. The state owns about 66.9 million square feet of building space and leases an additional 5.2 million square feet. Furthermore, local government buildings, such as courthouses, city halls, K–12 schools, and other facilities, are estimated at an additional 60 million square feet. The Kentucky General Assembly has made great strides in the maintenance of public buildings. However, the potential for significant improvements and upgrades remains, reflecting opportunities for more energy savings through more energy-efficient equipment and practices.

This policy requires the Kentucky Finance and Administration Cabinet to improve the efficiency of energy and other resources in public buildings that receive 50% or more of their construction funding from the Commonwealth. The policy requires new buildings to achieve a reduction in energy use relative to DOE Executive Order 430.2B energy standard for commercial buildings and the 2009 IECC for residential buildings, and includes certification by a design professional or a nationally recognized third-party-verified green building certification system for commercial or residential buildings (e.g., LEED, ASHRAE/USGBC/IESNA Standard 189, or Green Globes New Construction).

RCI-8. Training and Education for Builders, Contractors, and Building Operators

The KCAPC recommends a policy to provide training, education, and outreach for builders, contractors, building operators, and code officials that encourages these building professionals to incorporate energy efficiency and GHG emission reduction considerations in the conduct of their work. Education and training should be mandatory and available to builders, contractors, and others involved in the construction of new buildings and the retrofitting and renovation of existing buildings. The recommendation develops technical/professional education courses and outreach programs for GHG emission reductions to increase the number of professionals trained in energy efficiency. It also requires targeted improvements in energy efficiency through educational programs for builders, building inspectors, and other building industry professionals to help ensure that the existing codes are implemented and enforced.

RCI-9. Building Commissioning and Recommissioning, Including Energy Tracking and Benchmarking, and Implement a Building Energy Labeling Program

The KCAPC recommends a policy to require building commissioning, labeling, and benchmarking. Ongoing commissioning is the continued implementation of preventive maintenance and performance reviews in order to keep building systems operating efficiently, involving energy tracking and benchmarking, system tune-ups, equipment and sensor calibrations, and staff retraining, among other program elements. This policy recommendation would initiate commissioning efforts for publicly owned buildings. The efforts would extend the scope of facilities to not only include capital construction, but also systematically address existing buildings and facility management processes. The recommendation would look at possible incentives for private facility owners who implement commissioning efforts for new construction and renovations, existing buildings, and/or facility management processes.

Tracking and benchmarking the energy used in a building provides valuable information, not only for comparative purposes between buildings of similar use classification, but also for identification of buildings that have high and/or low performance, in order to determine efficient utilization of energy and where resources need to be spent to reduce the energy costs. Benchmarking is commonly used to identify the minimally acceptable performance of buildings. Building energy labels provide information on the potential and actual energy usage of buildings, give feedback to building owners and operators on how their buildings are performing, provide insight into the value and potential long-term costs of a building and market-based forces to influence energy efficiency investment opportunities, and can serve as a tool to provide for differentiation in the marketplace.

RCI-10. Implement Advanced Metering Technologies and Associated Policies for Greater Load Management, Customer Control, Awareness, Price Signaling, etc.

Moved to Energy Supply Technical Work Group as policy recommendation ES-11.

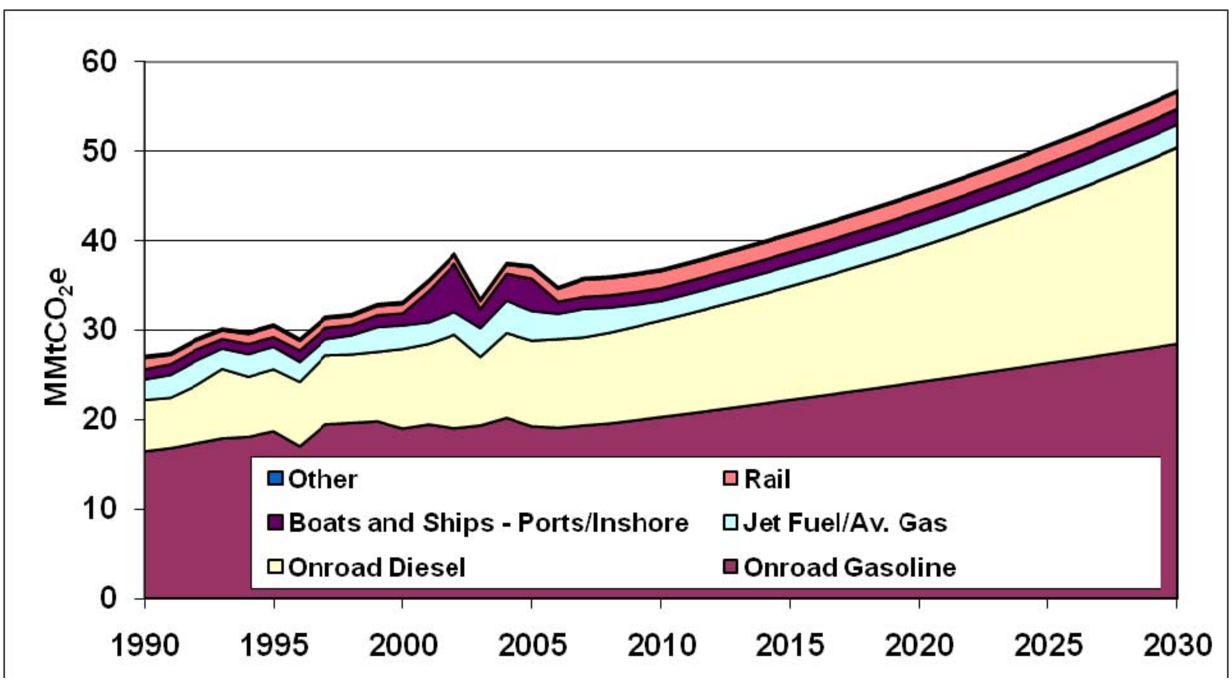
Chapter 6
Transportation and Land Use Sectors

Overview of Greenhouse Gas Emissions

Emissions from the transportation and land use (TLU) sectors include the emissions produced by the operation of light- and heavy-duty (on-road) vehicles, as well as emissions produced by off-road or specialized vehicles, aircraft, rail engines, and marine engines. Emissions accounted for in the TLU sectors include not only the direct emissions from vehicle exhaust, but also the "upstream" emissions associated with the extraction and transportation of raw materials (usually petroleum), as well as the emissions associated with the energy-intensive processes of refining, distributing, and pumping fuel.

The TLU sectors represented approximately 20% of Kentucky's greenhouse gas (GHG) emissions in the 2005 inventory. While smaller than the 27% share the sector represents on a nationwide scale, emissions from this sector are growing rapidly. Emissions grew from approximately 27 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) in 1990 to 37 $MMtCO_2e$ in 2005—a growth of over 35% in 15 years. The TLU sectors are projected to be the second-largest source of emissions growth after the energy supply sector over the 2005–2030 period. The sectors' emissions are projected to reach 57 $MMtCO_2e$ by 2030—more than doubling the 1990 estimate, with the largest share of that growth coming from on-road commercial vehicles burning diesel fuel. Figure 6-1 shows historic and projected transportation GHG emissions by fuel and source.

Figure 6-1. Transportation GHG Emissions by Fuel Source, 1990–2030



GHG = greenhouse gas; $MMtCO_2e$ - million metric tons of carbon dioxide equivalent; av. gas = aviation gas.

Key Challenges and Opportunities

Kentucky has substantial opportunities to reduce GHG emissions from transportation sources. The principal approaches to reducing GHG emissions from transportation and land use are:

- Improving vehicle fuel efficiency;
- Utilizing less carbon-intensive fuels, which produce lower volumes of GHG emissions per unit of energy provided; and
- Reducing travel volume or shifting travel to more energy-efficient modes, such as shared travel or transit.

Prior to the establishment of stricter federal corporate average fuel economy (CAFE) standards in 2007, in Kentucky and in the nation as a whole, vehicle fuel efficiency had improved little since the late 1980s. Many studies have documented the potential for substantial increases in efficiency, while maintaining vehicle size and performance. Automobile manufacturers typically oppose dramatic increases in fuel economy. Key points of contention include the costs to manufacturers and consumers. Even with the adoption of the new federal CAFE requirements, there are opportunities for further increases in fuel efficiency, while maintaining vehicle size and performance.

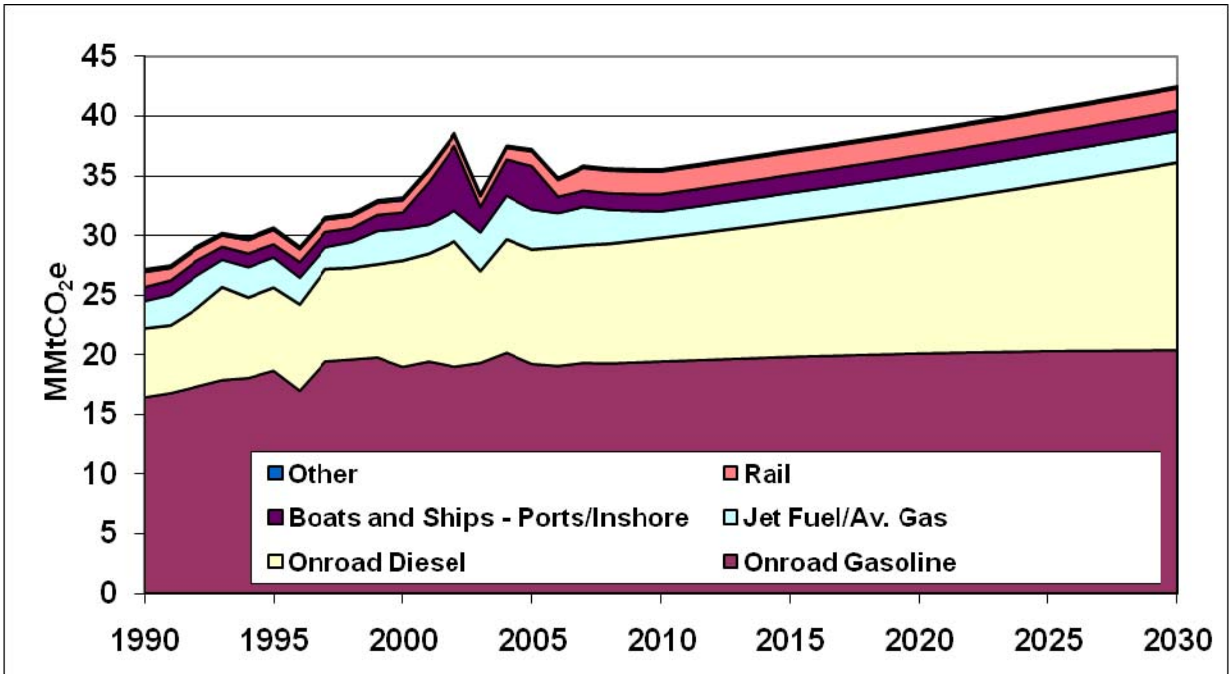
The use of fuels with lower per-mile GHG emissions could achieve larger market penetration in Kentucky. Conventional gasoline- and diesel-fueled vehicles can use low-level blends of biofuels, such as a blend of up to 15% ethanol in gasoline and up to 10% or even 20% biodiesel in diesel, depending on manufacturer's certifications. Alternative-technology vehicles can also use more concentrated biofuels blends, as well as other types of alternative fuels, such as electricity, natural gas, and hydrogen. The type of fuel used is a crucial determinant of a vehicle's GHG emissions from operation; while some alternative fuels are much cleaner options than gasoline or diesel, other alternative fuels offer relatively little GHG benefit.

Alternative fuels from biomass, cellulosic residues, and energy crops have been identified by the U.S. Department of Agriculture and U.S. Department of Energy as the best near-term opportunity to reduce foreign-oil dependence and GHG emissions from transportation. Key determinants of the possible impact to GHG emissions will be the development and deployment of new fuel types. At present, fuel distribution infrastructure is a constraining factor. Existing federal legislation provides incentives in the form of income and sales tax credits for investments in the production, storage, and distribution of biodiesel and ethanol.

Reducing vehicle miles traveled (VMT), particularly of single-occupancy vehicles (SOVs), is crucial to mitigating GHG emissions from transportation. Developing smarter land-use and transportation development patterns that reduce trip length and support transit, carpooling, ride sharing, biking, and walking can contribute substantially to this goal. A variety of pricing policies and incentive packages can also help to reduce VMT. Developing better planning methods and regulations, and increasing funding of multiple modes of transportation will be key components in achieving these goals.

As part of the development of the inventory and forecast (I&F) of Kentucky's GHG emissions, emission projections were developed for a lower-VMT future, which show that simply reducing the growth in VMT produces a much lower projection of overall emissions. Figure 6-2 displays the alternate GHG projection, which shows an emissions level of only 43 $MMtCO_2e$ by 2030, rather than the 57 $MMtCO_2e$ figure under the standard assumption.

Figure 6-2. Transportation GHG Emissions by Fuel Source under the Alternate Low-Growth VMT Projection, 1990–2030



av. gas = aviation gas; $MMtCO_2e$ - million metric tons of carbon dioxide equivalent; VMT = vehicle miles traveled.

Overview of Policy Recommendations and Estimated Impacts

The TLU Technical Work Group (TWG) developed recommendations for 10 policies (see Table 6-1) that were then reviewed, revised, and ultimately approved by the Kentucky Climate Action Plan Council (KCAPC) members present and voting. The KCAPC recommends for the Secretary's consideration a set of 10 policies for the TLU sector that offer the potential for major economic benefits and GHG emission savings. In fact, while all policies are expected to reduce emissions, three-quarters of those policies for which economic impacts were estimated are also expected to produce a net savings or economic benefit to Kentucky's economy.

Table 6-1. Summary List of TLU Policy Recommendations

Policy No.	Policy Option	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/$tCO_2e$)	Energy Savings (Million gallons) 2011–2030
		2020	2030	Total 2011–2030			
TLU-1	Bicycle and Pedestrian Comprehensive Plan and Infrastructure Development	0.055	0.087	1.049	–$445	–$424	–87
TLU-2/6	Livability, Brownfield Redevelopment, Downtown Revitalization, Location-Efficient Strategies, Land Use, Building Code Reform and Connectivity	*Not Quantified*					
TLU-3A	Transportation System Management	0.32	0.38	5.32	–$1,070	–$201	–604
TLU-3B/4	Transit Management and Infrastructure	0.07	0.15	1.56	$110	$71	–143
TLU-5	Education and Outreach for Vehicle Maintenance, Idle Reduction, and Co-Driving, and Promote Alternative Modes of Travel	*Not Quantified*					
TLU-7	Parking Management and Ride Sharing	0.204	0.345	4.032	–$2,327	–$554	–335
TLU-8	Strategies to Move Freight in More GHG-Efficient Ways	0.463	1.079	10.31	–$424	–$41.16	–2,786
TLU-9	Promote Consumption of Locally Produced Goods and Services	0.31	0.55	6.36	–$769	–$120.87	–472
TLU-10	Promote the Use of Alternative Transportation Fuels	0.312	1.015	8.475	$30.7	$3.63	–1,880.9
TLU-11	Promote the Use of Clean Vehicles	1.36	3.41	31.34	–$3,581	–$114.30	–2,330
	Sector Total After Adjusting for Integration	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**–7,980**
	Reductions from Recent Actions	**0**	**0**	**0**	**$0**	**$0**	**0**
	Sector Total Plus Recent Actions	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**7,980**

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: The numbering used to denote the above pending priority policy options is for reference purposes only; it does not reflect prioritization among these important draft policy options.

The U.S. Energy Independence and Security Act of 2007 (EISA) contains a provision to increase the corporate average fuel economy (CAFE) of light-duty vehicles (passenger cars and light trucks) to 35 miles per gallon by 2020. The I&F includes the CAFE and some partial compliance with EISA's Renewable Fuels Standard (RFS2) provisions. Increases in vehicle fuel economy resulting from EISA will lead to reduced CO_2 emissions from on-road vehicles. The effect of the new CAFE standards was accounted for prior to developing the estimates of GHG reductions from the various TLU policy recommendations discussed below.

Transportation and Land Use Sectors Policy Descriptions

The policy recommendations described briefly here not only result in significant emission reductions and cost savings, but also offer a host of additional benefits, such as reduced local air pollution; more livable, healthier communities; and increased transportation choices. Policies seeking to improve travel choices and reduce VMT would have the additional effect of reducing congestion and improving travel times and travel-time reliability, while allowing vehicles to idle less and operate at speeds where they are more efficient. Policies improving the efficiency of vehicles and supplying cleaner fuels would make those miles driven less emissions-intensive. Overall, most policies produce significant fuel savings, which results in savings directly to the driving public and to businesses. In several cases, these savings overwhelm any costs to comply with regulation or to implement new programs.

TLU-1. Bicycle and Pedestrian Comprehensive Plan and Infrastructure Development

This policy attempts to develop and promote sidewalks, bicycle lanes, and shared-use paths to increase pedestrian and bicycle travel, which will reduce energy demands and GHG emissions associated with automobile use. Today, increases in population and automobile use have resulted in complex transportation systems that accommodate more traffic, while often ignoring the needs of non-drivers. To maximize utilization of bicycle and pedestrian systems, sound guidance should be applied to future bicycle and pedestrian planning in Kentucky.

To encourage bicycling and walking, some roadways and developments need be retrofitted to make these activities easier and more inviting. A bicycle- and pedestrian-friendly community should provide facilities that allow people to bicycle and walk safely. While many roads are usable for local bicycling, others are undesirable because of excessive traffic and high speeds. Also, people may be walking less these days due to a lack of pedestrian accommodations. Since providing facilities alone may not lead to a change in behavior, downtown revitalization and density and mixed-use development planning are equally important to increase pedestrian and bicycle travel.

TLU-2/6. Livability, Brownfield Redevelopment, Downtown Revitalization, Location-Efficient Strategies, Land Use, Building Code Reform, and Connectivity

This policy bundle is intended to increase the number of walkable, bikable, compact, and mixed-use communities; provide incentives for their development; and extend these concepts wherever feasible in Kentucky. In addition, these policies encourage infill development, increase density in support of transit services, and thus promote preservation of undeveloped land outside urbanized areas.

These development practices are proven to reduce VMT and the associated GHG emissions. As a co-benefit, they also produce a built environment, which requires less extensive infrastructure to support a given population and employment base, resulting in lower capital, operating, and maintenance costs for the provision of water, sewer, and utility services.

TLU-3A. Transportation System Management

Transportation system management (TSM) is the concept of pairing transportation demand with transportation supply to help transportation networks serve the demand effectively and efficiently. TSM strategies can reduce the number of trips taken by SOVs, shorten trip lengths, reduce delay, increase the reliability of the network, and reduce idling (and/or other transportation actions that increase GHG emissions). The goal of TSM is to reduce the daily VMT per capita on the transportation network. An added benefit of effective TSM is reduced vehicle hours traveled (VHT) per capita, which measures the amount of traffic congestion delay. Both reduced VMT and reduced VHT are highly correlated with reduced GHG emissions.

TSM attempts to both improve transportation system performance and alter travel behavior through a combination of technological improvements, incentives, design, and restrictions. Technological improvements include traffic signal coordination, traveler information displays, lane management, real-time monitoring of traffic conditions to adapt/improve operations, and other intelligent transportation system applications. Incentives can include policies that financially favor desired behavior or allow users to gain a time advantage and include value pricing and smart parking strategies. System design includes access management; intersection improvements; bottleneck removal; and integrated, interconnected, intermodal systems to serve the mobility needs of people and goods and foster economic growth. Restrictions can prevent people from performing certain actions that would undermine the efficiency of the transportation system.

TLU-3B/4. Transit Management and Infrastructure

Transit management and infrastructure strategies are intended to make public transit a legitimate transportation choice for the citizens of Kentucky, which will reduce transportation related energy demand and GHG emissions. According to the U.S. Department of Transportation, the national average rate of CO_2 emissions per passenger-mile for bus transit is only two-thirds of that for private automobiles. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. Therefore, public transportation improvements are essential to reduce GHG emissions associated with transportation.

An important strategy in reducing GHG emissions produced from transportation sources is to reduce the growth rate in per-capita VMT. Providing alternatives to SOV can reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ride sharing, and vanpools. A higher rate of transit use can be achieved by efforts to expand transit services, ensure the safety and security of transit systems, and educate the public about transit options available in their community. The competitiveness of transit can be enhanced by providing livable, walkable, complete streets where transit can be cost-effective.

TLU-5. Education and Outreach for Vehicle Maintenance, Idle Reduction, and Co-Driving, and Promote Alternative Modes of Travel

Individual behaviors can influence the ability of Kentucky to meet its objectives of reducing energy demand and GHG emissions. The education and outreach policy is designed to inform citizens of how they can save energy, reduce costs, and protect the environment through their daily activities. To achieve the objective of a more informed citizenry, a comprehensive and coordinated education outreach program is required. Fuel efficiency improvement and promotion of alternative transportation modes are two key areas that have been identified as critical for raising awareness.

The education and outreach effort can take many forms. Kentucky can seek opportunities to cooperate and partner with existing promotional campaigns and public outreach. Development and implementation of a focused multimedia campaign will be a cornerstone of the educational program. Kentucky can also incorporate GHG messages into existing educational venues, such as the Kentucky Driver Manual and driver education classes provided by many Kentucky high schools. Creating a "Drive Smart–Drive Green" or other similarly monikered license plate may raise environmental awareness and provide funding for other education initiatives. Efforts to reach existing drivers can be made by distributing information when motor vehicle licenses or vehicle registrations are renewed. The state can also collaborate with the insurance industry to reduce insurance rates for drivers who have completed "green drivers training" and pledged to follow the guidelines.

TLU-7. Parking Management and Ride Sharing

The parking management and ride sharing strategy is intended to reduce GHG emissions and reduce fuel consumption by reducing the number of SOV trips. Parking management refers to policies and programs that result in more efficient use of parking resources. Reserved and preferential parking for high-occupancy vehicles (HOVs) near places of employment will further provide incentives to reduce SOV trips. HOV parking may be reserved at preferential locations, such as near building entrances or parking garage exits. Free or reduced-fee parking for HOVs may also be provided. Similarly, preferential parking and incentives can also be offered to drivers of vehicles with low GHG emission rates. Depending on effectiveness, these incentives could include preferential vehicle access to metered parking spaces or HOV lanes.

Providing safe and convenient park-and-ride lots will facilitate the use of carpooling, vanpooling, and transit. Most utilized park-and-ride lots are usually built in highly visible locations and have direct access to transit if available. Locating park-and-ride facilities near HOV-only highway lanes would complement this strategy. Promoting carpooling and vanpooling through ride share matching, marketing, and public awareness can encourage transition to HOVs for work trips.

TLU-8. Strategies to Move Freight in More GHG-Efficient Ways

On-road trucking continues to transport a majority of commercial goods, not just in Kentucky but throughout the United States. On a national level, the trucking industry delivers over 70% (by weight) of all the freight transported. In Kentucky, over 72% of the freight tonnage and over 90% of all commodities are delivered by truck. Shifting freight from trucks to barge and rail will decrease impacts on highway infrastructure and reduce GHG emissions, because these modes are able to move more freight by weight on the same amount of energy than are individual heavy trucks. The development of warehouses or distribution in the rural areas surrounding the larger cities in Kentucky is needed to improve the efficiency of the supply chain. With additional distribution space, the ability to coordinate freight movements in non-peak times will increase, resulting in reduced congestion and GHG emissions.

Trucks, too, can easily be made more fuel-efficient. Existing technologies, such as aerodynamic baffling on tractors and trailers, auxiliary power units to reduce idling, and sensors that allow trucks to pass weigh-in stations without stopping and idling, all offer emissions reductions from existing operations. These changes take effect without disrupting current freight logistics or requiring intensive capital investment.

Even with improvements, the challenge of significantly reducing GHG emissions within the trucking industry is very difficult. Intermodal freight movement can be more efficient than moving that same freight by a single mode of transport, but that benefit depends on the distance, weight, and time sensitivity of the shipment. The tonnage of freight moved by intermodal transportation in Kentucky is well below the national average. Kentucky has the opportunity to develop a strong intermodal infrastructure by improving intermodal connectors to increase rail and river capacity.

TLU-9. Promote Consumption of Locally Produced Goods and Services

Today, it is convenient to buy distantly produced goods (including food) whose retail prices appear to be cheaper. However, these "cheaper" goods are not always the most beneficial to Kentucky's economy, as there are hidden economic, environmental, and societal costs related to transporting distant products. Most produce in the United States is picked four to seven days before being placed on supermarket shelves, and is shipped for an average of 1,500 miles before being sold. This policy supports "buy local" programs, such as the Kentucky Department of Agriculture's Kentucky Proud marketing campaign, which promotes local cycling of dollars and resources, and reduces the need to haul freight.

This policy will facilitate the purchase of local goods (particularly agricultural products) and services produced in Kentucky. It will build on current initiatives wherever possible, such as the Kentucky Proud program, and may also entail the creation of new partnerships and initiatives. Its impacts are expected to include not only GHG emission reductions from reduced total freight travel, but also increased economic development as in-state producers are benefited.

TLU-10. Promote the Use of Alternative Transportation Fuels

Increasing use of alternative transportation fuels has the potential to result in savings of imported petroleum-based fuels and reduce the associated GHG emissions. State and local governments have the potential to "lead by example" by increasing the use of alternative transportation fuels in fleet vehicles.

Nationally, the U.S. transportation sector is not on track to achieve the targets for biofuels use set out in the RFS2 provisions; state policy can help to improve that performance. State policy can also encourage the adoption of domestically produced natural gas or electricity as well, displacing petroleum even further and offering economic benefits that come with domestic production and lower consumer costs.

In general, this promotion policy can take three forms. One option is to adopt a low-carbon fuel standard, which would require a certain amount or percentage of fuel sold within Kentucky to be a low-carbon fuel (e.g., ethanol or biodiesel). This percentage can gradually increase over time and the state can help facilitate transition to low-carbon fuels by regulating quality standards for fuel blends. A second option is to encourage alternative fuel production through state fuel procurement. This might require minimum volumes of cellulosic ethanol and biodiesel to be blended into gasoline and diesel fuel, commensurate with specified in-state production of these biofuels. This option will ensure a market for biofuel producers within Kentucky. A third option is to directly or indirectly provide incentives to private providers of alternative-fuel infrastructure. The development of an alternative-fuel infrastructure can aid in the promotion of alternative-fuel use and offset the expense of equipment and installation costs.

The policy selected in Kentucky would utilize biofuels produced within the state as part of the Agriculture, Forestry, and Waste sector recommendations of this final report. This policy represented hundreds of millions of gallons of both ethanol and biodiesel, largely produced from sources, such as cellulosic and woody biomass feedstocks, which offer better GHG-reduction potentials than conventional corn-based biofuels. These fuels were utilized to the extent possible as blends with gas and diesel that could be used in the existing fleet, in order to avoid forcing technology upgrades, which could be expensive and economically burdensome to impose.

TLU-11. Promote the Use of Clean Vehicles

Increasing use of cleaner vehicles has the potential to save imported petroleum-based fuels and reduce the associated GHG emissions. This policy is designed to reduce Kentucky's energy demands, as well as GHG emissions from the transportation sector. Clean vehicles reduce GHG emissions through fuel efficiency, advanced vehicle technologies, and/or use of low-carbon fuels. The use of clean vehicles can be promoted through incentives and education.

Clean vehicles include plug-in hybrids, natural gas vehicles, high-efficiency vehicles, hybrid-electric vehicles, electric vehicles, clean diesel vehicles, and clean diesel hybrid vehicles. Diesel vehicles have excellent fuel economy. When paired with up-to-date pollution-reduction devices either by retrofitting older vehicles or as required for new models (collectively referred to as "clean diesel" technologies), they can be an effective means to reduce GHGs.

The policy is oriented toward creating a financial incentive offered directly to consumers, which would provide a rebate on the purchase price of a new vehicle if that vehicle is significantly above the average for fuel efficiency of new vehicles, while also applying an additional fee to the purchase of vehicles significantly below the new-vehicle fuel efficiency average. The program's design is intended to be revenue-neutral, meaning that the revenue collected in fees on gas guzzlers is intended to be only enough to fund the incentives paid out to buyers of clean vehicles, thus costing the government nothing to implement. Research has indicated such incentives, when set at levels between $500 and $1,000 for both the incentive and the fee, can have a significant and rapid effect on the types of vehicles people buy. They are also intended to offset the tendency consumers have to underestimate the difference in costs of fuel use over many years between more efficient and less efficient vehicles.

Chapter 7
Cross-Cutting Issues

Overview of Cross-Cutting Issues

Some issues relating to climate policy cut across multiple, or even all, sectors. The Kentucky Climate Action Plan Council (KCAPC) addressed such issues explicitly in a separate Cross-Cutting Issues (CCI) Technical Work Group (TWG). Cross-cutting recommendations typically encourage, enable, or otherwise support emission mitigation activities and/or other climate actions. The types of policies considered for this sector are not readily quantifiable in terms of greenhouse gas (GHG) reductions and costs or cost savings. Nonetheless, if successfully implemented, they would most likely contribute to GHG emission reductions and implementation of the KCAPC's policy recommendations described in Chapters 3–6 of this report.

The CCI TWG developed eight policy recommendations for the Secretary's consideration (see Table 7-1) that were then reviewed, revised, and ultimately approved by the KCAPC members present and voting. Seven of the recommendations focus on enabling GHG emission reductions and mitigation activities, while one (CCI-3–Adaptation and Vulnerability) addresses adaptation to the changes expected from the effects of GHGs that will remain in the atmosphere for decades.

Table 7-1. Cross-Cutting Issues Policy Recommendations

No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effective-ness ($\$/tCO_2e$)
		2020	2030	Total 2011–2030		
CCI-1	Greenhouse Gas (GHG) Emission Inventories, Forecasts, Reporting, and Registry	*Not Quantified*				
CCI-2	Public Education and Outreach	*Not Quantified*				
CCI-3	Adaptation and Vulnerability	*Not Quantified*				
CCI-4	Statewide GHG Emission Reduction, Energy Intensity, and Energy Efficiency Goals, Targets, and Metrics	*Not Quantified*				
CCI-5	State and Local Government GHG Emission Reduction, Energy Intensity, and Energy Efficiency Activities (Lead by Example)	*Not Quantified*				
CCI-6	Local GHG Emission Reduction, Energy Intensity, and Energy Efficiency Actions	*Not Quantified*				
CCI-7	Financial Policies	*Not Quantified*				
CCI-8	Conduct an Impact Analysis of Federal GHG Constraints on Kentucky	*Not Quantified*				

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

Key Challenges and Opportunities

The KCAPC was charged with developing proposed GHG reduction goals for Kentucky, along with a set of policy recommendations designed to achieve such goals. The KCAPC is recommending a goal of reducing projected GHG emissions to 20% below 1990 levels by 2030. In addition to the GHG reduction goal, the KCAPC recommends that goals and targets for energy efficiency and energy intensity for each economic sector be developed in the near future to complement the overall GHG reduction goal.

The KCAPC based its recommendations on its review of the potential overall emission reduction estimates (as compared to the GHG emissions inventory and forecast for business as usual) for 35 of 48 policy recommendations for which emission reductions were quantified. It also considered in its deliberations the goals and targets included in *Kentucky's 7-Point Strategy for Energy Independence*.[1] While some of the other KCAPC policy recommendations were not readily quantifiable, some of them would most likely achieve or contribute to additional reductions, including several of the CCI policy recommendations.

A key challenge for the Commonwealth will be developing sector-specific goals, targets, and metrics for energy efficiency and energy intensity and integrating them with the GHG reduction goals. This process will require sector-specific data and the need to engage relevant stakeholders in the effort.

An additional challenge for the Commonwealth in seeking to achieve these GHG reduction, energy efficiency, and energy intensity goals will be to identify available resources needed to finance and implement many of the initiatives outlined in this report, particularly given the struggling economic conditions in the state and across the country. The KCAPC will need to work closely with other state, local, federal, and tribal governmental entities, the private sector, higher education institutions, citizens, and others to examine these opportunities.

Another key challenge for the Commonwealth is the need to proactively engage with the federal government in developing appropriate federal programs and policies that will not impair Kentucky's economy, and simultaneously work with other state and regional entities to design and implement strategies most effectively employed at the state and regional levels.

Overview of Policy Recommendations and Estimated Impacts

Cross-cutting issues include policies that apply across the board to all sectors and activities. Cross-cutting recommendations typically encourage, enable, or otherwise support emission mitigation activities and/or other climate actions. All are enabling policies that are not quantified in terms of tons of GHG reduction or costs.

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[1] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008.

Detailed descriptions of the individual CCI policy recommendations as presented to and approved by the KCAPC can be found in Appendix I of this report. A few of the key highlights of the Cross-Cutting Issues Policy Recommendations are:

- Kentucky should establish a GHG reduction goal of achieving a 20% reduction of GHGs below 1990 levels by 2030. It should also establish sector-specific energy efficiency and energy intensity goals, targets, and metrics through a proactive stakeholder process.
- Kentucky should update its GHG Emission Inventory and Forecast report biennially.
- The Commonwealth should prepare a comprehensive vulnerability assessment of the impacts of climate change and prepare appropriate adaptation strategies to address the key impacts.
- Kentucky should build upon current energy efficiency initiatives to expand its state "lead by example" efforts, and should develop a tool kit and help desk to assist local governments in doing likewise. Significant investment in education and outreach should be an integral element of this effort.
- The Commonwealth should develop alternative financing mechanisms to fund the policy recommendations contained in the KCAPC-recommended Climate Action Plan.
- In collaboration with neighboring states or states with similar economic circumstances, Kentucky should conduct an impact analysis of federal GHG constraints on Kentucky, and should partner with these states in striving to influence federal policy to be sensitive to Kentucky's concerns.

Cross-Cutting Issues Policy Descriptions

CCI-1. Greenhouse Gas (GHG) Emission Inventories, Forecasts, Reporting, and Registry

A comprehensive Kentucky GHG Emissions Inventory and Forecast (I&F) was completed by the KCAPC in 2010. The inventory includes six GHGs—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulfur hexafluoride (SF_6)—and weights these gases according to global warming potentials reported by the U.S. Environmental Protection Agency. The I&F provides a baseline of GHG emissions from 1990 through 2010 and projects GHG emissions through 2030. This comprehensive GHG emissions inventory will serve as a foundation for developing future emission projections and all future GHG emission regulatory and programmatic requirements. KCAPC recommends that the GHG I&F be updated biennially by the Kentucky Energy and Environment Cabinet (KEEC) using 2010 as a baseline year and 2005 as a trend benchmark year. Future GHG inventory updates should project emissions out to 2050 in 5-year increments. The ongoing GHG I&F process should include local governments and stakeholders. Two essential mechanisms of an inventory are reporting and registry functions.

GHG reporting reflects the measurement and reporting of GHG emissions to support goal development, tracking of GHG emissions, and efficient management of resources. GHG reporting can help sources identify GHG emission reduction opportunities, reduce risks, and potentially develop revenue associated with future GHG mandates by developing the required infrastructure in advance. GHG reporting is a precursor for sources to participate in GHG reduction programs, opportunities for recognition, and a GHG emission reduction registry, as well as to secure "baseline protection" (i.e., credit for early reductions).

A GHG registry enables recording of GHG emission reductions in a central repository with "transaction ledger" capacity to support tracking, management, and "ownership" of emission reductions; establish baseline protection; enable recognition of environmental leadership; and/or provide a mechanism for regional, multistate, and cross-border cooperation. Kentucky is a member of the Climate Registry.

CCI-2. Public Education and Outreach

The KCAPC recognizes the importance of public involvement and education regarding the issues of climate change to enhance communication and dialogue about climate issues. Establishing public education and outreach efforts will be key to building a broad base of awareness and support for the recommendations of this report. The KCAPC has identified numerous strategies over several years to do so in conjunction with academic, business, local government, and other partners in this process. These outreach efforts are spelled out in Appendix I and are targeted to the following audiences: state government, policymakers, future generations, community leaders and community-based organizations, citizens, industrial and economic sectors, and local governments.

CCI-3. Adaptation and Vulnerability

KEEC, in coordination with other state agencies and the universities, should undertake a comprehensive planning effort to assess the physical impacts of climate change on the natural environment and human health, and also to identify and evaluate adaptation opportunities. The assessment of impacts of climate change on the Commonwealth should include, but not be limited to, impacts on water quality and quantity, agriculture, recreation, fish and wildlife habitat, industry, and human health, and should take into account ongoing analytic efforts. To the extent possible, the analysis should include the economic impacts on these sectors within the Commonwealth, and should suggest adaptation strategies to minimize the effects of climate change on them.

CCI-4. Statewide GHG Emission Reduction, Energy Intensity, and Energy Efficiency Goals, Targets and Metrics

The KCAPC recommends the following goals, taking into account Governor Steven Beshear's *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence:*[2]

- *GHG Emission Reductions*— Reduce GHG emissions in Kentucky to 20% below 1990 levels by 2030.
- *Energy Intensity*—Develop a metric and possibly standards or goals for evaluating the energy intensity, or CO_2 emissions, per unit of product or service provided (e.g., 1 metric ton of CO_2 per megawatt-hour (MWh) of power delivered, or 3 MWh used per $1 million of product value). This is also sometimes called carbon intensity. These values are determined by comparison to regional or national averages within the same sector and industry.
- *Energy Efficiency*—Development of a metric and possibly standards or goals for gross state product (GSP) per unit of power consumed (industrial), or less overall energy use per hour of operation (homes, buildings, etc.). This is a means of maintaining current energy use, while reducing overall emissions through improvements that allow more energy use or more GSP for the same amount of fuel consumed in the process.

Kentucky should evaluate its key economic sectors, and determine baseline productivity within each of those sectors with respect to GSP or productivity per unit of relevant GHG emissions. The Commonwealth should develop an economic model to determine which of the three goals above within this strategy will have the most significant positive benefit in terms of sector GSP, while meeting national and state GHG goals. Kentucky should assign a responsible entity for this activity. Using a stakeholder process, the Commonwealth should develop a metric for measuring energy intensity and energy efficiency and propose specific energy intensity and efficiency targets (in terms of appropriate units) for each sector by 2014. The goals and targets should be reviewed within each sector periodically, with standards or targets adjusted accordingly as regional and national equivalencies change.

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[2] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, page v, November 2008.

CCI-5. State and Local Government GHG Emission Reduction, Energy Intensity, and Energy Efficiency Activities (Lead by Example)

State agencies have already begun to “lead by example” with numerous initiatives to enhance energy efficiency in state buildings and public schools. (See Appendix I for details about many of these initiatives that are already underway.) To further expand and advance these efforts, the Governor should assign or create a multi-agency body to direct ongoing state climate efforts and to coordinate with local government efforts. The agency should establish goals and targets by the end of 2012 to accomplish the following:

- Increase use of alternative fuels in the state fleet, and reduce roadblocks to the development of alternative fuel stations and recharge points for general public use.
- Identify ways to design, encourage, and provide incentives for regional interconnected energy systems.
- Improve energy efficiency in all new state-funded or bonded construction, renovation, or heating, ventilation, and air conditioning (HVAC) projects.
- Incorporate energy efficiency requirements into state purchasing practices.
- Promote culture change within state agencies and universities that promotes energy efficiency.
- Promulgate an appropriate no-idling policy for state vehicles.
- Initiate other activities to advance recommendations in the state climate action plan.
- Establish criteria and evaluation mechanisms to gauge the effectiveness of these initiatives.

The Commonwealth should adopt policies, goals, benchmarks, and reduction targets for energy efficiency and intensity strategies for state-owned or state-operated buildings, facilities, and vehicle fleets. To encourage broad adoption of and compliance with these new policies, the state should develop incentives for agencies, offices, and organizations that meet or exceed these established state benchmarks. To implement these new policies, the Governor should assign or create a multi-agency governmental body represented by staff from the Governor’s Office and all three branches of government (legislative, executive, and judicial), to direct ongoing state climate efforts, including coordination with local government activities. Additionally, all programs and capital development funded through state bonding mechanisms should be required to meet these new policies.

CCI-6. Local GHG Emission Reduction, Energy Intensity, and Energy Efficiency Actions

Many communities across Kentucky are actively engaged in developing GHG emission reduction strategies, are seeking energy savings through energy intensity and energy efficiency initiatives, and are striving to achieve effective air quality improvements. These communities’ existing efforts will be encouraged and supported by the Commonwealth. Additional communities interested in evaluating the vulnerabilities and opportunities posed by pending state and federal legislative changes and by predicted climate change will be provided encouragement and tools for developing a local plan of action.

To leverage these efforts, the state will develop a tool kit for local governments, institutions, and individuals to assist in planning and implementing effective strategies. The tool kit will utilize nationally recognized best practices (ICLEI–Local Governments for Sustainability, ENERGY STAR, LEED, etc.) to provide assistance with GHG emission reduction, energy intensity, and energy efficiency actions, and will collect "best lessons learned" by entities throughout the Commonwealth. It is not the intent of the state to utilize this policy to mandate how local governments or organizations should address this planning process. Rather, the state will be a partner to local communities by supporting, assisting, and coordinating these efforts where appropriate or beneficial.

The Commonwealth also recognizes that its communities need assistance with implementing their plans. The Commonwealth should establish a help desk within the multi-agency entity established under CCI-4 to provide assistance to communities in preparing and implementing plans through actions to reduce energy use; educate their communities; and lead in energy efficiency, GHG reduction, and energy intensity. The statewide process to develop consensus on targets and goals for GHG reduction, energy efficiency, and energy intensity will serve as a means to communicate the tools under development by the state, and most important, as a means to listen to the needs of the local communities across the state to guide further development, both of helpful tools and of the goals and targets themselves.

CCI-7. Financial Policies

Recognizing that some policy decisions to reduce GHG emissions will have costs, Kentucky must develop long-term funding to implement KCAPC-adopted actions. To accomplish this policy, Kentucky should formulate a financial and regulatory structure that promotes investments in cost-effective initiatives to promote improvements in energy efficiency and intensity. In order to secure financing required to implement KCAPC-adopted actions in the long term, to ensure efficient allocation of limited resources, and to deploy energy efficiency, and emission- and energy intensity-reduction strategies at scales across the Commonwealth, Kentucky will strive to achieve the following goals:

- Establish a revolving loan program, initially funded by the legislature and supported by receipt of low-interest payments, to fund required changes that improve energy efficiency and reduce energy intensity, potentially structured as a performance savings contract.
- Identify and aggressively pursue available grants, loans, and other funding to provide capital funding and operational assistance for changes within the public and private sectors in adapting to climate change and related policy changes.
- Provide for an economic analysis that identifies the least-cost and most effective alternative to improve energy efficiency and energy intensity for each goal in the Climate Action Plan.
- Develop a marketing plan to attract appropriate investment by existing companies and new investors in Kentucky's resources, taking into consideration the potential for increased energy costs.
- Identify streamlining actions that can be implemented for permitting new businesses or adopting revised permits for existing businesses, in order to best address changes in policy, law, and regulation.

- Take advantage of existing programs as vehicles for funding (e.g., Kentucky Bluegrass Turns Green, Green Bank of Kentucky).

The Commonwealth should immediately create a point of contact within each appropriate cabinet to aggressively seek and pursue funding from sources outside the state. All state employees charged with this goal should coordinate with each other to ensure efficient use of resources. The Climate Action Plan should be reviewed by the Kentucky Cabinet for Economic Development, with appropriate assistance from the Kentucky Department for Energy Development and Independence, and a plan of action should be developed. KEEC should also develop a plan to streamline permitting processes and reduce regulatory barriers to implementation of energy efficiency and energy intensity improvements.

CCI-8. Conduct an Impact Analysis of Federal GHG Constraints on Kentucky

Kentucky is the third-largest coal producer in the United States and has an electricity generation fleet that is more than 90% coal-fired. Approximately 49% of that power is delivered to an industrial sector that produces automobiles, appliances, aluminum, stainless steel, chemicals, and other products. With its high reliance on coal to meet its electric energy needs, Kentucky may be subject to disproportionally large economic and infrastructure impacts as a result of federal action to limit GHG emissions, relative to states with more options available to them, or relative to states with less industrial development. It is therefore imperative for Kentucky to make its voice and the voice of similar states heard in the national dialogue, to have a thorough understanding of its vulnerability, and to have in place an adaptation plan if and when such legislation or regulation is adopted (see CCI-3).

Federal legislation and regulations tend to assume that one size fits all, which is not the case for Kentucky and several of its neighbors. For this reason, collaborative regional and multi-state emission reduction efforts offer promise for developing compliance strategies that provide for greater opportunities for effective and sustainable successes. Utilizing alternative energy resources, clean coal technology, energy efficiency, and renewable resources through blended energy portfolios can result in a more diverse energy economy with acceptable economic costs.

Any regulatory framework on emissions must be constructed in a way that does not arbitrarily punish a Kentucky manufacturer for GHG emissions if that manufacturer is producing a greater amount of product for equal or lesser emission levels than equivalent activities elsewhere when adjusted for the regional energy portfolio. To avoid this disparity, a normalization approach, taking into account the amount of energy required and the value of the products produced, should be implemented.

Kentucky should take on a leadership role in the identification of partner states with similar interests regarding federal GHG mitigation policies, and should work to develop partnerships that protect the Commonwealth’s interests.

Appendix A
Kentucky Climate Action Plan Council Process

The Commonwealth of Kentucky established the Kentucky Climate Action Plan Council (KCAPC) process to identify opportunities for Kentucky to respond to the challenge of global climate change, while becoming more energy efficient and more energy independent, and spurring economic growth.

Recognizing the interconnectedness of energy, environment, and economic development, in June 2009 Governor Steven L. Beshear created the Kentucky Energy and Environment Cabinet (KEEC). Three departments within the EEC—Department for Environmental Protection, Department for Natural Resources, and Department for Energy Development and Independence—all participated in the Kentucky Climate Action planning process.

In December 2009, KEEC Secretary Dr. Len Peters appointed a diverse group of stakeholders representing academia, agriculture, business, forestry, industry, environmental groups and many levels of government to serve on the KCAPC. The Council was charged with collectively developing a climate action plan to mitigate sources of greenhouse gas (GHG) emissions and to establish benchmarks and timetables for implementing the KCAPC recommendations.

The KCAPC was organized into five Technical Work Groups (TWGs) to determine the most cost-effective approaches for improving energy efficiency and reducing Kentucky's GHG) emissions from key sectors of the economy. Additional industry experts, citizen representatives, and academics contributed to these sector-based groups. The members of TWGs are listed in Appendix B. The Commonwealth requested the Center for Climate Strategies (CCS), a nonprofit research organization that has provided technical assistance and facilitation of climate planning processes in more than 20 states, to assist in the development of the Kentucky Climate Action Plan. CCS provided technical analysis and facilitation of meetings and assisted with the production of this report.

A process memo between CCS and KEEC lays out the steps covered in each meeting and the full process followed by the KCAPC during its 19 months of deliberations and analysis. See: http://www.kyclimatechange.us/background-ccagrole.cfm.

Appendix B
Members of KCAPC Technical Work Groups

Agriculture, Forestry, and Waste Management (AFW) Technical Work Group Members

Pat Angel	Appalachian Reforestation Research Initiative
Joe Blackburn*	Office of Surface Mining
Tony Brannon	Murray State University
Mark Crocker	Center for Applied Energy Research, University of Kentucky
Don Halcolmb*	Farmer
Tony Hatton	Kentucky Division of Waste Management
Tim Hughes	Kentucky Governor's Office of Agricultural Policy
John Lamanna*	Republic Services, Inc.
Andy MacDonald	Kentucky Solar Partnership
Leah MacSwords	Kentucky Division of Forestry
Cam Metcalf	Kentucky Pollution Prevention Center
Bruce Pratt	Eastern Kentucky University
Scott Shearer	University of Kentucky
Richard Sturgill*	Pine Mountain Hardwood Lumber Company

Kentucky Department for Energy Development and Independence
Frank Moore and Tim Hughes, AFW Technical Work Group Liaisons

Center for Climate Strategies
Steve Roe, AFW Facilitator

Energy Supply (ES) Technical Work Group Members

Jack Bailey	Tennessee Valley Authority
Jim Booth	Booth Companies
Charlie Borders	Commissioner, Kentucky Public Service Commission
David Brown Kinloch*	Lock 7 Hydro Partners
Jim Cantrell	Marathon Oil Company
Joe Craft*	Alliance Resource Partners
William Daugherty*	Formerly of NGAS Resources, Inc.
Julie Jansen	Duke Energy
Glenn Jennings	Delta Natural Gas Co., Inc.
John Voyles	Louisville Gas and Electric/Kentucky Utilities
Mark Stallons*	Owen Electric Cooperative
Mahendra Sunkara	University of Louisville

Kentucky Department for Energy Development and Independence
Bob Amato, ES Technical Work Group Liaison

Center for Climate Strategies
Jeff Wennberg, ES Facilitator

Residential, Commercial, and Industrial (RCI) Technical Work Group Members

Cheryl Bruner	Louisville Gas and Electric/Kentucky Utilities
Dr. Don Colliver	University of Kentucky
Jim Gardner	Vice-Chairman, Kentucky Public Service Commission
Kelley Kline*	General Electric
Richard Maloney	Kentucky Division of Housing, Buildings and Construction
Matt Powell*	Century Aluminum of Kentucky
Ken Seibert	CMTA Consulting Engineers
Steve St. Angelo*	Toyota Motor Manufacturing of Kentucky
Sister Amelia Stenger*	GREENing Western Kentucky Project
Martha Tarrant*	RossTarrant Architects, Inc.
Wayne Turchetta	U.S. Green Building Council
Bob Weiss	Kentucky Home Builders Association

Kentucky Department for Energy Development and Independence
Greg Guess, RCI Technical Work Group Liaison

Center for Climate Strategies
Ken Colburn, RCI Facilitator

Transportation and Land Use (TLU) Technical Work Group Members

Max Conyers	Lexington Area Municipal Planning Organization
Bernadette Dupont	Kentucky Division, Federal Highway Administration
Susan Lambert	EarthWorks, LLC
Jesse Mayes	Kentucky Transportation Cabinet
Jim Newberry*	Former Mayor, Lexington, Kentucky
Greg Pritchett	Henderson County Riverport
Andy Reser	Cincinnati Area Municipal Planning Organization
José Sepulveda*	Kentucky Division, Federal Highway Administration
Lynn Soporowski	Kentucky Transportation Cabinet
Michelle Stites	Louisville Metro Air Pollution Control District
Richard Sutherland	ENTRAN

Kentucky Department of Air Quality
John Lyons and Millie Ellis, TLU Technical Work Group Liaisons

Center for Climate Strategies
Lewison Lem, TLU Facilitator

Cross-Cutting Issues (CCI)
Technical Work Group Members

Lauren Anderson	Louisville Metro Air Pollution Control Board
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Appendix C
Greenhouse Gas Emissions Inventory and Reference Case Projections

A separate report entitled "Kentucky Greenhouse Gas Inventory and Reference Case Projections, 1990–2020," was used throughout the Kentucky Climate Action Plan Council's (KCAPC's) process to provide detailed documentation on current and projected greenhouse gas (GHG) emissions. The preliminary draft report was reviewed by the Council and its five Technical Work Groups and revised to address comments approved by the KCAPC as the process and analysis moved forward.

At the third KCAPC meeting on June 2, 2010, the Council approved final changes to the GHG Inventory and Forecast Report. The final I&F report, incorporating all changes approved by the KCAPC, was posted to the KCAPC Web site and is attached here. The page numbering reflects that in the final I&F report.

Final Kentucky Greenhouse Gas Inventory and Reference Case Projections 1990–2030

Center for Climate Strategies
June 2010

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Executive Summary

The Center for Climate Strategies (CCS) prepared this report for the Kentucky Energy and Environment Cabinet (KEEC). The report presents an assessment of the State's greenhouse gas (GHG) emissions and anthropogenic sinks (carbon storage) from 1990 to 2030. The preliminary draft inventory and forecast served as a starting point to assist the State, as well as the Kentucky Climate Action Plan Council (KCAPC) and Technical Work Groups (TWGs), with an initial comprehensive understanding of Kentucky's current and possible future GHG emissions, and thereby informed the identification and analysis of policy options for mitigating GHG emissions.[1] The KCAPC and TWGs have reviewed, discussed, and evaluated the draft inventory and methodologies as well as alternative data and approaches for improving the draft GHG inventory and forecast. The inventory and forecast as well as this report have been revised to address the comments provided and approved by the KCAPC.

Emissions and Reference Case Projections (Business-as-Usual)

Kentucky's anthropogenic GHG emissions and anthropogenic sinks (carbon storage) were estimated for the period from 1990 to 2030. Historical GHG emission estimates (1990 through 2007)[2] were developed using a set of generally accepted principles and guidelines for State GHG emissions, relying to the extent possible on Kentucky-specific data and inputs when it was possible to do so. The reference case projections (2008-2030) are based on a compilation of various projections of electricity generation, fuel use, and other GHG-emitting activities for Kentucky, along with a set of simple, transparent assumptions described in the appendices of this report.

The inventory and projections cover the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential (GWP) weighted basis.[3]

As shown in Table ES-1, activities in Kentucky accounted for approximately 183 million metric tons (MMt) of gross[4] CO_2e emissions (consumption basis) in 2005, an amount equal to about

[1] "Draft Kentucky Greenhouse Gas Inventory and Reference Case Projections, 1990-2030," prepared by the Center for Climate Strategies for the Kentucky Energy and Environment Cabinet, January 2010.
[2] The last year of available historical data varies by sector; ranging from 2004 to 2008.
[3] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 2001). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth), See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in Climate Change 2001: The Scientific Basis. Contribution of Working Group 1 of the Intergovernmental Panel on Climate Change Cambridge University Press. Cambridge, United Kingdom. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.
[4] Excluding GHG emissions removed due to forestry and other land uses and excluding GHG emissions associated with exported electricity.

2.6% of total U.S. gross GHG emissions (based on 2005 U.S. data).[5] Kentucky's gross GHG emissions are rising at a faster rate than those of the nation as a whole (gross emissions exclude carbon sinks, such as forests). Kentucky's gross GHG emissions increased by about 34% from 1990 to 2005, while national emissions rose by 16% from 1990 to 2005. The growth in Kentucky's emissions from 1990 to 2005 is primarily associated with the electricity consumption and transportation sectors.

Estimates of carbon sinks within Kentucky's forests and soils, including urban forests, land use changes, and agricultural soil cultivation practices, have also been included in this report. The current estimates indicate that about 7.6 Million Metric Tons of Carbon Dioxide Equivalent ($MMtCO_2e$) emissions were stored in Kentucky biomass in 2005. This leads to net emissions of about 176 $MMtCO_2e$ in Kentucky in 2005, an amount equal to 2.8% of total U.S. net GHG emissions.

Figure ES-1 illustrates the State's emissions per capita and per unit of economic output.[6] On a per capita basis, Kentucky residents emitted about 37 metric tons (t) of gross CO_2e in 1990, much higher than the 1990 national per capita emissions of 25 tCO_2e. Unlike the national per capita emissions which remained nearly constant from 1990 to 2005, the Kentucky per capita emissions increased by 19% from 1990 to 2005. The electricity supply sector shows the greatest difference between per capita emissions in Kentucky and the US, at 22 tCO_2e per capita in Kentucky for this sector compared with 8 tCO_2e per capita nationally. This is because the electricity consumed in Kentucky relies on a high amount of coal in the generation fuel mix relative to the US as a whole; about 90% for Kentucky versus 50% for the US in 2005. The use of coal has led to low electricity rates in Kentucky compared to the rest of the country, which has allowed energy-intensive industries to flourish in the state, as acknowledged in Kentucky's Energy Plan.[7] Like the nation as a whole, Kentucky's economic growth exceeded emissions growth throughout the 1990-2005 period (leading to declining estimates of GHG emissions per unit of state product). From 1990 to 2005, emissions per unit of gross product dropped by 11% in Kentucky and by about 26% nationally.[8]

The principal sources of Kentucky's GHG emissions are electricity consumption; transportation; and residential, commercial, and industrial (RCI) fuel use accounting for 50%, 20%, and 17% of Kentucky's gross GHG emissions in 2005, respectively.

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[5] The national emissions used for these comparisons are based on 2005 emissions from Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006, April 15, 2008, US EPA #430-R-08-005, (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

[6] Historical Kentucky population statistics are compiled by Kentucky State Data Center from US Census Bureau data, are available at http://ksdc.louisville.edu/kpr/popest/est.htm.. Kentucky population projections through 2050 are available from the same source at http://ksdc.louisville.edu/kpr/pro/projections.htm.

[7] *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence,* Governor Steven L. Beshear, November 2008.

[8] Based on real gross domestic product (millions of chained 2000 dollars) that excludes the effects of inflation, available from the US Bureau of Economic Analysis (http://www.bea.gov/regional/gsp/). The national emissions used for these comparisons are based on 2005 emissions from *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006*, April 15, 2008, US EPA #430-R-08-005, (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

As illustrated in Figure ES-2 and shown numerically in Table ES-1, under the reference case projections, Kentucky's gross GHG emissions continue to grow, and are projected to climb to about 248 $MMtCO_2e$ by 2030, reaching 81% above 1990 levels. As shown in Figure ES-3, the electricity consumption sector is projected to be the largest contributor to future emissions growth in Kentucky, followed by emissions associated with transportation, and then by emissions associated with the increasing use of HFCs as substitutes for ozone-depleting chlorofluorocarbons (CFCs)[9].

Some data gaps exist in this analysis, particularly for the reference case projections. Key tasks include review and revision of key emissions drivers that will be major determinants of Kentucky's future GHG emissions (such as the growth rate assumptions for electricity generation and consumption, transportation fuel use, and RCI fuel use). Appendices A through H provide the detailed methods, data sources, and assumptions for each GHG sector. Also included are descriptions of significant uncertainties in emission estimates or methods and suggested next steps for refinement of the inventory and forecast. Appendix I provides background information on GHGs and climate-forcing aerosols.

GHG Reductions from Recent Actions

The federal Energy Independence and Security Act (EISA) of 2007 was signed into law in December 2007. This federal law contains several requirements that will reduce GHG emissions as they are implemented over the next few years. During the development of the inventory and forecast, sufficient information was identified (e.g., implementation schedules) to estimate GHG emission reductions associated with implementing the Corporate Average Fuel Economy (CAFE) requirements in Kentucky. Further reductions in transportation emissions will be achieved through the Obama plan for adopting the California vehicle CO_2 emission standards nationwide. The GHG emission reductions projected to be achieved by these recent federal actions are summarized in Table ES-2. This table shows a total reduction of about 6.2 $MMtCO_2e$ in 2030 from the business-as-usual reference case emissions, or a 2.5% reduction from the business-as-usual emissions in 2030 for all sectors combined. GHG emission reductions projected to be achieved by additional recent federal and state actions will be analyzed and quantified, where possible, through the KCAPC process.

[9] CFCs are also potent GHGs; they are not, however, included in GHG estimates because of concerns related to implementation of the Montreal Protocol (See Appendix I for additional information). HFCs are used as refrigerants in the residential, commercial, and industrial (RCI) direct fuel use and transport sectors as well as in the industrial sector; they are included here, however, within the industrial processes emissions.

Table ES-1. Kentucky Historical and Reference Case GHG Emissions, by Sector[a]

Million Metric Tons CO_2e	1990	2000	2005	2010	2015	2020	2025	2030	Explanatory Notes for Projections
Energy Use (CO_2, CH_4, N_2O)	**121.6**	**149.5**	**165.9**	**173.8**	**187.4**	**199.2**	**212.4**	**225.8**	
Electricity Use (Consumption)	**59.2**	**78.5**	**90.9**	**101.1**	**110.3**	**118.0**	**126.2**	**134.3**	
Electricity Production (in state)	68.5	89.1	98.4	105.4	115.0	123.0	131.5	140.0	
Coal	*68.3*	*88.7*	*93.6*	*101.2*	*110.3*	*118.0*	*126.3*	*134.4*	*See electric sector assumptions*
Natural Gas	*0.016*	*0.31*	*1.64*	*1.89*	*2.07*	*2.23*	*2.28*	*2.39*	*in Appendix A.*
Oil	*0.090*	*0.13*	*3.12*	*2.32*	*2.53*	*2.70*	*2.87*	*3.07*	
Biomass (CH_4 and N_2O)	*0.000*	*0.000*	*0.002*	*0.003*	*0.003*	*0.003*	*0.003*	*0.004*	
MSW/Landfill Gas	*0.000*	*0.000*	*0.036*	*0.057*	*0.062*	*0.066*	*0.071*	*0.076*	
Other Wastes	*0.000*	*0.000*	*0.008*	*0.007*	*0.008*	*0.009*	*0.009*	*0.010*	
Net Imported/Exported Electricity	-9.27	-10.58	-7.51	-4.30	-4.69	-5.01	-5.36	-5.70	Negative values represent net exported electricity
Residential/Commercial/ Industrial (RCI) Fuel Use	**26.7**	**30.4**	**31.2**	**28.3**	**29.1**	**28.8**	**28.5**	**27.7**	
Coal	8.54	5.77	5.88	5.28	5.61	5.56	5.40	5.04	Based on USDOE regional projections
Natural Gas	8.72	11.3	11.2	10.8	10.8	10.8	10.8	10.6	Based on USDOE regional projections
Oil	9.34	13.3	14.0	12.2	12.5	12.4	12.2	11.9	Based on USDOE regional projections
Wood (CH_4 and N_2O)	0.11	0.06	0.10	0.10	0.10	0.11	0.11	0.11	Based on USDOE regional projections
Transportation	**27.2**	**33.2**	**37.3**	**36.8**	**40.9**	**45.5**	**50.8**	**56.9**	
Onroad Gasoline	16.4	19.0	19.2	20.3	22.2	24.2	26.3	28.5	Based on VMT projections from KYTC
Onroad Diesel	5.77	8.90	9.59	10.8	12.7	15.1	18.2	22.0	Based on VMT projections from KYTC
Marine Vessels	1.17	1.35	3.63	1.43	1.50	1.57	1.64	1.70	Based on historical growth
Rail, Natural Gas, LPG, other	1.49	1.28	1.48	2.12	2.13	2.13	2.13	2.13	Based on USDOE regional projections
Jet Fuel and Aviation Gasoline	2.32	2.68	3.35	2.21	2.39	2.48	2.56	2.62	Based on FAA projected operations and AEO2009 efficiency gains
Fossil Fuel Industry	**8.51**	**7.33**	**6.50**	**7.46**	**7.05**	**6.91**	**6.91**	**6.90**	
Natural Gas Industry	4.00	3.59	3.43	3.95	4.06	4.17	4.30	4.47	
Oil Industry	0.077	0.058	0.047	0.052	0.057	0.062	0.069	0.076	
Coal Mining (CH_4)	4.43	3.68	3.03	3.46	2.93	2.67	2.53	2.35	Used AEO Central Appalachia coal production projections
Industrial Processes	**4.75**	**5.65**	**6.52**	**7.75**	**8.50**	**9.35**	**10.70**	**12.55**	
Cement Manufacture (CO_2)	0.37	0.35	0.54	0.53	0.59	0.64	0.69	0.73	Based on Portland Cement Association's Cement Outlook 2008.
Lime Manufacture (CO_2)	0.46	0.48	0.72	0.77	0.83	0.88	0.94	1.01	Based on analysis of historical growth
Limestone and Dolomite Use (CO_2)	0.31	0.28	0.32	1.08	1.08	1.08	1.08	1.08	No growth assumed due to conflicting historical data
Soda Ash (CO_2)	0.040	0.038	0.036	0.034	0.033	0.031	0.029	0.029	Based on employment

Million Metric Tons CO_2e	1990	2000	2005	2010	2015	2020	2025	2030	Explanatory Notes for Projections
									projections from Workforce KY
Iron & Steel (CO_2)	2.43	2.57	2.62	2.70	2.70	2.70	2.70	2.70	No growth assumed
Ammonia and Urea (CO_2)	0.011	0.010	0.007	0.008	0.008	0.008	0.008	0.008	Based on analysis of historical growth
ODS Substitutes (HFC, PFC)	0.005	1.02	1.48	1.90	2.56	3.32	4.59	6.35	Based on national projections (USEPA)
Electric Power T&D (SF_6)	0.60	0.34	0.34	0.31	0.29	0.28	0.27	0.26	Based on national projections (USEPA)
Aluminum Production (PFC)	0.53	0.57	0.46	0.42	0.41	0.40	0.40	0.39	Based on national projections (USEPA)
Waste Management	**2.18**	**2.13**	**2.16**	**2.33**	**1.75**	**1.87**	**1.98**	**2.10**	
Waste Combustion	0.11	0.17	0.20	0.21	0.21	0.21	0.21	0.21	Used growth rate calculated for 1995-2002 emissions growth
Landfills	1.71	1.56	1.54	1.68	1.09	1.18	1.27	1.37	Based on historical KY landfill emplacement; Used landfill disposal projections from waste management profile to estimate future emissions
Wastewater Management	0.36	0.40	0.41	0.44	0.46	0.48	0.50	0.52	Used growth rate calculated for 1990-2005 emissions growth
Agriculture	**7.89**	**6.96**	**7.88**	**7.05**	**6.81**	**6.65**	**6.56**	**6.59**	
Enteric Fermentation	3.25	2.91	3.12	3.14	3.06	3.02	3.04	3.16	Based on projected livestock population
Manure Management	0.48	0.48	0.53	0.45	0.42	0.40	0.40	0.41	Based on projected livestock population
Agricultural Soils	3.67	3.31	4.08	3.35	3.26	3.17	3.07	2.98	Used historical growth rate
Agricultural Burning	0.014	0.017	0.018	0.019	0.020	0.021	0.022	0.023	Used historical growth rate
Agricultural Liming	0.48	0.24	0.13	0.088	0.057	0.037	0.024	0.016	Based on historical agricultural liming estimate
Forest Wildfires (N_20 and CH_4)	**0.29**	**1.72**	**0.66**	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**	Based on average of historical emissions
Total Gross Emissions (Consumption Basis, Excludes Sinks)	**136.7**	**165.9**	**183.1**	**191.6**	**205.1**	**217.7**	**232.3**	**247.7**	
increase relative to 1990		*21%*	*34%*	*40%*	*50%*	*59%*	*70%*	*81%*	
Emissions Sinks	**-9.94**	**-7.77**	**-7.57**	**-7.57**	**-7.57**	**-7.57**	**-7.57**	**-7.57**	
Forested Landscape	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71	Held at 2005 levels
Urban Forestry and Land Use	-4.09	-1.92	-1.73	-1.73	-1.73	-1.73	-1.73	-1.73	Extrapolated based on historical data
Agricultural Soils (cultivation practices)	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	Held at 1997 levels based on most recent data available
Net Emissions (Includes Sinks)	**126.8**	**158.2**	**175.5**	**184.0**	**197.6**	**210.1**	**224.8**	**240.2**	
increase relative to 1990		*25%*	*38%*	*45%*	*56%*	*66%*	*77%*	*89%*	

[a] Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Figure ES-1. Historical Kentucky and US Gross GHG Emissions, Per Capita and Per Unit Gross Product

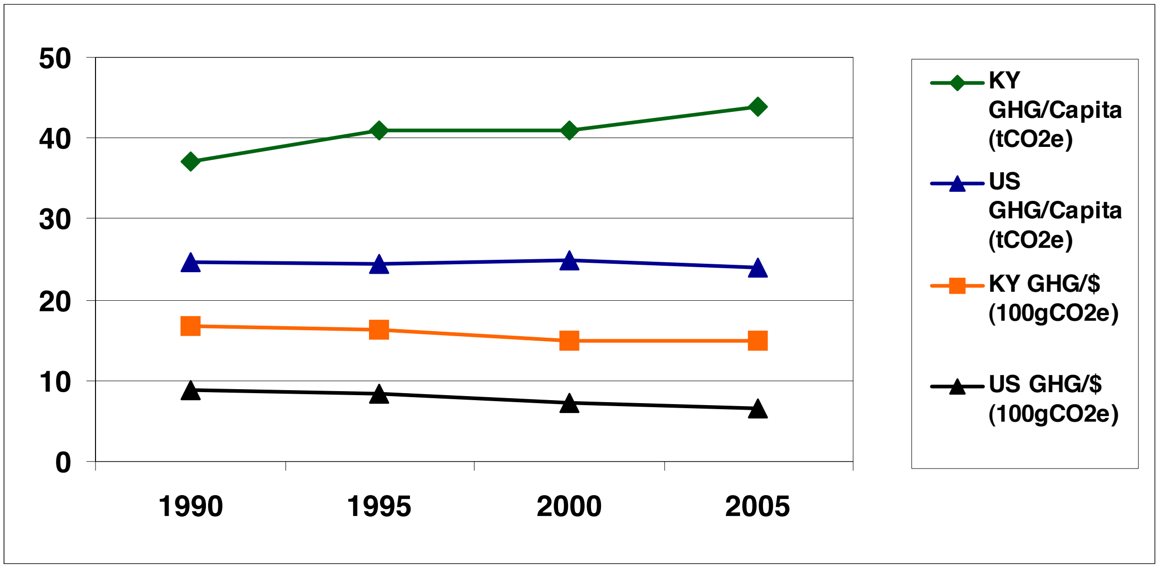
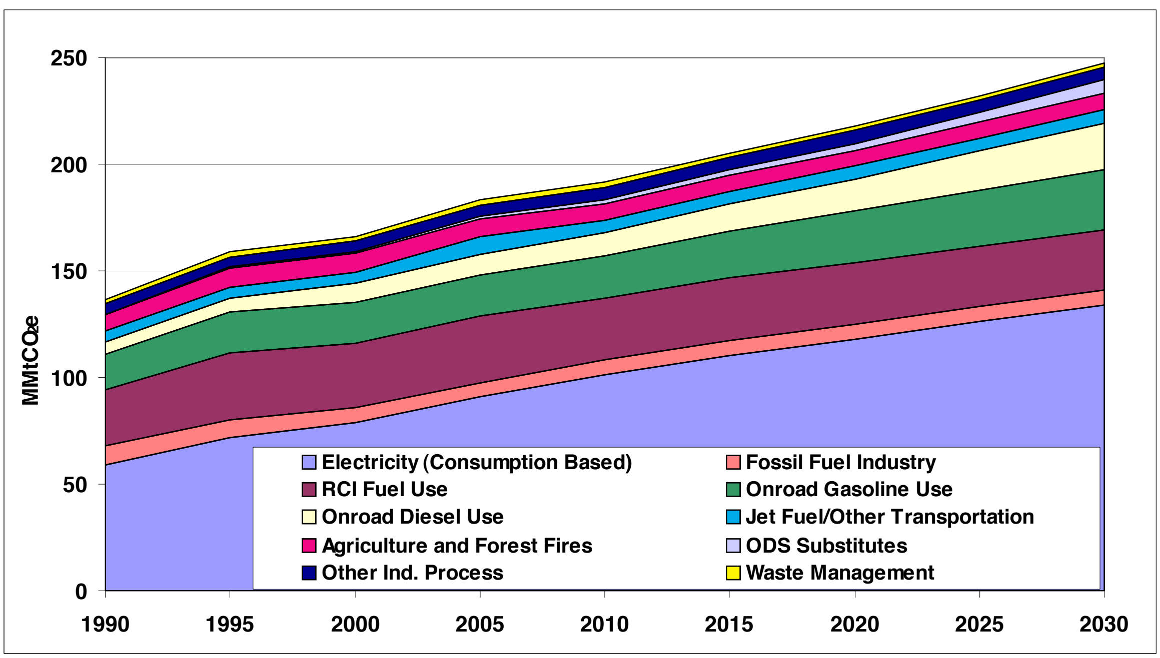
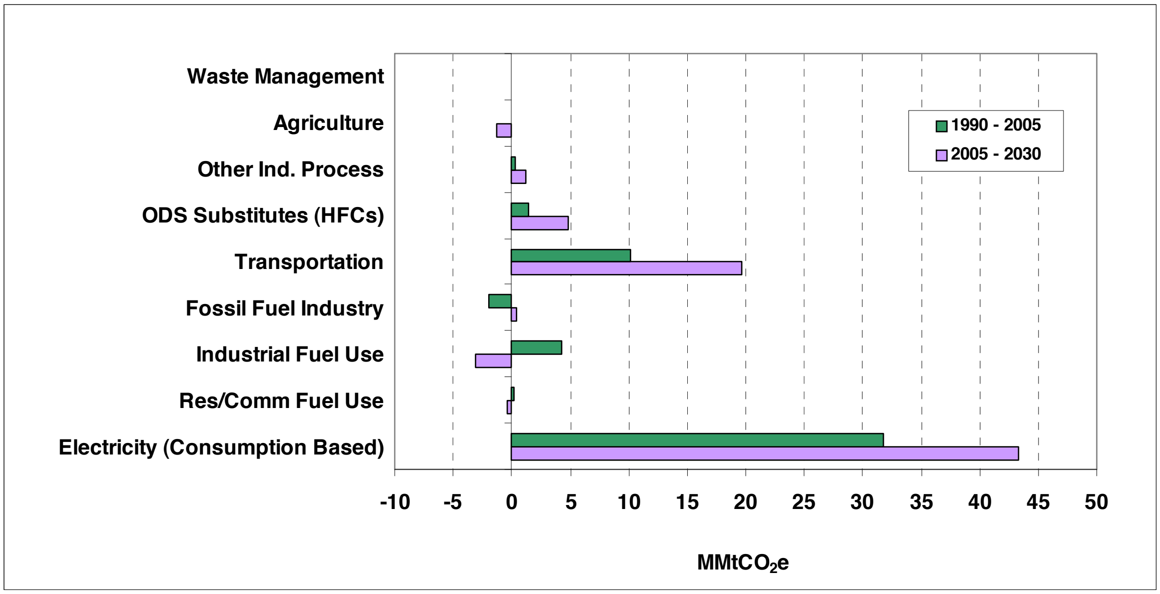


Figure ES-2. Kentucky Gross GHG Emissions by Sector, 1990-2030: Historical and Projected



RCI – direct fuel use in residential, commercial, and industrial sectors. ODS – ozone depleting substance.

Figure ES-3. Sector Contributions to Gross Emissions Growth in Kentucky, 1990-2030: Reference Case Projections ($MMtCO_2e$ Basis)



Res/Comm – direct fuel use in residential and commercial sectors. ODS – ozone depleting substance. HFCs – hydrofluorocarbons. Emissions associated with other industrial processes include all of the industries identified in Appendix D except emissions associated with ODS substitutes which are shown separately in this graph because of high expected growth in emissions for ODS substitutes.

Table ES-2. Emission Reduction Estimates Associated with the Effect of Recent Federal Actions in Kentucky (Consumption-Basis, Gross Emissions)

	GHG Reductions		GHG Emissions (MMtCO2e)	
	($MMtCO_2e$)		Business as Usual	With Recent Actions
Sector / Recent Action	**2020**	**2030**	**2030**	**2030**
Transportation and Land Use (TLU)				
Federal Corporate Average Fuel Economy (CAFE) Requirements plus California CO_2 Vehicle Standards	4.02	6.23	56.9	50.7
Total (All Sectors)			**247.7**	**241.5**

Table of Contents

Acronyms and Key Terms

AEO2009 – EIA's Annual Energy Outlook 2009

bbls – Barrels

BC – Black Carbon*

Bcf – Billion Cubic Feet

BOD – Biochemical Oxygen Demand

Btu – British Thermal Unit

C – Carbon*

$CaCO_3$ – Calcium Carbonate

CAFE – Corporate Average Fuel Economy

CAR – Climate Action Reserve

CCS – Center for Climate Strategies

CFCs – Chlorofluorocarbons*

CH_4 – Methane*

CO – Carbon Monoxide*

CO_2 – Carbon Dioxide*

CO_2e – Carbon Dioxide equivalent*

CRP – Federal Conservation Reserve Program

DOE – Department of Energy

DOT – Department of Transportation

EC – Elemental Carbon*

EIA – US DOE Energy Information Administration

EIIP – Emission Inventory Improvement Program

EISA – Energy Independence and Security Act

FAA – Federal Aviation Administration

FERC – Federal Energy Regulatory Commission

FHWA – Federal Highway Administration

FIA – Forest Inventory Analysis

Gg – Gigagrams

GHG – Greenhouse Gas*

GWh – Gigawatt-hour

GWP – Global Warming Potential*

H_2O – Water Vapor*

HBFCs – Hydrobromofluorocarbons*

HCFCs – Hydrochlorofluorocarbons*

HFCs – Hydrofluorocarbons*

Histosols - high organic content soils

HWP – Harvested Wood Products

IPCC – Intergovernmental Panel on Climate Change*

KCAPC – Kentucky Climate Action Plan Council

KEEC – Kentucky Energy and Environment Cabinet

km^2 – Square Kilometers

K-nitrogen – Kjeldahl nitrogen

kWh – Kilowatt-hour

KYDEP – Kentucky Department of Environmental Protection

KYTC - Kentucky Transportation Cabinet

LandGEM- Landfill Gas Emissions Model, version 3.02

lb – Pound

LF – Landfill

LFG – Landfill Gas

LFGTE – Landfill Gas Collection System and Landfill-Gas-to-Energy

LMOP – US EPA Landfill Methane Outreach Program

LPG – Liquefied Petroleum Gas

Mg – Megagrams

MMBtu – Million British thermal units

MMt – Million Metric tons

$MMtCO_2e$ – Million Metric tons Carbon Dioxide equivalent

MSW – Municipal Solid Waste

Mt – Metric ton (equivalent to 1.102 short tons)

MWh – Megawatt-hour

N – Nitrogen*

$(NH_2)_2CO$ – Urea

NH_3 – Ammonia

N_2O – Nitrous Oxide*

NASS – National Agriculture Statistical Service

NEI – National Emissions Inventory

NEMS – National Energy Modeling System

NF – National Forest

NMVOCs – Nonmethane Volatile Organic Compound*

NO_2 – Nitrogen Dioxide*

NO_x – Nitrogen Oxides*

O_3 – Ozone*

ODS – Ozone-Depleting Substance*

OM – Organic Matter*

OH – Hydroxyl radical*

OPS – Office of Pipeline Safety

PFCs – Perfluorocarbons*

PM – Particulate Matter*

ppb – parts per billion

ppm – parts per million

ppmv – parts per million by volume

PSC – Public Service Commission

RCI – Residential, Commercial, and Industrial

SAR – Second Assessment Report*

SED – State Energy Data

SF_6 – Sulfur Hexafluoride*

SIT – State Greenhouse Gas Inventory Tool

Sinks – Removals of carbon from the atmosphere, with the carbon stored in forests, soils, landfills, wood structures, or other biomass-related products.

SO_2 – Sulfur Dioxide*

t – metric ton

T&D – Transmission and Distribution

TAR – Third Assessment Report*

TLU – Transportation and Land Use

TWGs – Technical Work Groups

UNFCCC – United Nations Framework Convention on Climate Change

US – United States

US DOE – United States Department of Energy

US EPA – United States Environmental Protection Agency

USDA – United States Department of Agriculture

USFS – United States Forest Service

USGS – United States Geological Survey

VMT – Vehicle Mile Traveled

VOCs – Volatile Organic Compound*

VS – Volatile Solids

yr – Year

* See Appendix I for more information

Acknowledgements

We appreciate all of the time and assistance provided by contacts in Kentucky, as well as at federal agencies. Thanks go to in particular the staff at several Kentucky State Agencies for their inputs, in particular the Kentucky Transportation Cabinet, and to Talina Mathews of the Kentucky Energy and Environment Cabinet (KEEC) who provided key guidance for this analytical effort. Thanks also to Michael Gillenwater for directing preparation of Appendix I.

Summary of Findings

Introduction

The Center for Climate Strategies (CCS) prepared this report for the Kentucky Energy and Environment Cabinet (KEEC). The report presents an assessment of the State's greenhouse gas (GHG) emissions and anthropogenic sinks (carbon storage) from 1990 to 2030. The preliminary draft inventory and forecast served as a starting point to assist the State, as well as the Kentucky Climate Action Plan Council (KCAPC) and Technical Work Groups (TWGs), with an initial comprehensive understanding of Kentucky's current and possible future GHG emissions, and thereby informed the identification and analysis of policy options for mitigating GHG emissions.[10] The KCAPC and TWGs have reviewed, discussed, and evaluated the draft inventory and methodologies as well as alternative data and approaches for improving the draft GHG inventory and forecast. The inventory and forecast as well as this report have been revised to address the comments provided and approved by the KCAPC.

Emissions and Reference Case Projections (Business-as-Usual)

Kentucky's anthropogenic GHG emissions and anthropogenic sinks (carbon storage) were estimated for the period from 1990 to 2030. Historical GHG emission estimates (1990 through 2007)[11] were developed using a set of generally accepted principles and guidelines for State GHG emissions inventories, as described in the "Approach" section below, relying to the extent possible on Kentucky-specific data and inputs. The initial reference case projections (2008-2030) are based on a compilation of various projections of electricity generation, fuel use, and other GHG-emitting activities for Kentucky, along with a set of simple, transparent assumptions described in the appendices of this report.

The inventory and projections cover the six gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential- (GWP-) weighted basis.[12]

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[10] "Draft Kentucky Greenhouse Gas Inventory and Reference Case Projections, 1990-2030," prepared by the Center for Climate Strategies for the Kentucky Energy and Environment Cabinet, January 2010.

[11] The last year of available historical data varies by sector; ranging from 2004 to 2008.

[12] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 2001). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth), See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental Panel on Climate Change Cambridge University Press. Cambridge, United Kingdom. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.

It is important to note that the emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Kentucky's demands,* corresponding to a consumption-based approach to emissions accounting (see "Approach" section below). Another way to look at electricity emissions is to consider the *GHG emissions produced by electricity generation facilities in the State*. This report covers both methods of accounting for emissions, but for consistency, all total results are reported as *consumption-based*.

Kentucky Greenhouse Gas Emissions: Sources and Trends

Table 1 provides a summary of GHG emissions estimated for Kentucky by sector for the years 1990, 2000, 2005, 2010, 2015, 2020, 2025, and 2030. Details on the methods and data sources used to construct these estimates are provided in the appendices to this report**.** In the sections below, we discuss GHG emission sources (positive, or *gross*, emissions) and sinks (negative emissions) separately in order to identify trends, projections, and uncertainties clearly for each.

This next section of the report provides a summary of the historical emissions (1990 through 2007) followed by a summary of the reference-case projection-year emissions (2008 through 2030) and key uncertainties. We also provide an overview of the general methodology, principles, and guidelines followed for preparing the inventories. Appendices A through H provide the detailed methods, data sources, and assumptions for each GHG sector. Appendix I provides background information on GHGs and climate-forcing aerosols.

Table 1. Kentucky Historical and Reference Case GHG Emissions, by Sector[a]

Million Metric Tons CO_2e	1990	2000	2005	2010	2015	2020	2025	2030	Explanatory Notes for Projections
Energy Use (CO_2, CH_4, N_2O)	**121.6**	**149.5**	**165.9**	**173.8**	**187.4**	**199.2**	**212.4**	**225.8**	
Electricity Use (Consumption)	**59.2**	**78.5**	**90.9**	**101.1**	**110.3**	**118.0**	**126.2**	**134.3**	
Electricity Production (in state)	68.5	89.1	98.4	105.4	115.0	123.0	131.5	140.0	
Coal	*68.3*	*88.7*	*93.6*	*101.2*	*110.3*	*118.0*	*126.3*	*134.4*	*See electric sector assumptions*
Natural Gas	*0.016*	*0.31*	*1.64*	*1.89*	*2.07*	*2.23*	*2.28*	*2.39*	*in Appendix A.*
Oil	*0.090*	*0.13*	*3.12*	*2.32*	*2.53*	*2.70*	*2.87*	*3.07*	
Biomass (CH_4 and N_2O)	*0.000*	*0.000*	*0.002*	*0.003*	*0.003*	*0.003*	*0.003*	*0.004*	
MSW/Landfill Gas	*0.000*	*0.000*	*0.036*	*0.057*	*0.062*	*0.066*	*0.071*	*0.076*	
Other Wastes	*0.000*	*0.000*	*0.008*	*0.007*	*0.008*	*0.009*	*0.009*	*0.010*	
Net Imported/Exported Electricity	-9.27	-10.58	-7.51	-4.30	-4.69	-5.01	-5.36	-5.70	Negative values represent net exported electricity
Residential/Commercial/ Industrial (RCI) Fuel Use	**26.7**	**30.4**	**31.2**	**28.3**	**29.1**	**28.8**	**28.5**	**27.7**	
Coal	8.54	5.77	5.88	5.28	5.61	5.56	5.40	5.04	Based on USDOE regional projections
Natural Gas	8.72	11.3	11.2	10.8	10.8	10.8	10.8	10.6	Based on USDOE regional projections
Oil	9.34	13.3	14.0	12.2	12.5	12.4	12.2	11.9	Based on USDOE regional projections
Wood (CH_4 and N_2O)	0.11	0.06	0.10	0.10	0.10	0.11	0.11	0.11	Based on USDOE regional projections
Transportation	**27.2**	**33.2**	**37.3**	**36.8**	**40.9**	**45.5**	**50.8**	**56.9**	
Onroad Gasoline	16.4	19.0	19.2	20.3	22.2	24.2	26.3	28.5	Based on VMT projections from KYTC
Onroad Diesel	5.77	8.90	9.59	10.8	12.7	15.1	18.2	22.0	Based on VMT projections from KYTC
Marine Vessels	1.17	1.35	3.63	1.43	1.50	1.57	1.64	1.70	Based on historical growth
Rail, Natural Gas, LPG, other	1.49	1.28	1.48	2.12	2.13	2.13	2.13	2.13	Based on USDOE regional projections
Jet Fuel and Aviation Gasoline	2.32	2.68	3.35	2.21	2.39	2.48	2.56	2.62	Based on FAA projected operations and AEO2009 efficiency gains
Fossil Fuel Industry	**8.51**	**7.33**	**6.50**	**7.46**	**7.05**	**6.91**	**6.91**	**6.90**	
Natural Gas Industry	4.00	3.59	3.43	3.95	4.06	4.17	4.30	4.47	
Oil Industry	0.077	0.058	0.047	0.052	0.057	0.062	0.069	0.076	
Coal Mining (CH_4)	4.43	3.68	3.03	3.46	2.93	2.67	2.53	2.35	Used AEO Central Appalachia coal production projections
Industrial Processes	**4.75**	**5.65**	**6.52**	**7.75**	**8.50**	**9.35**	**10.70**	**12.55**	
Cement Manufacture (CO_2)	0.37	0.35	0.54	0.53	0.59	0.64	0.69	0.73	Based on Portland Cement Association's Cement Outlook 2008.
Lime Manufacture (CO_2)	0.46	0.48	0.72	0.77	0.83	0.88	0.94	1.01	Based on analysis of historical growth
Limestone and Dolomite Use (CO_2)	0.31	0.28	0.32	1.08	1.08	1.08	1.08	1.08	No growth assumed due to conflicting historical data
Soda Ash (CO_2)	0.040	0.038	0.036	0.034	0.033	0.031	0.029	0.029	Based on employment

Million Metric Tons CO_2e	1990	2000	2005	2010	2015	2020	2025	2030	Explanatory Notes for Projections
									projections from Workforce KY
Iron & Steel (CO_2)	2.43	2.57	2.62	2.70	2.70	2.70	2.70	2.70	No growth assumed
Ammonia and Urea (CO_2)	0.011	0.010	0.007	0.008	0.008	0.008	0.008	0.008	Based on analysis of historical growth
ODS Substitutes (HFC, PFC)	0.005	1.02	1.48	1.90	2.56	3.32	4.59	6.35	Based on national projections (USEPA)
Electric Power T&D (SF_6)	0.60	0.34	0.34	0.31	0.29	0.28	0.27	0.26	Based on national projections (USEPA)
Aluminum Production (PFC)	0.53	0.57	0.46	0.42	0.41	0.40	0.40	0.39	Based on national projections (USEPA)
Waste Management	**2.18**	**2.13**	**2.16**	**2.33**	**1.75**	**1.87**	**1.98**	**2.10**	
Waste Combustion	0.11	0.17	0.20	0.21	0.21	0.21	0.21	0.21	Used growth rate calculated for 1995-2002 emissions growth
Landfills	1.71	1.56	1.54	1.68	1.09	1.18	1.27	1.37	Based on historical KY landfill emplacement; Used landfill disposal projections from waste management profile to estimate future emissions
Wastewater Management	0.36	0.40	0.41	0.44	0.46	0.48	0.50	0.52	Used growth rate calculated for 1990-2005 emissions growth
Agriculture	**7.89**	**6.96**	**7.88**	**7.05**	**6.81**	**6.65**	**6.56**	**6.59**	
Enteric Fermentation	3.25	2.91	3.12	3.14	3.06	3.02	3.04	3.16	Based on projected livestock population
Manure Management	0.48	0.48	0.53	0.45	0.42	0.40	0.40	0.41	Based on projected livestock population
Agricultural Soils	3.67	3.31	4.08	3.35	3.26	3.17	3.07	2.98	Used historical growth rate
Agricultural Burning	0.014	0.017	0.018	0.019	0.020	0.021	0.022	0.023	Used historical growth rate
Agricultural Liming	0.48	0.24	0.13	0.088	0.057	0.037	0.024	0.016	Based on historical agricultural liming estimate
Forest Wildfires (N_20 and CH_4)	**0.29**	**1.72**	**0.66**	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**	Based on average of historical emissions
Total Gross Emissions (Consumption Basis, Excludes Sinks)	**136.7**	**165.9**	**183.1**	**191.6**	**205.1**	**217.7**	**232.3**	**247.7**	
increase relative to 1990		*21%*	*34%*	*40%*	*50%*	*59%*	*70%*	*81%*	
Emissions Sinks	**-9.94**	**-7.77**	**-7.57**	**-7.57**	**-7.57**	**-7.57**	**-7.57**	**-7.57**	
Forested Landscape	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71	Held at 2005 levels
Urban Forestry and Land Use	-4.09	-1.92	-1.73	-1.73	-1.73	-1.73	-1.73	-1.73	Extrapolated based on historical data
Agricultural Soils (cultivation practices)	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	Held at 1997 levels based on most recent data available
Net Emissions (Includes Sinks)	**126.8**	**158.2**	**175.5**	**184.0**	**197.6**	**210.1**	**224.8**	**240.2**	
increase relative to 1990		*25%*	*38%*	*45%*	*56%*	*66%*	*77%*	*89%*	

[a] Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Historical Emissions

Overview

In 2005, activities in Kentucky accounted for approximately 183 million metric tons (MMt) of *gross*[13] CO_2e emissions (consumption basis) in 2005, an amount equal to about 2.6% of total U.S. gross GHG emissions (based on 2005 U.S. data).[14] Kentucky's gross GHG emissions are rising at a faster rate than those of the nation as a whole (gross emissions exclude carbon sinks, such as forests). Kentucky's gross GHG emissions increased by about 34% from 1990 to 2005, while national emissions rose by 16% from 1990 to 2005. The growth in Kentucky's emissions from 1990 to 2005 is primarily associated with the electricity consumption and transportation sectors.

Figure 1 illustrates the State's emissions per capita and per unit of economic output.[15] On a per capita basis, Kentucky residents emitted about 37 metric tons (t) of gross CO_2e in 1990, much higher than the 1990 national per capita emissions of 25 tCO_2e. Unlike the national per capita emissions which remained nearly constant from 1990 to 2005, the Kentucky per capita emissions increased by 19% from 1990 to 2005. The electricity supply sector shows the greatest difference between per capita emissions in Kentucky and the US, at 22 tCO_2e per capita in Kentucky for this sector compared with 8 tCO_2e per capita nationally. This is because the electricity consumed in Kentucky relies on a high amount of coal in the generation fuel mix relative to the US as a whole; about 90% for Kentucky versus 50% for the US in 2005. The use of coal has led to low electricity rates in Kentucky compared to the rest of the country, which has allowed energy-intensive industries to flourish in the state, as acknowledged in Kentucky's Energy Plan.[16] Like the nation as a whole, Kentucky's economic growth exceeded emissions growth throughout the 1990-2005 period (leading to declining estimates of GHG emissions per unit of state product). From 1990 to 2005, emissions per unit of gross product dropped by 11% in Kentucky and by about 26% nationally.[17]

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[13] Excluding GHG emissions removed due to forestry and other land uses and excluding GHG emissions associated with exported electricity.

[14] The national emissions used for these comparisons are based on 2005 emissions from *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006*, April 15, 2008, US EPA #430-R-08-005, (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

[15] Historical Kentucky population statistics are compiled by Kentucky State Data Center from US Census Bureau data, are available at http://ksdc.louisville.edu/kpr/popest/est.htm.. Kentucky population projections through 2050 are available from the same source at http://ksdc.louisville.edu/kpr/pro/projections.htm.

[16] *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence,* Governor Steven L. Beshear, November 2008.

[17] Based on real gross domestic product (millions of chained 2000 dollars) that excludes the effects of inflation, available from the US Bureau of Economic Analysis (http://www.bea.gov/regional/gsp/). The national emissions used for these comparisons are based on 2005 emissions from *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006*, April 15, 2008, US EPA #430-R-08-005, (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

Figure 1. Historical Kentucky and US Gross GHG Emissions, Per Capita and Per Unit Gross Product

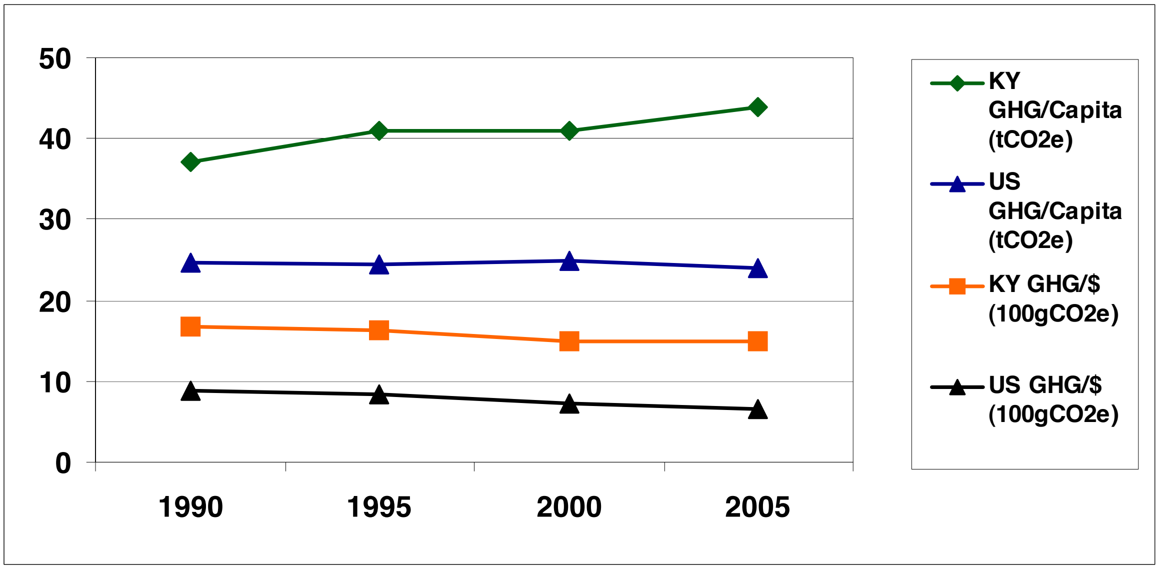


Figure 2 compares the contribution of gross GHG emissions by sector estimated for Kentucky to emissions for the U.S. for year 2005. Principal sources of Kentucky's GHG emissions are electricity consumption; transportation; and residential, commercial, and industrial (RCI) fuel use accounting for 50%, 20%, and 17% of Kentucky's gross GHG emissions in 2005, respectively.

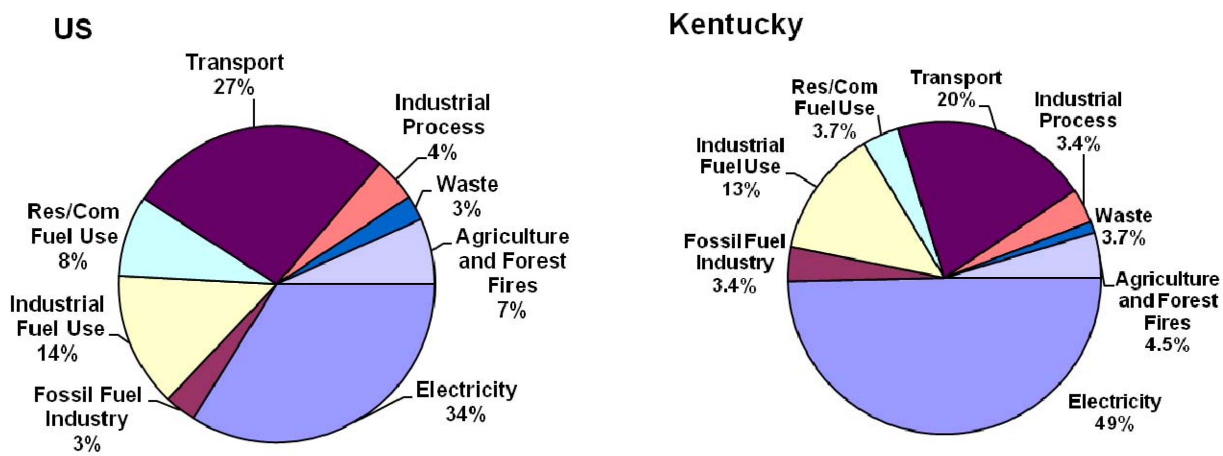
The next largest contributor of gross GHG emissions in 2005 is the agriculture and forest fires sector, accounting for about 4.7% of the 2005 gross GHG emissions in Kentucky. The agriculture sector includes emissions from enteric fermentation, manure management, agricultural soils, and agricultural burning. Forest fires include forest wildfires and prescribed burning.

The fossil fuel industries and industrial processes each account for about 3.6% of Kentucky's gross GHG emissions in 2005. The fossil fuel industry sector includes GHG emissions associated with natural gas production, processing, T&D, and pipeline fuel use, as well as with oil production and refining and coal mining. Industrial process emissions are dominated by the use of HFCs as substitutes for ozone-depleting chlorofluorocarbons (CFCs), which are rising rapidly through the historical and projection periods.[18] Other industrial process emissions result from CO_2 released during iron and steel, cement, and lime, and manufacturing; ammonia production; and soda ash, limestone, dolomite, and urea use. In addition, SF_6 is released during the use of electric power transmission and distribution (T&D) equipment, while aluminum production is responsible for the release of PFCs.

[18] CFCs are also potent GHGs; they are not, however, included in GHG estimates because of concerns related to implementation of the Montreal Protocol (See Appendix I for additional information). HFCs are used as refrigerants in the RCI and transport sectors as well as in the industrial sector; they are included here, however, within the industrial processes emissions.

The waste management sector accounts for about 1.2% of Kentucky's gross GHG emissions in 2005. The waste management sector is dominated by CH_4 emissions from landfills, but also includes emissions from waste combustion and wastewater management.

Figure 2. Gross GHG Emissions by Sector, 2005, Kentucky and US



Notes: Res/Com = residential and commercial fuel use sectors; emissions for the residential, commercial, and industrial fuel use sectors are associated with the direct use of fuels (natural gas, petroleum, coal, and wood) to provide space heating, water heating, process heating, cooking, and other energy end-uses. The commercial sector accounts for emissions associated with the direct use of fuels by, for example, hospitals, schools, government buildings (local, county, and state), and other commercial establishments. The industrial processes sector accounts for emissions associated with manufacturing and excludes emissions included in the industrial fuel use sector. The transportation sector accounts for emissions associated with fuel consumption by all on-road and non-highway vehicles. Non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, railway locomotives, boats, and ships. Emissions from non-highway agricultural and construction equipment are included in the industrial sector. Electricity = electricity generation sector emissions on a consumption basis (including emissions associated with electricity imported from outside of Kentucky and excluding emissions associated with electricity exported from Kentucky to other states).

Estimates of carbon sinks in Kentucky include urban forests, land use changes, and agricultural soil cultivation practices. Note that forest wildfires and prescribed burning are sources of GHG emissions are were included with the agriculture sector in Figure 2. Forestry activities and agricultural soil cultivation practices in Kentucky are estimated to be net sinks of GHG emissions in all years. The current estimates indicate that about 7.6 $MMtCO_2e$ were stored in Kentucky biomass in 2005. This leads to *net* emissions of 176 $MMtCO_2e$ in Kentucky in 2005, an amount equal to 2.8% of total US net GHG emissions.

A Closer Look at the Three Major Sources: Electricity Consumption, Transportation, and RCI Fuel Use

Electricity Consumption Sector

Electricity generation in Kentucky is dominated by steam units, which are primarily fueled by coal. Throughout the historical and forecasted periods, Kentucky power plant generation exceeds the electricity consumed in the state. The remaining electricity generated in Kentucky is assumed to be exported to neighboring regions. As shown in Figure 2, electricity consumption accounted for about 50% of Kentucky's gross GHG emissions in 2005 (about 91 $MMtCO_2e$), which was higher than the national average share of emissions from electricity consumption (34%).[19] The GHG emissions associated with Kentucky's electricity consumption sector increased by about 32 MMtCO_2e between 1990 and 2005, accounting for 69% of the state's growth in gross GHG emissions in this time period.

In 2005, emissions associated with Kentucky's electricity consumption (91 MMtCO_2e) were about 7.5 MMtCO_2e lower than those associated with electricity production (98 MMtCO_2e). The higher level for production-based emissions reflects GHG emissions associated with net exports of electricity to other states to neighboring regions.[20] Projections of electricity sales for 2008 through 2030 indicate that Kentucky will remain a net exporter of electricity. Emissions from net electricity exports are projected to increase over the 2008-2030 period, from 4.1 MMtCO_2e in 2008 to 5.7 MMtCO_2e in 2030. Overall, the reference case projection indicates that production-based emissions (associated with electricity generated in-state) will increase by about 42 MMtCO_2e from 2005 levels, and consumption-based emissions (associated with electricity consumed in-state) will increase by about 43 MMtCO_2e from 2005 to 2030.

The consumption-based approach can better reflect the emissions (and emissions reductions) associated with activities occurring in Kentucky, particularly with respect to electricity generation, use, and efficiency improvements, and is particularly useful for policy-making.

Transportation Sector

As shown in Figure 2, the transportation sector accounted for about 20% of Kentucky's gross GHG emissions in 2005 (about 37 MMtCO_2e), which was lower than the national average share of emissions from transportation fuel consumption (27%). The GHG emissions associated with Kentucky's transportation sector increased by 10 MMtCO_2e between 1990 and 2005, accounting for about 22% of the State's net growth in gross GHG emissions in this time period.

From 1990 through 2005, Kentucky's GHG emissions from transportation fuel use have risen steadily at an average rate of about 2.1% annually. In 2005, onroad gasoline vehicles accounted for about 52% of transportation GHG emissions. Onroad diesel vehicles accounted for another 26% of transportation emissions, and marine vessels for roughly 10%. Air travel, rail, and other sources (natural gas- and liquefied petroleum gas- (LPG) fueled-vehicles used in transport applications) accounted for the remaining 13% of transportation emissions. GHG emissions from onroad gasoline use grew 17% between 1990 and 2005. Meanwhile, GHG emissions from onroad diesel use rose 66% during that period, suggesting rapid growth in freight movement within or across the State. Emissions associated with marine fuel use increased by about 211% from 1990 to 2005, while emissions associated with aviation fuel consumption increased by 45% in the same period.

During the period from 2005 to 2030, emissions from transportation fuels are projected to rise at a rate of 1.7% per year. This leads to an increase of 20 MMtCO_2e in transportation emissions

[19] For the US as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the US imports only about 1% of its electricity, and exports even less.

[20] Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer demand. The current estimate reflects some very simple assumptions, as described in Appendix A.

from 2005 to 2030. The largest percentage increase in emissions over this time period is seen in onroad diesel fuel consumption, which is projected to increase by 129% from 2005 to 2030.

Residential, Commercial, and Industrial Fuel Use Sectors

Activities in the RCI[21] sectors produce GHG emissions when fuels are combusted to provide space heating, process heating, and other applications. In 2005, combustion of oil, natural gas, coal, and wood in the RCI sectors contributed about 17% (about 31 $MMtCO_2e$) of Kentucky's gross GHG emissions, below the RCI sector contribution for the nation (22%).

In 2005, the residential sector's share of total RCI emissions from direct fuel use was 13% (3.9 $MMtCO_2e$), the commercial sector accounted for 10% (3.1 $MMtCO_2e$), and the industrial sector's share of total RCI emissions from direct fuel use was 78% (24 $MMtCO_2e$). Overall, emissions for the RCI sectors (excluding those associated with electricity consumption) are expected to decrease by 11% between 2005 and 2030 to 28 $MMtCO_2e$. Emissions from the residential sector are projected to increase slightly by 0.8% from 2005 to 2030. In contrast, emissions from the commercial and industrial sectors are expected to decrease by 12% and 13%, respectively, from 2005 to 2030.

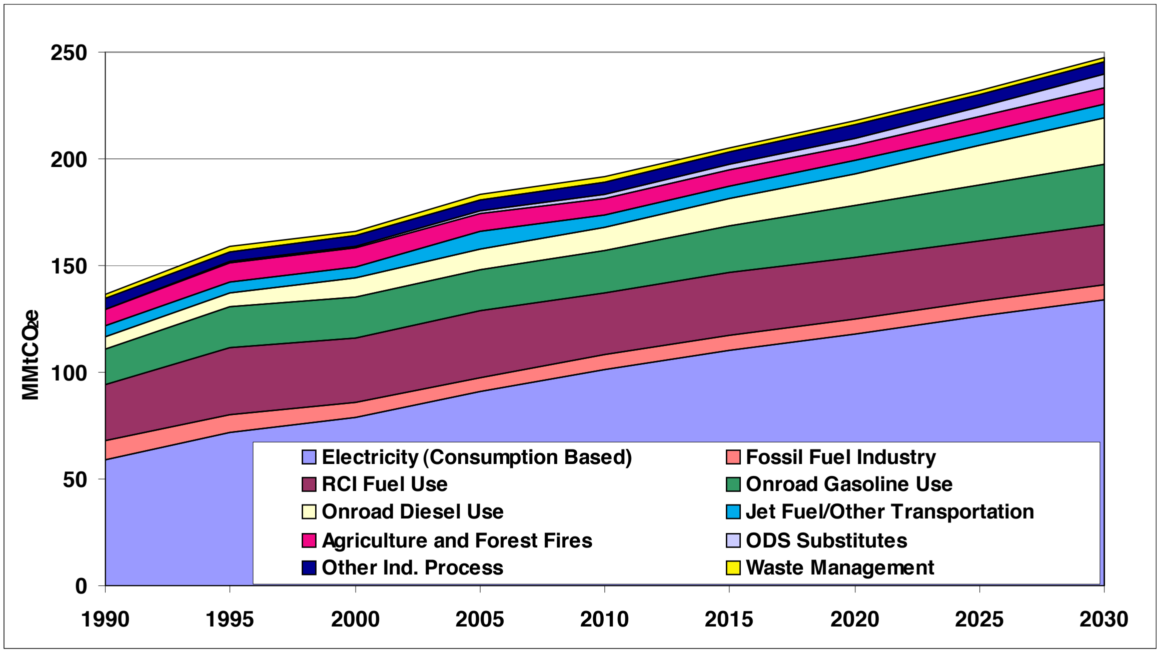
Reference Case Projections (Business as Usual)

Relying on a variety of sources for projections, as noted below and in the appendices, we developed a simple reference case projection of GHG emissions through 2030. As illustrated in Figure 3 and shown numerically in Table 1, under the reference case projections, Kentucky gross GHG emissions continue to grow steadily, climbing to about 248 $MMtCO_2e$ by 2030, 81% above 1990 levels. This equates to an annual growth rate of 1.2% per year from 2005 to 2030. Relative to 2005, the share of emissions associated with electricity consumption, transportation, and industrial processes increase to 54%, 23%, and 5%, respectively, in 2030. The share of emissions from the RCI fuel use, fossil fuel industries, waste management, and agriculture sectors all decrease by 2030, relative to 2005, to 11%, 3%, 0.8%, and 3%, respectively.

The electricity consumption sector is projected to be the largest contributor to future emissions growth, followed by emissions from transportation, ODS substitutes (HFCs), other industrial products, and the fossil fuel industry, as shown in Figure 4. Table 2 summarizes the growth rates that drive the growth in the Kentucky reference case projections as well as the sources of these data.

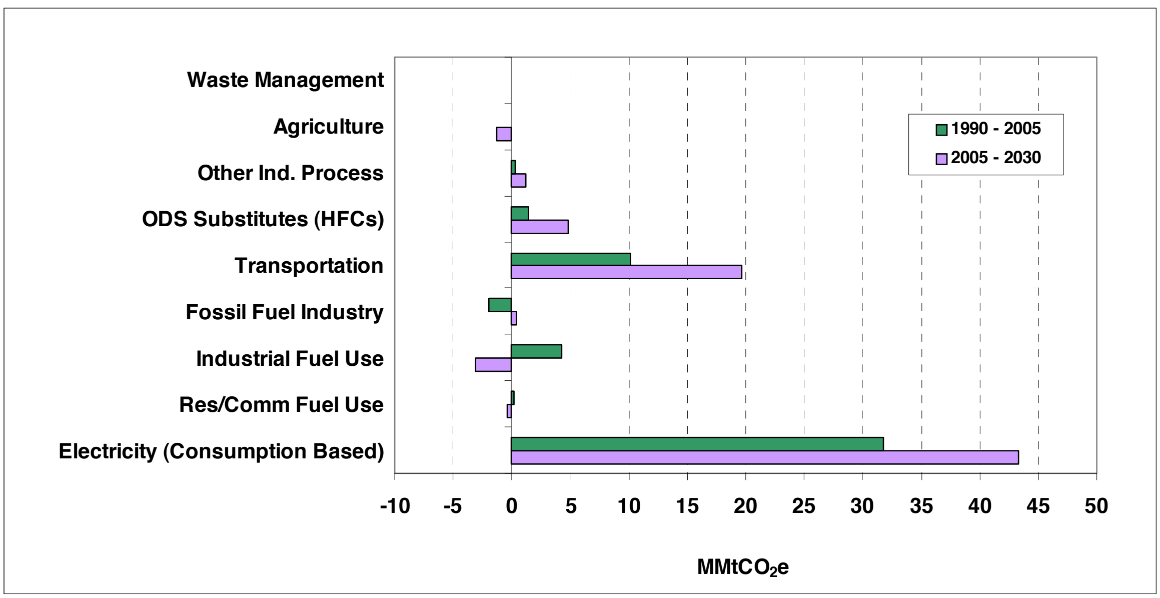
[21] The industrial sector includes emissions associated with agricultural energy use and fuel used by the fossil fuel production industry.

Figure 3. Kentucky Gross GHG Emissions by Sector, 1990-2030: Historical and Projected



RCI – direct fuel use in residential, commercial, and industrial sectors. ODS – ozone-depleting substance.

Figure 4. Sector Contributions to Gross Emissions Growth in Kentucky, 1990-2030: Historical and Reference Case Projections ($MMtCO_2e$ Basis)



Res/Comm – direct fuel use in residential and commercial sectors. ODS – ozone depleting substance. HFCs – hydrofluorocarbons. Emissions associated with other industrial processes include all of the industries identified in Appendix D except emissions associated with ODS substitutes which are shown separately in this graph because of high expected growth in emissions for ODS substitutes.

Table 2. Key Annual Growth Rates for Kentucky, Historical and Projected

	1990-2008	2008-2030	Sources
Population	0.82%	0.72%	Historical Kentucky population statistics are compiled by Kentucky State Data Center from US Census Bureau data, are available at http://ksdc.louisville.edu/kpr/popest/est.htm. Kentucky population projections through 2050 are available from the same source at http://ksdc.louisville.edu/kpr/pro/projections.htm
Electricity Sales	2.4%	1.5%	For 1990-2008, annual growth rate in total electricity sales for all sectors combined in Kentucky calculated from EIA State Electricity Profiles (Table 8) available from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls
Vehicle Miles Traveled	1.9%	2.2%	Based on historical VMT and projected VMT growth rates provided by Kentucky Transportation Cabinet

KCAPC Revisions

The following identifies the revisions that the Kentucky Climate Action Plan Council made to the inventory and reference case projections, thus explaining the differences between this report and the initial assessment completed in January 2010:

Electric Supply: There were several major changes from the initial version of the ES GHG I&F. First, the electricity sales forecast was changed from reliance on the AEO2009 to that of the most recent Kentucky utility forecasts provided to the Kentucky Public Service Commission (PSC). On average, this resulted in an increase in the electricity sales growth rate from about 0.5%/year to about 1.5%/year over the 2007 to 2030 period. Second, the amount of on-site electricity use was changed from reliance on the low levels assumed in AEO2009 to higher levels more consistent with Kentucky experience and industry standards. On average, this resulted in an increase in parasitic load from about 0.5% of total electricity production to 7% for coal stations and 2% for natural gas-fired and oil-fired power stations. Third, there were several typos in the original report denoting "imports"; these have since been corrected to "exports". Finally, the uncertainty section was revised to address the issue of KY-specific versus regional assumptions.

RCI Fuel Use: The changes discussed above for the electricity supply sector affecting the changes in the electricity sales forecast also have an impact on how the electricity emissions are allocated among the RCI sectors. This is reflected in Appendix B. In addition, a figure was added showing the breakout of RCI emissions by RCI sector and fuel type.

Transportation: KCAPC did not recommend any changes to the reference case transportation projections at this time. However, the KCAPC did recommend reviewing alternative VMT projections. In response to this request, Appendix C of this report presents the Kentucky transportation emissions under an alternative VMT growth scenario in which VMT growth follows projected population growth. Transportation emissions in this front section of the I&F report are unchanged from those reported in the draft I&F report.

Waste Sector:

- The landfill emissions were revised based on waste emplacement, flaring, and landfill-gas-to-energy data from Solid Waste Division.

- There is no controlled waste combustion in state, so default emissions for that category were removed.
- No industrial wastewater data available for key industries such as bourbon production so industrial wastewater emissions numbers remained unchanged.

Reference Case Projections with Recent Actions

The federal Energy Independence and Security Act (EISA) of 2007 was signed into law in December 2007. This federal law contains several requirements that will reduce GHG emissions as they are implemented over the next few years. During the development of the inventory and forecast, sufficient information was identified (e.g., implementation schedules) to estimate GHG emission reductions associated with implementing the Corporate Average Fuel Economy (CAFE) requirements in Kentucky. Further reductions in transportation emissions will be achieved through the Obama plan for adopting the California vehicle CO_2 emission standards nationwide.

The GHG emission reductions projected to be achieved by this recent federal action are summarized in Table 3. This table shows a total reduction of about 6.2 $MMtCO_2e$ in 2030 from the business-as-usual reference case emissions, or a 2.5% reduction from the business-as-usual emissions in 2030 for all sectors combined.

It is anticipated that the KCAPC process will result in identifying additional federal and Kentucky-specific recent actions that will be quantified throughout the KCAPC process.

The following provides a brief summary of the component of the EISA that was analyzed as a recent federal action.

Federal Corporate Average Fuel Economy Requirements: Subtitle A of Title I of EISA imposes new CAFE standards beginning with the 2011 model year vehicles. The average combined fuel economy of automobiles will be at least 35 mpg by 2020, with separate standards applying to passenger and non-passenger automobiles. The standard will be phased in, starting with the 2011 model year, so that the CAFE increases each year until the average fuel economy of 35 mpg is reached by 2020.

Table 3. Emission Reduction Estimates Associated with the Effect of Recent Actions in Kentucky (Consumption-Basis, Gross Emissions)

Sector / Recent Action	GHG Reductions (MMtCO$_2$e) 2020	GHG Reductions (MMtCO$_2$e) 2030	GHG Emissions (MMtCO$_2$e) Business as Usual 2030	GHG Emissions (MMtCO$_2$e) With Recent Actions 2030
Transportation and Land Use (TLU)				
Federal Corporate Average Fuel Economy (CAFE) Requirements plus California CO_2 Vehicle Standards	4.02	6.23	56.9	50.7
Total (All Sectors)			**247.7**	**241.5**

Key Uncertainties and Next Steps

Some data gaps exist in this inventory, and particularly in the reference case projections. Key tasks for future refinement of this inventory and forecast include review and revision of key drivers, such as the transportation, electricity demand, and RCI fuel use growth rates that will be major determinants of Kentucky's future GHG emissions (See Table 2 and Figure 4). These growth rates are driven by uncertain economic, demographic and land use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion.

Approach

The principal goal of compiling the inventories and reference case projections presented in this document is to provide the State of Kentucky with a general understanding of Kentucky's historical, current, and projected (expected) GHG emissions. The following sections explain the general methodology and the general principles and guidelines followed during development of these GHG inventories for Kentucky.

General Methodology

We prepared this analysis in consultation with Kentucky agencies, in particular, with the staff at KEEC. The overall goal of this effort is to provide simple and straightforward estimates, with an emphasis on robustness, consistency, and transparency. As a result, we rely on reference forecasts from best available State and regional sources where possible. Where reliable existing forecasts are lacking, we use straightforward spreadsheet analysis and constant growth-rate extrapolations of historical trends rather than complex modeling.

In most cases, we follow the same approach to emissions accounting for historical inventories used by the US EPA in its national GHG emissions inventory[22] and its guidelines for States.[23]

[22] *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2006*, April 15, 2008, US EPA #430-R-08-005, (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

[23] http://yosemite.epa.gov/oar/globalwarming.nsf/content/EmissionsStateInventoryGuidance.html.

These inventory guidelines were developed based on the guidelines from the IPCC, the international organization responsible for developing coordinated methods for national GHG inventories.[24] The inventory methods provide flexibility to account for local conditions. The key sources of activity and projection data used are shown in Table 4. Table 4 also provides the descriptions of the data provided by each source and the uses of each data set in this analysis.

General Principles and Guidelines

A key part of this effort involves the establishment and use of a set of generally accepted accounting principles for evaluation of historical and projected GHG emissions, as follows:

- **Transparency:** We report data sources, methods, and key assumptions to allow open review and opportunities for additional revisions later based on input from others. In addition, we report key uncertainties where they exist.

- **Consistency:** To the extent possible, the inventory and projections were designed to be externally consistent with current or likely future systems for State and national GHG emission reporting. We have used the EPA tools for State inventories and projections as a starting point. These initial estimates were then augmented and/or revised as needed to conform with State-based inventory and base-case projection needs. For consistency in making reference case projections, we define reference case actions for the purposes of projections as those *currently in place or reasonably expected over the time period of analysis*.

- **Priority of Existing State and Local Data Sources:** In gathering data and in cases where data sources conflicted, we placed highest priority on local and State data and analyses, followed by regional sources, with national data or simplified assumptions such as constant linear extrapolation of trends used as defaults where necessary.

- **Priority of Significant Emissions Sources:** In general, activities with relatively small emissions levels may not be reported with the same level of detail as other activities.

- **Comprehensive Coverage of Gases, Sectors, State Activities, and Time Periods:** This analysis aims to comprehensively cover GHG emissions associated with activities in Kentucky. It covers all six GHGs covered by US and other national inventories: CO_2, CH_4, N_2O, SF_6, HFCs, and PFCs. The inventory estimates are for the year 1990, with subsequent years included up to most recently available data (typically 2007), with projections to 2010, 2015, 2020, 2025, and 2030.

- **Use of Consumption-Based Emissions Estimates:** To the extent possible, we estimated emissions that are caused by activities that occur in Kentucky. For example, we reported emissions associated with the electricity consumed in Kentucky. The rationale for this method of reporting is that it can more accurately reflect the impact of State-based policy strategies such as energy efficiency on overall GHG emissions, and it resolves double-counting and exclusion problems with multi-emissions issues. This approach can differ

[24] http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm.

from how inventories are compiled, for example, on an in-state production basis, in particular for electricity.

For electricity, we estimate, in addition to the emissions due to fuels combusted at electricity plants in the State, the emissions related to electricity *consumed* in Kentucky. This entails accounting for the electricity sources used by Kentucky utilities to meet consumer demands. As this analysis is refined in the future, one could also attempt to estimate other sectoral emissions on a consumption basis, such as accounting for emissions from transportation fuel used in Kentucky, but purchased out-of-state. In some cases, this can require venturing into the relatively complex terrain of life-cycle analysis. In general, we recommend considering a consumption-based approach where it will significantly improve the estimation of the emissions impact of potential mitigation strategies. For example re-use, recycling, and source reduction can lead to emission reductions resulting from lower energy requirements for material production (such as paper, cardboard, and aluminum), even though production of those materials, and emissions associated with materials production, may not occur within the State.

Table 4. Key Sources for Kentucky Data, Inventory Methods, and Growth Rates

Source	Information provided	Use of Information in this Analysis
US EPA State Greenhouse Gas Inventory Tool (SIT)	US EPA SIT is a collection of linked spreadsheets designed to help users develop State GHG inventories. US EPA SIT contains default data for each State for most of the information required for an inventory for years from 1990 to 2007. The SIT methods are based on the methods provided in the Volume VIII document series published by the Emissions Inventory Improvement Program (http://www.epa.gov/ttn/chief/eiip/techreport/volume08/index.html).	Where not indicated otherwise, SIT is used to calculate emissions for 1990-2007 from RCI fuel combustion, transportation, industrial processes, agriculture and forestry, and waste. We use SIT emission factors (CO_2, CH_4, and N_2O per British thermal unit (Btu) consumed) to calculate energy use emissions.
US DOE Energy Information Administration (EIA) State Energy Data (SED)	EIA SED provides energy use data in each State, annually to 2007 for all RCI sectors and fuels	EIA SED is the source for most energy use data. Emission factors from US EPA SIT are used to calculate energy-related emissions.
EIA State Annual Electric Utility Data — EIA 906/920 Database	EIA provides information on the electric power industry generation by primary energy source for 1990 – 2007.	EIA 906/920 Database was used to determine the mix of in-state electricity generation by fuel. Electricity sales were projected off of 2007 sales provided in this reference.
EIA State Electricity Profiles	EIA provides information on electric power industry capability, generation, retail sales, and average retail price for 1990 through 2007 in this database.	Kentucky Electricity Profiles were used to determine the total electricity sales by sector for 1990-2007.
EIA AEO2009	EIA AEO2009 projects energy supply and demand for the US from 2006 to 2030. Energy production and consumption are estimated on a regional basis.	EIA AEO2009 is used to project electricity generation by fuel and changes in fuel use by the RCI sectors.
Kentucky Transportation Cabinet	Growth rates for projected vehicle miles traveled (VMT).	The growth rates were used to project onroad VMT.

Source	Information provided	Use of Information in this Analysis
US Department of Transportation (DOT), Office of Pipeline Safety (OPS)	Natural gas transmission pipeline mileage, distribution pipeline mileage, and number of services for 1990–2007.	OPS data entered into SIT to calculate historical emissions. Transmission and distribution pipeline emissions projected based on analysis of historical data.
EIA Natural Gas Navigator	EIA provides the number of gas and gas condensate wells and amount of gas flared and vented in Kentucky for 1990-2007.	Natural Gas Navigator data entered into SIT to calculate historical emissions. Gas well emissions and gas flaring emissions projected based on analysis of historical data.
PennWell Corporation Oil and Gas Journal	PennWell reports the number of gas processing plants in Kentucky for 1990-2007.	PennWell data entered into SIT to calculate historical emissions. Emissions projected based on analysis of historical data.
EIA Petroleum Navigator	Volume of crude oil production in Kentucky, regional crude oil input, regional refining capacity, and Kentucky's refining capacity for 1990-2007	EIA data entered into SIT to calculate historical emissions. Oil production emissions and oil refining emissions projected based on analysis of historical data.
US Forest Service	Data on forest carbon stocks for multiple years.	Data are used to calculate CO_2 flux over time (terrestrial CO_2 sequestration in forested areas).
USDS National Agricultural Statistics Service (NASS)	USDA NASS provides data on crops and livestock.	Crop production data used in SIT to estimate agricultural residue and agricultural soils emissions; livestock population data used in SIT to estimate manure and enteric fermentation emissions.

Details on the methods and data sources used to construct the inventories and forecasts for each source sector are provided in the following appendices:

- Appendix A. Electricity Use and Supply
- Appendix B. Residential, Commercial, and Industrial (RCI) Fuel Combustion
- Appendix C. Transportation Energy Use
- Appendix D. Industrial Processes
- Appendix E. Fossil Fuel Extraction and Distribution Industry
- Appendix F. Agriculture
- Appendix G. Waste Management
- Appendix H. Forestry

Appendix I provides additional background information from the US EPA on GHGs and global warming potential values.

Appendix A. Electricity Supply and Use

Overview

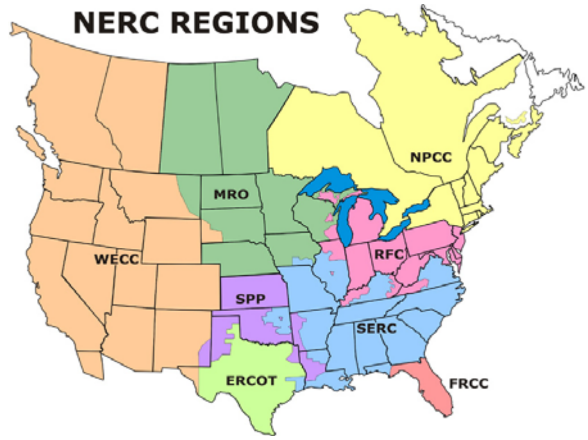
This appendix describes the data sources, key assumptions, and the methodology used to develop an inventory of greenhouse gas (GHG) emissions over the 1990-2007 period associated with the generation of electricity to meet electricity demand in Kentucky. It also describes the data sources, key assumptions, and methodology used to develop a reference case projection (forecast) of GHG emissions from the Base Year of 2007 over the 2008-2030 period associated with meeting electricity demand in the state. Specifically, the following topics are covered in this Appendix:

- *Data Sources:* This section provides an overview of the data sources that were used to develop the inventory and forecast, including publicly accessible websites where this information can be obtained and verified.
- *Greenhouse Gas Inventory methodology:* This section provides an overview of the methodological approach used to develop the Kentucky GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Methodology – Reference Case:* This section provides an overview of the methodological approach used to develop the Kentucky GHG forecast for the electric supply sector.
- *Greenhouse Gas Inventory Results:* This section provides an overview of key results of the Kentucky GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Results:* This section provides an overview of key results of the Kentucky GHG forecast for the electric supply sector.

Data Sources

We considered several sources of information in the development of the inventory and forecast of carbon dioxide equivalent (CO_2e) emissions from Kentucky power plants. These are briefly summarized below:

- *2007 EIA-906/920 Monthly Time Series Data*. This is a database file available from the Energy Information Administration (EIA) of the United States (US) Department of Energy (DOE). The information in the database is based on information collected from utilities in Forms EIA-906/920 and EIA-860 for the forecast Base Year of 2007. Data were extracted for Kentucky. Data from these forms provide, among other things, fuel consumption and net generation in power stations located in Kentucky for 2007 by plant type. This information can be accessed from http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html.
- *Annual Energy Outlook 2009*. This is an output of an EIA analysis using the National Energy Modeling System (NEMS), a model that forecasts electric expansion/electricity demand in the US. In particular, regional outputs for the East Central Area Reliability Coordination Agreement (ECAR) region and the Southeastern Reliability Council (SERC) region were used (see map). For the purposes of the analysis, 75% of the state was assumed to be within SERC and the balance within ECAR. The ECAR and SERC results include forecasts of transmission and distribution losses through the year 2030. This information is available in



supplemental tables that can be accessed directly from http://www.eia.doe.gov/oiaf/aeo/supplement/index.html. The source of the map is http://www.epis.com/EnergyLinks/Reliability%20Regions/reliability_regions.htm.

- *Monthly Cost and Quality of Fuels for Electric Plants*. This information is available from the Federal Energy Regulatory Commission (FERC). The database relies on information collected from utilities in the FERC-423 form. It was used to determine the share of coal type (i.e., whether bituminous or sub-bituminous) as well as the coal quantity consumed in Kentucky power plants over the period 1990-2007. It was also used to determine the share of oil type (i.e., whether fuel oil #2, #4, #5, or #6) as well as the oil quantity consumed in Kentucky power plants over the period 1990-2007. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/page/ferc423.html.
- *State Electricity Profiles*. This information is available from the EIA. The database compiles capacity, net generation, and total retail electricity sales by state. It was used to cross check other data sources regarding Base Year levels for sales, generation, and primary energy use. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html.
- *State electricity sales data*. This information is available from the EIA. The database compiles total retail electricity sales by state. It was used to determine total sales of electricity across all sectors for the period 1990 through the Base Year of 2007. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls.
- *State electricity generation data*. This information is available from the EIA. The database compiles total net electricity generation by state. It was used to determine total net generation of electricity across all fuel types for the period 1990 through the Base Year of 2007. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/epa/generation_state.xls.
- *State primary energy use for electricity generation data*. This information is available from the EIA. The database compiles total primary energy consumption by state. It was used to determine total primary energy use across all fuel types for the period 1990 through the Base Year of 2007. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/epa/consumption_state.xls.
- *State combined heat and power (CHP) production characteristics*. This information is available from the EIA. The database compiles primary energy consumption by state for combined heat and power facilities, both commercial and industrial. It was used to determine total shares of energy use between commercial and industrial applications across all fuel types for the period 1990 through the Base Year of 2007. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html.
- *State renewable energy data*. This information is available from the EIA. The database compiles net generation by state for all types of renewable energy. Where 'other wastes' were

noted in the EIA data tables, they are assumed to be biomass wastes (e.g., switchgrass, agricultural wastes, paper pellets). It was used to determine total shares of energy use between commercial and industrial applications across all fuel types for the period 1990 through the Base Year of 2007. It can be accessed directly from http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html

- *Energy conversion factors*. This is based on Table A-31 of Appendix 2 in the USEPA's 2009 GHG Inventory for the US. The table is entitled "Key assumptions for estimating CO2 emissions". This information can be accessed directly from the following website: http://www.epa.gov/climatechange/emissions/downloads09/Annex2.pdf.
- *Fuel combustion oxidation factors*. This is based on the IPCC's assumed default values. This information can be accessed directly from: http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1wb1.pdf.
- *Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emission factors*. For all fuels except Municipal Solid Waste (MSW), these emission factors are based on Appendix A of the USEPA's 2003 GHG inventory for the US. For MSW, emission factors are based on the EIA's Office of Integrated Analysis and Forecasting, Voluntary Reporting of Greenhouse Gases Program, Table of Fuel and Energy Source: Codes and Emission Coefficients. This information can be accessed directly from http://www.eia.doe.gov/oiaf/1605/coefficients.html.
- *Global warming potentials*. These are based on values proposed by the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report. This information can be accessed directly from http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm.

Greenhouse Gas Inventory Methodology

The GHG inventory period was considered to be 1990-2007. The methodology used to develop the Kentucky inventory of GHG emissions associated with electricity production and consumption is based on methods developed by the IPCC and used by the USEPA in the development of the US GHG inventory. It involved applying GHG emission factors to annual fuel consumed in KY for the production of electricity at utility/non-utility and combined heat and power facilities.

The GHG inventory was estimated on both a production and consumption basis. The production estimate involved tallying up the GHG emissions associated with the operation of power plants physically located in Kentucky, regardless of ownership. The consumption estimate involved tallying up the GHG emissions associated with consumption of electricity in Kentucky, regardless of where the electricity was produced.

Also, the GHG inventory was estimated based on emissions at the point of electric generation only. That is, GHG emissions associated with the upstream fuel cycle process such as primary fuel extraction, transport to refinery/processing stations, refining, beneficiation, and transport to the power station are not included as these are accounted for in other parts of the overall state GHG inventory.

The assumptions and calculation process is briefly summarized below in the bullets below. Key Outputs for the 2007 Base Year are summarized in Table A1 and Figure A1.

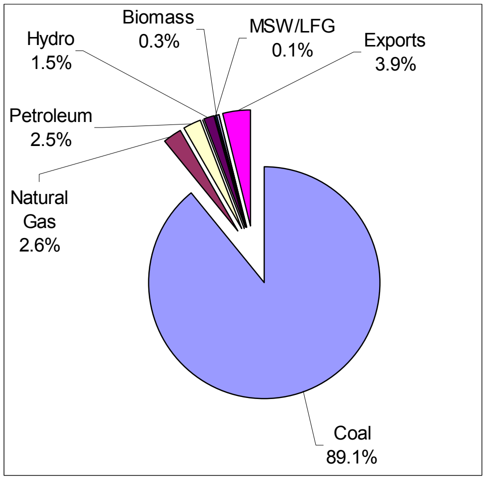
- Determine gross annual primary energy consumption by Kentucky power and CHP stations by plant and fuel type. For coal, this involved determining the coal quality shares (i.e., share of bituminous or sub-bituminous); for oil, this involved determining the oil quality shares (i.e., share of fuel oil #2, #4, #5, and #6 used).
- Determine gross annual generation associated with net power exports. This is the amount of electric generation associated with out-of-state demand.
- Multiply gross annual primary energy consumption by Kentucky power and CHP stations by the appropriate CO_2e emission factors. This provides an estimate of Kentucky GHG inventory on a production basis.
- Multiply annual gross generation associated with net power exports by the weighted average carbon emission intensity (in units of metric tons of CO_2e per megawatt-hour [tCO_2e/MWh]) of the KY power supply sector. This provides an estimate of GHG emissions produced in-state but associated with out-of-state electricity demand.
- Subtract the emissions associated with net power exports from the production-based emissions. This provides an estimate of the GHG inventory on a consumption basis.

Table A1. Summary of Kentucky Electric Generator Characteristics for the 2007 Base Year (utilities and non-utilities only)

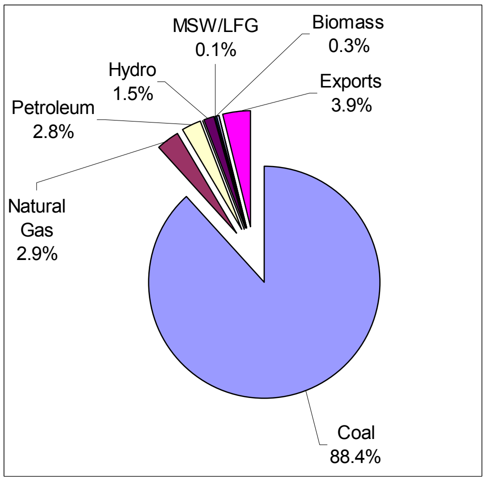
Fuel	Gross Generation (GWh)	Net Generation (GWh)	Fuel use (Trillion Btu)	Heat rate (Btu/KWh)	Emissions ($MtCO_2e$)
Coal	97,294	90,483	973	9,998	90.38
Natural Gas	1,632	1,600	20	12,190	1.07
Other Gases	5	5	0	NA	0.00
Petroleum	2,848	2,791	32	11,382	2.36
Nuclear	0	0	0	NA	0.00
Hydroelectric	1,669	1,669	17	10,320	0.00
Geothermal	0	0	0	NA	0.00
Solar/PV	0	0	0	NA	0.00
Wind	0	0	0	NA	0.00
MSW Landfill gas	93	93	1	10,500	0.05
Biomass	0	0	0	NA	0.00
Other wastes	16	16	0	10,500	0.01
Pumped storage	0	0	0	NA	0.00
Exports	4,220	3,939	43	10,076	3.83
Imports	0	0	0	NA	0
Total (production-based)	***103,557***	***96,656***	***1,043***		***93.86***
Total (consumption-based)	***99,336***	***92,718***	***1,001***		***90.04***

Figure A1. Total KY Generation, energy and CO_2e emissions (electric generators and CHP) – 2007 Base Year

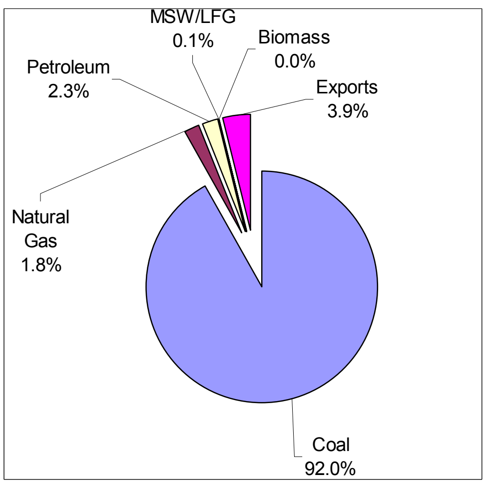
a. Gross Generation (109,740 GWh)



b. Primary Energy (1,115 Trillion Btu)



c. Emissions (99.60 MMtCO2e)



Greenhouse Gas Forecast Methodology – Reference Case

The GHG forecast period was considered to be 2007 – 2030, with 2007 as the historical Base Year. Ideally, constructing a GHG forecast should be based on detailed system planning information for KY over the entire planning period, including information such as projected sales, gross in-state generation, supply-side efficiency improvements, planned capacity additions and retirements by plant type/vintage, and changes over time regarding losses associated with on-site use and transmission and distribution (T&D).

While some of this information was available in Kentucky, some key data were not available at the time the forecast was prepared. Therefore, it was necessary to use the data that was available and pose working assumptions for data that was unavailable. For the period 2008 through and including 2030, these assumptions, together with the methodological steps used for forecasting CO_2e emissions, are described below. Key Outputs are summarized in Table A2.

Total electricity sales. Growth rates were based on the Total Energy Forecast for PSC Regulated Electric G&T Utilities as obtained from the KY PSC and were assumed as outlined below:

- 2008 – 2012: 2.62%/year
- 2012 – 2016: 1.13%/year
- 2016 – 2020: 1.32%/year
- 2020 – 2024: 1.32%/year
- 2024 – 2028: 1.30%/year
- 2028 – 2030: 1.45%/year

Coal quality. It was assumed that the coal quality used in Kentucky power stations (i.e., share of anthracite, bituminous, lignite, sub-bituminous, and coal wastes used) was the same as the Base Year.

Gross generation. Gross generation was calculated using the following assumptions:

- The growth rate for gross generation on a production basis (i.e., net generation plus on-site electricity use for all in-state units) was assumed to grow at the same rate as in-state sales.
- The resource mix remained the same in all forecast years as in the Base Year.
- Transmission and distribution (T&D) losses (in %) were assumed to be equal to the SERC/ECAR average as reported in AEO2009.
- Gross generation on a consumption basis was calculated on a pro rata basis after accounting for T&D losses and plant-specific on-site losses.
- Gross generation associated with exports was calculated as the difference between the production and consumption estimates.

Combustion efficiency. Improvements of fuel-specific heat rates were assumed to be consistent with trends in the SERC/ECAR average as reported in AEO2009.

Primary energy use. Primary energy use was calculated using the following assumptions:

- Primary energy use by fuel type was calculated as the product of fuel-specific gross generation and fuel-specific heat rate.

- The production-based estimate of primary energy use was calculated as the sum of the fuel-specific calculations above
- The consumption-based estimate of primary energy use was calculated by multiplying the system heat rate by estimate of consumption-based gross generation.
- The primary energy use associated with exports was calculated as the difference between the production and consumption based estimates.

Carbon dioxide-equivalent emissions. Total emissions of CO2, CH4, and N2O were calculated using the following assumptions:

- Global warming potentials of 1, 21, and 310 were applied to CO2, CH4, and N2O, respectively, in order to calculate CO2e emissions.
- Oxidation factors of 0.99, 0.995, and 0.99 were applied to coal, natural gas, and oil, respectively, in order to calculate CO2e emissions.
- Production-based CO2e emissions by fuel type were calculated as the product of fuel-specific primary energy and fuel-specific GHG emission factors.
- Consumption-based CO2e emissions were calculated as the product of system CO2e intensity (i.e., tCO2e/MWh) and the consumption-based estimate of gross generation.
- The CO2e emissions associated with exports was calculated as the difference between the production and consumption based estimates.

Table A2. Summary of Kentucky Electric Generator Characteristics for the 2007 Base Year (utilities, non-utilities, and CHP)

Key Assumptions	2007	2030	Average Annual Growth / Change (%)
Kentucky retail electricity demand (GWh)	92,404	130,526	1.51%
Gross generation from Kentucky power stations and CHP facilities (GWh)	109,740	155,014	1.51%
to meet Kentucky retail electricity demand	105,268	148,696	1.51%
exported to ECAR/SERC regions	4,472	6,317	1.51%
Transmission and Distribution (T&D) Losses (%)	4.5%	5.0%	0.42%

Results

The following subsections provide an overview of the results of the GHG emissions inventory and reference case projections estimated using the assumptions and methodological approach described above.

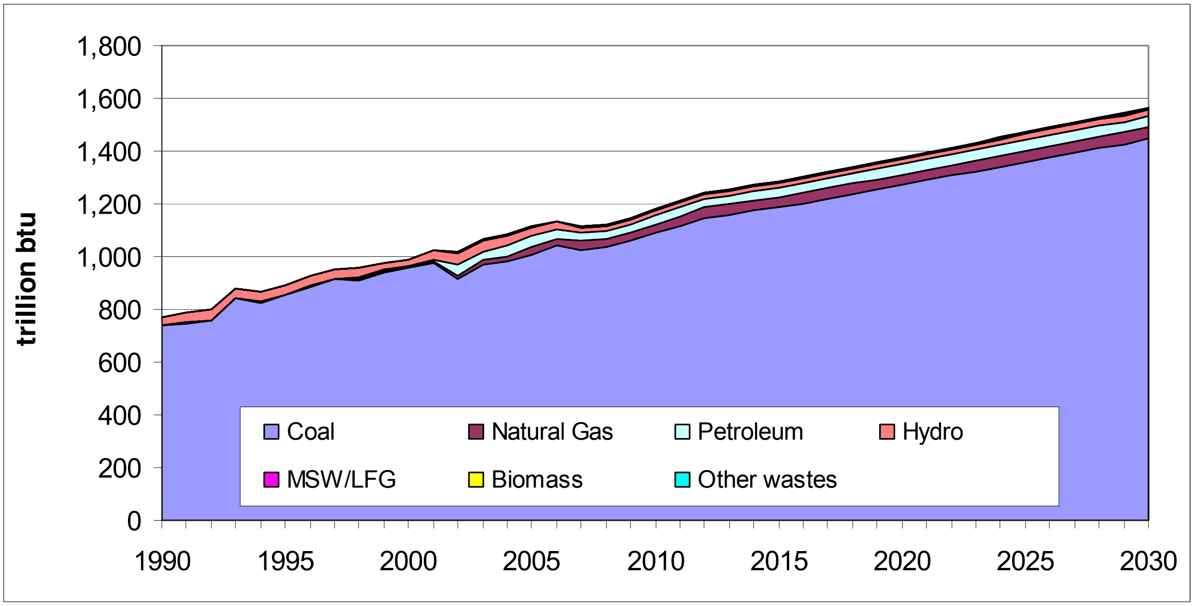
Primary Energy Consumption

Total primary energy consumption associated with electricity generation in Kentucky is summarized in Figure A2. Primary energy consumption in Kentucky is dominated by coal resources.

Gross Generation

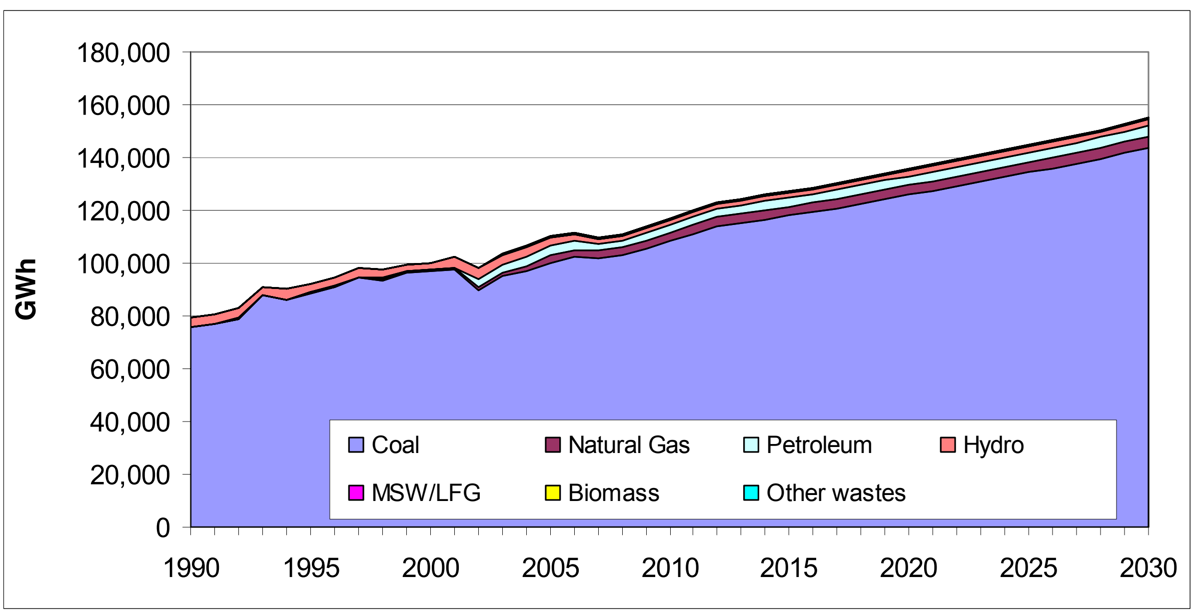
Total gross generation by Kentucky power plants and CHP facilities is summarized in Figure A3. Gross generation in Kentucky is dominated by steam units using coal. The composition of electric generation to meet local demand and for export is summarized in Figure A4.

Figure A2. Total Gross Primary Energy Use



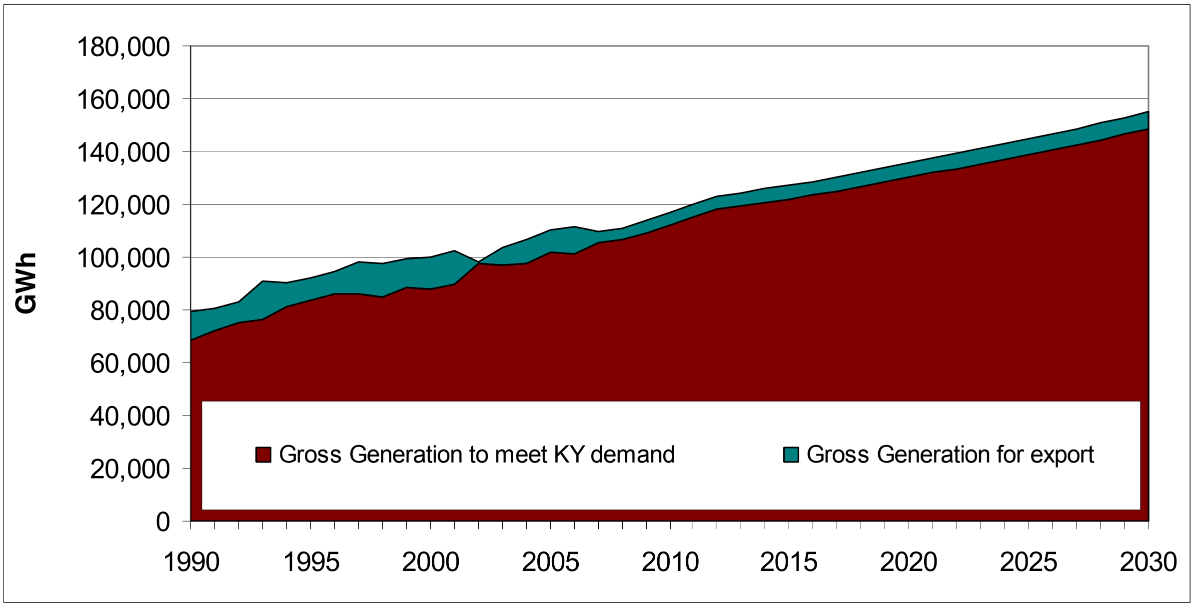
Source: Results in table based on approach described in text.

Figure A3. Total Gross Generation



Source: Results in table based on approach described in text.

Figure A4. Composition of Gross Generation to Meet Kentucky's Electricity Demand

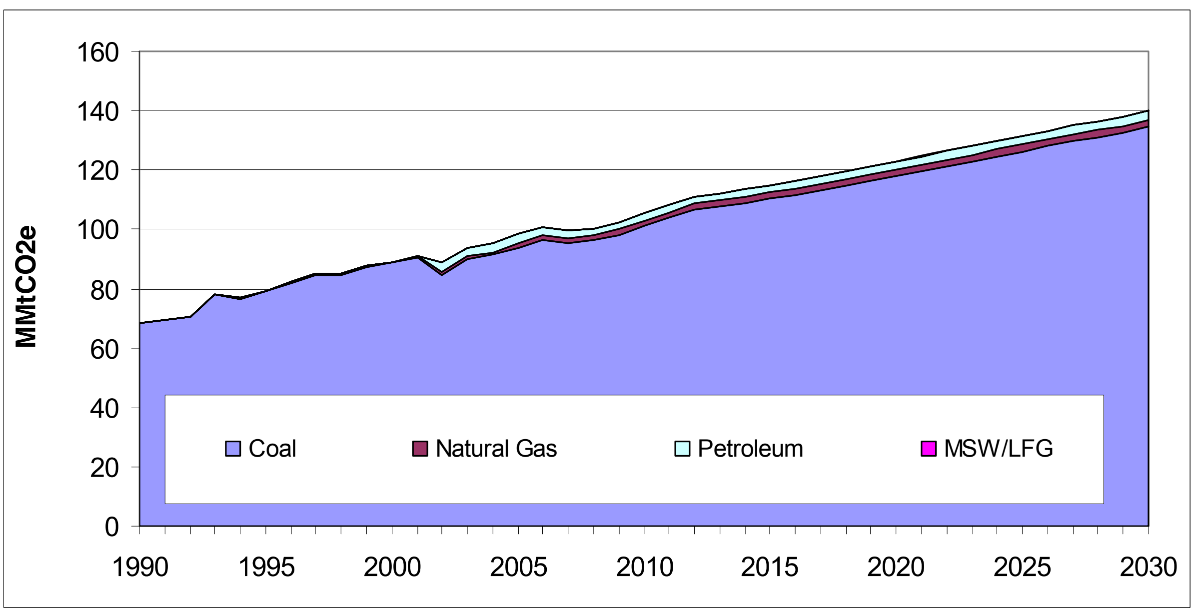


Source: Results in table based on approach described in text.

Total Gross GHG Emissions

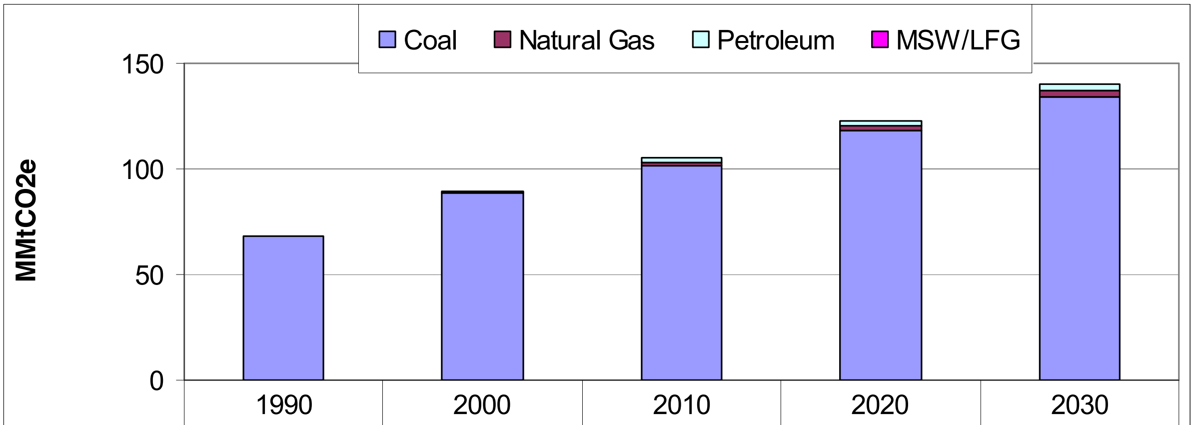
Total emissions associated with generation by Kentucky power plants are summarized in Figures A5 and A6 by fuel (production basis). On a production basis, emissions were about 99.6 $MMtCO_2e$ in 2007 and are projected to increase to about 140.0 $MMtCO_2e$ in 2030, representing an overall increase of about 41% during this 23-year period.

Figure A5. Total Gross GHG Emissions Associated with Kentucky Electricity Production by Fuel Type, all years



Source: Results in table based on approach described in text.

Figure A6. Total Gross GHG Emissions Associated with Kentucky Electricity Production by Fuel Type, every 10 years



	1990	2000	2010	2020	2030
MSW/LFG	0	0	0	0	0
Petroleum	0	0	2	3	3
Natural Gas	0	0	2	2	2
Coal	68	89	101	118	134

Source: Results in table based on approach described in text.

Key Uncertainties

Key sources of uncertainty underlying the estimates above are as follows:

- For the inventory period, 1990-2007, the data used in this initial preliminary analysis are based on state-specific, well-vetted historical data. The uncertainty associated with these reported values is considered to be low.
- For the forecast period, 2007-2030:
  - ✓ *Sales:* The forecast relies on the most recent KY sales forecast assembled by the KY PSC on the basis of utility Integrated Resource Plans. The uncertainty associated with these reported values is considered to be acceptable.
  - ✓ *Other:* Annual values in the forecast rely on simplifying assumptions regarding fuel mix, level of exports, on-site electricity use, transmission and distribution losses, and improvements in combustion efficiency. The uncertainty associated with these assumed values is considered to be high.

Appendix B. Residential, Commercial, and Industrial (RCI) Fuel Combustion

Overview

Activities in the RCI[25] sectors produce carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) emissions when fuels are combusted to provide space heating, water heating, process heating, cooking, and other energy end-uses. Carbon dioxide accounts for over 99% of these emissions on a million metric tons (MMt) of CO_2 equivalent (CO_2e) basis in Kentucky. In addition, since these sectors consume electricity, one can also attribute emissions associated with electricity generation to these sectors in proportion to their electricity use.[26] Direct use of oil, natural gas, coal, and wood in the RCI sectors accounted for an estimated 31 MMtCO_2e of gross greenhouse gas (GHG) emissions in 2005.[27]

Emissions and Reference Case Projections

Emissions from direct fuel use were estimated using the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SIT) software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for RCI fossil and wood fuel combustion.[28] The default data used in SIT for Kentucky are from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) *State Energy Data* (SED). SIT information goes through 2007, after which emissions need to be forecasted.

Note that the EIIP methods for the industrial sector exclude from CO_2 emission estimates the amount of carbon that is stored in products produced from fossil fuels for non-energy uses. For example, the methods account for carbon stored in petrochemical feedstocks, and in liquefied petroleum gases (LPG) and natural gas used as feedstocks by chemical manufacturing plants (i.e., not used as fuel), as well as carbon stored in asphalt and road oil produced from petroleum. The carbon storage assumptions for these products are explained in detail in the EIIP guidance

[25] The industrial sector includes emissions associated with agricultural energy use and fuel used by natural gas transmission and distribution (T&D) and oil and gas production industries.

[26] Emissions associated with the electricity supply sector (presented in Appendix A) have been allocated to each of the RCI sectors for comparison of those emissions to the fuel-consumption-based emissions presented in Appendix B. Note that this comparison is provided for information purposes and that emissions estimated for the electricity supply sector are not double-counted in the total emissions for the state. One could similarly allocate GHG emissions from natural gas T&D, other fuels production, and transport-related GHG sources to the RCI sectors based on their direct use of gas and other fuels, but we have not done so here due to the difficulty of ascribing these emissions to particular end-users. Estimates of emissions associated with the transportation sector are provided in Appendix C, and estimates of emissions associated with natural gas T&D are provided in Appendix E.

[27] Emissions estimates from wood combustion include only N_2O and CH_4. Carbon dioxide emissions from biomass combustion are assumed to be "net zero", consistent with US EPA and Intergovernmental Panel on Climate Change (IPCC) methodologies, and any net loss of carbon stocks due to biomass fuel use should be accounted for in the land use and forestry analysis.

[28] GHG emissions were calculated using SIT, with reference to *EIIP, Volume VIII*: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", August 2004, and Chapter 2 "Methods for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion", August 2004.

document.[29] The fossil fuel types for which the EIIP methods are applied in the SIT software to account for carbon storage include the following categories: asphalt and road oil, coking coal, distillate fuel, feedstocks (naphtha with a boiling range of less than 401 degrees Fahrenheit), feedstocks (other oils with boiling ranges greater than 401 degrees Fahrenheit), LPG, lubricants, miscellaneous petroleum products, natural gas, pentanes plus,[30] petroleum coke, residual fuel, still gas, and waxes. Data on annual consumption of the fuels in these categories as chemical industry feedstocks were obtained from the EIA SED.

Table B1 shows historic and projected growth rates for electricity sales by sector. For 2008 to 2030, the annual growth rate in the electricity sales for all of the RCI sectors combined is estimated to be 1.5%. Data provided by the Kentucky Public Service Commission (PSC) included electricity sale growth rates for overall electricity sales in the state associated with major regulated utilities. These growth rates were assumed to be representative of overall sales for all electricity production facilities. However, electricity sale growth rates associated with the residential, commercial, and industrial sectors were not available and have been estimated based on the approach described below.

Table B1. Electricity Sales Annual Growth Rates, Historical and Projected

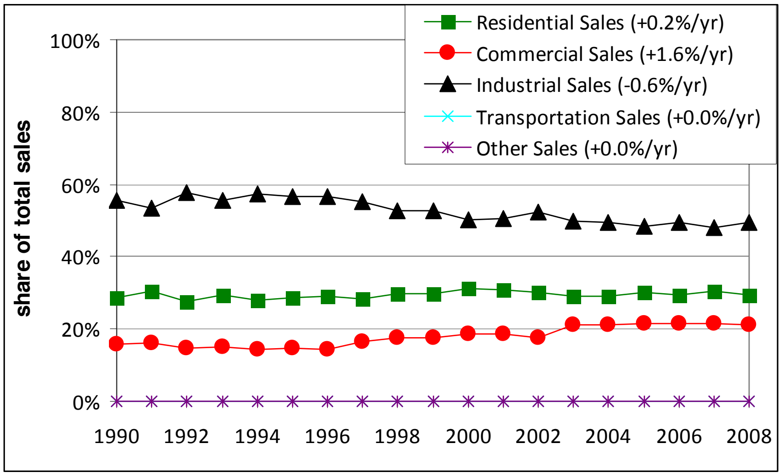
Sector	**1990-2008***	**2008-2030**
Residential	2.8%	1.5%
Commercial	2.9%	3.0%
Industrial	2.0%	0.7%
Total	**2.4%**	**1.5%**

* 1990-2007 compound annual growth rates calculated from Kentucky electricity sales by year from EIA state electricity profiles (Table 8), http://www.eia.doe.gov/cneaf/electricity/st_profiles/e_profiles_sum.html.

A comparison was first made of the sector electricity sale shares for the period 1990-2008 to discern any obvious trends that could be useful is projecting sectoral sales. This comparison is summarized in Figure B1 and shows that noticeable trends are evident. For example, over the 1990-2008 historical period, the share of residential sales has been growing at a rate of 0.2%/year while the share of industrial sales has been declining at a rate of 0.6%/year. To account for the fact that the "Other sales" category has been assimilated into the other sectors from 2003 onward, an adjustment was made in which its share was assimilated pro-rata into the other sectors on a pro-rata basis for the period 1990-2003.

[29] EIIP, Volume VIII: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", August 2004.
[30] A mixture of hydrocarbons, mostly pentanes and heavier fractions, extracted from natural gas.

Figure B1. **Summary of Sectoral Share Trends of Electricity Sales in Kentucky**



For the purposes of developing an initial projection of sectoral electricity sales in Kentucky, it was assumed that the trends in sectoral electricity sales would continue over the 2009-2030 period in a manner similar to the 1990-2008 period. Table B2 summarizes the projected shares in 2008 and 2030 after normalizing to 100%. Intervening year shares were estimated by linear interpolation.

Table B2. **Summary of Assumptions for Sectoral Shares of Electricity Sales in Kentucky**

	Electricity Sale Shares	
Sector	**2008**	**2030**
Residential Sales	29.5%	29.5%
Commercial Sales	21.1%	29.0%
Industrial Sales	49.4%	41.5%
Transportation Sales	0.0%	0.0%
Other Sales	0.0%	0.0%
All Sector Sales	100.0%	100.0%

Once sectoral shares were estimated for each demand sector for each year in the forecast period, these shares were multiplied by the projected total sales that had been previously calculated by use of the Kentucky PSC's overall electricity sale growth rates. A summary of the projected sectoral sales is summarized in Table B3 for 2008 and 2030, together with average annual growth rates over the 2008-2030 period. It is important to note that these sectoral electricity sale estimates have high uncertainty bounds and should be reviewed and vetted by the RCI TWG before they are used in any analysis of GHG mitigation options for RCI sectors.

Table B3. **Summary of Projected Sectoral Electricity Sales in Kentucky, 2008–2030**

Sector	Electricity sales (GWh) 2008	Electricity sales (GWh) 2030	Average annual growth rate (%/yr)
Residential Sales	27,562	38,545	1.54%
Commercial Sales	19,669	37,793	3.01%
Industrial Sales	46,198	54,188	0.73%
Transportation Sales	0	0	0.00%
Other Sales	0	0	0.00%
All Sector Sales	93,429	130,526	1.53%

Table B4 shows historical and projected growth rates for energy use by sector and fuel type. Reference case emissions from direct fuel combustion were estimated based on fuel consumption forecasts from EIA's *Annual Energy Outlook 2009* (AEO2009).[31] For the RCI sectors, annual growth rates for natural gas, oil, wood, and coal were calculated from the AEO2009 regional forecast that EIA prepared for the East South Central modeling region. For the residential sector, the AEO2009 annual growth rate in fuel consumption from 2007 through 2030 was normalized using the AEO2009 population forecast and then weighted using Kentucky's population forecast over this period. Kentucky's rate of population growth is expected to average about 0.73% annually between 2007 and 2030.[32] Growth rates for the commercial and industrial sectors were based on the AEO2009 East South Central regional estimates of growth in fuel consumption which reflect expected responses of the economy — as simulated by the EIA's National Energy Modeling System — to changing fuel and electricity prices and changing technologies, as well as to structural changes within each sector (such as shifts in subsectoral shares and in energy use patterns).

[31] EIA AEO2009 with Projections to 2030 (http://www.eia.doe.gov/oiaf/archive.html#aeo).
[32] Population data for historical years (1990-2008) is from http://ksdc.louisville.edu/kpr/popest/est.htm . Kentucky population projections (2009-2030) are from "Projections of Total Population" (http://ksdc.louisville.edu/kpr/pro/projections.htm).

Table B4. Historical and Projected Average Annual Growth in Energy Use in Kentucky, by Sector and Fuel, 1990-2030

	1990-2007[a]	2007-2010[b]	2010-2015[b]	2015-2020[b]	2020-2025[b]	2025-2030[b]
Residential						
petroleum	-1.9%	1.9%	-1.6%	0.4%	0.6%	0.4%
natural gas	-0.6%	6.5%	-0.4%	0.4%	0.3%	0.0%
coal	-5.3%	2.9%	-1.7%	-0.5%	-0.6%	-0.5%
wood	-3.5%	2.0%	0.6%	1.5%	0.5%	0.6%
Commercial						
petroleum	-2.6%	-1.5%	-0.3%	0.3%	0.7%	0.6%
natural gas	0.4%	2.9%	-0.2%	0.1%	0.4%	0.3%
coal	-0.6%	-0.5%	0.0%	0.0%	0.0%	0.0%
wood	-1.4%	0.0%	0.0%	0.0%	0.0%	0.0%
Industrial						
petroleum	2.0%	-5.8%	0.9%	-0.4%	-0.3%	-0.5%
natural gas	2.5%	-3.1%	0.7%	-0.6%	0.0%	-0.8%
coal	-5.4%	-7.1%	1.7%	-0.1%	-0.4%	-1.4%
wood	14.0%	-1.6%	-0.6%	0.9%	0.8%	0.7%

[a] Compound annual growth rates calculated from EIA SED historical consumption by sector and fuel type for Kentucky. Latest year for which EIA SED information was available for each sector and fuel type is 2007. Petroleum includes distillate fuel, kerosene, and liquefied petroleum gases for all sectors plus residual oil for the commercial and industrial sectors.
[b] Figures for growth periods starting after 2007 are calculated from AEO2009 projections for EIA's East South Central region. Regional growth rates for the residential sector are adjusted for Kentucky's projected population.

Results

Figures B2, B3, and B4 show historical and projected emissions for the RCI sectors in Kentucky from 1990 through 2030. These figures show the emissions associated with the direct consumption of fossil fuels and, for comparison purposes, show the share of emissions associated with the generation of electricity consumed by each sector, allocated to the RCI subsectors using the methodology described above.

The residential sector's share of total RCI emissions from direct fuel use and electricity was 24% in 1990, increased to 26% in 2005, and is projected to increase slightly to 27% in 2030. The commercial sector's share of total RCI emissions from direct fuel use and electricity use was 16% in 1990, increased to 18% in 2005, and is projected to increase to 26% by 2030. The industrial sector's share of total RCI emissions from direct fuel use and electricity use was 60% in 1990, decreased to 56% in 2005, and is projected to decrease to 47% by 2030. Emissions associated with the generation of electricity to meet RCI demand accounts for about 87% of the emissions for the residential sector, 88% of the emissions for the commercial sector, and 67% of the emissions for the industrial sector, on average, over the 1990 to 2030 time period. From 1990 to 2030, natural gas consumption is the next highest source of emissions for the residential and commercial sectors, accounting, on average, for about 11% and 9% of total emissions, respectively. For the industrial sector, emissions associated with the combustion of petroleum, coal, and natural gas account for about 16%, 9%, and 8% respectively, on average, from 1990 to 2030.

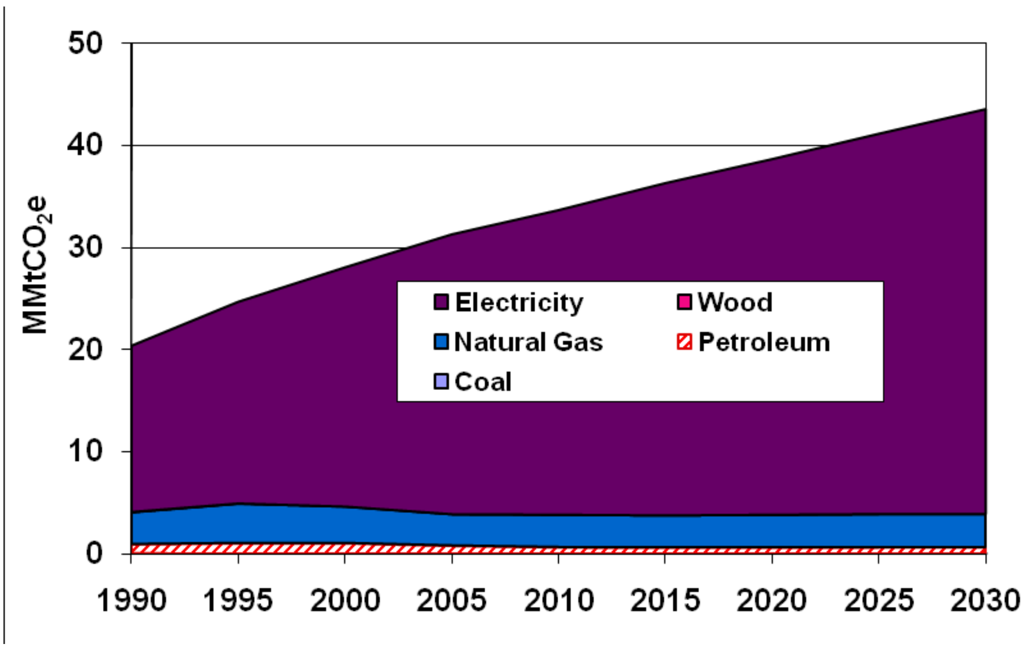
Residential Sector

Figure B2 presents the emission inventory and reference case projections for the residential sector. Figure B2 was developed from the emissions data in Table B5a. Table B5b shows the relative contributions of emissions associated with each fuel type to total residential sector emissions.

For the residential sector, emissions from electricity and direct fossil fuel use in 1990 were about 20 MMtCO$_2$e, and are estimated to increase to about 44 MMtCO$_2$e by 2030. Emissions associated with the generation of electricity to meet residential energy consumption demand accounted for about 80% of total residential emissions in 1990, and are estimated to increase to 91% of total residential emissions by 2030. In 1990, natural gas consumption accounted for about 15% of total residential emissions, and is estimated to account for about 7% of total residential emissions by 2030. Residential sector emissions associated with the use of coal, petroleum, and wood in 1990 were about 1.0 MMtCO$_2$e combined, and accounted for about 5% of total residential emissions. By 2030, emissions associated with the consumption of these three fuels are estimated to decrease slightly to 0.7 MMtCO$_2$e, accounting for 2% of total residential sector emissions by that year.

For the 25-year period 2005 to 2030, residential-sector GHG emissions associated with the use of electricity, natural gas and wood are expected to increase at average annual rates of about 1.5%, 0.2% and 0.8% respectively. Emissions associated with the use of coal and petroleum are expected to decrease annually by about -3.0% and -0.7% respectively. Total GHG emissions for this sector increase by an average of about 1.3% annually over the 25-year period.

Figure B2. Residential Sector GHG Emissions from Fuel Consumption



Source: CCS calculations based on approach described in text.

Note: Emissions associated with coal and wood combustion are too small to be seen on this graph. GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

Table B5a. Residential Sector Emissions Inventory and Reference Case Projections ($MMtCO_2e$)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Coal	0.07	0.04	0.06	0.06	0.03	0.03	0.03	0.03	0.03
Petroleum	0.87	1.00	0.99	0.74	0.62	0.58	0.59	0.61	0.62
Natural Gas	3.10	3.85	3.57	3.07	3.17	3.13	3.19	3.24	3.24
Wood	0.10	0.08	0.04	0.05	0.06	0.06	0.06	0.06	0.07
Electricity	16.29	19.76	23.44	27.41	29.84	32.56	34.83	37.25	39.65
Total	20.43	24.73	28.10	31.33	33.71	36.36	38.71	41.19	43.60

Source: CCS calculations based on approach described in text.

Table B5b. Residential Sector Proportions of Total Emissions by Fuel Type (%)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Coal	0.4%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%
Petroleum	4.3%	4.0%	3.5%	2.4%	1.8%	1.6%	1.5%	1.5%	1.4%
Natural Gas	15.2%	15.6%	12.7%	9.8%	9.4%	8.6%	8.3%	7.9%	7.4%
Wood	0.5%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%
Electricity Consumption	79.7%	79.9%	83.4%	87.5%	88.5%	89.5%	90.0%	90.4%	90.9%

Source: CCS calculations based on approach described in text.
Note: The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table B3a.

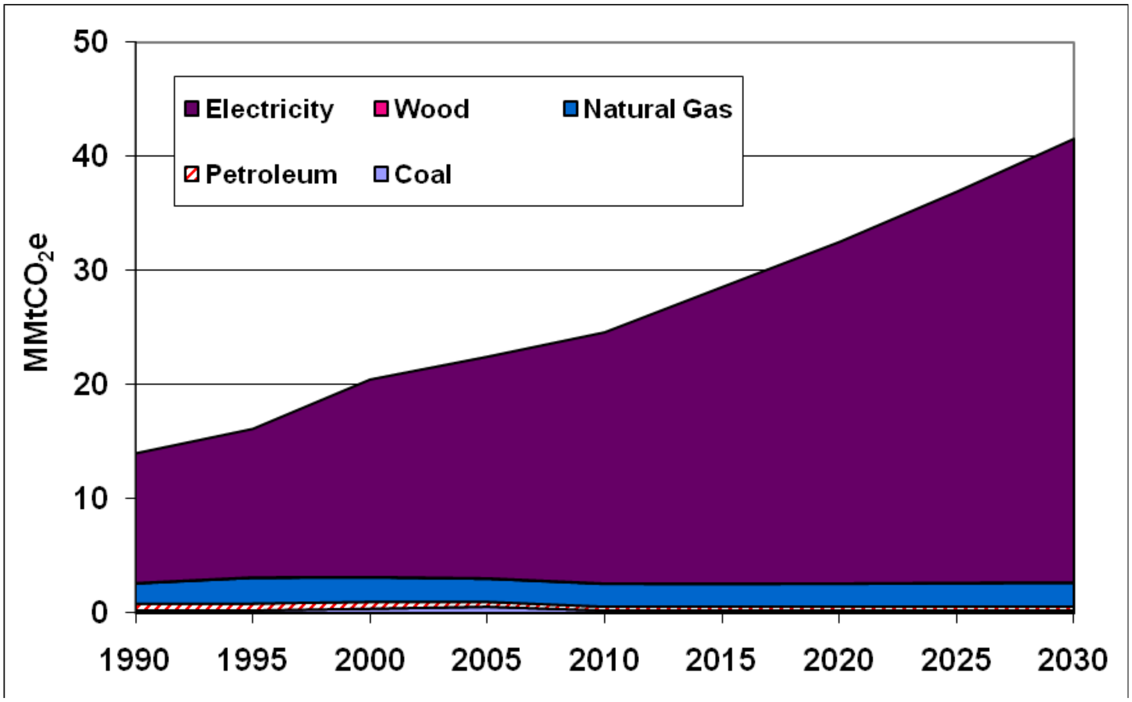
Commercial Sector

Figure B3 presents the emission inventory and reference case projections for the commercial sector. Figure B3 was developed from the emissions data in Table B6a. Table B6b shows the relative contributions of emissions associated with each fuel type to total commercial sector emissions.

For the commercial sector, emissions from electricity and direct fossil fuel use in 1990 were about 14 $MMtCO_2e$, and are estimated to increase to about 42 $MMtCO_2e$ by 2030. Emissions associated with the generation of electricity to meet commercial energy consumption demand accounted for about 81% of total commercial emissions in 1990, and are estimated to increase to 93% of total commercial emissions by 2030. In 1990, natural gas consumption accounted for about 13% of total commercial emissions and is estimated to account for about 5% of total commercial emissions by 2030. Commercial sector emissions associated with the use of coal, petroleum, and wood in 1990 were about 0.9 $MMtCO_2e$ combined, and accounted for about 6% of total commercial emissions. By 2030, emissions associated with the consumption of these three fuels are estimated to be 0.7 $MMtCO_2e$ and to account for 2% of total commercial sector emissions.

For the 25-year period from 2005 to 2030, commercial sector GHG emissions associated with the use of electricity and natural gas are expected to increase at average annual rates of about 2.8%, and 0.1% respectively. Emissions associated with the use of coal, petroleum and wood are expected to decline from 2005 levels at average annual rates of -3.5%, -0.4% and -0.1%, respectively. Total GHG emissions for this sector increase by an average of about 2.5% annually over the 25-year period.

Figure B3. Commercial Sector GHG Emissions from Fuel Consumption



Source: CCS calculations based on approach described in text.
Note: Emissions associated with coal and wood combustion are too small to be seen on this graph. GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

Table B6a. Commercial Sector Emissions Inventory and Reference Case Projections ($MMtCO_2e$)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Coal	0.28	0.26	0.42	0.60	0.25	0.25	0.25	0.25	0.25
Petroleum	0.60	0.63	0.62	0.44	0.37	0.37	0.37	0.39	0.40
Natural Gas	1.76	2.25	2.14	2.02	1.99	1.97	1.99	2.03	2.06
Wood	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Electricity	11.37	13.01	17.30	19.42	22.02	26.00	29.93	34.27	38.88
Total	14.02	16.17	20.49	22.49	24.63	28.59	32.55	36.94	41.59

Source: CCS calculations based on approach described in text.

Table B6b. Commercial Sector Proportions of Total Emissions by Fuel Type (%)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Coal	2.0%	1.6%	2.1%	2.7%	1.0%	0.9%	0.8%	0.7%	0.6%
Petroleum	4.3%	3.9%	3.0%	2.0%	1.5%	1.3%	1.2%	1.0%	1.0%
Natural Gas	12.5%	13.9%	10.4%	9.0%	8.1%	6.9%	6.1%	5.5%	5.0%
Wood	0.1%	0.07%	0.03%	0.04%	0.03%	0.03%	0.03%	0.02%	0.02%
Electricity Consumption	81.1%	80.5%	84.4%	86.4%	89.4%	90.9%	92.0%	92.8%	93.5%

Source: CCS calculations based on approach described in text.
Note: The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table B4a.

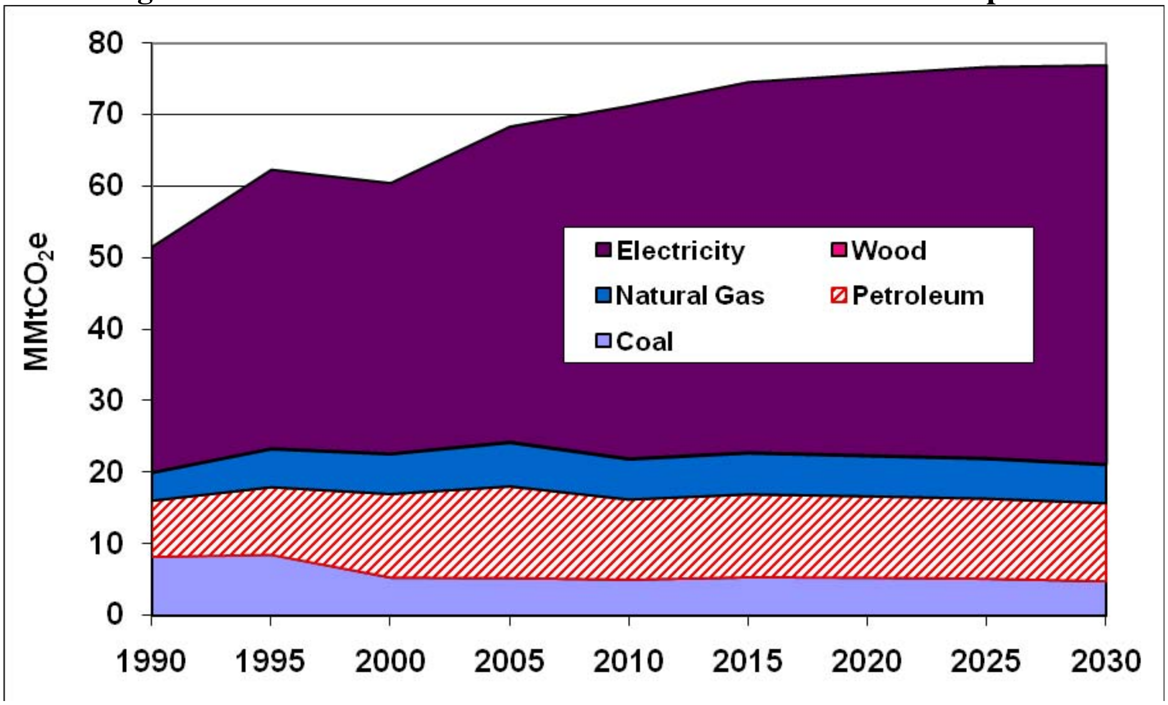
Industrial Sector

Figure B4 presents the emission inventory and reference case projections for the industrial sector. Figure B4 was developed from the emissions data in Table B7a. Table B7b shows the relative contributions of emissions associated with each fuel type to total industrial sector emissions.

For the industrial sector, emissions from electricity and direct fuel use in 1990 were about 51 $MMtCO_2e$ and are estimated to increase to about 77 $MMtCO_2e$ by 2030. Emissions associated with the generation of electricity to meet industrial energy consumption demand accounted for about 61% of total industrial emissions in 1990, and are estimated to increase to about 73% of total industrial emissions by 2030. In 1990, natural gas consumption accounted for about 8% of total industrial emissions, and is estimated to decrease slightly to 7% of total industrial emissions by 2030. Coal consumption accounted for about 16% of total industrial emissions in 1990, and is estimated to decline to about 6% of total industrial emissions by 2030. In 1990, petroleum consumption accounted for about 15% of total industrial emissions, and is estimated to decrease to about 14% of total industrial emissions by 2030. Emissions associated with wood consumption by the industrial sector are about 0.1% of total emissions or less from 1990 through 2030.

For the 25-year period from 2005 to 2030, industrial sector GHG emissions associated with the use of electricity and wood are expected to increase at an average annual rate of about 0.9% and 0.4%, respectively. Emissions associated with the use of petroleum, coal, and natural gas are expected to decrease annually by about -0.6%, -0.4%, and -0.5%, respectively. Total GHG emissions for the industrial sector increase by about 0.5% annually over the 25-year period.

Figure B4. Industrial Sector GHG Emissions from Fuel Consumption



Source: CCS calculations based on approach described in text.
Note: Emissions associated with wood combustion are too small to be seen on this graph. GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.

Table B7a. Industrial Sector Emissions Inventory and Reference Case Projections ($MMtCO_2e$)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Coal	8.19	8.47	5.30	5.23	5.00	5.33	5.29	5.13	4.77
Petroleum	7.86	9.47	11.70	12.83	11.22	11.60	11.39	11.20	10.93
Natural Gas	3.87	5.31	5.55	6.10	5.61	5.74	5.60	5.55	5.34
Wood	0.00	0.01	0.01	0.04	0.04	0.03	0.04	0.04	0.04
Electricity	31.52	38.96	37.80	44.07	49.28	51.77	53.24	54.66	55.74
Total	51.45	62.23	60.35	68.25	71.14	74.48	75.55	76.58	76.83

Source: CCS calculations based on approach described in text.

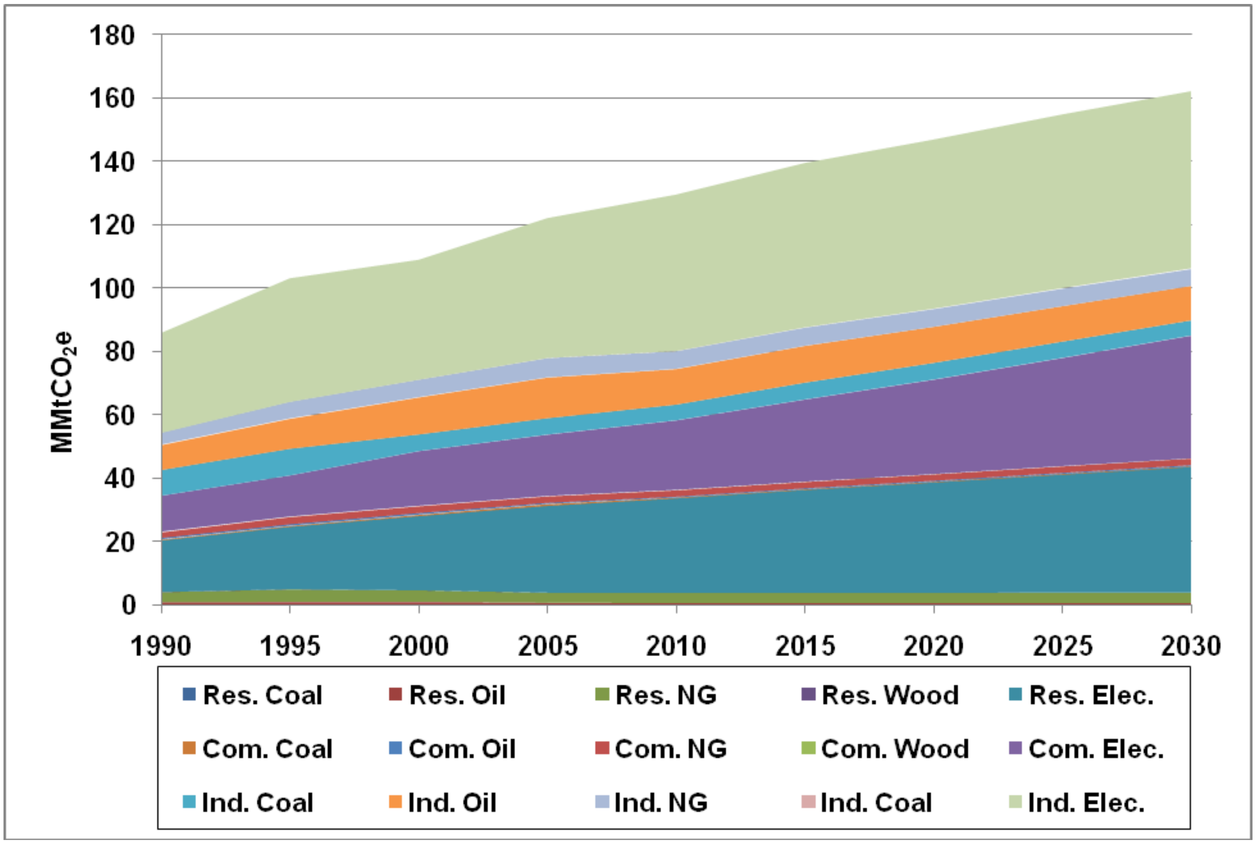
Table B7b. Industrial Sector Proportions of Total Emissions by Fuel Type (%)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Coal	15.9%	13.6%	8.8%	7.7%	7.0%	7.2%	7.0%	6.7%	6.2%
Petroleum	15.3%	15.2%	19.4%	18.8%	15.8%	15.6%	15.1%	14.6%	14.2%
Natural Gas	7.5%	8.5%	9.2%	8.9%	7.9%	7.7%	7.4%	7.2%	7.0%
Wood	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%
Electricity	61.3%	62.6%	62.6%	64.6%	69.3%	69.5%	70.5%	71.4%	72.6%

Source: CCS calculations based on approach described in text.
Note: The percentages shown in this table reflect the emissions for each fuel type as a percentage of total emissions shown in Table B5a.

Figure B5 illustrates the GHG emissions from the individual residential, commercial, and industrial sectors by fuel type.

Figure B5. RCI GHG Emissions from Fuel Consumption by Fuel Type and Sector



Source: CCS calculations based on approach described in text.
GHG emissions include all six standard GHGs, expressed in $MMtCO_2e$.
Res. = Residential sector; Com. = Commercial sector; Ind. = Industrial sector; NG = natural gas; Elec. = Electricity

Key Uncertainties

Key sources of uncertainty underlying the estimates above are as follows:

- Population and economic growth are the principal drivers for electricity and fuel use. The reference case projections are based on regional fuel consumption projections for EIA's East South Central modeling region. Consequently, there are significant uncertainties associated with the projections. Future work should attempt to base projections of GHG emissions on fuel consumption estimates specific to Kentucky to the extent that such data become available.
- The AEO2009 projections assume no large long-term changes in relative fuel and electricity prices, relative to current price levels and to US DOE projections for fuel prices. Price changes would influence consumption levels and, to the extent that price trends for competing fuels differ, may encourage switching among fuels, and thereby affect emissions estimates.

Appendix C. Transportation Energy Use

Overview

The transportation sector is one of the largest sources of greenhouse gas (GHG) emissions in Kentucky. In 2005, carbon dioxide (CO_2) accounted for about 97% of transportation GHG emissions from fuel use. Most of the remaining GHG emissions from the transportation sector are due to nitrous oxide (N_2O) emissions from gasoline engines.

Emissions and Reference Case Projections

Historical GHG emissions were estimated using the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SIT) software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for the sector.[33,34] For onroad vehicles, the CO_2 emission factors are in units of pounds (lb) per million British thermal unit (MMBtu) and the methane (CH_4) and N_2O emission factors are both in units of grams per vehicle mile traveled (VMT). Key assumptions in this analysis are listed in Table C1. The default fuel consumption data within SIT were used to estimate emissions, with the most recently available fuel consumption data (2007 in most cases) from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) *State Energy Data* (SED) included in the SIT.[35] The default VMT data in SIT were replaced with annual VMT supplied by the Kentucky Transportation Cabinet (KYTC).[36] The State-level Kentucky VMT was allocated to vehicle types using the default vehicle mix data in SIT from the Federal Highway Administration (FHWA)[37].

Onroad Vehicles

Onroad vehicle gasoline and diesel emissions were projected based on VMT forecasts provided by KYTC[4] and growth rates developed from national vehicle type VMT forecasts reported in EIA's *Annual Energy Outlook* 2009 (AEO2009). The AEO2009 data were incorporated because they indicate significantly different VMT growth rates for certain vehicle types (e.g., much higher growth rates for heavy-duty diesel VMT compared to light-duty gasoline vehicle VMT over this period). The procedure first applied the AEO2009 vehicle type-based national growth rates to 2008 estimates of Kentucky VMT by vehicle type. These data were then used to calculate the estimated proportion of total VMT by vehicle type in each year. Next, these proportions were applied to the KYTC estimates for total projected VMT in the State for each year, using a total annual growth rate of 2.2%, to yield the vehicle type VMT estimates. The resulting annual VMT growth rates by vehicle type are displayed in Table C2.

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[33] CO_2 emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter. 1. "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", August 2004.

[34] CH_4 and N_2O emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter. 3. "Methods for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion", August 2004.

[35] Energy Information Administration, State Energy Consumption, Price, and Expenditure Estimates (SED), http://www.eia.doe.gov/emeu/states/_seds.html.

[36] Jesse Mayes, Transportation Engineer Specialist, Kentucky Transportation Cabinet.

[37] Highway Statistics, Federal Highway Administration, http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm.

Table C1. Key Assumptions and Methods for the Transportation Inventory and Projections

Vehicle Type and Pollutants	Methods
Onroad gasoline, diesel, natural gas, and LPG vehicles – CO_2	**Inventory (1990 – 2007)** EPA SIT and fuel consumption from EIA SED **Reference Case Projections (2008 – 2030)** Gasoline and diesel fuel projected using VMT projections from KYTC, adjusted by current fuel efficiency improvement projections from EPA. Other onroad fuels projected using East South Central Region fuel consumption projections from EIA AEO2009 adjusted using state-to-regional ratio of population growth.
Onroad gasoline and diesel vehicles – CH_4 and N_2O	**Inventory (1990 – 2008)** EPA SIT with State total VMT replaced by KYTC VMT allocated to vehicle types using default data in SIT. **Reference Case Projections (2009 – 2030)** VMT projected annual growth rate from KYTC.
Non-highway fuel consumption (jet aircraft, gasoline-fueled piston aircraft, boats, locomotives) – CO_2, CH_4 and N_2O	**Inventory (1990 – 2007)** EPA SIT and fuel consumption from EIA SED. Commercial marine vessel fuel consumption based on national fuel consumption allocated to Kentucky based on Waterborne Commerce data. **Reference Case Projections (2008 – 2030)** Aircraft growth rates are based on estimates of operations data for Kentucky in the FAA's Terminal Area Forecast for 2007-2030 data. Rail and marine gasoline projected based on historical data.

Table C2. Kentucky Vehicle Miles Traveled Compound Annual Growth Rates

Vehicle Type	2008-2010	2010-2015	2015-2020	2020-2025	2025-2030
Heavy Duty Diesel Vehicle	2.77%	2.60%	2.34%	2.24%	2.21%
Heavy Duty Gasoline Vehicle	1.91%	1.92%	1.82%	1.80%	1.97%
Light Duty Diesel Truck	8.56%	11.11%	12.71%	11.47%	9.41%
Light Duty Diesel Vehicle	8.56%	11.11%	12.71%	11.47%	9.41%
Light Duty Gasoline Truck	2.13%	1.98%	1.83%	1.68%	1.59%
Light Duty Gasoline Vehicle	2.13%	1.98%	1.83%	1.68%	1.59%
Motorcycle	2.13%	1.98%	1.83%	1.68%	1.59%

Onroad gasoline and diesel fuel consumption were forecasted by developing a set of growth factors that adjusted the VMT projections to account for improvements in fuel efficiency. Fuel efficiency projections were taken from EPA's MOBILE6.2 model to represent projected fleetwide in-use fuel consumption, prior to the implementation of the new fuel efficiency standards resulting from the 2007 Energy Independence and Security Act. The resulting onroad fuel consumption growth rates are shown in Table C3. Growth rates for projecting CO_2 emissions from natural gas and LPG vehicles were calculated by allocating the AEO2009 consumption of these fuels in the East South Central region and allocating this to Kentucky based on the ratio of the State's projected population to the region's projected population. Similarly, growth rates for projecting CO_2 emissions from lubricants consumption were calculated based on the AEO2009 East South Central "other petroleum" category growth, also normalized using state to regional population projections.

Table C3. Kentucky Onroad Fuel Consumption Compound Annual Growth Rates

Fuel Growth Factors	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030
Onroad gasoline	1.82%	1.82%	1.75%	1.68%	1.59%
Onroad diesel	3.11%	3.29%	3.50%	3.79%	3.87%
Natural Gas	8.10%	12.62%	6.37%	2.59%	0.95%
LPG	-4.22%	-0.27%	-0.28%	-0.26%	-0.20%
Lubricants	-1.00%	0.35%	0.12%	-0.05%	-0.12%

Aviation

For the aircraft sector, emission estimates for 1990 to 2007 are based on SIT methods and fuel consumption from EIA. Emissions were projected from 2008 to 2030 using the Terminal Area Forecast from the Federal Aviation Administration, adjusted by an estimate of improved aircraft efficiency, from the AEO2009. To estimate changes in jet fuel consumption, aircraft operations from air carrier, air taxi/commuter, and military aircraft were first summed for each year of interest. The post-2007 estimates were adjusted to reflect the projected increase in national aircraft fuel efficiency (indicated by increased number of seat miles per gallon), as reported in AEO2009. Because AEO2009 does not estimate fuel efficiency changes for general aviation aircraft, forecast changes in aviation gasoline consumption were based solely on the projected number of itinerant general aviation aircraft operations in Kentucky, which was obtained from the FAA source noted above. The resulting compound annual average growth rates are displayed in Table C4.

Table C4. Kentucky Aviation Fuels Compound Annual Growth Rates

Fuel	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030
Aviation Gasoline	–2.95%	0.41%	0.43%	0.46%	0.47%
Jet Fuel	–11.89%	1.53%	0.77%	0.62%	0.50%

Rail and Marine Vehicles

For the rail and recreational marine sectors, 1990-2007 estimates are based on SIT methods and fuel consumption from EIA. Marine gasoline consumption was projected to 2030 based on a linear regression of the 1990 through 2007 historical data. The historical data for rail shows no significant positive or negative trend; therefore, no growth was assumed for this sector.

For the commercial marine sector (marine diesel and residual fuel), 1990-2007 emission estimates are based on SIT emission rates applied to estimates of Kentucky marine vessel diesel and residual fuel consumption. Because the SIT default relies on marine vessel fuel consumption estimates that represent the State in which fuel is sold rather than consumed, an alternative method was used to estimate Kentucky marine vessel fuel consumption. Kentucky fuel consumption estimates were developed by allocating 1990-2007 national diesel and residual oil vessel bunkering fuel consumption estimates obtained from EIA, excluding fuel used for international bunkering.[38] Marine vessel fuel consumption data were allocated to Kentucky using the marine vessel activity allocation methods/data compiled to support the development of EPA's National Emissions Inventory (NEI).[39] In keeping with the NEI, 75% of each year's distillate fuel and 25% of each year's residual fuel were assumed to be consumed within the port area (remaining consumption was assumed to occur while ships are underway). National port area fuel consumption was allocated to Kentucky based on year-specific freight tonnage data by state as reported in "Waterborne Commerce of the United States, Part 5 – Waterways and Harbors National Summaries."[40] Growth rates for the commercial marine sector were calculated based on a forecasted trend of the resulting historical diesel and residual commercial marine fuel consumption.

The resulting compound annual average growth rates for the rail and marine categories are displayed in Table C5.

Table C5. Kentucky Rail and Marine Fuels Compound Annual Growth Rates

Fuel	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030
Marine Gasoline	2.77%	1.42%	1.33%	1.24%	1.17%
Marine Diesel	1.86%	0.86%	0.82%	0.79%	0.76%
Marine Residual	-12.10%	-0.81%	-0.84%	-0.88%	-0.92%
Rail	0.00%	0.00%	0.00%	0.00%	0.00%

Nonroad Engines

It should be noted that fuel consumption data from EIA includes nonroad gasoline and diesel fuel consumption in the commercial and industrial sectors. Emissions from these nonroad engines, including nonroad vehicles such as snowmobiles and dirt bikes, are included in the inventory and forecast for the residential, commercial, and industrial (RCI) sectors (see Appendix B). Table C6 shows how EIA divides gasoline and diesel fuel consumption between the transportation, commercial, and industrial sectors.

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[38] US Department of Energy, Energy Information Administration, "Petroleum Navigator" (diesel data obtained from http://tonto.eia.doe.gov/dnav/pet/hist/kd0vabnus1a.htm; residual data obtained from http://tonto.eia.doe.gov/dnav/pet/hist/kprvatnus1a.htm). Data for international bunker fuels obtained from EPA's *2009 Inventory of Greenhouse Gas Emissions and Sinks*, Table 3-53, available at http://www.epa.gov/climatechange/emissions/index.html, and earlier versions for some intermediate years.

[39] See methods described in ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf

[40] "Waterborne Commerce of the United States" http://www.iwr.usace.army.mil/ndc/wcsc/wcsc.htm. Note that it was necessary to estimate 1990-1996 values by applying the available 1997 Kentucky percentage of national waterborne tonnage.

Table C6. EIA Classification of Gasoline and Diesel Consumption

Sector	Gasoline Consumption	Diesel Consumption
Transportation	Highway vehicles, marine	Vessel bunkering, military use, railroad, highway vehicles
Commercial	Public non-highway, miscellaneous use	Commercial use for space heating, water heating, and cooking
Industrial	Agricultural use, construction, industrial and commercial use	Industrial use, agricultural use, oil company use, off-highway vehicles

Results

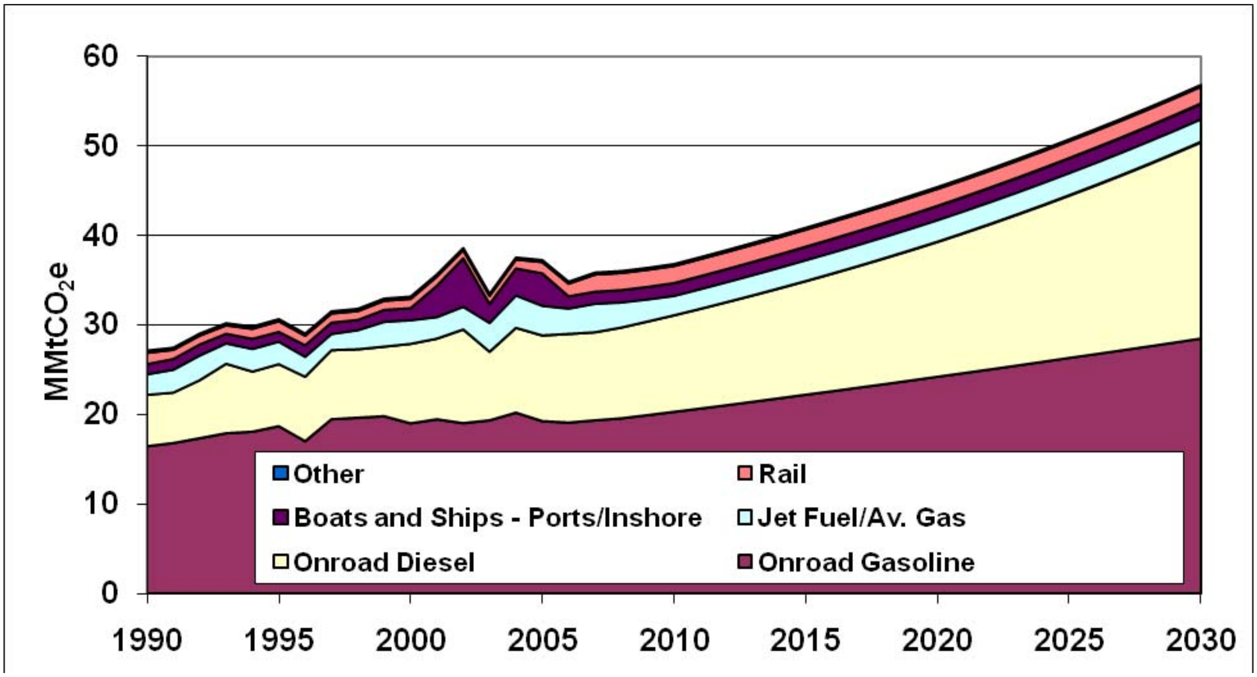
As shown in Figure C1, onroad gasoline and diesel consumption accounts for the largest share of transportation GHG emissions. Emissions from onroad gasoline vehicles increased by about 17% from 1990 to 2005 to account for 61% of total transportation emissions in 2005. GHG emissions from onroad diesel fuel consumption increased by 66% from 1990 to 2005, and by 2005 accounted for 23% of GHG emissions from the transportation sector. Emissions from boats and ships along Kentucky waterways accounted for 4% of transportation emissions in 2005. Aircraft emissions increased 45% between 1990 and 2005, and made up 8% of Kentucky transportation emissions in 2005. Rail emissions increase by 1% between 1990 and 2005, and made up 4% of Kentucky's transportation emissions in 2005. Emissions from all other categories combined (natural gas and LPG, and oxidation of lubricants) contributed less than 1% of total transportation emissions in 2005.

GHG emissions from all onroad vehicles combined are projected to increase by 75% between 2005 and 2030. This growth comes primarily from the diesel sector, with onroad gasoline emissions projected to increase 48% and emissions from onroad diesel consumption projected to increase by 129% between 2005 and 2030. Kentucky emissions from boats and ships decrease 53% over the forecast period. Similarly, emissions from aviation fuels are projected to decrease by 22% between 2005 and 2030. See Table C7 and Figure C1 for more information.

Table C7. Transportation GHG Emissions by Fuel, 1990-2030

Source	1990	1995	2000	2005	2010	2015	2020	2025	2030
Onroad Gasoline	16.4	18.7	19.0	19.2	20.3	22.2	24.2	26.3	28.5
Onroad Diesel	5.8	7.0	8.9	9.6	10.8	12.7	15.1	18.2	22.0
Jet Fuel/Av. Gas	2.3	2.6	2.7	3.4	2.2	2.4	2.5	2.6	2.6
Boats and Ships - Ports/Inshore	1.2	1.1	1.4	3.6	1.4	1.5	1.6	1.6	1.7
Rail	1.3	1.2	1.0	1.3	1.9	1.9	1.9	1.9	1.9
Other	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	***27.2***	***30.7***	***33.2***	***37.3***	***36.8***	***40.9***	***45.5***	***50.8***	***56.9***

Figure C1. Transportation GHG Emissions by Source and Fuel, 1990-2030



Source: CCS calculations based on approach described in text.

Sensitivity Test Results Based Upon Alternative VMT Forecast

The Transportation and Land Use Technical Working Group (TLU TWG) recommended to the KCAPC that an alternative VMT forecast be developed to determine the sensitivity of transportation emissions to the VMT growth assumptions in the BAU reference case projections. This recommendation was based on a concern that the BAU VMT annual growth rate of 2.2% does not reflect recent Kentucky or national historical patterns in VMT. The KCAPC approved the development of an alternative growth scenario that shows about 20% increase in VMT between 2005 and 2030 based upon an assumption that VMT growth mirrors projected population growth. With the approval of this recommendation by the KCAPC, an alternative VMT projection was developed with the results presented here.

The annual growth rates from the official state forecast for population growth[41] for each year were applied to the latest historical year of VMT data, 2008, through 2030. These alternative VMT estimates were then used as the only change from the BAU GHG reference case projection in order to produce a ‘sensitivity analysis’ result for a forecast of transportation sector GHG emissions.

Table C8 shows the VMT annual growth rates used in the alternative sensitivity test analysis. Table C9 shows the annual fuel consumption growth rates that result from the alternative VMT

[41] The population growth rates are from the Kentucky State Data Center, University of Louisville, http://ksdc.louisville.edu/kpr/pro/projections.htm

forecast. Table C10 shows the transportation GHG emissions forecast using the alternative VMT projections. The sensitivity test shows that the alternative VMT growth rates produce a significant difference in forecast GHG emissions for on-road vehicles. The baseline forecast for onroad gasoline GHG emissions is 28.5 $MMtCO_2e$ in the year 2030, while the alternative scenario produces an estimate of 20.4 $MMtCO_2e$, which represents a difference of 8.1 $MMtCO_2e$. The baseline forecast for onroad diesel GHG emissions is 22.0 $MMtCO_2e$ for the year 2030, while the alternative scenario produces an estimate of 15.7 $MMtCO_2e$, which represents a difference of 6.3 $MMtCO_2e$. The overall GHG forecast estimate for the transportation and land use sector changes from 56.9 $MMtCO_2e$ in 2030 to 42.6 $MMtCO_2e$, which represents a difference of 14.3 $MMtCO_2e$ in 2030.

Table C8. Kentucky Vehicle Miles Traveled Compound Annual Growth Rates using Alternate VMT Projections

Vehicle Type	2008-2010	2010-2015	2015-2020	2020-2025	2025-2030
Heavy Duty Diesel Vehicle	1.34%	1.15%	0.87%	0.74%	0.68%
Heavy Duty Gasoline Vehicle	0.50%	0.48%	0.36%	0.31%	0.44%
Light Duty Diesel Truck	7.05%	9.55%	11.09%	9.84%	7.77%
Light Duty Diesel Vehicle	7.05%	9.55%	11.09%	9.84%	7.77%
Light Duty Gasoline Truck	0.71%	0.54%	0.37%	0.19%	0.07%
Light Duty Gasoline Vehicle	0.71%	0.54%	0.37%	0.19%	0.07%
Motorcycle	0.71%	0.54%	0.37%	0.19%	0.07%

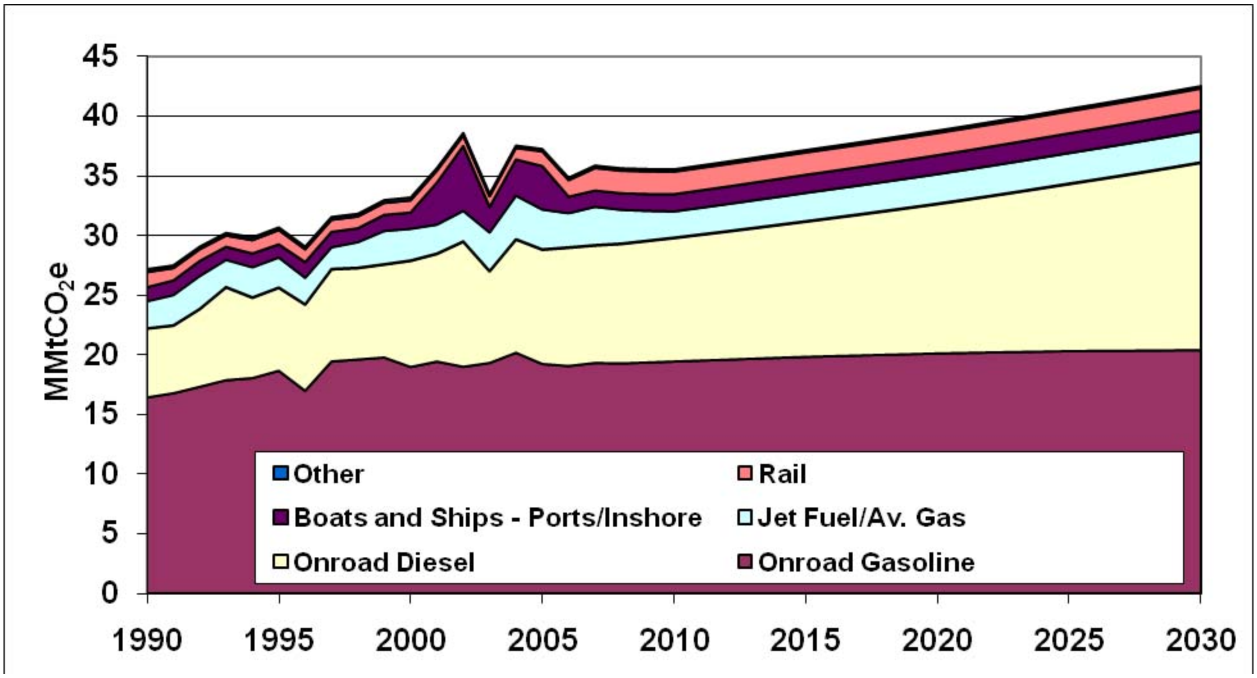
Table C9. Kentucky Onroad Fuel Consumption Compound Annual Growth Rates using Alternate VMT Projections

Fuel Growth Factors	2007-2010	2010-2015	2015-2020	2020-2025	2025-2030
Onroad gasoline	0.41%	0.39%	0.29%	0.20%	0.08%
Onroad diesel	1.68%	1.84%	2.01%	2.27%	2.32%

Table C10. Transportation GHG Emissions by Fuel using Alternate VMT Projections, 1990-2030

Source	1990	1995	2000	2005	2010	2015	2020	2025	2030
Onroad Gasoline	16.4	18.7	19.0	19.2	19.4	19.8	20.1	20.3	20.4
Onroad Diesel	5.8	7.0	8.9	9.6	10.4	11.3	12.5	14.0	15.7
Jet Fuel/Av. Gas	2.3	2.6	2.7	3.4	2.2	2.4	2.5	2.6	2.6
Boats and Ships - Ports/Inshore	1.2	1.1	1.4	3.6	1.4	1.5	1.6	1.6	1.7
Rail	1.3	1.2	1.0	1.3	1.9	1.9	1.9	1.9	1.9
Other	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Total	***27.2***	***30.7***	***33.2***	***37.3***	***35.6***	***37.2***	***38.8***	***40.7***	***42.6***

Figure C2. Transportation GHG Emissions by Source and Fuel using Alternate VMT Projections, 1990-2030



Key Uncertainties

Uncertainties in Onroad Fuel Consumption

A major uncertainty in this analysis is the conversion of the projected VMT to fuel consumption. These are based on first allocating Kentucky's total VMT projections by vehicle type using national vehicle type growth projections from AEO2009 modeling, which may not reflect Kentucky conditions. The conversion of the VMT data to fuel consumption also includes national assumptions regarding fuel economy by vehicle type.

Energy Independence and Security Act of 2007

The reference case projections documented here do not include the corporate average fuel economy (CAFE) or biofuels provisions (or any other provisions) of the Energy Independence and Security Act of 2007. Increases in vehicle fuel economy resulting from this act would lead to reduced CO_2 emissions from onroad vehicles. Reductions attributable to the CAFE provisions of this Act are quantified as a recent action.

Uncertainties in Aviation Fuel Consumption

The jet fuel and aviation gasoline fuel consumption from EIA is actually fuel *purchased* in the state, and therefore includes fuel consumed during state-to-state flights and international flights. The fuel consumption associated with international air flights should not be included in the state inventory; however, data were not available to subtract this consumption from total jet fuel estimates. Another uncertainty associated with aviation emissions is the use of general aviation forecasts to project aviation gasoline consumption. General aviation aircraft consume both jet fuel and aviation gasoline, but fuel specific data were not available.

Uncertainties in Marine Fuel Consumption

There are several assumptions that introduce uncertainty into the estimates of commercial marine fuel consumption. These assumptions include:

- 75% of marine diesel and 25% of residual fuel is consumed in port
- The proportion of freight tonnage at ports in Kentucky to the total national freight tonnage reflects the proportion of national marine fuel that is consumed in Kentucky.

Appendix D. Industrial Processes

Overview

Emissions in the industrial processes category span a wide range of activities, and reflect non-combustion sources of greenhouse gas (GHG) emissions from several industries. The industrial processes that exist in Kentucky, and for which emissions are estimated in this inventory, include the following:

- Carbon Dioxide (CO_2) from:
  - Production of cement, lime, iron and steel, and ammonia;[42]
  - Consumption of limestone, dolomite, and soda ash;
- Sulfur hexafluoride (SF_6) from transformers used in electric power transmission and distribution (T&D) systems;
- Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) from consumption of substitutes for ozone-depleting substances (ODS) used in cooling and refrigeration equipment; and
- PFCs from aluminum production.

Other industrial processes that are sources of GHG emissions but are not found in Kentucky include the following:

- CO_2 from taconite production;
- Nitrous oxide (N_2O) from nitric and adipic acid production;
- HFCs, PFCs, and SF_6 from semiconductor manufacturing;
- SF_6 from magnesium production and processing; and
- HFCs from HCFC-22 production.

Emissions and Reference Case Projections

Greenhouse gas emissions for 1990 through 2006 were estimated using the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SIT) software, and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for this sector.[43] Table D1 identifies for each emissions source category the information needed for input into SIT to calculate emissions, the data sources used for the analysis described here, and the historical years for which emissions were calculated based on the availability of data.

[42] Note that CO_2 emissions from urea application is estimated as part of the same category as ammonia production.
[43] GHG emissions were calculated using SIT, with reference to EIIP, Volume VIII: Chapter. 6. "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes", August 2004. Referred to as "EIIP" below.

Table D1. Approach to Estimating Historical Emissions

Source Category	Time Period	Required Data for SIT	Data Source
Cement Manufacture	1990 - 2006	Metric tons (Mt) of clinker produced and masonry cement produced each year.	Historical production for Kentucky from USGS Minerals Yearbook, Cement Statistics and Information (http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb).
Lime Manufacture	1990-2006	Mt of lime produced each year.	Historical production for Kentucky from USGS Minerals Yearbook, Lime Statistics and Information.(http://minerals.usgs.gov/minerals/pubs/commodity/lime/index.html#myb).
Limestone and Dolomite Consumption	1994 - 2006	Mt of limestone and dolomite consumed.	Historical consumption (sales) for Kentucky from USGS Minerals Yearbook, Crushed Stone Statistics and Information, (http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/). In SIT, the state's total limestone consumption (as reported by USGS) is multiplied by the ratio of national limestone consumption for industrial uses to total national limestone consumption. Additional information on these calculations, including a definition of industrial uses, is available in Chapter 6 of the EIIP guidance document. Default limestone production data are not available in SIT for 1990 – 1993; data for 1994 were used for 1990 – 1993 as a surrogate to fill in production data missing for these years.
Soda Ash Consumption	1990 - 2006	Mt of soda ash consumed for use in consumer products such as glass, soap and detergents, paper, textiles, and food.	Historical emissions are calculated in SIT based on the state's population and national per capita soda ash consumption from the US EPA national GHG inventory. -- National historical consumption (sales) for US from USGS Minerals Yearbook, Soda Ash Statistics and Information (http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/). -- National emissions from *US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005*, US EPA, Report #430-R-07-002, April 2007 (http://epa.gov/climatechange/emissions/usinventoryreport.html). -- US (1990-2000 and 2000-2005) and state (2000-2005) population from US Census Bureau (http://www.census.gov/popest/states/NST-ann-est.html). -- State (1990-2000) population from US Census Bureau (http://www.census.gov/popest/archives/2000s/vintage_2001/CO-EST2001-12/CO-EST2001-12-24.html).
Iron and Steel Production	1990-2007	Mt of crude steel produced by production method.	The basic activity data needed are the quantities of crude steel produced (defined as first cast product suitable for sale or further processing) by production method. Default steel production data are not available in SIT for 1990 – 1996; data for 1997 were used for 1990 – 1996 as a surrogate to fill in production data missing for these years.
Ammonia Production and Urea Application	1990-2006	Mt of ammonia produced and urea consumed	SIT default activity data for urea application for 1990-2006; no default activity data for ammonia production in Kentucky; urea activity data is based on national USGS data.
ODS Substitutes	1990 - 2006	Based on state's population and estimates of emissions per capita from the US EPA national GHG inventory.	References for US EPA national emissions and US Census Bureau national and state population figures are cited under the data sources for soda ash above.
Electric Power	1990 -	Emissions from 1990	National emissions are apportioned to the state based on the ratio of

Source Category	Time Period	Required Data for SIT	Data Source
T&D Systems	2006	to 2006 based on the national emissions per kilowatt-hour (kWh) and state's electricity use provided in SIT.	state-to-national electricity sales data provided in the Energy Information Administration's (EIA) Electric Power Annual (http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html). Reference for US EPA national emissions is cited under the data sources for soda ash above.
Aluminum Production	1990-2006	Mt of aluminum produced	Historical production for Kentucky from USGS Minerals Yearbook, Aluminum Annual Report.

Table D2 lists the data and methods that were used to estimate future activity levels related to industrial process emissions and the annual compound growth rates computed from the data/methods for the reference case projections. Because available forecast information is generally for economic sectors that are too broad to reflect trends in the specific emissions producing processes, the majority of projections are based on historical activity trends. In particular, state historical trends were analyzed for three periods: 1990-2006, 1995-2006, and 2000-2006 (or the closest available approximation of these periods). A no growth assumption was assumed when the historical periods indicated divergent activity trends (i.e., growth in certain periods and decline in other periods). In cases where the historical periods indicated either continual growth or decline, the smallest annual rate of growth/decline was selected from the values computed for each period. This conservative assumption was adopted because of the uncertainty associated with utilizing historical trends to estimate future emission activity levels.

Table D2. Approach to Estimating Projections for 2007 through 2030

Source Category	Projection Assumptions	Data Source	Annual Growth Rates (%)				
			2006 to 2010	2010 to 2015	2015 to 2020	2020 to 2025	2025 to 2030
Cement Manufacture	Growth rates computed from Portland Cement Association's Cement Outlook 2008	Portland Cement Association's Cement Outlook 2008	-1.21	2.07	1.75	1.49	1.22
Lime Manufacture	Smallest historical annual decline in state production from each of three periods analyzed	Annual change in Kentucky lime production:1990-2006 = 2.93%; 1996-2006 = 1.32%; and 2000-2006 = 7.55%	1.32	1.32	1.32	1.32	1.32
Limestone and Dolomite Consumption	No growth assumption based on conflicting state historical consumption trends; forecast information too broad	Annual change in Kentucky limestone and dolomite consumption:1990-2006 = 11.03%; 1996-2006 = 9.29%; and 2000-2006 = 25.49%	0.00	0.00	0.00	0.00	0.00
Soda Ash Consumption	Growth rate computed from 2006-2016 employment projections in Basic Chemical Manufacturing sector	Workforce KY 2006-2016 Basic Chemical Manufacturing employment	-1.01	-1.01	-1.01	-1.01	-1.01

Source Category	Projection Assumptions	Data Source	Annual Growth Rates (%)				
			2006 to 2010	**2010 to 2015**	**2015 to 2020**	**2020 to 2025**	**2025 to 2030**
Iron and Steel Production	No change assumed due to anomalously large historical growth rates for a limited historical period and conflicting projected decline in Kentucky Primary Metals employment		0.00	0.00	0.00	0.00	0.00
Urea Consumption	Smallest historical annual decline in state consumption from each of three periods analyzed	Annual change in Kentucky urea consumption: 1990-2006 = -1.72%; 1996-2006 = -0.41%; and 2000-2006 = -2.24%	-0.41	-0.41	-0.41	-0.41	-0.41
ODS Substitutes	National growth in emissions associated with the use of ODS substitutes.	Annual growth rates calculated based on sum of US national emissions projections from 2005-2020 for six categories of ODS substitutes presented in Appendix D, Tables D-1 through D-6 in the US EPA report, *Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases 1990-2020*, EPA Report 430-R-06-003, http://www.epa.gov/nonco2/econ-inv/international.html	4.80	6.37	5.03	6.70	6.70
Electric Power T&D Systems	National growth rate (based on technology adoption forecast scenario reflecting industry participation in EPA voluntary stewardship program to control emissions).	Annual growth rates calculated based on US national emissions projections from 2005-2020 presented in Appendix D, Table D-10 in the US EPA report, *Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases 1990-2020* , EPA Report 430-R-06-003; http://www.epa.gov/nonco2/econ-inv/international.html.	-1.05	-0.86	-0.79	-0.79	-0.79
Aluminum Production	National growth rate	Annual growth rates calculated based on US national emissions for 2005-2020 for "Technology-Adoption" scenario for Aluminum Production from Appendix D, Table D-9 in Global Anthropogenic Emissions of Non-CO2 Greenhouse Gases 1990-2020 (EPA Report 430-R-06-003); http://www.epa.gov/nonco2/econ-inv/international.html, assumed 2020-2030 growth same as 2015-2010	-0.35	-0.26	-0.22	-0.22	-0.22

Results

Figures D1 and D2 show historical and projected emissions for the industrial processes sector from 1990 to 2030. Table D3 shows the historical and projected emission values upon which Figures D1 and D2 are based. Total gross Kentucky GHG emissions were about 4.8 $MMtCO_2e$ in 1990, 6.5 $MMtCO_2e$ in 2005, and are projected to increase to about 12.5 $MMtCO_2e$ in 2030. Emissions from the overall industrial processes category are expected to grow by about 2.7% annually from 2005 through2030, as shown in Figures D1 and D2, with emissions growth primarily associated with the increasing use of HFCs and PFCs in refrigeration and air conditioning equipment.

Figure D1. GHG Emissions from Industrial Processes, 1990-2030

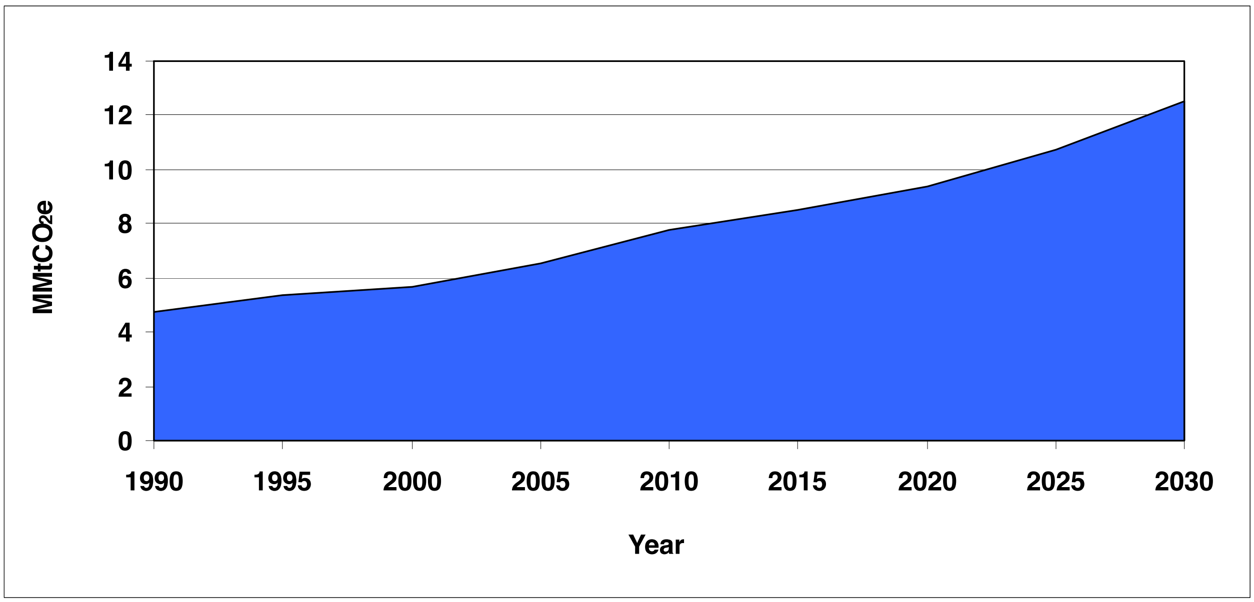


Figure D2. GHG Emissions from Industrial Processes, 1990-2030, by Source

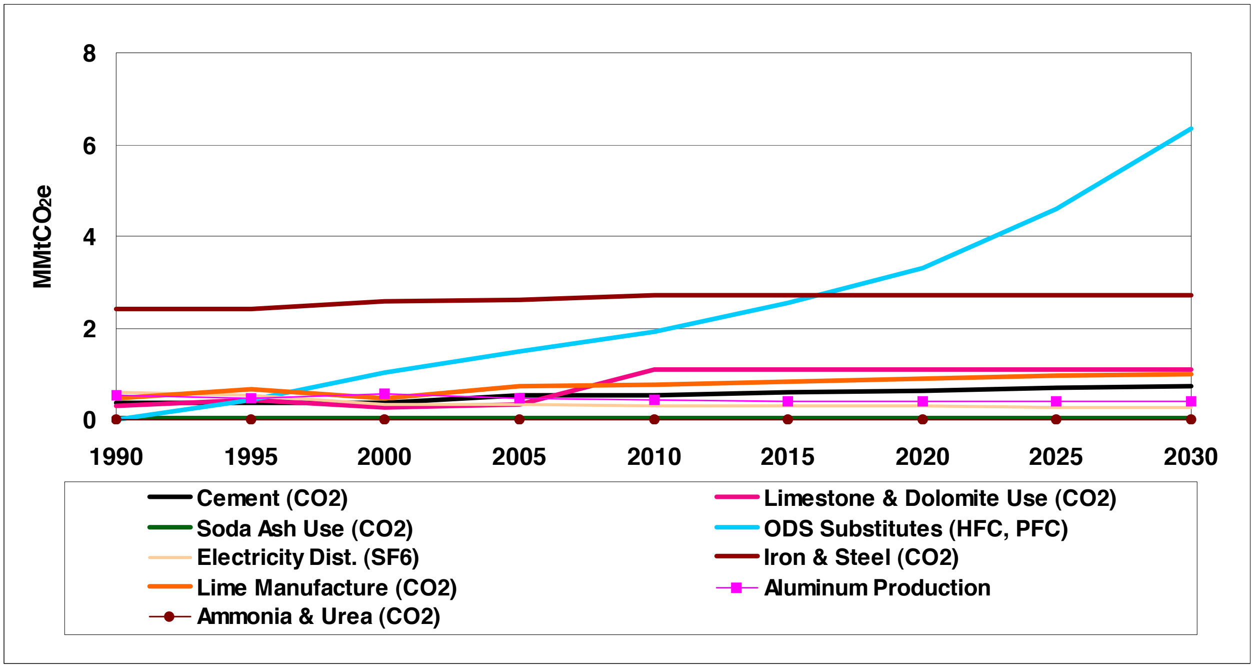


Table D3. Historical and Projected Emissions for the Industrial Processes Sector ($MMtCO_2e$)

Industry / Pollutant	1990	1995	2000	2005	2010	2015	2020	2025	2030
Cement (CO2)	0.37	0.36	0.35	0.54	0.53	0.59	0.64	0.69	0.73
Lime Manufacture (CO2)	0.46	0.67	0.48	0.72	0.77	0.83	0.88	0.94	1.01
Limestone & Dolomite Use (CO2)	0.31	0.43	0.28	0.32	1.08	1.08	1.08	1.08	1.08
Soda Ash Use (CO2)	0.040	0.040	0.038	0.036	0.034	0.033	0.031	0.029	0.028
Iron & Steel (CO2)	2.43	2.43	2.57	2.62	2.70	2.70	2.70	2.70	2.70
Ammonia and Urea (CO2)	0.011	0.009	0.010	0.007	0.008	0.008	0.008	0.008	0.008
ODS Substitutes (HFC, PFC)	0.005	0.42	1.02	1.48	1.90	2.56	3.32	4.59	6.35
Electricity Dist. (SF6)	0.60	0.53	0.34	0.34	0.31	0.29	0.28	0.27	0.26
Aluminum Production	0.53	0.47	0.57	0.46	0.42	0.41	0.40	0.40	0.39
Total	**4.75**	**5.35**	**5.65**	**6.52**	**7.75**	**8.50**	**9.35**	**10.7**	**12.5**

Cement Manufacture

The default production data used for Kentucky shows that both clinker and masonry cement are produced in the State. Clinker is an intermediate product from which finished Portland and masonry cement are made. Clinker production releases CO_2 when calcium carbonate ($CaCO_3$) is heated in a cement kiln to form lime (calcium oxide) and CO_2 (see Chapter 6 of EIIP guidance document). Emissions are calculated by multiplying annual clinker production by emission factors to estimate emissions associated with the clinker production process (0.507 metric ton

(Mt) of CO_2 emitted per Mt of clinker produced) and cement kiln dust (0.020 $MtCO_2$ emitted per Mt of clinker CO_2 emitted).

Masonry cement requires additional lime, over and above the lime used in the clinker. During the production of masonry cement, non-plasticizer additives such as lime, slag, and shale are added to the cement, increasing its weight by 5%. Lime accounts for approximately 60% of the added substances. About 0.0224 $MtCO_2$ is emitted for every Mt of masonry cement produced, relative to the CO_2 emitted during the production of a Mt of clinker (see Chapter 6 of EIIP guidance document).

As shown in Figure D2 and Table D3, emissions from this source are estimated to be about 0.4 $MMtCO_2e$ in 1990 and are projected to increase to about 0.7 $MMtCO_2e$ by 2030. Historical clinker and masonry cement production data for Kentucky obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate CO_2 emissions for 1990-2006. Emissions were projected through 2030 using rates specific to each projection period that were computed from Portland Cement Association's Cement Outlook 2008.

Lime Manufacture

Lime is a manufactured product that is used in many chemical, industrial, and environmental applications including steel making, construction, pulp and paper manufacturing, and water and sewage treatment. Lime is manufactured by heating limestone (mostly $CaCO_3$) in a kiln, creating calcium oxide and CO_2. The CO_2 is driven off as a gas and is normally emitted to the atmosphere, leaving behind a product known as quicklime. Some of this quicklime undergoes slaking (combining with water), which produces hydrated lime. The consumption of lime for certain uses, specifically the production of precipitated $CaCO_3$ and refined sugar, results in the reabsorption of some airborne CO_2 (see Chapter 6 of EIIP guidance document.).

Emissions associated with lime manufacture were estimated for 1990 through 2006 using the amount of lime produced and an emission factor of 0.75 $MtCO_2$ per ton high-calcium lime and 0.87 $MtCO_2$ per ton dolomitic lime produced. The annual growth rate was developed from an analysis of historical growth, selecting the smallest historical annual decline in state production (1.32% from 1996 to 2006) from each of three periods analyzed. CO_2 emissions from lime production in Kentucky were estimated at about 0.46 $MMtCO_2e$ in 1990, 0.72 $MMtCO_2e$ in 2005, and 0.94 $MMtCO_2e$ in 2030.

Limestone and Dolomite Consumption

Limestone and dolomite are basic raw materials used by a wide variety of industries, including the construction, agriculture, chemical, glass manufacturing, and environmental pollution control industries, as well as in metallurgical industries such as magnesium production. Emissions associated with the use of limestone and dolomite to manufacture steel and glass and for use in flue-gas desulfurization scrubbers to control sulfur dioxide emissions from the combustion of coal in boilers are included in the industrial processes sector.[44]

[44] In accordance with EIIP Chapter 6 methods, emissions associated with the following uses of limestone and dolomite are not included in this category: (1) crushed limestone consumed for road construction or similar uses (because these uses do not result in CO_2 emissions), (2) limestone used for agricultural purposes (which is counted

Historical limestone and dolomite consumption (sales) data for Kentucky obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate CO_2 emissions for 1990-2006. Default data were not available in the SIT for the years from 1990 to 1993, so the 1994 emissions estimate was applied to these years. Emission projections from 2007 to 2030 are held constant at 2006 levels, reflecting the conflicting trends observed for the historical periods analyzed. Relative to total industrial non-combustion process emissions, CO_2 emissions from limestone and dolomite consumption are low (about 0.31 $MMtCO_2e$ in 1990, 0.32 $MMtCO_2e$ in 2005, and 1.08 $MMtCO_2e$ in 2030).

Soda Ash Consumption

Commercial soda ash (sodium carbonate) is used in many consumer products such as glass, soap and detergents, paper, textiles, and food. Carbon dioxide is also released when soda ash is consumed (see Chapter 6 of EIIP guidance document). SIT estimates historical emissions based on the state's population and national per capita soda ash consumption from the US EPA national GHG inventory. Growth in this category was estimated as a 1.01% annual decline based on 2006-2016 employment projections in the Basic Chemical Manufacturing sector for Kentucky. CO_2 emissions from soda ash consumption are low, estimated at about 0.04 $MMtCO_2e$ in 1990, 0.04 $MMtCO_2e$ in 2005, and at about0.03 $MMtCO_2e$ in 2030.

Iron and Steel Production

The SIT shows production of iron and steel in Kentucky from 1997 through 2006. The production of iron and steel generate process-related CO_2 emissions. Iron is produced by reducing iron ore with metallurgical coke in a blast furnace to produce pig iron; this process emits CO_2 emissions. Pig iron is used as a raw material in the production of steel. The production of metallurgical coke from coking coal produces CO_2 emissions as well.

The EPA SIT methodology was used to estimate Kentucky's CO_2 emissions from iron and steel production (see Table D1). The basic activity data needed are the quantities of crude steel produced (defined as first cast product suitable for sale or further processing) by production method. Default SIT emission factors of 0.08 $MtCO_2$ per Mt, 1.46 $MtCO_2$ per Mt, and 1.72 $MtCO_2$ per Mt production were used for EAF steel production from scrap metal, BOF production without coke ovens, and BOF production with coke ovens, respectively. Emissions estimated for 1997 were also applied to the years 1990-1996 since the production data were missing for those years. As shown in Figure D2 and Table D3, emissions in 1990 were 2.4 $MMtCO_2e$ and are projected to increase slightly to about 2.7 $MMtCO_2e$ in 2030. No growth was assumed for iron and steel emissions from 2007 to 2030 due to anomalously large historical growth rates for a limited historical period in combination with a conflicting projected decline in Kentucky Primary Metals employment.

under the methods for the agricultural sector), and (3) limestone used in cement production (which is counted in the methods for cement production).

Ammonia Production/Urea Application

Ammonia (NH_3) and urea ($(NH_2)_2CO$) are both synthetically created chemicals with a wide variety of uses. Ammonia is primarily used as a fertilizer, though it also has applications as a refrigerant, a disinfectant, and in the production of chemicals such as urea and nitric acid. Ammonia production involves the conversion of a fossil fuel hydrocarbon into pure hydrogen, which is then combined with nitrogen to create NH_3. This process involves the release of carbon dioxide as a byproduct. Urea, a different type of synthetic chemical, is also primarily used as a fertilizer, though it is also used commercially in several industrial and chemical processes. Urea is created by a chemical process with ammonia as a key component.

The default production and consumption data in SIT show no ammonia production in Kentucky over the historical period. Emissions from urea application are estimated to be fairly low at 0.011 $MMtCO_2e$ in 1990, decreasing to 0.007 in 2005, and increasing slightly to 0.008 by 2030. and decreased to 0.49 $MMtCO_2e$ in 2005 (see blue line in Figure D2). A decline in growth of 0.41% annually from 2007 to 2030 was applied based on the smallest historical annual decline in state consumption from each of three periods analyzed.

Substitutes for Ozone-Depleting Substances (ODS)

HFCs and PFCs are used as substitutes for ODS, most notably CFCs (CFCs are also potent warming gases, with global warming potentials on the order of thousands of times that of CO_2 per unit of emissions) in compliance with the *Montreal Protocol* and the *Clean Air Act Amendments of 1990*.[45] Even low amounts of HFC and PFC emissions, for example, from leaks and other releases associated with normal use of the products, can lead to high GHG emissions on a CO_2e basis. Emissions in Kentucky from this sector are estimated to have increased from 0.01 $MMtCO_2e$ in 1990 to about 1.5 $MMtCO_2e$ in 2005, and to further increase to 6.3 $MMtCO_2e$ in 2030. The projected rates of increase for these emissions are based on projections for national emissions from the US EPA report referenced in Table D2.

Electric Power Transmission and Distribution

Emissions of SF_6 from electrical equipment have experienced declines since the mid nineties, mostly due to voluntary action by industry. Sulfur hexafluoride is used as an electrical insulator and interrupter in the electric power T&D system. The largest use for SF_6 is as an electrical insulator in electricity T&D equipment, such as gas-insulated high-voltage circuit breakers, substations, transformers, and transmission lines, because of its high dielectric strength and arc-quenching abilities. Not all of the electric utilities in the US use SF_6; use of the gas is more common in urban areas where the space occupied by electric power T&D facilities is more valuable.[46]

[45] As noted in EIIP Chapter 6, ODS substitutes are primarily associated with refrigeration and air conditioning, but also many other uses including as fire control agents, cleaning solvents, aerosols, foam blowing agents, and in sterilization applications. The applications, stocks, and emissions of ODS substitutes depend on technology characteristics in a range of equipment types. For the US national inventory, a detailed stock vintaging model was used to track ODS substitutes uses and emissions, but this modeling approach has not been completed at the state level.

[46] US EPA, Draft User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF_6 Emissions from Industrial Processes Using the State Inventory Tool, prepared by ICF International, March 2007.

As shown in Figure D2 and Table D3, SF_6 emissions from electric power T&D are about 0.60 $MMtCO_2e$ in 1990 and decrease to about 0.34 $MMtCO_2e$ in 2005. Emissions further decrease t about 0.26 $MMtCO_2e$ in 2030. Emissions in Kentucky from 1990 to 2006 were estimated based on the estimates of emissions per kilowatt-hour (kWh) of electricity consumed from the US EPA GHG inventory, and the ratio of Kentucky's to the US electricity consumption (sales) estimates available from the Energy Information Administration's (EIA) Electric Power Annual and provided in SIT (see Table D1). The national trend in US emissions estimated for 2007-2030 for the technology-adoption scenario shows expected decreases in these emissions at the national level (see Table D2), and the same rate of decline is assumed for emissions in Kentucky. The decline in SF_6 emissions in the future reflects expectations of future actions by the electric power industry to reduce these emissions.

Aluminum Production

Emissions of tetrafluoromethane and hexafluoroethane, both PFCs, occur during the reduction of alumina in the primary smelting process. The aluminum production industry is thought to be the largest source of these two PFCs. Emissions from aluminum production are calculated in the SIT by multiplying the quantity of aluminum produced by an emission factor of 0.4255 Mt carbon equivalent per Mt aluminum produced.

The SIT shows aluminum production activity in Kentucky throughout the historical period. Emissions were then projected using national growth rates based on US national emissions for 2005-2020 for a technology adoption scenario for the aluminum production industry as indicated in Table D2. GHG emissions in Kentucky from aluminum production are estimated at 0.53 $MMtCO_2e$ in 1990, 0.46 $MMtCO_2e$ in 2005, and declining to 0.39 $MMtCO_2e$ in 2030.

Key Uncertainties

Key sources of uncertainty underlying the estimates above are as follows:

- Since emissions from industrial processes are determined by the level of production and the production processes of a few key industries—and in some cases, a few key plants—there is relatively high uncertainty regarding future emissions from the industrial processes category as a whole. Future emissions depend on the competitiveness of Kentucky manufacturers in these industries, and the specific nature of the production processes used in Kentucky. Emissions in this draft inventory were based on default activity data provided in the SIT. These data should be reviewed and modified as necessary based on actual data reported by Kentucky facilities.
- The projected largest source of future industrial emissions, HFCs and PFCs used in cooling applications, is subject to several uncertainties as well. Emissions through 2030 and beyond will be driven by future choices regarding mobile and stationary air conditioning technologies and the use of refrigerants in commercial applications, for which several options currently exist.
- Due to the lack of reasonably specific projection surrogates, historical trend data were used to project emission activity level changes for multiple industrial processes. There is significant uncertainty associated with any projection, including a projection that assumes

that past historical trends will continue in future periods. Reflecting this uncertainty, the lowest historical annual rate of increase/decrease was selected as a conservative assumption for use in projecting future activity level changes. These assumptions on growth should be reviewed by industry experts and revised to reflect their expertise on future trends especially for the cement and lime manufacture, iron and steel production, magnesium casting, and taconite production industries.

- For the industries for which EPA default activity data and methods were used to estimate historical emissions, future work should include efforts to obtain state-specific data to replace the default assumptions.
- For the electricity T&D and semiconductor industries, future efforts should include a survey of companies within these industries to determine the extent to which they are implementing techniques to minimize emissions to improve the emission projections for these industries.

Appendix E. Fossil Fuel Industries

Overview

The inventory for this subsector of the Energy Supply sector includes methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) emissions associated with the production, processing, transmission, and distribution of fossil fuels in Kentucky.[47] In 2007, emissions from the subsector accounted for an estimated 7.64 million metric tons (MMt) of CO_2 equivalent (CO_2e) of total gross greenhouse gas (GHG) emissions in Kentucky, and are estimated to decrease to 6.90 MMtCO_2e by 2030.

Emissions and Reference Case Projections

Oil and Gas Production

In 2007, Kentucky's crude oil production totaled 7,000 barrels (bbls) per day, accounting for only 0.1% of US production. The peak year of oil production in Kentucky was 1983 (22,000 bbls per day). Production steadily declined until 2000 and has remained relative stable since.[48] Proved crude oil reserves are 24 million bbls, which is also 0.1% of the US total.[49] Though Kentucky has only minor oil production, it is home to two operating petroleum refineries located in Catlettsburg and Somerset. Both of these primarily process petroleum received from out of state: Catlettsburg from the Gulf Coast and Somerset from neighboring states. The crude oil distillation capacity between the two facilities is 231,500 bbls per day.[50]

Kentucky is also responsible for about 1% of the Nation's natural gas production, the majority of which originates in the Big Sandy field located in eastern portion of the State. In 2007, Kentucky consumed approximately 230 billion cubic feet (Bcf) of natural gas while it produced only 95 Bcf. The majority of the difference was supplied by pipeline from the Gulf Coast. Industry is responsible for about 50% of the natural gas consumption in the State.[50]

The vast majority (99%) of Kentucky's oil and gas emissions comes from the natural gas sector, predominantly in the production and transportation of natural gas through the State's transmission pipelines. Historically, pipeline fuel consumption was the leading contributor; however, there has been a steep decline in this subsector since the mid-1990s and it now accounts for only 17% of natural gas emissions.

Oil and Gas Industry Emissions

Emissions can occur at several stages of production, processing, transmission, and distribution of oil and gas. Based on the information provided in the Emission Inventory Improvement Program

[47] Note that emissions from natural gas consumed as lease fuel (used in well, field, and lease operations) and plant fuel (used in natural gas processing plants) are included in Appendix B in the industrial fuel combustion category.
[48] US Department of Energy (DOE), Energy Information Administration (EIA), "Crude Oil Production", accessed from http://tonto.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm, December 2009.
[49] US DOE, EIA, "Crude Oil Proved Reserves, Reserves Changes, and Production," accessed from http://tonto.eia.doe.gov/dnav/pet/pet_crd_pres_dcu_SKY_a.htm, December 2009.
[50] "State Energy Profiles: Kentucky", US DOE, EIA website, accessed from http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=KY, December 2009.

(EIIP) guidance[51] for estimating emissions for this sector, transmission pipelines are large diameter, high-pressure lines that transport gas from production fields, processing plants, storage facilities, and other sources of supply over long distances to local distribution companies or to large volume customers. Sources of CH_4 emissions from transmission pipelines include leaks, compressor fugitives, vents, and pneumatic devices. Distribution pipelines are extensive networks of generally small diameter, low-pressure pipelines that distribute gas within cities or towns. Sources of CH_4 emissions from distribution pipelines are leaks, meters, regulators, and mishaps. Carbon dioxide, CH_4, and N_2O emissions occur as the result of the combustion of natural gas by internal combustion engines used to operate compressor stations.

With nearly 16,600 active gas-producing wells in the state, 4 operational gas processing plants, and more than 24,000 miles of gas pipelines, there are significant uncertainties associated with estimates of Kentucky's GHG emissions from this sector. This is compounded by the fact that there are no regulatory requirements to track GHG emissions. Therefore, estimates based on emissions measurements in Kentucky are not possible at this time.

The EPA's State Greenhouse Gas Inventory Tool (SIT) facilitates the development of a rough estimate of state-level GHG emissions. GHG emission estimates are calculated by multiplying emissions-related activity levels (e.g., miles of pipeline, number of compressor stations) by aggregate industry-average emission factors. Key information sources for the activity data are the US Department of Energy's Energy Information Administration (EIA)[52] and the US Department of Transportation's Office of Pipeline Safety (OPS).[53] Emissions were estimated using the SIT, with reference to methods/data sources outlined in the EIIP guidance document for natural gas and oil systems.[54] Emissions of CO_2, CH_4, and N_2O associated with pipeline natural gas combustion were estimated using SIT emission factors[55] and Kentucky's 1990-2007 natural gas data from EIA for the "consumed as pipeline fuel" category.[56]

Unfortunately OPS has not collected data from pipeline operators using a consistent set of reporting requirements over the 1990-2007 analysis period. In particular, OPS has only required operators to report state-level data for their transmission/gathering pipelines since 2001 and state-level data for their distribution pipelines since 2004. Before these dates, a number of Kentucky pipeline records report data as multi-state totals. To estimate a complete time-series of natural gas transmission/gathering pipeline data, CCS compiled surrogate data to back-cast the 2001 transmission/gathering pipeline mileage and the 2004 distribution pipeline mileage/service counts for each year back to 1990.

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[51] Emission Inventory Improvement Program, Volume VIII: Chapter 5. "Methods for Estimating Methane Emissions from Natural Gas and Oil Systems," August 2004.
[52] US DOE, EIA website, http://www.eia.doe.gov/, December 2009.
[53] US Department of Transportation, Office of Pipeline Safety, "Distribution, Transmission and Liquid Annual Data," accessed from http://ops.dot.gov/stats/DT98.htm, December 2009.
[54] Emission Inventory Improvement Program, Volume VIII: Chapter. 5. "Methods for Estimating Methane Emissions from Natural Gas and Oil Systems", August 2004.
[55] GHG emissions were calculated using SIT, with reference to *EIIP, Volume VIII*: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels," August 2004, and Chapter 2 "Methods for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion," August 2004.
[56] US DOE, EIA, *State Energy Consumption, Price, and Expenditure Estimates (SEDS)*, accessed from http://www.eia.doe.gov/emeu/states/_seds.html, December 2009.

Coal Mining Emissions
Methane occurs naturally in coal seams, and is typically vented during mining operations for safety reasons. Coal mine methane emissions are usually considerably higher, per unit of coal produced, from underground mining than from surface mining. Underground coal mines continue to emit CH_4 the mines have been abandoned or shut down. The rate of CH_4 emitted decreases over time, and is also affected by factors such as gas content and characteristics of coal, flooding, CH_4 flow capacity of the mine, the presence of vent holes, and mine seals.

Kentucky had 417 operational coal mines (more than any other state), which together produced more than 115 million short tons of coal in 2007.[57] Of Kentucky's 417 coal mines in 2007, 201 were underground and 216 were surface mines. This inventory includes CH_4 emissions from operational coal mines as reported by the US EPA, and includes emissions from underground coal mines, surface mines, and post-mining activities.[58]

Table E1 provides an overview of data sources and approaches used to develop fossil fuel sector emission estimates for Kentucky, including a description of the surrogate data that were used to back-cast natural gas transmission/gathering and distribution pipeline mileage data for the historical analysis period.

Emission Forecasts
Table E1 provides an overview of data sources and approaches used to develop projected fossil fuel sector emission estimates for Kentucky. The approach to forecasting sector emissions/activity consisted of compiling and comparing two alternative sets of annualized growth rates for each emissions activity – one using Annual Energy Outlook (AEO) 2009 forecast data for each 5-year time-frame over the 2007-2030 analysis period (except the final time period which includes 2022 to 2030), and the other using the historical 1990-2007 activity data for each of 3 periods (i.e., 1990 to 2007, 1995 to 2007, and 2000 to 2007). Because available AEO forecast information is for a broad region that may not reflect Kentucky-specific trends (e.g., AEO forecasts of natural gas production are for the East South Central Region, which includes 3 states in addition to Kentucky), the AEO forecast growth rates were only used when they were in-line with the Kentucky historical growth rates. Therefore, some oil and gas production sector projections are based on state-level historical activity/emissions trends. In cases where of each the three historical periods indicated continual growth or decline, the period with the smallest annual rate of growth/decline was used in the projection. This conservative assumption was adopted because of the uncertainty associated with utilizing historical trends to estimate future emission activity levels.

It is important to note that potential improvements to production, processing, and pipeline technologies that could result in GHG emissions reductions are generally not accounted for in the projections analysis.

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[57] *Annual Coal Report 2008, Preliminary Release*, DOE/EIA-0584 (2008), "Table 1. Coal Production and Number of Mines by State and Mine Type, 2008-2007," US DOE, EIA, September 2009, http://www.eia.doe.gov/cneaf/coal/page/acr/table1.html.
[58] US Environmental Protection Agency, "Inventory Of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007", April 2009

Table E1. Approach to Estimating Historical/Projected Emissions from Fossil Fuel Systems

	Approach to Estimating Historical Emissions		**Surrogate Data Used to Backcast Activity to 1990**	**Forecasting Approach**
Activity	***Required SIT Data***	***Data Source***		***Projection Assumption***
Natural Gas Production	Number of gas/ associated wells	Gas wells - EIA[59]		Annual growth rate (1.84%) based on smallest annualized increase in the number of natural gas wells from each of 3 periods analyzed (1995-2007).
Natural Gas Processing	Number of gas processing plants	*Oil and Gas Journal*[60]		Assumed no growth because last 9 years of data show nearly constant number of gas processing plants (excluding anomaly in 2002).
Natural Gas Transmission	Miles of gathering pipeline	Office of Pipeline Safety[53]	KY natural gas production as reported by EIA[61]	Used AEO 2009[62] East South Central natural gas flows projections since annual decline over forecast period (-0.70%) is in-line with long-term historical KY transmission emissions trend.
	Miles of transmission pipeline		Average of volume of natural gas transported into KY and transported out of KY, from EIA[63]	
	Number of gas transmission compressor stations	EIIP[64]		
	Number of gas storage compressor stations	EIIP[65]		

[59] US DOE, EIA, "Kentucky Natural Gas Number of Gas and Gas Condensate Wells," accessed from http://tonto.eia.doe.gov/dnav/ng/hist/na1170_sky_8a.htm, December 2009.
[60] PennWell Corporation, "Worldwide Gas Processing," *Oil and Gas Journal* (1990-2007 June/July issues).
[61] US DOE, EIA, "Natural Gas Withdrawals and Production," accessed from http://tonto.eia.doe.gov/dnav/ng/ng_prod_sum_a_EPG0_FPD_mmcf_a.htm, December 2009.
[62] US DOE, Energy Information Administration, "Annual Energy Outlook 2009 with Projections to 2030," accessed from http://www.eia.doe.gov/oiaf/archive/aeo09/index.html, December 2009.
[63] US DOE, EIA, "International & Interstate Movements of Natural Gas by State," accessed from http://tonto.eia.doe.gov/dnav/ng/ng_move_ist_a2dcu_nus_a.htm, December 2009.
[64] Number of gas transmission compressor stations = miles of transmission pipeline x 0.006 – EIIP, Volume VIII: Chapter 5, March 2005.
[65] Number of gas storage compressor stations = miles of transmission pipeline x 0.0015 EIIP. Volume VIII: Chapter 5, March 2005.

Table E1. Approach to Estimating Historical/Projected Emissions from Fossil Fuel Systems (continued)

Activity	Approach to Estimating Historical Emissions: *Required SIT Data*	Approach to Estimating Historical Emissions: *Data Source*	Surrogate Data Used to Backcast Activity to 1990	Forecasting Approach: *Projection Assumption*
Natural Gas Distribution	Miles of distribution pipeline by pipeline material type; Total number of services; Number of unprotected steel services; Number of protected steel services	Office of Pipeline Safety[53]	Sum of industrial, residential and commercial KY natural gas consumers, from EIA[66]	Used AEO 2009 East South Central natural gas consumption projections since annual growth over forecast period (0.69%) is in-line with long-term historical KY distribution emissions trend.
Natural Gas Pipeline Fuel Use (CO_2, CH_4, N_2O)	Volume of natural gas consumed by pipelines	EIA[56]		Assumed no growth due to volatility in historical data and inconsistency with AEO 2009 projections.
Oil Production	Annual production	EIA[67]		Annual growth rate (2.27%) based on smallest annualized increase in historical oil production from each of 3 periods analyzed (1995-2007).
Oil Refining	Annual volume refined	EIA[68]		Annual rate of decline (-0.07%) based on smallest annualized decrease in historical oil refining from each of 3 periods analyzed (1990-2007).
Oil Transport	Annual volume transported	Unavailable (per SIT, assumed oil refined = oil transported)		(same as oil refining)
Coal Mining	Methane emissions in million cubic feet	US EPA[16]		Used AEO Central Appalachia coal production projections since annual decline over forecast period (-1.95%) is in-line with long-term historical KY coal mining emissions trend.

66 US DOE, EIA, "Number of Natural Gas Consumers," accessed from http://tonto.eia.doe.gov/dnav/ng/ng_cons_num_a_EPG0_VN3_Count_a.htm . December 2009.

67 US DOE, EIA, "Annual Kentucky Field Production of Crude Oil," accessed from http://tonto.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=mcrfpky1&f=A, December 2009.

68 Refining is assumed to be equal to the total input of crude oil into PADD II times the ratio of Kentucky's refining capacity to PADD II's total refining capacity. No data for 1996 and 1998, so linear interpolation used to estimate values in these years. Data are from US DOE, EIA, "Petroleum Navigator." PADD capacity data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/8_na_8do_r20_4a.htm. PADD crude input data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=mgirip22&f=A. State capacity data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/8_na_8do_sky_4a.htm, December 2009.

Results

Table E2 displays the estimated emissions from the fossil fuel industry in Kentucky for select years over the period 1990 to 2030. Emissions from this sector declined by 10% from 1990 to 2007 and are projected to decline by an additional 10% between 2007 and 2030. Natural gas production and transmission and coal mining are the major contributors to both recent historic and future year emissions.

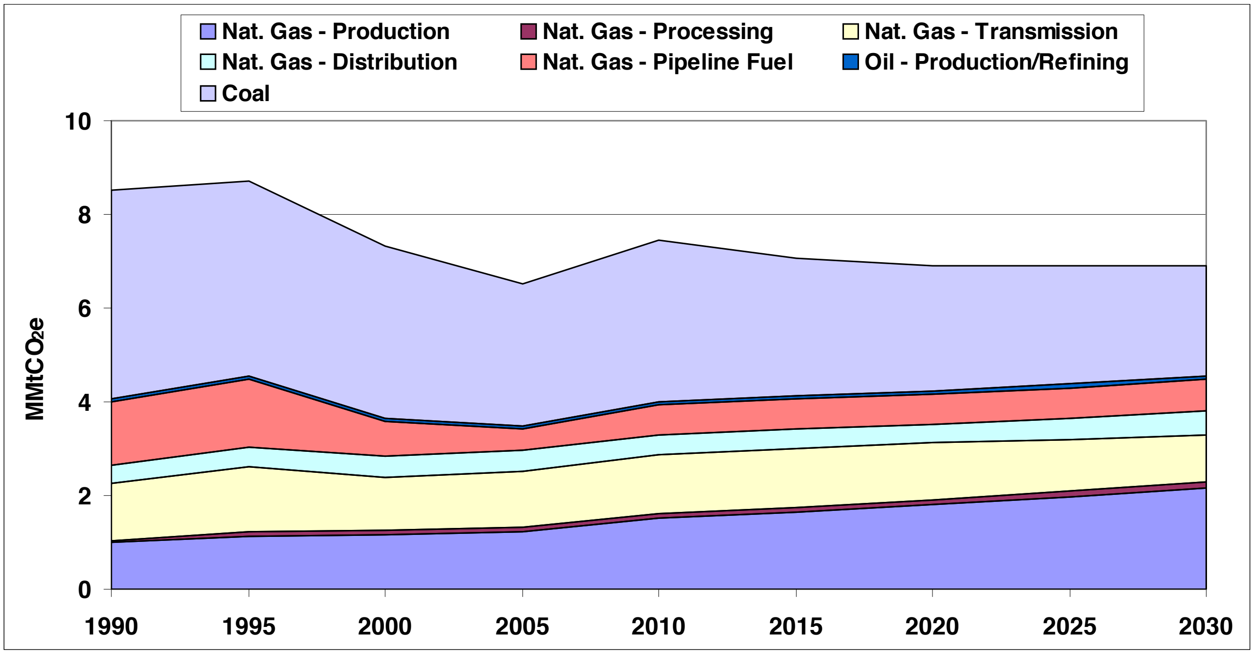
Table E2. Historical and Projected Emissions for the Fossil Fuel Industry

(Million Metric Tons CO_2e)	1990	1995	2000	2005	2007	2010	2015	2020	2025	2030
Fossil Fuel Industry	8.51	8.70	7.33	6.50	7.64	7.46	7.05	6.91	6.91	6.90
Natural Gas Industry	4.00	4.49	3.59	3.43	3.83	3.95	4.06	4.17	4.30	4.47
Production	*0.99*	*1.13*	*1.16*	*1.22*	*1.43*	*1.51*	*1.65*	*1.81*	*1.98*	*2.17*
Processing	*0.05*	*0.08*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*	*0.10*
Transmission	*1.23*	*1.41*	*1.12*	*1.20*	*1.21*	*1.26*	*1.26*	*1.21*	*1.12*	*1.01*
Distribution	*0.37*	*0.41*	*0.44*	*0.45*	*0.44*	*0.42*	*0.40*	*0.40*	*0.45*	*0.54*
Flaring	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Pipeline Fuel	*1.36*	*1.46*	*0.76*	*0.45*	*0.65*	*0.65*	*0.65*	*0.65*	*0.65*	*0.65*
Oil Industry	0.08	0.06	0.06	0.05	0.05	0.05	0.06	0.06	0.07	0.08
Production	*0.07*	*0.05*	*0.05*	*0.04*	*0.04*	*0.04*	*0.05*	*0.05*	*0.06*	*0.07*
Refining	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Coal Mining	4.43	4.15	3.68	3.03	3.75	3.46	2.93	2.67	2.53	2.35

Note: CCS calculations based on approach described in text.

Figure E1 displays process-level emission trends from the fossil fuel industry, on an $MMtCO_2e$ basis.

Figure E1. Fossil Fuel Industry Emission Trends (MMtCO$_2$e)



Source: CCS calculations based on approach described in text.

Key Uncertainties

Key sources of uncertainty underlying the estimates above are as follows:

- Current levels of fugitive emissions. These are based on industry-wide averages, and until estimates are available for local facilities, significant uncertainties remain.
- Due to data limitations associated with OPS reporting, natural gas distribution, gathering, and transmission pipeline emissions in earlier years were estimated by assuming that changes in each emissions producing activity were related to changes in activity levels for surrogates for the emissions activity.[69]
- Because pipeline emissions are a function of both pipeline mileage/service counts and the type of pipeline material (e.g., plastic vs. cast iron), this approach does not account for emissions changes that would have occurred from any changes in pipeline material between 1990 and 2004.
- Projections of future production of fossil fuels. The assumptions used for the projections do not reflect all potential future changes that could affect GHG emissions, including potential changes in regulations and emissions-reducing improvements in oil and gas production, processing, and pipeline technologies.

[69] For example, gathering pipeline emissions were back-cast to pre-2001 years by applying the ratio of Kentucky natural gas production in each pre-2001 year to Kentucky natural gas production in 2001.

Appendix F. Agriculture

Overview

The emissions discussed in this appendix refer to non-energy methane (CH_4) and nitrous oxide (N_2O) emissions from both livestock and crop production. These include emissions and sinks of carbon dioxide (CO_2) in agricultural soils. Energy emissions related to agricultural practices (combustion of fossil fuels to power agricultural equipment) are included in the residential, commercial, and industrial (RCI) fuel consumption sector estimates (see Appendix B). The primary GHG sources and sinks - livestock production and crop production are further subdivided as follows:

- *Livestock production – enteric fermentation:* CH_4 emissions from enteric fermentation are the result of normal digestive processes in ruminant and non-ruminant livestock. Microbes in the animal digestive system break down food and emit CH_4 as a by-product. More CH_4 is produced in ruminant livestock because of digestive activity in the large fore-stomach.
- *Livestock production – manure management:* CH_4 and N_2O emissions from the storage and treatment of livestock manure (e.g., in compost piles or anaerobic treatment lagoons) occur as a result of manure decomposition. The environmental conditions of decomposition drive the relative magnitude of emissions. In general, the more anaerobic the conditions are, the more CH_4 is produced because decomposition is aided by CH_4-producing bacteria that thrive in oxygen-limited conditions. In contrast, N_2O emissions are increased under aerobic conditions.
  Emission estimates from manure management are based on manure that is stored and treated on livestock operations (e.g. dairies, feedlots, swine operations). Emissions from manure deposited directly on land by grazing animals and emissions from manure that is applied to agricultural soils as an amendment are accounted for in the next sector.
- *Livestock production, agricultural soils – livestock:* this source sector covers N_2O emissions resulting from animal excretions directly on agricultural soils (e.g. pasture, paddock or range) or manure spreading on agricultural soils.
- *Crop production, agricultural soils – fertilizers:* The management of agricultural soils can result in N_2O emissions and net fluxes of CO_2 (causing emissions or sinks). In general, soil amendments that add nitrogen to soils can also result in N_2O emissions. Nitrogen additions drive the underlying soil nitrification and de-nitrification cycle, which produces N_2O as a by-product.
  The emissions estimation methodologies used in this inventory account for several sources of N_2O emissions from agricultural soils, including decomposition of crop residues, synthetic and organic fertilizer application, manure application, sewage sludge application, nitrogen fixation, and histosols (high organic soils, such as wetlands or peatlands) cultivation (see additional agricultural soils subsectors below).
  Both direct and indirect emissions of N_2O occur from the application of manure, fertilizer, and sewage sludge to agricultural soils. Direct emissions occur at the site of application and indirect emissions occur when nitrogen leaches to groundwater or in surface runoff and enters the nitrification/denitrification cycle.

- *Crop production, agricultural soils – crops:* this source sector covers N_2O emissions from decomposition of crop residues, production of nitrogen fixing crops, and the cultivation of histosols.
- *Crop production, agricultural soils – liming:* the practice of adding limestone and dolomite to agricultural soils (for neutralizing acidic soil conditions) results in CO_2 emissions.
- *Crop production, agricultural soils – rice cultivation:* CH_4 emissions occur during rice cultivation; however, rice is not grown in Kentucky.
- *Crop production, agricultural soils – soil carbon:* the net flux of CO_2 in agricultural soils depends on the balance of carbon losses from management practices and gains from organic matter inputs to the soil. Carbon dioxide is absorbed by plants through photosynthesis and ultimately becomes the carbon source for organic matter inputs to agricultural soils. When inputs are greater than losses, the soil accumulates carbon and there is a net sink of CO_2 into agricultural soils. In addition, soil disturbance from the cultivation of histosols releases large stores of carbon from the soil to the atmosphere in the form of CO_2 (Note: N_2O emissions from cultivation of histosols are covered under the *Agricultural soils - crops* sector above).
- *Crop production, residue burning:* CH_4 and N_2O emissions are produced when crop residues are burned (CO_2 is emitted as well, however, since the source of carbon is biogenic, these emissions are not included in the inventory).

Emissions and Reference Case Projections

Inventory Data

GHG emissions for 1990 through 2006 were estimated using the United States Environmental Protection Agency's (US EPA) State Inventory Tool (SIT) software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for the sector.[70] In general, the SIT methodology applies emission factors developed for the US to activity data for the agriculture sector. Activity data include livestock population statistics, amounts of fertilizer applied to crops, and trends in manure management practices. This methodology is based on international guidelines developed by sector experts for preparing GHG emissions inventories.[71]

Data on crop production in Kentucky from 1990 to 2006 and on the number of animals in the state from 1990 to 2006 were obtained from the United States Department of Agriculture (USDA), National Agriculture Statistical Service (NASS) and incorporated as defaults in SIT.[72] The default SIT manure management system assumptions for each livestock category were used for this inventory. SIT data on fertilizer usage came from *Commercial Fertilizers*, a report from

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[70] GHG emissions were calculated using SIT, with reference to Emission Inventory Improvement Program, Volume VIII: Chapter 8. "Methods for Estimating Greenhouse Gas Emissions from Livestock Manure Management", August 2004; Chapter 10. "Methods for Estimating Greenhouse Gas Emissions from Agricultural Soil Management", August 2004; and Chapter 11. "Methods for Estimating Greenhouse Gas Emissions from Field Burning of Agricultural Residues", August 2004.

[71] Revised 1996 1ntergovermental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories, published by the National Greenhouse Gas Inventory Program of the IPCC, available at (http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm); and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, published in 2000 by the National Greenhouse Gas Inventory Program of the IPCC, available at: (http://www.ipcc-nggip.iges.or.jp/public/gp/english/).

[72] USDA, NASS (http://www.nass.usda.gov/Statistics_by_State/Kentucky/index.asp).

the Fertilizer Institute. Details for each of the livestock and crop production subsectors are provided below.

Livestock production – enteric fermentation. SIT default data on livestock populations are taken from the USDA NASS and are available from 1990-2006. Methane emission factors specific to each type of animal by region (e.g. dairy cattle, beef cattle, sheep, goats, swine, and horses) are provided in SIT.

Livestock production – manure management. The same population data used above for enteric fermentation are also used as input to estimate CH_4 and N_2O emissions from manure management. Population estimates are multiplied by an estimate for typical animal mass and a volatile solids (VS) production rate to estimate the total VS produced. The VS estimate for each animal type is then multiplied by a maximum potential CH_4 emissions factor and a weighted CH_4 conversion factor to derive total CH_4 emissions. The methane conversion factor adjusts the maximum potential methane emissions based on the types of manure management systems employed in Kentucky.

Nitrous oxide emissions are derived using the same animal population estimates above multiplied by the typical animal mass and a total Kjeldahl nitrogen (K-nitrogen) production factor. The total K-nitrogen is multiplied by a non-volatilization factor to determine the fraction that is managed in manure management systems. The unvolatilized portion is then divided into fractions that get processed in either liquid (e.g. lagoons) or solid waste management systems (e.g. storage piles, composting). Each of these fractions is then multiplied by an N_2O emission factor, and the results summed, to estimate total N_2O emissions.

Livestock and Crop Production, agricultural soils - fertilizers, crops, and livestock. The fertilizers subsector covers direct and indirect N_2O emissions from the application of synthetic and organic fertilizers. The crops subsector covers N_2O emissions from nitrogen fixing crops, decomposition of crop residues, and cultivation of high organic content soils (histosols). The livestock subcategory covers N_2O emissions from animal excretions directly onto the land area or from manure applied to soils as an amendment.

Emissions of N_2O occur naturally as part of the nitrogen cycle. However, various soil management practices have significantly increased the amount of N_2O going into the atmosphere. There are three source categories of nitrous oxide emissions from soil management. The first is direct emissions from agricultural cropping practices, which occur at the site primarily through applications of fertilizer or decomposition of crop residues, cultivation of histosols, and through the production of nitrogen fixing crops. Data inputs used to calculate the direct emissions from agricultural cropping practices include:

1. The amount of nitrogen applied to the soil through fertilizers (synthetic and organic);
2. Animal population, mass and N emitted per unit of animal mass;
3. Amount of manure intentionally applied to soils;
4. Amount of residue left on cropland and the N content of such residues; and
5. Acreage of histosols cultivated (these data were not available for Kentucky).

A variety of factors can influence the amount of N_2O produced through these agricultural cropping practices, such as temperature, water content, soil pH, etc.

Another direct emissions source of N_2O from agricultural soils comes from animal excretions directly onto the land area (e.g. pasture, paddock, or range). This requires data on animal population, mass and N emitted per unit of animal mass, as well as the amount of manure left on the soil.

Emissions of N_2O can also occur on an indirect basis from nitrogen applied to soils. These emissions occur through the volatilization of ammonia and oxides of nitrogen, which can then be re-deposited, enter the nitrification/denitrification cycle, and be emitted as N_2O in another location; or through leaching/runoff of N, which can enter the nitrification/denitrification cycle on or off-site, and then be emitted as N_2O. To calculate these emissions, the data used above on nitrogen inputs from fertilizers and animals to crop soils are used again along with factors on the fraction of nitrogen volatilized (10% for synthetic fertilizers and 20% for organic fertilizer nitrogen), and an IPCC-based emission factor for N_2O emissions from the re-deposited nitrogen (0.01 kg N_2O-N/kg N re-deposited).

Data on crop production in Kentucky from 1990 to 2006 from the USDA NASS were used to calculate N_2O emissions from crop residues and crops that fix nitrogen, as well as CH_4 emissions from agricultural residue burning. Emissions for the other agricultural crop production practices categories (i.e., synthetic and organic fertilizers) were also calculated through 2006.

Data were not available to estimate nitrogen released by the cultivation of histosols (i.e., the number of acres of high organic content soils). However, as discussed in the following section for soil carbon, the Natural Resources Ecology Laboratory at Colorado State University estimated zero CO_2 emissions for organic soils in Kentucky for 1997, suggesting that the area of cultivated high organic content soils was either very small or zero in Kentucky. Therefore, N_2O emissions from cultivated histosol soils were also assumed to be zero.

Crop production – liming. Additions of lime for pH adjustment and urea fertilizer to soils release carbon dioxide as these compounds are decomposed. Data on limestone and dolomite application from 1990-2004 were available from the Land-Use Change and Forestry Module of SIT. The SIT emission factor of 0.06 Mt C/Mt limestone/dolomite was used to estimate CO_2 emissions. Limestone/dolomite application data are not specific to land use; however, CCS assumed that the applications were all applied to agricultural soils. Data specific to urea application were not readily available; hence, the emissions are not captured in this inventory. The data in SIT are provided in terms of total commercial fertilizer N applied.

Crop production – rice cultivation. Methane emissions occur during rice cultivation as a result of the anaerobic decomposition of organic materials in flooded fields. No rice cultivation occurs in Kentucky.

Crop production – soil carbon. Net carbon fluxes from agricultural soils have been estimated by researchers at the Natural Resources Ecology Laboratory at Colorado State University, and are reported in the *U.S. Inventory of Greenhouse Gas Emissions and Sinks*[73] and the *U.S. Agriculture and Forestry Greenhouse Gas Inventory*. The estimates are based on the Intergovernmental Panel on Climate Change (IPCC) methodology for soil carbon adapted to conditions in the US. Preliminary state-level estimates of CO_2 fluxes from mineral soils and emissions from the cultivation of organic soils were reported in the *U.S. Agriculture and*

[73] *U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2006* (and earlier editions), US Environmental Protection Agency, Report # 430-R-06-002, April 2006. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

Forestry Greenhouse Gas Inventory. Currently, these are the best available data at the state-level for this category. The inventory also reports national estimates of CO_2 emissions from limestone and dolomite application from the United States Geological Survey (USGS).[74] However, these are now included above under the *Agricultural soils – liming* subsector.

Carbon dioxide fluxes resulting from specific management practices were reported. These practices include: conversions of cropland resulting in either higher or lower soil carbon levels; additions of manure; participation in the Federal Conservation Reserve Program (CRP); and cultivation of organic soils (with high organic carbon levels). For Kentucky, Table F2 shows a summary of the latest estimates available from the USDA, which are for 1997.[75] These data show that changes in agricultural practices are estimated to result in a net sink of 1.14 $MMtCO_2e$/yr in Kentucky. Since data are not yet available from USDA to make a determination of whether the emissions are increasing or decreasing, the net sink of 1.14 $MMtCO_2e$/yr is assumed to remain constant.

Note that emissions from agricultural soils estimated using the SIT were multiplied by a national adjustment factor to reconcile differences between methodologies used in EPA's National Inventory of Greenhouse Gas Emissions and the SIT. The national adjustment factor varies substantially from year to year resulting in the introduction of noise into the agricultural soils categories. The Agriculture, Forestry and Waste Technical Working Group should discuss whether the National Adjustment Factor should be applied in the Kentucky Inventory and Forecast.

Crop production – residue burning. Agricultural residue burning is conducted in Kentucky. The default SIT method was used to calculate emissions along with NASS crop production data through 2006. The SIT methodology calculates emissions by multiplying the amount (e.g., bushels or tons) of each crop produced by a series of factors to calculate the amount of crop residue produced, the resultant dry matter, the carbon/nitrogen content of the dry matter, the fraction of dry matter burned, the combustion efficiency, and emission factors for N_2O and CH_4. Future work on this category should include an assessment to refine the SIT default assumptions.

Reference Case Projections

Future reference case emissions from both livestock and crop production were estimated based on the annual growth rate in emissions [million metric ton (MMt) carbon dioxide equivalent (CO_2e) basis] for each source sector from 1990 to 2006. For livestock production, the default data in SIT accounting for the percentage of each livestock category using each type of manure management system was used for this inventory.

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[74] State-level annual application rates of limestone and dolomite to agricultural purposes were provided from the Minerals Yearbook "Crushed Stone" from the USGS website: http://minerals.er.usgs.gov/minerals/pubs/commodity/stone_crushed/.

[75] *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2001*. Global Change Program Office, Office of the Chief Economist, US Department of Agriculture. Technical Bulletin No. 1907, 164 pp. March 2004. http://www.usda.gov/oce/global_change/gg_inventory.htm; the data are in appendix B table B-11. The table contains two separate IPCC categories: "carbon stock fluxes in mineral soils" and "cultivation of organic soils." The latter is shown in the second to last column of Table F2. The sum of the first nine columns is equivalent to the mineral soils category.

Table F1 shows the annual growth rates applied to estimate the reference case projections by agricultural sector. Emissions from enteric fermentation and agricultural soils were projected based on the annual growth rate in historical emissions ($MMtCO_2e$ basis) for these categories in Kentucky for 1990 to 2006.

Table F1. Growth Rates Applied for the Agricultural Sector

Agricultural Category	Growth Rate	Basis for Annual Growth Rate*
Enteric Fermentation	-0.03%	Historical emissions for 1990-2006.
Manure Management	-0.9%	Historical emissions for 1990-2006.
Agricultural Burning	0.9%	Historical emissions for 1990-2006.
Agricultural Soils – Direct Emissions		
Fertilizers	-1.0%	Historical emissions for 1990-2006.
Crop Residues	-0.3%	Historical emissions for 1990-2005. 2005 was used instead of 2006, because that year is seen as an outlier.
Nitrogen-Fixing Crops	-0.9%	Historical emissions for 1990-2005. 2005 was used instead of 2006, because that year is seen as an outlier.
Histosols	n/a	Not included in inventory.
Livestock	-1.7%	Historical emissions for 1990-2006.
Agricultural Soils – Indirect Emissions		
Fertilizers	-0.7%	Historical emissions for 1990-2006.
Livestock	-3.1%	Historical emissions for 1990-2006.
Leaching/Runoff	-1.3%	Historical emissions for 1990-2006.

* Compound annual growth rates shown in this table were calculated using the growth rate in historical emissions ($MMtCO_2e$ basis) from 1990 through the most recent year of data. These growth rates were applied to forecast emissions from the latest year of inventory data to 2025.

The growth rates for enteric fermentation and manure management are driven by livestock populations and manure management methods. From 1990 through 2006, dairy cattle populations declined by about 45%. The growth rate for beef cattle during the 16-year period from 1990 through 2006 was 5%. The swine population in Kentucky declined about 65% from 1990 through 2006. The growth rates shown in Table F1 are calculated using the trend in emissions from 1990 through 2006 associated with the historical livestock populations and default SIT assumptions on manure management systems used in Kentucky. Future work should include an evaluation to improve the growth rates used for the reference case projections (e.g. based on available studies of future agricultural activity in Kentucky). Such an evaluation should also include an assessment to improve the growth rates for forecasting emissions associated with the use of fertilizers containing nitrogen. Use of fertilizers that contain nitrogen in Kentucky indicated a total growth rate of 12% between 1990 and 2006; however, fertilizer use peaked in 2004.

Results

As shown in Figure F1, gross GHG emissions from agricultural sources range between about 7.89 and 6.59 $MMtCO_2e$ from 1990 through 2030, respectively. See Table F2 for more information on Kentucky gross GHG emissions. Enteric fermentation is the only major emissions category growing in the forecast period in Kentucky, and accounted for about 48% (3.25 $MMtCO_2e$) of total agricultural emissions in 1990 and is estimated to account for about 58% (3.16 $MMtCO_2e$) of total agricultural emissions in 2030. The manure management category, accounted for 7.1% (0.48 $MMtCO_2e$) of total agricultural emissions in 1990 and is estimated to account for about 7.5% (0.41 $MMtCO_2e$) of total agricultural emissions in 2030.

The agricultural soils category shows 1990 emissions accounting for 61% (4.15 $MMtCO_2e$) of total agricultural emissions and 2030 emissions estimated to be about 55% (3.00 $MMtCO_2e$) of total agricultural emissions. Because soil carbon is estimated to be a net sink of CO_2 in Kentucky, it is not included in the gross GHG emissions. See Table F3 for more information on soil carbon estimates. Including the CO_2 sequestration from soil carbon changes, the historic and projected emissions for the agriculture sector on a net basis would range between about 6.75 and 5.45 $MMtCO_2e$/yr from 1990 through 2030, respectively.

Table F2. Gross GHG Emissions from Agriculture 1990-2030 ($MMtCO_2e$)

Source Sector	1990	1995	2000	2005	2010	2015	2020	2025	2030
Enteric Fermentation	3.25	3.47	2.91	3.12	3.14	3.06	3.02	3.04	3.16
Manure Management	0.48	0.52	0.48	0.53	0.45	0.42	0.40	0.40	0.41
Ag Soils-Fertilizers	0.79	0.75	0.79	0.81	0.73	0.71	0.69	0.66	0.64
Ag Soils-Crops	0.77	0.74	0.79	0.88	0.75	0.75	0.75	0.75	0.75
Ag Soils-Livestock	2.11	2.07	1.73	2.38	1.87	1.80	1.73	1.66	1.60
Ag Soils-Liming	0.48	0.32	0.24	0.13	0.09	0.06	0.04	0.02	0.02
Agricultural Burning	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Gross Total	**7.89**	**7.88**	**6.96**	**7.88**	**7.05**	**6.81**	**6.65**	**6.56**	**6.59**
Soil Carbon (Cultivation Practices)	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14	-1.14
Net Total	**6.75**	**6.74**	**5.82**	**6.74**	**5.91**	**5.67**	**5.51**	**5.42**	**5.45**

Table F3. GHG Emissions from Soil Carbon Changes Due to Cultivation Practices ($MMtCO_2e$)

Changes in cropland			Changes in Hayland				Other			Total[4]
Plowout of grassland to annual cropland[1]	Cropland manage-ment	Other cropland[2]	Cropland converted to hayland[3]	Hayland manage-ment	Cropland converted to grazing land[3]	Grazing land manage-ment	CRP	Manure application	Cultivation of organic soils	Net soil carbon emissions
0.95	(0.11)	(0.07)	(0.84)	(0.04)	(0.77)	0.00	(0.11)	(0.15)	0.00	(1.14)

Based on USDA 1997 estimates. Parentheses indicate net sequestration.

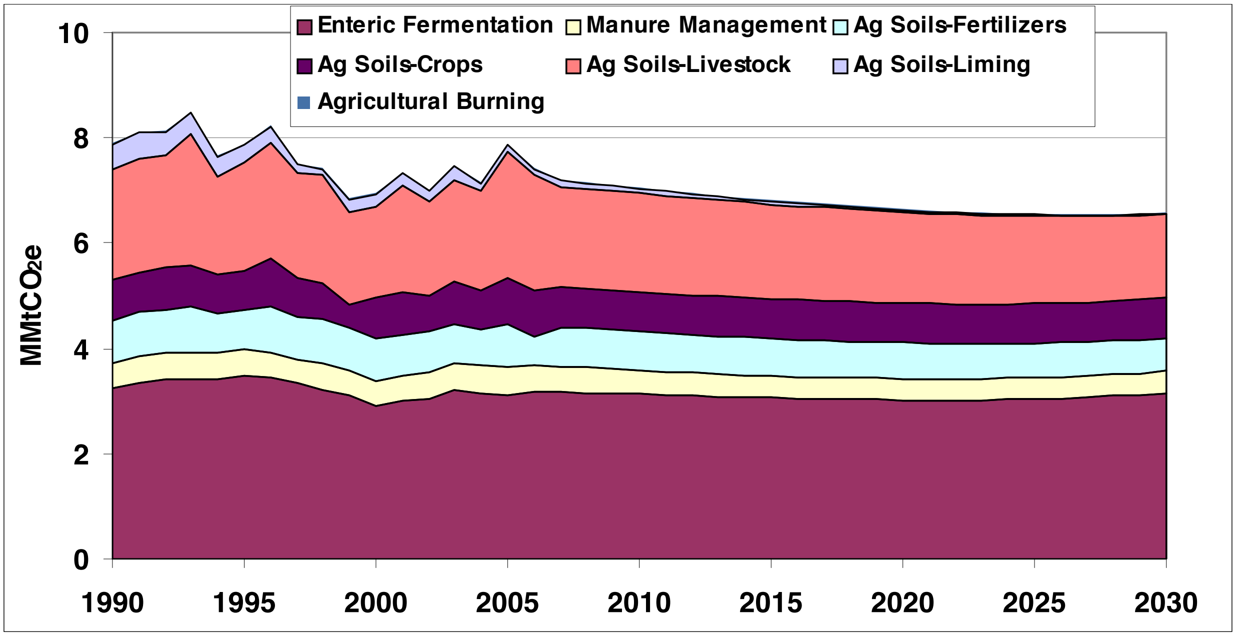
[1] Losses from annual cropping systems due to plow-out of pastures, rangeland, hayland, set-aside lands, and perennial/horticultural cropland (annual cropping systems on mineral soils, e.g., corn, soybean, cotton, and wheat).

[2] Perennial/horticultural cropland and rice cultivation.

[3] Gains in soil carbon sequestration due to land conversions from annual cropland into hay or grazing land.

[4] Total does not include change in soil organic carbon storage on federal lands, including those that were previously under private ownership, and does not include carbon storage due to sewage sludge applications.

Figure F1. Gross GHG Emissions from Agriculture 1990-2030



Source: CCS calculations based on approach described in text.
Notes: Ag Soils – Crops category includes: incorporation of crop residues and nitrogen fixing crops (no cultivation of histosols estimated in Kentucky); emissions for agricultural residue burning are too small to be seen in this chart. Soil carbon sequestration is not shown (see Table F2).

Agricultural burning emissions were estimated to be very small based on the SIT activity data (<0.02 MMtCO_2e/yr from 1990 to 2006). This agrees with the USDA Inventory, which also reports a low level of residue burning emissions (0.02 MMtCO_2e).[76]

The only standard IPCC source categories missing from this report are N_2O emissions from cultivation of histosols.

Key Uncertainties

Emissions from enteric fermentation and manure management are dependent on the estimates of animal populations and the various factors used to estimate emissions for each animal type and manure management system (i.e., emission factors that are dependent on several variables, including manure production levels, volatile solids contents of manures, and CH_4 formation potential). Each of these factors has some level of uncertainty. Also, animal populations fluctuate throughout the year, and thus using point estimates introduces uncertainty into the average annual estimates of these populations. In addition, there is uncertainty associated with the original population survey methods employed by USDA. CCS believes that the largest contributors to uncertainty in emissions from manure management are the emission factors, which are derived from limited data sets.

[76] http://www.usda.gov/oce/global_change/AFGG_Inventory/AppendixB.pdf *U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005*. Global Change Program Office, Office of the Chief Economist, US Department of Agriculture.

As mentioned above, for emissions associated with changes in agricultural soil carbon levels, the only data currently available are for 1997. When newer data are released by the USDA, these should be reviewed to represent current conditions as well as to assess trends. In particular, given the potential for some Conservation Reserve Program acreage to retire and possibly return to active cultivation prior to 2030, the current size of the CO_2 sink could be appreciably affected (possibly even turning this net sink into a net source of CO_2 in the future).

Another contributor to uncertainty in the emission estimates is the projection assumptions. This inventory assumes that the average annual rate of change in future year emissions will follow the historical average annual rate of change from 1990 through 2006. For example, the historical data for 1990 through 2006 show an increase in the use of fertilizers. However, since 2004 fertilizer use has declined, which may be the start of a trend towards reduced fertilizer use. In such a case, the predicted growth of 1990-2006 may be an overestimate.

Note that emissions from agricultural soils estimated using the SIT were multiplied by a national adjustment factor to reconcile differences between methodologies used in EPA's National Inventory of Greenhouse Gas Emissions and the SIT. The Agriculture, Forestry and Waste Technical Working Group should discuss whether the National Adjustment Factor is appropriate for Kentucky's Inventory and Forecast, or if agricultural soils emissions estimates should be unadjusted.

Trees on agricultural lands are included in the forestry I&F through statistical plot sampling and are grouped together with all other forest acres. Trees on agricultural lands are also included in the National Woodland Owners survey of forests on private lands. However, since trees on agricultural lands are grouped together with all other forest acres and not separated into their own category, they have not been included in the agriculture I&F. It would be helpful in the future to delineate the inventory of trees on agricultural lands since these would most likely be managed differently than traditional forest lands.

Appendix G. Waste Management

Overview
GHG emissions from waste management include:

- Solid waste management – methane (CH_4) emissions from municipal and industrial solid waste landfills (LFs), accounting for CH_4 that is flared or captured for energy production (this includes both open and closed landfills);
- Solid waste combustion – CH_4, carbon dioxide (CO_2), and nitrous oxide (N_2O) emissions from the combustion of solid waste in incinerators or waste to energy plants; and
- Wastewater management – CH_4 and N_2O from municipal wastewater and CH_4 from industrial wastewater (WW) treatment facilities.

Inventory and Reference Case Projections

Municipal Solid Waste Historical and Projected Management Profile

The basis for the municipal solid waste (MSW) management profile was the 2009 Division of Waste Management Annual Report.[77] These data present the amount of MSW landfilled in Kentucky, the amount of waste imported, the amount of waste exported, and the amount of waste recycled for the years 1994 through 2008. The state data summaries provided the quantity of waste composted and the amount of waste combusted at waste-to-energy (WTE) facilities.[78] Note that food waste composting data were not available. The composting totals represent yard waste only.

MSW generation is defined as the sum of MSW landfill disposal, MSW combustion, and MSW recovery. MSW combustion includes combustion at WTE facilities, combustion of commercial and institutional waste without energy recovery, and open burning of residential waste. Recovery includes recycling and composting.

The MSW generation totals presented in the KY DEP Waste Management Annual Report do not include combustion. Therefore, the recycling percentages calculated in this appendix will not match those from the KY DEP report. KY DEP states that the 2005 MSW recycling rate in Kentucky was 23.4%, compared to the national 2005 MSW recycling rate of 30.0%. However, the 2005 MSW recycling rate for Kentucky when combustion is included is 21.3%.[79]
The amount of waste generated was back-cast for each year between 1990 and 1994 by applying the calculated 1994 per-capita MSW generation rate (based on US Census Bureau population data) to the population in Kentucky for 1990 through 1993. The MSW generation was forecast through 2030 by applying a growth factor of 2.6% to the per-capita generation for each year during the period 2009-2030. This growth factor is the average annual change in per-capita

[77] KY DEP. 2009. "Kentucky Division of Waste Management Annual Report." Available at: http://www.waste.ky.gov/NR/rdonlyres/0B9284F4-BA60-4A58-97C5-F4E51F041AE1/0/DWMannualreport2009FINAL.pdf.
[78] KY DEP. "State Data Report." Available for years 2004 through 2007 at: http://www.waste.ky.gov/branches/rla/Statewide+Solid+Waste+Management+Report.htm.
[79] Note that the KY MSW recycling rates do not include composting.

generation over the period 1995-2008 (1994 was omitted from this calculation, as the per-capita generation rate was very low and would have produced very large generation estimates for future years). The amount of waste recycled, composted, landfilled, and combusted were estimated in the back-cast and projected years by maintaining the ratios of waste managed through these methods for the periods 1990-1993, and 2009-2030, respectively. A subset of the data and projections are presented in Table G1.

Industrial waste is not explicitly included in the profile presented in Table G1. However, it is likely that industrial waste is co-mingled with MSW at some of the waste disposal facilities in Kentucky.

Table G1. MSW Management Profile – Historical and Projected (short tons)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
MSW Disposed + Diverted	3,854,180	5,081,168	4,964,650	6,369,594	7,691,122	8,900,035	10,265,175	11,815,380	13,597,132
Non-energy MSW Incineration & Open Burning	418,359	293,490	306,620	332,176	428,773	553,459	714,405	922,153	1,190,314
MSW Generated	4,272,539	5,374,657	5,271,270	6,701,771	8,119,895	9,453,494	10,979,580	12,737,533	14,787,446
KY Population	3,686,892	3,887,427	4,041,769	4,165,958	4,265,117	4,351,188	4,424,431	4,489,662	4,554,998
Generation per capita	1.16	1.38	1.30	1.61	1.90	2.17	2.48	2.84	3.25
Total MSW Landfilled in KY	3,655,128	4,476,904	4,375,652	5,157,185	5,373,596	6,120,430	6,963,777	7,921,451	9,022,170
MSW Imported (landfilled)	183,786	269,833	515,136	663,686	909,423	1,035,816	1,178,544	1,340,620	1,526,904
MSW Exported (landfilled)	125,549	210,728	202,029	191,923	287,194	413,587	556,315	718,391	904,675
Kentucky MSW Landfilled	3,596,891	4,417,799	4,062,545	4,685,422	4,751,367	5,498,201	6,341,548	7,299,222	8,399,941
MSW Combusted (Waste-to-Energy)	47,434	58,260	53,575	61,789	62,659	72,508	83,630	96,259	110,775
MSW Diverted	209,855	605,108	848,530	1,622,383	2,877,096	3,329,326	3,839,998	4,419,898	5,086,417
MSW Recycled	183,607	529,423	742,398	1,429,490	2,517,236	2,912,902	3,359,701	3,867,069	4,450,220
MSW Composted	26,248	75,685	106,132	192,893	359,860	416,424	480,297	552,830	636,196

The process of estimating direct GHG emissions from the waste sector is detailed in the following section of this appendix. These GHG emissions estimates utilize the landfill disposal information in the above table in order to estimate methane emissions from landfills in Kentucky. The direct GHG emissions estimates do not capture the embedded energy in landfilled waste that could have been recycled. These materials represent a large potential for life-cycle GHG reductions as a result of the emissions from raw materials extraction and new product manufacturing that are avoided when waste is recycled, rather than landfilled. It is the experience of CCS that approximately 10% of estimated GHG reductions from additional recycling efforts are attributed to direct reductions in methane at landfills, while the remainder of the GHG reductions are based on a reduction in life-cycle emissions. Composting also reduces life-cycle GHG emissions from waste management, as the finished compost product may be applied to crop fields, gardens, and landscape construction sites to increase soil carbon and moisture retention, and reduce the need for fossil fuel-derived nitrogen fertilizers.

Solid Waste Management

MSW Landfills. For solid waste management, CCS used the US EPA State Inventory Tool (SIT),[80] the historical and projected waste management profile detailed above, and the US EPA Landfill Methane Outreach Program (LMOP) landfills database[81] as starting points to estimate emissions. The LMOP data serve to identify which landfills currently utilize landfill gas to energy (LFGTE) technology, and to estimate annual waste emplacement for each landfill.

A list of landfills in the state available at the KY DEP website was used to supplement the LMOP database.[82] These additional data included information on one site that was not present in the LMOP database (the Hopkins County Regional Landfill). The KY DEP website also contains a county-by-county data report for 2007, which helped CCS estimate the amount of waste disposed at each landfill in 2007.[83] Six of these sites collect landfill gas (LFG) for use in a LFGTE combustion facility, with one more expecting to capture and utilize LFG by 2009. The Outler Loop Bioreactor had a pipeline to GE Appliance Park installed in 1996; after that year its emissions were assumed to be zero.[84] Eight other landfills have flaring equipment.[85] The rest of the sites were assumed to be uncontrolled. KY DEP provided a list of 50 landfills that were closed between 1992 and 1995. Waste emplacement data are not available for these landfills so they were not included in the inventory. Consequently, the total historical emissions for this sector reported in this inventory are an underestimate.

Annual waste emplacement was only available for 2004 through 2007. However, the data is very disaggregated, and CCS did not have the resources to compile the data for 2004, 2005, and 2006.

[80] U.S. EPA. "State Greenhouse Gas Inventory Tool, Draft 2/26/2010." Excel model and User Guide available at: http://securestaging.icfconsulting.com/sit/
[81] LMOP database is available at: http://www.epa.gov/lmop/proj/index.htm. Retrieved on December 12, 2009.
[82] KY DEP. 2008. "2007 Statewide Municipal Solid Waste Management Update." Available at: http://www.waste.ky.gov/NR/rdonlyres/BC9C4AE9-75B8-4E23-B53F-ABC9B0D1B445/0/2007StatewideSolidWasteSummaryrevised9508.pdf.
[83] KY DEP. 2008. "2007 County Annual Report Summary." Available at: http://www.waste.ky.gov/NR/rdonlyres/C439D7BB-DB52-49A3-A180-D2B35A06F3D6/0/2007ARSummary.pdf.
[84] Communicated to R. Anderson, CCS by George Gilbert, KY DEP, May, 2010.
[85] Communicated to R. Anderson, CCS by Tim Hubbard, George Gilbert, and Ron Gruzesky, KY DEP, April 2010.

CCS adjusted the landfill disposal totals from the 2007 County-by-County Data Report, so that the total amount of waste landfilled was equal to the landfill disposal total from the 2007 Statewide Solid Waste Management Report. This adjustment was necessary because the county-by-county data does not include any imported waste. CCS used the adjusted 2007 disposal totals and total waste-in-place data from the LMOP database to estimate annual emplacement at each landfill. The 2007 waste emplaced was subtracted from the total waste emplaced, and the remaining amount was divided by the number of years the landfill was open to estimate historical annual emplacement.

Historical annual waste emplacement was entered into SIT for each landfill to estimate CH_4 emissions. For the LFGTE and flared landfills, CCS assumed that the overall methane collection and control efficiency is 75%.[86] Of the methane not captured by a landfill gas collection system, it is further assumed that 10% is oxidized before being emitted to the atmosphere. Recent literature corroborates the use of an oxidation rate, supporting a default oxidation rate of 10%.[87]

For forecast years it was assumed that flaring equipment would be installed once a landfill reached 1 million tons of waste emplaced. It was assumed that landfills that have crossed this threshold but which do not yet have a flare would have one operational by 2011. It was assumed that no new LFGTE would be installed during the policy period.[88] Future emissions were estimated by assuming linear growth in the amount of waste landfilled (1.13%).

Composting. *Not included in GHG I&F.* Composting is a GHG mitigation strategy because it is thought to produce fewer GHG emissions than landfill disposal, and provides a finished product that can serve as a soil amendment that reduces the need for fossil fuel-based fertilizers and . However, any composting operations in Kentucky are likely emitters of CH_4 and N_2O. The Climate Action Reserve (CAR) is currently drafting a Composting Protocol that will provide methods for quantifying GHG emissions from composting operations. However, at this time, CCS has not quantified GHG emissions from composting operations.

Industrial Solid Waste Landfills. CCS used the EPA State Inventory Tool (SIT) default for industrial solid waste landfills. This default is based on national data indicating that industrial landfilled waste is emplaced at approximately 7 percent of the rate of MSW emplacement. We assumed that this additional industrial waste emplacement occurs beyond that already addressed in the emplacement rates for MSW sites described above. Due to a lack of data, no controls were assumed for industrial waste landfilling.

[86] As per EPA's AP-42 Section on Municipal Solid Waste Landfills: http://www.epa.gov/ttn/chief/ap42/ch02/final/c02s04.pdf.
[87] Jeffrey P. Chanton, David K. Powelson, and Roger B. Green , "Methane Oxidation in Landfill Cover Soils, is a 10% Default Value Reasonable?" J Environ Qual 2009 38: 654-663. Review available at: http://www.terradaily.com/reports/Landfill_Cover_Soil_Methane_Oxidation_Underestimated_999.html
[88] There are no pending LFGTE applications at this time in Kentucky, as communicated to R. Anderson, CCS by George Gilbert, KY DEP, May, 2010.

Solid Waste Combustion

WTE Combustion. Waste-to-energy combustion emissions are not accounted for in this I&F sector, as those emissions would be counted in the Electricity Supply I&F.

Incineration. There is no controlled combustion within the state.

Residential Open Burning. Open burning of MSW at residential sites (e.g. backyard burn barrels) is illegal in Kentucky, however some open burning likely contributes to GHG emissions. The US EPA's 2002 National Emissions Inventory estimates the quantity of waste burned at residential sites in Kentucky.[89] Emissions from open burning were calculated using SIT emissions factors and waste characteristics for municipal waste combustion. Future emissions were estimated using a 1% annual growth rate. Most illegal open burning investigated by the Air Quality division is industrial, such as demolition debris and tires.[90] However, there is no data on how much of this occurs so it was not included in the total.

Wastewater Management

Municipal WW Management. GHG emissions from municipal wastewater treatment were also estimated. For municipal wastewater treatment, emissions are calculated in EPA's SIT based on state population, assumed biochemical oxygen demand (BOD) and protein consumption per capita, and emission factors for N_2O and CH_4.[91] The key SIT default values are shown in Table G2 below. A revised value for the percentage of state residents not on septic (46%) was provided by KY DEP. Municipal wastewater emissions were based on the growth rate for 1990-2007, which was 0.97% per year.

Table G2. SIT Key Default Values for Municipal Wastewater Treatment

Variable	Default Value
BOD	0.09 kg /day-person
Amount of BOD anaerobically treated	16.25%
CH_4 emission factor	0.6 kg/kg BOD
Kentucky residents not on septic	46%
Water treatment N_2O emission factor	4.0 g N_2O/person-yr
Biosolids emission factor	0.005 kg N_2O-N/kg sewage-N

Source: U.S. EPA State Inventory Tool – Wastewater Module; methodology and factors taken from U.S. EPA, Emission Inventory Improvement Program, Volume 8, Chapter 12, October 1999: www.epa.gov/ttn/chief/eiip/techreport/volume08/.

Industrial WW Management. For industrial wastewater emissions in Kentucky, SIT provides default assumptions and emission factors for the red meat industry. The SIT default activity data were used to estimate emissions for red meat production. Emissions were projected to 2030

[89] EPA, ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/nonpoint/2002nei_final_nonpoint_documentation0206version.pdf
[90] Communicated to R. Anderson, CCS by John Lyons, Air Quality Division, April 2010.
[91] Processing and emissions data from individual wastewater treatment plants were not available; communicated to R. Anderson, CCS by Peter Goodman, Division of Water, April 2010.

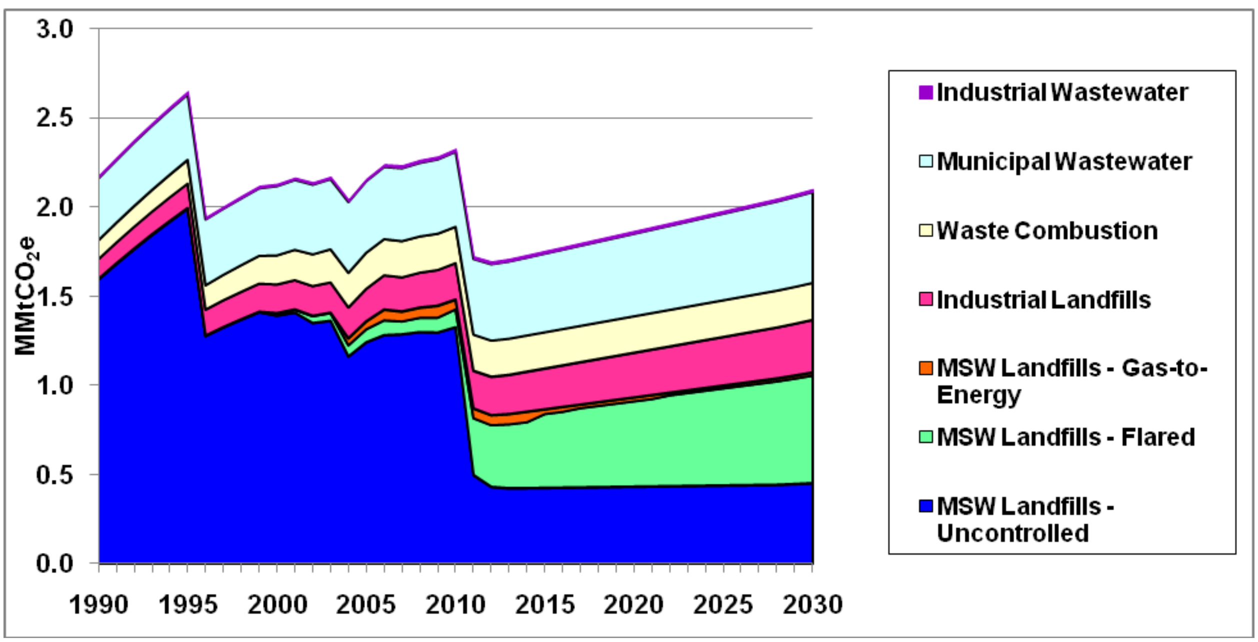
based on the 1990-2007 annual growth rate (0.01%). Data for other industries including Fruits & Vegetables, Poultry, Pulp & Paper, and Bourbon were not available.[92]

Results

Figure G1 and Table G3 show the emission estimates for the waste management sector. Overall, the sector accounts for 2.09 MMtCO$_2$e in 2005. By 2030, emissions are expected to grow slightly to 2.10 MMtCO$_2$e/yr. The largest contributor to waste management emissions is the solid waste sector, in particular, solid waste landfills. In 2005, uncontrolled, flared, and LFGTE municipal landfills accounted for 60% of total waste management emissions. By 2030, the contribution from these sites is expected to be about 22%. Industrial landfills accounted for 8% and 14% of the sector's emissions in 2005 and 2030, respectively. Waste combustion accounted for about 9% of the waste sector emissions in 2005 and 10% in 2030.

In 2005, about 19% of the waste management sector emissions were contributed by municipal wastewater treatment systems and 1% of emissions were contributed by industrial wastewater. Note that these estimates are based on the default parameters listed in Table G1 above, and might not adequately account for existing controls or management practices (e.g. anaerobic digesters served by a flare or other combustion device). By 2030, the contribution to the total waste sector emissions from municipal and industrial wastewater treatment sectors are expected to represent 24% and 1% of emissions, respectively.

Figure G1. Kentucky GHG Emissions from Waste Management



Notes: MSW - Municipal Solid Waste

[92] Communicated to R. Anderson, CCS by Peter Goodman, Division of Water, April 2010.

Table G3. Kentucky GHG Emissions from Waste Management (MMtCO$_2$e)

Source	1990	1995	2000	2005	2010	2015	2020	2025	2030
MSW Landfills - Gas-to-Energy	0.00	0.00	0.00	0.04	0.05	0.03	0.02	0.01	0.02
MSW Landfills - Flared	0.00	0.00	0.01	0.07	0.10	0.42	0.48	0.55	0.60
MSW Landfills - Uncontrolled	1.59	1.99	1.39	1.24	1.33	0.42	0.43	0.44	0.45
Industrial Landfills	0.11	0.14	0.16	0.18	0.20	0.23	0.25	0.27	0.29
Waste Combustion	0.11	0.13	0.17	0.20	0.21	0.21	0.21	0.21	0.21
Municipal Wastewater	0.35	0.37	0.39	0.40	0.42	0.44	0.46	0.49	0.51
Industrial Wastewater	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**2.18**	**2.65**	**2.13**	**2.16**	**2.33**	**1.75**	**1.87**	**1.98**	**2.10**

Key Uncertainties

Data for closed landfills that are not covered by the LMOP database are not available. Therefore, such landfills are not included in this analysis. The modeling only accounts for currently uncontrolled sites that will need to apply controls during the period of analysis due to triggering the requirements of the federal New Source Performance Standards/Emission Guidelines but does not account for new landfills that will be uncontrolled. As noted above, the available data do not cover all of the open and closed landfills in Kentucky, particularly the 50 closed in the early 1990's. For this reason, emissions are underestimated for landfills.

Landfills are considered a sink for carbon, as some landfilled waste contains biogenic carbon that is either perpetually trapped in the landfill, or is released at a much slower rate that it would be if it were not landfilled. Currently, the estimated value for this sink is considered in the Forestry I&F Appendix. The landfill carbon sink estimates in that appendix are based on population data and default parameters, rather than the waste management profile described in this appendix.

For industrial landfills, emissions were estimated using national defaults (with industrial landfills emitting 7% of MSW landfill emissions). It could be that the available MSW emplacement data within the KY DEP data used to model the MSW emissions already captures some industrial LF emplacement. As with overall MSW landfill emissions, industrial landfill emissions are projected to increase between 2005 and 2030. Hence, the industrial landfill inventory and forecast has a significant level of uncertainty and should be investigated further. For example, the existence of active industrial landfills that are not already represented in the LMOP database should be determined. If there are no separate sites just for industrial waste and the existing municipal waste emplacement data are thought to include all industrial wastes, then the separate estimate for industrial landfill emissions can be excluded from the inventory.

The State of Kentucky has no waste combustion facilities that are active, and open burning of waste is illegal. Some open burning is known to occur, but there is significant uncertainty about the quantity. Residential open burning was estimated based on national emissions inventory methods and rural population estimates. Illegal burning of industrial waste such as demolition debris and tires may occur in the state but there is no data currently available to estimate this so it was not included in the inventory. Likewise the burning of storm debris was not included. State-level data of open burning surveys would improve this element of the I&F.

According to the SIT default assumption, zero wastewater biosolids are applied to soils. In this inventory, N_2O emissions associated with these biosolids would be included in the wastewater sector. It is likely that some biosolids are applied to soils in Kentucky. Therefore, emissions from this source are likely underestimated. The SIT Agriculture Module contains estimates of total Activated Sewage Sludge soil application and the associated GHG emissions. Other key uncertainties with the wastewater sector are associated with the application of SIT default values for the parameters listed in Table G2 above (e.g. the fraction of BOD that is anaerobically decomposed). The SIT defaults for emission factors used to estimate wastewater emissions were derived from national data. Waste combustion emissions were also based on a factor derived from national data.

Data on industrial wastewater were not available for most industries including: fruits and vegetables, pulp and paper, poultry, and bourbon. Therefore these are not represented in this inventory. Hence the estimate of emissions from industrial wastewater is likely an underestimate. The addition of activity data from these industries would improve the I&F.

Appendix H. Forestry & Land Use

Overview

Forestland emissions refer to the net carbon dioxide (CO_2) flux[93] from forested lands in Kentucky, which account for about 50% of the state's land area.[94] The dominant forest type in Kentucky is oak-hickory which made up about 77% of forested lands in 1997. Other common forest types are oak-pine at 7% of forested land, and maple-beech-birch at 6% of forested land.

Through photosynthesis, CO_2 is taken up by trees and plants and converted to carbon in biomass within the forests. Carbon dioxide emissions occur from respiration in live trees, decay of dead biomass, and combustion (both wildfires and biomass removed from forests for energy use). In addition, carbon is stored for long time periods when forest biomass is harvested for use in durable wood products. Carbon dioxide flux is the net balance of CO_2 removals from and emissions to the atmosphere from the processes described above.

The forestry sector GHG emissions (including net CO_2 flux) are categorized into two primary subsectors:

- *Forested Landscape:* this consists of carbon flux occurring on lands that are not part of the urban landscape. Fluxes covered include net carbon sequestration, carbon stored in harvested wood products (HWP) or landfills, and emissions from forest fires.
- *Urban Forestry and Land Use:* this covers carbon sequestration in urban trees, flux associated with carbon storage from landscape waste and food scraps in landfills, and nitrous oxide (N_2O) emissions from settlement soils (those occurring as a result of application of synthetic fertilizers).

Inventory and Reference Case Projections

Forested Landscape

For over a decade, the United States Forest Service (USFS) has been developing and refining a forest carbon modeling system for the purposes of estimating forest carbon inventories. The methodology is used to develop national forest CO_2 fluxes for the official *US Inventory of Greenhouse Gas Emissions and Sinks*. The national estimates are compiled from state-level data. The Kentucky forest CO_2 flux data in this report come from the national analysis and are provided by the USFS. See the footnotes below for the most current documentation for the forest carbon modeling.[95] Additional forest carbon information is in the form of specific carbon conversion factors.[96]

[93] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.
[94] Total forested acreage is 12.7 million acres in 1997. Acreage by forest type available from the USFS at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/KY.htm. The total land area in Kentucky is 25 million acres (http://www.50states.com/kentucky.htm).
[95] The most current citation for an overview of how the USFS calculates the inventory based forest carbon estimates as well as carbon in harvested wood products is from the US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2007 (and earlier editions), US Environmental Protection Agency, April 2009, available at: http://epa.gov/climatechange/emissions/usinventoryreport.html. Both Annex 3.12 and Chapter 7 LULUCF are useful

The forest CO_2 flux methodology relies on input data in the form of plot-level forest volume statistics from the Forest Inventory Analysis (FIA). FIA data on forest volumes are converted to values for ecosystem carbon stocks (i.e., the amount of carbon stored in forest carbon pools) using the FORCARB2 modeling system. Coefficients from FORCARB2 are applied to the plot level survey data to give estimates of C density [megagrams (Mg) per hectare] for a number of separate C pools. Additional background on the FORCARB system is provided in a number of publications.[97]

Carbon dioxide flux is estimated as the change in carbon mass for each carbon pool over a specified time-frame. Forest biomass data from at least two points in time are required. The change in carbon stocks between time intervals is estimated for specific carbon pools (Live Tree, Standing Dead Wood, Understory, Down & Dead Wood, Forest Floor, and Soil Organic Carbon) and divided by the number of years between inventory samples. Annual increases in carbon density reflect carbon sequestration in a specific pool; decreases in carbon density reveal CO_2 emissions or carbon transfers out of that pool (e.g., death of a standing tree transfers carbon from the live tree to standing dead wood pool). The amount of carbon in each pool is also influenced by changes in forest area (e.g., an increase in area could lead to an increase in the associated forest carbon pools and the estimated flux). The sum of carbon stock changes for all forest carbon pools yields a total net CO_2 flux for forest ecosystems.

In preparing these estimates, USFS estimates the amount of forest carbon in different forest types as well as separate carbon pools. The different forest types also include separate ownership classes: those in the national forest (NF) system; and those that are not federally-owned (private and other public forests). Additional details on the forest carbon inventory methods can be found in Annex 3 to the US EPA's 2007 GHG inventory for the US.[98]

Annualized FIA data, as shown in Table H1, display a net decrease in forested area (6% between 1990 and 2005). Information on the number of forest surveys and the year these were conducted was not accessible from the FIA database during the development of this appendix due to a problem with the web site hosting the FIADB 2.1 component of the Carbon Calculation Tool.[99]

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sources of reference. See also Smith, J.E., L.S. Heath, and M.C. Nichols (in press), *US Forest Carbon Calculation Tool User's Guide: Forestland Carbon Stocks and Net Annual Stock Change*, Gen Tech Report, Newtown Square, PA: US Department of Agriculture, Forest Service, Northern Research Station.

[96] Smith, J.E., and L.S. Heath (2002). "A model of forest floor carbon mass for United States forest types," Res. Pap. NE-722. Newtown Square, PA: US Department of Agriculture, Forest Service, Northeastern Research Station. 37 p., or Jenkins, J.C., D.C. Chojnacky, L.S. Heath, R.A. Birdsey (2003), "National-scale biomass estimators for United States tree species", *Forest Science*, 49:12-35.

[97] Smith, J.E., L.S. Heath, and P.B. Woodbury (2004). "How to estimate forest carbon for large areas from inventory data", *Journal of Forestry*, 102: 25-31; Heath, L.S., J.E. Smith, and R.A. Birdsey (2003), "Carbon trends in US forest lands: A context for the role of soils in forest carbon sequestration", In J. M. Kimble, L. S. Heath, R. A. Birdsey, and R. Lal, editors. *The Potential of US Forest Soils to Sequester Carbon and Mitigate the Greenhouse Effect*. CRC Press, New York; and Woodbury, Peter B.; Smith, James E.; Heath, Linda S. 2007, "Carbon sequestration in the US forest sector from 1990 to 2010", *Forest Ecology and Management*, 241:14-27.

[98] Annex 3 to EPA's 2007 report, which contains estimates for calendar year 2005, can be downloaded at: http://www.epa.gov/climatechange/emissions/downloads06/07Annex3.pdf.

[99] http://www.nrs.fs.fed.us/pubs/2394.

Underlying data, including the years for which forest surveys were conducted, will be added in subsequent revisions to this Appendix. Based on annualized data, forest land decreased linearly from 1990 to 2005, which appears to have caused a reduction in carbon stocks in most carbon pools. However, modeled gains in the live tree pools led to overall carbon stocks remaining fairly level between 1990 and 2005 as shown in Table H1.

Table H1. USFS Forest Carbon Pool Data for Kentucky

Forest Pool	1990 (MMtC)	1995 (MMtC)	2000 (MMtC)	2005 (MMtC)
Live Tree – Above Ground	310.7	315.4	320.1	324.8
Live Tree – Below Ground	59.7	60.5	61.4	62.2
Understory	15.2	14.8	14.5	14.1
Standing Dead	14.3	14.1	13.9	13.7
Down Dead	24.7	25.1	25.5	25.8
Forest Floor	37.2	36.4	35.6	34.8
Soil Carbon	204.1	200.9	197.6	194.3
Totals	**666**	**667**	**668**	**670**
Forest Area	**1990 (10^3 acres)**	**1993 (10^3 acres)**	**2004 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	5,081	4,985	4,889	4,793
Timberland	4,945	4,851	4,757	4,664

MMtC = million metric tons of carbon. Positive numbers indicate net emission. Multiply MMtC by 3.67 (44/12) to convert to $MMtCO_2$.

Totals may not sum exactly due to independent rounding.

Data source: Smith, James, et al. *US Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change* (http://www.nrs.fs.fed.us/pubs/2394), November 2007.

In addition to the forest carbon pools, additional carbon is stored in biomass removed from the forest for the production of HWP. Carbon remains stored in the durable wood products pool or is transferred to landfills where much of the carbon remains stored over a long period of time. The USFS uses a model referred to as WOODCARB2 for the purposes of modeling national HWP carbon storage.[100] Limited and somewhat dated state-level information for Kentucky was provided to CCS by USFS.[101]

As shown in Table H2, about 1.4 million metric tons (MMt) of CO_2 per year (yr) is estimated by the USFS to be sequestered annually (1990-2005) in wood products. Also shown in this table is the total flux estimate including all forest pools of -2.3 $MMtCO_2e$/yr.[102]

Based on discussions with the USFS, CCS recommends excluding the soil carbon pool from the overall forest flux estimates due to a high level of uncertainty associated with these estimates.

[100] Skog, K.E., and G.A. Nicholson (1998), "Carbon cycling through wood products: the role of wood and paper products in carbon sequestration", *Forest Products Journal*, 48(7/8):75-83; or Skog, K.E., K. Pingoud, and J.E. Smith (2004), "A method countries can use to estimate changes in carbon stored in harvested wood products and the uncertainty of such estimates", *Environmental Management*, 33(Suppl. 1): S65-S73.
[101] Obtained from the Harvested Wood Product model developed by Ken Skog, USFS.
[102] Jim Smith, USFS, *US. Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change* (http://www.nrs.fs.fed.us/pubs/2394), November 2007.

The forest carbon flux estimates provided in the summary tables at the front of this report are those without the soil carbon pool. The resulting estimates provided at the bottom of Table H2 are in line with the observed changes in forest area and carbon stocks during this time period (i.e. losses in forest area offset by growing live tree carbon pools).

Table H2. USFS Annual Forest CO_2 Fluxes for Kentucky

Forest Pool	1990-2005 Flux ($MMtCO_2$)
Forest Carbon Pools (non-soil)	-3.3
Soil Organic Carbon	2.4
Harvested Wood Products	-1.4
Totals	**-2.3**
Totals (excluding soil carbon)	**-4.7**

Totals may not sum exactly due to independent rounding.
Data source: Smith, James, et al. US Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change (http://www.nrs.fs.fed.us/pubs/2394), USFS, November 2007.

For historical emission estimates, CCS used the annualized carbon flux and carbon stock data for the period 1990-2005 using the Carbon Calculation Tool. For the reference case projections (2005-2030), the forest area and carbon densities of forestlands were assumed to remain at the same levels as in 2005. Information is not available on the near term effects of climate change and their impacts on forest productivity. Nor were data readily-available on projected losses in forested area.

Urban Forestry & Land Use

GHG emissions from urban forestry and land use for 1990 through 2005 were estimated using the US EPA State Inventory Tool (SIT) software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for this sector.[103] In general, the SIT methodology applies emission factors developed for the US to activity data for the urban forestry sector. Activity data include urban area, urban area with tree cover, amount of landfilled yard trimmings and food scraps, and the total amount of synthetic fertilizer applied to settlement soils (e.g., parks, yards, etc.). This methodology is based on international guidelines developed by sector experts for preparing GHG emissions inventories.[104] Table H3 displays the emissions and reference case projections for Kentucky.

Changes in carbon stocks in urban trees are equivalent to tree growth minus biomass losses resulting from pruning and mortality. Net carbon sequestration was calculated using data on crown cover area. The default urban area data in SIT (which grew from 2,604 square kilometers

[103] GHG emissions were calculated using SIT, with reference to EIIP, Volume VIII: Chapter 8.
[104] Revised 1996 1ntergovermental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, published by the National Greenhouse Gas Inventory Program of the IPCC, available at (http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm; and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, published in 2000 by the National Greenhouse Gas Inventory Program of the IPCC, available at: (http://www.ipcc-nggip.iges.or.jp/public/gp/english/).

[km^2] to 3,479 km^2 between 1990 and 2005) was multiplied by the state estimate of the percent of urban area with tree cover (30% for Kentucky) to estimate the total area of urban tree cover. These default SIT urban area tree cover data represent area estimates taken from the US Census and coverage for years 1990 and 2000.[105] Estimates of urban area in the intervening years (1990-1999) and subsequent years (2001-2005) are interpolated and extrapolated, respectively.

Table H3. Urban Forestry Emissions and Reference Case Projections (MMtCO$_2$e)

	1990	1995	2000	2005	2015	2025	2030
Urban Trees	-0.71	-0.80	-0.86	-0.94	-0.94	-0.94	-0.94
Landfilled Yard Trimmings and Food Scraps	-3.46	-1.82	-1.15	-0.88	-0.88	-0.88	-0.88
N_2O from Settlement Soils	0.08	0.08	0.09	0.08	0.08	0.08	0.08
Total	**-4.09**	**-2.53**	**-1.92**	**-1.73**	**-1.73**	**-1.73**	**-1.73**

Estimates of net carbon flux of landfilled yard trimmings and food scraps were calculated by estimating the change in landfill carbon stocks between inventory years. The SIT estimates for the amount of landfilled yard trimmings decreased significantly during the 1990's. CCS believes that this is consistent with changes in the waste management industry during this period. Therefore, the forecast was based on an extrapolation of the flux from 2000-2005, which show relatively constant rates of landfilling these materials.

Settlement soils include all developed land, transportation infrastructure, and human settlements of any size. Projections for urban trees and settlement soils were kept constant at 2005 levels. Table H4 provides a summary of the estimated flux for the entire forestry and land use sector.

Table H4. Forestry and Land Use GHG Emissions and Reference Case Projections (MMtCO$_2$e)

Subsector	1990	1995	2000	2005	2015	2025	2030
Forested Landscape (excluding soil carbon)	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71	-4.71
Urban Forestry and Land Use	-4.09	-2.53	-1.92	-1.73	-1.73	-1.73	-1.73
Forest Wildfires	0.29	0.87	1.72	0.66	0.68	0.68	0.68
Sector Total	**-8.51**	**-6.37**	**-4.91**	**-5.77**	**-5.75**	**-5.75**	**-5.75**

Wildfire and Prescribed Burning Emissions

Biomass burned in forest fires emits CO_2, methane (CH_4), and N_2O, in addition to many other gases and pollutants. Since CO_2 emissions are captured under total carbon flux calculations in the USFS modeling described above, CCS used SIT to estimate CH_4 and N_2O emissions. CCS used available state data from the State of Kentucky, Division of Forestry to estimate emissions.[106] Acres burned were used for the years 1990-2008 and the forest type of "other temperate forests" was assumed in SIT to calculate historical emissions. Note that these data

[105] Dwyer, John F.; Nowak, David J.; Noble, Mary Heather; Sisinni, Susan M. 2000. Connecting people with ecosystems in the 21st century: an assessment of our nation's urban forests. Gen. Tech. Rep. PNW-GTR-490.
[106] State of Kentucky, Division of Forestry: http://www.forestry.ky.gov/situationreport/.

appear to be restricted to wildfires and not to include any prescribed burns.

Due to the yearly fluctuation of forest fire data, projected emissions for 2009-2030 were assumed to be the average of 1990-2008 fire emissions. These emission estimates are presented in Table H4, along with the total emissions from the forestry and land use sector.

Key Uncertainties

It is important to note that there were methodological differences in the FIA surveys in the pre- versus post-1999 time-frame. The FIA data form the basis of the USFS forest carbon pool modeling and the different survey methods could produce varying estimates of forested area and carbon density. For example, the FIA program modified the definition of forest cover for the woodlands class of forestland (considered to be non-productive forests). Earlier FIA surveys defined woodlands as having a tree cover of at least 10%, while the newer sampling methods used a woodlands definition of tree cover of at least 5% (leading to more area being defined as woodland). In woodland areas, the earlier FIA surveys might not have inventoried trees of certain species or with certain tree form characteristics (leading to differences in both carbon density and forested acreage). Given that the forested land in Kentucky is dominated by timberlands (productive forests), CCS does not believe that the definitional differences noted above have had a significant impact on the forest flux estimates provided in this report.

Also, FIA surveys since 1999 include all dead trees on the plots, but data prior to that are variable in terms of these data. The modifications to FIA surveys are a result of an expanded focus in the FIA program, which historically was only concerned with timber resources, while more recent surveys have aimed at a more comprehensive gathering of forest biomass data. In addition, the FIA program has moved from periodic to annual inventory methods – FIA now has Kentucky on a continuous 5-year cycle. The effect of these changes in survey methods has not been estimated by the USFS.

Regarding the forecast for the forested landscape, potentially the largest source of uncertainty relates to the influence that future changes in climate will have on Kentucky's forests to sequester carbon. Regarding future land use change, FIA data indicate that forested acreage is decreasing at the state-level. It is unclear whether these trends will continue.

Emissions from wildfires and prescribed burns were estimated. It appears that the available data from the KY Division of Forestry covered wildfires, but not prescribed burns. To the extent that prescribed burning is employed in the state, the emissions could represent an important data gap.

Much of the urban forestry and land use emission estimates rely on national default data and could be improved with state-specific data (e.g. urban area under canopy cover).

Appendix I. Greenhouse Gases and Global Warming Potential Values: Excerpts from the Inventory of US Greenhouse Emissions and Sinks: 1990-2000

Original Reference: Material for this Appendix is taken from the *Inventory of US Greenhouse Gas Emissions and Sinks: 1990 - 2000*, US Environmental Protection Agency, Office of Atmospheric Programs, EPA 430-R-02-003, April 2002 www.epa.gov/globalwarming/ publications/emissions. Michael Gillenwater directed the preparation of this appendix.

Introduction

The *Inventory of US Greenhouse Gas Emissions and Sinks* presents estimates by the United States government of US anthropogenic greenhouse gas emissions and removals for the years 1990 through 2000. The estimates are presented on both a full molecular mass basis and on a Global Warming Potential (GWP) weighted basis in order to show the relative contribution of each gas to global average radiative forcing.

The Intergovernmental Panel on Climate Change (IPCC) has recently updated the specific global warming potentials for most greenhouse gases in their Third Assessment Report (TAR, IPCC 2001). Although the GWPs have been updated, estimates of emissions presented in the US *Inventory* continue to use the GWPs from the Second Assessment Report (SAR). The guidelines under which the *Inventory* is developed, the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997) and the United Nations Framework Convention on Climate Change (UNFCCC) reporting guidelines for national inventories[107] were developed prior to the publication of the TAR. Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values. This excerpt of the US *Inventory* addresses in detail the differences between emission estimates using these two sets of GWPs. Overall, these revisions to GWP values do not have a significant effect on US emission trends.

Additional discussion on emission trends for the United States can be found in the complete *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2000*.

What is Climate Change?

Climate change refers to long-term fluctuations in temperature, precipitation, wind, and other elements of the Earth's climate system. Natural processes such as solar-irradiance variations, variations in the Earth's orbital parameters, and volcanic activity can produce variations in climate. The climate system can also be influenced by changes in the concentration of various gases in the atmosphere, which affect the Earth's absorption of radiation.

The Earth naturally absorbs and reflects incoming solar radiation and emits longer wavelength terrestrial (thermal) radiation back into space. On average, the absorbed solar radiation is balanced by the outgoing terrestrial radiation emitted to space. A portion of this terrestrial radiation, though, is itself absorbed by gases in the atmosphere. The energy from this absorbed terrestrial radiation warms the Earth's surface and atmosphere, creating what is known as the

[107] See FCCC/CP/1999/7 at www.unfccc.de.

"natural greenhouse effect." Without the natural heat-trapping properties of these atmospheric gases, the average surface temperature of the Earth would be about 33°C lower (IPCC 2001).

Under the UNFCCC, the definition of climate change is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." Given that definition, in its Second Assessment Report of the science of climate change, the IPCC concluded that:

> *Human activities are changing the atmospheric concentrations and distributions of greenhouse gases and aerosols. These changes can produce a radiative forcing by changing either the reflection or absorption of solar radiation, or the emission and absorption of terrestrial radiation (IPCC 1996).*

Building on that conclusion, the more recent IPCC Third Assessment Report asserts that "[c]oncentrations of atmospheric greenhouse gases and their radiative forcing have continued to increase as a result of human activities" (IPCC 2001).

The IPCC went on to report that the global average surface temperature of the Earth has increased by between 0.6 ± 0.2°C over the 20th century (IPCC 2001). This value is about 0.15°C larger than that estimated by the Second Assessment Report, which reported for the period up to 1994, "owing to the relatively high temperatures of the additional years (1995 to 2000) and improved methods of processing the data" (IPCC 2001).

While the Second Assessment Report concluded, "the balance of evidence suggests that there is a discernible human influence on global climate," the Third Assessment Report states the influence of human activities on climate in even starker terms. It concludes that, "[I]n light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations" (IPCC 2001).

Greenhouse Gases

Although the Earth's atmosphere consists mainly of oxygen and nitrogen, neither plays a significant role in enhancing the greenhouse effect because both are essentially transparent to terrestrial radiation. The greenhouse effect is primarily a function of the concentration of water vapor, carbon dioxide, and other trace gases in the atmosphere that absorb the terrestrial radiation leaving the surface of the Earth (IPCC 1996). Changes in the atmospheric concentrations of these greenhouse gases can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC 1996). Holding everything else constant, increases in greenhouse gas concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth).

Climate change can be driven by changes in the atmospheric concentrations of a number of radiatively active gases and aerosols. We have clear evidence that human activities have affected concentrations, distributions and life cycles of these gases (IPCC 1996).

Naturally occurring greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Several classes of halogenated substances that contain fluorine, chlorine, or bromine are also greenhouse gases, but they are, for the most part, solely a product of industrial activities. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) are halocarbons that contain chlorine, while halocarbons that contain bromine are referred to as bromofluorocarbons (i.e., halons). Because CFCs, HCFCs, and halons are stratospheric ozone depleting substances, they are covered under the Montreal Protocol on Substances that Deplete the Ozone Layer. The UNFCCC defers to this earlier international treaty; consequently these gases are not included in national greenhouse gas inventories. Some other fluorine containing halogenated substances—hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6)—do not deplete stratospheric ozone but are potent greenhouse gases. These latter substances are addressed by the UNFCCC and accounted for in national greenhouse gas inventories.

There are also several gases that, although they do not have a commonly agreed upon direct radiative forcing effect, do influence the global radiation budget. These tropospheric gases—referred to as ambient air pollutants—include carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and tropospheric (ground level) ozone (O_3). Tropospheric ozone is formed by two precursor pollutants, volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of ultraviolet light (sunlight). Aerosols—extremely small particles or liquid droplets—often composed of sulfur compounds, carbonaceous combustion products, crustal materials and other human induced pollutants—can affect the absorptive characteristics of the atmosphere. However, the level of scientific understanding of aerosols is still very low (IPCC 2001).

Carbon dioxide, methane, and nitrous oxide are continuously emitted to and removed from the atmosphere by natural processes on Earth. Anthropogenic activities, however, can cause additional quantities of these and other greenhouse gases to be emitted or sequestered, thereby changing their global average atmospheric concentrations. Natural activities such as respiration by plants or animals and seasonal cycles of plant growth and decay are examples of processes that only cycle carbon or nitrogen between the atmosphere and organic biomass. Such processes—except when directly or indirectly perturbed out of equilibrium by anthropogenic activities—generally do not alter average atmospheric greenhouse gas concentrations over decadal timeframes. Climatic changes resulting from anthropogenic activities, however, could have positive or negative feedback effects on these natural systems. Atmospheric concentrations of these gases, along with their rates of growth and atmospheric lifetimes, are presented in Table I1.

Table I1. Global Atmospheric Concentration (ppm Unless Otherwise Specified), Rate of Concentration Change (ppb/year) and Atmospheric Lifetime (Years) of Selected Greenhouse Gases

Atmospheric Variable	CO_2	CH_4	N_2O	SF_6[a]	CF_4[a]
Pre-industrial atmospheric concentration	278	0.700	0.270	0	40
Atmospheric concentration (1998)	365	1.745	0.314	4.2	80
Rate of concentration change[b]	1.5[c]	0.007[c]	0.0008	0.24	1.0
Atmospheric Lifetime	50-200[d]	12[e]	114[e]	3,200	>50,000

Source: IPCC (2001)
[a] Concentrations in parts per trillion (ppt) and rate of concentration change in ppt/year.
[b] Rate is calculated over the period 1990 to 1999.
[c] Rate has fluctuated between 0.9 and 2.8 ppm per year for CO_2 and between 0 and 0.013 ppm per year for CH_4 over the period 1990 to 1999.
[d] No single lifetime can be defined for CO_2 because of the different rates of uptake by different removal processes.
[e] This lifetime has been defined as an "adjustment time" that takes into account the indirect effect of the gas on its own residence time.

A brief description of each greenhouse gas, its sources, and its role in the atmosphere is given below. The following section then explains the concept of Global Warming Potentials (GWPs), which are assigned to individual gases as a measure of their relative average global radiative forcing effect.

Water Vapor (H_2O). Overall, the most abundant and dominant greenhouse gas in the atmosphere is water vapor. Water vapor is neither long-lived nor well mixed in the atmosphere, varying spatially from 0 to 2 percent (IPCC 1996). In addition, atmospheric water can exist in several physical states including gaseous, liquid, and solid. Human activities are not believed to directly affect the average global concentration of water vapor; however, the radiative forcing produced by the increased concentrations of other greenhouse gases may indirectly affect the hydrologic cycle. A warmer atmosphere has an increased water holding capacity; yet, increased concentrations of water vapor affects the formation of clouds, which can both absorb and reflect solar and terrestrial radiation. Aircraft contrails, which consist of water vapor and other aircraft emittants, are similar to clouds in their radiative forcing effects (IPCC 1999).

Carbon Dioxide (CO_2). In nature, carbon is cycled between various atmospheric, oceanic, land biotic, marine biotic, and mineral reservoirs. The largest fluxes occur between the atmosphere and terrestrial biota, and between the atmosphere and surface water of the oceans. In the atmosphere, carbon predominantly exists in its oxidized form as CO_2. Atmospheric carbon dioxide is part of this global carbon cycle, and therefore its fate is a complex function of geochemical and biological processes. Carbon dioxide concentrations in the atmosphere increased from approximately 280 parts per million by volume (ppmv) in pre-industrial times to 367 ppmv in 1999, a 31 percent increase (IPCC 2001). The IPCC notes that "[t]his concentration has not been exceeded during the past 420,000 years, and likely not during the past 20 million years. The rate of increase over the past century is unprecedented, at least during the past 20,000 years." The IPCC definitively states that "the present atmospheric CO_2 increase is caused by anthropogenic emissions of CO_2" (IPCC 2001). Forest clearing, other biomass burning, and some non-energy production processes (e.g., cement production) also emit notable quantities of carbon dioxide.

In its second assessment, the IPCC also stated that "[t]he increased amount of carbon dioxide [in the atmosphere] is leading to climate change and will produce, on average, a global warming of the Earth's surface because of its enhanced greenhouse effect—although the magnitude and significance of the effects are not fully resolved" (IPCC 1996).

Methane (CH_4). Methane is primarily produced through anaerobic decomposition of organic matter in biological systems. Agricultural processes such as wetland rice cultivation, enteric fermentation in animals, and the decomposition of animal wastes emit CH_4, as does the decomposition of municipal solid wastes. Methane is also emitted during the production and distribution of natural gas and petroleum, and is released as a by-product of coal mining and incomplete fossil fuel combustion. Atmospheric concentrations of methane have increased by about 150 percent since pre-industrial times, although the rate of increase has been declining. The IPCC has estimated that slightly more than half of the current CH_4 flux to the atmosphere is anthropogenic, from human activities such as agriculture, fossil fuel use and waste disposal (IPCC 2001).

Methane is removed from the atmosphere by reacting with the hydroxyl radical (OH) and is ultimately converted to CO_2. Minor removal processes also include reaction with Cl in the marine boundary layer, a soil sink, and stratospheric reactions. Increasing emissions of methane reduce the concentration of OH, a feedback which may increase methane's atmospheric lifetime (IPCC 2001).

Nitrous Oxide (N_2O). Anthropogenic sources of N_2O emissions include agricultural soils, especially the use of synthetic and manure fertilizers; fossil fuel combustion, especially from mobile combustion; adipic (nylon) and nitric acid production; wastewater treatment and waste combustion; and biomass burning. The atmospheric concentration of nitrous oxide (N_2O) has increased by 16 percent since 1750, from a pre industrial value of about 270 ppb to 314 ppb in 1998, a concentration that has not been exceeded during the last thousand years. Nitrous oxide is primarily removed from the atmosphere by the photolytic action of sunlight in the stratosphere.

Ozone (O_3). Ozone is present in both the upper stratosphere, where it shields the Earth from harmful levels of ultraviolet radiation, and at lower concentrations in the troposphere, where it is the main component of anthropogenic photochemical "smog." During the last two decades, emissions of anthropogenic chlorine and bromine-containing halocarbons, such as chlorofluorocarbons (CFCs), have depleted stratospheric ozone concentrations. This loss of ozone in the stratosphere has resulted in negative radiative forcing, representing an indirect effect of anthropogenic emissions of chlorine and bromine compounds (IPCC 1996). The depletion of stratospheric ozone and its radiative forcing was expected to reach a maximum in about 2000 before starting to recover, with detection of such recovery not expected to occur much before 2010 (IPCC 2001).

The past increase in tropospheric ozone, which is also a greenhouse gas, is estimated to provide the third largest increase in direct radiative forcing since the pre-industrial era, behind CO_2 and CH_4. Tropospheric ozone is produced from complex chemical reactions of volatile organic compounds mixing with nitrogen oxides (NO_x) in the presence of sunlight. Ozone, carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter are included in the category referred to as "criteria pollutants" in the United States under the Clean Air Act and its subsequent amendments. The tropospheric concentrations of ozone and these other pollutants are short-lived and, therefore, spatially variable.

Halocarbons, Perfluorocarbons, and Sulfur Hexafluoride (SF_6). Halocarbons are, for the most part, man-made chemicals that have both direct and indirect radiative forcing effects. Halocarbons that contain chlorine—chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), methyl chloroform, and carbon tetrachloride—and bromine—halons, methyl bromide, and hydrobromofluorocarbons (HBFCs)—result in stratospheric ozone depletion and are therefore controlled under the Montreal Protocol on Substances that Deplete the Ozone Layer. Although CFCs and HCFCs include potent global warming gases, their net radiative forcing effect on the atmosphere is reduced because they cause stratospheric ozone depletion, which is itself an important greenhouse gas in addition to shielding the Earth from harmful levels of ultraviolet radiation. Under the Montreal Protocol, the United States phased out the production and importation of halons by 1994 and of CFCs by 1996. Under the Copenhagen Amendments to the Protocol, a cap was placed on the production and importation of HCFCs by non-Article 5 countries beginning in 1996, and then followed by a complete phase-out by the year 2030. The ozone depleting gases covered under the Montreal Protocol and its Amendments are not covered by the UNFCCC.

Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) are not ozone depleting substances, and therefore are not covered under the Montreal Protocol. They are, however, powerful greenhouse gases. HFCs—primarily used as replacements for ozone depleting substances but also emitted as a by-product of the HCFC-22 manufacturing process—currently have a small aggregate radiative forcing impact; however, it is anticipated that their contribution to overall radiative forcing will increase (IPCC 2001). PFCs and SF_6 are predominantly emitted from various industrial processes including aluminum smelting, semiconductor manufacturing, electric power transmission and distribution, and magnesium casting. Currently, the radiative forcing impact of PFCs and SF_6 is also small; however, they have a significant growth rate, extremely long atmospheric lifetimes, and are strong absorbers of infrared radiation, and therefore have the potential to influence climate far into the future (IPCC 2001).

Carbon Monoxide (CO). Carbon monoxide has an indirect radiative forcing effect by elevating concentrations of CH_4 and tropospheric ozone through chemical reactions with other atmospheric constituents (e.g., the hydroxyl radical, OH) that would otherwise assist in destroying CH_4 and tropospheric ozone. Carbon monoxide is created when carbon-containing fuels are burned incompletely. Through natural processes in the atmosphere, it is eventually oxidized to CO_2. Carbon monoxide concentrations are both short-lived in the atmosphere and spatially variable.

Nitrogen Oxides (NO_x). The primary climate change effects of nitrogen oxides (i.e., NO and NO_2) are indirect and result from their role in promoting the formation of ozone in the troposphere and, to a lesser degree, lower stratosphere, where it has positive radiative forcing effects. Additionally, NO_x emissions from aircraft are also likely to decrease methane concentrations, thus having a negative radiative forcing effect (IPCC 1999). Nitrogen oxides are created from lightning, soil microbial activity, biomass burning – both natural and anthropogenic fires – fuel combustion, and, in the stratosphere, from the photo-degradation of nitrous oxide (N_2O). Concentrations of NO_x are both relatively short-lived in the atmosphere and spatially variable.

Nonmethane Volatile Organic Compounds (NMVOCs). Nonmethane volatile organic compounds include compounds such as propane, butane, and ethane. These compounds participate, along with NO_x, in the formation of tropospheric ozone and other photochemical oxidants. NMVOCs are emitted primarily from transportation and industrial processes, as well as biomass burning and non-industrial consumption of organic solvents. Concentrations of NMVOCs tend to be both short-lived in the atmosphere and spatially variable.

Aerosols. Aerosols are extremely small particles or liquid droplets found in the atmosphere. They can be produced by natural events such as dust storms and volcanic activity, or by anthropogenic processes such as fuel combustion and biomass burning. They affect radiative forcing in both direct and indirect ways: directly by scattering and absorbing solar and thermal infrared radiation; and indirectly by increasing droplet counts that modify the formation, precipitation efficiency, and radiative properties of clouds. Aerosols are removed from the atmosphere relatively rapidly by precipitation. Because aerosols generally have short atmospheric lifetimes, and have concentrations and compositions that vary regionally, spatially, and temporally, their contributions to radiative forcing are difficult to quantify (IPCC 2001).

The indirect radiative forcing from aerosols is typically divided into two effects. The first effect involves decreased droplet size and increased droplet concentration resulting from an increase in airborne aerosols. The second effect involves an increase in the water content and lifetime of clouds due to the effect of reduced droplet size on precipitation efficiency (IPCC 2001). Recent research has placed a greater focus on the second indirect radiative forcing effect of aerosols.

Various categories of aerosols exist, including naturally produced aerosols such as soil dust, sea salt, biogenic aerosols, sulphates, and volcanic aerosols, and anthropogenically manufactured aerosols such as industrial dust and carbonaceous aerosols (e.g., black carbon, organic carbon) from transportation, coal combustion, cement manufacturing, waste incineration, and biomass burning.

The net effect of aerosols is believed to produce a negative radiative forcing effect (i.e., net cooling effect on the climate), although because they are short-lived in the atmosphere—lasting days to weeks—their concentrations respond rapidly to changes in emissions. Locally, the negative radiative forcing effects of aerosols can offset the positive forcing of greenhouse gases (IPCC 1996). “However, the aerosol effects do not cancel the global-scale effects of the much longer-lived greenhouse gases, and significant climate changes can still result” (IPCC 1996).

The IPCC’s Third Assessment Report notes that “the indirect radiative effect of aerosols is now understood to also encompass effects on ice and mixed-phase clouds, but the magnitude of any such indirect effect is not known, although it is likely to be positive” (IPCC 2001). Additionally, current research suggests that another constituent of aerosols, elemental carbon, may have a positive radiative forcing (Jacobson 2001). The primary anthropogenic emission sources of elemental carbon include diesel exhaust, coal combustion, and biomass burning.

Global Warming Potentials

Global Warming Potentials (GWPs) are intended as a quantified measure of the globally averaged relative radiative forcing impacts of a particular greenhouse gas. It is defined as the cumulative radiative forcing—both direct and indirect effects—integrated over a period of time from the emission of a unit mass of gas relative to some reference gas (IPCC 1996). Carbon dioxide (CO_2) was chosen as this reference gas. Direct effects occur when the gas itself is a greenhouse gas. Indirect radiative forcing occurs when chemical transformations involving the original gas produce a gas or gases that are greenhouse gases, or when a gas influences other radiatively important processes such as the atmospheric lifetimes of other gases. The relationship between gigagrams (Gg) of a gas and Tg CO_2 Eq. can be expressed as follows:

$$\text{Tg CO}_2\text{ Eq} = (\text{Gg of gas}) \times (\text{GWP}) \times \left(\frac{\text{Tg}}{1{,}000\text{ Gg}}\right) \text{where,}$$

Tg CO_2 Eq. = Teragrams of Carbon Dioxide Equivalents
Gg = Gigagrams (equivalent to a thousand metric tons)
GWP = Global Warming Potential
Tg = Teragrams

GWP values allow policy makers to compare the impacts of emissions and reductions of different gases. According to the IPCC, GWPs typically have an uncertainty of roughly ±35 percent, though some GWPs have larger uncertainty than others, especially those in which lifetimes have not yet been ascertained. In the following decision, the parties to the UNFCCC have agreed to use consistent GWPs from the IPCC Second Assessment Report (SAR), based upon a 100 year time horizon, although other time horizon values are available (see Table I2).

> *In addition to communicating emissions in units of mass, Parties may choose also to use global warming potentials (GWPs) to reflect their inventories and projections in carbon dioxide-equivalent terms, using information provided by the Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report. Any use of GWPs should be based on the effects of the greenhouse gases over a 100-year time horizon. In addition, Parties may also use other time horizons. (FCCC/CP/1996/15/Add.1)*

Greenhouse gases with relatively long atmospheric lifetimes (e.g., CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) tend to be evenly distributed throughout the atmosphere, and consequently global average concentrations can be determined. The short-lived gases such as water vapor, carbon monoxide, tropospheric ozone, other ambient air pollutants (e.g., NO_x, and NMVOCs), and tropospheric aerosols (e.g., SO_2 products and black carbon), however, vary spatially, and consequently it is difficult to quantify their global radiative forcing impacts. GWP values are generally not attributed to these gases that are short-lived and spatially inhomogeneous in the atmosphere.

Table I2. Global Warming Potentials (GWP) and Atmospheric Lifetimes (Years) Used in the Inventory

Gas	Atmospheric Lifetime	100-year GWP[a]	20-year GWP	500-year GWP
Carbon dioxide (CO_2)	50-200	1	1	1
Methane (CH_4)[b]	12±3	21	56	6.5
Nitrous oxide (N_2O)	120	310	280	170
HFC-23	264	11,700	9,100	9,800
HFC-125	32.6	2,800	4,600	920
HFC-134a	14.6	1,300	3,400	420
HFC-143a	48.3	3,800	5,000	1,400
HFC-152a	1.5	140	460	42
HFC-227ea	36.5	2,900	4,300	950
HFC-236fa	209	6,300	5,100	4,700
HFC-4310mee	17.1	1,300	3,000	400
CF_4	50,000	6,500	4,400	10,000
C_2F_6	10,000	9,200	6,200	14,000
C_4F_{10}	2,600	7,000	4,800	10,100
C_6F_{14}	3,200	7,400	5,000	10,700
SF_6	3,200	23,900	16,300	34,900

Source: IPCC (1996)
[a] GWPs used here are calculated over 100 year time horizon
[b] The methane GWP includes the direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor. The indirect effect due to the production of CO_2 is not included.

Table I3 presents direct and net (i.e., direct and indirect) GWPs for ozone-depleting substances (ODSs). Ozone-depleting substances directly absorb infrared radiation and contribute to positive radiative forcing; however, their effect as ozone-depleters also leads to a negative radiative forcing because ozone itself is a potent greenhouse gas. There is considerable uncertainty regarding this indirect effect; therefore, a range of net GWPs is provided for ozone depleting substances.

Table I3. Net 100-year Global Warming Potentials for Select Ozone Depleting Substances*

Gas	Direct	Net_{min}	Net_{max}
CFC-11	4,600	(600)	3,600
CFC-12	10,600	7,300	9,900
CFC-113	6,000	2,200	5,200
HCFC-22	1,700	1,400	1,700
HCFC-123	120	20	100
HCFC-124	620	480	590
HCFC-141b	700	(5)	570

Gas	Direct	Net_{min}	Net_{max}
HCFC-142b	2,400	1,900	2,300
$CHCl_3$	140	(560)	0
CCl_4	1,800	(3,900)	660
CH_3Br	5	(2,600)	(500)
Halon-1211	1,300	(24,000)	(3,600)
Halon-1301	6,900	(76,000)	(9,300)

Source: IPCC (2001)
* Because these compounds have been shown to deplete stratospheric ozone, they are typically referred to as ozone depleting substances (ODSs). However, they are also potent greenhouse gases. Recognizing the harmful effects of these compounds on the ozone layer, in 1987 many governments signed the *Montreal Protocol on Substances that Deplete the Ozone Layer* to limit the production and importation of a number of CFCs and other halogenated compounds. The United States furthered its commitment to phase-out ODSs by signing and ratifying the Copenhagen Amendments to the *Montreal Protocol* in 1992. Under these amendments, the United States committed to ending the production and importation of halons by 1994, and CFCs by 1996. The IPCC Guidelines and the UNFCCC do not include reporting instructions for estimating emissions of ODSs because their use is being phased-out under the *Montreal Protocol*. The effects of these compounds on radiative forcing are not addressed here.

The IPCC recently published its Third Assessment Report (TAR), providing the most current and comprehensive scientific assessment of climate change (IPCC 2001). Within that report, the GWPs of several gases were revised relative to the IPCC's Second Assessment Report (SAR) (IPCC 1996), and new GWPs have been calculated for an expanded set of gases. Since the SAR, the IPCC has applied an improved calculation of CO_2 radiative forcing and an improved CO_2 response function (presented in WMO 1999). The GWPs are drawn from WMO (1999) and the SAR, with updates for those cases where new laboratory or radiative transfer results have been published. Additionally, the atmospheric lifetimes of some gases have been recalculated. Because the revised radiative forcing of CO_2 is about 12 percent lower than that in the SAR, the GWPs of the other gases relative to CO_2 tend to be larger, taking into account revisions in lifetimes. However, there were some instances in which other variables, such as the radiative efficiency or the chemical lifetime, were altered that resulted in further increases or decreases in particular GWP values. In addition, the values for radiative forcing and lifetimes have been calculated for a variety of halocarbons, which were not presented in the SAR. The changes are described in the TAR as follows:

New categories of gases include fluorinated organic molecules, many of which are ethers that are proposed as halocarbon substitutes. Some of the GWPs have larger uncertainties than that of others, particularly for those gases where detailed laboratory data on lifetimes are not yet available. The direct GWPs have been calculated relative to CO_2 using an improved calculation of the CO_2 radiative forcing, the SAR response function for a CO_2 pulse, and new values for the radiative forcing and lifetimes for a number of halocarbons.

References

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Appendix D
Methods for Quantification

Attached to this appendix is the Memo from the Center for Climate Strategies that sets forth the methods used in quantifying the greenhouse gas (GHG) emission reductions and direct costs/cost savings associated with the policy recommendations. The memo also provides examples of the distinction between "direct" and "indirect" costs. In addition, the combined impacts of all of the policy recommendations within and between each sector were estimated as if all of the recommendations were implemented together. This involves eliminating any overlaps in coverage of affected entities that would occur to avoid double counting of impacts. This memorandum was submitted to the Kentucky Climate Action Plan Council on August 4, 2010 and subsequently adopted via an e-mail approval process. In addition to this general Quantification Assumptions Memo (QAM) each of the four TWGs had sector-specific QAMs prepared and approved by the KCACP and these can be found on the KCACP web site in the Post-Meeting #7 materials.

Center for Climate Strategies
Helping States and Nations Tackle Climate Change

www.climatestrategies.us

Memo

To: Kentucky Climate Action Plan Council

From: The Center for Climate Strategies

Subject: Quantification of Climate Mitigation Policy Options

Date: August 4, 2010

This memo summarizes key elements of the recommended methodology for estimating GHG impacts and cost effectiveness for draft policy options for analysis considered amenable to quantification. The quantification process is intended to support custom design and analysis of draft policy options, and provide both consistency and flexibility. Feedback is encouraged.

Key guidelines include:

- Focus of analysis: **Net GHG reduction potential** in physical units of million metric tons (MMt) of carbon dioxide equivalent (CO_2e) and **net cost per metric ton reduced** in units of dollars per metric ton of carbon dioxide equivalent ($/t$CO_2e$). Where possible, full life cycle analysis is used to evaluate the net energy (and emissions) performance of actions (taking into account all energy inputs and outputs to production). Net analysis of the effects of carbon sequestration is conducted where applicable.
- Cost-effectiveness: Because monetized dollar value of GHG reduction benefits are not available, physical benefits are used instead, measured as dollars per metric ton of carbon dioxide equivalent ($/t$CO_2e$) (cost or savings per ton) or "cost effectiveness" evaluation. Both positive costs and cost savings (negative costs) are estimated as a part of compliance cost.
- Geographic inclusion: Measure GHG impacts of activities that occur within the state, regardless of the actual location of emissions reductions. For instance, a major benefit of recycling is the reduction in material extraction and processing (e.g. aluminum production). While a policy option may increase recycling in Kentucky, the reduction in emissions may occur where this material is produced. Where significant emissions impacts are likely to occur outside the state, this will be clearly indicated. These emissions reductions are counted towards the achievement of the state's emission goal, since they result from actions taken by the state.

- Direct vs. indirect effects: "Direct effects" are those borne by the entities implementing the policy recommendation. For example, direct costs are net of any financial benefits or savings to the entity. "Indirect effects" are defined as those borne by the entities other than those implementing the policy recommendation. Indirect effects will be quantified on a case-by-case basis depending on magnitude, importance, time available, need and availability of data. (See additional discussion and list of examples below.)
- Non-GHG (external) impacts and costs: Include in qualitative terms where deemed important. Quantify on a case-by-case basis as needed depending on need and where data are readily available.
- Discounting and annualizing: Discount a multi-year stream of net costs (or savings) to arrive at the "net present value cost" of the cost of implementing a policy option. Discount costs in constant 2005 dollars using a 5% annual real discount rate for the project period of 2010 through 2030 (unless otherwise specified for the particular policy option). Capital investments are represented in terms of annualized or amortized costs through 2030. Create an annualized cost per ton by dividing the present value cost or cost savings by the cumulative reduction in tons of GHG emissions.
- Time period of analysis: Count the impacts of actions that occur during the project time period and, using annualized emissions reduction and cost analysis, report emissions reductions and costs for specific target years of 2020 and 2030. Where additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, show these for comparison and potential inclusion.
- Aggregation of cumulative impacts of policy options: In addition to "stand alone" results for individual options, estimate cumulative impacts of all options combined. In this process we avoid simple double counting of GHG reduction potential and cost when adding emission reductions and costs associated with all of the policy recommendations. To do so we note and or estimate interactive effects between policy recommendations using analytical methods where significant overlap or equilibrium effects are likely.
- Policy design specifications and other key assumptions: Include explicit notation of timing, goal levels, implementing parties, the type of implementation mechanism, and other key assumptions as determined by the Kentucky Climate Action Plan Council (KCAPC).
- Transparency: Include policy design choices (above) as well as data sources, methods, key assumptions, and key uncertainties. Use data and comments provided by KCAPC to ensure best available data sources, methods, and key assumptions using their expertise and knowledge to address specific issues in Kentucky. Modifications will be made through facilitated decisions.

For additional reference see the economic analysis guidelines developed by the Science Advisory Board of the US EPA available at:
http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html.

Examples of Direct/Indirect Net Costs and Savings

Note: These examples are meant to be illustrative.

Residential, Commercial, and Industrial (RCI) Sectors

Direct Costs and/or Savings

- Net capital costs (or incremental costs relative to standard practice) of improved buildings, appliances, equipment (cost of higher-efficiency refrigerator versus refrigerator of similar features that meets standards)
- Net operation and maintenance (O&M) costs (relative to standard practice) of improved buildings, appliances, equipment, including avoided/extra labor costs for maintenance (less changing of compact fluorescent light (CFL) or light-emitting diode (LED) bulbs in lamps relative to incandescent)
- Net fuel (gas, electricity, biomass, etc.) costs (typically as avoided costs from a societal perspective)
- Cost/value of net water use/savings
- Cost/value of net materials use/savings (for example, raw materials savings via recycling, or lower/higher cost of low-global warming potential (GWP) refrigerants)
- Direct improved productivity as a result of industrial measures (measured as change in cost per unit output, for example, for an energy/GHG-saving improvement that also speeds up a production line or results in higher product yield)

Indirect Costs and/or Savings

- Re-spending effect on economy
- Net value of employment impacts
- Net value of health benefits/impacts
- Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)
- Net embodied energy of materials used in buildings, appliances, equipment, relative to standard practice
- Improved productivity as a result of an improved working environment, such as improved office productivity through improved lighting (though the inclusion of this as indirect might be argued in some cases)

Energy Supply (ES) Sector

Direct Costs and/or Savings

- Net capital costs (or incremental costs relative to reference case technologies) of renewables or other advanced technologies resulting from policies

- Net O&M costs (relative to reference case technologies) renewables or other advanced technologies resulting from policies
- Avoided or net fuel savings (gas, coal, biomass, etc.) of renewables or other advanced technologies relative to reference case technologies resulting from policies
- Total system costs (net capital + net O&M + avoided/net fuel savings + net imports/exports + net transmission and distribution (T&D) costs) relative to reference case total system costs

Indirect Costs and/or Savings

- Re-spending effect on economy
- Higher cost of electricity reverberating through economy
- Energy security
- Net value of employment impacts
- Net value of health benefits/impacts
- Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

Agriculture, Forestry, and Waste Management (AFW) Sectors

Direct Costs and/or Savings

- Net capital costs (or incremental costs relative to standard practice) of facilities or equipment (e.g., manure digesters and associated infrastructure, generator; ethanol production facility)
- Net O&M costs (relative to standard practice) of equipment or facilities
- Net fuel (gas, electricity, biomass, etc.) costs or avoided costs
- Cost/value of net water use/savings

Indirect Costs and/or Savings

- Net value of employment impacts
- Net value of human health benefits/impacts
- Net value of ecosystem health benefits/impacts (wildlife habitat; reduction in wildfire potential; etc.)
- Value of net environmental benefits/impacts (value of damage by air or water pollutants on structures, crops, etc.)
- Net embodied energy of water use in equipment or facilities relative to standard practice
- Reduced VMT and fuel consumption associated with land use conversions (e.g., as a result of forest/rangeland/cropland protection policies)

Transportation and Land Use (TLU) Sector

Direct Costs and/or Savings

- Incremental cost of more efficient vehicles net of fuel savings.
- Incremental cost of implementing Smart Growth programs, net of saved infrastructure costs.
- Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure costs (e.g., roads)
- Incremental cost of alternative fuel, net of any change in maintenance costs

Indirect Costs and/or Savings

- Health benefits of reduced air and water pollution.
- Ecosystem benefits of reduced air and water pollution.
- Value of quality-of-life improvements.
- Value of improved road safety.
- Energy security
- Net value of employment impacts

Appendix E
Agriculture, Forestry, and Waste Sectors Policy Recommendations

Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/$tCO_2e$)
		2020	2030	Total 2011–2030		
AFW-1	Forestry Management for Carbon Sequestration	0.04	0.07	0.86	$17.4	$20.3[1]
AFW-2	Expanded Use of Biomass Feed-stocks for Electricity, Heat, and Steam Production	*Costs/GHG Reductions Captured in ES-1, ES-5 and ES-7 Analysis*				
AFW-3a	On-Farm Energy Production	*GHG reductions accounted for in policies where biomass is used for Fuel (ES, RCI, & TLU)*				
AFW-3b	On-Farm Energy Efficiency Improvements	0.21	0.45	4.5	–$94	–$21
AFW-4	In-State Liquid/Gaseous Biofuels Production	*Costs/GHG Reductions Captured in TLU-10 Analysis*				
AFW-5a	Soil Carbon Management—NT/CT	0.37	0.74	7.8	$6	$1
AFW-5b	Soil Carbon Management—Winter Cover Crops	0.95	1.9	20	$141	$7
AFW-6	Increase Productivity of Abandoned, Underutilized, and Reclaimed Lands[2]	2.7	5.8	58	$50	$1
AFW-7a	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Mined Lands	0.02	0.09	0.16	–$19	–$120
AFW-7b	Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands—Other Lands	0.55	1.0	11	$61	$5
AFW-8	Advanced MSW Reuse, Recycling, and Organic Waste Management Programs	0.84	1.3	16	$167	$10
AFW-9	Landfill Methane Energy Programs	1.4	2.4	29	$29	$1
	Sector Total After Adjusting for Overlaps	**4.4**	**7.9**	**90**	**$308**	**$3**
	Reductions From Recent Actions	**0**	**0**	**0**	**$0**	**$0**
	Sector Total Plus Recent Actions	**4.4**	**7.9**	**90**	**$308**	**$3**

[1] The benefits of increased forest carbon sequestration will last far beyond the policy period. When GHG reductions and cost-effectiveness are calculated considering the lifetime of the forest (~50 years), the results are 3.3 $MMtCO_2e$ and 5.3 $/$tCO_2e$, respectively.

[2] This policy overlaps with policies in the ES sector; the overlapping benefits and costs were removed in the overall KCAPC process results shown for total benefits and costs in the final report.

$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; ES = Energy Supply; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MSW = municipal solid waste; NT/CT = no till/conservation tillage; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative NPV represents positive net cash flows from the policy recommendation (i.e., the costs of the policy recommendation, when levelized over their expected lifetimes, are less than expected expenditures).Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

Totals do not equal sum of individual policy recommendations due to subtraction of overlaps.

Table AFW-1 shows the potential biomass resources available in Kentucky. These volumes are expected to be available by 2025; however, the total amounts would require changes in land use, not all of which have been included in the policy recommendations described in this document. Total biomass availability by year is shown in Table AFW-2. Note that the TWG did not consider other potential feedstock sources such as, municipal solid waste (except urban wood waste), including paper, cardboard, food/yard waste, or other organic materials.

Table AFW-1. Potential Annual Biomass Resource Supply in Kentucky[3]

Biomass Resource	Annual Potential Biomass Supply (thousand dry tons)	Delivered Cost[4] ($2007/dry ton)	Notes
Crop Residues	2,300	$74[5]	2009 Executive Task Force on Biomass and Biofuels Development in Kentucky.[6]
Agricultural Energy Crops	3,600	$40[7]	2009 Executive Task Force. Aspirational goal—would require land use change. About half of this total is achieved through implementing AFW-6.
Additional Energy Crops	3,780	$85[8]	Assume plantings on 25% of acreage not in Conservation Reserve Program (CRP). 2009 Executive Task Force. Aspirational goal—would require land use change.

[3] The cumulative impact of biomass production on the sustainability of food, feed, other commodity supplies, and other natural resources needs to be evaluated and monitored.

[4] Delivered cost expressed in units of $/dry ton.

[5] "Estimating a Value for Corn Stover," Ag Decision maker File A1-70, December 2007. Available at: http://www.extension.iastate.edu/agdm/crops/html/a1-70.html. The maximum a livestock owner would pay for corn stover as feed. Additional transportation costs of $14.75 were assumed, taken from Iowa State University, University Extension publication, "Estimated Costs for Production, Storage and Transportation of Switchgrass."

[6] Governor's Office of Agricultural Policy and Kentucky Energy and Environment Cabinet, "Final Report from the Executive Task Force on Biomass and Biofuels Development in Kentucky," December 10, 2009, accessible at http://agbioworks.org/pdfs/KYBiomass_FinalReport_Dec2009.pdf.

[7] Ibid., page 11.

[8] University of Iowa., Center for Global and Regional Environmental Research. "Estimating the Economic Impact of Substituting Switchgrass for Coal for Electric Generation in Iowa." 2005. Available at: http://www.iowaswitchgrass.com/__docs/pdf/8-6-0%20Final%20Report.pdf.

Biomass Resource	Annual Potential Biomass Supply (thousand dry tons)	Delivered Cost[4] ($2007/dry ton)	Notes
Forest Residues	3,160	$58[9]	Unextracted wood and bark from current timber harvesting and material from thinnings and other forest improvement treatments. 2009 Executive Task Force. This assumes that it is available for extraction at an economically feasible cost without damaging stands or future growth in those forest acres.
Forest—Annual Net Growth (currently unused)	1,900[10]		2009 Executive Task Force.
Primary & Secondary Mill Residue	1,485[11]		2005 National Renewable Energy Laboratory report.
Urban Wood	340	$0[12]	2009 Executive Task Force.
Anticipated production improvements and land use changes	8,435	–	2009 Executive Task Force.
Total Sources by 2025–2030	25,000	—[13]	5,800 currently available; 19,200 with near-term production and technology changes.

Table AFW-2 shows biomass supply and demand for Kentucky. The total available biomass matches that shown in Table AFW-1, although this achievable biomass figure is not reached until 2025. As can be seen in Table AFW-2, there is sufficient biomass for all years to meet the needs of the three energy supply recommendations, as well as the advanced biofuel recommendation.

The biomass demand split shown in Table AFW-2 is driven primarily by the amount of biomass needed for cellulosic ethanol production to ensure that the demand requirements of Transportation and Land Use (TLU) policy recommendation TLU-10 are met with in-state production. Future market conditions, including the cost of biomass and fossil fuels, will drive the relative penetration of biofuel use within each sector. Continued study and refinement of this initial

[9] Based on Pennsylvania woody biomass estimate from John Karkash. Cited woody biomass value at $29/green ton. Converted to dry tons, results in a cost of $58/ton.

[10] This may include unharvested trees that are increasing in size on property for which there is no plan to harvest, or specific species that landowners are allowing to grow to a larger size, or trees set aside for other more profitable use in a traditional timber market. Annual net growth may also include some undesirable species that could be harvested for biomass energy.

[11] Kentucky facilities may already be using this for energy.

[12] The costs of municipal solid waste and urban waste are often negative due to tipping fees. $0 cost was chosen to be conservative.

[13] "The Task Force concludes that 25 million tons of biomass per year, produced within a sustainable environment defined by the Commonwealth with land-use changes involving 15% of Kentucky's farmland, is feasible by 2025 if improvements in yield and adaptability are realized." Available at: http://energy.ky.gov/Documents/BTF/Final%20Report.pdf.

biomass supply/demand assessment and allocation between sectors is warranted in the future. Note that the biomass needs for AFW-6 are not shown here, since they overlap with the biomass needs of ES-1, ES-5, and ES-7.

Table AFW-2. Biomass Supply/Demand for Policy Recommendations

Year	Projected Biomass Supply	ES Needs (ES-1, ES-5 ES-7)	AFW-4 Goal (Covers TLU-10)	Surplus in Projected Biomass Supply[14]
	1,000 dry tons			
2011	5,800	0	57	5,743
2012	7,171	383	89	6,699
2013	8,542	764	177	7,601
2014	9,913	1,145	310	8,458
2015	11,284	4,622	532	6,131
2016	12,655	5,003	753	6,899
2017	14,026	8,568	975	4,483
2018	15,397	8,946	1,241	5,210
2019	16,768	12,666	1,507	2,595
2020	18,139	13,635	1,675	2,829
2021	19,510	17,941	2,153	–584
2022	20,881	18,566	2,552	–237
2023	22,252	19,205	2,712	335
2024	23,623	19,862	2,871	890
2025	25,000	20,536	3,031	1,433
2026	25,000	20,627	3,190	1,183
2027	25,000	20,719	3,350	931
2028	25,000	20,800	3,509	691
2029	25,000	20,884	3,669	447
2030	25,000	20,983	3,828	189

[14] Table AFW-2 shows there is sufficient biomass in KY to meet the demands of ES-1, ES-5, ES-7 and AFW-4 for all years except for 2021 and 2022. Any shortage would affect ES-5 first, and given the very small shortages indicated, only ES-5. Given that biomass availability has been conservatively estimated and ES-5 biomass demand may not be as high as shown in this table, this analysis assumes sufficient biomass is available to meet all biomass needs even in the two constrained years.

AFW-1. Forestry Management for Carbon Sequestration

Policy Description

Carbon dioxide (CO_2) is captured and stored in trees, soil, and other forest biomass. Forest management activities that promote forest production have the potential to increase net CO_2 sequestration rates and enhance greenhouse gas (GHG) benefits. Retaining forest management where it is currently practiced and expanding the area covered by management plans would stimulate the rate of production, in terms of both forest growth and the amount of biomass harvested. A managed forest is a healthier and more productive one. The healthier a forest, the better the trees grow, and the better the trees grow, the more carbon they sequester.

From the history of Kentucky's forests, we can see that there is no single statement regarding the value of Kentucky's forests. Value, like beauty, is in the eye of the beholder. Attitudes toward Kentucky's forests have changed, diversified, and shifted throughout Kentucky's history, and will continue to do so as the concerns of our culture, the status of the resource, and the desired end uses fluctuate in the future.

Economic incentives are often the easiest way to promote new ideas. Due to the financial significance of forest-related products, Kentucky stands to benefit greatly from sustainable management. Traditionally, wood products have stimulated forest management, and practices such as agro-forestry provide alternative ways to produce revenue on forestland. Currently, many policies are being discussed and developed nationally with regard to carbon sequestration and biofuels for energy.

Policy Design

Goals: Increase net carbon sequestration in Kentucky's forests by completing forest management plans on one million acres of currently forested lands by 2025.

Timing: See above.

Parties Involved: Kentucky Division of Forestry, Kentucky Woodland Owners Association, U.S. Department of Agriculture (USDA) United States Forest Service (USFS), USDA Farm Services Agency, Mountain Association for Community Economic Development, University of Kentucky, nongovernment organizations, Kentucky Department of Fish and Wildlife Resources.

Other: None identified.

Implementation Mechanisms

- Promote carbon-marketing opportunities to increase interest in forest management.
  - Carbon sequestration represents a potential avenue to assist with afforestation and reforestation programs. Currently, the Climate Action Reserve is the most advanced program for forestry projects in the United States.

- Promote opportunities for landowners and businesses to participate in the various certification systems.

- Expand state financial support for cost-share programs.
- Develop information related to improving carbon sequestration in a manner that improves forest health and productivity, while sustaining biodiversity and other natural resource benefits.
- Look for opportunities and provide necessary resources to improve forest health and productivity on state-owned forests.
- Offer new initiatives that provide landowners incentives to improve forest resources, encourage proper management, promote sustainability of forestlands, and benefit the forest products industry. Practices may include:
  - increased stocking of poorly stocked lands,
  - thinning and density management,
  - fertilization and waste recycling,
  - expanded short-rotation woody crops (for fiber and energy),
  - expanded use of genetically preferred species,
  - modified biomass removal practices,
  - fire management and risk reduction,
  - pest and disease management, and
  - promoting biodiversity of forests to improve ecosystem services and sustainability.
- Prepare educational materials to inform forest landowners about certification systems and carbon market opportunities.
- Increase the percentage of forest management plans that are actively renewed.

Related Policies/Programs in Place

- The Kentucky Division of Forestry's Forest Stewardship Program and Landowner Services provides forest landowners support on improving forest management.
- The Kentucky Division of Forestry's forest health program focuses on identifying and monitoring for potential insect, disease, and invasive, and exotic plant problems that threaten our forestlands.
- The Kentucky Forest Conservation Act regulates all commercial loggers and requires the use of best management practices to help protect water quality.
- The Kentucky Master Logger Program is an education program that teaches logging methods that benefit both industry and the forest.
- The Mountain Association for Community Economic Development (MACED) promotes sustainable forest management and seeks to compensate forest owners for increased carbon sequestration through carbon offsets.

Type(s) of GHG Reductions

CO_2: Carbon sequestration through additional tree growth and improved productivity of forests.

Estimated GHG Reductions and Net Costs or Cost Savings

Table AFW-1-1. Summary of AFW-1

Quantification Factors	2020	2030	Units
GHG Emission Reductions	0.04	0.07	$MMtCO_2e$
Net Present Value (2011–2030)		$17.4	$ Million
Cumulative Emissions Reductions (2011–2030)		0.86	$MMtCO_2e$
Cost-Effectiveness (2011–2030)		$20.3	$/tCO_2e$
Cumulative Emissions Reductions (2011–2075)		3.3	$MMtCO_2e$
Cost-Effectiveness (2011–2075)		$5.3	$/tCO_2e$

$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Scott Shouse, forester at MACED.
- Kentucky Statewide Assessment of Forest Resources, Part 1: Issue 4: Forest Management. Available at: http://forestry.ky.gov/LandownerServices/Pages/ForestlandAssessment.aspx.

Quantification Methods

GHG Reductions

This policy seeks to improve carbon sequestration in Kentucky forests by implementing forest management plans on 1,000,000 acres by 2025. Forest management plans increase the health and often the productivity of the forest. Depending on landowners' goals, forest management plans may be focused on increased harvesting productivity, wildlife management, hunting (such as deer leases), aesthetic value, or other objectives.

Table AFW-1-2 summarizes the number of acres enrolled annually in a forest management program, the cumulative acres treated throughout the policy period, the increased carbon sequestration, and the costs of completing forest management plans.

Kentucky forests currently sequester 3.3 metric tons of carbon dioxide equivalent (tCO_2e/acre/year), which is roughly the equivalent of one 18-inch oak tree per acre per year.[15] This amounts to approximately 2.8% growth per year.

[15] Scott Shouse, MACED, personal communication to R. Anderson, CCS, via phone, December 2010. This number is based on 35,000 acres worth of forest inventory data across Eastern Kentucky and the USFS growth & yield model (based on Forest Inventory and Analysis (FIA) Program data), and includes mortality.

Table AFW-1-2. GHG Savings and Costs of Forest Management Plans

Year	Acres Treated Annually	Cumulative Acres Treated	BAU Carbon Sequestration in Those Acres (metric tons CO_2e/acre/year)	Additional Sequestration Those Acres Due to Management Plans (metric tons CO_2e/acre/year)	Cost ($2005)	Discounted Cost (million $2005)
2011	66,667	66,667	220,000	4,400	1,600,000	1.60
2012	66,667	133,333	440,000	8,800	1,600,000	1.52
2013	66,667	200,000	660,000	13,200	1,600,000	1.45
2014	66,667	266,667	880,000	17,600	1,600,000	1.38
2015	66,667	333,333	1,100,000	22,000	1,600,000	1.32
2016	66,667	400,000	1,320,000	26,400	1,600,000	1.25
2017	66,667	466,667	1,540,000	30,800	1,600,000	1.19
2018	66,667	533,333	1,760,000	35,200	1,600,000	1.14
2019	66,667	600,000	1,980,000	39,600	1,600,000	1.08
2020	66,667	666,667	2,200,000	44,000	1,600,000	1.03
2021	66,667	733,333	2,420,000	48,400	1,600,000	0.98
2022	66,667	800,000	2,640,000	52,800	1,600,000	0.94
2023	66,667	866,667	2,860,000	57,200	1,600,000	0.89
2024	66,667	933,333	3,080,000	61,600	1,600,000	0.85
2025	66,667	1,000,000	3,300,000	66,000	1,600,000	0.81
2026	0	1,000,000	3,300,000	66,000	0	0.00
2027	0	1,000,000	3,300,000	66,000	0	0.00
2028	0	1,000,000	3,300,000	66,000	0	0.00
2029	0	1,000,000	3,300,000	66,000	0	0.00
2030	0	1,000,000	3,300,000	66,000	0	0.00
Total	**1,000,000**			**858,000**		**17.44**

BAU = business as usual; CO_2e = carbon dioxide equivalent; GHG = greenhouse gas.

It was assumed that a change in forest management would increase forest carbon sequestration by 2% above the baseline sequestration rate.[16] This is consistent with carbon sequestration rates published for average- and high-productivity Loblolly and shortleaf pine stands in the southeastern United States, which show a 5% gain in carbon sequestration in the high-productivity stands. GHG savings were estimated by multiplying total acreage under forest management plans by 0.066 metric tons CO_2e/acre/year (3.3 metric tons CO_2e/acre/year times 2.8%).

Some percentage of forests under management will continue to be harvested. Harvested wood products may be used for durable wood products and will continue to sequester carbon even after

[16] There is significant uncertainty regarding this number. It is assumed that the carbon sequestration improvement would be above zero, but it is unknown what exactly it would be. Most academic and research reports focus on the upper limit of carbon sequestration under ideal forest management scenarios, rather than techniques that could be implemented on a statewide basis. There is a paucity of literature on carbon sequestration effects of forest management plans for the average landowner.

being removed from the forest. This analysis, however, does not attempt to estimate disposition of harvested wood products from managed forests.

Cost Analysis

The cost of preparing a forest management plan is estimated to be $24 per acre.[17] It is assumed that this cost is incurred in the first year. For most forest owners in Kentucky, there will be other costs incurred to implement the forest management plan, such as timber stand improvement, clearing, and treatment. These are not estimated at this time due to a lack of specific data.

Additional revenue may be realized by forest landowners who register for carbon offsets. This would decrease the overall cost of the policy. However, this revenue stream has not been included in this analysis due to a lack of data. Landowners who enroll in a carbon credit program would need to perform both a baseline inventory and a 10-year inventory to estimate sequestration. These costs are also not included in this analysis at this time due to lack of data.

Long-Term Effects

Benefits from improved forest carbon sequestration will be realized long after the end of the policy period considered in this analysis (2030). Improved forest management techniques are expected to provide long-term benefits to acres under management. To illustrate the potential long-term impact of forest improvement, it is assumed that increased carbon sequestration in managed forests persists for the life cycle of a forest stand—at least 50 years. Consequently, acres that are enrolled in a forest management program in 2011 will continue to have benefits through 2061. Additional benefits would be realized, even if no additional costs are expended. Long-term GHG savings and cost=effectiveness are summarized in Table AFW-1-3. If long-term benefits are included, GHG reductions would be 3.3 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) rather than the 0.86 $MMtCO_2e$ realized during the policy period of 2011–2030.

Table AFW-1-3. Long-Term Effects of Improved Forest Carbon Sequestration through Management Plans

Period	GHG Reductions ($MMtCO_2e$)	Cost-Effectiveness ($/$tCO_2e$)
2011–2030	0.86	$20.32
2011–2075	3.3	$5.28

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Key Assumptions

- Acres are enrolled linearly over the policy period. Kentucky forests sequester 3.3 tCO_2e/acre/year.
- Forest management would increase forest carbon sequestration by 2%.
- The cost of preparing a forest management plan is estimated to be $24 per acre.

[17] Scott Shouse, MACED, personal communication to R. Anderson, CCS, via email, December 2010. It would take a forester approximately a day and a half to walk the property, interview the landowner, and write the plan for a 30-100 acre property. At $480 a day, that comes out to $720. Average land ownership in Kentucky is 30 acres. The per-acre cost for a 30-acre plot is $24.

Key Uncertainties

- There is significant uncertainty regarding the improved forest carbon sequestration of 2%.
- The analysis does not include quantification or disposition of harvested wood products.
- The costs currently only include creation of forest management plans, not other tasks or techniques that would be required to implement the plans. At the time of printing of this report, there is insufficient data to determine the various remedies that would be required in the state's privately owned forests; therefore, the costs of the remedies are not included in the quantification. Inclusion of these costs would increase the total cost of this policy.
- The costs do not include enrollment in carbon offset programs or carbon credit revenue streams. At the time of printing of this report, there is insufficient data available to include this revenue stream in the evaluation. Inclusion of carbon credit revenue would reduce the cost of this policy recommendation.
- Additionally, weather and natural disasters, such as wildfire, ice storms, tornados, etc., can have deleterious effects on forest health and could affect the implementation of forest management plans.

Additional Benefits and Costs

- Forests with management plans often include side benefits of improved wildlife habitats, water quality, soil quality, and aesthetic value.
- Enrollment in carbon credit programs would provide additional revenue streams for landowners and may result in increased active renewal of plans.

Feasibility Issues

It is unclear if there are an adequate number of forestry professionals available to prepare forest management plans and assist landowners in the implementation of those plans.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

AFW-2. Expanded Use of Biomass Feedstocks for Electricity, Heat, and Steam Production

Policy Description

This policy dedicates a sustainable quantity of biomass for efficient conversion to energy and economical production of heat, steam, and electricity. Biomass sources may include agricultural residues (crop residues, wasteland grass and weeds, animal bedding, etc.); wood industry residues (slabs, sawdust, trimmings, etc.); urban waste; and managed agriculture crops (wood from woodlands, switchgrass, etc.) grown for profit from the biomass industry. Other sources may be residues from land restoration activity and land clearing for roads and strip mines.

Biomass should be used in an environmentally friendly and sustainable manner. Proper facility siting and feedstock use should be considered (e.g., proximity of users to biomass, impacts on water supply and quality, control of air emissions, solid waste management, cropping management, nutrient management, soil and nonsoil carbon management, and impacts on biodiversity and wildlife habitat). The objective is to reduce GHG emissions through displacement of fossil fuels, considering life-cycle GHG emissions associated with viable production, collection, hauling, and energy conversion and distribution systems.

Policy Design

Goals: Supply biomass sufficient to displace meet ES TWG goals for biomass power production by 2030.

This policy will focus on the production and delivery of biomass for electricity, heat, and steam. GHG reductions and costs from utilizing the biomass as fuel will be considered under the Energy Supply (ES) policy recommendations ES-1, ES-5, and ES-7.

Timing: Linear implementation through 2030.

Parties Involved

- Parties involved in the production and transportation of biomass feedstocks, including farmers, landowners, local businesses, land planners, rural agencies, local units of government, state and local environmental agencies, renewable energy developers and providers, community action agencies, forest product industries with waste products, conservation groups, the Kentucky Division of Forestry, Kentucky's Natural Resources Conservation Service (NRCS), and state universities.
- Parties involved with utilization of the biomass as fuel will be included under ES-1, ES-5, and ES-7.

Other

- Excess biomass may be exported from the state, or used for liquid biofuel production, if ES policies are not able to use the biomass supply outlined herein.

- Biomass products would be processed into a product that can be used for co-firing in electrical and heating boilers throughout the state.

Implementation Mechanisms

- Utilize energy crops, agriculture residues, forestry and wood industry residues to achieve the goal.
- Promote biomass harvested from marginal production acres without necessarily reducing food production.
- Ensure best management practices for extraction are followed.
- Use funds from the Kentucky Agricultural Development Fund, NRCS Environmental Quality Incentives Program (EQIP), and state cost sharing through NRCS.
- Establish biomass production with the support and development guidelines of NRCS. Encourage organic fertilizer (manure) for biomass production.
- Provide venues/opportunities to coordinate biomass suppliers with biomass end users.
- Note: Do not plant crops (invasives) that will have a negative impact on Kentucky species. Encourage use of plants that are native or noninvasive, or have passed testing protocols for invasiveness and overall environmental impact. Avoid species that excessively deplete soil or water resources—i.e., plants that are more of a drain on the environment than the energy they produce.
- Harvest all biomass products sustainably without depriving soils of important organic components for reducing erosion. Maintain soil nutrients and structure, and do not deplete wildlife habitat or jeopardize future feedstocks in quantity or quality.
- Evaluate the life-cycle energy costs and carbon emissions for each feedstock.
- Locate the preparation facilities in feasible areas to decrease transportation costs, and decrease GHG emissions from the transportation source, for both the raw products and the location at which the product would be used.
- Install manure digesters and energy recovery projects in hog, dairy, and poultry operations.
- Use community and multi-facility digesters, as they are far more cost-efficient than units on individual operations.

Related Policies/Programs in Place

The governor's Executive Task Force on Biomass and Biofuels Development in Kentucky validated Kentucky's biomass production capabilities within a sustainable environment, based upon information gathered during the task force meetings.[18]

Type(s) of GHG Reductions

CO_2, N_2O, CH_4: Displaces CO_2, methane (CH_4), and nitrous oxide (N_2O) emissions from fossil fuel combustion.

[18] See Final Report at: http://agbioworks.org/pdfs/KYBiomass_FinalReport_Dec2009.pdf.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources

- Biomass Supply Table.
- Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence*, November 2008.
- Governor's Office of Agricultural Policy and Energy and Environment Cabinet. *Final Report from the Executive Task Force on Biomass and Biofuels Development in Kentucky*. December 10, 2009, accessible at: http://agbioworks.org/pdfs/KYBiomass_FinalReport_Dec2009.pdf.
- A. Milbrandt. *A Geographic Perspective on the Current Biomass Resource Availability in the United States*. Technical Report NREL/TP-560-39181. Golden, CO: U.S. Department of Energy, National Renewable Energy Laboratory, December 2005. Available at: www.nrel.gov/docs/fy06osti/39181.pdf.
- S. Debolt et al. "Life cycle assessment of native plants and marginal lands for bioenergy agriculture in Kentucky as a model for south-eastern USA." *Global Change Biology Bioenergy* 2009, 1: 308-316.

Quantification Methods

- The benefits of this recommendation are dependent on developing in-state production capacity that achieves GHG benefits beyond petroleum fuels.
- The use of biomass for electricity generation is being considered within the ES recommendations.. To avoid double counting, this AFW analysis will only consider the production costs and potential quantities of biomass for Kentucky. The distribution costs and GHG savings will be accounted for in the ES Technical Work Group (TWG) analysis.

Biomass Availability and Costs

Table AFW-1 of this appendix summarizes biomass availability in Kentucky. It is assumed that various types of biomass supply will be utilized in proportion to their current availability, although this may not be the case, since feedstocks are geographically sensitive, and future feedstock supplies may differ in proportionate makeup from current supplies.

The costs and availability of these biomass feedstocks come from the biomass supply estimate. Costs were divided into five categories: agricultural residues, agricultural energy crops, woody energy crops, woody residues, and waste feedstocks. The costs used in this analysis are shown in Table AFW-2-1, and are discussed in greater detail earlier in Table AFW-1.

Table AFW-2-1. Delivered Cost/Dry Ton of Various Feedstocks

Type of Feedstock	Cost per Dry Ton
Agricultural Energy Crop	$40
Woody Energy Crop	$85
Agricultural Residues	$74
Woody Biomass Residues	$58
Waste	$0
Per-Ton Weighted Average (based on proportion of current supply)	**$64**

Table AFW-2-2 summarizes the costs of supplying enough biomass to meet the AFW-2 goal.

Table AFW-2-2. Cost Summary of Biomass Supply to Meet the AFW-2 Goal

Year	Estimated Biomass Required (million dry tons)	Cost of Delivered Biomass (million $)	Discounted Cost (million $)
2011	0.0	0	0
2012	0.94	$60	$54
2013	1.88	$120	$104
2014	2.81	$180	$148
2015	3.75	$240	$188
2016	5.15	$330	$246
2017	6.55	$419	$298
2018	7.95	$509	$345
2019	9.35	$598	$385
2020	10.76	$688	$422
2021	11.48	$735	$430
2022	12.21	$782	$435
2023	12.94	$828	$439
2024	13.67	$875	$442
2025	14.38	$920	$443
2026	14.41	$922	$422
2027	14.45	$924	$403
2028	14.48	$927	$385
2029	14.52	$929	$368
2030	14.55	$931	$351
Total			**$6,308**

The total discounted cost of supplying the biomass needed to meet the AFW-2 goal is $6.3 billion. Note that this cost does not account for the benefit of replacing the fossil fuel feedstock. Those costs will be accounted for in ES-1. Additionally, this cost does not account for the costs of any land-use changes necessary to meet the biomass supply goal.

The GHG savings of using biomass in place of fossil fuel for electricity generation will also be accounted for in ES-1, ES-5, and ES-7.

Key Assumptions: The proportion of each biomass feedstock used to meet the goal is based on the proportion of current supply for each feedstock.

Key Uncertainties

- The potential availability of the unharvested above-ground biomass growth on timberland acres will be influenced by landowner willingness to harvest; available markets for the broad range of biomass species, size, or condition; and costs of harvesting, processing, and transportation.
- Multiple initiatives propose utilization of biomass (e.g., ES, TLU and Residential, Commercial, and Industrial [RCI]). The overlapping impacts of these initiatives on feedstock supply need to be considered to ensure the sustainability of feedstock supply and other natural resources.
- On January 12, 2011, the U.S. Environmental Protection Agency (EPA) issued a three-year deferment on the inclusion of GHG emissions from biogenic sources from regulation under the EPA GHG Tailoring Rule that went into effect on January 2, 2011. While this is positive to the operational costs of projects currently utilizing biomass feedstocks, the continued uncertainty may impact the increased utilization of biomass feedstocks.

Additional Benefits and Costs

Biomass production can create permanent jobs and may help offset job losses in other industries, including the coal industry.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

AFW-3. On-Farm Energy Production and Efficiency Improvements

Policy Description

Renewable energy may be produced and used on site at individual agricultural operations or regionally through various businesses to achieve better economies of scale. For example, on-farm production of grains and oilseeds for ethanol and biodiesel, biomass for new-generation biofuels and electric generation, and the use of solar heating and power will reduce CO_2 emissions by displacing the use of fossil-based fuels. Energy conservation for agricultural operations will result in increased efficiency. For example, improved grain-drying systems; livestock facility upgrades to ventilation, lighting, heating, and cooling components; and expanded use of precision agriculture systems will also reduce fossil fuel use.

Policy Design

Goals: Achieve a 25% improvement in the energy efficiency of agricultural operations, while increasing the productivity and conversion of crops, residues, and other farm resources to meet the ES, TLU, and RCI needs by 2030.

Timing: Progress is already underway, as evidenced by growth in ethanol and biodiesel production and increased utilization of federal and state programs to improve on-farm energy efficiency.

- Current biomass production capabilities are estimated at 12–15 metric tons per year (t/yr) with minimal land-use changes. Approximately 30% of this volume is expected from forestry and woody biomass production, 30% from energy crop production, 20% from waste forest products, and 20% from agricultural waste.
- Potential biomass production capabilities by 2030 are estimated at 25 t/yr, but could involve land-use changes of approximately 2 million acres, or 15% of Kentucky's farmland. Approximately 20% of this volume is expected from forestry and woody biomass production, 60% from energy crop production, 10% from waste forest products, and 10% from agricultural waste.
- Increase biomass feedstock utilization from 3–5 t/yr to an estimated 25 t/yr by 2030.

Parties Involved: Leadership is being shown on multiple fronts from governmental, educational, agricultural, and other business entities. The Kentucky Energy and Environment Cabinet (KEEC) is working closely with the Governor's Office of Agricultural Policy to develop strategies for improved on-farm energy efficiency and increasing biomass and biofuel production and utilization. Continued funding for the Kentucky Agricultural Development Fund will provide financial resources for research, demonstration, and capitalization in this area. The Kentucky Agricultural Council has over 60 member agricultural, educational, and governmental organizations that have identified agri-energy investments, education, and awareness as a priority area. The Kentucky Renewable Energy Consortium has provided leadership in developing and advancing a “25x’25” initiative.[19] These networks are promoting dialogue, research, funding, and policy development to advance these activities.

Other: None identified.

Implementation Mechanisms

- Identify a single agency to coordinate biomass development efforts.
- Develop policies to mitigate demand risks.
- Develop policies to mitigate supply risks.
- Define and develop a sustainable biomass industry.
- Develop capitalization mechanisms.
- Expand applied research and development (R&D) of biomass production in Kentucky.
- Educate farmers about production opportunities as well as the species of crops and specific varieties and production techniques that maximize net farm income, while protecting natural resources.
- Encourage farmer investment in renewable energy production facilities.
- Initiate applied R&D and implementation of more efficient byproduct utilization in Kentucky.
- Increase educational opportunities and material for agricultural producers in the area of on-farm energy efficiency.
- Explore and develop agreements with bordering states to cooperate in the production of biofuels and byproduct utilization.
- Advance state support to develop an adequate infrastructure for the delivery of biofuels within the Commonwealth by examining the needs for infrastructure development that matches the future supply of biofuels with the potential demand.
- Work with the Kentucky Petroleum Marketers Association, the Kentucky Clean Fuels Coalition, and others to locate biofuel suppliers and promote their availability to all farmers in those markets.
- Identify current biofuel promotion programs and coordinate with those organizations to develop new programs as part of a comprehensive promotion campaign.
- Identify and develop incentives to upgrade the material handling capabilities at a coal-fired power plant to allow co-firing of biomass at a rate of up to 10%.
- Produce herbaceous energy crops on underutilized pasture land, abandoned or reclaimed mine land, and abandoned agricultural land. Note: do not plant crops (invasives) that will have a negative impact on Kentucky species. Encourage use of plants that are native or noninvasive, or have passed testing protocols for invasiveness and overall environmental impact. Avoid

[19] "'25x'25" is an initiative to obtain 25% of Kentucky’s energy from renewable resources, such as wind, solar, and biofuels, by the year 2025.

species that excessively deplete soil or water resources—i.e., plants that are more of a drain on the environment than the energy they produce.

- Produce woody energy crops (cottonwood, hybrid poplar, and black locust) on underutilized pasture land, abandoned or reclaimed mine land, and abandoned agricultural land, and investigate the removal of woody residues from forestry operations.
- Implement a system to co-fire a range of feedstocks available in Kentucky at a coal power plant:
  - Develop incentives to allow farms and forests to produce feedstocks for energy production on non-cropland.
  - Demonstrate techniques for establishing energy crops on abandoned or reclaimed mine land and other land that requires additional considerations (e.g., deep ripping, rocky, steep slopes, or transplanting).
  - Establish and demonstrate effective harvest, storage, and transportation practices for herbaceous and woody biomass.
  - Document the range in fossil energy, labor, productivity, and cost required to grow, transport, and produce electricity from biomass.
- Co-fire material for five days to evaluate electric power production, emissions, and other operational changes due to co-firing biomass.
- Evaluate alternative practices to improve the sustainability of energy crop production:
  - Track changes in soil properties, adaptability to wildlife improvements, and environmental impacts.
  - Evaluate the potential of Terra Preta (biochar) for improving and sequestering carbon in energy crop plantations.
- Determine the overall change in GHG emissions and the cost of electric power from biomass.
- Develop a pilot-scale project to focus on producing biomass on underutilized marginal land in eastern and central Kentucky.
- Convert 2 million acres, or 15% of Kentucky's farmland, from low-valued forage and hay production to higher-valued energy crops.
- Establish significant levels of public–private partnerships to design, build, and operate new farm-to-market processes.
- Increase statewide education, workforce development, and economic development activities to support a fast-growing biomass and biofuels industry and infrastructure.
- Do not account for recyclable material (particularly paper and plastics) in the calculations for available biomass for fuel purposes. The loss of this material to energy production would be detrimental to manufacturers who use it for stock in producing products with recycled content. The main effort toward this material should be recovery for reuse as raw materials for manufacturing recycled-content products.

On-Farm Energy Efficiency

- Develop outreach programs to improve on-farm energy efficiency that include identification of areas where the greatest savings can be achieved. Examples include the use of more fuel-efficient equipment, more energy-efficient lighting systems, and less energy-intensive irrigation practices.
- Encourage the development and adoption of life-cycle cost-benefit and carbon impact analyses that promote options for more sustainable food production and processing.
- Increase energy efficiency and sustainability awareness and implementation on Kentucky farms by promoting more on-farm and local energy sources, technology upgrades to equipment and facilities, displacement of fossil fuels, and more efficient whole-farm and watershed planning.
- Facilitate technology transfer from universities to the farm to augment carbon footprint reductions. Develop the network locally to put the transfer in place.

Related Policies/Programs in Place

The Governor's Executive Task Force on Biomass and Biofuels Development in Kentucky validated Kentucky’s biomass production capabilities within a sustainable environment, based upon information gathered during the task force meetings.[20]

Type(s) of GHG Reductions

CO_2, CH_4 and N_2O: Reduced life-cycle GHG emissions through lower fossil fuel consumption.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources: See text.

Quantification Methods

Kentucky Biomass Energy

Based on discussion with the AFW TWG, it was decided that the costs and GHG savings of this goal would not be quantified, because the use of biomass for energy purposes is being pursued in ES-1, ES-5, ES-7, and TLU-10.

Energy Efficiency

This analysis considers the costs and benefits of improving the energy efficiency of Kentucky farms. Total GHG savings and costs are summarized in Table AFW-3-1.

[20] Final Report available at: http://agbioworks.org/pdfs/KYBiomass_FinalReport_Dec2009.pdf.

Table AFW-3-1. Summary of EE GHG Savings and Net Costs

Year	Implementation Path	Electricity Savings (GWh)	Diesel Fuel Savings (million gallons)	Propane Fuel Savings (million gallons)	In-State GHG Savings ($MMtCO_2e$)	Fuel Cycle GHG Savings ($MMtCO_2e$)	Total Cost, EE (Installation and Energy Audits)	Total Cost Savings, EE (Electricity and Fuel, million $)	Total Cost of EE (million $)	Discounted Cost of EE Program (million $)
2010	0%	0	0	0.0	0.00	0.00	$0.0	$0.0	$0.0	$0.0
2011	0%	0	0	0.0	0.00	0.00	$0.0	$0.0	$0.0	$0.0
2012	1%	15	1	0.1	0.02	0.02	$24.9	$3.4	$21.5	$15.3
2013	3%	30	2	0.2	0.05	0.05	$24.9	$7.1	$17.8	$12.0
2014	4%	45	2	0.3	0.07	0.07	$24.9	$11.1	$13.8	$8.9
2015	5%	60	3	0.4	0.09	0.10	$24.9	$15.2	$9.7	$6.0
2016	7%	75	4	0.5	0.12	0.12	$24.9	$19.4	$5.5	$3.2
2017	8%	89	5	0.6	0.14	0.15	$24.9	$23.7	$1.1	$0.6
2018	9%	104	5	0.7	0.17	0.17	$24.9	$28.3	–$3.4	–$1.8
2019	11%	119	6	0.8	0.19	0.20	$24.9	$32.8	–$7.9	–$4.0
2020	12%	134	7	0.9	0.21	0.22	$24.9	$37.2	–$12.3	–$5.9
2021	13%	149	8	1.0	0.24	0.24	$24.9	$41.2	–$16.3	–$7.5
2022	14%	164	8	1.2	0.26	0.27	$24.9	$45.6	–$20.7	–$9.0
2023	16%	179	9	1.3	0.28	0.29	$24.9	$50.0	–$25.2	–$10.5
2024	17%	194	10	1.4	0.31	0.32	$24.9	$54.2	–$29.4	–$11.6
2025	18%	209	11	1.5	0.33	0.34	$24.9	$58.4	–$33.5	–$12.6
2026	20%	224	12	1.6	0.35	0.37	$24.9	$63.1	–$38.2	–$13.7
2027	21%	238	12	1.7	0.38	0.39	$24.9	$67.1	–$42.2	–$14.4
2028	22%	253	13	1.8	0.40	0.42	$24.9	$72.0	–$47.2	–$15.4
2029	24%	268	14	1.9	0.42	0.44	$24.9	$77.7	–$52.8	–$16.4
2030	25%	283	15	2.0	0.45	0.46	$24.9	$82.2	–$57.3	-–$16.9
Total					**4.48**	**4.64**			**–$317**	**–$94**

EE = energy efficiency; GHG =greenhouse gas; GWh = gigawatt-hours; MMBtu = million British thermal units; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

The possible improvements will vary, depending on the size, technologies used, and type of farm. Chicken farms, row crops, and dairy farms are likely to have very different efficiency opportunities. Energy audits serve to inform farmers of the most cost-effective changes that can be made to improve their overall energy efficiency. Table AFW-3-2 shows a list of the technologies that are most often considered in each of the different farm types. This is by no means a complete list; it is merely meant to illustrate the types of technologies that can result in significant energy savings.

Table AFW-3-2. Promising Energy Efficiency Technologies[21]

Chicken Farms	Dairy Farms	Row Crops
Insulate Sidewall Curtain and Ceiling	Energy-Efficient Lighting	Energy-Efficient Lighting
Radiant Heaters	Compressor/Refrigerator Heat Recovery	Energy-Efficient Heating
Add Attic Inlets	Variable-Speed Vacuum Pumps	Energy-Efficient Irrigation Systems
Tunnel Inlet Doors	Plate Cooler	Energy-Efficient Motors
High-Efficiency Fans	High-Efficiency Fans	Energy-Efficient Grain Dryers

The GHG benefits were calculated based on the avoided emissions from these new technologies. The GHG benefit for fuel savings was calculated based on the fuel-cycle emissions factor for diesel fuel (11.25 kilograms [kg] CO_2e/gallon),[22] although only the direct emissions factor (10.15 kg CO_2e/gallon) is counted as part of the in-state reductions. The CO_2e associated with the electricity saved in each year is estimated by multiplying megawatt-hours (MWh) saved by the Kentucky-specific emission factor for electricity production, 1.017 tCO_2e/MWh. This figure for emissions/MWh comes from the Kentucky I&F, and is outlined in the Common Assumptions Memo. Total on-farm energy use was estimated based on National Agricultural Statistics Service (NASS) data.[23] It was assumed that the primary energy expenditures were on diesel fuel, propane, and electricity. Electricity was estimated to make up 33% of total farm energy consumption, based on the USDA national average.[24] Propane makes up 7%, and the remainder was assumed to be diesel fuel, although it is likely that some of this will actually be gasoline. Given the similarities between gasoline and diesel emission factors, the impact of this assumption is likely to be negligible. The estimate of energy expenditures was converted to energy consumption, based on the average electricity, propane, and diesel fuel price in Kentucky in 2007. This resulted in an estimated 58 million gallons of diesel fuel used on Kentucky farms, 8 million gallons of propane, and 1,132 GWh of electricity. These figures are used as the baseline on-farm energy consumption estimate in this analysis.

Energy audits are an essential part of improving on-farm energy efficiency in order to meet the AFW-3 goal. It is assumed that these audit programs will find energy efficiency gains at a similar cost/benefit to that of the efficiency technologies considered in this analysis, and allow the goal of a 25% reduction in on-farm energy use to be met. It was further assumed that each farm can achieve a 33% reduction in energy consumption through energy efficiency.

The energy efficiency savings possible will obviously vary from farm to farm. A 2009 University of Kentucky report examined the costs and energy efficiency savings of various technologies on

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[21] The dairy farm and greenhouse information come from an audit checklist provided by ENSave. Based on e-mail communication between Amelia Gulkis, Program Development Manager at EnSave, and Jackson Schreiber on 7/28/10.

[22] Based on an estimate from Argonne National Laboratory's GREET Model, version 1.8c.

[23] National Agricultural Statistics Service. Figure was expressed in Kentucky statewide energy expenditures ($226 million). Available at: http://www.nass.usda.gov/Statistics_by_State/Kentucky/index.asp.

[24] USDA. U.S. Agriculture and Forestry Greenhouse Gas Inventory 1990–2005, Chapter 5, "Energy Use in Agriculture." Available at: http://www.usda.gov/oce/climate_change/AFGG_Inventory/5_AgriculturalEnergyUse.pdf.

Kentucky chicken farms.[25] This study indicated that most energy efficiency measures had a payback period of between 1 and 7 years, with an average of 4 years. It was assumed that the chicken farm information in the University of Kentucky study is representative of the capital investment and energy efficiency savings that can be achieved on all Kentucky farms. If the energy savings and costs are significantly different on varying farm types, then these results will be subject to change.

Energy audits will target larger farms first because those are the most likely to achieve cost-effective reductions. The costs of energy audits are estimated based on the estimates provided by two New York energy auditors. The average cost of an energy audit for a Kentucky farm is assumed to be $1,750.[26]

The GHG savings from energy efficiency come from reduced electricity consumption, as well as reduced propane and diesel fuel use. The GHG savings that can be achieved through energy efficiency projects are shown in Table AFW-3-3, and the costs of energy efficiency are shown in Table AFW-3-4.

Table AFW-3-3. GHG Reductions from Energy Efficiency on Kentucky Farms

Year	Implementation Path	Electricity Savings (GWh)	Diesel Fuel Savings (million gallons)	Propane Fuel Savings (million gallons)	In-State GHG Savings ($MMtCO_2e$)	Fuel-Cycle GHG Savings ($MMtCO_2e$)
2010	0%	0	0	0.0	0.00	0.00
2011	0%	0	0	0.0	0.00	0.00
2012	1%	15	1	0.1	0.02	0.02
2013	3%	30	2	0.2	0.05	0.05
2014	4%	45	2	0.3	0.07	0.07
2015	5%	60	3	0.4	0.09	0.10
2016	7%	75	4	0.5	0.12	0.12
2017	8%	89	5	0.6	0.14	0.15
2018	9%	104	5	0.7	0.17	0.17
2019	11%	119	6	0.8	0.19	0.20
2020	12%	134	7	0.9	0.21	0.22
2021	13%	149	8	1.0	0.24	0.24
2022	14%	164	8	1.2	0.26	0.27
2023	16%	179	9	1.3	0.28	0.29
2024	17%	194	10	1.4	0.31	0.32
2025	18%	209	11	1.5	0.33	0.34

[25] University of Kentucky. 2009. "Poultry Production Manual." Available at: http://www.ca.uky.edu/poultryprofitability/Production_manual/Chapter1_PHES_results/Chapter1.html.

[26] Based on e-mail communication between Amelia Gulkis, Program Development Manager at EnSave, and Jackson Schreiber on 7/28/10. Ms. Gulkis indicated prices from $1,250 for a basic audit to $3,000 for a more intensive energy audit. Dick Peterson at Northeast Agriculture Technology Corporation indicated a cost ranging from $1,200 to $2,500, with an average between $1,500 and $2,000. For all farm types, the average cost of $1,750 was used.

Year	Implementation Path	Electricity Savings (GWh)	Diesel Fuel Savings (million gallons)	Propane Fuel Savings (million gallons)	In-State GHG Savings ($MMtCO_2e$)	Fuel-Cycle GHG Savings ($MMtCO_2e$)
2026	20%	224	12	1.6	0.35	0.37
2027	21%	238	12	1.7	0.38	0.39
2028	22%	253	13	1.8	0.40	0.42
2029	24%	268	14	1.9	0.42	0.44
2030	25%	283	15	2.0	0.45	0.46
Total					**4.48**	**4.64**

GHG = greenhouse gas; GWh = gigawatt-hours; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table AFW-3-4. Costs/Cost Savings from Energy Efficiency on Kentucky Farms

Year	Number of Farms Participating	Cost of Energy Audits	Cost of EE Installation (million $)	Electricity Savings (million $)	Fuel Savings (million $)	Total Cost of EE (million $)
2010	0	$0	$0.0	$0.0	$0.0	$0.0
2011	0	$0.0	$0.0	$0.0	$0.0	$0.0
2012	3,237	$5.7	$19.2	$1.2	$2.2	$21.5
2013	6,474	$5.7	$19.2	$2.3	$4.8	$17.8
2014	9,711	$5.7	$19.2	$3.4	$7.7	$13.8
2015	12,947	$5.7	$19.2	$4.5	$10.6	$9.7
2016	16,184	$5.7	$19.2	$5.7	$13.7	$5.5
2017	19,421	$5.7	$19.2	$6.7	$17.0	$1.1
2018	22,658	$5.7	$19.2	$7.9	$20.3	–$3.4
2019	25,895	$5.7	$19.2	$9.2	$23.6	–$7.9
2020	29,132	$5.7	$19.2	$10.3	$26.9	–$12.3
2021	32,368	$5.7	$19.2	$11.5	$29.7	–$16.3
2022	35,605	$5.7	$19.2	$12.6	$33.0	–$20.7
2023	38,842	$5.7	$19.2	$13.8	$36.3	–$25.2
2024	42,079	$5.7	$19.2	$14.9	$39.3	–$29.4
2025	45,316	$5.7	$19.2	$16.1	$42.4	–$33.5
2026	48,553	$5.7	$19.2	$17.2	$45.9	–$38.2
2027	51,789	$5.7	$19.2	$18.4	$48.7	–$$42.2
2028	55,026	$5.7	$19.2	$19.5	$52.5	–$47.2
2029	58,263	$5.7	$19.2	$20.7	$57.0	–$52.8
2030	61,500	$5.7	$19.2	$22.1	$60.1	–$57.3
Total						**–$317**

EE = energy efficiency.

Tables AFW-3-3 and AFW-3-4 show the estimated cost and GHG reductions that could come with an aggressive energy efficiency push. The discounted costs of energy efficiency on Kentucky farms are shown in Table AFW-3-5.

Table AFW-3-5. Discounted Costs of Energy Efficiency in AFW-3

Year	Total Costs of EE (million $)	Total Discounted Costs of EE (million $)
2010	$0.0	$0.0
2011	$0.0	$0.0
2012	$21.5	$15.3
2013	$17.8	$12.0
2014	$13.8	$8.9
2015	$9.7	$6.0
2016	$5.5	$3.2
2017	$1.1	$0.6
2018	–$3.4	–$1.8
2019	–$7.9	–$4.0
2020	–$12.3	–$5.9
2021	–$16.3	–$7.5
2022	–$20.7	–$9.0
2023	–$25.2	–$10.5
2024	–$29.4	–$11.6
2025	–$33.5	–$12.6
2026	–$38.2	–$13.7
2027	–$42.2	–$14.4
2028	–$47.2	–$15.4
2029	–$52.8	–$16.4
2030	–$57.3	–$16.9
Total	**–$317**	**–$94**

EE = energy efficiency.

Key Assumptions: See text.

Key Uncertainties

Feedstock Availability

- There are significant uncertainties regarding the quantification of economic trade-offs and subsidies for biomass production.
- Without more information on the types of energy being displaced, it is impossible to estimate the overall costs or GHG savings of using biomass feedstocks versus other fuel sources.
- The AFW-4 analysis examines the overall costs of cellulosic ethanol production, and the AFW-2 analysis looks at electricity co-firing. The emission factors for biomass used are national figures, and do not take into account Kentucky-specific issues. In addition, there is no estimate of emissions/Btu for biomass in the transportation sector, since this biomass would need to be converted into cellulosic ethanol first.

- It would be very difficult to more than double biomass availability in Kentucky by 2030 without devoting significant new acreage to energy crops. It is uncertain if these acres are available.
- There would likely be significant infrastructure costs to deliver these quantities of biomass to the needed locations in Kentucky.
- On January 12, 2011, EPA issued a three-year deferment on the inclusion of GHG emissions from biogenic sources from regulation under the EPA GHG Tailoring Rule that went into effect on January 2, 2011. While this is positive to the operational costs of projects currently utilizing biomass feedstocks, the continued uncertainty may impact the increased utilization of biomass feedstocks.

Energy Efficiency

- It is uncertain if the energy efficiency gains being found in the energy audit program are realistic. It is possible that some of the energy efficiency investments needed to reach the goal of increasing on-farm efficiency by 25% will be quite expensive. If that is the case, then the cost estimates will not be accurate.
- It is difficult to estimate energy consumption on Kentucky farms, because that data are not collected in a single place. A more detailed estimate of Kentucky on-farm energy use would improve the accuracy of this analysis.

Additional Benefits and Costs

Energy Efficiency

Reduced non-GHG pollutions caused by the combustion of diesel fuel. Many of the strategies discussed in this section are shown to save water, labor hours, and equipment wear. There will also likely be reductions in local air pollutants, such as volatile organic compounds (VOCs) and nitrogen oxides (NO_x) from reduced fuel consumption.

Feasibility Issues

The ability to meet the goal of this policy is dependent on setting aggressive targets for biomass production and providing sufficient incentives.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

AFW-4. In-State Liquid/Gaseous Biofuels Production

Policy Description

This policy increases the sustainable in-state production and use of liquid and gaseous biofuels from agriculture, forestry, and municipal waste sources to displace the use of fossil fuel. Displacement of traditional fossil fuels with biofuel usually results in a net reduction in GHGs.

This policy promotes the use of sustainable practices in production of biomass from crop residues and dedicated biomass crops that take advantage of underutilized land resources without detrimental effects on human food resources. Additionally, this policy would encourage the use of agriculture and forestry crops that sequester carbon or are at least carbon neutral, as necessary for an overall reduction in GHGs.

Biofuel technologies and production systems can take advantage of solar energy stored in biomass from agricultural and forestry resources for liquid and gaseous biofuel production. Biofuel systems can also capture discarded energy available in the waste stream. Emerging biofuel technologies, such as pyrolysis, Fischer-Tropsch synthesis, utilization of microorganisms, and other novel technologies, can improve utilization of feedstocks.

Policy Design

Goals: Generate sufficient biofuels to meet Kentucky's share of the federal Renewable Fuels Standard. According to the U.S. Energy Information Administration (EIA), Kentucky accounted for 1.60% of national fuel consumption, and therefore is responsible for 335 million gallons of renewable fuels in 2022. It is uncertain what the federal standard will be for the years 2023–2030, but it was assumed that the quantities of biofuel required would increase from 335 million gallons in 2022 to 479 million gallons in 2030.[27]

Timing: See goal above.

Parties Involved: Private waste industry, biofuel producers, farmers and feedstock producers, forest and agricultural landowners, municipal solid waste (MSW) managers, researchers, venture capitalists.

Other: Ensure quantification costs reflect current federal policy.

Implementation Mechanisms

- Identify a single agency to coordinate biomass development efforts.
- Define and develop a sustainable biomass industry.

[27] This policy is tied to TLU-10 (Promote the Use of Alternative Transportation Fuels). This recommendation focuses on in-state production of transportation biofuels, while TLU-10 focuses on the demand side. Based on current projections of available biomass to meet the needs of this recommendation and supplies for AFW-2 (which are used to satisfy ES sector demands from recommendations ES-2, ES-5, and ES-7), the in-state production of transportation biofuels (cellulosic ethanol) is more than adequate to meet the needs of the TLU-10 ethanol requirements.

- Develop capitalization mechanisms.
- Expand applied R&D of biomass production in Kentucky.
- Educate farmers about production opportunities as well as the species of crops, specific varieties, and production techniques that maximize net farm income, while protecting natural resources.
- Encourage farmer investment in renewable energy production facilities.
- Initiate applied R&D and implementation of more efficient byproduct utilization in Kentucky.
- Increase educational opportunities and material for agricultural producers in the area of on-farm energy efficiency.
- Explore and develop agreements with bordering states to cooperate in the production of biofuels and byproduct utilization.
- Advance state support to develop an adequate infrastructure for the delivery of biofuels within the Commonwealth by examining the needs for infrastructure development that matches the future supply of biofuels with the potential demand.
- Work with the Kentucky Petroleum Marketers Association, the Kentucky Clean Fuels Coalition, and others to locate biofuel suppliers and promote their availability to all farmers in those markets.
- Identify current biofuel promotion programs and coordinate with those organizations to develop new programs as part of a comprehensive promotion campaign.
- Produce herbaceous energy crops (switchgrass, Indian grass, big bluestem, and *Miscanthus giganteus*) on underutilized pasture land, abandoned or reclaimed mine land, and abandoned agricultural land. Note: do not plant crops (invasives) that will have a negative impact on Kentucky species. Encourage use of plants that are native or noninvasive, or have passed testing protocols for invasiveness and overall environmental impact. Avoid species that excessively deplete soil or water resources—i.e., plants that are more of a drain on the environment than the energy they produce.
- Produce woody energy crops (cottonwood, hybrid poplar, and black locust) on underutilized pasture land, abandoned or reclaimed mine land, and abandoned agricultural land, and investigate the removal of woody residues from forestry operations.
- Evaluate alternative practices to improve the sustainability of energy crop production:
    - Track changes in soil properties, adaptability to wildlife improvements, and environmental impacts.
    - Evaluate the potential of Terra Preta (biochar) for improving and sequestering carbon in energy crop plantations.
- Determine the overall change in GHG emissions and the cost of electric power from biomass.
- Develop a pilot-scale project to focus on producing biomass on underutilized marginal land in eastern and central Kentucky.

- Convert 2 million acres, or 15% of Kentucky's farmland, from low-valued forage and hay production to higher-valued energy crops.
- Establish significant levels of public–private partnerships to design, build, and operate new farm-to-market processes.
- Increase statewide education, workforce development, and economic development activities to support a fast-growing biomass and biofuels industry and infrastructure.
- Do not account for recyclable material (particularly paper and plastics) in the calculations for available biomass for fuel purposes. The loss of this material to energy production would be detrimental to manufacturers who use it for stock in producing products with recycled content. The main effort toward this material should be recovery for reuse as raw materials for manufacturing recycled-content products.

Related Policies/Programs in Place

- The Governor's Executive Task Force on Biomass and Biofuels Development in Kentucky validated Kentucky's biomass production capabilities within a sustainable environment, based upon information gathered during the task force meetings.
- Kentucky has two biorefinery locations that produce biomass-based ethanol—one from corn and one from beverage waste. Total production capacity is 38 million gallons per year.[28]

Type(s) of GHG Reductions

CO_2, N_2O, CH_4: Displaces emissions from fossil fuel combustion. Note that GHG reductions from use of the biomass as fuel will be accounted for under the TLU policy recommendations.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources

- Argonne National Laboratories (ANL) GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model.
- National Renewable Energy Laboratory (NREL)/, *Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover*, NREL/TP-510-32438 (Golden, CO, June 2002).
- Sarah C. Brechbill and Wallace E. Tyner, "The Economics of Biomass Collection, Transportation, and Supply to Indiana Cellulosic and Electric Utility Facilities," Working Paper #08-03, April 2008, Department of Agricultural Economics, Purdue University.
- EIA, Biofuels in the U.S. Transportation Sector, February 2007.
- EIA, *Annual Energy Outlook* (AEO) 2009.

Quantification Methods

[28] Renewable Fuels Association. Available at: http://www.ethanolrfa.org/bio-refinery-locations.

The benefits of this recommendation are dependent on developing in-state production capacity that achieves GHG benefits beyond petroleum fuels. The advanced biofuels being considered in this analysis are cellulosic ethanol, soy biodiesel and other non–corn-starch-based biofuels. Corn or other starch-based ethanol currently accounts for 34 million gallons per year of potential production in Kentucky. However, this figure has not increased in several years, and starch-based ethanol production is not increasing in the revised renewable fuel standard (RFS), so it is not included in this analysis.

TLU-10 is quantifying the GHG benefits of biofuels in Kentucky. To avoid double counting, this AFW analysis will only consider the production costs and potential quantities of advanced biofuel for Kentucky. The distribution costs and GHG savings will all be counted in the TLU analysis.

Table AFW-4-1 lists the quantity of biofuels required in each year to meet Kentucky's share (1.60%) of the new federal renewable fuel standard (RFS2). The RFS2 only outlines biofuel quantities through 2022. It was assumed that there would continue to be a small increase in the production of cellulosic ethanol and biodiesel between 2022 and 2030. The quantity of biofuels produced in this analysis will be made to match Kentucky's share of the RFS. Biofuel producers will have to ensure that their feedstocks are of the type necessary to meet the RFS2 requirements, which could exclude some types of agricultural and forest feedstocks.

Table AFW-4-1. Quantity of Biofuel Required for Kentucky Share of RFS

Year	Cellulosic Ethanol (million gallons)	Biodiesel (million gallons)
2011	4	18
2012	8	24
2013	16	28
2014	28	32
2015	48	40
2016	68	48
2017	88	56
2018	112	64
2019	136	72
2020	167	72
2021	215	72
2022	255	80
2023	271	80
2024	287	80
2025	303	88
2026	319	88
2027	335	88
2028	351	96
2029	367	96
2030	383	96

RFS = renewable fuel standard.

Biomass Availability and Costs

Biomass availability in Kentucky was discussed earlier in this analysis, as shown in the Biomass Supply Assessment at the beginning of this appendix. The quantity of biomass required to meet Kentucky's cellulosic ethanol share of the RFS2 is shown in Table AFW-4-2. While the value of available biomass remaining in 2030 appears large, these remaining supplies are currently presumed to be used to supply ES-2, ES-5 and ES-7. As mentioned in the biomass supply assessment, it is possible that other feedstocks might also be available within the policy period, such as other organic components of the municipal solid waste stream.

Table AFW-4-2. Biomass Resources in Kentucky

Biomass Feedstock	Amount Annually Available (2030) (thousand dry short tons)	Amount Required in Biofuel Analysis (2030) (thousand dry short tons)	Amount Remaining (2030) (thousand dry short tons)
Crop Residues	2,300	532	1,768
Agricultural Energy Crops	3,600	832	2,768
Forest Energy Crops	3,780	874	2,906
Forest Residues	3,160	730	2,430
Forest—Annual Net Growth (currently unused)	1,900	439	1,461
Primary & Secondary Mill	1,485	343	1,142
Urban Wood	340	79	261
Land Use and Technology Advances	8,435		
Total	**25,000**	**3,828**	**21,172**

The costs and availability of these biomass feedstocks come from the biomass supply estimate. Costs were divided into five categories: agricultural residues, agricultural energy crops, woody energy crops, woody residues, and waste feedstocks. The costs used in this analysis are shown in Table AFW-4-3, and are discussed in greater detail in the biomass supply estimate in Table AFW-1, earlier in the analysis.

Table AFW-4-3. Delivered Cost/Dry Ton of Various Feedstocks

Biomass Feedstock	Cost/Dry Ton
Agricultural Energy Crop	$40
Woody Energy Crop	$85
Agricultural Residues	$74
Woody Biomass Residues	$58
Waste	$0
Current Supply	**$64**

Cellulosic Ethanol Costs

The cellulosic ethanol costs of this recommendation are estimated based on the capital and operating costs of cellulosic ethanol production plants. A study by NREL was used to estimate the operation and maintenance costs of a 70-million-gallon/year cellulosic ethanol plant.[29] Annual cellulosic ethanol production is derived from an estimated ethanol yield per ton of biomass. The assumed yield is 70 gal/ton biomass in 2011, increasing to 90 gal/ton biomass by 2012 and to 100 gal/ton biomass by 2020.[30] The capital costs of a cellulosic plant came from an average of the capital cost estimates for seven biofuel plants across the country. Using this method, the average capital cost of a new cellulosic ethanol plant is $564 million. A new plant will need to be built for every 70 million gallons of annual ethanol production needed. It was assumed that the capital costs will be paid according to a cost recovery factor over the 20-year lifetime of the plant. The cost of biomass feedstocks made up a significant portion (~60%) of variable costs. Therefore, we replaced the NREL estimate of feedstock costs ($30/ton) with more current estimates of the cost of delivered biomass, mentioned in the previous section. The plant proposed by the NREL study produces some excess electricity, although the costs and benefits of generating this electricity are not considered in this analysis. The wholesale costs/gallon are estimated based on overall costs divided by gallons produced. The costs of cellulosic ethanol production are shown in Table AFW-4-4.

Table AFW-4-4. Cost Summary for Cellulosic Ethanol Plants

Year	Cellulosic Ethanol Plants Required	Biomass Required (million dry tons)	Biomass Feedstock Costs ($MM)	Other Annual Operating Costs ($MM)	Annualized Capital Costs ($MM)	Total Cellulosic Ethanol Production Costs ($MM)	Cellulosic Ethanol Produced (MMgal/yr)	Wholesale Cellulosic Ethanol Cost/Gallon ($MM)
2011	1	0.1	$3	$5	$3	$8	4	$1.98
2012	1	0.1	$5	$9	$5	$14	8	$1.79
2013	1	0.2	$11	$18	$10	$28	16	$1.79
2014	1	0.3	$19	$32	$18	$50	28	$1.79
2015	1	0.5	$33	$54	$31	$85	48	$1.79
2016	1	0.8	$46	$77	$44	$121	68	$1.79
2017	2	1.0	$60	$99	$57	$157	88	$1.79
2018	2	1.2	$76	$127	$73	$199	112	$1.79
2019	2	1.5	$92	$154	$88	$242	136	$1.79
2020	3	1.7	$103	$179	$109	$288	167	$1.72
2021	4	2.2	$132	$230	$141	$370	215	$1.72
2022	4	2.6	$156	$272	$167	$439	255	$1.72
2023	4	2.7	$166	$289	$177	$466	271	$1.72
2024	5	2.9	$176	$306	$187	$493	287	$1.72
2025	5	3.0	$186	$323	$198	$521	303	$1.72
2026	5	3.2	$196	$340	$208	$548	319	$1.72

[29] National Renewable Energy Laboratory, *Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover*, NREL/TP-510-32438 (Golden, CO, June 2002). Accessed November 2010 at www. nrel.gov/docs/fy02osti/32438.pdf.

[30] J. Ashworth, U.S. Department of Energy, National Renewable Energy Laboratory, personal communication with S. Roe, Center for Climate Strategies (CCS), April 2007.

Year	Cellulosic Ethanol Plants Required	Biomass Required (million dry tons)	Biomass Feedstock Costs ($MM)	Other Annual Operating Costs ($MM)	Annualized Capital Costs ($MM)	Total Cellulosic Ethanol Production Costs ($MM)	Cellulosic Ethanol Produced (MMgal/yr)	Wholesale Cellulosic Ethanol Cost/Gallon ($MM)
2027	5	3.3	$205	$357	$219	$576	335	$1.72
2028	6	3.5	$215	$374	$229	$603	351	$1.72
2029	6	3.7	$225	$391	$239	$630	367	$1.72
2030	6	3.8	$235	$408	$250	$658	383	$1.72

$MM = million dollars; MMgal/yr = million gallons per year.

Soy Biodiesel Costs

Kentucky's current biodiesel capacity is 54 million gallons per year. To meet the AFW-4 goals, this capacity will increase to 96 million gal/yr by 2030. Capital costs are estimated to be $25 million for a 25-million gal/yr plant, based on industry estimates.[31]

Feedstock costs are estimated to be by far the largest portion of biodiesel costs. Soy oil is converted into biodiesel at an efficiency of 7.5 lbs soy oil needed per gallon biodiesel.[32] This is a relatively mature technology, so while efficiency improvements are possible, it is unlikely that feedstock requirements will decline significantly. Soy oil costs are estimated to be $0.525/lb as of 11/12/10, based on information in The Jacobsen.[33] Soy costs have increased since 2000, but have actually decreased since 2008. No reliable forecast for soy costs could be located; therefore, soy costs are held constant in this analysis. Soy costs fluctuate constantly, and this has a significant impact on overall biodiesel cost-effectiveness. For example, for every $0.10 increase in the price of soy oil, biodiesel costs in this analysis increase by $0.75/gal. Other biodiesel production costs are estimated to be $0.49/gal.[34] The production costs of biodiesel and the estimated cost per gallon are provided in Table 4-5.

Table AFW-4-5. Cost Summary for Biodiesel Plants

Year	Number of Biodiesel Plants Needed	Annual Capital Cost of Biodiesel (million $)	Feedstock Required (short tons)	Feedstock Costs (million $)	Additional Production Costs (million $)	Total Biodiesel Costs (million $)	$/Gallon
2011	3	$6.0	202,500	$213	$26.2	$245	$4.54
2012	3	$6.0	202,500	$213	$26.2	$245	$4.54
2013	3	$6.0	202,500	$213	$26.2	$245	$4.54
2014	3	$6.0	202,500	$213	$26.2	$245	$4.54
2015	3	$6.0	202,500	$213	$26.2	$245	$4.54

[31] Based on e-mail communication between Jackson Schreiber and Tom Verry, Director of Outreach and Development, National Biodiesel Board.

[32] The Jacobsen Biodiesel Upper Midwest Feedstock Values. Available at: http://www.thejacobsen.com/directory/main.htm.

[33] Ibid.

[34] Ibid.

Year	Number of Biodiesel Plants Needed	Annual Capital Cost of Biodiesel (million $)	Feedstock Required (short tons)	Feedstock Costs (million $)	Additional Production Costs (million $)	Total Biodiesel Costs (million $)	$/Gallon
2016	3	$6.0	202,500	$213	$26.2	$245	$4.54
2017	3	$6.0	209,363	$220	$27.1	$253	$4.53
2018	3	$6.0	239,272	$251	$31.0	$288	$4.52
2019	3	$6.0	269,181	$283	$34.9	$324	$4.51
2020	3	$6.0	269,181	$283	$34.9	$324	$4.51
2021	3	$6.0	269,181	$283	$34.9	$324	$4.51
2022	4	$8.0	299,090	$314	$38.8	$361	$4.53
2023	4	$8.0	299,090	$314	$38.8	$361	$4.53
2024	4	$8.0	299,090	$314	$38.8	$361	$4.53
2025	4	$8.0	328,999	$346	$42.6	$396	$4.52
2026	4	$8.0	328,999	$346	$42.6	$396	$4.52
2027	4	$8.0	328,999	$346	$42.6	$396	$4.52
2028	4	$8.0	358,908	$377	$46.5	$432	$4.51
2029	4	$8.0	358,908	$377	$46.5	$432	$4.51
2030	4	$8.0	358,908	$377	$46.5	$432	$4.51

Retail Costs and Quantity of Biofuel Provided

The TLU-10 analysis requires costs for each biofuel. These costs are based on the production costs, although there are other costs that must be accounted for to estimate the cost at the pump. It can be difficult to estimate the difference in fuel costs between wholesale (cost to the producer) and retail (cost to the consumer) fuel costs. The 2010 AEO does not estimate the wholesale costs of cellulosic ethanol, but does estimate the wholesale costs of corn ethanol. When these costs are compared with the retail cost estimates, the markup is typically $.045–$0.65/gal.[35] This figure is used as a stand-in for the cost difference between wholesale and retail cellulosic ethanol. This factor is not applied to biodiesel because it is assumed to be included in overall biodiesel production costs. The delivered costs of biofuels are displayed in Table AFW-4-6. These fuel costs and quantities, and the resulting GHG savings of biofuel usage are calculated in the TLU-10 analysis.

[35] U.S. EIA. *Annual Energy Outlook* 2010. Available at: http://www.eia.doe.gov/oiaf/archive/aeo10/index.html.

Table AFW-4-6. Delivered Biofuel Costs/Gallon

Year	Quantity of Cellulosic Ethanol (E100) Provided (million gallons)	Cellulosic Ethanol Retail Cost ($/gallon)	Quantity of Biodiesel (B100) Provided (million gallons)	Biodiesel Retail Cost ($/gallon)
2011	4	$2.53	54	$4.54
2012	8	$2.39	54	$4.54
2013	16	$2.38	54	$4.54
2014	28	$2.32	54	$4.54
2015	48	$2.22	54	$4.54
2016	68	$1.99	54	$4.54
2017	88	$2.11	56	$4.53
2018	112	$2.21	64	$4.52
2019	136	$2.25	72	$4.51
2020	167	$2.22	72	$4.51
2021	215	$2.25	72	$4.51
2022	255	$2.23	80	$4.53
2023	271	$2.48	80	$4.53
2024	287	$2.57	80	$4.53
2025	303	$2.57	88	$4.52
2026	319	$2.59	88	$4.52
2027	335	$2.59	88	$4.52
2028	351	$2.61	96	$4.51
2029	367	$2.62	96	$4.51
2030	383	$2.63	96	$4.51

B100 = 100% biodiesel; E100 = 100% ethanol.

Key Uncertainties

- This recommendation's costs are highly dependent on the price of feedstock, which is still relatively uncertain for many types of feedstock. If feedstock prices prove higher on a per-ton basis than currently estimated, then this recommendation may have a net cost rather than a net revenue.
- Emission factors for these fuels come from national estimates. Depending on the blending, components, and production practices, emission factors can be significantly affected.
- There is considerable uncertainty in modeling the indirect effects (land-use changes) of biofuel production.
- Lack of a robust feedstock portfolio, including an inventory of potential lands for energy plantations, makes it very difficult to clearly identify barriers to increased availability and supply, and to understand the cumulative impact on the sustainability of feedstock, food/fiber, and other commodity supplies and natural resources. Additional study is needed on this topic to ensure that crop lands devoted to energy feedstocks do not adversely affect Kentucky's ability meet its needs for food and fiber. For example, to supply the 96 million gallons of

biodiesel by 2030, an additional 1.6 million acres of soybeans would be needed, which is more than double the state's current crop land devoted to soybean cultivation (assuming 1.5 gallons of soy oil/bushel and 40 bushels/acre).

- Within the policy period, there is an expectation that new feedstock sources and energy-conversion technologies will become commercially feasible. These include biodiesel from crops suitable for marginal agricultural lands, bio-oils produced by biomass pyrolysis, and potentially production from algal oils. These new feedstocks/conversion technologies could greatly reduce the need for new crop acreage devoted to conventional crops (soybeans).
- On January 12, 2011, EPA issued a three-year deferment on the inclusion of GHG emissions from biogenic sources from regulation under the EPA GHG Tailoring Rule that went into effect on January 2, 2011. While this is positive to the operational costs of projects currently utilizing biomass feedstocks, the continued uncertainty may impact the increased utilization of biomass feedstocks.

Additional Benefits and Costs

Other benefits or costs of a low-carbon fuel standard that are not quantified here include:

- The impact (positive or negative) on other local air pollutants of concern, such as VOCs and NO_x.
- The sustainability of production.
- Flexibility to adjust based on the emergence of other technologies that might result in greater or more cost-effective GHG reductions.
- The impact on food prices.
- The impact on fuel tax revenue.
- The impact on the cost of goods delivery (i.e., fuel prices).
- The impact on small engines.
- Other environmental impacts, such as water quality and quantity, and conservation of land.
- Creation of in-state jobs and economic development associated with feedstock production, transport, and conversion.

The NREL study on the costs and benefits of a cellulosic ethanol plant finds that the facility would generate additional electricity beyond the operational needs. This was not considered in the analysis due to the uncertainty of the amount of electricity produced, although this could provide an additional revenue stream for cellulosic producers.

A recent article in *Science* magazine, "Sustainable Biofuels Redux," indicates that without proper management, intensive biofuel production can carry with it a significant environmental cost. The article pointed out that practices, such as conservation tillage and advanced nutrient management, as well as additional research on low-impact biofuel production, can help mitigate the environmental risks of expanded biofuel use.[36]

Feasibility Issues

- There is some uncertainty regarding the future in-state transportation fleet's ability to consume the volumes of biofuel to be produced under this recommendation. For that to happen, it will require coordinated effort on both the production and the demand-sides to ensure that the full GHG benefits are achieved. This includes the need for additional blending facilities (either at the bulk plant or direct blending at the gasoline station) and a large flex-fuel fleet to consume higher ethanol blends. (See TLU-10 for more information.)
- See the Key Uncertainties section, above, for additional issues.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

[36] Robertson, Philip, et al. "Sustainable Biofuels Redux." *Science* 322, October 3, 2008. Available at: www.sciencemag.org.

AFW-5. Soil Carbon Management

Policy Description

The amount of carbon stored in the soil can be increased by the adoption of such practices as conservation, no-till cultivation, and crop rotation. Reducing summer fallow and increasing winter cover crops are complementary practices that reduce the need for conventional tillage. In addition, the application of biochar (i.e., charcoal) may also increase soil carbon content and stabilize soil carbon. By reducing mechanical soil disturbance, these practices reduce the oxidation of soil carbon compounds and allow more stable aggregates to form. Other benefits include reduced wind and water erosion, reduced fuel consumption, and improved wildlife habitat. This policy recommendation would encourage soil productivity and carbon sequestration through the use of biochar, winter over-crops, and such practices as crimping/rolling.[37]

Note that Kentucky may lead the country in no-till agriculture. Kentucky farmers have made a considerable shift to no-till agriculture in the last decade. Consequently, this policy recommendation may have limited potential in Kentucky compared to other states.

Policy Design

Goals: Increase the number of acres using tillage practices that increase the amount of soil carbon and reduce GHG emissions, including:

- Plant winter cover crops on 50% of the currently winter-fallow land by 2030.
- Convert 25% of the currently conventionally tilled land to no-till or reduced-tillage by 2030.
- Encourage development and production of nitrogen-fixing crops that return nitrogen to the soil.

Timing: Linear rate of implementation through 2030.

Parties Involved: Kentucky Department of Agriculture, USDA, private farmers.

Other: None.

Implementation Mechanisms

Soil Carbon Management

- Promote conservation tillage for GHG benefits.

[37] "'Cover crop rolling' is an advanced no-till technique. It involves flattening a high-biomass cover crop to produce a thick, uniform mat of mulch. A cash crop is then no-tilled into the mulch. If the right kind of roller is used on the right cover crop at the right time, the rolling process itself will kill or partially kill the cover crop." From Introduction to cover crop rolling and the Virginia-USDA Crimper Roller Demonstration Project, 2006, United States Department of Agriculture. Available at: ftp://ftp-fc.sc.egov.usda.gov/VA/Technical/conservation_planning/Crop_Agr/VA.Roller.FS.Sept.06.III.pdf.

- Based on existing research, develop and conduct targeted research programs to identify crop systems that could achieve soil carbon gains through changes in practices/technology, while still achieving net GHG benefits per unit of output (i.e., taking into consideration soil carbon gains, energy consumption, nutrient/pesticide/herbicide use, etc.). Develop and promote best management practices for producers that are adapted to regional differences and farming practices.
- Promote applicable farming practices that achieve net GHG benefits by providing technical assistance and financial support for small and medium-size farm operations.
- Develop assessment models so that growers can make decisions on how they can reduce their carbon footprint. This can be enhanced with support of emerging approaches to increase long-term soil carbon content, such as conservation tillage roller crimpers, which combine winter cover crops with conservation tillage, while reducing or eliminating the need for chemical fertilizers. Also, explore new approaches, like the application of biochar, which may enhance soil carbon stability.
- Work locally through Conservation Districts to get back to basics on equipment and techniques to make conservation tillage successful.

Related Policies/Programs in Place

- The 2007 Federal Farm Bill offers a variety of cost-share programs for landowners implementing USDA NRCS practices.
- USDA NRCS offers a variety of cost-share programs for producers who improve their system management by implementing NRCS-approved practice standards.

Type(s) of GHG Reductions

CO_2, CH_4 and N_2O: Reductions occur through a variety of methods, including carbon sequestration in agricultural soils and potentially nitrogen mineralization; reduced life-cycle GHG emissions through lower fuel consumption and nutrient inputs; and reduced N_2O emissions from nitrogen runoff or leaching.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources: See text below.

Quantification Methods: This analysis considers the costs and benefits of improving the soil carbon sequestration on Kentucky farms. Total GHG savings and costs are summarized in Table AFW-5-1.

Table AFW-5-1. Summary of AFW-5

Year	Implementation Path	Additional Acres of NT/CT Needed	Total In-State GHG Savings, NT/CT ($MMtCO_2e$)	Total GHG Savings, NT/CT ($MMtCO_2e$)	Discounted Cost, NT/CT ($MM)	Additional Winter Cover Crop Acres	GHG Savings, Carbon Sequestration, Winter Cover Crops ($MMtCO_2e$)	Discounted Net Cost, Winter Cover Crops ($MM)
2010	0%	0	0.00	0.00	0.0	0	0.00	0.0
2011	5%	28,451	0.04	0.04	0.1	56,100	0.09	1.2
2012	10%	56,901	0.07	0.07	0.2	112,200	0.19	2.3
2013	15%	85,352	0.11	0.11	0.3	168,300	0.28	3.3
2014	20%	113,802	0.15	0.15	0.3	224,400	0.38	4.2
2015	25%	142,253	0.19	0.19	0.3	280,501	0.47	5.0
2016	30%	170,704	0.22	0.22	0.3	336,601	0.57	5.7
2017	35%	199,154	0.26	0.26	0.3	392,701	0.66	6.3
2018	40%	227,605	0.30	0.30	0.3	448,801	0.76	6.9
2019	45%	256,055	0.33	0.34	0.3	504,901	0.85	7.4
2020	50%	284,506	0.37	0.37	0.3	561,001	0.95	7.8
2021	55%	312,957	0.41	0.41	0.4	617,101	1.04	8.2
2022	60%	341,407	0.45	0.45	0.4	673,201	1.14	8.5
2023	65%	369,858	0.48	0.49	0.3	729,301	1.23	8.7
2024	70%	398,308	0.52	0.52	0.4	785,401	1.33	9.0
2025	75%	426,759	0.56	0.56	0.4	841,502	1.42	9.1
2026	80%	455,209	0.60	0.60	0.3	897,602	1.52	9.3
2027	85%	483,660	0.63	0.64	0.4	953,702	1.61	9.4
2028	90%	512,111	0.67	0.67	0.3	1,009,802	1.71	9.5
2029	95%	540,561	0.71	0.71	0.3	1,065,902	1.80	9.5
2030	100%	569,012	0.74	0.75	0.3	1,122,002	1.90	9.6
Total			**7.8**	**7.9**	**6.3**		**19.9**	**140.6**

$MM = million dollars; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; NT/CT = no till/conservation tillage.

Total harvested cropland in Kentucky was estimated at about 5.1 million acres in 2007.[38] For the purposes of this analysis, it is assumed that conservation practices include conservation till (no-till (NT) and strip-till) and other conservation farming practices that provide enhanced ground cover, or other crop management practices that achieve similar soil carbon benefits. Conservation tillage (CT) is defined as any system that leaves 50% or more of the soil covered with residue.[39]

[38] USDA. Kentucky Fact Sheet. Available at: http://www.ers.usda.gov/statefacts/KY.htm.

[39] The definitions of tillage practices from the Conservation Technology Information Center are used under this policy. However, only no-till/strip-till and ridge-till are considered "conservation tillage" practices. No-till means leaving the residue from last year's crop undisturbed until planting. Strip-till means no more than one-third of the row width is disturbed with a coulter, residue manager, or specialized shank that creates a strip. If shanks are used, nutrients may be injected at the same time. Ridge-till means that 4–6-inch-high ridges are formed at cultivation. Planters using specialized attachments scrape off the top 2 inches of the ridge before placing the seed in the ground.

Based on the policy design parameters, the schedule for acres to be put into conservation tillage/no-till cultivation is displayed in Table AFW-5-2. This table shows the number of additional NT/CT acres that need to be adopted by 2030. Data from the Conservation Technology Information Center indicated that no-till practices are common in Kentucky, accounting for 55% of acres in 2004.[40]

This analysis assumes that the rate of carbon accumulation occurs for 20 years, which extends beyond the policy period. It is assumed that the sequestration rate of 1.25 tCO_2e/acre/yr provided by the Nicholas Institute for the carbon credit program is reliable for the state of Kentucky.[41] Additional GHG savings from reduced fossil fuel consumption are estimated by multiplying the fossil diesel emission factor and diesel fuel reduction per acre estimate. The reduction in fossil diesel fuel use from the adoption of CT methods is 3.5 gal/acre.[42] The in-state fossil diesel GHG emission factor of 10.15 tCO_2e/1,000 gal was then multiplied by the gallons saved to get tons of CO_2e reduced.[43]

There are also GHG savings estimated based on reductions in commercial fertilizer use. It was estimated that NT/CT practices can reduce nitrogen (N) fertilizer needs by as much as 50%–90%.[44] In an effort to be conservative, the 50% reduction estimate was used. This was applied to the average N fertilizer application on each farm acre (6.9 kg N/acre), estimated by dividing total N applications in Kentucky (from the I&F) by the number of farmland acres in Kentucky (14.0 million). The GHG savings were estimated based on the percentage reduction in N application multiplied by the overall emissions from N application (from the I&F). This is then combined with a figure for the life-cycle emissions of N fertilizer to account for the rest of the emissions associated with fertilizer manufacturing, transport, and application (0.857 kg CO_2e/kg of N).[45] These life-cycle emissions are added separately, because they are likely to occur out of state. GHG savings from carbon sequestration and reduced fuel and fertilizer use are shown in Table AFW-5-2.

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[40] 2004 data from Conservation Technology Information Center (includes no-till and ridge-till practices). Percentage of Kentucky cropland that employs no till.

[41] "Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States." October 2010. Nicholas Institute for Policy Studies. The figure of 1.25 tCO_2e/acre/year is based on the national average of CT/NT data.

[42] Reduction associated with conservation tillage compared with conventional tillage. Available at: http://www.ctic.purdue.edu/resourcedisplay/293/, accessed October 2010.

[43] California Climate Action Registry Emissions Factor for diesel fuel.

[44] Based on communication with John Graham, Soil Quality Specialist, USDA-NRCS, on 9/17/10.

[45] West, T.O., and G. Marland. 2001. "A Synthesis of Carbon Sequestration, Carbon Emissions, and Net Carbon Flux in Agriculture: Comparing Tillage Practices in the United States." *Agriculture, Ecosystems & Environment* September 2002, 91(1-3):217-232. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6T3Y-46MBDPX-10&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=4bf71c930423acddffbcef6d46d763c3.

Table AFW-5-2. GHG Reductions from No Till/Conservation Tillage Practices

Year	Implementation Percentage	Additional Acres of NT/CT Needed	GHG Savings (NT/CT) ($MMtCO_2e$)	Gallons of Fuel Saved	GHG Savings from Reduced Fuel Use ($MMtCO_2e$)	Reduced N Use (metric tons)	GHG Savings from Reduced N Applications ($MMtCO_2e$)
2010	0%	0	0.00	0	0.000	0	0.000
2011	5%	28,451	0.04	99,577	0.001	197	0.001
2012	10%	56,901	0.07	199,154	0.002	393	0.001
2013	15%	85,352	0.11	298,731	0.003	590	0.002
2014	20%	113,802	0.14	398,308	0.004	786	0.002
2015	25%	142,253	0.18	497,885	0.005	983	0.003
2016	30%	170,704	0.21	597,462	0.006	1,180	0.004
2017	35%	199,154	0.25	697,040	0.007	1,376	0.004
2018	40%	227,605	0.28	796,617	0.008	1,573	0.005
2019	45%	256,055	0.32	896,194	0.009	1,770	0.006
2020	50%	284,506	0.36	995,771	0.010	1,966	0.006
2021	55%	312,957	0.39	1,095,348	0.011	2,163	0.007
2022	60%	341,407	0.43	1,194,925	0.012	2,359	0.007
2023	65%	369,858	0.46	1,294,502	0.013	2,556	0.008
2024	70%	398,308	0.50	1,394,079	0.014	2,753	0.009
2025	75%	426,759	0.53	1,493,656	0.015	2,949	0.009
2026	80%	455,209	0.57	1,593,233	0.016	3,146	0.010
2027	85%	483,660	0.60	1,692,810	0.017	3,343	0.011
2028	90%	512,111	0.64	1,792,387	0.018	3,539	0.011
2029	95%	540,561	0.68	1,891,964	0.019	3,736	0.012
2030	100%	569,012	0.71	1,991,541	0.020	3,932	0.012

GHG = greenhouse gas; N = nitrogen; NT/CT = no till/conservation tillage.

The life-cycle emissions of fuel production and distribution as well as fertilizer production are shown in Table AFW-5-3. The table also shows the total GHG savings of NT/CT on an in-state and life-cycle basis.

Table AFW-5-3. Total GHG Savings of No Till/Conservation Tillage Practices

Year	Total In-State GHG Savings ($MMtCO_2e$)	Additional Life-Cycle Savings ($MMtCO_2e$)	Total GHG Savings ($MMtCO_2e$)
2010	0.00	0.000	0.00
2011	0.04	0.000	0.04
2012	0.07	0.001	0.07
2013	0.11	0.001	0.11
2014	0.15	0.001	0.15
2015	0.19	0.001	0.19
2016	0.22	0.002	0.22
2017	0.26	0.002	0.26
2018	0.30	0.002	0.30
2019	0.33	0.003	0.34
2020	0.37	0.003	0.37
2021	0.41	0.003	0.41
2022	0.45	0.003	0.45
2023	0.48	0.004	0.49
2024	0.52	0.004	0.52
2025	0.56	0.004	0.56
2026	0.60	0.004	0.60
2027	0.63	0.005	0.64
2028	0.67	0.005	0.67
2029	0.71	0.005	0.71
2030	0.74	0.006	0.75
Total	**7.81**		**7.87**

GHG = greenhouse gas.

Kentucky has one of the highest rates of NT/CT practices in the country, and while the cost-effectiveness of NT/CT will vary based on factors on the ground, it can in many cases be the most cost-effective management practice.[46] The costs of additional NT/CT come from a University of Kentucky Cooperative Extension Service publication on no-till wheat, which found that NT/CT practices resulted in slightly reduced yield, which amounted to lost revenue of just over $17.[47] There are also cost savings associated with NT/CT from reduced fuel and nitrogen requirements. The cost savings from reduced fuel consumption are estimated by multiplying the gallons saved by the forecast price for diesel in that year. The cost savings of reduced fertilizer use are estimated by multiplying the tons of fertilizer saved by the cost of fertilizer ($435/ton). The costs of this expansion of NT/CT practices in Kentucky are shown in Table AFW-5-4.

[46] "No-Till Wheat Grain Production in Kentucky." University of Kentucky Cooperative Extension Service. 2000. Located online at: http://www.ca.uky.edu/agc/pubs/id/id136/ID136.pdf.

[47] Estimated a cost of $11.80/acre in lost yield, which when discounted forward to 2005 dollars is just over $17/acre. "Comparing No-Till and Tilled Wheat in Kentucky." University of Kentucky Cooperative Extension Service. 2009. Located online at: http://www.ca.uky.edu/agc/pubs/id/id177/id177.pdf.

Table AFW-5-4. Costs of Conservation Tillage Program

Year	Cost, Reduced Fuel Consumption ($MM)	Cost, Reduced Fertilizer Use ($MM)	Additional Cost, Lost Yield, NT/CT ($MM)	Total Cost ($MM)	Discounted Cost ($MM)
2010	$0.0	$0.0	$0.0	$0.0	$0.0
2011	–$0.2	–$0.1	$0.5	$0.2	$0.1
2012	–$0.5	–$0.2	$1.0	$0.3	$0.2
2013	–$0.8	–$0.2	$1.5	$0.4	$0.3
2014	–$1.2	–$0.3	$2.0	$0.5	$0.3
2015	–$1.5	–$0.4	$2.5	$0.6	$0.3
2016	–$1.9	–$0.5	$3.0	$0.6	$0.3
2017	–$2.3	–$0.5	$3.5	$0.6	$0.3
2018	–$2.7	–$0.6	$4.0	$0.6	$0.3
2019	–$3.1	–$0.7	$4.5	$0.7	$0.3
2020	–$3.5	–$0.8	$5.0	$0.7	$0.3
2021	–$3.8	–$0.9	$5.5	$0.8	$0.4
2022	–$4.2	–$0.9	$6.0	$0.8	$0.4
2023	–$4.6	–$1.0	$6.4	$0.8	$0.3
2024	–$5.0	-$1.1	$6.9	$0.9	$0.4
2025	-$5.3	–$1.2	$7.4	$1.0	$0.4
2026	–$5.7	–$1.2	$7.9	$0.9	$0.3
2027	–$6.1	–$1.3	$8.4	$1.0	$0.4
2028	–$6.5	–$1.4	$8.9	$1.0	$0.3
2029	–$7.1	–$1.5	$9.4	$0.9	$0.3
2030	–$7.5	–$1.6	$9.9	$0.9	$0.3
Total					**$6.3**

$MM = million dollars; NT/CT = no till/conservation tillage.

<u>Winter Cover Crops</u>

Winter cover crops can allow farmers to increase their revenue by growing an additional crop during the winter months. Kentucky is one of the few states where these types of management practices are viable and can improve revenue. It is possible to grow a winter cover crop of clover or hairy vetch, which both have nitrogen-fixing properties, and can decrease the overall amount of N applications required. Potential revenue and GHG savings are possible from reduced N requirements, but these were not included in this analysis due to lack of data.

The goal is to plant winter cover crops on 50% of the currently winter fallow land by 2030. The acres of winter fallow land in Kentucky were estimated based on the acres of corn and soybean crops, minus the acres of wheat, barley, and oat crops. This assumes that corn and soybeans are the crops most likely to be fallow during the winter, and that all wheat, barley, and oat crops in the state are grown as winter crops. According to the NASS, there were an estimated 2.48 million acres of corn and soybean crops in Kentucky in 2007.[48] Winter wheat, oats, and barley accounted for 240,000 acres in 2007.[49] Therefore, there are an estimated 2.24 million acres of winter fallow land in Kentucky. Based on this estimate, the goal for this recommendation is to convert 1.12 million of these acres into winter cover crops by 2030.

Carbon sequestration for winter cover crops includes 1.69 tCO_2e/acre/yr provided by the Nicholas Institute.[50] This figure will be multiplied by the number of acres in the program to estimate total GHG savings.

The costs and cost savings of winter cover crops come from a publication by the Appropriate Technology Transfer for Rural Areas (ATTRA) group, which estimates a seeding cost of $46/acre for winter cover crops.[51] This is partially offset by the estimated increase in revenue of $17/acre when comparing winter cover crops with winter fallow land.[52] It is important to note that there is a tradeoff here when winter cover crops replace fallow land. When farmers of corn and soybean crops choose not to grow a winter cover crop, they can lengthen the growing season of their primary crop, which can increase revenues. The ATTRA study found that growing a winter cover crop on average had more revenue than letting the land remain fallow, but it is possible that this will depend on a variety of factors, such as the sale price of soybeans, corn, and small grains, as well as the costs of such inputs as N fertilizers. The GHG sequestration as well as costs and cost savings are shown in Table AFW-5-5.

[48] USDA/NASS. 2007 Census of Agriculture for Kentucky. Available at: http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_1_State_Level/Kentucky/index.asp.

[49] Ibid.

[50] "Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States." October 2010. Nicholas Institute for Policy Studies. The figure of 1.69 tCO_2e/acre/yr is based on the national average of winter cover crop data.

[51] The estimate of costs comes from establishment costs for seeding, from the ATTRA publication: "Overview of Cover Crops and Green Manures." July 2003. Available at: http://attra.ncat.org/attra-pub/PDF/covercrop.pdf. This cites a cost figure of $28/acre for seeding winter cover crops. These costs are discounted forward to 2005 dollars, which results in a cost of $46/acre.

[52] The estimate of revenue is comparing the revenue from winter cover crops compared to fallow land, from the ATTRA publication: "Overview of Cover Crops and Green Manures." July 2003. Available at: http://attra.ncat.org/attra-pub/PDF/covercrop.pdf. This article cites a $64/acre winter cover crops average profitability value, compared with revenue of $54/acre for fallow land. This net profit of $10/acre was then discounted forward to 2005 dollars, which results in a profit of $17/acre.

Table AFW-5-5. GHG Savings and Costs from Winter Cover Crops

Year	Implementation Path	Additional Winter Cover Crop Acres	GHG Savings, Carbon Sequestration ($MMtCO_2e$)	Costs, Winter Cover Crops ($MM)	Revenue, Winter Cover Crops ($MM)	Net Cost, Winter Cover Crops ($MM)	Discounted Net Cost, ($MM)
2010	0%	0	0.00	$0.0	$0.0	$0.0	$0.0
2011	5%	56,100	0.09	$2.6	$0.9	$1.6	$1.2
2012	10%	112,200	0.19	$5.1	$1.9	$3.2	$2.3
2013	15%	168,300	0.28	$7.7	$2.8	$4.9	$3.3
2014	20%	224,400	0.38	$10.2	$3.8	$6.5	$4.2
2015	25%	280,501	0.47	$12.8	$4.7	$8.1	$5.0
2016	30%	336,601	0.57	$15.4	$5.6	$9.7	$5.7
2017	35%	392,701	0.66	$17.9	$6.6	$11.3	$6.3
2018	40%	448,801	0.76	$20.5	$7.5	$12.9	$6.9
2019	45%	504,901	0.85	$23.0	$8.5	$14.6	$7.4
2020	50%	561,001	0.95	$25.6	$9.4	$16.2	$7.8
2021	55%	617,101	1.04	$28.1	$10.3	$17.8	$8.2
2022	60%	673,201	1.14	$30.7	$11.3	$19.4	$8.5
2023	65%	729,301	1.23	$33.3	$12.2	$21.0	$8.7
2024	70%	785,401	1.33	$35.8	$13.2	$22.7	$9.0
2025	75%	841,502	1.42	$38.4	$14.1	$24.3	$9.1
2026	80%	897,602	1.52	$40.9	$15.1	$25.9	$9.3
2027	85%	953,702	1.61	$43.5	$16.0	$27.5	$9.4
2028	90%	1,009,802	1.71	$46.1	$16.9	$29.1	$9.5
2029	95%	1,065,902	1.80	$48.6	$17.9	$30.7	$9.5
2030	100%	1,122,002	1.90	$51.2	$18.8	$32.4	$9.6
Total			**19.9**				**$141**

$MM = million dollars; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Key Assumptions: See text.

Key Uncertainties

- The GHG sequestration for NT/CT and winter cover crops comes from a Nicholas Institute publication on the nationals average GHG savings achieved from these practices. It is possible that these averages do not reflect GHG savings in Kentucky.
- The costs of both of these practices will vary based on a variety of local conditions, such as crop, equipment, and fuel prices. Given the popularity of NT/CT practices in Kentucky, it is possible that the costs of expanding NT/CT are overestimated in this analysis.

Additional Benefits and Costs

One benefit of many types of winter cover crops is nitrogen fixation, which can reduce the need for additional N inputs. This could result in both GHG and cost savings.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

AFW-6. Increase Productivity of Abandoned, Underutilized, and Reclaimed Lands

Policy Description

Establish crops on abandoned, underutilized, reclaimed, previously mined, and marginal agricultural lands that are not currently producing. Plant forage crops, native grasses, or energy crops, as appropriate. In addition, implement such practices as site and soil preparation, erosion control, and addition of soil additives to ensure conditions that support healthy growth. This policy can include planting on previously mined surface mines where appropriate.

The production of crops is the best use for much of the previously mined land in Kentucky due to site conditions or constraints. Improving the productivity of all mined lands will increase land value and foster better stewardship by landowners. Furthermore, production of biomass crops on marginal lands could help Kentucky meet its renewable energy goals without the need to convert food-producing agricultural lands to biomass production.

Policy Design

Goals

- Carry out inventory and evaluation of candidate acres amenable to crop production. (This will be completed in conjunction with AFW-7, which promotes afforestation and reforestation.)
- Convert 20% of currently available post-mined and abandoned agricultural land to biomass crop production by 2030.
- Increased per-area yields of crops raised on mined areas through application of soil amendments.

Timing: Linear implementation through 2030.

Parties Involved: Improving mined land productivity will involve individual landowners and groups that represent/communicate with landowners interacting with entities that provide technical information on productivity improvement practices, entities that provide information on where landowners can find vendors and materials needed to effect productivity improvement practices and entities, and institutions that provide financial incentives for landowners to become better stewards of their land.

These include private landowners, mining companies, farmers, foresters, Department of Natural Resources (DNR), Division of Mine Permits, Division of Mine Reclamation Enforcement, Kentucky Division of Forestry, Kentucky Department of Agriculture, Office of Surface Mining Reclamation and Enforcement ([OSM] U.S. Department of the Interior), NRCS, Kentucky Division of Conservation, Kentucky Division of Water, The Appalachian Regional Reforestation Initiative, the University of Kentucky.

Other: Mined areas that are sloped are generally suitable for tree crops due to the substrates being less compacted and better drained than mined areas that are flat. Flat areas are generally more suitable for the production of crops of herbaceous plants. The productivity of flat areas used for the production of forage crops can be improved by application of soil amendments. The most economical way to improve the productivity of herbaceous crops is to apply amendments that increase soil pH, thereby increasing the availability of nutrients to plants. Flat areas not used for the production of forage crops are typically dominated by herbaceous plants and smaller amounts of shrubs and trees. The productivity of these areas can be improved by converting them to complete forest cover, which will increase the rate of soil development/productivity and provide numerous ecosystem and economic benefits.

Improving mined land productivity through forest establishment involves a long-term investment by a landowner. The threat of investment loss due to wildfire is a significant disincentive for forest establishment.

It should be noted that sites that were mined for coal after 1977 must be reclaimed to a condition capable of supporting an approved “post-mining land use” (PMLU) that is in accordance with the landowner’s wishes and identified in the permit application. To achieve complete bond release, the permittee must make a demonstration to the Cabinet that the land use has been achieved and must provide several years of productivity demonstrations supportive of the approved PMLU (e.g., number of tree stems/acre, hay in tons/acre, animal units/acre, bushels of corn/acre, etc.). There is a minimum 5-year bond liability period after mining and reclamation has been completed. Once a mine site has been granted a complete bond release. OSM then terminates jurisdiction over the permit area, and control is relinquished back to the surface owner.

Implementation Mechanisms

- Carry out inventory/assessment of candidate abandoned, underutilized, reclaimed, or previously mined sites in the state that are amenable to planting.
- Create "best practices" documentation for planting on these categories of land.
- Provide landowner incentives, such as conservation easements, cost-sharing programs, and tax credits.

Related Policies/Programs in Place

- OSM has a working group that reviews current reclamation policies and practices and provides guidance for development on mined lands.
- Note that the Kentucky DNR has jurisdiction over reclaimed mined lands.
- USDA’s Biomass Crop Assistance Program (BCAP) was included in the 2008 Farm Bill. BCAP provides payments of up to 75% of the costs of establishing eligible perennial crops. BCAP producers must be part of a “BCAP project area” that is physically located within an economically viable distance from a biomass conversion facility.

Type(s) of GHG Reductions

CO_2: Avoided emissions from coal combustion.

Estimated GHG Reductions and Net Costs or Cost Savings

Table AFW-6-1. Summary of AFW-6

Quantification Factors	2020	2030	Units
GHG Emission Reductions	2.74	5.79	$MMtCO_2e$
Net Present Value (2011–2030)		$50	$ Million
Cumulative Emissions Reductions (2011–2030)		58	$MMtCO_2e$
Cost-Effectiveness (2011–2030)		$0.9	$/$tCO_2e$

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Estimates of underutilized post-mined and agricultural lands in Kentucky, expected biomass crop yield, and the energy content of the biomass were obtained from a study of bioenergy potential on marginal lands by DeBolt et al.[53] DeBolt calculated the area of underutilized agricultural lands in Kentucky by analyzing historical data records to identify change on land that had been abandoned from use in agriculture but that had not transitioned to secondary forests, urban areas, aquatic ecosystems (such as rivers, streams, and wetlands), or transit infrastructure. DeBolt estimated the area of underutilized post-mined lands, lands that were in production and are now fallow, based on data from the Kentucky State Abandoned Mine Report for coal (2008), the Kentucky Mine Mapping Information System (2008), and Kentucky Geological Survey (2007) annual reports for examining enterprise land-use shifts other than coal.[54] The energy content of the biomass from the DeBolt study assumes co-firing with coal. The crop yield and energy content values for switchgrass were chosen because they are roughly midway between the values for the other two biomass crop species considered in the study (eastern gamagrass and big bluestem).
- The estimated cost of biomass crop production ($40/dry ton) was taken from the final report of the Kentucky Task Force on Biomass and Biofuels Development.[55] The cost of delivered coal for electricity production for the Southeast Region was taken from EIA's AEO 2010.[56] These values are shown in Table AFW-6-3.

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[53] Debolt, S., J.E. Campbell, R. Smith, M. Montross, and J. Stork, "Life cycle assessment of native plants and marginal land for bioenergy agriculture in Kentucky as a model for south-eastern USA." *GCB Bioenergy* 2009. 1:308-316, doi: 10.1111/j.1757-1707.2009.01023.x.

[54] See Debolt, S., J.E. Campbell, R. Smith, M. Montross, and J. Stork, "Life cycle assessment of native plants and marginal land for bioenergy agriculture in Kentucky as a model for south-eastern USA." *GCB Bioenergy* 2009. 1:308-316, doi: 10.1111/j.1757-1707.2009.01023.x.

[55] "Final Report From the Executive Task Force on Biomass and Biofuels Development in Kentucky," Governor's Office of Agricultural Policy and the Kentucky Energy and Environment Cabinet, December 10, 2009, accessible at: http://agbioworks.org/pdfs/KYBiomass_FinalReport_Dec2009.pdf.

[56] U.S. EIA, *Annual Energy Outlook 2010*, Table 16. Available at: http://www.eia.doe.gov/oiaf/aeo/supplement/index.html.

Quantification Methods

Biomass Crops

The amount of currently available land was estimated by adding the amounts of underutilized post-mined lands (0.3 million hectares or 741,316 acres)) and underutilized agricultural land (1.9 million hectares or 4,695,002 acres). Quantification parameters are summarized in Table AFW-6-2. The goal of converting 20% of this land to biomass crop production by 2030 was assumed to be linearly implemented over the 2012–2030 period, as shown in Table AFW-6-3. The amount of energy produced from biomass crops grown on these lands was estimated using the amount of land converted, and the crop yield and energy content from the DeBolt study (3.25 t/acre and 0.0178 MMBtu/kg). Since biomass fuel is renewable, the CO_2 emissions from combustion of this fuel do not contribute to overall GHG emissions. Therefore, replacing a portion of coal with biomass fuel reduces emissions. The amount of emissions avoided was estimated by assuming that an amount of coal equal to the amount of biomass in terms of energy produced would be replaced, reducing emissions by 0.096 tCO_2e/MMBtu.

Biomass production costs were estimated based on the per-acre crop yield and the estimate of $40 per dry ton of biomass. The overall cost was estimated by subtracting the cost of the replaced coal from the cost of biomass production.

Table AFW-6-2. Quantification Parameters Used to Estimate GHG Reductions and Costs

Parameter	Value	Unit	Value	Unit
Underutilized Post-Mine Land in Kentucky	0.3	Million hectares	741,316	acres
Underutilized Agricultural Land in Kentucky	1.9	Million hectares	4,695,002	acres
Total Available Land in Kentucky	5.4	Million acres		
Biomass Yield on Mined and Abandoned Land	3,250	kg/acre		
Energy Content of Biomass	0.018	MMBtu/kg	7,150	Lb/acre
Coal Emissions	0.092	tCO_2e/MMBtu	0.008	MMBtu/lb
Cost of Biomass Production	$40	$2007/dry ton		
Delivered Fuel Cost for Coal Used for Electricity	$2.20	$2008/MMBtu		

GHG = greenhouse gas; kg = kilogram; lb = pound; MMBtu = million British thermal units; tCO_2e = metric ton of carbon dioxide equivalent.

Table AFW-6-3. GHG Reductions and Costs of Biomass Production

Year	Additional Acres Producing Biomass Crops	Acreage (million acres)	Energy Produced (billion Btu)	$MMtCO_2e$ from Coal Avoided	Biomass Production Costs (million $)	Coal Cost Savings (million $)	Discounted Costs (million $)
2011	0%	0.00	0	0.00	$0	$0	$0.0
2012	1%	0.06	3,314	0.30	$8	$7	$0.7
2013	2%	0.11	6,628	0.61	$16	$15	$1.4
2014	3%	0.17	9,942	0.91	$25	$22	$1.9
2015	4%	0.23	13,256	1.22	$33	$29	$2.5
2016	5%	0.29	16,570	1.52	$41	$36	$2.9
2017	6%	0.34	19,884	1.83	$49	$44	$3.3
2018	7%	0.40	23,199	2.13	$57	$51	$3.7
2019	8%	0.46	26,513	2.44	$66	$58	$4.0
2020	9%	0.52	29,827	2.74	$74	$66	$4.3
2021	11%	0.57	33,141	3.05	$82	$73	$4.6
2022	12%	0.63	36,455	3.35	$90	$80	$4.8
2023	13%	0.69	39,769	3.66	$98	$87	$5.0
2024	14%	0.74	43,083	3.96	$107	$95	$5.2
2025	15%	0.80	46,397	4.27	$115	$102	$5.3
2026	16%	0.86	49,711	4.57	$123	$109	$5.4
2027	17%	0.92	53,025	4.88	$131	$117	$5.5
2028	18%	0.97	56,339	5.18	$139	$124	$5.5
2029	19%	1.03	59,653	5.49	$148	$131	$5.6
2030	20%	1.09	62,968	5.79	$156	$139	$5.6
Total				**57.9**	**$1,557**	**$1,385**	**$50**

Btu = British thermal unit; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

<u>Soil Amendments</u>

The costs and benefits of using soil amendments to increase productivity on marginal lands were not quantified. While a number of studies have suggested an increase in productivity on lands using coal combustion by-products and other types of soil amendments, quantitative measurements of the increase in carbon sequestration were not available. Also, the effects of soil amendments can vary widely, depending on the type of amendment, the condition of the soil, and the species being grown. A University of Kentucky study found that compost and fertilizer soil amendments improved productivity in loblolly pine in plots in eastern Kentucky, but not in plots located western Kentucky. For northern red oak, productivity appeared to be inhibited by the use of compost without fertilizer in western Kentucky, while this was not the case in eastern Kentucky.[57] More study is needed to determine the benefits of using soil amendments on specific types of land and plant species in Kentucky.

[57] Graves, D., et al., "Carbon Sequestration on Surface Mine Lands: Final Report, October 2003-September 2006." University of Kentucky, Department of Forestry, U.S. DOE Award Number: DE-FC26-02NT41624.

Key Assumptions: A full life-cycle assessment, including the energy required for agricultural production, coal mining, and processing and transportation of biomass and coal, was not included in this quantification. Also, soil carbon sequestration from biomass cultivation was not included.

Key Uncertainties

- There is uncertainty associated with the cost of biomass production. Cultivation of biomass on potentially degraded land may be more expensive than $40/dry ton, due to lower yields and additional fertilizer or soil amendment needs. Estimates of crop yields and energy content are also uncertain. A recent study by Aravindhakshan et al. estimated a cost of \$7/tCO_2e for replacing coal with biomass.[58] This study assumed a cost of $40/dry ton for biomass with an energy content of 0.015 MMBtu/kg and a cost of $1.83/MMBtu for coal.
- On January 12, 2011, EPA issued a three-year deferment on the inclusion of GHG emissions from biogenic sources from regulation under the EPA GHG Tailoring Rule that went into effect on January 2, 2011. While this is positive to the operational costs of projects currently utilizing biomass feedstocks, the continued uncertainty may impact the increased utilization of biomass feedstocks.

Additional Benefits and Costs

Cultivating biomass crops and increasing the productivity of forage crops on abandoned lands would increase soil and biomass carbon sequestration on these lands.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

[58] Aravindhakshan, S., F. Epplin, and C. Taliaferro, "Economics of switchgrass and *Miscanthus* relative to coal as feedstock for generating electricity." *Biomass and Bioenergy* 2010, 34:1375-1383.

AFW-7. Reforestation, Afforestation, and Restoration of Mined Lands and Other Non-forested Lands

Policy Description

Establish forests on lands that are not currently forested (e.g., underutilized land not currently in agricultural production, forest, or development—“afforestation”), and promote forest cover and associated carbon stocks by regenerating or establishing forests in areas with little or no present forest cover (“reforestation”). In addition, implement such practices as site and soil preparation, erosion control, and stand stocking to ensure conditions that support forest growth. This policy can include forestation of previously mined surface mines, as well as non-forested riparian areas.

Promote mine reforestation practices that (1) plant high-value hardwood trees on reclaimed coal-mined lands, (2) increase the survival and growth rates of planted trees, and (3) expedite the establishment of forest habitat through natural succession.

Policy Design

Goals

- *Promote abandoned and mined land reforestation*—Increase the number of post-mined acres reforested annually by 10% per year by 2020.
- *Encourage reforestation and afforestation*—Increase the number of acres converted to forestland by 300,000 acres by 2030.

Timing: Linear implementation of goal through 2030.

Parties Involved

- *Promote abandoned and mined land reforestation*—DNR, Division of Mine Permits, Division of Mine Reclamation Enforcement, Kentucky Division of Forestry, Kentucky Department of Fish and Wildlife Resources, OSM, NRCS, Kentucky Division of Conservation, Kentucky Division of Water, Appalachian Regional Reforestation Initiative (ARRI), University of Kentucky.
- *Encourage reforestation and afforestation*—Kentucky Woodland Owners Association, Kentucky Division of Forestry, Kentucky Resources Council, Division of Conservation, Kentucky Farm Bureau, Kentucky Department of Fish and Wildlife Resources, NRCS, Kentucky Tree Farm Committee, Mountain Association for Community Economic Development, Kentucky Forest Industries Association, state senators and representatives, University of Kentucky.

Other

- Clarify targets focused on reforestation (AFW-7) versus planting (AFW-6).

- Re-establish trees, at appropriate spacing, on forested land that is currently understocked. Interplant stands that are currently thinner than carrying capacity to increase biomass and diversify age classes.
- Avoid planting monocultures to minimize the risks of insects and disease, while increasing the habitat value for wildlife and overall biodiversity. Favor the planting of native trees appropriate to habitat type and local climate conditions. Consider future climate trends and plant species most able to adapt and thrive over changing conditions.

Implementation Mechanisms

- Increase the number of conservation easements, forestland tax credits legislation, and cost-share funding available for reforestation.
- Implement the Forestry Reclamation Approach (FRA) developed by scientists at the University of Kentucky and other research institutions across Appalachia.
- Encourage the active mining industry in Kentucky to implement the FRA approach on new mine sites.
- Promote restoration of forests on older or "legacy" surface mines (pre-federal law and post-federal law mine sites), such as abandoned mine land sites, bond forfeiture sites, or any post-bond release surface mines in Kentucky where reclamation took place without the benefits of proper reforestation.
- Encourage backfilling or covering of previously mined areas with acceptable rooting medium that will support trees and cover highly alkaline materials.
- Provide education on species that are most likely to survive, compatible with site conditions, and that will provide long-term erosion control.
- Carry out an inventory/assessment of candidate sites in the state that are amenable to reforestation. Create reforestation plans for these sites.

Related Policies/Programs in Place

- The FRA focuses on foresting reclaimed coal-mined land under the Surface Mining Control and Reclamation Act (http://arri.osmre.gov/FRApproach.shtm).
- ARRI is a cooperative effort by the Appalachian states and OSM to encourage restoration of high-quality forests on reclaimed coal mines in the eastern United States and to promote the FRA. (See more details at http://arri.osmre.gov/ and http://arri.osmre.gov/Partnerships/green_forest_works/gfw.htm.)
- OSM has a working group that reviews current reclamation policies and practices and provides guidance to promote woody species use and development on mined lands.
- Note that the Kentucky DNR has jurisdiction of reclaimed mined lands.

Type(s) of GHG Reductions

CO_2: Carbon sequestered in new tree growth and in forest soils.

Estimated GHG Reductions and Net Costs or Cost Savings

Table AFW-7-1. Summary of AFW-7

Quantification Factors	Post-mined Lands	Other Lands	Total AFW-7	Units
GHG Emission Reductions 2020	0.017	0.55	0.57	$MMtCO_2e$
GHG Emission Reductions 2030	0.09	0.99	1.1	$MMtCO_2e$
Net Present Value (2011–2030)	–$19	$61	$42	$ Million
Cumulative Emission Reductions (2011–2030)	0.16	11.2	11.4	$MMtCO_2e$
Cost-effectiveness (2011–2030)	–$119	$5.4	$3.7	$/tCO_2e$

$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- The number of acres of afforested post-mined land for 2008, 2009, and 2010 was obtained from Phase III bond release data, which reflect 5 years of successful revegetation.[59] The cost savings from reforesting using FRA compared to other reclamation practices was obtained from the University of Kentucky Land Reclamation Web site.[60] Estimates of carbon sequestration rates for reclaimed mine sites with different post-mining land uses were obtained from a review paper by Sperow.[61] Carbon sequestration rates as high as 2.8 t/hectare have been measured in post-mined lands reclaimed using the FRA method.[62] However, because of variation in the carbon sequestration potential of different lands, the slightly lower value of 2.5 t/hectare from the Sperow review was chosen as a more conservative estimate.
- The costs associated with establishing and managing forestland were obtained from a USFS report on private timberland conversion and management.[63] Carbon stocks for oak-pine stands in the Southeast were also obtained from the USFS.[64]

Quantification Methods: Table AFW-7-2 presents the quantification inputs for post-mined lands. The current level of reforestation of mined lands was estimated by averaging the Phase III bond release acreages for 2008, 2009, and 2010, resulting in 3,018 acres. This acreage is assumed to increase by 10% per year, and the amount over 3,018 acres is assumed to be the additional

[59] Paul Rothman, Kentucky Department for Surface Mining Reclamation and Enforcement, personal communication with Holly Lindquist, CCS, October 2010.

[60] Land Reclamation, University of Kentucky, Commonwealth Collaboratives. Available at: http://www.udy.edu/UE/CC/enviro/land.php.

[61] M. Sperow. "Carbon Sequestration Potential in Reclaimed Mine Sites in Seven East-Central States," *Journal of Environmental Quality* 35(4): 1428-1438. Available at: https://www.soils.org/publications/jeq/articles/35/4/1428.

[62] Maharaj, S., C. Barton, T. Karathanasis, H. Rowe, S. Rimmer. "Distinguishing 'New' from 'Old' Organic Carbon in Reclaimed Coal Mine Sites Using Thermogravimetry: II. Field Validation." *Soil Science* 2007, 172:302-312

[63] USFS, Regional Cost Information for Private Timberland Conversion and Management, September 2006. Available at: http://www.fs.fed.us/pnw/pubs/pnw_gtr684.pdf.

[64] Smith, J.E., et al. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States*. USFS GTE NE-343, Table B45. Available at: http://nrs.fs.fed.us/pubs/gtr/ne_gtr343.pdf.

acres converted to forest resulting from this policy. Land that is not reforested after mining use is assumed to be converted to wildlife habitat, which is required to be at least 30% forested. The per-acre increase in carbon sequestration over BAU was estimated by subtracting the estimated carbon sequestration for wildlife habitat from the estimated carbon sequestration for reforested lands. Carbon sequestration for wildlife habitat was estimated by using a weighted average of 30% forest and 70% pasture. GHG reductions and costs for reforestation on post-mined lands are summarized in Table AFW-7-3.

Table AFW-7-2. Quantification Inputs for Post-Mined Lands

Parameter	Value	Unit
Annual Reforestation of Mined Lands	3,018	acres
Cost Difference between FRA Reforestation and Other Reclamation Practices	–$2,000	$/acre
Carbon Sequestration for Reforested Lands	2.50	tC/ha
Carbon Sequestration for Wildlife Habitat	2.01	tC/ha
Incremental Carbon Sequestration	0.49	tC/ha

FRA = Forestry Reclamation Approach; tC/ha = metric tons of carbon per hectare.

Table AFW-7-3. GHG Reductions and Costs for Post-Mined Lands

Year	Additional Acres Planted This Year	Total Cumulative Acres	Total MMtC/yr	Total $MMtCO_2e/yr$	Costs (million $)	Discounted Costs (million $)
2011	302	302	0.000	0.000	–$0.60	–$0.57
2012	634	935	0.000	0.001	–$1.27	–$1.15
2013	999	1,934	0.000	0.001	–$2.00	–$1.73
2014	1,400	3,335	0.001	0.002	–$2.80	–$2.30
2015	1,842	5,177	0.001	0.004	–$3.68	–$2.89
2016	2,328	7,505	0.001	0.005	–$4.66	–$3.47
2017	2,863	10,368	0.002	0.008	–$5.73	–$4.07
2018	3,451	13,819	0.003	0.010	–$6.90	–$4.67
2019	4,098	17,917	0.004	0.013	–$8.20	–$5.28
2020	4,809	22,727	0.005	0.017	–$9.62	–$5.91
2021	5,592	28,319	0.006	0.021	–$11.18	–$6.54
2022	6,453	34,772	0.007	0.03	–$12.91	–$7.19
2023	7,400	42,172	0.008	0.03	–$14.80	–$7.85
2024	8,442	50,614	0.010	0.04	–$16.88	–$8.53
2025	9,588	60,202	0.012	0.04	–$19.18	–$9.22
2026	10,848	71,050	0.014	0.05	–$21.70	–$9.94
2027	12,235	83,285	0.017	0.06	–$24.47	–$10.68
2028	13,760	97,045	0.019	0.07	–$27.52	–$11.44
2029	15,438	112,484	0.022	0.08	–$30.88	–$12.22
2030	17,284	129,767	0.026	0.09	–$34.57	–$13.03
Total				**0.159**		**–$19**

GHG = greenhouse gas; MMtC/yr = million metric tons of carbon per year $MMtCO_2e/yr$ = million metric tons of carbon dioxide equivalent per year.

For other nonforested lands, the goal of reaching reforestation/afforestation of 300,000 acres was assumed to be implemented linearly over the 2011–2030 period. Acreages were calculated for three stand age ranges (0–5 years, 5–10 years, and 10–20 years). Carbon sequestration rates were estimated for these age ranges by calculating the average annual increase in carbon from the USFS carbon stock data for oak-pine stands in the Southeast at stand ages of 0, 5, 10, 15, and 20 years, shown in Table AFW-7-4. The carbon sequestered by each stand age range was then summed to estimate the total carbon sequestered by all acres in the program. Program costs were estimated by multiplying the total cumulative acres by per acre estimates of Conservation Reserve Program (CRP) payments to landowners ($106/acre/year) and site preparation, planting, and management costs. Also included in the annual cost estimate was the annual salary for the hiring one new forester ($70,000). GHG reductions and costs are summarized in Table AFW-7-5.

Table AFW-7-4. Quantification Inputs for Other Non-forested Lands

Parameter	Value	Unit
Acres Converted by 2030	300,000	acres
Conservation Easement Costs	$106	$/acre/year
Site Preparation Costs	$87	$2002/acre
Planting Costs	$119	$2002/acre
Management Costs	$1.92	$2002/acre
Additional Program Costs	$70,000	$/year
Stand Age: Carbon Stock		
0	20.3	tC/acre
5	25	tC/acre
10	31.4	tC/acre
15	36.5	tC/acre
20	41.6	tC/acre
Stand Age: Carbon Sequestration		
0–5	0.94	tC/acre/yr
5–10	1.28	tC/acre/yr
10–20	1.02	tC/acre/yr

tC/acre/yr = metric tons of carbon per acre per year.

Table AFW-7-5. GHG Reductions and Costs for Other Non-forested Lands

Year	Total Cumulative Acres	Acres Planted This Year	Acres Planted Before This Year (0–5 yrs old)	Acres Planted Before This Year (5–10 yrs old)	Acres Planted Before This Year (10–20 yrs old)	Total $MMtCO_2e$/yr	Costs ($)	Discounted Costs ($)
2011	0	0	0	0	0	0.00	$70,000	$66,667
2012	15,789	15,789	0	0	0	0.05	$4,922,741	$4,465,071
2013	31,579	15,789	15,789	0	0	0.11	$4,967,532	$4,291,140
2014	47,368	15,789	31,579	0	0	0.16	$5,012,322	$4,123,650
2015	63,158	15,789	47,368	0	0	0.22	$5,057,112	$3,962,380
2016	78,947	15,789	63,158	0	0	0.27	$5,101,902	$3,807,118
2017	94,737	15,789	78,947	0	0	0.33	$5,146,692	$3,657,658
2018	110,526	15,789	78,947	15,789	0	0.40	$5,191,483	$3,513,800
2019	126,316	15,789	78,947	31,579	0	0.47	$5,236,273	$3,375,348
2020	142,105	15,789	78,947	47,368	0	0.55	$5,281,063	$3,242,115
2021	157,895	15,789	78,947	63,158	0	0.62	$5,325,853	$3,113,916
2022	173,684	15,789	78,947	78,947	0	0.70	$5,370,644	$2,990,575
2023	189,474	15,789	78,947	78,947	15,789	0.76	$5,415,434	$2,871,920
2024	205,263	15,789	78,947	78,947	31,579	0.82	$5,460,224	$2,757,784
2025	221,053	15,789	78,947	78,947	47,368	0.87	$5,505,014	$2,648,006
2026	236,842	15,789	78,947	78,947	63,158	0.93	$5,549,804	$2,542,429
2027	252,632	15,789	78,947	78,947	78,947	0.99	$5,594,595	$2,440,903
2028	268,421	15,789	78,947	78,947	78,947	0.99	$5,639,385	$2,343,281
2029	284,211	15,789	78,947	78,947	78,947	0.99	$5,684,175	$2,249,421
2030	300,000	15,789	78,947	78,947	78,947	0.99	$5,728,965	$2,159,187
Total						**11.24**		**$60,622,369**

$MMtCO_2e$/yr = million metric tons of carbon dioxide equivalent per year.

Key Assumptions: Land that is not reforested after mining use is assumed to be converted to wildlife habitat, which is required to be at least 30% forested. For calculating carbon sequestration of wildlife habitat, this land use was assumed to be 70% grassland and 30% forest.[65]

Key Uncertainties

There is significant uncertainty associated with carbon sequestration rates, particularly those for mine lands. Amichev et al. found that rates of carbon capture ranged from 0.7 to 6.7 metric tons per hectare (or 1.91 to 18.2 tons per acre), depending on mine soil quality.[66]

[65] Paul Rothman, Kentucky Department for Surface Mining Reclamation and Enforcement, personal communication with Holly Lindquist, CCS, December 2010.

[66] Amichev, B., J.A Burger, and J.A. Rodrigue, "Carbon Sequestration by Forests and Soils on Mined Land in the Midwestern and Appalachian Coalfields: Preliminary Results," presented at The 25th West Virginia Surface Mine Drainage Task Force Symposium, April 18–22, 2004.

Additional Benefits and Costs

In addition to the coast savings realized by using the FRA over traditional reclamation practices, lands reclaimed to forests sell for as much as 20% higher than those reclaimed to wildlife habitat.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

AFW-8. Advanced MSW Reuse, Recycling, and Organic Waste Management Programs

Policy Description

Increase the reuse and recycling and reduce the generation of waste in order to limit GHG emissions associated with landfill methane generation and with the production of raw materials relative to recycled materials. Increase the breadth and depth of recycling programs, provide incentives for the recycling of construction materials, enhance markets for recycled materials, and increase average participation/recovery rates for all existing programs. Encourage the reduction of the biodegradable volume of waste emplaced through recycling and composting of organic wastes (e.g., lawn and garden waste, food waste, wood, and paper). Encourage the conversion of the wastes from composting, anaerobic digestion, or other technologies from residential, commercial, and government sectors through programs that reduce the generation of wastes. Reduce waste generation at the source to reduce both landfill emissions as well as upstream production emissions, and reduce the energy needs associated with handling and disposing of the wastes.

Note the linkage to AFW-9 covering landfill methane energy programs. To the extent that this policy achieves lower levels of biodegradable waste emplacement in the future, lower levels of landfill methane will be generated.

Policy Design

Goals

- Achieve a 40% recycling rate for common household recyclable materials by 2025.
- Achieve a 50% diversion rate for all MSW by 2025.

Timing: In 2008, Kentuckians recycled 34.6% of common household recyclable materials (aluminum, cardboard, steel, plastic, newspaper, glass, and paper) and 39% of all MSW, including common household recyclables and sludge, concrete, compost, and asphalt. Beginning in 2004, recyclers were required to report annually to their respective county the amount of MSW collected for recycling. This has helped the state to track the amount of materials recycled. Kentucky's PRIDE (Personal Responsibility in a Desirable Environment) Fund was amended, and in 2007, the first recycling grants were awarded to local governments to pay for the development and expansion of recycling programs and household hazardous waste management. Kentucky Recycling Interest Group (KRIG) joined KPPC in 2007 to facilitate a statewide program to enhance the recycling infrastructure in the Commonwealth. KPPC also operates the Kentucky Industrial Materials Exchange, which helps find industrial users for materials that may otherwise end up in landfills or other disposal facilities.

Parties Involved: KEEC, private waste management and recycling companies, end users and transporters of recycled materials, KRIG, counties and other local units of government, environmental groups and citizens of the Commonwealth, Kentucky Recycling and Marketing Assistance (KRMA) Program, Area Development Districts (ADDs).

Other: None.

Implementation Mechanisms

- Continue education efforts across the Commonwealth, focusing on reducing the waste generated, reusing materials to the extent possible, and recycling as much of the waste generated as possible.
- Include the goal of achieving a 40% recycling rate by 2025 in legislation in order to increase its chances of being met.
- Continue working with local governments to make sure they are aware of the availability of grant funds to support recycling efforts in their communities.
- Continue the support, development, and expansion of markets for all recycled materials, as is currently the mission of the KRMA Program.
- Encourage efforts by cities and county governments to develop infrastructure for recycling.
- Encourage efforts by local governments and ADDs to develop cooperative agreements with other local governments in their areas for the purposes of developing regional recycling centers.
- Encourage efforts by private industry and local governments to begin programs to remove biodegradable wastes from the waste stream. This includes the use of digesters, and composting and reusing yard wastes, wastewater sludge (as long as it is done safely), and animal wastes.
- Consider a landfill disposal ban for electronic scrap (e-scrap) and other waste materials that present potential environmental harm if there are acceptable reuse and recycling alternatives, so that the ban would not result in an unacceptable increase in illegal discharge.
- Consider deposit systems or their equivalent for high-risk or large-volume products, only if they would create an efficient, effective, and equitable collection and utilization infrastructure.
- Develop and implement an effective and efficient data collection system for measuring solid waste generation, reduction, utilization, and disposal. The system should measure and track trends on the magnitude and percentage of solid waste generated, reduced, utilized, and disposed of. To get the most accurate recycling tonnage numbers, recycling organizations, both commercial and government-operated, should register and report directly to KEEC. A fee should be imposed to help cover the costs of inspecting and managing the data. The fee should be based on a tonnage-processed sliding scale.

Related Policies/Programs in Place

Local governments across the state have various levels of financial resources and infrastructure available for recycling programs. In many rural communities, curbside recycling is not available. Recycling grants are available to counties and cities through the Kentucky PRIDE Fund, which is administered by KEEC. In 2002, House Bill 174, the legislation creating PRIDE, was passed, which established an environmental remediation fee of $1.75 per ton on solid waste disposed of in Kentucky. In 2006, Senate Bill 50 amended the statute to provide grant funds for recycling and household hazardous waste. The PRIDE Fund currently generates approximately $10.8 million per year, of which $5 million can be used for open-dump cleanups, recycling, and household hazardous waste grants. In addition to the programs identified previously, Kentucky has a Waste Tire Trust Fund, administered by KEEC, which provides funding for “waste tire amnesties” to address waste tires found and to help in development of recycling and end-use markets for waste tires in the state. KEEC also issues crumb rubber grants to schools and communities yearly from monies provided by the Waste Tire Trust Fund. Kentucky’s state paper recycling program, which serves more than 115 state agencies in Frankfort, offers free pickup and free document destruction of governmental office paper.

Type(s) of GHG Reductions

- Avoided emission of CH_4 at MSW landfills due to a reduction in the total amount of waste deposited at landfills.
- Avoided emission of CO_2 and associated GHGs from the reduction of the amount of virgin materials and energy consumption necessary for the production of products and packaging, as the total mass produced of these items would be reduced. The EPA WAste Reduction Model (WARM) used to estimate these reductions accounts for the origin of carbon sequestered in raw materials.[67] Therefore, CO_2 emissions from the combustion or decomposition of biogenic waste are not counted toward the total emissions. CH_4 and N_2O emissions due to landfilling or combustion of biogenic waste, as well as avoided future CO_2 sequestration, are counted toward the net fuel-cycle emissions of each waste management practice.
- Avoided emission of CO_2 and associated GHGs due to reduced amount of material transported.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources

- GHG emission reductions were estimated using WARM.[68]
- The inputs for the model were based on updated waste management data provided by the Kentucky Division of Waste Management (KY DWM).[69]

[67] “WAste Reduction Model (WARM).” November 2009. Available at: http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html. EPA created WARM to help solid waste planners and organizations track and voluntarily report GHG emission reductions from several different waste management practices. WARM is available both as a Web-based calculator and as a Microsoft Excel spreadsheet. WARM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in tCe, tCO_2e, and energy units (MMBtu) across a wide range of material types commonly found in MSW. For an explanation of the methodology, see the EPA report *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*, EPA530-R-02-006. Available at: http://epa.gov/climatechange/wycd/waste/SWMGHGreport.html.

[68] Ibid.

[69] Personal communication from T. Hubbard and G. Gilbert (DWM) via e-mail on October 4, 2010. Personal communication from G. Gilbert via telephone on October 20, 2010. The information provided by DWM updated the data used to develop the KY Waste I&F. Specifically, it was brought to light that the waste identified as “MSW” in the DWM Annual Reports includes non-household waste, such as construction and demolition debris, which is mostly inert (does not produce landfill gas emissions). The updated information provided by DWM allowed CCS to break out household waste from non-household waste.

- Cost parameters were either provided by KY DWM or defaults used by the Center for Climate Strategies (CCS) in other state processes.

Quantification Methods

Table AFW-8-1. Summary of AFW-8

Quantification Factors	2020	2030	Units
GHG Emission Reductions	0.84	1.29	$MMtCO_2e$
Net Present Value (2011–2030)		$167	$ Million
Cumulative Emission Reductions (2011–2030)		16.4	$MMtCO_2e$
Cost-Effectiveness (2011–2030)		$10.1	$/tCO_2e$

$/tCO₂e = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; MMtCO₂e = million metric tons of carbon dioxide equivalent.

Tables AFW-8-2, AFW-8-3, AFW-8-4, and AFW-8-5 display the results of the GHG emissions reduction and cost-effectiveness quantitative analyses for recycling and composting. Table AFW-8-6 displays the 2010–2030 summary results for all elements of AFW-8. The parameters and methods for determining cost-effectiveness for recycling and composting are different enough to warrant separate summary tables, although these two waste management strategies are usually grouped together under the single term "diversion." Following these tables is more detailed documentation of the assumptions, parameters, and calculations used to generate the estimated GHG emission reductions and net cost of additional waste diversion activities in Kentucky. The cumulative GHG reduction for 2010–2030 is 16.4 $MMtCO_2e$, and the cost-effectiveness is $10/$tCO_2e$.

Tables AFW-8-2, AFW-8-3, AFW-8-4, and AFW-8-5 display the results of the GHG emission reduction and cost-effective analyses for the lifetime of projects directly related to AFW-8—meaning that a project that begins in 2030, which is assumed to have a 15-year lifespan, will produce GHG reductions through 2044. However, only GHG reductions and net costs through 2030 for AFW-8 are counted in the summary table at the beginning of this appendix, in order to maintain consistency with other mitigation options.

Table AFW-8-2. GHG Reduction Analysis and Results—Recycling

Year	Household Waste Recycled (short tons)	Non-household Waste Recycled (short tons)	Avoided In-State Landfill Disposal (short tons)	Avoided Export Landfill Disposal (short tons)	Household Waste Recycling GHG Reductions ($MMtCO_2e$)	Non-household Waste Recycling GHG Reductions ($MMtCO_2e$)
2010	0	0	0	0	0.00	0.00
2011	12,636	46,016	54,725	3,927	0.04	0.04
2012	25,272	92,033	109,450	7,855	0.08	0.08
2013	37,908	138,049	164,175	11,782	0.12	0.12
2014	50,544	184,065	218,900	15,709	0.16	0.17
2015	63,179	230,082	273,625	19,636	0.20	0.21
2016	76,544	276,475	329,382	23,638	0.24	0.25
2017	89,909	322,867	385,138	27,639	0.28	0.29
2018	103,274	369,260	440,894	31,640	0.32	0.33
2019	116,639	415,653	496,651	35,641	0.36	0.38
2020	130,004	462,046	552,407	39,643	0.40	0.42
2021	143,824	508,674	608,808	43,690	0.44	0.46
2022	157,645	555,301	665,208	47,738	0.49	0.50
2023	171,465	601,929	721,609	51,785	0.53	0.54
2024	185,285	648,557	778,010	55,833	0.57	0.59
2025	199,105	695,185	834,410	59,880	0.61	0.63
2026	199,685	697,208	836,839	60,054	0.62	0.63
2027	200,264	699,232	839,267	60,229	0.62	0.63
2028	200,844	701,255	841,696	60,403	0.62	0.63
2029	201,423	703,278	844,124	60,577	0.62	0.64
2030	202,003	705,302	846,553	60,752	0.62	0.64
2031	188,638	658,909	790,797	56,750	0.58	0.60
2032	175,273	612,516	735,040	52,749	0.54	0.55
2033	161,908	566,123	679,284	48,748	0.50	0.51
2034	148,543	519,731	623,527	44,746	0.46	0.47
2035	135,178	473,338	567,771	40,745	0.42	0.43
2036	121,358	426,710	511,370	36,698	0.37	0.39
2037	107,538	380,082	454,970	32,650	0.33	0.34
2038	93,717	333,454	398,569	28,603	0.29	0.30
2039	79,897	286,826	342,168	24,555	0.25	0.26
2040	66,077	240,199	285,768	20,508	0.20	0.22
2041	52,862	192,159	228,614	16,406	0.16	0.17
2042	39,646	144,119	171,461	12,305	0.12	0.13
2043	26,431	96,079	114,307	8,203	0.08	0.09
2044	13,215	48,040	57,154	4,102	0.04	0.04
Total					**11.9**	**12.2**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table AFW-8-3. GHG Reduction Analysis and Results—Composting

Year	Tons Composted (short tons)	Avoided In-State Landfill Disposal (short tons)	Avoided Export Landfill Disposal (short tons)	Composting GHG Reductions ($MMtCO_2e$)
2010	0	0	0	0.00
2011	19,320	17,996	1,233	0.002
2012	38,639	35,993	2,465	0.003
2013	57,959	53,989	3,698	0.005
2014	77,278	71,986	4,930	0.007
2015	96,598	89,982	6,163	0.008
2016	116,076	108,126	7,406	0.010
2017	135,553	126,269	8,648	0.012
2018	155,031	144,413	9,891	0.013
2019	174,509	162,556	11,134	0.015
2020	193,986	180,700	12,376	0.017
2021	213,563	198,936	13,625	0.019
2022	233,139	217,171	14,874	0.020
2023	252,715	235,407	16,123	0.022
2024	272,292	253,642	17,372	0.024
2025	291,868	271,878	18,621	0.025
2026	292,717	272,669	18,675	0.025
2027	293,567	273,460	18,729	0.026
2028	294,416	274,252	18,784	0.026
2029	295,266	275,043	18,838	0.026
2030	296,115	275,834	18,892	0.026
2031	276,638	257,691	17,649	0.024
2032	257,160	239,547	16,407	0.022
2033	237,682	221,403	15,164	0.021
2034	218,205	203,260	13,921	0.019
2035	198,727	185,116	12,679	0.017
2036	179,151	166,881	11,430	0.016
2037	159,574	148,645	10,181	0.014
2038	139,998	130,410	8,932	0.012
2039	120,422	112,174	7,683	0.010
2040	100,845	93,938	6,434	0.009
2041	80,676	75,151	5,147	0.007
2042	60,507	56,363	3,860	0.005
2043	40,338	37,575	2,574	0.004
2044	20,169	18,788	1,287	0.002
Total				**0.51**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table AFW-8-4. Cost-Effectiveness Analysis and Results—Recycling

Year	Annual O&M Costs ($MM)	Annual Capital Costs ($MM)	Annual Collection Costs ($MM)	Avoided Landfill Tipping Fees ($MM)	Avoided Transport Costs ($MM)	Annual Recycled Material Revenue ($MM)	Net Policy Costs (Recycling) ($MM)	Discounted Recycling Costs ($MM)
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2011	$2.35	$0.77	$0.10	$2.12	$0.01	$0.38	$0.71	$0.68
2012	$4.69	$1.54	$0.20	$4.23	$0.02	$0.76	$1.42	$1.29
2013	$7.04	$2.31	$0.30	$6.35	$0.04	$1.14	$2.13	$1.84
2014	$9.38	$3.08	$0.41	$8.46	$0.05	$1.52	$2.84	$2.33
2015	$11.7	$3.85	$0.51	$10.6	$0.06	$1.91	$3.55	$2.78
2016	$14.1	$4.62	$0.61	$12.7	$0.07	$2.29	$4.26	$3.18
2017	$16.5	$5.40	$0.72	$14.9	$0.08	$2.68	$4.97	$3.53
2018	$18.9	$6.17	$0.83	$17.0	$0.09	$3.07	$5.68	$3.85
2019	$21.3	$6.94	$0.94	$19.2	$0.11	$3.46	$6.39	$4.12
2020	$23.7	$7.71	$1.04	$21.4	$0.12	$3.85	$7.11	$4.36
2021	$26.1	$8.48	$1.15	$23.5	$0.13	$4.24	$7.82	$4.57
2022	$28.5	$9.25	$1.27	$25.7	$0.14	$4.63	$8.53	$4.75
2023	$30.9	$10.0	$1.38	$27.9	$0.16	$5.03	$9.25	$4.90
2024	$33.4	$10.8	$1.49	$30.1	$0.17	$5.42	$9.96	$5.03
2025	$35.8	$12.3	$1.60	$32.3	$0.18	$5.81	$11.4	$5.51
2026	$35.9	$11.6	$1.60	$32.4	$0.18	$5.83	$10.7	$4.89
2027	$36.0	$10.8	$1.61	$32.4	$0.18	$5.85	$9.90	$4.32
2028	$36.1	$10.8	$1.61	$32.5	$0.18	$5.86	$9.90	$4.11
2029	$36.2	$10.0	$1.62	$32.6	$0.18	$5.88	$9.12	$3.61
2030	$36.3	$9.25	$1.62	$32.7	$0.18	$5.90	$8.35	$3.15
2031	$33.9	$8.48	$1.51	$30.6	$0.17	$5.51	$7.64	$2.74
2032	$31.5	$7.71	$1.41	$28.4	$0.16	$5.12	$6.93	$2.37
2033	$29.1	$6.94	$1.30	$26.3	$0.15	$4.73	$6.21	$2.02
2034	$26.7	$6.17	$1.19	$24.1	$0.13	$4.34	$5.50	$1.71
2035	$24.3	$5.40	$1.08	$22.0	$0.12	$3.96	$4.79	$1.41
2036	$21.9	$4.62	$0.97	$19.8	$0.11	$3.56	$4.08	$1.15
2037	$19.5	$3.85	$0.86	$17.6	$0.10	$3.17	$3.36	$0.90
2038	$17.1	$3.08	$0.75	$15.4	$0.09	$2.78	$2.65	$0.68
2039	$14.7	$2.31	$0.64	$13.2	$0.07	$2.38	$1.94	$0.47
2040	$12.3	$0.77	$0.53	$11.0	$0.06	$1.99	$0.45	$0.10
2041	$9.80	$0.77	$0.42	$8.84	$0.05	$1.59	$0.51	$0.11
2042	$7.35	$0.77	$0.32	$6.63	$0.04	$1.19	$0.58	$0.12
2043	$4.90	$0.00	$0.21	$4.42	$0.02	$0.80	–$0.13	–$0.03
2044	$2.45	$0.00	$0.11	$2.21	$0.01	$0.40	–$0.06	–$0.01
Total							**$178**	**$86**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table AFW-8-5. Cost-Effectiveness Analysis and Results—Composting

Year	Annual O&M Costs ($MM)	Annual Capital Costs ($MM)	Annual Collection Costs ($MM)	Avoided Landfill Tipping Fees ($MM)	Avoided Transport Costs ($MM)	Value of Composted Material ($MM)	Total Annual Composting Costs ($MM)	Discounted Composting Costs ($MM)
2010	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
2011	$0.58	$0.77	$0.16	–$0.08	$0.00	$0.21	$1.37	$1.31
2012	$1.16	$0.77	$0.31	–$0.16	$0.01	$0.43	$1.97	$1.79
2013	$1.74	$0.77	$0.47	–$0.24	$0.01	$0.64	$2.57	$2.22
2014	$2.32	$1.54	$0.62	–$0.32	$0.01	$0.85	$3.94	$3.24
2015	$2.90	$1.54	$0.78	–$0.40	$0.02	$1.06	$4.54	$3.56
2016	$3.48	$1.54	$0.93	–$0.49	$0.02	$1.28	$5.14	$3.84
2017	$4.07	$2.31	$1.09	–$0.57	$0.02	$1.49	$6.52	$4.63
2018	$4.65	$2.31	$1.24	–$0.65	$0.03	$1.71	$7.12	$4.82
2019	$5.24	$2.31	$1.40	–$0.73	$0.03	$1.92	$7.73	$4.98
2020	$5.82	$3.08	$1.56	–$0.81	$0.03	$2.13	$9.10	$5.59
2021	$6.41	$3.08	$1.71	–$0.89	$0.04	$2.35	$9.71	$5.68
2022	$6.99	$3.08	$1.87	–$0.97	$0.04	$2.56	$10.3	$5.75
2023	$7.58	$3.85	$2.03	–$1.06	$0.04	$2.78	$11.7	$6.20
2024	$8.17	$3.85	$2.19	–$1.14	$0.05	$3.00	$12.3	$6.21
2025	$8.76	$4.62	$2.34	–$1.22	$0.05	$3.21	$13.7	$6.58
2026	$8.78	$3.85	$2.35	–$1.22	$0.05	$3.22	$12.9	$5.93
2027	$8.81	$3.85	$2.36	–$1.23	$0.05	$3.23	$13.0	$5.66
2028	$8.83	$4.62	$2.36	–$1.23	$0.05	$3.24	$13.8	$5.72
2029	$8.86	$3.85	$2.37	–$1.23	$0.05	$3.25	$13.0	$5.15
2030	$8.88	$3.85	$2.38	–$1.24	$0.05	$3.26	$13.0	$4.92
2031	$8.30	$3.85	$2.22	–$1.16	$0.05	$3.04	$12.4	$4.46
2032	$7.71	$3.08	$2.06	–$1.08	$0.04	$2.83	$11.1	$3.78
2033	$7.13	$3.08	$1.91	–$0.99	$0.04	$2.61	$10.5	$3.41
2034	$6.55	$3.08	$1.75	–$0.91	$0.04	$2.40	$9.85	$3.06
2035	$5.96	$2.31	$1.59	–$0.83	$0.03	$2.19	$8.48	$2.50
2036	$5.37	$2.31	$1.44	–$0.75	$0.03	$1.97	$7.87	$2.21
2037	$4.79	$2.31	$1.28	–$0.67	$0.03	$1.76	$7.26	$1.95
2038	$4.20	$1.54	$1.12	–$0.59	$0.02	$1.54	$5.89	$1.50
2039	$3.61	$1.54	$0.97	–$0.50	$0.02	$1.32	$5.28	$1.28
2040	$3.03	$0.77	$0.81	–$0.42	$0.02	$1.11	$3.90	$0.90
2041	$2.42	$0.77	$0.65	–$0.34	$0.01	$0.89	$3.27	$0.72
2042	$1.82	$0.77	$0.49	–$0.25	$0.01	$0.67	$2.65	$0.56
2043	$1.21	$0.00	$0.32	–$0.17	$0.01	$0.44	$1.25	$0.25
2044	$0.61	$0.00	$0.16	–$0.08	$0.00	$0.22	$0.63	$0.12
Total							**$264**	**$120**

$MM = million dollars; O&M = operations and maintenance.

Table AFW-8-6. Summary Table for AFW-8 GHG Reduction and Cost-Effectiveness

Year	GHG Emission Reductions ($MMtCO_2e$)	Net Program Cost Recycling ($MM)	Net Program Cost Composting ($MM)	Total Net Program Cost ($MM)	Discounted Cost ($MM)
2010	0.00	$0.00	$0.00	$0.00	$0.00
2011	0.08	$0.71	$1.37	$2.08	$1.98
2012	0.16	$1.42	$1.97	$3.39	$3.07
2013	0.25	$2.13	$2.57	$4.70	$4.06
2014	0.33	$2.84	$3.94	$6.78	$5.58
2015	0.41	$3.55	$4.54	$8.09	$6.34
2016	0.50	$4.26	$5.14	$9.40	$7.02
2017	0.58	$4.97	$6.52	$11.5	$8.17
2018	0.67	$5.68	$7.12	$12.8	$8.67
2019	0.75	$6.39	$7.73	$14.1	$9.10
2020	0.84	$7.11	$9.10	$16.2	$10.0
2021	0.92	$7.82	$9.71	$17.5	$10.3
2022	1.01	$8.53	$10.3	$18.9	$10.5
2023	1.10	$9.25	$11.7	$20.9	$11.1
2024	1.18	$9.96	$12.3	$22.3	$11.2
2025	1.27	$11.4	$13.7	$25.1	$12.1
2026	1.27	$10.7	$12.9	$23.6	$10.8
2027	1.28	$9.9	$13.0	$22.9	$10.0
2028	1.28	$9.9	$13.8	$23.7	$9.83
2029	1.28	$9.1	$13.0	$22.1	$8.76
2030	1.29	$8.4	$13.0	$21.4	$8.06
Total	**16.4**	**$134**	**$173**	**$307**	**$167**

$MM = million dollars; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Solid Waste Historical and Projected Management Profile

The basis for the MSW management profile was the 2010 *Kentucky Division of Waste Management Annual Report*, as well as input directly from KY DWM.[70] These data present the amounts of waste landfilled, imported, exported, and recycled in Kentucky during 1994–2009. The state data summaries provided the quantity of waste composted.[71] The amount of waste combusted at waste-to-energy (WTE) facilities was reported directly by DWM.[72] Note that food waste composting data were not available. The composting totals represent yard waste only.

[70] Kentucky Department of Environmental Protection (KY DEP). 2010. "Kentucky Division of Waste Management Annual Report." Available at: http://waste.ky.gov/Annual%20Reports/DWM%20Annual%20Report%20for%202010.pdf.

[71] KY DEP. "State Data Report." Available for 2004–2007 at: http://www.waste.ky.gov/branches/rla/Statewide+Solid+Waste+Management+Report.htm.

[72] Personal communication from G. Gilbert via telephone on October 20, 2010.

MSW generation is defined as the sum of MSW landfill disposal, MSW combustion, and MSW recovery. MSW combustion includes combustion at WTE facilities, combustion of commercial and institutional waste without energy recovery, and open burning of residential waste. Recovery includes recycling and composting.

The MSW generation totals presented in the KY DWM Waste Management Annual Report do not include combustion. Therefore, the recycling percentages calculated in this appendix will not match those from the KY DWM report. KY DWM states that the 2005 MSW recycling rate in Kentucky was 23.4%, compared to the national 2005 MSW recycling rate of 30.0%.

The amount of waste generated was back-cast for each year between 1990 and 1994 by applying the calculated 1994 per-capita MSW generation rate (based on U.S. Census Bureau population data) to the population in Kentucky for 1990 through 1993. The MSW generation was forecast through 2030 by applying the 2009 per-capita generation rate of 1.51 tons/person/year by the projected population in each year. The amounts of waste recycled, composted, landfilled, and combusted were estimated in the back-cast years by maintaining the ratios of waste managed through these methods for the periods 1990–1993 and 2009–2030. A subset of the data and projections is presented in Table AFW-8-7, the BAU waste management profile.

Typically, MSW includes only residential and commercial waste that would be accepted at most non-hazardous waste disposal facilities. However, the "MSW" figures reported in the KY DWM annual reports include non-household waste, such as construction and demolition (C&D) debris and sewage sludge used for daily cover.[73] In direct communication with CCS, KY DWM suggested that CCS utilize the U.S. average per-person household waste generation rate of 4.5 lbs/person/day to estimate household waste generation in Kentucky. The BAU household waste management projection is displayed in Table AFW-8-8. The remaining tons of waste from the overall waste management profile that are not included in the household waste management forecast are assumed to be non-household waste. The BAU non-household waste forecast is shown in Table AFW-8-9.

[73] Per the Policy Design section of AFW-8 completed by the AFW TWG, the assumed household waste materials include aluminum, cardboard, steel, plastic, newspaper, glass, and paper. Compostable organics are assumed to be excluded from household waste. It is assumed that only household waste is combusted.

Table AFW-8-7. Kentucky BAU Waste Management Profile— Historical and Projected (short tons)

Parameter	1990	1995	2000	2005	2010	2015	2020	2025	2030
Waste Generated	3,809,352	5,026,109	4,914,019	6,311,200	6,454,462	6,584,715	6,695,554	6,794,269	6,893,143
KY Population	3,686,892	3,887,427	4,041,769	4,165,958	4,265,117	4,351,188	4,424,431	4,489,662	4,554,998
Generation per Capita	1.03	1.29	1.22	1.51	1.51	1.51	1.51	1.51	1.51
Total Waste Landfilled in KY	3,655,128	4,476,904	4,375,652	5,157,185	4,897,611	4,644,158	4,713,130	4,774,557	4,836,083
Waste Imported (Landfilled)	183,786	269,833	515,136	663,686	851,175	807,126	819,113	829,789	840,482
Waste Exported (Landfilled)	125,549	210,728	202,029	191,923	304,476	260,427	272,414	283,090	293,783
KY-Generated Waste Landfilled	3,596,891	4,417,799	4,062,545	4,685,422	4,350,912	4,097,459	4,166,431	4,227,858	4,289,384
Waste Combusted (Waste to Energy)	2,606	3,201	2,944	3,395	3,153	2,969	3,019	3,063	3,108
Waste Diverted	209,855	605,108	848,530	1,622,383	2,100,397	2,142,784	2,178,853	2,210,976	2,243,152
Waste Recycled	183,607	529,423	742,398	1,429,490	1,837,685	1,874,770	1,906,327	1,934,433	1,962,584
Waste Composted	26,248	75,685	106,132	192,893	262,712	268,014	272,525	276,543	280,568

BAU = business as usual; KY = Kentucky.

Table AFW-8-8. Kentucky BAU Household Waste BAU Forecast (short tons)

Parameter	2010	2015	2020	2025	2030
Household Waste Generated	3,502,727	3,573,413	3,633,564	3,687,135	3,740,792
Household Waste Exported (Landfilled)	160,088	148,348	155,176	161,257	167,348
Kentucky Household Waste Landfilled	2,127,543	2,185,695	2,218,156	2,247,066	2,276,022
Household Waste Combusted (Waste to Energy)	3,153	2,969	3,019	3,063	3,108
Household Waste Recycled	1,211,944	1,236,401	1,257,213	1,275,749	1,294,314

BAU = business as usual.

Table AFW-8-9. Kentucky BAU Non-household Waste BAU Forecast (short tons)

Parameter	2010	2015	2020	2025	2030
Non-household Waste Generated	2,951,735	3,011,302	3,061,990	3,107,134	3,152,351
Non-household Waste Exported (Landfilled)	144,388	133,785	139,943	145,427	150,920
Kentucky Non-household Waste Landfilled	1,918,893	1,971,134	2,000,408	2,026,480	2,052,593
Non-household Waste Recycled	625,741	638,369	649,114	658,684	668,270
Non-household Waste Composted	262,712	268,014	272,525	276,543	280,568

BAU = business as usual.

The AFW TWG goals to divert 40% of household waste and 50% of all waste by 2025 were applied to the BAU forecasts described in the previous three tables. The amount of non-household waste diverted under the policy scenario is found by multiplying total generation in Kentucky in 2025 by 50%, then subtracting the amount of household waste diverted in 2025 (40% multiplied by the household waste generated in 2025). Note that non-household waste includes composting, as well as recycling. The ratio of recycling to composting is held constant throughout the policy scenario. The annual total waste diversion for both household and non-household waste is assumed to annually ramp-up from the 2010 baseline through full implementation of the targets in 2025. The annual projected household and non-household waste management profiles for the policy scenario are displayed in Tables AFW-8-10 and AFW-8-11. Table AFW-8-12 displays the forecast incremental recycling and composting that results from the implementation of the AFW-8 targets.

Table AFW-8-10. Kentucky Policy Household Waste BAU Forecast (short tons)

Parameter	2010	2015	2020	2025	2030
Household Waste Generated	3,502,727	3,573,413	3,633,564	3,687,135	3,740,792
Household Waste Exported (Landfilled)	160,088	144,332	146,676	147,925	153,513
Kentucky Household Waste Landfilled	2,127,543	2,126,532	2,096,652	2,061,292	2,087,854
Household Waste Combusted (Waste to Energy)	3,153	2,969	3,019	3,063	3,108
Household Waste Recycled	1,211,944	1,299,580	1,387,217	1,474,854	1,496,317

Table AFW-8-11. Kentucky Policy Non-household Waste BAU Forecast (short tons)

Parameter	2010	2015	2020	2025	2030
Non-household Waste Generated	2,951,735	3,011,302	3,061,990	3,107,134	3,152,351
Non-household Waste Exported (Landfilled)	144,388	133,785	139,943	145,427	150,920
Kentucky Non-Household Waste Landfilled	1,918,893	1,971,134	2,000,408	2,026,480	2,052,593
Non-household Waste Recycled	625,741	638,369	649,114	658,684	668,270
Non-household Waste Composted	262,712	268,014	272,525	276,543	280,568

Table AFW-8-12. Incremental Waste Diversion (short tons)

Parameter	2010	2015	2020	2025	2030
Household Waste Recycled	0	63,179	130,004	199,105	202,003
Non-household Waste Recycled	0	230,082	462,046	695,185	705,302
Non-household Waste Composted	0	96,598	193,986	291,868	296,115

The direct GHG emission reduction estimates that are based on the preceding BAU and Policy scenarios do not capture the embedded energy in landfilled waste that could have been recycled. Many waste materials—especially metals, plastics, and concrete—represent a large potential for life-cycle GHG reductions as a result of the emissions from raw materials extraction and new product manufacturing that are avoided when waste is recycled, rather than landfilled. Based on its extensive experience working with international and U.S. state and regional organizations striving to adapt to and mitigate the effects of climate change, CCS estimates that approximately 10% of estimated GHG reductions from additional recycling efforts is attributed to direct reductions in methane at landfills, while the remainder of the GHG reductions is based on a reduction in life-cycle emissions. Composting also reduces life-cycle GHG emissions from waste management, as the finished compost product may be applied to crop fields, gardens, and landscape construction sites to increase soil carbon and moisture retention, and reduce the need for fossil fuel-derived nitrogen fertilizers.

Solid Waste Characterization Forecast

The BAU and policy scenario characterization for household waste is based on an EPA MSW characterization report.[74] The disposed waste was divided between disposal at landfills and combustion at WTE facilities according to the proportion of each management method to total waste disposal. Table AFW-8-13 displays the source characterization data used to develop the projected household waste characterization. Table AFW-8-14 displays the projected BAU household waste management scenario in 2030, while Table AFW-8-15 displays the projected policy household waste management scenario in 2030. These tables were used as input for WARM to determine the GHG reductions resulting from increased diversion of household waste.

Table AFW-8-13. Baseline Household Waste Characterization Assumptions

WARM Category	Percent of Generation	Percent of Diversion
Aluminum Cans	0.74%	1.18%
Steel Cans	1.17%	2.51%
Glass	6.18%	4.86%
HDPE	2.72%	0.98%
LDPE	2.99%	0.57%
PET	1.90%	1.26%
Corrugated Cardboard	15.1%	39.3%
Magazines/Third-Class Mail	3.84%	5.29%
Newspaper	4.48%	13.4%
Office Paper	3.08%	7.41%
Phonebooks	0.43%	0.69%
Textbooks	0.68%	0.31%
Mixed Paper (general)	11.8%	7.81%
Mixed Metals	8.69%	8.80%
Mixed Plastics	7.67%	0.85%
Mixed Recyclables	26.6%	4.80%
Mixed MSW	1.92%	0.00%
Total	**100%**	**100%**

HDPE = high-density polyethylene; LDPE = low-density polyethylene; MSW = municipal solid waste; PET = polyethylene terephthalate.

[74] Municipal Solid Waste (MSW) in the United States: 2008 Facts and Figures. Data Tables available at: http://www.epa.gov/osw/nonhaz/municipal/msw99.htm.

Table AFW-8-14. WARM Input—BAU Household Waste Management Scenario Characterization: 2030 (short tons)

WARM Category	Tons Generated	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	27,774	15,209	12,549	16	N/A
Steel Cans	43,944	32,431	11,499	15	N/A
Copper Wire					N/A
Glass	231,135	62,848	168,073	214	N/A
HDPE	101,776	12,749	88,914	113	N/A
LDPE	111,858	7,381	104,344	133	N/A
PET	71,148	16,327	54,751	70	N/A
Corrugated Cardboard	565,187	508,668	56,447	72	N/A
Magazines/Third-Class Mail	143,817	68,440	75,282	96	N/A
Newspaper	167,406	150,666	16,719	21	N/A
Office Paper	115,092	95,950	19,118	24	N/A
Phonebooks	15,980	8,946	7,024	9	N/A
Textbooks	25,491	4,026	21,438	27	N/A
Dimensional Lumber					N/A
Medium-density Fiberboard					N/A
Food Scraps		N/A			35,360
Yard Trimmings		N/A			646,454
Grass		N/A			
Leaves		N/A			
Branches		N/A			
Mixed Paper (general)	439,632	101,094	338,108	430	N/A
Mixed Paper (primarily residential)					N/A
Mixed Paper (primarily from offices)					N/A
Mixed Metals	324,921	113,842	210,810	268	N/A
Mixed Plastics	286,874	10,959	275,564	351	N/A
Mixed Recyclables	996,848	84,779	910,911	1,159	N/A
Mixed Organics		N/A			
Mixed MSW	71,909	N/A	71,817	91	N/A
Carpet					N/A
Personal Computers					N/A
Clay Bricks		N/A		N/A	N/A
Concrete				N/A	N/A
Fly Ash				N/A	N/A
Tires					N/A
Total	**3,740,792**	**1,294,314**	**2,443,370**	**3,108**	

BAU = business as usual; HDPE = high-density polyethylene; LDPE = low-density polyethylene; MSW = municipal solid waste; N/A = not available; PET = polyethylene terephthalate; WARM = WAste Reduction Model.

Table AFW-8-15. WARM Input—Policy Waste Management Scenario Characterization: 2030 (short tons)

WARM Category	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted
Aluminum Cans	17,582	10,176	16	N/A
Steel Cans	37,492	6,438	15	N/A
Copper Wire				N/A
Glass	72,657	158,264	214	N/A
HDPE	14,738	86,924	113	N/A
LDPE	8,533	103,193	133	N/A
PET	18,875	52,203	70	N/A
Corrugated Cardboard	508,668	56,447	72	N/A
Magazines/Third-Class Mail	79,121	64,601	96	N/A
Newspaper	150,666	16,719	21	N/A
Office Paper	103,583	11,485	24	N/A
Phonebooks	10,343	5,628	9	N/A
Textbooks	4,654	20,810	27	N/A
Dimensional Lumber				N/A
Medium-density Fiberboard				N/A
Food Scraps	N/A			35,360
Yard Trimmings	N/A			646,454
Grass	N/A			
Leaves	N/A			
Branches	N/A			
Mixed Paper (general)	116,871	322,331	430	N/A
Mixed Paper (primarily residential)				N/A
Mixed Paper (primarily from offices)				N/A
Mixed Metals	131,610	193,043	268	N/A
Mixed Plastics	12,670	273,854	351	N/A
Mixed Recyclables	208,254	787,436	1,159	N/A
Mixed Organics	N/A			
Mixed MSW	N/A	71,817	91	N/A
Carpet				N/A
Personal Computers				N/A
Clay Bricks	N/A		N/A	N/A
Concrete			N/A	N/A
Fly Ash			N/A	N/A
Tires				N/A
Total	**1,496,317**	**2,241,367**	**3,108**	

HDPE = high-density polyethylene; LDPE = low-density polyethylene; MSW = municipal solid waste; N/A = not available; PET = polyethylene terephthalate; WARM = WAste Reduction Model.

The non-household waste characterization is based upon three sources: the aforementioned EPA MSW Characterization report for compostable organics (yard and food waste), a data appendix from the North East Biosolids and Residuals Association (NEBRA) for the sewage sludge totals,[75] and an EPA 2003 C&D waste characterization report for all other non-household waste.[76]

For the BAU non-household waste characterization, it is assumed that all composted materials are yard waste. This assumption is consistent with Kentucky Division of Waste Management (DWM) county-level waste management data from 2007.[77] For the policy non-household waste characterization, the amount of material composted is broken down between food and yard waste according to the EPA MSW Characterization report.[78]

WARM does not provide GHG reduction estimates for sewage sludge. Therefore, as a simplifying assumption, there is no assumed incremental change between the BAU and policy scenario characterization for sewage sludge. The sewage sludge disposal and beneficial use (recycled as agricultural soil amendment) totals are adjusted to 2030 based on the percentage of total generation from the data year in the NEBRA report (2004).

Table AFW-8-16 displays the C&D waste characterization. The amount of C&D recycled is the difference between the projected non-household waste recycled for each scenario and the sewage sludge "recycled." The proportion of total recycling for each C&D material is equal to its proportional contribution to total generation. Clay bricks are not a valid recycling input for WARM. Therefore, it is assumed that all clay bricks are disposed of at landfills.

Table AFW-8-16. Characterization of C&D Debris

Material	Percent of Generation (by mass)
Concrete	45%
Wood	25%
Drywall	10%
Asphalt	5%
Metals	5%
Bricks	5%
Plastics	5%

C&D = construction and demolition.

Tables AFW-8-17 and AFW-8-18 display the 2030 characterization BAU and policy scenario projections for non-household waste, respectively. These characterizations were used as inputs for

[75] NEBRA. 2007. Appendix D. "U.S. and State-by-State Biosolids Regulation Quality, Treatment, and End Use and Disposal Data." Available at: http://www.nebiosolids.org/uploads/pdf/NtlBiosldsRpt-AppD-AL-MO.pdf.

[76] U.S. EPA. 2009. "Estimating 2003 Building-Related Construction and Demolition Materials Amounts." Available at: http://www.epa.gov/osw/conserve/rrr/imr/cdm/pubs/cd-meas.pdf.

[77] Kentucky Department of Environmental Protection. "State Data Report." Available for years 2004 through 2007 at: http://www.waste.ky.gov/branches/rla/Statewide+Solid+Waste+Management+Report.htm.

[78] Municipal Solid Waste (MSW) in the United States: 2008 Facts and Figures. Data Tables available at: http://www.epa.gov/osw/nonhaz/municipal/msw99.htm.

WARM in order to estimate GHG reductions due to increased diversion of non-household waste in Kentucky.[79]

Table AFW-8-17. WARM Input—BAU Non-household Waste Management Scenario Characterization: 2030 (short tons)

WARM Category	Generation	Recycling	Landfill Disposal	Combustion	Composting
Aluminum Cans					N/A
Steel Cans					N/A
Copper Wire					N/A
Glass					N/A
HDPE					N/A
LDPE					N/A
PET					N/A
Corrugated Cardboard					N/A
Magazines/Third-Class Mail					N/A
Newspaper					N/A
Office Paper					N/A
Phonebooks					N/A
Textbooks					N/A
Dimensional Lumber	517,990	168,839	349,151		N/A
Medium-Density Fiberboard					N/A
Food Scraps	86,531	N/A	86,531		–
Yard Trimmings	895,523	N/A	614,955		280,568
Grass		N/A			
Leaves		N/A			
Branches		N/A			
Mixed Paper (general)					N/A
Mixed Paper (primarily residential)					N/A
Mixed Paper (primarily from offices)					N/A
Mixed Metals	103,598	33,768	69,830		N/A
Mixed Plastics	103,598	33,768	69,830		N/A
Mixed Recyclables					N/A
Mixed Organics		N/A			
Mixed MSW		N/A			N/A
Carpet					N/A
Personal Computers					N/A
Clay Bricks	103,598	N/A	103,598	N/A	N/A
Concrete	932,382	303,910	628,471	N/A	N/A
Fly Ash				N/A	N/A

[79] Sewage sludge is included in these tables, but is not an input for WARM. Thus, it was not included in the model runs completed by CCS.

WARM Category	Generation	Recycling	Landfill Disposal	Combustion	Composting
Tires					N/A
Drywall	207,196	67,536	139,660		N/A
Asphalt	103,598	33,768	69,830		N/A
Sewage Sludge	98,338	26,682	71,657		N/A
Total	**3,152,351**	**668,270**	**2,203,513**	**—**	**280,568**

BAU = business as usual; HDPE = high-density polyethylene; LDPE = low-density polyethylene; MSW = municipal solid waste; N/A = not available; PET = polyethylene terephthalate; WARM = WAste Reduction Model.

Table AFW-8-18. WARM Input—Policy Non-household Waste Management Scenario Characterization: 2030 (short tons)

WARM Category	Generation	Recycling	Landfill Disposal	Combustion	Composting
Aluminum Cans					N/A
Steel Cans					N/A
Copper Wire					N/A
Glass					N/A
HDPE					N/A
LDPE					N/A
PET					N/A
Corrugated Cardboard					N/A
Magazines/Third-Class Mail					N/A
Newspaper					N/A
Office Paper					N/A
Phonebooks					N/A
Textbooks					N/A
Dimensional Lumber	517,990	354,445	163,545		N/A
Medium-Density Fiberboard					N/A
Food Scraps	86,531	N/A	65,656		20,875
Yard Trimmings	895,523	N/A	339,715		555,808
Grass		N/A			
Leaves		N/A			
Branches		N/A			
Mixed Paper (general)					N/A
Mixed Paper (primarily residential)					N/A
Mixed Paper (primarily from offices)					N/A
Mixed Metals	103,598	70,889	32,709		N/A
Mixed Plastics	103,598	70,889	32,709		N/A
Mixed Recyclables					N/A
Mixed Organics		N/A			
Mixed MSW		N/A			N/A
Carpet					N/A
Personal Computers					N/A

WARM Category	Generation	Recycling	Landfill Disposal	Combustion	Composting
Clay Bricks	103,598	N/A	103,598	N/A	N/A
Concrete	932,382	638,000	294,381	N/A	N/A
Fly Ash				N/A	N/A
Tires					N/A
Drywall	207,196	141,778	65,418		N/A
Asphalt	103,598	70,889	32,709		N/A
Sewage Sludge	98,338	26,682	71,657		N/A
Total	**3,152,351**	**1,373,572**	**1,202,096**	**—**	**576,683**

HDPE = high-density polyethylene; LDPE = low-density polyethylene; MSW = municipal solid waste; N/A = not available; PET = polyethylene terephthalate; WARM = WAste Reduction Model.

GHG Benefits

Tables AFW-8-19 and AFW-8-20 display the WARM results for 2030 GHG reductions due to increased diversion of household and non-household waste, respectively. Table AFW-8-19 shows that the total GHG reduction in 2030 from increased diversion of household waste is about 0.62 $MMtCO_2e$, but less than 1% of this total is due to incremental landfill GHG emission reductions. The remainder of the GHG reductions is a result of the energy-cycle benefit of waste diversion.

Table AFW-8-20 shows the incremental GHG reductions from the increased diversion of non-household waste. This table indicates a negative incremental landfill GHG emissions reduction. The reason for this negative value is that dense woody materials, such as yard waste and dimensional lumber, decay over a very long period of time and are considered by WARM to sequester carbon at landfills. Therefore, while the energy-cycle GHG reduction for non-household wastes is substantial, the direct GHG reductions at landfills are actually negative due to reduced sequestration

Table AFW-8-19. WARM Outputs: Energy-Cycle Emissions Reduction for Diversion of Household Waste (2030)

WARM Outputs	Emissions Reduction
Recycling Share of Incremental Diversion (%)	100%
Composting Share of Incremental Diversion (%)	0%
Incremental Landfill GHG Reduction (tCO_2e)	2,123
Incremental Combustion GHG Reduction (tCO_2e)	0
Incremental Recycle GHG Reduction (tCO_2e)	621,571
Incremental Compost GHG Reduction (tCO_2e)	0
Combined Incremental Recycle GHG Reduction (tCO_2e)	623,694
Combined Incremental Compost GHG Reduction (tCO_2e)	0
Total GHG Reduction (tCO_2e)	**623,694**

GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent.

Table AFW-8-20. WARM Outputs: Energy-Cycle Emissions Reduction for Diversion of Non-household Waste (2030)

WARM Outputs	Emissions Reduction
Recycling Share of Incremental Diversion (%)	70%
Composting Share of Incremental Diversion (%)	30%
Incremental Landfill GHG Reduction (tCO_2e)	–110,800
Incremental Combustion GHG Reduction (tCO_2e)	0
Incremental Recycle GHG Reduction (tCO_2e)	715,588
Incremental Compost GHG Reduction (tCO_2e)	58,532
Combined Incremental Recycle GHG Reduction (tCO_2e)	637,551
Combined Incremental Compost GHG Reduction (tCO_2e)	25,769
Total GHG Reduction (tCO_2e)	**663,320**

GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent.

Cost Analysis

The costs involved with recycling include additional capital and operation and maintenance (O&M) costs for materials recycling facilities (MRFs) needed to meet the incremental demand for processing of recyclable materials. Cost savings include avoided landfill tip fees and waste transport cost (less any cost for recyclable material disposal and transport), and revenue generated from recycled materials. It is assumed that collection costs with additional recycling are equivalent to current collection costs of curbside waste and recycling pickup, as the collection cost of additional recycling will be offset by less waste collected for disposal.

Capital and O&M costs are based on a reference case single-stream MRF.[80] The evaluation of the reference case MRF is based on a capital cost of $8 million and an annual O&M cost of $40 per ton. This facility processes about 60,000 tons of recyclables per year. Capital costs are annualized using the capital recovery factor method, assuming 5% interest and a 15-year project life. Kentucky will need about 17 new MRFs that can process 60,000 tons per year of single-stream recyclables to meet the target set by AFW-8. Annual capital costs are found by assessing the number of new facilities needed in each year and summing the annualized capital cost of these facilities, in addition to any facilities still within 15 years of the start of operation.

Table AFW-8-21 displays the transportation costs and tipping fees for each waste management strategy. These data were provided by DWM, except where noted. The values in this table were utilized to determine the net transportation cost (or cost savings) and net disposal cost (or cost savings) of recycling on a per-ton basis, relative to disposal strategies.

[80] Reference case MRF data provided to CCS by New York State Department of Environmental Conservation and Casella Waste Systems, Inc. These cost estimates are approximations based on recent MRFs constructed in New York State. DWM did not provide CCS with capital and O&M costs. Therefore, these New York data were used as a proxy.

The value of recycled materials used in this analysis is \$6.50/ton for single-stream recyclables.[81] This value is highly variable; therefore, projections based on it are uncertain.

Table AFW-8-21. Waste Management Transportation Costs and Tipping Fees

Management Strategy	Transportation Cost (\$/ton)	Tipping Fee (\$/ton)
In-State Landfill Disposal	\$4	\$34
Out-of-State Disposal	\$7	\$40
Waste-to-Energy Combustion	\$4	\$65
Recycling	\$4	\$0[82]
Composting	\$4	\$40

The net costs for increased composting in Kentucky were estimated by adding the additional costs for collection (the same cost as recycling, \$8.03/ton)[83] to the net cost for composting operations. The net cost for composting operations is the sum of the capital and operating costs of composting, minus the revenue generated through the sale of compost and the net avoided tipping fees for landfilling or combustion (see Table AFW-8-21).

Information on the capital and operating costs of composting facilities was received from Cassella Waste Systems, Inc., during the analysis of a similar option in Vermont.[84] These data are summarized in Table AFW-8-22.

Table AFW-8-22. Capital and Operating Costs of Composting Facilities

Annual Volume (tons)	Capital Costs (\$1,000)	Operating Costs (\$/ton)
<1,500	\$75	\$25
1,500–10,000	\$200	\$50
10,000–30,000	\$2,000	\$40
30,000–60,000+	\$8,000	\$30

It is assumed that the composting facilities to be built within the policy period would tend to be from the largest category (a capital cost of \$8 million, and an O&M cost of \$30/ton) shown in Table AFW-8-22.[85] As with the assumptions for recycling facilities and equipment, composting

[81] The New York State Department of Environmental Conservation states that New York City makes \$7–\$12 million on recyclable materials. Divided \$10 million by New York City recycling tonnage in 2008, based on cost curves data. Rounded to the nearest \$0.50. **Kentucky data not reported.**

[82] Value not known; assumed to be zero.

[83] Assumed that additional curbside collection will be needed to reach aggressive source-separated composting goals. Based on \$30/year/household from EPA collection cost worksheet (http://www.epa.gov/osw/conserve/tools/localgov/economics/collection.htm). Converted to \$/ton based on census data for the number of people per household (http://quickfacts.census.gov/qfd/states/21000.html) and the 2009 per-capita waste generation rate.

[84] P. Calabrese (Cassella Waste Systems, Inc.), personal communication with S. Roe (CCS) June 5, 2007. Because the cost was not originally specified in terms of 2007\$, assume the cost to be valid for 2006.

[85] Conference with the AFW-3 subgroup indicated that this is a reasonable representation of the costs associated with new composting facilities in New York.

facilities/equipment are assumed have a 15-year operating life and to be retired after 15 years. It is assumed that a facility will be added (incurring an additional $8 million in capital cost) for every 60,000 tons of waste composted, plus additional facilities to replace those that are retired prior to 2030. Capital costs are levelized using the Cost Recovery Factor method, assuming a 15-year project life and a 5% interest rate. As the implementation period ends in 2030, it is assumed that no additional capital expenditure is needed past this year. The number of incremental tons that are treated from capital assumed for this recommendation decreases linearly until the last facility has been retired in 2045.The compost value is assumed to be $11/ton.[86]

Key Assumptions

The cost analysis for recycling was not separately completed for household recyclables and C&D waste. While the cost of additional curbside collection was only applied to household waste, all other cost parameters are applied to household and C&D waste equally. This is a simplifying assumption that could be improved given sufficient data availability.

For the household and non-household waste management input data to WARM, the key assumption is that none of the goals would be achieved via existing programs in place. To the extent that those programs will achieve, or partly achieve, the goals of this policy, the estimated GHG reductions would be lower.

Biomass derived from landfilled waste may be diverted for use in electricity, heat, and steam generation facilities. Such a diversion would not reduce total carbon emissions, because the carbon in the waste biomass is biogenic. However, more of this biogenic carbon is emitted as CH_4 in landfill emissions than as biomass combustion emissions. Such a diversion would likely reduce the overall GHG emissions from landfills in Kentucky.

Imported waste is not included in this assessment. It is assumed that waste is not imported into Kentucky for the purpose of processing recyclable materials. The assumption is that the imported waste is sorted and sent straight to landfills or waste-to-energy facilities.

The costs for recycling assume that single-stream MRFs will be built to meet incremental demand. While single-stream recycling can increase participation and reduce collection costs, the capital and O&M costs at single-stream MRFs are greater than dual-stream facilities. In reality, a mix of these facilities will be built to meet demand.

Currently, there is very little capacity to recycle glass. This is due to the energy and costs involved in doing so. A great deal of successful glass diversion is through re-use of glass containers. It is believed that WARM does not take the lack of glass recycling capacity into account.

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86 Cornell Waste Management Institute. 2006. "NYSAR^3 Compost Session, 17th Annual NYS Recycling Conference." Available at: http://cwmi.css.cornell.edu/NYSAR3compost.htm. Compost value cited to be $10/yard^3. Assuming a dry solids content of 55% and a bulk density of 0.5 tons/yard, the value of composted material was calculated to be $11/ton of initial feedstock.

Key Uncertainties

Mechanisms to assess recycling penetration rates and to encourage curbside participation are difficult to quantify.

Additional Benefits and Costs

- Biomass, such as yard waste, might have a higher-value use as an energy source for electricity or biofuels, as opposed to compost.
- The cost benefit of replacing fertilizer with compost would lower the overall cost of this policy.
- Yard waste can be used as a stabilizer for manure in anaerobic digesters.

Feasibility Issues

Factors that could affect whether the goals can be achieved include whether the local governments in rural communities can continue to gain the necessary resources to conduct curbside recycling and to build the infrastructure necessary to sustain an increase in recycling efforts. Markets for recyclable materials will also be a factor in whether recycling volumes will increase.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

AFW-9. Landfill Methane Energy Programs

Policy Description

Collect and treat methane at solid waste landfill sites, including those not meeting minimum regulatory waste emplacement volumes, which would require installation of gas collection systems. Use the renewable energy (methane) created at landfills during anaerobic degradation of wastes to produce power, such as electricity, steam, space heat, or motor fuels (compressed or liquefied natural gas). Increasing use of renewable energy, including landfill gas, is noted as one of the seven strategies under Kentucky's November 2008 Energy Plan, *Intelligent Energy Choices for Kentucky's Future: Kentucky's 7-Point Energy Strategy*.[87] Kentucky has seven active landfill gas-to-energy (LFGTE) projects, with several other potential candidate sites.

This recommendation is linked to AFW-8 covering waste reduction, use of waste management feedstocks for fuels, reuse, recycling, and composting. There is also potential linkage to AFW-2 and AFW-4, which address expanding biomass utilization options to produce energy, which would divert materials from the MSW stream that would normally go into landfills. If these options result in a lower volume of biodegradable wastes for emplacement in landfills in the future, lower levels of methane will be generated for collection and use as renewable energy sources.

Policy Design

Goals

- Implement controls or waste management options at MSW landfills, such that 50% of the methane emissions that would be generated under uncontrolled conditions are avoided by 2025.
- By 2025, utilize the maximum amount feasible of the 50% methane reduction above for LFGTE purposes.
- By 2025, increase annual renewable energy production from LFGTE projects to 88 MW/year, which is the potential energy output equivalent of 50% of the total volume of solid waste disposed of annually. *[Depending on the outcome of the modeling for AFW-8, this goal may need to be reduced, since there would be less waste going into the landfills.]*

Timing

- *By 2025, reduce methane emissions by 50%*—In terms of overall impacts to the environment from GHG emissions, methane is 16 times more damaging than CO_2. In accordance with EPA regulations, all landfills with volumes of waste exceeding 3.2 million cubic yards (MCY) total permitted space and 50 megagrams per year, non-methane organic carbons, must have measures in place to contain and/or flare methane. Only 27.2% of the annual MSW disposed of in landfills currently remains uncollected or flared, while 42.6% of the MSW is flared. By

[87] Gov. Steven L. Beshear, *Intelligent Energy for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008. Available at: http://www.energy.ky.gov/energyplan2008/.

2025, with improved equipment and gas collection systems, achieve a 50% reduction in methane emissions. This would be collection and flaring of 2,120,509 CY/yr X 0.5 = approx. 1 MCY/yr of MSW, or 13% of the waste stream.

- *By 2025, implement incentives by regulations or other measures*—Currently 30% of the annual MSW disposed of in landfills generates methane, which is collected and reused for LFGTE. By 2025, implement incentives by regulations or other measures to facilitate and encourage utilities and other private and public entities to use landfill gas for renewable energy production—specifically, to increase the percentage of renewable energy produced from LFGTE projects from its current rate of 30% of the annual total potential energy output equivalent from solid waste disposal to 50%. In terms of potential energy generated for electricity or natural gas use, this would be an increase from the current 52.9 MW/yr to 88 MW/yr. Of the seven active landfill sites, six are used to generate electricity, having a combined 16.9 MW of production capacity. The seventh, by far the largest landfill in the state, provides 0.72 million cubic feet of gas per day to an industrial park for use in steam boilers—equal to 36 MW of energy generated, or approximately half of the methane collected at the landfill. Studies have shown that 80% of the methane is generated within 5 years following initial MSW disposal in the landfill. After the 5-year period, the level of methane generated is significantly reduced.

Parties Involved: This recommendation would apply to all private and public waste management operators of currently active Subtitle D contained landfills.[88] It would also apply to public and private electric and gas utility entities and companies who may be consumers and end users of the renewable energy sources provided by the methane. This would also apply to those who regulate energy production, transportation, and use, including KEEC, the Public Protection Cabinet, the Public Service Commission (PSC), the Federal Energy Regulatory Commission and U.S. Department of Transportation, and city and county governments.

Other: It should be noted one of the main goals represented in this policy statement of increasing the recovery of methane produced by landfills in the state for conversion to LFGTE uses would be directly affected by implementation of several of the other options, including those that divert biomass and other forms of biodegradable waste from emplacement in landfills. This will reduce the amount of methane that would be produced for capture and reuse by LFGTE sites, affecting long-range supplies of methane that may be generated by landfills. Thus, it could impact the market and future projections of waste in place and energy potential that could be generated from the waste.

Implementation Mechanisms

The policy goals could be achieved via a combination of improving the collection efficiency of existing landfill gas (LFG) collection systems, developing additional LFGTE projects, or through other methods. Implementation of this policy may require the enactment of enabling legislation and subsequent regulation by the PSC, including development of statewide interconnection guidelines, and/or development of a renewable portfolio standard. Policies should be designed to incorporate the following:

[88] A contained landfill consists of an area of approximately 50 acres, of which 15 acres is currently active.

- Increase the sustainability of landfill energy management by promoting a waste management hierarchy with a renewable energy production focus versus collection and treatment only.
- Develop a work group of waste industry stakeholders, including landfill operators and utility companies, who would propose measures that will help enhance the sustainability and economic viability of renewable energy production.
- Study financial incentives or policies that could be implemented by governmental bodies, which will enhance the market stability and demand for renewable energies, including LFG.
- To the extent practicable, capture and utilize LFG at all existing landfills. The policy may need to be different for large versus small landfills. If the economics of shipment of pipeline gas are not favorable, then the addition of some on-site facilities to use the energy might be needed.
- Conduct studies to determine the most appropriate policies for future waste collection and conversion to biomass fuels.
- Perform a survey or audit of existing LFGTEs, and develop a database of existing emissions and collection efficiencies (e.g., possibly in coordination with EPA's Landfill Methane Outreach Program. Optimize energy production at existing landfill methane projects through operational efficiency.
- Encourage participation in EPA's Landfill Methane Outreach and Methane to Markets programs.

Related Policies/Programs in Place

- U.S. EPA Landfill Methane Outreach Program (LMOP).
- U.S. EPA Methane to Markets Program.

Type(s) of GHG Reductions

- **CH_4:** Reductions through increased collection and control efficiency of landfill gas and through combustion of landfill methane.
- **CH_4, N_2O and CO_2:** Reduction of fossil fuels and associated GHGs through the use of landfill methane for energy.

Estimated GHG Reductions and Net Costs or Cost Savings

Data Sources

- Landfill methane emissions calculated using the EPA Landfill Gas Emission Model (LandGEM)[89] based on updated waste management data provided by the Kentucky Division of Waste Management.[90]

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[89] U.S. EPA's Landfill Gas Emissions Model—LandGEM, version 3.02. (http://www.epa.gov/ttn/catc/dir1/landgem-v302.xls).

[90] Personal communication from T. Hubbard and G. Gilbert (DWM) via e-mail on October 4, 2010. Personal communication from G. Gilbert via telephone on October 20, 2010. The information provided by DWM updated the data used to develop the Kentucky Waste I&F. Specifically, it was brought to light that the waste identified as

- Capital and O&M costs for landfill gas collection and utilization equipment were taken from EPA's Landfill Gas Energy Cost Model (LFGcost).[91]
- The assumed cost of electricity is based on future Southeastern Reliability Coordination Agreement prices from the EIA AEO.[92]

Quantification Methods

Table AFW-9-1. Summary of AFW-9

Quantification Factors	2020	2030	Units
GHG Emission Reductions	1.41	2.44	$MMtCO_2e$
Net Present Value (2011–2030)		$28.8	$ Million
Cumulative Emissions Reductions (2011–2030)		28.8	$MMtCO_2e$
Cost-Effectiveness (2011–2030)		$1.0	$/tCO_2e$

$/tCO₂e = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Tables AFW-9-2 and AFW-9-3 display the results of the GHG emission reduction and cost-effectiveness quantitative analyses, respectively. Following these tables is more detailed documentation of the assumptions, parameters, and calculations used to generate the estimated GHG emission reductions and net cost of additional landfill methane capture and utilization. The cumulative GHG reduction for 2010–2030 is 28.8 $MMtCO_2e$ and the cost-effectiveness is \$1/tCO_2e. Tables AFW-9-2 and AFW-9-3 displays the results of the GHG emission reduction and cost-effective analyses for the lifetime of projects directly related to AFW-9, meaning that a project that begins in 2030, which is assumed to have a 15-year lifespan, will produce GHG reductions through 2044. However, only GHG reductions and net costs through 2030 are counted in the AFW summary table at the beginning of this appendix in order to maintain consistency with other mitigation options.

"MSW" in the DWM annual reports includes non-household waste, such as C&D debris, which is mostly inert (does not produce landfill gas emissions). The updated information provided by DWM allowed CCS to break out household waste from non-household waste.

[91] U.S. EPA, Landfill Methane Outreach Program. Landfill Gas Energy Cost Model (LFGcost), Version 2.2. More information on LFGcost is available at: http://www2.ergweb.com/lmop/samples/model.asp.

[92] Supplemental Tables to the *Annual Energy Outlook 2010*, Table 80. Available at: http://www.eia.doe.gov/oiaf/aeo/supplement/index.html.

Table AFW-9-2. GHG Reduction Analysis and Results

Year	TWG LFG Capture Goal (% of BAU)	BAU CH_4 Emissions from Uncontrolled Landfills (tCO_2e)	GHG Benefit: CH_4 Reduction from LFG Control and CH_4 Destruction ($MMtCO_2e$)	CH_4 Controlled (m^3 CH_4)	Electricity Generated (50% of Controlled CH_4 Used for LFGTE) (MWh)	GHG Benefit: Avoided Electricity Production ($MMtCO_2e$)	Total GHG Benefit ($MMtCO_2e$)
2010	0%	3,951,834	—	—	—	—	—
2011	3%	3,973,087	0.13	5,045,189	6,407	0.01	0.14
2012	7%	3,969,657	0.26	10,081,667	12,804	0.01	0.28
2013	10%	3,964,744	0.40	15,103,785	19,182	0.02	0.42
2014	13%	3,958,354	0.53	20,105,923	25,535	0.03	0.55
2015	17%	3,950,491	0.66	25,082,484	31,855	0.03	0.69
2016	20%	3,949,827	0.79	30,093,919	38,219	0.04	0.83
2017	23%	3,947,322	0.92	35,087,305	44,561	0.05	0.97
2018	27%	3,975,505	1.06	40,386,081	51,290	0.05	1.11
2019	30%	4,001,095	1.20	45,726,797	58,073	0.06	1.26
2020	33%	4,024,166	1.34	51,100,520	64,898	0.07	1.41
2021	37%	4,044,788	1.48	56,498,630	71,753	0.07	1.56
2022	40%	4,062,927	1.63	61,911,273	78,627	0.08	1.71
2023	43%	4,100,964	1.78	67,698,452	85,977	0.09	1.86
2024	47%	4,136,099	1.93	73,530,640	93,384	0.09	2.03
2025	50%	4,230,584	2.12	80,582,552	102,340	0.10	2.22
2026	50%	4,320,837	2.16	82,301,648	104,523	0.11	2.27
2027	50%	4,407,053	2.20	83,943,874	106,609	0.11	2.31
2028	50%	4,489,421	2.24	85,512,772	108,601	0.11	2.36
2029	50%	4,568,115	2.28	87,011,705	110,505	0.11	2.40
2030	50%	4,643,303	2.32	88,443,870	112,324	0.11	2.44
2031	47%	4,643,303	2.17	82,547,612	104,835	0.11	2.27
2032	43%	4,643,303	2.01	76,651,354	97,347	0.10	2.11
2033	40%	4,643,303	1.86	70,755,096	89,859	0.09	1.95
2034	37%	4,643,303	1.70	64,858,838	82,371	0.08	1.79
2035	33%	4,643,303	1.55	58,962,580	74,882	0.08	1.62
2036	30%	4,643,303	1.39	53,066,322	67,394	0.07	1.46
2037	27%	4,643,303	1.24	47,170,064	59,906	0.06	1.30
2038	23%	4,643,303	1.08	41,273,806	52,418	0.05	1.14
2039	20%	4,643,303	0.93	35,377,548	44,929	0.05	0.97
2040	17%	4,643,303	0.77	29,481,290	37,441	0.04	0.81
2041	13%	4,643,303	0.62	23,585,032	29,953	0.03	0.65
2042	10%	4,643,303	0.46	17,688,774	22,465	0.02	0.49
2043	7%	4,643,303	0.31	11,792,516	14,976	0.02	0.32
2044	3%	4,643,303	0.15	5,896,258	7,488	0.01	0.16
Total		**151,676,415**	**43.7**	**1,664,356,178**	**2,113,732**	**2.1**	**45.8**

Year	TWG LFG Capture Goal (% of BAU)	BAU CH_4 Emissions from Uncontrolled Landfills (tCO_2e)	GHG Benefit: CH_4 Reduction from LFG Control and CH_4 Destruction ($MMtCO_2e$)	CH_4 Controlled (m^3 CH_4)	Electricity Generated (50% of Controlled CH_4 Used for LFGTE) (MWh)	GHG Benefit: Avoided Electricity Production ($MMtCO_2e$)	Total GHG Benefit ($MMtCO_2e$)
Total (2010–2030)		**86,670,170**	**27.4**	**1,045,249,087**	**1,327,466**	**1.4**	**28.8**

BAU = business as usual; GHG = greenhouse gas; LFG = landfill gas; LFGTE = landfill gas to energy; m^3 CH_4 = cubic meters of methane; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent; TWG = Technical Work Group.

Table AFW-9-3. Cost-Effectiveness Analysis and Results

Year	Capital Cost LFG for Collection from Uncontrolled Landfills ($MM)	O&M Cost for LFG Collection from Uncontrolled Landfills ($MM)	Total Annual Cost for LFG Collection from Uncontrolled Landfills ($MM)	Electricity Purchase Price ($/kWh)	Annual Revenue ($MM)	Net Annual Cost ($MM)	Discounted Costs ($MM)
2010	$0.00	$0.00	$0.00	$0.079	$0.00	$0.00	$0.0
2011	$0.96	$0.07	$1.02	$0.076	$0.49	$0.60	$0.6
2012	$1.44	$0.10	$1.54	$0.077	$0.99	$0.65	$0.6
2013	$2.39	$0.17	$2.56	$0.076	$1.46	$1.27	$1.1
2014	$2.87	$0.20	$3.07	$0.076	$1.94	$1.33	$1.1
2015	$3.83	$0.26	$4.09	$0.075	$2.39	$1.97	$1.5
2016	$4.31	$0.30	$4.61	$0.076	$2.90	$2.00	$1.5
2017	$5.27	$0.36	$5.63	$0.077	$3.43	$2.56	$1.8
2018	$5.75	$0.40	$6.14	$0.077	$3.95	$2.59	$1.8
2019	$6.70	$0.46	$7.17	$0.077	$4.47	$3.16	$2.0
2020	$7.18	$0.50	$7.68	$0.077	$5.0	$3.18	$1.9
2021	$8.14	$0.56	$8.70	$0.077	$5.5	$3.74	$2.2
2022	$8.62	$0.59	$9.2	$0.077	$6.1	$3.75	$2.1
2023	$9.6	$0.66	$10.2	$0.077	$6.6	$4.28	$2.3
2024	$10.5	$0.73	$11.3	$0.077	$7.2	$4.80	$2.4
2025	$10.5	$0.73	$11.3	$0.077	$7.9	$4.11	$2.0
2026	$10.1	$0.69	$10.7	$0.077	$8.0	$3.39	$1.6
2027	$9.6	$0.66	$10.2	$0.077	$8.2	$2.69	$1.2
2028	$9.1	$0.63	$9.7	$0.078	$8.5	$1.88	$0.8
2029	$8.14	$0.56	$8.70	$0.078	$8.6	$0.64	$0.3
2030	$8.14	$0.56	$8.70	$0.079	$8.9	$0.39	$0.1
2031	$7.18	$0.50	$7.68	$0.079	$8.3	–$0.11	$0.0
2032	$6.70	$0.46	$7.17	$0.079	$7.7	–$0.06	$0.0
2033	$5.75	$0.40	$6.14	$0.079	$7.1	–$0.56	–$0.2
2034	$5.27	$0.36	$5.63	$0.079	$6.5	–$0.51	–$0.2
2035	$4.31	$0.30	$4.61	$0.079	$5.9	–$1.01	–$0.3
2036	$3.83	$0.26	$4.09	$0.079	$5.3	–$0.97	–$0.3

Year	Capital Cost LFG for Collection from Uncontrolled Landfills ($MM)	O&M Cost for LFG Collection from Uncontrolled Landfills ($MM)	Total Annual Cost for LFG Collection from Uncontrolled Landfills ($MM)	Electricity Purchase Price ($/kWh)	Annual Revenue ($MM)	Net Annual Cost ($MM)	Discounted Costs ($MM)
2037	$2.87	$0.20	$3.07	$0.079	$4.73	–$1.46	–$0.4
2038	$1.92	$0.13	$2.05	$0.079	$4.14	–$1.96	–$0.5
2039	$0.96	$0.07	$1.02	$0.079	$3.55	–$2.46	–$0.6
2040	$0.96	$0.07	$1.02	$0.079	$2.96	–$1.87	–$0.4
2041	$0.48	$0.03	$0.51	$0.079	$2.37	–$1.82	–$0.4
2042	$0.48	$0.03	$0.51	$0.079	$1.77	–$1.23	–$0.3
2043	$0.48	$0.03	$0.51	$0.079	$1.18	–$0.64	–$0.1
2044	$0.00	$0.00	$0.00	$0.079	$0.59	–$0.59	–$0.1
Total	**$174.3**	**$12.0**	**$186.3**	**$2.7**	**$164.6**	**$33.7**	**$25.0**
Total (2010–2030)	**$133.1**	**$9.2**	**$142.3**	**$1.6**	**$102.5**	**$49.0**	**$28.8**

$MM = million dollars; LFG = landfill gas; O&M = operation and maintenance.

GHG Benefits

Table AFW-9-2 shows the ramp-up of implementation to reach the policy goals (total incremental control accounts for 50% of emissions at uncontrolled landfills by 2025, providing the policy goal of 50%). The table shows the BAU uncontrolled methane emissions from the Kentucky I&F, adjusted for the fraction of waste that is considered inert (or very slowly decomposing biogenic) C&D debris waste. Based on the waste characterization in AFW-8, about 69% of the waste disposed of in Kentucky landfills is household waste, compostable organics, or sewage sludge. Next, the table provides the incremental amount of methane controlled due to the policy in each year, and the electricity generation associated with the methane collected. Per the Policy Design section of AFW-9, it is assumed that 50% of the methane captured at currently uncontrolled landfills will be utilized for energy generation.

The electricity generated from this methane is shown next in Table AFW-9-2 using a nominal heat rate of 11,078 Btu/kWh taken from the ES I&F inputs. The GHG benefit of displaced grid electricity is calculated using the marginal grid emission factor of 1.017 tCO_2e/MWh. This figure for emissions/MWh comes from the Kentucky I&F, and is outlined in the Common Assumptions Memo provided to the AFW TWG. The total GHG benefit is shown in the final column by summing the columns for methane destruction and avoided electricity production based on the portion of methane combusted that is utilized for electricity generation (50%).

Cost Analysis

Table AFW-9-3 summarizes the cost analysis. Capital costs are determined based on the incremental LFG collected in each year, the capital cost per volume of LFG collected (based on EPA LFGcost data shown under the Key Assumptions section below), and a capital recovery factor of 0.096 (15-year project life, 5% interest). Annual O&M costs are also derived from LFGcost data for a standard engine/generator set and collection system for landfills with greater than 1 million tons of waste emplaced, small engine/generator set and collection system for landfills with less than 1 million toms waste emplaced, and the incremental amount of LFG collected. Revenue from the sale of electricity generated by the policy projects is estimated from the electricity generation estimate in Table AFW-9-2 and an electricity production value based on the EIA AEO Southeastern Reliability Coordination Agreement prices (provided in Table AFW-9-3).[93] Total annual costs are the sum of annualized capital and O&M costs minus the value of electricity produced. Discounted costs are brought back to 2009$ using a 5% discount rate. The cost-effectiveness estimate of $1/t$CO_2$e is determined from the total discounted costs divided by total reductions (2010–2030).

Using the results from an LFGcost run (Tables AFW-9-4), the costs of AFW-9 implementation are estimated based on whether the methane is converted to usable energy by a small engine or large engine (800 kilowatts and greater, landfill waste in place [WIP] greater than 1 million tons.).[94] Small landfills (less than 1 million tons WIP) are assumed to utilize small-engine technology. Input data from the model were developed from the landfill data utilized for the AFW-8 BAU waste management profile. Note that the data in Table AFW-9-4 do not include the revenue that these projects will receive from electricity sales or energy savings. The assumed mix of small engine versus standard engine is based on the proportion of current WIP at each class of landfill in Kentucky. A capital recovery factor of 0.096 (15-year project life, 5% interest) is applied to annualize capital costs.

Table AFW-9-4. LFGcost Modeling Results (per landfill)

EPA LFG Cost Modeling Data	Scenario 1 Small Engine (<800 kW, <1MM tons WIP)	Scenario 2 Standard Engine (>800 kW, >1MM tons WIP)
Total Capital	$660,448	$6,237,687
Average Annual O&M	$59,270	$361,004
Annual average Reductions (MMtCO_2e)	0.087	1.397
Capital Cost per tCO_2e Reduced	$7.63	$4.47
O&M Cost per tCO_2e Reduced	$0.68	$0.26
Blended Cost-Effectiveness		
Baseline Share of Methane Control in Kentucky	24%	76%
Fractional cost-Effectiveness, Capital ($/t$CO_2$e)	$1.82	$3.40
Fractional cost-Effectiveness, O&M ($/t$CO_2$e)	$0.16	$0.20
Average Cost-Effectiveness, Capital ($/t$CO_2$e)	**$5.22**	
Average Cost-Effectiveness, O&M (tCO_2e)	**$0.36**	

$/t$CO_2$e = dollars per metric ton of carbon dioxide equivalent; EPA = U.S. Environmental Protection Agency; kW = kilowatt; LFG = landfill gas; m^3 CH_4 = cubic meters of methane; MM = million; MMtCO_2e = million metric tons of carbon dioxide equivalent; O&M = operation and maintenance; tCO_2e = metric tons of carbon dioxide equivalent; WIP = waste in place.

[93] Supplemental Tables to the *Annual Energy Outlook 2010*, Table 80. Available at: http://www.eia.doe.gov/oiaf/aeo/supplement/index.html.

[94] U.S. EPA, Landfill Methane Outreach Program. Landfill Gas Energy Cost Model (LFGcost), Version 1.4. Model run performed by B. Strode on June 24, 2008. More information on LFGcost is available at: http://www.epa.gov/lmop/res/index.htm.

LFGcost was used to estimate the potential tCO_2e of LFG that could be captured at the average landfill in Kentucky. This number was divided by the CH_4 captured at currently uncontrolled landfills to determine the number of landfills at which controls would be put in place. By 2025, 26 currently uncontrolled landfills would need to be controlled in order to meet the AFW-9 targets. The number of landfills is multiplied by the fractional capital cost and fractional O&M cost from Table AFW-9-4 to yield the annual capital cost and annual O&M cost, respectively.

Key Assumptions

The analysis only assumes the adoption of LFG controls is possible at landfills identified as "candidate" or "potential" by the LMOP database.

Each of the cost inputs above contains key assumptions; additional study of these inputs could reduce the associated uncertainty in the cost estimates. Key inputs to the cost analysis taken from LFGcost include:

- Value of electricity generated: per EIA AEO Southeastern Reliability Coordination Agreement price forecast;
- LFG collection efficiency: 85%;
- LFG methane content: 50%;
- Number of LFG wellheads (assume 1 well/acre): 62 for large landfills, 17 for small landfills;
- Financing: 15 years (minimum expected equipment life), 5% interest rate, 100% financing.

Key Uncertainties

The analysis does not factor in the closure of specific landfills or the adoption of LFG controls at specific landfills outside of the BAU forecast. Modeling GHG emissions and reductions at individual sites is beyond the scope of this analysis; however, the approach used is consistent with the methods used to develop the GHG forecast for the waste management sector.

Growth rates for organic materials being landfilled are highly uncertain and will depend on recycling and composting goals and actual diversions. If full implementation of the AFW-8 targets is achieved, the 2030 and cumulative 2010–2030 GHG reductions that result from the AFW-9 mitigation targets are reduced to 2.12 and 26.6 $MMtCO_2e$, respectively. The implementation costs should not change dramatically, since the amount of capital and O&M cost inputs will be the same and the revenue generated should be only marginally lower than if waste disposal continues at BAU rates.

The offset natural gas benefit estimate is based only on the global warming potential of methane, relative to CO_2. It does not account for other life-cycle emissions related to natural gas production and combustion, which are also being offset through landfill gas utilization.

Additional Benefits and Costs

- The reduction in LFG emissions into the atmosphere would greatly improve air quality for the communities surrounding the landfills.

- Collecting and utilizing LFG can reduce the risk of potentially dangerous underground methane pockets that can occur at capped landfills.
- Increasing the emphasis on environmentally sound post-disposal treatment of waste will create job markets for the design, construction, and operation of controls.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

Appendix F
Energy Supply Sector Policy Recommendations

Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($\$/tCO_2e$)
		2020	2030	Total 2011–2030		
ES-1	Biomass Development and Efficiency Improvements at Existing Power Plants					
	Supply-side efficiency	1.6	2.1	27.4	$240	$8.8
	Biomass co-firing	4.0	4.5	65.1	$1,065	$16.34
	Total	5.7	6.5	92.5	$1,305	$14.1
	Dedicated biomass					
	Stoker technology	0.4	0.4	8.2	$342	$41.5
	Fluidized bed technology	0.4	0.4	8.2	$242	$29.4
ES-2	Demand-Side Energy Efficiency and Management Programs	*Moved to Residential, Commercial, and Industrial Technical Work Group as policy RCI-3.*				
ES-3	Advanced Fossil Fuel Technology (IGCC, CCSR, Advanced Pulverized Coal, CFB) Incentives, Support, or Requirements					
	Scenario 1 (Supercritical without CCSR)					
	800 MW retired	0.7	0.7	7.4	$127.9	$17.2
	1,600 MW retired	1.9	1.9	21.1	$423.1	$20.1
	Scenario 2 (Conventional NGCC without CCSR)					
	600 MW retired	1.7	1.7	18.7	$307.2	$16.4
	1,200 MW retired	2.9	2.9	32.0	$544.0	$17.0
	*Scenario 3 (Supercritical with CCSR)**					
	800 MW retired	2.3	2.3	24.8	$824.8	$33.2
	1,600 MW retired	7.4	7.4	78.6	$2,729.5	$34.7
	Scenario 4 (Advanced NGCC with CCSR)					
	600 MW retired	2.4	2.4	26.8	$561.7	$21.0
	1,200 MW retired	4.2	4.2	46.3	$994.7	$21.5

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($\$/tCO_2e$)
		2020	2030	Total 2011–2030		
ES-4	CCSR Enabling Policies, R&D, Infrastructure, and Incentives Including Enhanced Oil Recovery Using CO_2 (quantification considers CCSR demonstration project only)					
	*1 plant retrofitted**	1.8	1.8	23.5	$893.3	$37.9
	2 plants retrofitted	3.8	3.8	49.9	$1,891.7	$37.9
ES-5	Pricing Strategies to Promote Efficiency and Renewables Including Net Metering, Feed-In Tariff, Interconnection Rules, Inclined Rates, and Examination of the Standard Rate Structure (quantification considers feed-In tariff only)	1.2	5.2	43.9	$1,206	$27.5
ES-6	New Nuclear Energy Capacity	0.0	19.5	116.7	$2,481	$21.3
ES-7	Renewable Energy Incentives and Barrier Removal, Including CHP					
	*Scenario 1 (mixed renewable)**	15.1	22.2	263.6	$5,489	$20.8
	Scenario 2 (biomass)	15.1	22.3	272.2	$4,368	$16.0
	Scenario 3 (out-of-state wind)	15.1	22.3	272.2	$3,012	$11.1
	Scenario 4 (solar PV)	15.1	22.2	271.4	$8,157	$30.1
ES-8	Technology Research and Development (Not Including CCSR or Wind Potential Study) (quantification considers solar PV demonstration projects only)	0.013	0.013	0.24	$39.6	$164.9
ES-9	Policies to Support Wind Energy	*Not Quantified*				
ES-10	Shale Gas Development and Natural Gas Transportation Infrastructure and Gas-to-Liquids Technology	0.013	0.028	0.271	$22.3	$82.5
	Gas-to Liquids-Technology	0.039	0.077	0.763	$137.3	$179.1
ES-11	Smart Grid, Including Transmission and Distribution Efficiency (quantification considers smart grid only)	6.45	13.35	135.73	$3,608.4	$26.6
ES-12	Coal-to-Liquids Production: GHG Emission Reduction Incentives, Support, or Requirements (EPA Estimate—3.7% GHG increase)	0.02 *Increase*	0.10 *Increase*	0.73 *Increase*	$630	N/A

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)
		2020	2030	Total 2011–2030		
	Coal-to-Liquids Production: GHG Emission Reduction Incentives Support, or Requirements (EPA Lower Bound—5% GHG decrease)	0.03	0.14	0.99	$688	$697
	Sector Total After Adjusting for Overlaps	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**
	Reductions From Recent Actions (EISA Title II requirements for new appliances and lighting)	**0.0**	**0.0**	**0.0**	**$0**	**$0**
	Sector Total Plus Recent Actions	**37.4**	**75.8**	**755.9**	**$17,911.5**	**$24**

$\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; CCSR = carbon capture and storage or reuse; CFB = circulating fluidized bed; CHP = combined heat and power; CO_2 = carbon dioxide; DSM = demand-side management; EERS = energy efficiency resource standard; EISA = Energy Independence and Security Act of 2007; EPA = U.S. Environmental Protection Agency; GHG = greenhouse gas; IGCC = integrated gasification combined cycle; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MW = megawatts; NGCC = natural gas combined cycle; N/A = not applicable; PBF = performance-based financing; PV = photovoltaics; RCI = Residential, Commercial, and Industrial; R&D = research and development; RE = renewable energy.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative net present value represents positive net cash flows from the policy (i.e., the costs of the policy, when levelized over their expected lifetimes, are less than expected expenditures). Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

*These scenarios were used in the sector totals. The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policy recommendations.

ES-1. Biomass Development and Efficiency Improvements at Existing Power Plants

Policy Description

As directed by 2007 House Bill (HB)[1] and subsequent amendments to Kentucky Revised Statutes (KRS) 152.720, the Governor's Office of Energy Policy published a strategic action plan, *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence*[1] (Kentucky's Energy Plan), which outlined seven strategies to restructure Kentucky's energy portfolio to continue Kentucky's role as an energy leader. Although biomass development constitutes a significant role in the first three strategies, this recommended policy will primarily focus on Strategy 2: Increase Kentucky's Use of Renewable Energy listed in Kentucky's Energy Plan. This policy recommendation is intended to include both new and repowered existing stand-alone plants, as well as co-firing biomass at fossil-fuel electric generating units. This policy will also include energy efficiency improvements at existing fossil-fuel electric generating units.

The average coal-fired power plant in Kentucky is more than 35 years old. There have been significant advances in power generation technology during the lives of Kentucky's power plants. Implementing efficiency improvements at existing power plants has the potential to decrease carbon dioxide (CO_2) and other emissions on a pound per million British thermal unit (lb/MMBtu) basis, while at the same time reducing fuel costs. However, uncertainties in the Clean Air Act's New Source Review (NSR) Program pose a significant disincentive not only to power plant efficiency improvements, but also to biomass co-firing, because in some cases such a project may be deemed a "major modification" that results in additional emissions, triggering additional pollution control requirements that can cost hundreds of millions of dollars. Refinements in the regulatory program are needed to fully achieve the potential benefits of biomass co-firing and efficiency improvements at existing power plants.

Policy Design

Goals: The goals of this policy recommendation are to generate 4,182,000 megawatt-hours (MWh) of electricity from biomass by 2025 and to improve the efficiency of existing generating units greater than 250 megawatts (MW).

In accordance with the Kentucky Energy Plan, by 2025:

- Kentucky's biomass resources can potentially contribute more than 50% of Kentucky's renewable energy and energy efficiency potential.
- New jobs can be created resulting from an energy-producing sector utilizing biomass.
- Kentucky can utilize the estimated 3.5 million dry tons per year of underutilized woody biomass to generate electricity to meet energy demands.

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[1] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence,* page v, November 2008.

- Utilizing biomass resources can help achieve the 25% renewable energy and efficiency goal.
- Utilizing biomass resources can provide and reach the annual target of 4,182,000 MWh.

The lack of a biomass supply chain is a major impediment to the use of biomass in Kentucky. Biomass development will require creation of the infrastructure necessary to support the procurement, transport, and utilization of biomass.

Promoting *efficiency improvements at existing power plants* has the potential to make a significant contribution toward reduction of Kentucky's carbon footprint. Current technologies could achieve efficiency improvements in the range of 3%–5% for the current generating fleet. For such an effort to be feasible, regulatory actions at both the state and the federal levels would be necessary. Efficiency improvements will be analyzed in two steps to determine potential cost/benefits: first, as applied to all 500-MW or greater generating units, and second as applied to all 250–500-MW units.

Timing: The new generation and improvements should be phased in to the fleet between 2013 and 2025.

Parties Involved

- Electric generators and biomass producers located in Kentucky may be affected by this policy.
- All regulatory agencies involved with permitting, determining compliance, and enforcing regulatory requirements will also be involved in implementing this policy. The agencies involved may include the following:
  - Public Service Commission (PSC),
  - U.S. Environmental Protection Agency (EPA),
  - Federal Land Manager,
  - U.S. Army Corp of Engineers,
  - Kentucky Division for Air Quality,
  - Kentucky Division of Water,
  - Kentucky Division of Waste Management,
  - Kentucky Division of Forestry, and
  - U.S. Forest Service (USFS).

Other: It is necessary for a regulating authority or legislative body to establish standards for low-impact, sustainably harvested biomass and ensure that biomass used as fuel to meet the goals of this policy meets these standards.

To meet the 2025 goals set forth in the Kentucky Energy Plan, electric generation from biomass will have to increase by nearly 12 times the amount currently generated.

The Division for Air Quality should review the NSR Program and determine strategies to allow for the power plant efficiency improvement projects in the framework of the NSR program. In addition, the Division for Air Quality should consult and provide technical information to EPA for consideration to determine whether power plant efficiency projects should be exempt from NSR permitting.

Implementation Mechanisms

Biomass Energy Development

- Creation of the infrastructure necessary to support the procurement, transport, and utilization of biomass.
- Enactment of complementary policies, such as:
  - A renewable portfolio standard (RPS) that ensures demand for the resource.
  - Cost recovery mechanisms for utilities that burn biomass.

Power Plant Efficiency Improvements

- Determine which improvements can be performed without triggering NSR.
- Develop a strategy to amend the NSR regulations to allow efficiency improvements to be made without triggering NSR.
- Utilities should include efficiency improvements in their Integrated Resource Plans (IRPs).
- Allow power plant efficiency improvements to count toward an efficiency portfolio standard (EPS).

Related Policies/Programs in Place

Biomass Energy Development

- There are tax incentives for renewable energy generators of residential, commercial, and utility-scale systems. Additionally, the Kentucky Energy Plan provides goals for energy efficiency and renewable energy capacity.
- The University of Kentucky (UK) is partnering with the East Kentucky Power Cooperative (EKPC) on a pilot project to co-fire biomass at EKPC's circulating fluidized-bed generators.
- See the Governor's Biomass Task Force Report: http://energy.ky.gov/resources/Pages/EnergyPlan.aspx.

Type(s) of GHG Reductions

All measures under this policy result in a reduction in the amount of fossil fuel required to produce a given amount of electricity, or the amount of CO_2 emitted per unit of fuel consumed. Greenhouse gases (GHGs) reduced are those associated with combustion, predominantly CO_2.

Estimated GHG Reductions and Net Costs or Cost Savings

Summary results are presented in Table ES-1-1.

Table ES-1-1. Summary Results for ES-1

Quantified Scenarios	GHG Emission Reductions ($MMtCO_2e$)			Incremental Cost (Million 2009$, Present Value)	Cost of Saved CO_2e (2009$/$tCO_2e$ avoided)
	2020	2030	Cumulative		
ES-1. Biomass development and Efficiency Improvements at Existing Power Plants					
Supply-side efficiency	1.6	2.1	27.4	$240	$8.8
Biomass co-firing	4.0	4.5	65.1	$1,065	$16.3
Total	**5.6**	**6.6**	**92.5**	**$1,305**	**$14.1**

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Business-as-usual (BAU) coal generation based on the Kentucky Energy Supply (ES) inventory and forecast (I&F).
- 2008 U.S. Energy Information Administration (EIA), EIA-923 Monthly Time Series File for capacity, annual net generation, and fuel use by unit.
- Cost and performance characteristics for supply-side efficiency improvements from Sargent & Lundy report, entitled "Coal-Fired Power Plant Heat Rate Reductions" (2008). Available at: http://www.epa.gov/airmarkt/resource/docs/coalfired.pdf.
- Capital cost for biomass co-firing from U.S. Department of Energy (DOE) entitled: "Biomass Cofiring in Coal-Fired Boilers"; fixed operation and maintenance (O&M) costs from the ES Technical Work Group (TWG).
- Levelized coal fuel price of 2.83/MMBtu (2009$) based on *Annual Energy Outlook* (AEO) 2011.
- Biomass fuel prices from: U.S. Department of Agriculture (USDA) USFS fact sheet for Kentucky (2007); assumed weighted average of $3.8/MMBtu (forest residues, mill residues, and urban wood residues).
- Biomass use levels based on the policy description.
- Application of supply-side efficiency improvement as per the policy description.

Quantification Methods: In order to quantify this policy, the first step was to establish capacity and performance characteristics (i.e., heat rate, capacity factor) for Kentucky power stations for the latest year data were available (i.e., 2008). The next step was to establish cost and performance assumptions for each of the supply-side efficiency improvements and biomass co-firing. Supply-side efficiency improvements were phased in linearly starting in 2012 at 10% per year; biomass co-firing was phased in linearly starting in 2012 at 10% per year up to 4,182 gigawatt-hours (GWh). The costs and benefits of dedicated biomass combustion were based on the available remaining supplies as calculated by the Agriculture, Forestry, and Waste (AFW) Technical Work Group (TWG), considering both stoker and fluidized bed boiler types. Costs were compared on the basis of levelized costs.[2] To avoid double counting of biomass GHG reductions, the reductions from ES-1 are accounted for in ES-7, Renewable Energy Incentives and Barrier Removal, Including CHP.

Key Assumptions

The following supply-side efficiency improvement technologies were considered:

- Economizer
- Neural network
- Intelligent sootblowers
- Air heaters
- Acid dew point control
- Turbine overhaul
- Feedwater heaters
- Boiler feed pumps
- Induced draft (ID) axial fans and variable frequency drives
- Flue gas desulfurization (FGD) system modifications
- Electrostatic precipitator (ESP) system modifications
- Selective catalyst reduction (SCR) system modifications
- Cooling tower packing upgrade

Since information was not available regarding the status of improvements that had been undertaken at each unit/plant relative to the technologies considered in the analysis, it was assumed that 50% of the supply-side efficiency improvements had already been installed at Kentucky coal steam power stations, hence limiting the scope of potential GHG reductions from the baseline. The cost and performance assumptions for the technologies noted above are provided in Tables ES-1-2.

[2] Annex 1 to this document presents an overview of the calculation of levelized costs. Annex 2 presents a sensitivity analysis of the capital recovery factor, a component of the levelized cost calculation.

Tables ES-1-2. ES-1 Cost and Performance Assumptions

Technologies	Heat Rate Reduction (Btu/kWh)	Capital Cost (million 2009$)	Fixed O&M (million 2009$/yr)	Variable O&M (million 2009$/yr)
Economizer				
200 MW	75	$2.5	$0.05	$0
500 MW	75	$4.5	$0.1	$0
900 MW	75	$7.5	$0.15	$0
Neural Network				
200 MW	75	$0.5	$0.05	$0
500 MW	65	$0.75	$0.05	$0
900 MW	25	$0.75	$0.05	$0
Intelligent Sootblowers				
200 MW	90	$0.3	$0.05	$0
500 MW	60	$0.5	$0.05	$0
900 MW	60	$0.5	$0.05	$0
Air Heaters				
200 MW	25	$0.4	$0.05	$0
500 MW	25	$0.65	$0.075	$0
900 MW	25	$1.1	$0.1	$0
Acid Dew Point Control				
200 MW	85	$2.5	$0.05	$0.26
500 MW	85	$6.25	$0.075	$0.6375
900 MW	85	$10.75	$0.1	$1.125
Turbine Overhaul				
200 MW	200	$6	$0	$0
500 MW	200	$12	$0	$0
900 MW	200	$15	$0	$0
Feedwater Heaters				
200 MW	50	$0	$0.03	$0
500 MW	50	$0	$0.06	$0
900 MW	50	$0	$0.08	$0
Boiler Feed Pumps				
200 MW	37.5	$0.3	$0	$0
500 MW	37.5	$0.55	$0	$0
900 MW	37.5	$0.75	$0	$0
ID Axial Fans and Variable Frequency Drives				
200 MW	80	$6.25	$0.025	$0
500 MW	80	$10	$0.038	$0
900 MW	80	$15.5	$0.06	$0
Pollution Control Modifications: FGD System				
200 MW	25	$0.5	$0.025	$0
500 MW	25	$0.15	$0.05	$0
900 MW	25	$0.25	$0.075	$0
Pollution Control Modifications: ESP System				
200 MW	2.5	$0.1	$0.0125	$0
500 MW	2.5	$0.25	$0.0125	$0
900 MW	2.5	$0.4	$0.0125	$0

Technologies	Heat Rate Reduction (Btu/kWh)	Capital Cost (million 2009$)	Fixed O&M (million 2009$/yr)	Variable O&M (million 2009$/yr)
Pollution Control Modifications: SCR System				
200 MW	5	$0.25	$0.0125	$0.025
500 MW	5	$0.5	$0.025	$0.06
900 MW	5	$1	$0.05	$0.1
Cooling Tower Packing Upgrade				
200 MW	35	$1.5	$0.0375	$0
500 MW	35	$3	$0.0625	$0
900 MW	35	$5	$0.0875	$0

Btu = British thermal unit; ESP = electrostatic precipitator; FGD = flue gas desulfurization; ID = induced draft; kWh = kilowatt-hour; MW = megawatt; MWh = megawatt-hour; O&M = operations and maintenance; SCR = selective catalyst reduction.

The biomass resource available to utilize in stand-alone facilities and the cost assumptions were obtained from analysis conducted by the AFW TWG and are summarized in tables AFW-1 and AFW-2 in the AFW appendix of this final report. A weighted-average cost of biomass was assumed at $65/dry ton (rounded) over the planning period. The biomass available (i.e., less amounts used in other sectors) for use in stoker and fluidized bed boilers was assumed to be 354,000 dry short tons per year (i.e., about 4 trillion British thermal units (Btu)/year).

The cost and performance assumptions for technologies using biomass are provided in Table ES-1-3.

Table ES-1-3. Cost and Performance Assumptions for Biomass Technologies

Parameter	Co-firing	Stoker (25 MW)*	Stoker (75 MW)*	Fluidized Bed (75 MW)*
Heat Rate (Btu/kWh)	11,500	11,373	11,373	9,483
Capital Cost (2009$/kW)	$158.0	$2,935	$2,114	$1,967
T&D (2009$/kW)	$0	$80.0	$80.0	$80.0
Capital Recovery Factor	0.115	0.115	0.115	.0115
Fixed O&M (2009$/kW-yr):	$40.0	$99.5	$86.3	$55.2
Variable O&M (2009 mills/kWh)	0.0	10.0	10.0	6.7
Levelized Fuel Price (2009$/MWh)	$62.0	$62.8	$62.8	$52.4
Levelized Cost (2009$/MWh)[3]	$71.6	$139.2	$122.9	$102.7

$/kW = dollars per kilowatt; $/kW-yr = dollars per kilowatt-year; Btu = British thermal unit; kWh = kilowatt-hour; MWh = megawatt-hour; O&M = operation and maintenance.

*Stoker and Fluidized Bed examples are direct fired dedicated biomass facilities.

[3] Annex 1 to this document presents an overview of the calculation of levelized costs. Annex 2 presents a sensitivity analysis of the capital recovery factor, a component of the levelized cost calculation.

Summary results are presented in Table ES-1-4 for the dedicated biomass option using stoker and fluidized bed boiler types. The totals shown are in addition to those shown in Table ES 1-1 and utilize the remaining fuel from AFW 1 that is not accounted for elsewhere.

Table ES-1-4. Summary Results for Stoker and Fluidized Bed Technologies

Technologies	GHG Emission Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009$/$tCO_2e$ avoided)
	2020	2030	Cumulative		
Stoker	0.4	0.4	8.2	$342	$41.5
Fluidized Bed	0.4	0.4	8.2	$242	$29.4

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Key Uncertainties

Biomass Energy Development

Key uncertainties include the issue of demand for biomass. It is uncertain what the demand for biomass resources will be without a renewable standard, and how or if utilities will receive cost recovery to utilize biomass. Current least-cost guidelines may deny generators PSC rate recovery for retrofit or new biomass generation.

On January 12, 2011, EPA issued a three-year deferment on the inclusion of GHG emissions from biogenic sources from regulation under the EPA GHG Tailoring Rule that went into effect on January 2, 2011. While this is positive to the operational costs of projects currently utilizing biomass feedstocks, the continued uncertainty may impact the increased utilization of biomass feedstocks.

Power Plant Efficiency Improvements

Another uncertainty is the ability to change NSR regulations. The modeled improvements are not additive, and some are already in place. Specific NSR requirements cannot be known without a plant-by-plant and technology-by-technology analysis, which is beyond the scope of this study. It cannot be determined to what degree these efficiency and biomass improvements can be installed without amending NSR rules, although a significant number of efficiency measures that did not trigger NSR regulatory processes have already been adopted (see below). Among some of those that have not yet been adopted, there is likelihood that NSR is an obstacle. For the purpose of this analysis, it is assumed that the remaining opportunities will be fully available without NSR restrictions. Therefore, absent timely relief from NSR, these results overstate the supply-side efficiency opportunities. Current least-cost guidelines may deny generators PSC rate recovery for some energy efficiency retrofits.

Supply-side efficiency measures are partially implemented in the existing fleet. It is not known precisely which measures are installed on each plant. The ES TWG estimates that approximately 50% of the potential measures studied here have already been installed, and their benefits are already in the baseline. Therefore, the future potential for supply-side efficiency improvements is assumed to be one-half of the system-wide potential, assuming none of the measures is installed. A more precise estimate could be made if detailed plant-by-plant information becomes available.

Additional Benefits and Costs

Biomass Energy Development

Additional benefits include economic development opportunities if biomass resources are developed in-state. Specifically jobs could be created to plant, harvest, transport, process, and burn the biomass. In additional to GHGs, pollution such as sulfur dioxide (SO_2) could be reduced by utilizing biomass resources. Ratepayers may pay more per kilowatt-hour (kWh) for electricity derived from renewables, including biomass.

Power Plant Efficiency Improvements

- Increase energy output without increasing emissions.
- Energy independence
- Coal plants would stay in service longer.

Feasibility Issues

Biomass Energy Development

An RPS or similar mechanism will be necessary to drive demand for electricity by biomass. Without demand, supply will not materialize.

Power Plant Efficiency Improvements

The ability to change NSR regulations.

Status of Group Approval

Approved.

Level of Group Support

Unanimous, with one abstention.

Barriers to Consensus

None.

ES-2. Demand-Side Energy Efficiency and Management Programs

Note: This policy duplicates the Residential, Commercial, and Industrial (RCI) TWG recommendation RCI-3. Thus, it was deleted by the KCAPC as being redundant here.

ES-3. Advanced Fossil Fuel Technology (IGCC, CCSR, Advanced Pulverized Coal, CFB) Incentives, Support, or Requirements

Policy Description

Advanced fossil technologies for electric generation include more efficient—and thus lower-emitting—generation technologies. Advanced fossil technologies combined with carbon capture and storage or reuse (CCSR) may have the potential to significantly lower CO_2 emissions associated with fossil fuel-based electricity generation. Advanced fossil technologies that could be considered include advanced pulverized coal (advanced supercritical or ultra-supercritical units), integrated gasification combined-cycle (IGCC) units, advanced circulating fluidized-bed (CFB) technology, and advanced natural gas combined-cycle (NGCC) units.

Policies to encourage the development of these technologies may include mandates or incentives to use advanced coal technologies for new coal plants, such as a mandate that requires new fossil fuel-fired power plant designs that must accommodate CCSR, or must achieve a specific higher efficiency rating or lower net CO_2 emission rate. Alternatively, a mandate might require that all or a portion of new fossil fuel plants be of a certain stage of development (e.g., most proven, highest efficiency).

Incentives may take the form of full recovery of prudently incurred utility investments in advanced fossil fuel technologies, direct subsidies, or assistance in financing electric generating projects. A combination of mandates and incentives is also possible.

Policy Design

In consideration of the Kentucky's Energy Plan's seven strategies, which establish 2025 as a target date, the proposed policy design elements should include:

- Appropriate legislative action to address barriers.
- Support for demonstration unit deployment.
- Cost recovery and/or other incentives.
- Adequate agency oversight.

It is important to note that all electric generation facilities must be approved by either the PSC or Kentucky's State Board on Electric Generation and Transmission Siting on a case-by-case basis (excluding those built by the Tennessee Valley Authority [TVA] and municipal utilities).

Goals

- The goal of this policy is to facilitate the development of at least one advanced fossil fuel electric generating project utilizing coal and one utilizing natural gas by 2020. In an effort to illustrate and quantify potential cost/benefits for deploying advanced fossil fuel technology designs, calculations from this goal are based on the replacement of the equivalent amount of capacity of older, existing coal-fired (or natural gas) units within the state. It will be assumed that each new plant will be 800-MW coal and 600-MW natural gas, nominally. It is important to note that transmission capability must be assessed for any new large-generator interconnection, as well as the impact of removing any existing generation resource. Transmission upgrades may result in increased costs for the analyses.

- Newly required or replacement baseload electric generation utilizing fossil fuels should be advanced fossil fuel technology designs. These generating resources may originate from entities filing IRPs or merchant sources.

Timing: Coincident with new or replacement baseload electric generation needs, assume 2016 deployment for the natural gas unit and 2020 for the coal unit.[4]

Parties Involved: Key parties involved in implementation of this policy include the legislative bodies from Commonwealth of Kentucky, the PSC, Kentucky's State Board on Electric Generation and Transmission Siting, and Kentucky energy suppliers.

Other: None identified.

Implementation Mechanisms

Specific mechanisms that should be implemented include:

- CCSR liability concerns should be addressed. Legislation would likely be necessary.
- The state should encourage the development, demonstration, and deployment of at least one advanced fossil fuel electric generating project utilizing coal and natural gas within the next 10 years. Each project should consider the appropriate application of CCSR (if the CCSR technology is commercially proven or the proposed project provides design characteristics for retrofitting CCSR in the future).
- The state should ensure a cost recovery mechanism, which includes pre-approval consistent with the current PSC process and contemporaneous cost recovery exists for the demonstration projects.
- In addition to established review criteria, the PSC and/or Kentucky's State Board on Electric Generation and Transmission Siting should review all new electric generating facilities using fossil fuels to ensure the thermal cycle design is the most efficient (and hence the lowest CO_2-emitting design for a specified fuel) technology choice available for the proposed fossil fuel (coal or natural gas) that has proven reliability. Legislation would likely be necessary.

Related Policies/Programs in Place

The Carbon Management Research Group (CMRG) will carry out a 10-year program of research to develop and demonstrate cost-effective and practical technologies for reducing and managing CO_2 emissions in existing coal-fired electric power plants. DEDI is investigating sites to test sequestration of locally produced CO_2.

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[4] It typically takes at least 10 years to move a project from the concept stage to commercialization. Thus, 2020 would be the earliest the project would be in operation.

The Kentucky Geological Survey (KGS) conducted a feasibility study of carbon capture, utilization, and sequestration in Kentucky. That study has resulted in development of projects involving actual CO_2 sequestration in a test well in Hancock County, and planning for another test well in eastern Kentucky.

The Kentucky Energy and Environment Cabinet (KEEC) has helped provide funds to the Center for Applied Energy Research (CAER) to commercialize sequestration of CO_2 emissions from power plants in an algae bioreactor.

CMRG is a consortium of major power companies, the University of Kentucky, CAER, and KEEC. CMRG will carry out a 10-year, $24-million research program to develop and demonstrate cost-effective, practical technologies for reducing and managing CO_2 in existing coal-fired electric power plants. Three main research projects are envisioned:

- Investigation of post-combustion CO_2 control technologies using the CAER pilot plant. CAER will complete a detailed parametric testing for the particular coal that will be fired in a slip-stream field-testing site, and will provide the optimum operational conditions as well as solvent management protocol.
- Slip-stream investigation of post-combustion CO_2 control technologies at a consortium power plant. CAER will complete a portable slip-stream apparatus fabrication, installation, and commissioning.
- Development of chemical looping combustion/gasification for solid fuels. CAER will complete design and fabrication of a bench-scale redox apparatus.

Type(s) of GHG Reductions

All measures under this policy result in a reduction in the amount of fossil fuel required to produce a given amount of electricity, or the amount of CO_2 emitted per unit of fuel consumed. GHGs reduced are those associated with combustion, predominantly CO_2.

Estimated GHG Reductions and Net Costs or Cost Savings

Table ES-3-1 presents summary results for the various scenarios considered in the quantification.

Table ES-3-1. ES-3 Summary Results for Quantified Scenarios

Quantified Scenarios	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $/t$CO_2e$ avoided)
	2020	2030	Cumulative through 2030		
Scenario #1 (Supercritical without CCS)					
800 MW retired	0.7	0.7	7.4	$127	$17.2
1,600 MW retired	1.9	1.9	21.1	$423	$20.1
Scenario #2 (Conventional NGCC without CCS)					
600 MW retired	1.7	1.7	18.7	$307	$16.4
1,200 MW retired	2.9	2.9	32.0	$544	$17.0

Quantified Scenarios	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $/tCO_2e$ avoided)
	2020	2030	Cumulative through 2030		
Scenario #3 (Supercritical with CCS)					
800 MW retired	2.3	2.3	24.8	$825	$33.2
1,600 MW retired	7.4	7.4	78.6	$2,730	$34.7
Scenario #4 (Advanced NGCC with CCS)					
600 MW retired	2.4	2.4	26.8	$562	$21.0
1,200 MW retired	4.2	4.2	46.3	$995	$21.5

$/tCO_2e = dollars per metric ton of carbon dioxide equivalent; CCS = carbon capture and storage; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MW = megawatt; NGCC = natural gas combined cycle.

Data Sources

- Same as ES-1 for BAU coal generation, 2008 power station inventory, and coal price projection.
- Cost and performance characteristics for supercritical coal (with and without carbon capture and storage [CCS]) and NGCC with CCS from the DOE National Energy Technology Laboratory (NETL) report entitled: “Cost and Performance Baseline for Fossil Energy Plants, Vol. 1, DOE/NETL-2007/1281” (2007).
- Capital cost conventional NGCC (without CCS) from EIA cost and performance assumptions for the AEO 2011.
- Levelized natural gas fuel price of $7.49/MMBtu (2009$) based on *Annual Energy Outlook* (AEO) 2011
- Task 692, Subtask 2.6—Review of Power Plant Cost and Performance Assumptions for NEMS; Technology Documentation Report by R.W. Beck and SAIC, June 2010
- TWG inputs.

Quantification Methods: In order to quantify this recommendation, the first step was to establish capacity and performance characteristics (i.e., heat rate, capacity factor) for Kentucky power stations for the latest year data were available (i.e., 2008). The next step was to rank these units in order of decreasing heat rates. For the coal scenarios (see description in the “Key Assumptions” section below), the units with the highest heat rates comprising capacity of about 800 MW and 1,600 MW were assumed to be replaced with new supercritical coal units, with and without CCS. For the natural gas scenarios, the units with the highest heat rates comprising capacity of about 600 MW and 1,200 MW were assumed to be replaced with new NGCC units, with and without CCS. The next step was to establish cost and performance assumptions for existing and new units. An online year of 2020 was assumed for all scenarios. Costs were compared on the basis of levelized cost.

Key Assumptions: Four scenarios were considered, as follows:

- *Scenario #1:* Replace about 800 MW and 1,600 MW of lowest efficiency with supercritical coal without CCS.
- *Scenario #2:* Replace about 600 MW and 1,200 MW of lowest efficiency with conventional NGCC without CCS.
- *Scenario #3:* Replace about 800 MW and 1,600 MW of lowest efficiency with supercritical coal with CCS.
- *Scenario #4:* Replace about 600 MW and 1,200 MW of lowest efficiency with advanced NGCC with CCS.

Table ES-3-2 summarizes the capacity to be replaced by the new supercritical coal and new NGCC. The orange-shaded cells correspond to the 800 MW (actually 781 MW modeled) and 1,600 MW (actually 1,753 MW modeled) scenarios; the yellow-shaded rows correspond to the 600 MW (actually 593 MW modeled) and 1,200 MW (actually 1,186 MW modeled) scenarios.[5]

Table ES-3-2. Existing Capacity

Capacity Sorted by Heat Rate (Descending Order)				Cumulative			
Nameplate Capacity (MW)	Heat Rate (Btu/kWh)	Generation (GWh)	Fuel use (trillion Btu)	Capacity (MW)	Fuel Use (trillion Btu)	Generation (GWh)	Heat Rate (Btu/kWh)
12	14,759	1.5	0.02	12	0.02	1.5	14,759
32	14,759	4.3	0.06	44	0.09	5.8	14,759
96	14,239	109.1	1.55	140	1.64	114.9	14,265
75	0	0.0	0.00	215	1.64	114.9	14,265
27	11,769	130.8	1.54	242	3.18	245.8	12,936
27	11,769	130.8	1.54	269	4.72	376.6	12,530
81	11,769	392.5	4.62	350	9.34	769.1	12,142
81	11,769	392.5	4.62	431	13.96	1161.7	12,016
81	11,769	392.5	4.62	512	18.58	1554.2	11,953
81	11,769	392.5	4.62	593	23.20	1946.8	11,916
75	11,444	0.0	0.00	668	23.20	1946.8	11,916
114	11,444	0.0	0.00	781	23.20	1946.8	11,916
200	11,303	741.0	8.38	981	31.57	2687.8	11,747
205	11,303	759.5	8.59	1,186	40.16	3447.3	11,649
566	11,253	2995.2	33.71	1,753	73.86	6442.5	11,465

Btu = British thermal unit; GWh = gigawatt= hour; kWh = kilowatt-hour; MW = megawatt.

Table ES-3-3 summarizes the cost and performance characteristics of supercritical coal that were used in the quantification.

[5] The four scenarios are not additive; that is, they are different versions of similar policies. Any combination of two or more of these scenarios will require revised analysis to consider the impact of replacing additional coal units. The scenario selected for inclusion in the all-sector totals is scenario #3.

Table ES-3-3. Supercritical Coal Cost and Performance Characteristics

Parameter	Supercritical Coal	Supercritical Coal with CCS
Size (MW)	550	545
Heat Rate (Btu/kWh)	8,726	12,534
Capacity Factor (%)	85%	85%
Carbon Capture (%)	0%	90%
Capital Recovery Factor	0.115	0.115
Capital Cost (2009$/kW)	$1,655	$5,009
T&D Capital Cost (2009$/kW)	$80	$80
Levelized Fuel Prices (2009$/MWh)	$24.7	$35.47
Fixed O&M (2009 $/kW-yr)	$30.47	$38.51
Variable O&M (2009 mills/kWh)	5.99	9.18
Levelized Costs (2009$/MWh)[6]	$61.57	$128.42

Btu = British thermal unit; CCS = carbon capture and storage; GWh = gigawatt-hour; kW = kilowatt; kWh = kilowatt-hour; kW-yr = kilowatt-year; MW = megawatt; MWh = megawatt-hour.

Table ES-3-4 summarizes the cost and performance characteristics of NGCC units that were used in the quantification.

Table ES-3-4. NGCC Cost and Performance Characteristics

Parameter	Conventional NGCC without CCS	Advanced NGCC with CCS
Size (MW)	540	340
Heat Rate (Btu/kWh)	7,050	7,525
Capacity Factor (%)	75%	85%
Carbon Capture (%)	0%	90%
Capital Recovery Factor	0.115	0.115
Capital Cost (2009$/kW)	$967	$2,036
T&D Capital Cost (2009$/kW)	$80	$80
Levelized Fuel Prices (2009$/MWh)	$52.8	$56.36
Fixed O&M (2009 $/kW-yr)	$14.22	$29.89
Variable O&M (2009 mills/kWh)	3.37	6.37
Levelized Costs (2009$/MWh)	$78.77	$103.2

Btu = British thermal unit; CCS = carbon capture and storage; GWh = gigawatt-hour; kW = kilowatt; kWh = kilowatt-hour; kW-yr = kilowatt-year; MW = megawatt; MWh = megawatt-hour; NGCC = natural gas combined cycle.

[6] Annex 1 to this document presents an overview of the calculation of levelized costs. Annex 2 presents a sensitivity analysis of the capital recovery factor, a component of the levelized cost calculation.

Key Uncertainties

- State of the technology and costs of capture and storage alternatives.
- Approvals of the necessary certificates for regulated or non-regulated entities. Consideration for approval of a supply-side resource that may not be the least-cost alternative at the time of implementation.
- Legal uncertainties for carbon sequestration, including permitting, pore space ownership, property, and mineral rights issues.
- Detailed understanding of the geologic formations across the state and suitability for long-term storage with commensurate liability considerations.
- Ability to gain approvals for this resource in the event a federal or state renewable energy standard is mandated.

Additional Benefits and Costs

- Replacement of older technology will reduce emissions while preserving the utilization of key natural resources that are abundantly available in the state.
- Creation of construction employment opportunities and preservation of full-time employment at the selected site(s) for the advanced fossil-fuel technology and the mining or natural gas industries.
- As indicated previously, this advanced fossil fuel supply-side resource may not be the least-cost alternative at the time of implementation.

Feasibility Issues

Additional supply-side resources must receive approval from the regulatory bodies in the state, based on a case-by-case demonstrated need. Gaining the environmental permits presents significant obstacles that must be overcome, particularly in the carbon sequestration arena.

Status of Group Approval

Approved.

Level of Group Support

Unanimous, with one abstention.

Barriers to Consensus

The two objections are based on the state’s continued investment in and over-reliance on coal and that the costs for this policy are too high.

ES-4. CCSR Enabling Policies, R&D, Infrastructure, and Incentives, Including Enhanced Oil Recovery Using CO_2

Policy Description

Fossil fuels are the primary fuel for electricity generation in Kentucky and in the United States, and will remain so, according to EIA's latest AEO projections.[7] For fossil fuels to operate in a GHG-constrained world, the capture of CO_2 from natural gas- and coal-fueled power plants, and the successful storage or utilization (in a manner permanently preventing its entry into the atmosphere or oceans) of that carbon are necessary. Steps to encourage the development of carbon capture, storage and utilization require a multi-pronged approach.

The Commonwealth has partnered with private utilities and federal agencies in investments in the study of carbon capture technology development at existing power plants. This is one piece of the puzzle. The further characterization of the capacity of the geology in Kentucky to successfully store carbon after capture is also a necessary investment. Kentucky has funded several successful projects to date, but more is needed to be done to facilitate large-scale storage by private entities. The legal and regulatory issues involved around CCS also have to be addressed.

For the purpose of this policy, "utilization" is assumed to mean enhanced oil and gas recovery, and algae fuel development. Utilization of CO_2 for these purposes and other uses has been funded in part, but more work needs to be done in this area as well. Generators of CO_2 may not be located near areas with adequate storage or utilization potential, so transportation issues involved with intrastate and interstate pipelines must also be addressed.

Policy Design

- Develop policy recommendations that address the intrastate and interstate legal and regulatory issues concerning CO_2 storage and transportation.
- Develop funding mechanisms to scale up the carbon capture research presently being done in order to prove feasibility at a larger scale.
- Develop a proposal for a demonstration plant for the integration of a commercialized capture retrofit project for potential federal funding.
- Develop funding mechanisms that will facilitate the further evaluation of carbon storage and utilization potential in the Commonwealth. The policy should address the impacts on efficiency if CCSR technology is applied to existing units, as there will be an associated loss of capacity from those units (parasitic load increases).

[7] U.S. Energy Information Administration. *Annual Energy Outlook 2011*. Available at: http://www.eia.gov/oiaf/aeo/tablebrowser/ - release=AEO2011&subject=0-AEO2011&table=2-AEO2011&region=1-6&cases=ref2011-d020911a.

Goals

- Site a commercial-size (250-MW) retrofit demonstration project for CCS or utilization in the Commonwealth.
- Address the legal and regulatory issues, including pore space ownership and long-term environmental stewardship and risk management.
- Conduct additional studies of the potential for storage and utilization capacity.

Timing

- By 2012, work with CMRG to address the intrastate and interstate legal and regulatory issues, including pore space ownership and long-term environmental stewardship and risk management.
- By 2018, site a commercial-size demonstration project for CCS or utilization in the Commonwealth.

Parties Involved: DOE, Kentucky General Assembly, PSC, KEEC, universities, KGS, and regulated utilities.

Other: Promote education and outreach programs for carbon storage and transportation.

Implementation Mechanisms

- Propose legislation addressing access to pore space for geological storage, permitting for geologic storage, and long-term environmental stewardship and risk management.
- Continued funding of investigation of geologic storage, as well as the potential for enhanced oil and gas recovery.
- Continued funding of projects seeking to increase the viability of, or to reduce the cost and energy penalty associated with, capture of CO_2 at existing power plants.
- Incentives for new fossil fuel power plants with CCS.

Related Policies/Programs in Place

- HB 1 provided funding for carbon storage research wells, one in East Kentucky—one in West Kentucky—as well as wells investigating enhanced oil and gas recovery potential. One deep well in West Kentucky has been constructed in Hancock County by a partnership between KGS, the Commonwealth of Kentucky, and the Kentucky Consortium for Carbon Storage.
- Wells in Hopkins County and Henderson County (both are in West Kentucky) are in progress or are completed to investigate enhanced oil recovery potential, a project led by KGS.
- A Devonian shale well is under development in East Kentucky to investigate enhanced gas recovery potential, a project led by KGS.
- KGS has issued a report on the geological storage potential in Kentucky, based upon existing data.

- The Midwest Regional Carbon Sequestration Partnership has completed the Duke Energy East Bend CO_2 injection test in Northern Kentucky.
- CAER is conducting a three-year investigation of the use of algae for carbon management in coal-fired power plants. This project receives funding from KEEC.
- CMRG, a partnership between CAER and utilities, industry groups, and governments, is focusing on reducing the cost and increasing the feasibility of carbon capture at existing facilities. This partnership receives funding from KEEC.
- A legal issues working group has met and forwarded recommendations regarding the legal issues associated with geological storage of CO_2.
- CO_2 capture and storage projects that are part of a project eligible for Kentucky Incentives for Energy Independence Act (IEIA) tax incentives can offset some of the capital costs.

Type(s) of GHG Reductions

All measures under this policy result in a reduction in the amount of CO_2 emitted per unit of fuel consumed. GHGs reduced are CO_2.

Estimated GHG Reductions and Net Costs or Cost Savings

Table ES-4-1 presents the summary results for the scenario considered in the quantification.

Table ES-4-1. ES-4 Summary Results for CCSR Demonstration Project

Quantified Scenarios	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $/$tCO_2e$ avoided)
	2020	2030	Cumulative through 2030		
CCSR Demonstration Project					
1 plant retrofitted	1.8	1.8	23.5	$893	$37.9
2 plants retrofitted	3.8	3.8	49.9	$1,892	$37.9

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Same as ES-1 for BAU coal generation, 2008 power station inventory, and coal price projection.
- "CO_2 Capture From Existing Coal-Fired Power Plants," NETL, Revised Final Results, December 2007.
- TWG input.

Quantification Methods: In order to quantify this policy, the first step was to establish capacity and performance characteristics (i.e., heat rate, capacity factor) for potential Kentucky power stations to be retrofitted. A 250-MW pulverized coal station of average efficiency was assumed to be retrofitted with CCS, using power plant data from the latest year available (i.e., 2008). The next step was to establish cost and performance assumptions for retrofitting. An online year of 2018 was assumed. Costs were compared on the basis of levelized cost.

Key Assumptions: The key assumptions for the capacity to be retrofitted with CCS are summarized as follows:

- Retrofit 250-MW coal station (average efficiency) with CCS.
- 90% carbon capture.
- Capacity penalty: 16%.
- Energy penalty: 33%.
- Incremental capital cost: $1,400/kilowatt (kW).
- Total incremental cost: $71.2/MWh (capital, fixed O&M, variable O&M, fuel) based on a capital recovery factor of 0.115.[8]

Key Uncertainties

- Cost recovery for CCS projects by utilities will likely not be allowed until there are requirements at the federal level. This delays implementation of these projects.
- The feasibility of large-scale integrated retrofit of an existing power plant has not been demonstrated.
- The price of CCSR at the scale needed to impact the GHG footprint of existing facilities is expected to be high, but must be demonstrated to be feasible without jeopardizing reliability.
- The cost of capture technology and the energy penalty associated with capture may be prohibitive at this time.
- Kentucky has many power plants near state borders. There is no clear indication of how interstate movement of CO_2 in a storage field would be addressed, with differing property rights delineation in each state.

Additional Benefits and Costs

The infrastructure needed to move CO_2 from sources to storage or utilization is significant. No existing pipelines exist and would have to be built at significant cost.

Feasibility Issues

- The cost of CCSR without a mandate would likely not be borne by utilities at this time, because of lack of cost recovery.
- Interstate issues of CO_2 geologic storage must be dealt with by interstate compacts or federal action.
- Public acceptance of CO_2 pipelines or injection has been an issue in other states.

[8] The capital recovery factor of 0.115 was obtained using a range of assumptions about debt/equity ratio, corporate tax level, and other variables. See Annex 2.

Status of Group Approval

Approved.

Level of Group Support

Unanimous, with one abstention.

Barriers to Consensus

The member objecting believes that the costs for GHG reductions in this policy are too high, the technology is not yet proven, that Kentucky is overly reliant on coal and needs to diversify and that coal extraction has other negative environmental impacts.

ES-5. Pricing Strategies to Promote Efficiency and Renewables, Including Net Metering, Feed-In Tariff, Interconnection Rules, Inclined Rates, and Examination of the Standard Rate Structure

Policy Description

Pricing Strategies

Pricing strategies can be used to encourage energy efficiency, conservation and demand response. Such strategies can take many forms and are best implemented by individual utilities working in concert with regulatory bodies to best address the needs of its particular customer group.

Pricing strategies can reduce GHGs in two ways. The first is to encourage conservation. Some pricing mechanisms encourage utilities to facilitate their customers' reduction in consumption, while others encourage customers to reduce consumption directly. Often, a single mechanism cannot encourage both the utility and customer to conserve. The second approach is to reduce peak loads so that more efficient generation and delivery infrastructure can be utilized.

Opportunities exist for utilities to employ more sophisticated rate structures than have been available in the past due to advanced metering. Nevertheless, it must be recognized that such rate structures require advanced metering with a higher cost and necessitates aggressive customer education and acceptance, and the recovery of these costs through customer charges must be allowed by the regulatory agency.

Inclining Block Rates

Inclining block rates as they refer to energy charges are mainly employed for smaller consumers, residential and general service, where the customer group is fairly homogenous and only basic kWh metering is available. For inclining block rates to be effective in encouraging energy efficiency, conservation, or demand response, the higher-use blocks must be significantly more expensive, and at that level may not be cost-based. This can have an adverse economic impact on low-income customers, who often lack the resources to reduce consumption by replacing energy-consuming devices with high-efficiency units, or by modifying housing to promote energy efficiency, conservation, or demand response.

Flat Block Rates

Flat block rates as they refer to energy charges are mainly employed for smaller consumers, residential and general service, where the customer group is fairly homogenous and only basic kWh metering is available. This rate design utilizes only a customer charge and energy charge with the fixed demand component bundled within the energy charge at an average load factor. Although a better alignment of costs with pricing, flat block rates offer no incentive for the customer to modify consumption patterns by either improving efficiency or conserving energy. This rate structure is not well suited to promote energy efficiency, conservation, or demand response unless used as a transitional rate to a more effective time-of-day rate, or when combined with a demand charge.

Time-of-Day Rates

Time-of-day rates are currently directed at larger customers because of the historically higher cost of the required metering. However, with the availability of advanced metering at lower prices, this rate structure may be appropriate for use by a larger number of customers. Customers will have the flexibility to modify consumption patterns, reducing both their cost and their contribution to system peaks with a customer charge, a flat energy charge, and a demand charge divided into appropriate tiers.

This pricing structure is the most advantageous for all types of customers in aligning price with cost, sending the appropriate signal to the customer, and modifying consumption patterns to maximize system efficiency and conservation. Time-of-day rates primarily promote demand response (decrease peak demand). When combined with an aggressive and robust customer education plan, they can also promote energy efficiency and conservation. Such plans should involve all stakeholder groups and include innovative tools for customers to manage their energy use.

To date, these tools are in the development stage; consequently, the use of alternative transitional rate structures may be helpful while the utility is developing the educational information and tools to assist the customer in taking full advantage of time-of-day rate structures. Critical peak pricing may also be effectively combined with traditional time-of-day rates to possibly deliver an excellent cost-based price signal to encourage energy efficiency, conservation, and demand response.

Real-Time Rates

Real-time rates require advanced metering and communication with the customer, with real-time price signals on a real-time basis of minutes, hours, or next day. Directed at larger customers because of the sophistication needed to monitor the pricing and react operationally, they have not been readily accepted by customers. Typically, electric energy billings account for a relatively small portion of commercial/industrial total expenses; hence, customers do not believe the proposed savings justify the effort. While the rate structure is appropriate for large customers, it is not recommended, since customer acceptance is low.

Fixed-Cost Recovery Rates

Fixed-cost recovery rates may take several forms, and are dependent on the proper classification of fixed and variable costs into customer, energy, and demand components. Properly identifying fixed and variable costs and assigning them to the customer classes as customer, energy, or capacity is the starting point. Whatever rate design is chosen and approved by the PSC, it should then follow cost-of-service rates as closely as possible. Customer charges must fully reflect customer cost. Energy charges must be limited as nearly as possible to only reflecting variable cost. Fixed-cost recovery rates can be used very effectively to transition to time of-use rates described above.

Seasonal Differentials and Power Factor Recognition

Other rate considerations include seasonal differentials and power factor recognition. Seasonal differentials are useful in assigning cost, but have little impact on consumption patterns unless used in conjunction with other techniques, such as time-of-day pricing. Power factor recognition, either through kW correction or kilovolt-ampere (kVA) billing, is vital for providing larger customers an accurate price signal.

All rate designs have strengths and weaknesses, and their effectiveness depends upon the characteristics of the rate class to which the rate is being applied. Time-of-day rates are the most appropriate rate to promote energy efficiency, conservation, and demand response, and are recommended when combined with an aggressive and robust customer education plan, involving all stakeholder groups and innovative tools for the customer to manage their energy use. In order to manage customer satisfaction and transition to effective energy efficiency rates, it is recommended that a menu of rate options be available to utilities and the PSC as utilities transition from traditional rate structures to more innovative time-of-use rate structures.

Interconnection Rules and Net Metering

The purpose of interconnection rules and net metering policies is to facilitate the cost-effective interconnection of renewable or distributed energy resources onto the power grid, supporting the expansion of the supply of renewable electricity.

The development of renewable energy sources is one of many avenues that should be considered toward the goal of reducing GHG emissions. The rules for interconnecting new renewable power generators onto the electricity grid can be a hindrance to, supportive of, or neutral to the development of these new generators.

Net metering is an important aspect of interconnection, which has played a critical role in the development of distributed renewable energy. Under net metering, the retail electricity supplier credits renewable power supplied to the grid by an eligible generator. This credit may be crucial to the financial viability of most renewable electricity projects. A net metering law may establish a standard procedure for interconnecting renewable energy systems, thereby removing significant administrative barriers.

It should be noted that net metering is distinctly different from the Qualifying Facilities rules, which govern the interconnection of facilities intending to sell power to the grid. The distinction is important, because net metering exists to serve facilities aiming to meet some or all of their annual electricity demand, rather than those built for the purpose of selling power. Interconnection under net metering is more financially attractive to the customer-generator than the Qualifying Facilities tariffs. Under net metering, the customer's renewable generation is credited at the retail rate. Under Qualifying Facilities, the generator is paid the avoided cost rate, which is less than the retail rate, making net metering a more favorable policy for renewables.

It should also be noted that numerous organizations dedicated to advancing the deployment of renewables have identified net metering and supporting interconnection standards as key facilitating policies. These include (but are not limited to) the Interstate Renewable Energy Council, the Solar Energy Industries Association, and DOE.

Feed-In Tariff

A feed-in tariff (FIT) establishes rates for renewable power and mandates electric utilities to purchase that renewable power under long-term contracts at these above-market rates. FITs are also known as "production-based incentives," because the payments are based on the amount of electricity generated by the facility and recorded on a meter. Many incentive programs, such as tax credits and rebates, pay people for purchasing and installing equipment, but there is no verification that the systems actually generate power. Under FITs, payments are only made for electricity generated onto the grid.

Policy Design

Pricing Strategies

Goals: The goal is to implement time-of-day rates consistent with the timing of ES-2 and ES-11. Modification of consumption patterns resulting in increased system efficiency may be measured through decreased system peaks, increased system load factors, and increased system power factors. Even without a reduction in kWh sales, these impacts may result in a reduction of GHGs, since transmission/distribution losses are related to load exponentially.

Timing: Time-of-day rates should be implemented consistent with the timing of RCI-3 and ES-11.

Parties Involved: Utilities, PSC, Attorney General, customers, community action groups, and other interested parties.

Other: Effective implementation of time-of-day rates depends upon the use of advanced metering infrastructure (AMI) and smart grid technologies recommended in RCI-3 and ES-11.

Interconnection Rules and Net Metering

Goals: The goal of this policy is to establish effective net metering and interconnection rules to facilitate the connection of renewable or distributed energy resources to the grid.

Net metering improvements should be based on the following:

- Change the cap on the size of eligible systems. This will enable large industrial and commercial customers to participate in net metering.
- Adjust the cap on the aggregate total of net metering generation from 1% to 5% of peak demand for each utility.
- Allow third-party ownership of systems eligible for net metering. This will enable customers to lease renewable energy equipment or enter into power purchase agreements for the purchase of renewable power and utilize net metering.
- Allow utility ownership of renewable DG, storage solutions, and/or energy conservation devices "behind" the customer meter, with recovery equal to the cost of new generation capacity.

Timing: The measures to amend the net metering guidelines should be considered by the Kentucky legislature in 2012. For the purpose of analysis, assume the necessary legislation is in place by July 2012.

Parties Involved: Kentucky retail electric suppliers and their customers, renewable energy companies, environmental groups, Attorney General, PSC.

Other: None identified.

Feed-in Tariff

A Kentucky FIT should apply to the following renewable energy technologies: solar, wind, low-impact biomass/biogas, and hydroelectric. The rates paid to renewable energy producers would be established by the PSC for each technology, and would be based on the total cost for generating the power, allowing a reasonable payback period. Utilities would be mandated to purchase power from any renewable energy generator within the state who meets the technical requirements. Residential and small commercial systems would all be eligible to participate.

FITs would be established for each eligible technology, and different rates would be allowable within a class of technology based on size or other factors, where the PSC finds that these differences significantly affect the cost of generating power.

Every two years, the PSC would review the tariffs for each technology and adjust the rates and interconnection guidelines as appropriate. The amount paid for the renewable power would be recovered by the utilities through a surcharge on the customer's monthly bill.

The rates established by the PSC would be binding on municipal utilities, but not on TVA distributors.

Goals: Consistent with strategy 2 of the Kentucky Energy Plan, the FIT would be structured to contribute 5% of Kentucky's total generation in 2025.

Timing: For the purpose of analysis, assume the necessary legislation is in place by July 2012, and the PSC will establish an administrative case to set the guidelines for the FIT within 180 days of the enactment of FIT legislation.

Parties involved: Electric utilities, industrial customers, Attorney General, renewable energy companies, environmental and public interest organizations.

Implementation Mechanisms

Interconnection Rules and Net Metering

Modification of the state's interconnection and net metering rules as described here would require an act of the legislature. The recommended language would specify raising the capacity limit for eligible systems and direct the PSC to open a case to amend the state's net metering and interconnection standards.

Feed-in Tariff

A FIT would be implemented through an act of the legislature. The recommended language would ideally define the broad principles of the FIT and direct the PSC to define the specific parameters of the policy. To achieve full statewide implementation, the FIT would also have to be implemented by TVA for its service territory within Kentucky.

Related Policies/Programs in Place

Utilities are required to allow net metering of electricity up to 30 kW and only up to the customer's usage.

Type(s) of GHG Reductions

This policy encourages the replacement of fossil-fired generation with renewables. Therefore, the GHGs reduced are those associated with combustion, principally CO_2 and NO_x.

Estimated GHG Reductions and Net Costs or Cost Savings

Table ES-5-1 presents summary results for the FIT scenario considered in the quantification.

Table ES-5-1. ES-5 Summary Results for Feed-In Tariff Scenario

Quantified Scenario	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009\$, Present Value)	Cost of Saved CO_2e (2009 \$/tCO_2e avoided)
	2020	2030	Cumulative through 2030		
Pricing Strategies (i.e., feed-in tariff)	1.2	5.2	43.9	$1,206	$27.5

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- FIT levels (cents/kWh) from direct TWG input based on Ontario FIT experience
- FIT renewable generation levels from Council input obtained during Council Meeting #6.
- BAU renewable generation based on the Kentucky ES GHG I&F.

Quantification Methods: The quantification of this policy focused on the FIT. It was premised on the notion that the underlying goal is expressed in strategies 2 and 3 in Kentucky's Energy Plan, which involved obtaining 25% of Kentucky energy from renewables and energy efficiency by 2025. The Energy Plan proposes that 18% will be provided by energy efficiency measures as identified by the RCI TWG, 2% will be offered by biofuels policies as identified by the Transportation and Land Use (TLU) TWG, and the remaining 5% will be provided by renewable generation. To quantify this policy, the first step was to establish the FIT levels. For solar photovoltaics (PV), $0.42/kWh was assumed; for other renewables, $0.10/kWh was assumed. This policy does not advocate carve-outs, but for the purpose of quantification, the next step was to establish any carve-outs for particular resources. A 5% carve-out was assumed for solar PV; that is, 5% of 5%, or 0.25% of the total generation. The next step was to establish incremental renewable generation levels (see the Key Assumptions section below). Costs were compared on the basis of levelized costs[9] between the generation resources displaced in the BAU scenario and the replacement renewable generation through the FIT.

Given that the FIT is analyzed as a component of the 25% Renewable and Energy Efficiency Plan goal, this analysis assumes that the FIT and the other policy components (RCI-3 and TLU-10) are implemented as a group.

Key Assumptions: The incremental renewable generation levels are summarized in Table 5-2. "Non-solar PV renewables" refers to renewable generation other than solar PV that would be introduced as a result of the FIT (i.e., in-state wind, landfill gas, conventional hydro, run-of-river hydro, biomass).[10] It was assumed that coal-fired generation would be displaced by these levels.

Table ES-5-2. Incremental Renewable Generation Levels (GWh)

Renewable Energy Technologies	2015	2020	2025	2030
Solar/Photovoltaic	0	53	221	237
Non-solar PV Renewables	0	1,009	4,205	4,499
Total	**0**	**1,062**	**4,426**	**4,736**

GWh = gigawatt-hours; PV = photovoltaics.

It is important to note that there is renewable generation already assumed in the BAU. When these BAU levels are added to the incremental renewable generation associated with the FIT, the total levels of renewable generation are as summarized in Table ES-5-3.

Table ES-5-3. Total Assumed Renewable Generation (GWh)

Renewable Energy Technologies	2015	2020	2025	2030
BAU Hydroelectric	1,935	2,063	2,203	2,357
FIT Solar/Photovoltaics	0	53	221	237
FIT Non-solar PV Renewables	0	1,009	4,205	4,499
Wind	0	0	0	0
BAU Landfill Gas	111	118	126	135
BAU Biomass	429	458	489	523
Total	**2,475**	**3,700**	**7,244**	**7,751**

BAU = business as usual; FIT = feed-in tariff; GWh = gigawatt-hours; PV = photovoltaics.

Table ES-5-4 summarizes the Kentucky electric system resource portfolio after the introduction of the FIT.

[9] Annex 1 to this document presents an overview of the calculation of levelized costs. Annex 2 presents a sensitivity analysis of the capital recovery factor, a component of the levelized cost calculation.

[10] Based upon the biomass availability assessment shown in table AFW-2, and assuming biomass contributes 100% of the non-solar PV renewables in ES-5, there is sufficient biomass in Kentucky to meet all ES demands (ES-1, ES-7, and ES-5) for all years, except for 2021, 2022, and 2030. In 2021, the expected shortfall is 0.8 million dry tons of biomass, in 2022 it is 0.5 million dry tons, and in 2030 it is 0.1 million dry tons. Since non-solar PV renewables includes resources other than biomass, the ES-5 generation target can be achieved in all years without violating constraints on biomass availability.

Table ES-5-4. Total Generation (GWh) and Renewables Share after the Feed-in Tariff (%)

Resource Portfolio	2015	2020	2025	2030
Fossil Resources (coal, NG, other gases, oil, other)	124,808	131,983	137,632	147,263
Renewable Resources without FIT (hydro, LFG, biomass)	2,475	2,639	2,818	3,015
FIT Solar/Photovoltaics	0	53	221	237
FIT Non-solar PV Renewables	0	1,009	4,205	4,499
Total	**127,284**	**135,684**	**144,876**	**155,014**
Renewable Share of Total Generation (%)	**1.9%**	**2.7%**	**5.0%**	**5.0%**

FIT = feed-in tariff; GWh = gigawatt-hours; LFG = landfill gas; NG = natural gas; PV = photovoltaics.

Key Uncertainties

Interconnection Rules and Net Metering

Implementation of these policy changes are straightforward and follow the path many other states have already taken. There are no significant uncertainties affecting the implementation of these policies.

Feed-in Tariff

In 2010, the National Renewable Energy Laboratory (NREL) published a report examining the question of potential legal barriers to the implementation of FITs in the United States. Federal PURPA law limits the ability of utilities to pay above wholesale rates for electric supplies. The NREL report pointed to a number of strategies whereby FITs can be implemented without challenging these federal laws. These legal issues remain a significant uncertainty for FIT policies in the United States. As many states and jurisdictions are pursuing FIT policies, there are many people seeking to resolve these uncertainties. In 2010, NREL published a policymaker's guide to FITs, which addresses this issue, as well.[11]

Additional Benefits and Costs

Interconnection rules and net metering supporting the expanded use of renewable energy will result in economic development in the renewable energy sector.

FIT policies have been documented to stimulate dramatic increases in investment in renewable energy infrastructure in regions that have implemented them. This has resulted in substantial increases in related employment. FITs would also ensure within-state development of renewable energy and DG, which brings numerous societal benefits. This contrasts with other policies, such as an RPS, which may not necessarily promote in-state development of renewables at the same scale.

[11] U.S. Department of Energy, National Renewable Energy Laboratory. *A Policymaker's Guide to Feed-In Tariff Policy Design*. Technical Report NREL/TP-6A2-44849. July 2010. Available at: http://www.nrel.gov/docs/fy10osti/44849.pdf.

Feasibility Issues

Interconnection Rules and Net Metering

Implementation of these policy changes are straightforward and follow the path many other states have already taken. There are no technical barriers affecting the feasibility of these actions.

Feed-in Tariff

The feasibility of FIT policies being successfully implemented hinges on the answers to how to craft a FIT policy that would fit within the legal limits of federal law, and what the ability of the Kentucky General Assembly is to pass FIT legislation within the current political climate. Opponents to FIT policy may argue that it could raise the price of electricity, and members of the General Assembly may be adverse to this potential outcome.

This analysis projects the cost and effectiveness of these policy recommendations applied throughout the Commonwealth, including the regions served by TVA. TVA is not under the jurisdiction of the PSC or the Kentucky Legislature, Therefore, to achieve the full benefits of these policies, TVA and its distributors would have to adopt the same or similar policies and apply them in their Kentucky service territory.

Status of Group Approval

Approved.

Level of Group Support

Unanimous, with one abstention.

Barriers to Consensus

None.

ES-6. New Nuclear Energy Capacity

Policy Description

Nuclear power has historically been a low-GHG source of electricity. However, no new commercial reactor has come on line in the United Sates since 1996, due to high capital costs, the absence of a repository or technology for permanent disposal of nuclear waste, and pubic concerns for safety. The federal government has been supportive of nuclear expansion, emphasizing its importance in maintaining a diverse energy supply and its reputation for producing electricity with negligible pollutant emissions during operation. Congress has also offered significant financial subsidies for new nuclear plants, in an effort to jump-start the industry.

Steps to encourage nuclear power options in the state would have to begin with the removal of the statutory ban against constructing a nuclear plant in Kentucky (KRS 278-605 and 610). Steps could also include providing a streamlined siting review and streamlined appeals process and enacting policies to reduce the risk to capital. The state could serve as a facilitator in developing a new nuclear facility, recognizing the cost and financing burdens such a facility could impose on existing state companies. Small-scale nuclear options could also be considered.

Policy Design

Develop policy recommendations to encourage the licensing and construction of baseload nuclear power plants in Kentucky. State-level legislative and regulatory approaches are needed to overcome barriers and facilitate construction of new nuclear plants.

Goals: Install 2,000 MW of nuclear generation in Kentucky.

Timing: Remove barriers and improve regulatory approaches in 2012, and install baseload operating units by 2025.[12]

Parties Involved: Kentucky General Assembly, PSC, Nuclear Regulatory Commission (NRC), KEEC, regulated utilities, municipal utilities, TVA, and energy company consortia.

Other: Promote programs to develop job opportunities in the construction and operation of nuclear units.

Implementation Mechanisms

- For this policy to be implemented, the statutory ban on construction of a nuclear power plant would need to be removed during the 2012 session of the General Assembly.
- DEDI should support the siting of potential nuclear power plants in compliance with NRC requirements and maintain a list of potential sites.

[12] As noted under Key Uncertainties, the lead time required for siting, design, permitting, and construction of a new nuclear generation facility could be longer than the date proposed here.

- DEDI or other appropriate state agency should develop an effective and consistent oversight program that could include permitting consistent with federal timelines, providing needed infrastructure, and working with local communities and interest groups to ensure the potential concerns are identified early and that involved parties are fully informed of the considerations for siting and operations.
- State utilities should incorporate the nuclear power option into the IRP process for selection of new generating unit types. Small or modular nuclear reactor designs should be considered, as well as gigawatt-scale reactors.
- The state should create a program of incentives that reduce the risk of capitalizing and financing new nuclear power plants that include rate recovery of a portion of construction costs prior to operation (construction work in progress), and tax incentives.
- The state should develop and implement a public engagement plan to gather and address stakeholder feedback and concerns.
- The state should work with vocation training institutes in Kentucky to ensure that trained personnel are available to staff the construction and operation of nuclear power plants and work with state universities to support the nuclear engineering and related degreed fields necessary to support nuclear generation.
- Energy companies should consider joint ownership of nuclear generators.
- Companies or organizations that are considering nuclear power should be approached about locating in Kentucky.

Related Policies/Programs in Place

DEDI has published the Kentucky Alternative Energy Site Bank Evaluation. It evaluated 41 industrial sites in Kentucky for suitability of various energy projects, including nuclear generation (http://energy.ky.gov/Documents/2009FinalReportSiteBankIII.pdf).

Type(s) of GHG Reductions

Nuclear generation would displace fossil generation. GHGs reduced are those associated with combustion, predominantly CO_2 and NO_x.

Estimated GHG Reductions and Net Costs or Cost Savings

Table ES-6-1 presents summary results for the nuclear generation capacity scenario considered in the quantification.

Table ES-6-1. Summary Results for ES-6

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $/t$CO_2e$ avoided)
		2020	2030	Cumulative through 2030		
ES-6	New Nuclear Energy Capacity	0.0	19.5	116.7	$2,480	$21.3

$/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Same as ES-1 for BAU coal generation, 2008 power station inventory, and coal price projection.
- AEO 2011 assumptions and a new fixed charge factor assumption of 0.115.
- TWG input.

Quantification Methods: To quantify this policy, the first step was to establish capacity and performance characteristics (i.e., heat rate, capacity factor) for Kentucky power stations for the latest year data for which were available (i.e., 2008). The next step was to rank these units in order of decreasing heat rates. The units with the highest heat rates comprising capacity of about 2,000 MW were assumed to be replaced with a new nuclear power station. The next step was to establish cost and performance assumptions for existing and new units. An online year of 2025 was assumed. Costs were compared on the basis of levelized cost relative to three different cost estimates.

The ES TWG recognizes that the costs for nuclear plant construction in the United States have historically experienced significant overruns driven by delays and financing charges. However, for consistency across baseload ES policies (including ES-3), the nuclear cost assumptions for ES-6 have been taken from a study performed by R.W. Beck and SAIC for EIA in June 2010 and adjusted based on AEO 2011 assumptions.

Key Assumptions: It was assumed that the nameplate capacity of the nuclear power plant is 2,000 MW. Table ES-6-2 summarizes the capacity to be replaced by the new nuclear power plant. The orange-shaded cells correspond to the characteristics of the capacity modeled.

Table ES-6-2. Capacity Sorted by Heat Rate

Capacity Sorted by Heat Rate (Descending Order)				Cumulative			
Nameplate Capacity (MW)	Heat Rate (Btu/kWh)	Generation (GWh)	Fuel Use (trillion Btu)	Capacity (MW)	Fuel Use (trillion Btu)	Generation (GWh)	Heat Rate (Btu/kWh)
12	14,759	1.5	0.02	12	0.02	1.5	14,759
32	14,759	4.3	0.06	44	0.09	5.8	14,759
96	14,239	109.1	1.55	140	1.64	114.9	14,265
75	0	0.0	0.00	215	1.64	114.9	14,265
27	11,769	130.8	1.54	242	3.18	245.8	12,936
27	11,769	130.8	1.54	269	4.72	376.6	12,530
81	11,769	392.5	4.62	350	9.34	769.1	12,142
81	11,769	392.5	4.62	431	13.96	1161.7	12,016
81	11,769	392.5	4.62	512	18.58	1554.2	11,953
81	11,769	392.5	4.62	593	23.20	1946.8	11,916
75	11,444	0.0	0.00	668	23.20	1946.8	11,916
114	11,444	0.0	0.00	781	23.20	1946.8	11,916
200	11,303	741.0	8.38	981	31.57	2687.8	11,747

Capacity Sorted by Heat Rate (Descending Order)				Cumulative			
Nameplate Capacity (MW)	Heat Rate (Btu/kWh)	Generation (GWh)	Fuel Use (trillion Btu)	Capacity (MW)	Fuel Use (trillion Btu)	Generation (GWh)	Heat Rate (Btu/kWh)
205	11,303	759.5	8.59	1,186	40.16	3447.3	11,649
566	11,253	2995.2	33.71	1,753	73.86	6442.5	11,465
293	11,121	1817.0	20.21	2,046	94.07	8259.5	11,389

Btu = British thermal unit; GWh = gigawatt-hour; kWh = kilowatt-hour; MW = megawatt; MWh = megawatt-hour.

One scenario was considered using the capital cost and performance characteristics in the R.W. Beck/SAIC study cited earlier (adjusted based on AEO 2011 assumptions), except for fuel costs, which are not provided in the source and have been assumed to be $1.0/MMBtu over the planning period and a capital recovery factor of 0.115. This assumption replaces the three-scenario approach used for initial explorations. The cost and performance characteristics of nuclear units that were used in the quantification are summarized in Table ES-6-3.

Table ES-6-3. Nuclear Unit Cost and Performance Characteristics

Cost and Performance Characteristics	AEO 2011
Size (MW)	2,236
Heat Rate (Btu/kWh)	10,453
Capacity Factor (%)	90%
Capital Recovery Factor	0.115
Capital Cost (2009$/kW)	$5,275
T&D Capital Cost (2009$/kW)	$80
Levelized Fuel Prices (2009$/MWh)	$10.45
Fixed O&M (2009 $/kW-yr)	$87.69
Variable O&M (2009 mills/kWh)	2.0
Levelized Costs (2009$/MWh)[13]	$110.7

AEO = Annual Energy Outlook; Btu = British thermal unit; GWh = gigawatt-hour; kW = kilowatt; kWh = kilowatt-hour; kW-yr = kilowatt-year; MW = megawatt; MWh = megawatt-hour; O&M = operations and maintenance.

Key Uncertainties

- The state of the technology and costs of construction, including cost overruns.
- Uncertainty concerning the ultimate fate of spent fuel, including the lack of a federal depository and the potential that on-site storage will become a utility or state responsibility.
- Approvals of the necessary certificates for regulated or non-regulated entities. Consideration for approval of a supply-side resource that may not be the least-cost alternative at the time of implementation.
- The ability to gain approvals for this resource.

[13] Annex 1 to this document presents an overview of the calculation of levelized costs. Annex 2 presents a sensitivity analysis of the capital recovery factor, a component of the levelized cost calculation.

- Whether the proposed operational date of 2025 can be achieved, given the lead time needed for design, siting, permitting, construction, etc.
- The ability to remove the Kentucky statutory prohibition against nuclear construction prior to a permanent federal nuclear waste repository (KRS 278.605).
- The level of public opposition to nuclear power historically evident in coal states.
- The ES TWG recognizes that the costs for nuclear plant construction in the United States have historically experienced significant overruns driven by delays and financing charges. However, for consistency across baseload ES policies (including ES-3), the nuclear cost assumptions for ES-6 have been taken from AEO 2011.

Additional Benefits and Costs

- Replacement of older technology will reduce emissions.
- Creation of construction employment opportunities and preservation of full-time employment at the selected site(s).
- Nuclear power can provide large amounts of baseload power with high capacity factors—85%–95%—with minimal CO_2 emissions.
- The potential need for Kentucky to develop and license an in-state low-level waste disposal facility to manage the increased volume of these wastes might increase the cost of this policy.

Feasibility Issues

- Additional supply-side resources must receive approval from the regulatory bodies in the state based on a case-by-case demonstrated need. Gaining the environmental permits presents significant obstacles that must be overcome.
- Availability of capital to build a gigawatt-class nuclear unit.
- Questionable public acceptance of new nuclear generation facilities.

Status of Group Approval

Approved.

Level of Group Support

Majority, with one abstention and four objections.

Barriers to Consensus

The members opposed to this policy stated that they believe the cost represented by the analysis is unrealistically low. Objectors argued that cost overruns have always been a major part of constructing nuclear power plants in North America, with the average cost overrun being 207%. Two objectors also preferred to mention that this resource may not be the least-cost alternative at the time of this policy’s implementation. The majority disagreed and chose not to include this language on the basis that this same statement would apply to all ES policies, not just ES-6.

ES-7. Renewable Energy Incentives and Barrier Removal, Including CHP

Policy Description

Renewable Portfolio Standard

Renewable portfolio standards (RPS) require utilities to meet a portion of their electricity demand with electricity generated with renewable resources. Twenty-nine states and the District of Columbia have enacted some form of portfolio standard. Kentucky's Energy Plan sets a target of 16% efficiency and 1000 MW of renewable electricity by 2025.

An RPS, with an energy efficiency component, will mandate the use of renewable sources of electricity and may stimulate energy efficiency programs. It is extremely difficult to increase the use of renewable electricity to the state energy profile without a legislative mandate. The cost of generating electricity from renewable resources is typically higher than from conventional resources, such as coal. The levelized energy cost (LEC) of a coal-fired power plant may be as low as $.03/kWh, whereas the LEC for solar electricity could be as high as $0.30/kwh. This is important, because the PSC must approve the procurement of renewable electricity and cost recovery for utilities within its jurisdiction. If a utility can generate or purchase the electricity at a lower cost, the PSC must approve the acquisition of electricity above this cost.

RPS policies vary across the states that have adopted them, and Kentucky should review its own renewable opportunities and craft an RPS that best suits the state. For example, Kentucky's Energy Plan cited that residential electricity use was 24% above the national average in 2006. The opportunity exists to use electricity more efficiently. A Kentucky portfolio standard could incorporate efficiency mandates. Additionally, the Executive Task Force on Biomass and Biofuel Development determined that Kentucky has an opportunity to meet a percentage of energy demand with biomass, and can develop energy crops and a supply chain that will facilitate their development and use.

Additionally, a policy should not discourage distributed sources of renewable electricity, because such sources can provide benefits. Distributing solar energy throughout a region that has adequate sun could reduce the demand for electricity at the source. Distributed renewable systems can sometimes use existing transmission and distribution (T&D) lines. A Kentucky portfolio standard should allow for deployment of distributed sources of renewable electricity.

In addition to establishing demand for renewable electricity through a portfolio standard, Kentucky should consider support for locally or at least regionally supplied renewable resources. Since Kentucky has significant potential to grow biomass for energy, policies could be derived that ensure supply is available to meet the standard set by the legislature. A portfolio standard is just one part of the equation; supply must also develop.

Hydroelectric Development

Licensing and siting barriers are associated with the development of hydroelectric power plants. Federal Energy Regulatory Commission (FERC) licensing can take 2–5 years. Siting is specific to the resource and the availability of dams, since constructing new dams is controversial. Kentucky currently has 783 MW of installed hydroelectric capacity in the state. According to the Hydroelectric Assessment prepared by Idaho National Laboratory, Kentucky has a potential of approximately 900 MW. Within this potential is approximately 265 MW of power associated with facilities already under construction, and 42 MW of power associated with sites that are not already dammed.

It is possible to address the economic barrier that exists. Currently IEIA already includes hydroelectric facilities as eligible projects for tax incentives, provided they generate 1 MW of power or more and incur a $1 million investment.

New hydro capacity and improvements to existing hydro plants that result in added capacity should qualify as a renewable energy resource under a state portfolio standard.

Combined Heat and Power

Combined heat and power (CHP) and waste heat recovery are systems that enable a consumer to make better use of waste heat or thermal energy associated with industrial processes or power production. Several barriers exist to increasing these systems. One of the biggest barriers is the spark spread, which is the difference between the cost of fuel for the CHP system to produce power and heat on site and the offset cost of purchased grid power. A second barrier is the use of standby charges, which are set to reflect the costs associated with generating the electricity if a CHP system fails to generate its agreed-upon amount of electricity.

Barrier Removal

The large-scale development (1 MW and greater) of grid-based and distributed renewable energy resources could offer benefits and opportunities for Kentucky.

Financial, educational, and regulatory barriers exist to the large-scale development of renewable energy resources in Kentucky. Effective policies are needed to remove these barriers and provide adequate incentives.

Financial Barriers

Renewable technologies entail high capital costs, but for some (wind, solar, hydro), no recurring fuel costs. Financial incentives are needed to offset the low cost of the current conventional energy system and to provide to the investor the financial return necessary to invest in the higher capital costs of renewable technologies.

On a per unit of electricity basis, renewable electricity typically costs more than electricity generated from existing coal plants in Kentucky. Environmental regulation and energy policy (such as taxing carbon) could increase the cost of power from those plants, but it will take a substantial increase to make some forms of distributed renewable electricity cost-effective.

Other financial barriers are the up-front cost of large-scale, distributed renewable electricity systems and the cost to finance those systems.

Specifically related to solar power, a financing model—the Third-Party Partnership Model—was developed to address these barriers and to efficiently use federal tax credits available for solar power. An entity, such as a school, hosts a large solar system (500 kW-1 MW) and purchases the electricity from that system. A solar developer serves as the broker and receives the solar renewable electricity credits that are sold. The third party provides the upfront capital, and in return receives income from the electricity sales and reduced tax liability associated with the renewable energy tax credits.

Implementing this model is difficult, since regulated electric utilities have the exclusive right to sell power in their service territory. The host may, therefore, be required to purchase electricity from the utility that serves its area, and not from the solar project. This barrier could be removed by allowing a host to purchase the renewable electricity up to a specific system size. This financing model is especially important when financing distributed energy projects for entities without tax liability, such as schools.

Educational Barriers

There is a great need of education among the public and decision makers about renewable energy and its availability in Kentucky. The large-scale development of distributed renewable energy must engage a much larger segment of the population in the generation of power than is presently the case. A broad, intensive, and long-term educational campaign is needed to educate the citizenry about energy fundamentals and renewable energy.

Regional Renewable Energy Planning Group

Kentucky presently has very little renewable energy generation, and the question of the state's true potential for generating renewable power remains a subject of debate. Each state has its own unique, local resources (natural, human, infrastructural, economic) and its own particular needs. A Regional Renewable Energy Planning Group would invite each of Kentucky's neighboring states (and perhaps others from the region) to work together to find opportunities to solve common problems, to share resources and knowledge, and to cooperate in the common goals of cutting GHG emissions and developing a thriving renewable energy economy.

Policy Design

Renewable Portfolio Standard

Goals: Enact a portfolio standard that incorporates efficiency and renewable electricity resources.

- The standard would require sellers of electricity to obtain the following percentages of electricity from renewable energy resources or from energy efficiency improvements:
  - 2011–2013: 3%
  - 2014–2016: 6%
  - 2017–2018: 9%

- 2019–2020: 12%
- 2021–2039: 15%

Timing: For the purpose of analysis, assume the necessary legislation is in place by July 2011.

This policy, along with policies that ensure local supply of renewable resources, must be timed to coincide in such a way that the local resource is available to meet the standard at each benchmark year. If local resources are not available, renewable electricity will likely be purchased from other states.

Parties Involved: PSC, customers, energy developers, energy auditors and contractors, existing hydroelectric permit holders, potential hydroelectric developers, utilities, Cabinet for Economic Development, the CAER at the University of Kentucky, consumers with CHP or waste heat recovery systems.

Other

- *Hydroelectric Generation*—Properly define hydroelectric resources within the state portfolio standard to ensure efficiency improvements that increase capacity are included, despite the fact that changes are being made to an existing plant.
- *CHP*—Properly define CHP *and* waste heat recovery within the state portfolio standard to ensure that the systems could contribute to a utility's compliance with any part of the standard (efficiency, renewable—if powered by a renewable resource).

Barrier Removal

Goals: Three strategies are called for to address the barriers described above.

- *RPS or FITs*—The establishment of either an RPS or FITs has been found to be a mechanism for promoting the development of renewable energy.
- *Third-Party Partnership Model*—Enable the benefits of the Third-Party Partnership Model for distributed renewable energy systems by allowing the host entity to purchase the generation from on-site systems.
- *Renewable Energy Education Program*—A well-funded, long-term statewide education program needs to be developed to educate the general population and decision makers about energy fundamentals and renewable energy. This program would also address conservation and energy efficiency and enable customers to better understand where their energy comes from, what their options are for using less energy and lowering energy costs, and how to become renewable energy generators. This program could be funded by a systems benefit charge (SBC).

Timing: For the purpose of analysis, assume the necessary legislation is in place by July 2011.

Parties Involved: These policies would be implemented through an act of the legislature. Electric utilities, PSC, Center for Renewable Energy Research and Environmental Stewardship (CRERES), the Conn Center at the University of Louisville (which manages CRERES), the CAER at UK, Attorney General, Kentucky's industrial and manufacturers' associations (they would have positions on any changes to the PSC and creation of the SBC and the FIT), renewable energy businesses, environmental and public interest organizations. All energy consumers, including residential, low-income, seniors, commercial, and industrial.

Other: None identified.

Regional Renewable Energy Planning Group

- Identify opportunities for interstate collaboration to meet needs for renewable energy and GHG emission reduction.
- Identify barriers to transmission of renewable power across the region (and into/out of Kentucky) (FERC issue).
- Identify opportunities for sharing the economic benefits and costs of renewable energy development.
- Develop solutions to common problems related to renewable energy development and GHG emission reductions.

Goals: This sub-policy does not have specific quantifiable goals at this point.

Timing: The Regional Renewable Energy Planning Group would be initiated in 2011, and would continue meeting so long as its activities were fruitful.

Parties Involved

- States invited would include Kentucky, Ohio, Indiana, Illinois, Missouri, Tennessee, North Carolina, Virginia, and West Virginia.
- DEDI personnel (Renewable Energy staff).
- Representatives from electric utilities, local and regional renewable energy businesses.
- Local and regional environmental and public interest organizations.
- Energy consumer organizations, the Attorney General, Kentucky Industrial Utilities Customers, etc.
- Oak Ridge National Laboratory.

Other: None identified.

Implementation Mechanisms

This type of policy would need to be established in statute by the General Assembly.

Related Policies/Programs in Place

There are complementary policies in place, such as the net metering law that allows owners of renewable energy systems to pay for the difference between the electricity they generate and the electricity they produce. There are also incentives for renewable energy generators of residential, commercial, and utility-scale systems. Additionally, Kentucky's Energy Plan provides goals for energy efficiency and renewable energy capacity.

Type(s) of GHG Reductions

Renewable energy incentives seek to displace fossil generation with renewables. GHG reductions are the products of combustion, principally CO_2 and NO_x.

Estimated GHG Reductions and Net Costs or Cost Savings

Table ES-7-1 presents summary results for the four renewable energy incentives quantified.

Table ES-7-1. ES-7 Summary Results for Four Renewable Energy Incentive Scenarios

Quantified Scenarios	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $/$tCO_2e$ avoided)
	2020	2030	Cumulative through 2030		
Scenario 1 (mixed renewable)[14]	15.1	22.2	263.6	$5,489	$20.6
Scenario 2 (biomass)	15.1	22.3	272.2	$4,368	$16.0
Scenario 3 (out-of-state wind)	15.1	22.3	272.2	$3,012	$11.1
Scenario 4 (solar photovoltaics)	15.1	22.2	271,0	$8,157	$30.1

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Same as ES-1 for BAU coal generation, 2008 power station inventory, coal price projection, biomass fuel price, and co-firing cost and performance.
- Wind resource availability based on NREL-generated wind resource map for Kentucky.
- In-state and out-of-state wind cost and performance assumptions based on TWG input.
- Centralized solar PV and conventional hydro cost and performance assumptions from AEO 2011.
- Hydrokinetic cost and performance assumptions from Electric Power Research Institute (EPRI) report entitled: "System Level Design, Performance, Cost and Economic Assessment—Alaska River In-Stream Power Plants" (2008).
- Levelized capital recovery factors from La Capra report entitled: "New York Renewable Portfolio Standard Cost Study Update: Main Tier Target and Resources" (2008).

Quantification Methods: In order to quantify this policy, the first step was to establish the type of generation that would be displaced by new renewable generation. It was assumed that coal generation would be displaced. The next step was to establish the resource mix among specific technologies that would comprise annual incremental renewable generation relative to the phase-in schedule described in the policy. The next step was to establish cost and performance

[14] Scenario 1 Mixed Renewables was selected by the Council in their meeting on February 2, 2011 to be used for the analysis of ES and all-sector Action Plan policy results.

assumptions for each of the resources included to meet the policy goals (capital, fixed/variable O&M, fuel, and transmission costs were incorporated into the analysis). Costs were compared on the basis of levelized cost for the various sources. Coal steam (95%) and natural gas combustion turbine (NGCT—5%) were assumed for intermittent renewable back-up, as needed. During ramp-up and ramp-down for back-up power, a heat rate penalty of 15% was assumed.

Key Assumptions: The total renewable generation (i.e., renewable energy in the BAU scenario plus incremental renewable generation from the policy) as a percentage of total utility generation prior to any energy efficiency reductions:

- 2011–2013: 3%
- 2014–2016: 6%
- 2017–2018: 9%
- 2019–2020: 12%
- 2021–2030: 15%

There are several potential mixes of incremental renewable generation (i.e., the amount that is over and above the renewable generation in the BAU scenario) that may serve Kentucky well toward meetings its goals. For this reason, the costs and benefits of this policy were analyzed from a scenario perspective. Specifically, four scenarios were considered as described below.

- *Mixed renewable scenario:* Assumes a mix of renewable resources.
- *Biomass scenario:* Assumes aggressive use of in-state biomass resources in dedicated biomass and co-firing applications; in-state wind generation kept to *de minimis* levels.
- *Wind scenario:* Assumes aggressive use of out-of-state wind resources; in-state wind generation kept to *de minimis* levels.
- *Solar PV scenario:* Assumes aggressive use of solar PV; in-state wind generation kept to *de minimis* levels; balance obtained from out-of-state wind resources.

Incremental renewable generation assumptions for each of the four ES-7 scenarios analyzed are summarized in Tables ES-7-2 through ES 7-5. For the years 2011–2014, incremental renewable generation levels in all scenarios are assumed to be zero.

Table ES-7-2. Mixed Renewable Scenario Incremental Generation (GWh)

Renewable Energy Technologies	2010	2015	2020	2025	2030
Energy Efficiency (as supply-side resource)	0	0	0	0	0
Landfill Gas	0	0	0	0	0
Conventional Hydropower	0	507	1,014	1,800	2,178
Hydrokinetic (in-river)	0	100	200	200	300
Municipal Waste	0	0	0	0	0
Geothermal	0	0	0	0	0
Pumped Storage	0	0	0	0	0
Wood and Other Biomass	0	3,331	9,121	10,734	11,000

Renewable Energy Technologies	2010	2015	2020	2025	2030
Biomass Co-firing	0	1,156	2,000	4,000	4,182
Solar Photovoltaic	0	0	679	1,154	1.363
In-State Wind	0	69	172	293	430
Out-of-State Wind	0	0	0	0	0
Total Incremental Generation	**0**	**5,163**	**13,186**	**18,181**	**19,453**

GWh = gigawatt-hour.

Table ES-7-3. Biomass Scenario Incremental Generation (GWh)

Renewable Energy Technologies	2010	2015	2020	2025	2030
Energy efficiency (as supply-side resource)	0	0	0	0	0
Landfill Gas	0	0	0	0	0
Conventional Hydropower	0	500	676	1,000	1,000
Hydrokinetic (in-river)	0	150	200	300	300
Municipal Waste	0	0	0	0	0
Geothermal	0	0	0	0	0
Pumped Storage	0	0	0	0	0
Wood and Other Biomass	0	3,918	9,224	11,000	11,000
Biomass Co-firing	0	0	2,000	4,000	4,182
Solar Photovoltaic	0	160	200	250	250
In-State Wind	0	43	87	130	173
Out-of-State Wind	0	392	800	1,501	2,548
Total Incremental Generation	**0**	**5,163**	**13,187**	**18,181**	**19,453**

GWh = gigawatt-hour.

Table ES-7-4. Wind Scenario Incremental Generation (GWh)

Renewable Energy Technologies	2010	2015	2020	2025	2030
Energy Efficiency (as supply side resource)	0	0	0	0	0
Landfill Gas	0	0	0	0	0
Conventional Hydropower	0	338	676	1,452	1,452
Hydrokinetic (in-river)	0	100	200	300	300
Municipal Waste	0	0	0	0	0
Geothermal	0	0	0	0	0
Pumped Storage	0	0	0	0	0
Wood and Other Biomass	0	447	447	447	447
Biomass Co-firing	0	0	2,000	4,000	4,182
Solar Photovoltaic	0	100	200	250	250
In-State Wind	0	43	87	130	173
Out-of-State Wind	0	4,134	9,576	11,419	12,649
Total Incremental Generation	**0**	**5,163**	**13,186**	**18,180**	**19,453**

GWh = gigawatt-hour.

Table ES-7-5. Solar PV Scenario Incremental Generation (GWh)

Renewable Energy Technologies	2010	2015	2020	2025	2030
Energy Efficiency (as supply side resource)	0	0	0	0	0
Landfill Gas	0	0	0	0	0
Conventional Hydropower	0	1,000	1,000	1,452	1,452
Hydrokinetic (in-river)	0	100	200	300	300
Municipal Waste	0	0	0	0	0
Geothermal	0	0	0	0	0
Pumped Storage	0	0	0	0	0
Wood and Other Biomass	0	447	447	447	447
Biomass Co-firing	0	1,000	2,000	4,182	4,182
Solar Photovoltaic	0	1,000	2,000	3,000	3,000
In-State Wind	0	43	87	130	173
Out-of-State Wind	0	1,573	7,452	8,669	9,898
Total Incremental Generation	**0**	**5,163**	**13,186**	**18,180**	**19,453**

GWh = gigawatt-hour.

Total utility/non-utility renewable generation (GWh) in the BAU scenario is summarized in Table ES-7-6. Cost and performance characteristics are summarized in Table ES-7-7.

Table ES-7-6. Total Utility/Non-utility BAU Renewable Generation (GWh)

Resource	2007	2015	2020	2025	2030
Hydroelectric	1,669	1,935	2,063	2,203	2,357
Geothermal	0	0	0	0	0
Solar/PV	0	0	0	0	0
Wind	0	0	0	0	0
Landfill gas	93	108	116	123	132
Biomass	0	0	0	0	0

BAU = business as usual; GWh = gigawatt-hour; PV = photovoltaics.

Table ES-7-7. Cost and Performance Characteristics

Parameter	Wind		Solar Photovoltaic	Conventional Hydro	Biomass Co-firing	Hydro-kinetic	Dedicated Biomass (Fluidized Bed)
	In-State	Out-of-State					
Size (MW)	50	50	5	500	580	5	75
Heat Rate (Btu/kWh)	N/A	N/A	N/A	N/A	11,500	N/A	9,483
Capacity Factor (%)	28%	35%	14%	50%	85%	29%	90%
Capacity Credit (%)	20%	100%	80%	100%	100%	100%	100%
Levelized Costs (2009$/MWh)[15]	$100	$82	$393.7	$76.7	$71.8	$212.8	$99.4

Btu/kWh = British thermal units per kilowatt-hour; MW = megawatts; MWh = megawatt-hour; N/A = not applicable.

[15] Annex 1 to this document presents an overview of the calculation of levelized costs. Annex 2 presents a sensitivity analysis of the capital recovery factor, a component of the levelized cost calculation.

Back-up power requirements associated with intermittent renewable generation in order to meet electric demand during peak periods for each of the four scenarios are summarized in Table ES-7-8.

Table ES-7-8. Backup Power Requirements to Meet Electric Demand during Peak Periods

Quantified Scenarios	Coal Steam (GWh)				NGCT (GWh)			
	2015	2020	2025	2030	2015	2020	2025	2030
Scenario 1 (mixed renewable scenario)	31	152	258	342	2	8	14	18
Scenario 2 (biomass scenario)	42	61	85	104	2	3	4	5
Scenario 3 (out-of-state wind scenario)	42	61	85	104	2	3	4	5
Scenario 4 (solar PV scenario)	130	260	390	409	7	14	21	22

GWh = gigawatt-hour; NGCT = natural gas combustion turbine; PV = photovoltaics.

Key Uncertainties

- Cost of providing the renewable electricity and meeting the efficiency targets.
- TVA is not required to implement state policies. TVA could choose to implement similar policy measures.
- Methods for measuring compliance with the efficiency target (how will the utilities demonstrate the target has been met?).
- On January 12, 2011, EPA issued a three-year deferment on the inclusion of GHG emissions from biogenic sources from regulation under the EPA GHG Tailoring Rule that went into effect on January 2, 2011. While this is positive to the operational costs of projects currently utilizing biomass feedstocks, the continued uncertainty may impact the increased utilization of biomass feedstocks.

Additional Benefits and Costs

Additional benefits include economic development opportunities if renewable resources are developed in state. Specifically, jobs could be created to develop the renewable resources. Additionally, demand for renewable resources could spur manufacturing opportunities. Jobs would be created to work toward energy efficiency targets. Customers who take advantage of energy efficiency programs and incentives that may be created in response to this policy will likely see a decrease in their electricity bills. In addition to GHGs, pollution, such as SO_2 and nitrogen dioxide could be reduced by developing renewable resources. Customers may pay more per kWh for electricity derived from renewables.

Feasibility Issues

There are no feasibility issues at this time.

Status of Group Approval

Approved.

Level of Group Support

Super-majority, with one abstention and one objection.

Barriers to Consensus

The objection was based on a recognition that this policy may not be needed due to upcoming federal regulations in the Clean Air Transport Rule.

ES-8. Technology Research and Development (Not Including CCSR or Wind Potential Study)

Policy Description

Kentucky has historically benefited from low-cost energy supplies due to the state's bountiful supply of fossil fuel resources. However, with increasing environmental pressures on the utilization of these resources, it is imperative that the state develop a broader portfolio of environmentally feasible technologies for energy production. Technology research, development, and demonstration RD&D) must play a critical role in the development of economically feasible solutions for Kentucky's future.

Kentucky, historically, has invested heavily in research and development (R&D) for fossil fuels. This policy will develop a roadmap for expanding the research into renewable energy sources, energy efficiency technologies, distributed/grid-scale storage, carbon-free fuel generation, and pyrolysis of municipal solid waste, and will provide for large-scale demonstrations, as well as smaller deployments in residential or commercial applications. The policy should enable development of Kentucky-specific roadmaps for implementation of renewable energy generation and conservation technologies.

One area of particular interest is the demonstration of solar electric generation. While PV technology has been around for many years, it is only recently that its prices have begun to come down to the point that PVs are being installed as part of utilities' generation mix. In other parts of the country, PVs are now being installed on a utility scale. While PV prices are not yet competitive with cheaper generation currently in use in Kentucky, it is important that utilities gain some experience now with this technology, so adoption will be easier as PV prices come down and fossil fuel costs rise. Utilities need to gain experience with how to interconnect and integrate utility-scale PVs into their systems. This will help to quantify the benefits of this technology that will help utilities provide valuable power during expensive summer peak periods. Another area of related interest is with utility-scale/substation-scale energy storage to enable adaptation of solar electricity and peak-demand management.

Policy Design

Goals

- A comprehensive roadmap for the ultimate deployment of solar electricity, renewable energy storage, solar fuels, wind, biofuels, and other renewable energy forms within the Commonwealth should be developed. The roadmap should identify areas of basic and/or applied research required for ultimate deployment of the technologies. In addition, demonstration projects should be identified.
- A directed research effort for each technology gap identified in the roadmap should be formulated. Research opportunity notices should be periodically be issued.
- Where technologies are sufficiently mature, demonstration and/or pilot projects to bring the technologies to commercial readiness should be facilitated.

- DEDI should develop funding mechanisms for RD&D projects.
- DEDI should develop communication plans regarding these technologies.
- For analysis of this policy recommendation, the following assumptions should be used: Install five utility-scale PV power plants of at least 1 MW each, with one of the plants being at least 5 MW. Each of the major utilities in Kentucky should be targeted as partners in installing these plants. Subsidies need to be supplied to bring the cost of these pilot plants down to the point where they are cost competitive for the participating utilities. These pilot plants may be installed directly by the utility, or by an independent power producer working with a utility, in the utilities service territory.

Timing

- *December 2012*—Publish a comprehensive renewable energy roadmap.
- *January 2013*—Issue R&D notices.
- *February 2013*—Issue demonstration project notices.
- *March 2013*—Announce first-round funding for demonstration projects.
- *April 2013*—Announce first-round funding for R&D projects.
- *2013*—Parties, including utilities and others, should form a working group to identify potential projects and project locations. This group should also quantify the level and source of subsidies needed for each demonstration project, and work on securing these funds.
- *2014*—Install the first of the 5 demonstration projects.
- *2015*—Install the remaining 4 demonstration projects.
- *2016 and beyond*—Take data from these projects that will aid in the installation of future utility-scale PV plants.

Parties Involved: Parties involved in the implementation of this policy include state legislative bodies and government offices, PSC, utilities and other energy suppliers, universities and other research entities, CRERES.

Implementation Mechanisms

DEDI is currently organized to implement this policy. The first aspect of implementation is to identify a panel of leading experts in each research area to assist in the development of the renewable roadmap.

Funding mechanisms for the R&D efforts would have to be identified or created. These mechanisms could include direct appropriations from the legislature, loans for demonstration projects, or the institution of an R&D surcharge on utility services. In addition, rate recovery for the larger projects should be allowed.

Related Policies/Programs in Place

University of Kentucky Renewable Energy Initiative

Type(s) of GHG Reductions

ES-8 reductions are associated with a series of solar PV demonstration projects that will displace fossil generation. GHGs reduced will be the products of combustion, principally CO_2 and NO_x.

Estimated GHG Reductions and Net Costs or Cost Savings

Table ES-8-1 presents summary results for ES-8.

Table ES-8-1. ES-8 Summary Results

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $/tCO_2e$ avoided)
		2020	2030	Cumulative through 2030		
ES-8	Technology R&D; Solar PV Demonstrations	0.01	0.01	0.24	$39.6	$164.9

$/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; MMtCO_2e = million metric tons of carbon dioxide equivalent; PV = photovoltaics; R&D = research and development.

Data Sources: Same as previously indicated.

Quantification Methods: To quantify this policy, the first step was to establish the type of generation that would be displaced by the new solar PV generation. It was assumed that coal generation would be displaced. The next step was to establish cost and performance assumptions for solar PV to meet the policy goals (capital, fixed/variable O&M, fuel, and transmissions costs were incorporated into the analysis). Costs were compared on the basis of levelized cost. The penetration was low enough that generation from NGCTs was not needed for backup generation.

Key Assumptions: The following assumptions were made:

- 4 centralized solar PV installations of 1 MW each.
- 1 centralized solar PV installation of 5 MW.
- The same cost and performance assumptions as used in ES-7.

Key Uncertainties

The key uncertainties for the implementation of this policy are the sources of funding for RD&D projects and utility cost recovery mechanisms.

Additional Benefits and Costs

- Benefits over and above those quantified for the solar demonstration will be the development of renewable technologies to further reduce GHGs and improve technology efficiencies, and the development of new technologies.
- With respect to the solar PV demonstration component, an important additional benefit is the experience that utilities in Kentucky will gain with respect to interconnection, dispatch, and impact of system peaks. Once utilities can quantify the benefit of shaving summer peak loads, it will be easier to calculate the benefit of these systems in a cost-benefit analysis.

- If solar PV manufacturing plants were built in Kentucky, it could bring additional manufacturing jobs and revenues to the Commonwealth.

Feasibility Issues

- The primary obstacle to the implementation of a state-sponsored R&D effort will be the allocation of funding. The development of the R&D roadmap should include a mapping of the desired research projects to federal, industrial, and other funding programs.
- Cost recovery for R&D projects, such as the solar demonstration project described herein, will be an issue for the successful implementation of a program involving utilities in Kentucky.
- With respect to solar PV manufacturing, two aspects are essential: (1) the availability of a local solar PV market; and (2) the manufacturing R&D expertise and personnel needed.

Status of Group Approval

Approved.

Level of Group Support

Unanimous, with one abstention.

Barriers to Consensus

None.

ES-9. Policies to Support Wind Energy

Policy Description

Kentucky does not currently have any wind farms built or under development, despite the fact that most U.S. states have at least one utility-scale wind project. Kentucky's lack of development is most likely attributed to a weak wind resource, low electricity prices, and lack of a renewable energy mandate.

Despite lack of development, Kentucky's wind resource continues to be a subject of debate. Fueling this debate is the recent publication by the National Renewable Energy Lab (NREL) of new wind resource maps and corresponding data, which are intended to establish an onshore resource potential for each state. Prior to the release of these maps, Kentucky relied on older versions of the map that assumed wind turbines would be built at a lower hub height than what is currently being developed. The new NREL maps show more wind capacity in Kentucky at a 100-meter hub height; however, that capacity is not at a capacity factor high enough to be considered by industry for economic development. The current industry standard for development is a minimum of a 30% capacity factor.

While the wind maps and calculations by NREL are helpful in understanding U.S. wind resources, they lead to additional questions and the need for more data. Specifically, the maps were developed using a model that was then validated with actual data points. NREL has not collected wind speed data throughout Kentucky. Some states, such as Michigan, have taken the process a step further by installing wind speed instruments on tall towers to further validate the wind maps and better characterize the resource.

Kentucky could see wind farm development in the future. The Commonwealth has good transmission system lines (69 kilovolts [kV] and up) across the state that might serve a distributed network of wind farms. While other states may have higher wind speeds, some of the sparsely populated sites are far from electric transmission. Additionally, wind turbine hub heights are increasing, thereby taking advantage of higher wind speeds, and Kentucky might also benefit from machines with longer blade lengths that are suitable for lower wind speeds.

If Kentucky is to develop wind capacity, it needs to better understand the resource. The state should collect wind data to further validate or identify bias within the wind map. The data should be published and may be used when crafting policies.

Policy Design

Goals

- *Spring 2012*—Convene a Statewide Wind Working Group, consisting of experts from government, utilities, independent power producers (IPPs), and universities, to identify funding sources, tower locations, and an entity to manage and ensure the wide dissemination of the data.

- *Summer–Fall 2012*—Identify 10 potential wind sites around Kentucky, for placement of meteorological towers. Locations should have good wind potential, as per the NREL studies, should have the potential for large development of multiple units with good potential construction access, and should be located within a reasonable distance of a transmission line. Whenever possible, equipment should be installed on existing structures to reduce cost. Areas deemed by NREL to have less certain wind speed, such as along ridge lines, should also be targeted for wind data collection sites.
- *Fall–Winter 2012*—Quantify the cost of monitoring, and acquire the funds necessary to install the monitoring equipment and towers. Arrange for NREL to accommodate the data and make revisions to Kentucky's wind potential if possible and if needed.
- *Spring 2013–Summer 2014*—Install equipment and collect and process data. Towers would collect wind speed data at an elevation appropriate to extrapolate information about wind speeds at 100 m and 120 m.
- *Spring 2013–Summer 2014*—Identify turbine designs that are best suited for Kentucky's resource and landscape.
- *Fall 2014*—Disseminate monitoring results to utilities, independent power producers, and the general public who might be interested in smaller installations in the general areas.
- *Spring 2013–Fall 2014*—Identify and work on state policy and legislative changes necessary for large-scale wind implementation, provided the data indicate a need for this resource. Complete an economic impact analysis based on the data to include levelized energy cost, impact on tax revenue, jobs, and electricity rates. Based on the findings of the analysis, the working group will recommend next steps, which may include specific goals for installed capacity.

Timing: See above.

Parties Involved: Participants in the Statewide Wind Working Group would include experts from government, utilities, IPPs, independent transmission organizations, and universities.

Other: None identified.

Implementation Mechanisms

A Statewide Wind Working Group, consisting of experts from government, utilities, IPPs, and universities should convene to identify funding sources, tower locations, and an entity to manage and ensure the wide dissemination of the data.

Related Policies/Programs in Place

Having a better understanding of wind speeds in Kentucky could play a major role in the adoption of an RPS (ES-7) and FITs (ES-5). If lawmakers and utilities have a better understanding of how much wind potential there is in Kentucky, they will have a better idea regarding how much this resource can be relied upon when setting goals and policies.

A number of parties in Kentucky are already monitoring wind speed. East Kentucky Power Cooperative and Iberdrola are collecting data at a few sites in Kentucky at utility-scale turbine heights, and Kentucky Mesonet is collecting wind data at lower tower heights at about 50 locations. Working and coordinating with these existing monitoring programs might result in earlier implementation of systematic high-elevation wind monitoring at a lower cost.

Type(s) of GHG Reductions

ES-9 does not directly reduce GHGs, as it is a research policy. However, if the outcome of the research is the development of in-state wind farms then the indirect reductions will be the products of combustion, principally CO_2 and NO_x.

Estimated GHG Reductions and Net Costs or Cost Savings

While this policy is considered to be non-quantifiable, per se, as it involves a number of wind-related research activities, it is important to note that it will help to support and promote these new levels of wind generation in Kentucky that are associated with other policies in this Climate Action Plan. These other policies will lead to new levels of wind generation in Kentucky—nearly a third of the total potential, as summarized in Table ES-9-1.

Table ES-9-1. Summary of In-State Wind Generation

ES Policy	New Wind Generation in Kentucky (GWh)						GHG Reductions in 2030 from Wind ($MMtCO_2e$)
	2007	2010	2015	2020	2025	2030	
ES-7	0	0	43–69	87–172	130–293	173–430	0.02–0.05

For ES-7 (Renewable Energy Incentives and Barrier Removal, Including CHP), the ranges reported in the table are based on the four scenarios considered under that policy recommendation.

GHG = greenhouse gas; GWh = gigawatt-hour; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources: Not applicable.

Quantification Methods: Not applicable.

Key Assumptions: Not applicable.

Key Uncertainties

The key uncertainty is the source and amount of the funding needed for the proposed study.

Additional Benefits and Costs

The primary benefit is the understanding of the wind resource. It is possible that data could reveal that the wind resource is limited. The benefit is the ability of this information to influence policy. If there is a strong wind resource, that information will support wind development. If there isn't a strong resource, policymakers may work to develop other renewables. Knowledge that shapes policy and investment is the benefit.

Another benefit beyond simply gathering data, determining actual wind speeds at locations around Kentucky may jump-start wind development in Kentucky, by showing the viability of specific locations to potential developers, including the state's utilities.

The latest wind maps estimating wind speeds at higher elevations show improved potential in other areas of the state. However, development in these areas would see projects with higher than traditional capital costs, due to larger (taller) turbine requirements.

Feasibility Issues

Funding is the only issue. The equipment exists to implement this policy. Landowners, universities, or contractors could manage and analyze the data. It all comes down to finding the necessary funding.

There are no technical obstacles to the implementation of this policy. Considering the consensus among government agencies, utilities, and environmental groups that this study needs to be done, this should make finding funding more feasible.

One feasibility issue of importance will be who shares and who benefits from the cost of policy implementation. For funds already contributed to a data collection effort the question remains: Will these costs be recoverable from the "group" if data are shared?

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

ES-10. Shale Gas Development and Natural Gas Transportation Infrastructure and Natural Gas Liquids Technology

Policy Description

The Shale Gas policy is intended to help stimulate increased shale gas production and development in Kentucky. Increased Kentucky production will provide more natural gas supply as an alternative fuel to help reduce overall GHG emissions. Additional production could provide additional severance tax revenues to the state. Additional production could also have some impact on national supply/demand balance, and thus could have some—although probably limited—impact on natural gas prices.

The Natural Gas Transportation Infrastructure policy is intended to help provide for the development of a natural gas filling station infrastructure across Kentucky. This will help to replace oil-based fuels and will thus reduce GHG emissions from vehicles.

The Natural Gas Liquids (NGL) policy is intended to provide for the development of liquid fuels from natural gas. This will help to replace oil-based fuels and will reduce GHG emissions. There are two possible options for NGL fuels. The first is cryogenically liquefied natural gas (LNG), and the second is liquids removed from natural gas.

Diesel-fueled heavy vehicles converted to run on LNG offer four advantages: lower GHG emissions, lower emissions of air pollutants, significantly reduced cost compared to diesel, and reduced dependence on foreign oil. Liquids removed from natural gas prior to introducing it into a pipeline are higher-value products and can also help reduce consumption of oil-based fuels. Both of these alternatives should be pursued as part of Kentucky's energy strategy. This strategy contemplates the development of NGL capacity, which would produce an LNG fuel for heavy trucks.

These vehicles utilize natural gas, a domestic fuel that can help to lessen U.S. dependence on imported fuels. They can all help to stimulate Kentucky's economy and create jobs in the state, while continuing to develop Kentucky's natural gas reserves. Additionally, they can provide energy alternatives that help to reduce Kentucky's GHG emissions and also reduce the state's and the country's carbon footprint.

Policy Design

Goals: The goal for the Shale Gas policy is to provide for increased development of natural gas from shale formations, with an increase from the current annual production level of approximately 100 billion cubic feet per year (bcf/yr) to an annual level of 150 bcf/yr by 2020, through increased drilling as well as enhanced drilling methods.

The goal for the Natural Gas Transportation Infrastructure policy is to provide for the development of a statewide network of compressed natural gas (CNG) filling stations, in order to (1) have natural gas filling stations in all cities with populations greater than 10,000 by 2020, and

(2) facilitate the increased use of natural gas as a vehicle fuel, to support the deployment of 11,700 CNG vehicles by 2020.

The goal for the NGL policy is to provide for the development of liquid fuel from natural gas, so that such fuel could be used in 2,000 heavy vehicles by 2016 instead of oil-based fuels currently used, such as gasoline or diesel fuel. Also, a secondary goal is to provide liquids removal capacity to accommodate the 50% additional shale production goal by 2020. Removing more liquids from the natural gas produced in Kentucky will alleviate liquids issues in pipelines, and thus allow Kentucky production to be more easily marketable into interstate pipelines. The marketability of such liquids could provide additional revenues to producers, gas processors, and the state.

Timing: All policies are needed, and implementation should proceed on an expedited basis.

Parties Involved

- The Shale Gas policy would apply to all future drilling in Kentucky, and would involve natural gas producers as well as financial institutions (in support of funds for the investments) and state agencies overseeing permits, etc.
- The Natural Gas Transportation Infrastructure policy would involve natural gas distribution companies, the PSC, and the Transportation and Energy Cabinets.
- The NGL policy would involve natural gas producers, natural gas distribution companies, and natural gas transportation pipelines and midstream processing entities, and would support new activity in cryogenically liquefying and distributing LNG.

Other: The Natural Gas Transportation Infrastructure policy should include evaluation of the natural gas transmission and distribution infrastructure in Kentucky to determine suitable available capacity for this program.

Implementation Mechanisms

Shale gas development should be encouraged by state action to ease the regulatory, permitting, and lag time for new well development and completion. The legislature should consider tax or other incentives to stimulate this development.

Natural gas transportation infrastructure should be developed by planning and building CNG filling stations in cities of 10,000 people or more and along interstate highways in Kentucky. Funding for the station network should be sought from federal funds, and/or the legislature should consider tax or other incentives or providing funding. Consideration should be given to efforts in other states, such as Utah.

NGL efforts would involve natural gas producers selling their natural gas for conversion to liquid fuel, or for liquids removal and sale, and corresponding development of production facilities. This may require legislative action to provide incentives to producers and/or plant operators, especially if product market prices are not advantageous to producers and operators.

Related Policies/Programs in Place

None noted.

Type(s) of GHG Reductions

Principally CO_2 through the use of lower carbon natural gas in place of petroleum-based fuels.

Estimated GHG Reductions and Net Costs or Cost Savings

Summary results for ES-10 are given in Table ES-10-1.

Table ES-10-1. ES-10 Summary Results

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $/tCO_2e$ avoided)
		2020	2030	Cumulative through 2030		
ES-10	Natural Gas Transportation Infrastructure and Shale Gas Development Policies	0.013	0.028	0.271	$22.3	$82.5
	Natural Gas Liquids Technology	.039	.078	.763	$137.3[16]	$179.9

$/tCO₂e = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

Natural Gas Infrastructure Policy

Data for the inputs were taken from various sources:

- Data regarding carbon intensities and coefficients of fuels for the transportation sector, vehicle purchase costs, and projected new-vehicle fuel efficiency for both CNG and gasoline vehicles, were taken from Argonne National Laboratory's (ANL's) VISION model, which maintains extensive and detailed projections of fleet and fuel characteristics through the year 2100. These values are themselves derived from DOE AEO 2009 and 2010 projections and EPA's GREET tool, which is used to develop full fuel-cycle carbon emission profiles of fuels depending on location of source, feedstock, distribution pathway and tailpipe emissions.
- Data regarding fueling station cost were taken from the Los Angeles County Sanitation District's pilot program for CNG fueling station installations: http://www.lacsd.org/info/energyrecovery/alternativerenewablevehicle/jwpcpcompressed.asp.

Natural Gas Liquids Policy

In addition to the vehicle and energy resources listed for the Natural Gas Infrastructure Policy, the following were utilized for this strategy:

[16] This analysis did not take into consideration additional capital costs. Fuels produced in this scenario are assumed to be collected via infrastructure established in the Infrastructure and Shale Gas Development Policies strategy. Other fixed and variable costs were applied. See the Quantification Methods section for a full explanation.

- Center for Energy Economics, University of Texas at Austin's Jackson School of Geosciences. "Introduction to LNG: An Overview on Liquefied Natural Gas (LNG), Its Properties, Organization of the LNG Industry and Safety Considerations." January 2007. Available at: http://www.beg.utexas.edu/energyecon/lng/documents/CEE_INTRODUCTION_TO_LNG_FINAL.pdf.

Shale Gas Policy

- Data regarding natural gas consumption and fleet size, as well as projections of same, were taken from DOE and ANL projections as contained in the VISION models for 2009 and 2010. These values are freely available on the DOE and ANL Web sites.
- Cost estimates for developing horizontal wells were taken from sources at the Geosciences Department at Penn State University as well as Chesapeake Energy.[17] The two estimates were rounded to a 2005$ cost of $1,000,000 per well, with operating costs of approximately $1.00 per million cubic feet. Typical reserves for horizontal wells were assumed to be 2.5 bcf per well.[18]

Quantification Methods

Natural Gas Infrastructure Policy

Per the policy design of the ES TWG, the scenario involves the installation of 70 CNG fueling stations in cities around Kentucky by 2030. This value represents an average of just over two stations in each community with a population above 10,000, though the TWG considered that stations would most likely be concentrated in larger cities and along highway corridors.

Station service capacity, in volumes of fuel supplied per year, was used in combination with the projected fuel efficiency of new CNG vehicles and their projected annual vehicle miles of travel (VMT) to determine the fleet supported by the 70 stations. Each station was determined to support approximately 430 light-duty CNG vehicles (assuming a mix of light trucks and autos equivalent to Kentucky's light-duty fleet projections).

The new infrastructure was assumed to be put into place gradually, following a linear ramp-up of three or four new stations per year and reaching a total of 70 stations in 2030. Additional light-duty vehicles (LDVs) powered by CNG fuel were assumed to enter the market, only after fueling capacity for LDVs was established, and LDVs were expected to come online gradually. New LDVs were assumed to enter the market such that the size of the CNG-powered fleet consistently lagged two years behind the maximum capacity that the fueling infrastructure could support.

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[17] Terry Engelder, Professor Geosciences Penn State, http://live.psu.edu/story/28116, and Chesapeake Energy, Jim Gipson, quoted in http://www.popularmechanics.com/science/energy/coal-oil-gas/4318390.

[18] See: http://seekingalpha.com/article/68716-investing-in-the-marcellus-shale.

Table ES-10-2. Station and Fleet Growth Assumptions

Year	Number of Stations	Fleet Capacity Supported (431 per station)	Actual Fleet Growth Assumption	Gas Gallons Displaced (approximate)
2011	3	1,293	259	120,000
2012	7	3,017	862	399,900
2013	10	4,310	1,724	799,800
2014	14	6,035	2,931	1,359,800
2015	17	7,328	4,397	2,039,700
2016	21	9,052	5,948	2,759,700
2017	24	10,346	7,414	3,439,700
2018	28	12,070	8,966	4,159,700
2019	31	13,363	10,432	4,839,700
2020	35	15,088	11,984	5,559,700
2021	38	16,381	13,450	6,239,700
2022	42	18,105	15,001	6,959,700
2023	45	19,399	16,467	7,639,700
2024	49	21,123	18,019	8,359,700
2025	52	22,416	19,485	9,039,700
2026	56	24,141	21,037	9,759,700
2027	59	25,434	22,503	10,439,700
2028	63	27,158	24,054	11,159,700
2029	66	28,452	25,520	11,839,700
2030	70	30,176	27,072	12,559,700

GHG savings were determined through the above-mentioned carbon coefficients for gasoline and CNG, along with volumes of fuel determined to be used (CNG) or displaced (gasoline). Fuel costs and savings were also determined similarly.

Note that the additional fuel supply for this policy was assumed to come from the Shale Gas policy (see below). Because these two policies are assumed to work in concert (one providing the fuel and the other distributing the fuel), the two are reported together as a single policy for the purpose of GHG reduction impact and program cost.

<u>Natural Gas Liquids Policy</u>

This analysis contemplates the production of LNG fuel.

From the sources cited above, costs for plant operations were estimated as follows: processing and distribution costs were estimated at $3.70 per million Btu produced in 2005 dollars, per the estimates of researchers at the University of Texas at Austin.[19] Capital costs were assumed to be borne by pre-existing investments in natural gas infrastructure.

Fuel volumes were determined from the fleet mandates in this strategy. This approach involved using the projected fuel efficiency of heavy-duty vehicles and the projected VMT per year of heavy-duty trucks to be fueled by this fuel supply. This produced a projection of a fuel volume of approximately 31 million gallons in 2020, and 59 million gallons in 2030.

Table ES-10-3. LNG Strategy Fuel Requirement

Year	HDVs Fueled	Projected Annual VMT per HDV[20]	Projected Fleet-wide Average HDV MPG (using LNG fuel)	Gallons of LNG Required
2016	2,000	39,717	3.93	20,215,667
2020	3,143	41,125	4.12	31,419,750
2025	4,571	42,038	4.25	45,182,000
2030	6,000	42,297	4.33	58,695,667

HDV = heavy-duty vehicle; LNG = liquefied natural gas; MPG = miles per gallon; VMT = vehicle miles traveled.

Shale Gas Policy

The Shale Gas policy seeks to increase in-state production of natural gas from in-state reserves from 100 bcf/yr to 150 bcf/yr by 2020. By 2020, the energy content of this additional natural gas supply would be equivalent to that of approximately 411 million gallons of gasoline.

A number of factors make it unlikely that the vast majority of this new supply of natural gas will displace gasoline or diesel during 2011–2030:

- Current DOE projections for annual natural gas consumption as a transportation fuel in the entire United States reach approximately 90 million gallons per year, which is just below 20% of the amount this policy seeks to produce.
- DOE AEO projections for the natural-gas-powered fleet (which serve as a baseline for this analysis) indicate expectations of only modest growth: the fleet, currently numbering approximately 120,000 vehicles nationwide, would reach only 160,000 vehicles in 2030. The Natural Gas Infrastructure policy (above) would add 27,000 vehicles in Kentucky, representing a 60% increase in the entire nation's projected growth rate.
- Under the Natural Gas Infrastructure policy, Kentucky will put into place the capacity to distribute 1.53 bcf of natural gas by 2030, leaving the vast majority of newly produced shale gas without a distribution pathway through which it could enter the transportation-fuels market.

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[19] Center for Energy Economics, Jackson School of Geosciences, University of Texas at Austin. "Introduction to LNG." Retrieved August 3, 2011, from http://www.beg.utexas.edu/energyecon/lng/documents/CEE_INTRODUCTION_TO_LNG_FINAL.pdf.

[20] VMT and fleet-wide average mile-per-gallon estimates developed by ANL based on projections from DOE/EIA 2010 *Annual Energy Outlook*.

As a consequence of the small size of the market for natural gas as a fuel to displace gasoline or diesel, along with the projection of insignificant growth in demand for CNG as a transportation fuel in the absence of this policy, this analysis assumes that any supply not consumed pursuant to the Natural Gas Infrastructure policy will be directed to the energy sector, and cannot be assumed to achieve GHG reductions. Table ES-10-4 presents the volume assumptions developed with regard to amounts of natural gas directed to the transportation and energy sectors.

Table ES-10-4. Assumed Distribution of Natural Gas Produced in the Shale Gas Scenario (bcf)

Scenario Production Level	Natural Gas Supplied Through New Infrastructure	Remainder Directed to Energy Sector
5	0.0146	4.9854
10	0.0487	9.9513
15	0.0973	14.9027
20	0.1655	19.8345
25	0.2483	24.7517
30	0.3359	29.6641
35	0.4187	34.5813
40	0.5063	39.4937
45	0.5891	44.4109
50	0.6767	49.3233
50	0.7595	49.2405
50	0.8471	49.1529
50	0.9299	49.0701
50	1.0175	48.9825
50	1.1003	48.8997
50	1.1879	48.8121
50	1.2707	48.7293
50	1.3583	48.6417
50	1.4411	48.5589
50	1.5287	48.4713

bcf = billion cubic feet.

The volumes directed to transportation and to energy supply should be considered as upper bounds, because they do not assume any energy content loss during the processes of compression or liquefaction. Significant inefficiencies in those processes would reduce the amount directed toward the energy supply, but would not increase the amount displacing petroleum fuels, and thus would not increase the GHG reductions from this strategy.

Because this policy is assumed to direct a total of 14.75 bcf to the transportation sector over the 2011–2030 period, the costs of six wells were applied. The overall policy, seeking to produce 50 bcf/yr, would require over 300 wells over the period if the 2.5-bcf-per-well reserve estimate proves accurate.

Key Assumptions: See above.

Key Uncertainties

- Long-term market for gas liquids as supply increases.
- Number of vehicles converted or built to run on natural gas.
- Timing of any nationwide-imposed carbon constraints.
- Price of oil versus natural gas as input to vehicle fuel prices.
- Finding commercially producible natural gas.
- Gas well mechanical and treatment failures.

Additional Benefits and Costs

- Less dependence on foreign oil.
- Increased natural gas production increases economic development and jobs.
- Increased severance tax revenues.
- Reduced air pollution.
- Longer-lasting equipment.

Feasibility Issues

- Regulatory approvals/rules that might hinder vehicle conversions.
- Availability of drilling equipment and workforce.
- Timing of infrastructure build-out for filling stations.
- Timing of conversions of vehicles to run on natural gas.
- Availability of capital.

Status of Group Approval

Approved.

Level of Group Support

Super-majority, with one objection and one abstention.

Barriers to Consensus

None.

ES-11. Smart Grid, Including Transmission and Distribution Efficiency

Policy Description

The term "smart grid" has taken on wide range of meanings. Smart grid can be divided into two functional areas: customer load and use management, and T&D monitoring and control. Application of each can result in increased electrical efficiency, utilization, operational efficiency, reliability, or electricity load management. Each of the functional areas relies on advanced monitoring, controls, data analysis, and communications.

Kentucky's electric utilities are in various stages of deploying advanced metering infrastructure (AMI), or electric meters that are able to record consumption and other data hourly or more frequently, and are capable of two-way communication with a central location. The meters are also capable of communicating with equipment within the customer's premises. In addition to allowing customers to control their own usage more effectively, AMI enables various pricing strategies (specifically time-of-day rates and other approaches identified in ES-5, Pricing Strategies) designed to effectively implement energy efficiency, conservation, and demand response programs that can reduce GHG emissions. Successful implementation of AMI and key features of the Smart Grid are required to enable the pricing strategies recommended in ES-5.

T&D monitoring and control are other areas where energy losses and service improvements can be gained. Enhanced voltage monitoring and control, real-time ambient condition monitoring, and automated switching are examples of "smart technologies." Also, installation of higher-efficiency transformers and conductors can reduce energy losses in the delivery systems. T&D equipment is characterized by long-life assets, but replacements, when needed, should be with higher-efficiency designs over time. Distribution equipment is already subject to revised, higher-efficiency DOE standards, and higher-efficiency distribution transformers may not be cost-effective at this time.[21]

Installation of smart grid technologies will enable other technologies, such as integration of intermittent or distributed generation.

This policy should be designed to accelerate the deployment of smart grid technologies and electricity delivery efficiency improvements. Current legislation and/or regulations require utilities to provide service in a least-cost manner. Those requirements for least cost would have to be modified to accomplish the objectives of this policy.

Some studies have shown the use of prepay meters in conjunction with in-home displays to be an effective pricing strategy to reduce energy consumption. With prepay meters, customers pay in advance to "load up" their electric meter for the amount of money they want to budget for electricity. They utilize an in-home display to monitor their use and money left on the meter. Some utilities that have experience with prepay meters report that the approach tends to

[21] Report from Howard Industries, October 14, 2009. Available at: http://www.neppa.org/presentations/DOEFinalRule.pdf.

encourage customers to seek from the utility conservation and weatherization assistance. There continues to be a valid concern that this type of service would disadvantage low-income customers and result in service termination during critical periods of heat or cold. These concerns would have to be addressed in a prepay meter tariff or policy.

Policy Design

Goals

- Achieve 25% coverage for AMI by 2015, 50% by 2020, and 100% by 2025.
- Replace transmission infrastructure (transformers and conductors) with higher-efficiency equipment as projects are implemented. Reduce transmission losses by 10% by 2030.
- Replace distribution infrastructure (transformers and conductors) with higher-efficiency equipment as projects are implemented. Reduce distribution losses by 10% by 2030.

T&D losses are typically around 5%, so a 10% reduction in the losses would be 0.5% reduction of the net generation.

The use of a prepaid meter program should be studied to determine whether and the extent to which conservation and efficiency gains associated with prepaid meter programs are greater than those of AMI with in-home display. Any prepaid meter program should be designed to encourage conservation and efficiency for all customers and should not be targeted at low-income ratepayers. The programs should be completely voluntary, and customers should not be coerced into participating. Programs must provide similar hardship protections to customers as those provided to customers under traditional pricing mechanisms, such as protection against winter disconnection and access to heating assistance (both the subsidy and the crisis components of the Low Income Home Energy Assistance Program).

Timing: See above.

Parties Involved: These policies would apply to all electric utilities and will require enabling legislation, in the form of funding mechanisms and/or PSC authority for special rate treatment. Affected parties include electric utilities (PSC regulated, TVA distributors, and municipally owned) and customers.

Other: Pricing signals and active participation from customers will be necessary for end-use reduction. A renewable and efficiency standard would encourage grid enhancements as a means to meet the efficiency standard.

Implementation Mechanisms

Implementation mechanisms for AMI deployment include customer education programs, tax incentives for smart appliances, examination of regulatory recovery models, and identification of consumer value from implementation. Kentucky could provide financial incentives that support customer education regarding the benefits and use of AMI and Smart Meters. As end-use reduced consumption from pricing signals is predicated on consumer behavioral changes, it is necessary to educate consumers about the benefits and use of AMI/Smart Meters to gain their acceptance.

Related Policies/Programs in Place

Electricity pricing structure directly impacts the benefits of AMI deployment. Several smart grid grants have been awarded, and most electric utilities in the state are implementing smart grid technologies at some level. TVA distributors will likely begin phasing in time-of-day rates by April 1, 2011, due to changes in TVA's wholesale rate structure.

Type(s) of GHG Reductions

Smart meters enable end-use conservation programs and, in concert with T&D enhancements, and can reduce emissions associated with the combustion of fossil fuel for electricity, principally CO_2 and NO_x.

Estimated GHG Reductions and Net Costs or Cost Savings

Table ES-11-1 presents summary results for policy recommendation ES-11.

Table ES-11-1. ES-11 Summary Results

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009\$, Present Value)	Cost of Saved CO_2e (2009 \$/tCO_2e avoided)
		2020	2030	Cumulative through 2030		
ES-11	Smart Meters	6.5	13.4	135.7	$3,608	$26.6

\$/tCO_2e = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Cost of smart meters from: EPRI, "Advanced Metering Infrastructure (AMI)," February 2007. Available at: http://www.ferc.gov/eventcalendar/Files/20070423091846-EPRI%20-%20Advanced%20Metering.pdf.
- Kentucky population growth rate from Michael Bomford, Kentucky State University. Available at: http://organic.kysu.edu/KY-VMT-Projections.pdf.
- Elasticity of demand with smart meters from: Pacific Northwest National Laboratory. *The Smart Grid: An Estimation of the Energy and CO_2 Benefits*. January 2010. Available at: http://energyenvironment.pnnl.gov/news/pdf/PNNL-19112_Revision_1_Final.pdf.
- TWG input on the cost of AMI infrastructure.

Quantification Methods: The analysis of this policy focused on the costs and benefits associated with the penetration of smart meters for retail electricity customers. The modeling framework integrated physical and performance characteristics. The overall approach for smart meter penetration estimated the costs and GHG reductions associated with replacing existing metering with smart metering technology. The first step was to establish the annual targets for new equipment. The next step was to establish Baseline scenario absolute equipment levels. The next step was to establish costs for replacement of existing equipment. These were developed consistent with information from EPRI. Costs of incremental smart metering equipment were calculated on an annual as well as a present value basis. The next step was to calculate avoided GHG emissions and the cost of saved carbon given the assumption that coal was on the margin.

Key Assumptions: Table ES-11-2 presents the assumptions made regarding smart meter penetration levels.

Table ES-11-2. Smart Grid Market Penetration Level Assumptions

Electric Power Sector	Total Market Penetration of Smart Grid Technology (% of sector-specific stock)		
	2015	2020	2030
Commercial Smart Meter Market Penetration	25%	50%	100%
Residential Smart Meter Market Penetration	25%	50%	100%
Industrial Smart Meter Market Penetration	25%	50%	100%

Table ES-11-3 presents the assumptions made regarding the number of existing meters in 2007, growth rates through 2030, and the projected incremental cost of smart meters.

Table ES-11-3. Meter Assumptions

Sector	Parameter	Value	Notes
Residential Electricity Meters in Kentucky (million)	Number of meters in 2009	1.92	Number of Kentucky Residential electricity consumers (source: http://www.eia.gov/cneaf/electricity/esr/esr_sum.html).
	Meter growth rate, 2007–2050 (%/yr)	0.71%	Kentucky population growth rate from Kentucky State Data Center. Available at: http://ksdc.louisville.edu/kpr/pro/projections.htm.
	Cost per meter in 2010 (2009$/meter)	$225	EPRI, 2007. Advanced metering infrastructure. Available at: http://www.ferc.gov/eventcalendar/Files/20070423091846-EPRI - Advanced Metering.pdf.
Commercial Electricity Meters in Kentucky (million)	Number of meters in 2007	0.29	Number of Kentucky commercial electricity consumers (source: http://www.eia.gov/cneaf/electricity/esr/esr_sum.html).
	Meter growth rate, 2007–2050 (%/yr)	0.71%	Assumed the residential growth rate.
	Cost per meter in 2010 (2009$/meter)	$225	EPRI, 2007. Advanced metering infrastructure. Available at: http://www.ferc.gov/eventcalendar/Files/20070423091846-EPRI - Advanced Metering.pdf.
Industrial Electricity Meters in Kentucky (million)	Number of meters in 2007	0.01	Number of Kentucky industrial electricity consumers (source: http://www.eia.gov/cneaf/electricity/esr/esr_sum.html).
	Meter growth rate, 2007–2050 (%/yr)	0.73%	Assumed the industrial electricity growth rate.
	Cost per meter in 2010 (2009$/meter)	$225	EPRI, 2007. Advanced metering infrastructure. Available at: http://www.ferc.gov/eventcalendar/Files/20070423091846-EPRI - Advanced Metering.pdf.

AEO = Annual Energy Outlook; EPRI = Electric Power Research Institute; KSU = Kentucky State University; VMT = vehicle miles of travel; yr = year.

Table ES-11-4 presents the assumptions made regarding the impact of smart meters on electricity use.

Table ES-11-4. Assumed Smart Meter Impacts on Electricity Consumption

Sectoral End Use	Impact on:	Share of Sectoral Energy Use Reduced (%)
Residential Heat Pump & Air Conditioning	Conservation	1.2%
	Diagnostics	15.0%
	Enhanced monitoring & verification	7.0%
	Load shifting	0.3%
	Total	**23.4%**
Other Residential End Uses	Conservation	4.8%
	Diagnostics	0.0%
	Enhanced monitoring & verification	0.0%
	Load shifting	1.1%
	Total	**6.0%**
Small/Medium Commercial HVAC & Lighting	Conservation	3.3%
	Diagnostics	20.0%
	Enhanced monitoring & verification	7.0%
	Load shifting	0.4%
	Total	**30.7%**
Small/Medium Commercial Buildings	Conservation	2.2%
	Diagnostics	0.0%
	Enhanced monitoring & verification	0.0%
	Load shifting	0.7%
	Total	**2.9%**
Other Commercial End Uses	Conservation	0.5%
	Diagnostics	0.0%
	Enhanced monitoring & verification	0.0%
	Load shifting	0.8%
	Total	**1.3%**
Industrial End Uses	Conservation	0.0%
	Diagnostics	0.0%
	Enhanced monitoring & verification	0.0%
	Load shifting	0.0%
	Total	**0.0%**

HVAC = heating, ventilation, and air conditioning.

In addition, it was assumed that the incremental upper bound cost of commercial, residential, and industrial advanced metering infrastructure, over and above the cost of meters shown in Table ES-11-3 above, is $775 per meter installed (2009$), bringing total system costs to $1,000 for the advanced meter and associated infrastructure.

Key Uncertainties

Key uncertainties for AMI deployments include the cost of implementation; the cost of supporting communication and information technology systems or infrastructure; technology obsolescence; unproven and emerging technologies; uncertainties of cyber-security requirements; the lack of standards development; the uncertainty over regulatory treatment, requiring examination of traditional cost-recovery models to support wide-scale deployment; the ability of the entire cross-section of customers to accept and utilize smart grid/smart home technologies; whether consumers will modify behavior enough to significantly reduce peak load or energy usage; and proper pricing mechanisms or structures that lead customers to modify their behavior without creating dissatisfaction.

The key uncertainty for investment in T&D smart technologies is the cost/benefit analysis of the cost of power versus the reduction of electrical losses. Another uncertainty is the technology optimism for both the hardware and the system management software.

Additional Benefits and Costs

Additional benefits of AMI deployment may include consumers' increased awareness of energy consumption, the ability to remotely monitor and control household energy usage (only with proper and adequate communication and information technology infrastructure), the ability to gather and analyze consumption data, increased reliability (shorter disruption times), the utility having more system awareness due to more monitoring points, and the potential to optimize electrical vehicle charging to the distribution system.

Additional costs include increased security risks and potential loss of personal privacy (utilities will be able to monitor customers' real-time activities).

Feasibility Issues

The issues of regulatory cost recovery and cost-benefit analysis results may impede the achievement of this policy goal.

Status of Group Approval

Approved.

Level of Group Support

Super-majority, with one objection and one abstention.

Barriers to Consensus

None.

ES-12. Coal-to-Liquids Production: GHG Emission Reduction Incentives, Support, or Requirements

Policy Description

The Coal to Liquids (CTL) policy is based on the fact that coal is the only domestically obtainable asset recoverable and available in sufficient quantity to meet America's demand for chemicals and liquid transportation fuels that are currently manufactured using foreign oil supplies. In fact, 94% of this nation's Btu is found in U.S. coal reserves. Natural gas and crude oil represent 4% and 2%, respectively, of the Btu total. A robust CTL industry would have a large positive impact on energy independence and national security. Unfortunately, traditional manufacture of liquids from coal (as exemplified by SASOL in South Africa) emits considerably more (some say as much or more than double) GHGs than manufacturing the same liquids from oil. Consequently, any move toward developing a CTL industry that has GHG reduction as a primary goal must include a method of reducing GHG emissions in the CTL manufacturing process. Currently, the only options on the horizon for accomplishing that reduction are using CO_2 captured during the CTL manufacturing process for enhanced oil recovery (EOR) and/or coal bed methane recovery (CBMR), or capturing the CO_2 and sequestering it underground. Fortunately, both of these options appear feasible under the right circumstances (see Implementation Mechanisms).

The Coal to Gas (CTG) policy is based on using coal to enhance domestic natural gas supplies and to prevent the United States from becoming dependent on foreign supplies of natural gas. It shares many of the same characteristics, drivers, and constraints as CTL. The primary difference is that the supply-side characteristics (domestic supply and pricing) for oil support developing a CTL industry. Domestic natural gas supplies, on the other hand, have increased enormously in the last few years, and it appears that they will continue to increase for the foreseeable future. Demand for natural gas is also increasing, and with the advantage in GHG emissions per unit of power produced that natural gas has over coal, demand is expected to continue to rise. Consequently, the future for natural gas prices and the answer to whether a CTG industry would be economically viable are much less certain.

Therefore, it is recommended that the CTG industry should not be pursued at this time. However, it should be noted that the enablers for CTL (EOR and CCS) in a carbon-constrained world are also necessary to enable CTG. So if in the future CTG becomes more attractive economically, then the same actions discussed in the Implementation Mechanisms section of this policy will be as necessary for CTG as they are for CTL.

CTL, especially in a carbon-constrained environment, will be necessary to maintain (and potentially increase) demand for Kentucky coal. This will directly improve the nation's energy independence and security, and help to stimulate Kentucky's economy and create jobs, while continuing to develop Kentucky's coal reserves. It can also help to reduce Kentucky's GHG emissions and the state's and country's carbon footprint.

Policy Design

Goals: The goal for the CTL policy is to provide as many gallons of CTL diesel as Kentucky uses by 2025.

Timing: For the purpose of analysis, assume CTL production comes on line in 2018. Work on the Implementation Mechanisms (see below) should proceed on an expedited basis. For CTL to be viable in a carbon-constrained world, contracts and pipeline construction for EOR and enhanced CBMR projects must be developed as soon as possible, and carbon sequestration development must progress rapidly.

Parties Involved: The CTL policy will involve coal producers, pipeline builders, and oil producers (for EOR), carbon sequestration firms and KGS (for CCS development), financial institutions, and state agencies overseeing permits, etc.

Other: If a robust CTL industry results in additional demand for coal, educational institutions (both universities and technical colleges) must be ready to meet the demand for skilled workers, for both the CTL industry and the coal mining industry.

Implementation Mechanisms

Some implementation mechanisms that can be taken to improve the borrowing climate for the debt-financed portion of a CTL project include:

- A state guarantee to purchase some or all of the off-take from a facility, with or without a price floor and ceiling to help ensure the profitability of the plant (i.e., floor of $55/barrel [bbl] and a ceiling of $85/bbl).
- Cost-control of the facility's raw material through long-term guaranteed contracts with suppliers.
- Guarantees regarding timing of the permitting process.
- Assistance with direct payment for some of the preliminary design requirements. For example, a rule of thumb is that the cost of the front-end engineering design (FEED) is about 1% of the project cost. So on a $7 billion project, the FEED would cost about $70 million. The state could help defray that cost recoverable against IEIA incentives.
- Project cost share, possibly awarded competitively to the most attractive projects.
- Investment tax credits.
- Statutory exemption from standard rules that grant a given electric utility a monopoly on providing retail electricity in a certain geographic area (e.g., allow a gasification project to "wheel" any electricity generated from waste heat directly to a user at rates more favorable than the gasification project would get from the local utility).
- Provision of bond funding, or bond guarantees.
- Regulatory changes to ease right-of-way acquisition through eminent domain actions.

- Continuing the encouragement of a pilot system to enhance the comfort level of investors by producing quantities of fuel for testing by engine manufacturers and for standards development, as well as a training platform and development of improved technologies.
- Preferential funding for infrastructure requirements (such as local road improvements) that will facilitate operations at the proposed plant site."[22]

Related Policies/Programs in Place

CTL facilities meeting minimum criteria are eligible for tax incentives under IEIA. Biomass could be co-fired (co-gasified) in a CTL facility.

Type(s) of GHG Reductions

Emission reductions would be principally CO_2, although depending upon the assumptions used and performance of the CCSR technology, it is possible the policy could result in zero reductions or possibly a slight increase in emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The GHG reduction (or increase) and cost effectiveness of ES-12 are summarized in the Table ES-12-1.

Table ES-12-1. ES-12 Summary Results

Policy No.	Policy Option	GHG Reductions ($MMtCO_2e$)			Incremental Cost (million 2009$, Present Value)	Cost of Saved CO_2e (2009 $\$/tCO_2e$ avoided)
		2020	2030	Cumulative through 2030		
ES-12	Coal-to-Liquids Production: GHG Emission Reduction Incentives Support, or Requirements (EPA Estimate: 3.7% GHG increase)	0.02 *Increase*	0.10 *Increase*	0.73 *Increase*	$630	N/A
	Coal-to-Liquids Production: GHG Emission Reduction Incentives Support, or Requirements (EPA Lower Bound: 5% GHG decrease)	0.03	0.14	0.99	$688	$697

$\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; N/A = not applicable.

Data Sources

Data Regarding GHG Impacts

The GHG impacts assessed for this analysis are full fuel-cycle impacts, which seek to take into account not only the tailpipe emissions produced by burning the fuel in the automobile, but also the emissions associated with extraction, refining, and distribution steps taken prior to combustion by the end user. Emissions from these activities are referred to as "upstream"

[22] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence,* page 64, November 2008.

emissions or as “well-to-tank” emissions, indicating that they represent the emissions generated from getting the fuel from the point of extraction into the fuel tank where it will be consumed.

Many analyses have been completed that compare Fischer-Tropsch fuels (fuels produced by the process used to convert coal to a diesel substitute) against conventional petroleum fuels on a GHG emissions basis. These studies make varying assumptions, primarily about feedstocks that supply the Fischer-Tropsch process and about the extent to which *carbon capture and storage* technology can reduce the *upstream* emissions associated with refining the inputs into a transportation fuel. Table ES-12-2 attempts to briefly summarize the various estimates and to illustrate the basis for selection of the GHG factor most appropriate to this analysis.

Table ES-12-2. Estimates of Life-Cycle Emissions—CTL vs. Diesel Fuels

Source	Fuel Type and Production Method	Resulting Emissions Ratio (% of Diesel Life-Cycle Emissions)
Brandt and Farrell, UC Berkeley[23]	Coal to Liquids (without CCS)	164% (Low) to 189% (High)
	F-T Diesel with EOR	102% (Low) to 119% (High)
Hileman et al. (2008)[24]	F-T Diesel with CCS	10% above B5 (equal to 9% above unblended diesel)
Department of Energy’s National Energy Technology Laboratory (2008)[25]	CTL F-T Diesel with 100% Effective CCS (zero refining emissions)	5% to 12% below diesel (assuming low diesel efficiency)
EPA (2007)[26]	CTL F-T Diesel with CCS	3.7% above diesel (variable within a range of 4% below to 5% above)

B5 = a fuel blend of 5% biodiesel and 95% gasoline; CCS = carbon capture and storage; CTL = coal to liquids; EOR = enhanced oil recovery; EPA = U.S. Environmental Protection Agency; F-T = Fischer-Tropsch; UC = University of California.

The two most widely known estimates are the EPA and NETL estimates at the bottom of Table ES-12-2. The NETL estimate, which is the only estimate to find significant reductions, appears to achieve this by accounting for zero GHG emissions from refining (NETL, p. 10). The EPA report, by contrast, applies assumptions that electricity inputs (with their own emissions) are required to sequester carbon. Other resources also find that sequestration is less than 100% efficient—between 85% and 95% efficient, resulting in non-zero values from refining.

For the purpose of this analysis, the EPA estimate is used. The rationale behind this selection is the similarity of the non-zero emissions assumption to most other resources regarding the emission-reduction efficacy of methods such as EOR and coalbed methane recovery. Analyses of these methods generally find some emissions from (1) the fuels produced (oil and methane, respectively) and (2) less-than-complete capture of emissions generated.

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[23] See: http://erg.berkeley.edu/people/faculty/Brandt_Scraping_Public.pdf.

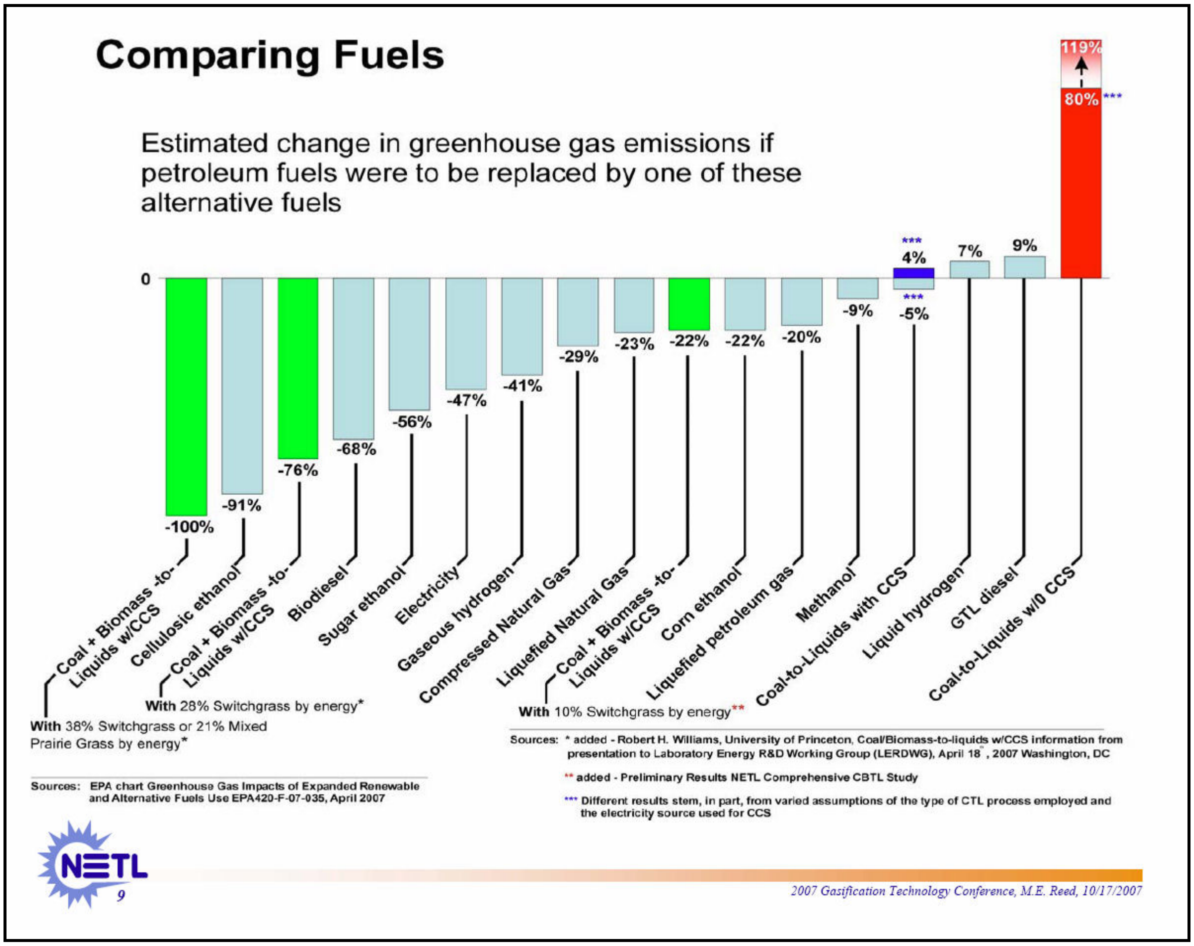
[24] See: http://www.airportattorneys.com/files/TRB08Hileman.pdf.

[25] See: http://www.netl.doe.gov/energy-analyses/pubs/CBTL%20Final%20Report.pdf.

[26] See: http://www.epa.gov/oms/renewablefuels/420f07035.pdf.

NETL produced Figure ES-12-1 to provide a summary of the comparative GHG emission intensities of a variety of fuels when compared against petroleum fuels (from the EPA report).[27]

Figure ES-12-1. Comparative GHG Impacts of Different Fuel Supply Pathways



This figure summarizes the above research in identifying that CTL fuels with aggressive CCS may be capable of emissions roughly in line with diesel emissions. Superior CCS, achieving capture of 95% or more of carbon emitted as part of the refining process, may achieve slight reductions (up to 4%) below diesel life-cycle emissions.

However, these numbers take into account neither the risk that CCS processes are not utilized to full potential (either because of cost or storage capacity considerations), nor the risk of leakage of stored gases, as has happened in the past.[28] These risks are significant in light of the estimate that CTL fuels are roughly twice as carbon intensive as diesel and gas in the absence of effective CCS (see the red bar at the right of Figure ES-12-1). Even under the most promising GHG

[27] See: www.netl.gov.

[28] See: http://www.scientificamerican.com/article.cfm?id=enhanced-oil-recovery.

reduction estimates, operation of CTL facilities without full CCS, even for a small share of operating time, would significantly worsen the emissions profile of the facility.

Quantification Methods: Kentucky's I&F was utilized to develop year-by-year estimates of overall diesel use in the state to determine the scale of CTL production volume necessary to meet this policy goal. Energy use baseline estimates from diesel were converted to GHG emission estimates based on the full fuel-cycle emissions of diesel and CTL fuels. Emission impacts were derived from the relative impact estimates developed by EPA and the overall emissions profile of the diesel fleet. Per the strategy design, CTL production was assumed to come online in 2018, and to reach target capacity by 2025, staying there through 2030. Table ES-12-3 presents the emission reductions resulting from CCS under the high and low EPA estimates of GHG impacts relative to the emissions of diesel.

Table ES-12-3. GHG Net Emissions Impact of CCS (EPA Range of Estimates)

Year	Low: –5% (GHG savings)	High: 3.70% (GHG increase)
2020	–0.027	0.020
2021	–0.039	0.029
2022	–0.053	0.039
2023	–0.069	0.051
2024	–0.087	0.064
2025	–0.094	0.069
2026	–0.102	0.075
2027	–0.110	0.082
2028	–0.119	0.088
2029	–0.128	0.095
2030	–0.137	0.102
Total	**–0.987**	**0.731**

CCS = carbon capture and storage; EPA = U.S. Environmental Protection Agency; GHG = greenhouse gas.

Program Costs and Competitiveness

In a 2010 report commissioned by the Natural Resources Defense Council, Advanced Resources International estimated that CTL fuel with EOR carbon-capture technology would be competitive and would find a market so long as oil prices stayed consistently above $70 per barrel, and the costs to store carbon stayed at or below $15/tCO$_2$ captured.[29]

Oil price projections must be taken with limited confidence. DOE base case projections expect imported crude oil to remain well above that $70 floor (actually between $95 and $110 per barrel) throughout the 2018–2030 period considered for this analysis. However, DOE also publishes a low-oil-price scenario, in which the projection for the price of a barrel is consistently

[29] See: http://www.adv-res.com/pdf/v4ARI%20CCS-CO2-EOR%20whitepaper%20FINAL%204-2-10.pdf.

below $45. While this is a lower boundary, this projection (along with the volatility of oil prices generally) indicates that the CTL industry will face significant risks from oil prices.

For the costs of CCS, two estimates were selected for the in-U.S. cost, both measured on a per-ton basis. The Organization of Petroleum Exporting Countries cited a lower cost, at roughly $22/t$CO_2$ stored,[30] while NETL estimated a much higher cost at $45/t$CO_2$ stored.[31] This analysis assumed a cost of $33.50, or the average of these two divergent estimates. This approach simplifies the inherently complex cost structure of purchasing significant new capital and accounting for depreciation, but does so in an attempt to benefit from past research that has synthesized the cost elements already. The estimate of the amount of carbon captured was derived from the midpoint of EPA's range of emissions from CTL fuels production without CCS (99% higher than petroleum) and EPA's midpoint for emissions from CTL with CCS (3.7%), to produce an amount equal to 95.3% of the emissions of fuel displaced.

Table ES-12-4. Carbon Sequestration Volumes and Costs

Year	Amount of Carbon Sequestered (3.7% Increase Scenario)	Cost of CCS per tCO_2 ($ millions, 3.7% Increase Scenario)	Amount of Carbon Sequestered (5% Savings Scenario)	Cost of CCS per tCO_2 ($ millions, 5% Decrease Scenario)
2018	0.1429	$4.79	0.1560	$5.22
2019	0.3113	$10.43	0.3397	$11.38
2020	0.5117	$17.14	0.5585	$18.71
2021	0.7367	$24.68	0.8040	$26.93
2022	1.0025	$33.58	1.0940	$36.65
2023	1.3068	$43.78	1.4261	$47.77
2024	1.6525	$55.36	1.8034	$60.41
2025	1.7894	$59.94	1.9528	$65.42
2026	1.9369	$64.89	2.1137	$70.81
2027	2.1011	$70.39	2.2929	$76.81
2028	2.2686	$76.00	2.4757	$82.93
2029	2.4437	$81.86	2.6668	$89.34
2030	2.6153	$87.61	2.8541	$95.61
Total	**18.8194**	**$630.45**	**20.5375**	**$688.01**

CCS = carbon capture and storage; tCO_2 = metric tons of carbon dioxide.

While these estimates are measured per ton, it is important to point out the capital-intensive nature of EOR facilities. The capital costs associated with this carbon-capture capability can

[30] See: http://www.opec.org/opec_web/en/press_room/905.htm.

[31] See: http://www.netl.doe.gov/energy-analyses/pubs/storing%20co2%20w%20eor_final.pdf.

reach into the hundreds of millions of dollars,[32] necessitating significant new resources and expanded access to financing.

Key Assumptions: This strategy assumes a roughly linear ramp-up from no new CTL capacity in 2017 to a capacity equal to Kentucky's diesel use in 2025, and rising with diesel use through 2030.

Key Uncertainties

For this technology to reduce GHGs, it will have to also utilize CCS (see ES-4). The CTL process lends itself to CO_2, but the time frame for the storage of the CO_2 is uncertain, as is the cost. Access to capital is another uncertainty. Since CTL will compete with petroleum, the price of oil is an important factor that is very uncertain; for CTL to be economically viable, crude oil must stay above a threshold amount for the life of a CTL plant.

It is not certain to the ES TWG whether the combustion of the CTL fuel results in more carbon emissions than the petroleum-based fuel it is displacing.

Another concern is the long-term effect of the use of the alternative fuel on engines. Manufacturers remain unsure about the use of these fuels, as there has not been enough research in this area. The recommendation to construct a small-scale pilot facility to produce CTL fuels to support such testing is in response to this concern.

Additional Benefits and Costs

The use of CTL will increase the energy independence of Kentucky and the nation by reducing our reliance on imported petroleum. This policy would lead to the continued and increased use of Kentucky coal-producing jobs, increased severance, and other tax revenue.

The benefits and cost of CO_2 reduction will be addressed in the technical evaluation.

Feasibility Issues

There are multiple feasibility issues, especially associated with the future availability and cost of CCS, as noted above and in related policies.

Status of Group Approval

Rejected.

Level of Group Support

Two in favor, two abstentions, four objections.

[32] See: http://stocks.investopedia.com/stock-analysis/2010/Enhanced-Oil-Recovery-Projects-APC-DNR-WLL-REN0820.aspx.

Barriers to Consensus

Members objecting to the inclusion of ES-12 believe that this policy does not reduce GHG emissions, and thus is inappropriate to be included in Kentucky's Climate Action Plan. The analysis conducted shows that even with carbon capture, optimistic assumptions are needed to achieve a tiny reduction in carbon emissions. When those optimistic assumptions are not used, this policy actually increases carbon emissions. The objectors believe that while this policy may have a place in a plan to increase coal use, it is not a strategy to reduce carbon emissions and should not be included in the Climate Action Plan.

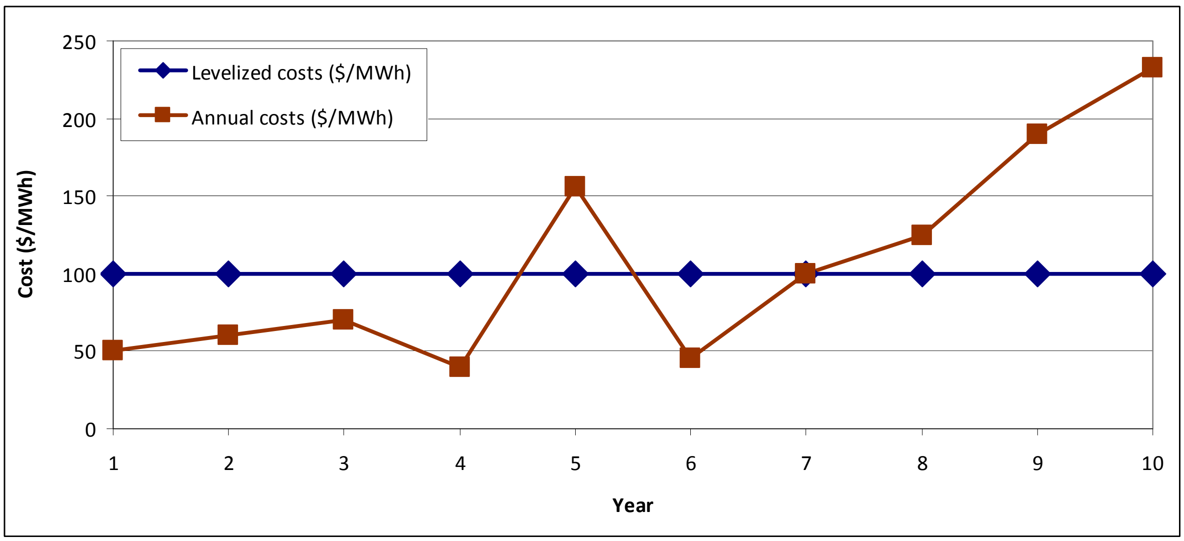
Annex 1. Calculation of Levelized Costs

This annex provides a brief conceptual overview as well as an annotated example regarding the calculation of levelized costs associated with power generation technology. Levelized costs are useful in evaluating financial feasibility and for directly comparing the cost of one technology against another.

Conceptual Overview of Levelized Costs

Levelized cost can be defined as a constant annual cost that is equivalent on a present value basis to the actual annual costs. That is, if one calculates the present value of levelized costs over a certain period, its value would be equal to the present value of the actual costs of the same period. Using levelized costs, often reported in dollars per megawatt-hour ($/MWh), allows for a ready comparison of technologies in any year—something that would be more difficult to do with differing annual costs. This concept is illustrated Figure ES-A-1. The present value of the levelized costs is equal to the present value of the annual costs.

Figure ES-A-1. Illustrative Comparison of Levelized and Actual Annual Costs



$/MWh = dollars per megawatt-hour.

Components of Levelized Costs

Several components make up levelized costs:

- *Capital costs:* Typically reported in units of dollars per kilowatt ($/kW), these costs include the total costs of construction, including land purchase, land development, permitting, interconnections, equipment, materials, and all other components. Construction financing costs are also included.

- *Fixed O&M:* Typically reported in units of dollars per kilowatt-year ($/kW-yr), these costs are for those that occur annually, regardless of how much the plant operates. They typically include staffing, overhead, regulatory filings, and miscellaneous direct costs.
- *Variable O&M:* Typically reported in units of dollars per megawatt-hour ($/MWh), these costs are for those that occur annually, based on how much the plant operates. They typically include costs associated with maintenance and overhauls, including repairs for forced outages, consumables, water use, and environmental compliance costs.
- *Fuel:* Typically reported in units of dollars per million British thermal units ($/MMBtu), these costs are for startup fuel use, as well as online fuel use.

Information Needed to Calculate Levelized Costs

Additional information is needed to calculate levelized costs, as briefly described below:

- *Plant size:* This refers to the size of the plant, expressed in units of megawatts (MW).
- *Capacity factor:* This refers to the share of the year that the plant is in operation, expressed as a percentage.
- *Capital recovery factor:* This refers to assumptions regarding the plant lifetime, the effective interest rate or discount rate used to amortize capital costs, and various other factors specific to the power industry (see subsection that follows). Expressed as a decimal, capital recovery factors are typically between 0.10 and 0.20. (See below and Annex 2 of this document for a detailed explanation of capital recovery factors and a sensitivity analysis of two capital recovery factor assumptions and their impacts on policy quantification results.)
- *Fuel price projection:* This refers to the projected price of the fuel used to produce electricity over the lifetime of the plant, expressed in units of $/MMBtu.
- *Heat rate:* This refers to the efficiency by which fuel is consumed for the production of electricity, expressed in units of British thermal units per kilowatt-hour (Btu/kWh).

Additional Information Regarding the Capital Recovery Factor

The capital recovery factor (CRF) depends on a number of factors, as briefly described below:

- *Cost of capital:* This refers to the capital needed to construct the power supply facility, and is typically obtained from a bank in the form of debt and funds borrowed from shareholders in the form of a reduction in shareholder retained earnings or an issuance of capital stock. The bank charges interest on the debt, and shareholders have an anticipated return on equity for the funds provided the company. The weighted-average cost of capital is the weighted average of the interest and the return on equity shareholders expect from investments of similar risk.
- *Income tax shelters:* Depending on how the facility is financed and how the plant cost is depreciated, income tax reductions can result that offset some of the cost. Depreciation is an expense on the income statement that has the effect of reducing income taxes, but is not an actual cash outflow. Therefore, its effect on cash flow is to reduce the income tax liability. Also, interest on debt is an expense on the income statement that, too, reduces the income tax burden, having the net effect of reducing the cost of financing with debt. On the other hand,

the costs of financing with equity are paid back to shareholders in the form of earnings and are not expensed on the income statement. Dividends paid to preferred shareholders are not tax deductible. Therefore, financing with equity provides no income tax sheltering effect for the business.

- *Property taxes:* While property tax rules vary from locality to locality, in most cases they are equal to some fraction of the assessed value of the property, which is often the book value. Depending upon the location, some facility improvements may be exempt from property tax.
- *Insurance:* The cost of insurance on the plant assets is normally included in the CRF. It is typically a small fraction of the book value of the plant assets.

Formulas Used to Calculate Levelized Costs

There are several formulas needed to convert the various units into the $/MWh units used to express levelized costs. These are briefly described below.

- *Capital costs (CC):* These costs are converted to $/MWh units as per the formula below:

  *Levelized capital cost = CC * CRF * conversion factor / (HPY * CF)*

  Where: CC = capital cost ($/kW)

  CF = capacity factor (%)

  HPY = hours per year = 8,760

  CRF = capital recovery factor

  conversion factor = 1,000 (convert from kW to MW)

- *Fixed O&M (FOM):* These costs are converted to $/MWh units as per the formula below:

  *Levelized fixed O&M cost = FOM * conversion factor / (HPY * CF)*

  Where: FOM = fixed O&M ($/kW-yr)

  CF = capacity factor (%)

  HPY = hours per year = 8,760

  conversion factor = 1,000 (convert from kW to MW)

- *Variable O&M (VOM):* These costs are already provided in units of $/MWh, so no conversion is needed.

- *Fuel costs (FC):* Each year's fuel price is converted to units of $/MWh as follows:

  *Fuel price = FP_t * HR / conversion factor*

  Where: FP_t = fuel price in year t ($/MMBtu)

  HR = heat rate (Btu/kWh)

  Conversion factor = 1,000 (convert from kW to MW)

  t = year in the plant lifetime

These annual fuel costs are then levelized as follows:

Levelized fuel cost = $[PV * DR * (1+DR)^t] / [(1 + DR)^t - 1]$

Where: PV = present value of discounted fuel cost stream

DR = discount rate

Example Calculation of Levelized Costs

The above information can be combined to develop the levelized cost for any technology. As an example, the case of a conventional natural gas-fired combined cycle plant is considered. Table ES-A-1 summarizes the starting assumptions. Levelized cost calculations are offered in the bullets that follow.

Table ES-A-1. Cost and Performance Assumptions for Illustrative Example Only

Parameter	Value	Annual Fuel Price (constant $/MMBtu)					
Size	**540**	**Year**	**Price**	**Year**	**Price**	**Year**	**Price**
Online year	2012	1	7.57	11	6.09	21	6.57
Fuel type	Natural gas	2	7.12	12	6.14	22	6.61
Heat rate (Btu/kWh)	7,064	3	7.54	13	6.20	23	6.83
Capacity factor (%)	65%	4	7.77	14	6.25	24	6.96
Discount rate (%)	5.0%	5	7.30	15	6.16	25	7.09
Operating life (years)	30	6	7.01	16	6.06	26	7.20
Capital recovery factor (%)	12%	7	6.77	17	6.18	27	7.25
Capital cost ($/kW)	703	8	6.47	18	6.25	28	7.30
Fixed O&M cost ($/kW-yr)	12.14	9	6.26	19	6.36	29	7.35
Variable O&M cost ($/MWh)	2.01	10	6.14	20	6.46	30	7.4

$/kW = dollars per kilowatt; $/kW-yr = dollars per kilowatt-year; $/MMBtu = dollars per million British thermal units; $/MWh = dollars per megawatt-hour; Btu/kWh = British thermal units per kilowatt-hour;

- *Capital costs:* The levelized capital cost is equal to:

  *Levelized capital cost = 703 * 0.12 * 1,000 / (8,760 *0.65) = $14.82/MWh*

- *Fixed O&M:* The levelized fixed O&M cost is equal to:

  *Levelized fixed O&M cost = 12.14 * 1,000 / (8,760 * 0.65) = $2.13/MWh*

- *Variable O&M:* The levelized variable O&M cost is equal to $2.01/MWh

- *Fuel costs:* The present value of the discounted fuel cost stream is equal to $104.35/MMBtu. The levelized fuel cost is equal to:

  $[104.35 * 0.05 * (1+0.05)^{30}] / [(1 + 0.05)^{30} - 1] = \$6.79/MMBtu$

  This levelized value is then converted to units of $/MWh as follows:

  *Levelized fuel cost = 6.79 * 7,064 / 1,000 = $47.97/MWh*

- *Total levelized cost:* The total levelized cost is equal to the sum of the above components, as follows:

  Total levelized cost = levelized CC + levelized FOM + VOM + levelized FC = 14.82 + 2.13 + 2.01 + 47.97 ***<u>= $66.93/MWh</u>***

Annex 2. Sensitivity Analysis of Capital Recovery Factor

This annex provides the results of a sensitivity analysis of the effect of the capital recovery factor (CRF) on the cost-effectiveness of the ES policies involving power generation. As indicated in the previous ES policy descriptions, a constant value of 0.115 was used across all fossil, nuclear, and biomass technologies. CRFs for renewable facilities as presented previously assume they will be merchant-owned or located out of state and are lower than CRFs for nonrenewable generation facilities. To assess the impact of the use of the CRF used, a sensitivity analysis was conducted. Table ES-A-2-1 provides a summary of the CRFs used in the sensitivity analysis. Table ES-A-2-2 summarizes the effect of the changes in the CRF on the cost-effectiveness of each of the ES policies involving power generation.

Table ES-A-2-1. Capital Recovery Factor Sensitivity Assumptions

Technology	Default CRF Assumption	CRF Assumption 2	CRF Assumption 3
Supercritical Coal	0.1150	0.1250	0.1350
Supercritical Coal with CCS	0.1150	0.1250	0.1350
Conventional NGCC	0.1150	0.1250	0.1350
Advanced NGCC with CCS	0.1150	0.1250	0.1350
Nuclear	0.1150	0.1250	0.1350
Biomass (Stoker)	0.1150	0.1250	0.1350
Biomass (Fluidized Bed)	0.1150	0.1250	0.1350
In-State Wind	0.0855	0.0855	0.0855
Solar Photovoltaics	0.0700	0.0700	0.0700
Conventional Hydro	0.1142	0.1142	0.1142
Hydrokinetic	0.1142	0.1142	0.1142
Biomass Co-firing	0.1150	0.1250	0.1350

CCS = carbon capture and storage; CRF = capital recovery factor; NGCC = natural gas combined cycle.

Table ES-A-2-2. Effect of Capital Recovery Factor Sensitivity Assumptions on Cost-Effectiveness of Energy Supply Policies Involving Power Generation

Policy	Cost-Effectiveness ($2009\$/tCO_2e$ avoided)		
ES-1: Biomass development and supply-side efficiency improvements at baseload stations	Default CRF Assumption	CRF Assumption 2	CRF Assumption 3
Supply-side efficiency	$12.8	$12.8	$12.8
Biomass co-firing	$20.5	$20.5	$20.5
Total	$18.2	$18.2	$18.2
ES-2: DSM and management programs			
ES-3: Advanced fossil fuel technology incentives, support for requirements			
Scenario #1 (supercritical without CCS)			
800 MW retired	$12.0	$14.3	$16.6
1,600 MW retired	$14.0	$16.6	$19.3
Scenario #2 (conventional NGCC without CCS)			
600 MW retired	$34.6	$35.4	$36.3
1,200 MW retired	$35.9	$36.8	$37.7
Scenario #3 (supercritical with CCS)			
800 MW retired	$30.2	$32.7	$35.2
1,600 MW retired	$31.5	$34.1	$36.7
Scenario #4 (advanced NGCC with CCS)			
600 MW retired	$49.7	$50.7	$51.8
1,200 MW retired	$50.9	$52.0	$53.1
ES-4: CCS demonstration retrofit project			
Scenario 1 (250 MW)	$37.3	$38.4	$39.5
Scenario 2 (1,090 MW)	$37.3	$38.4	$39.5
ES-5 Pricing strategies	$9.9	$9.9	$9.9
ES-6: New nuclear energy capacity	$21.2	$23.7	$26.4
ES-7: Renewable energy incentives			
Scenario 1 (mixed renewable scenario)	$17.4	$17.5	$17.6
Scenario 2 (biomass scenario)	$17.9	$18.9	$19.9
Scenario 3 (out-of-state wind scenario)	$12.8	$12.9	$13.0
Scenario 4 (solar PV scenario)	$32.8	$32.9	$33.0
ES-8: Technology R&D; Solar PV demonstrations	$166.1	$166.1	$166.1
ES-9: Policies to support wind			
ES-10: Shale gas development			
ES-11: Smart meters & distribution upgrade	$21.7	$21.7	$21.7
ES-12: Coal to liquids			

$\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; CCS = carbon capture and storage; CRF = capital recovery factor; DSM = demand-side management; MW = megawatts; NGCC = natural gas combined cycle; PV = photovoltaics; R&D = research and development.

Appendix G
Residential, Commercial, and Industrial Sectors Policy Recommendations

Summary List of Policy Recommendations*

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effective-ness 2011–2030 ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-1	Improve Building Codes for Energy Efficiency, Coupled with Improved Energy Code Training and Enforcement	0.4	1.2	9	–$213	–$23
RCI-2	Promote, Encourage, and Provide Incentives for "Beyond-Code" Efficiency in All Building Characteristics and Systems That Impact Energy Consumption	2	5	50	–$1,376	–$27
RCI-3	Expand Utility DSM Programs for Electricity	6	19	169	–$3,340	–$20
RCI-4	Develop and Implement Comprehensive Education, Outreach, and Marketing, Including Consumer Awareness, School Curriculum, Truth-in-Advertising, Technical Information and Support (e.g., How to Do GHG Inventories, Rationales for Action, etc.)	*Not Quantified*				
RCI-5	Financing Programs and Incentives for Energy Efficiency and CHP (PBF, Revolving Loans, etc.) (ONLY CHP QUANTIFIED)	12	22	259	$538	$2
RCI-6	Financing Programs, Incentives, Policies, and Research for Conversion to Renewable Energy or Low-Carbon Energy Sources (ONLY RENEWABLE ELECTRICITY QUANTIFIED)	1.4	4.4	35	$3,372	$96
RCI-7	Government Lead by Example (GLE) in Highly Efficient State and Local Government Buildings	0.7	1.6	15	–$16	–$1
RCI-8	Training and Education for Builders, Contractors, and Building Operators	*Not Quantified*				
RCI-9	Building Commissioning and Recommissioning, Including Energy Tracking and Benchmarking, and Implement a Building Energy Labeling Program	3	5	50	–$1,117	–$23

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million $)	Cost-Effective-ness 2011–2030 ($/$tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-10	Implement Advanced Metering Technologies and Associated Policies for Greater Load Management, Customer Control, Awareness, Price Signaling, etc.	*Moved to Energy Supply Technical Work Group as policy recommendation ES-11.*				
	Sector Total After Accounting for Overlaps	**19**	**38**	**408**	**$1,220**	**$3**
	Reductions From Recent Actions (Existing DSM Programs, HB 2 for Government Buildings)	**1.5**	**3.2**	**32**		
	Sector Total Plus Recent Actions	**20**	**42**	**441**		

Negative values in the Net Present Value (NPV) and the Cost-Effectiveness columns represent net cost savings. Negative NPV represents positive net cash flows from the policy recommendation (the costs of the policy, i.e., new energy efficiency equipment (air conditioners, furnaces, etc.), when levelized over their expected lifetimes, are less than expected energy expenditures. Policy recommendations with estimated cost savings still are likely to require significant up-front capital investment for the new energy efficiency equipment.

Totals may not add up due to rounding.

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; CHP = combined heat and power; DSM = demand-side management; GHG = greenhouse gas; HB = House Bill; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; N/A = not applicable; PBF = Public Benefit Fund.

GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five).

The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative $MMtCO_2e$ of GHG reductions (column five).

The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policies.

*This analysis reflects the use of full-fuel-cycle GHG emission factors.

On October 27, 2010, the RCI Technical Work Group (TWG) discussed the issue of direct versus "full-fuel-cycle" emission factors. Full-fuel-cycle GHG emission factors include the GHG emissions associated with the production, processing, transmission, and distribution of fuels and electricity. These "upstream" emissions associated with energy supply are 5%–25% greater than direct, or end-use, emission factors that are calculated as a result of fuel combustion at the power station or building. On the October 27 call, the RCI TWG decided to present the summary table above showing GHG emissions and cost-effectiveness based on full-fuel-cycle emission factors. The work group also decided that the results for each RCI policy recommendation should show both direct and full fuel cycle emissions factors. On balance, the difference in 2011–2030 cumulative GHG reductions is about 10% between the two methodologies. The choice of emission factor does not impact the net present value calculations. However, because cumulative 2011–2030 GHG emission reductions are increased under full-fuel-cycle emission factors, the $/ton cost-effectiveness estimates will differ modestly between the two methodologies.

Policy Overlap Discussion

The Kentucky Climate Action Plan Council (KCAPC) and the Residential, Commercial, and Industrial (RCI) Technical Work Group (TWG) quantified seven policy options to reduce the emissions of greenhouse gases (GHGs) in the RCI sector. RCI-10 (Advanced Metering) was duplicative with ES-11 and has been developed and quantified by the Energy Supply TWG. In addition to estimating the impacts of each individual policy, the *combined* impacts of the quantified policies were estimated, assuming that all were implemented together. This involved eliminating any overlaps in coverage that would occur to avoid double counting of impacts. Also, some of the policies in one sector overlapped with policies in another sector; therefore, these overlaps were identified and the impact analysis was adjusted to eliminate double counting of impacts associated with these intersectoral overlaps. This section identifies where these overlaps occurred and explains their treatment.

RCI Sector Cumulative Impacts Analysis Methodology

To assess the cumulative emission reductions for the policies in the RCI sector, it is necessary to consider any overlaps among the policies that affect similar types of energy use. Specifically, some policies (such as RCI-2) are defined by their goals for reducing energy use, while others (such as RCI-3, RCI-5, and RCI-6) are defined by addressing a specific type of energy use or supply. Policies were compared in terms of the type of energy use they target and the energy reduction measures each is expected to implement. Overlaps were identified and quantified by sector (RCI or government), type of energy use targeted (water heating, space heating, etc.), and measure (e.g., high efficiency air conditioning).

- RCI-1 (Improved Building Codes) is a regulatory policy that is assumed to take precedence over voluntary and incentive options. The GHG reductions and associated costs or benefits from this policy are not reduced to account for overlaps with other policies.
- RCI-2 ("Beyond Code" Energy Efficiency) is a combined electricity and fuels incentive policy. The policy is assumed to be incremental to, or occur on top of, the reductions that are achieved from the RCI-1 building codes policy. The GHG reductions and associated costs or benefits from this policy are not reduced to account for overlaps with other policies.
- RCI-3 (Expand Electric Utility DSM Programs) overlaps are estimated at the measure level. RCI-3 and RCI-2 are both policies that offer incentives to end users to purchase more efficient equipment. RCI-3 provides incentives for electricity measures, such as ENERGY STAR appliances, weatherization, and building heating, ventilating, and air conditioning (HVAC) measures. We estimate that these measures and targeted markets (end users) are similar to those expected to be provided incentives under RCI-2. Because of the similarity in measures and targets, the GHG reductions and associated costs or benefits from electric efficiency under this policy are reduced by 75% to account for overlaps with RCI-2. This estimate is conservative, to ensure that GHG reductions under RCI-3 are not double counted with RCI-2.
- RCI-5 (Financing for Combined Heat and Power [CHP]) is a supply-side policy recommendation that is quantified according to the expected demand for thermal resources in the commercial and industrial sectors. More efficient use of hot water from improved commercial building heating and cooling or domestic use of hot water under RCI-2 could reduce the supply of commercial CHP. Commercial GHG reductions and associated costs or

benefits from electric efficiency under this policy are reduced by 20% to account for potential overlaps with RCI-2. The KCAPC did not develop an RCI policy specifically to improve industrial energy efficiency that could reduce the supply of industrial CHP. Therefore, industrial GHG reductions and associated costs or benefits from the CHP policy are not reduced to account for overlaps with other policies.

- RCI-6 (Financing for Renewable Energy) is a supply-side policy recommendation that is quantified according to the expected demand in the residential and commercial sectors. More efficient use of hot water from improved building heating and cooling or domestic use of hot water under RCI-2 could reduce the supply of residential and commercial solar thermal, but these effects are separate from the installation of new solar hot water units. GHG reductions and associated costs or benefits from the solar photovoltaic element of this policy are not reduced to account for overlaps with other policies.
- RCI-7 (Government Lead by Example) is applied only to government energy consumption, while other policies address residential and commercial buildings. Government high-efficiency building standards typically show little overlap with utility programmatic investments and are additional to code improvements. The GHG reductions and associated costs or benefits from this policy are not reduced to account for overlaps with other policies.
- RCI-9 (Building Commissioning, Benchmarking, and Labeling) is composed of two main elements: commissioning as well as building audits that are the basis for benchmarking and labeling.

Commissioning new buildings is assumed to be a part of the “above code” or green building portion of RCI-2. Similarly, recommissioning existing buildings is a cost-effective program to reduce energy consumption that is assumed to fall under the retrofit element of RCI-2. Therefore, the GHG reductions and associated costs or benefits from the commissioning and recommissioning elements of the policy are reduced by 100% to account for overlaps with RCI-2. The net effect of the overlap reductions is to reduce GHG mitigation from the policy by 85% by 2030, as most of the reductions from the policy are estimated to result from commissioning and recommissioning.

While building audits are part of most residential energy efficiency programs, their penetration without the home sales element of this policy would be limited. A similar argument can be made for the limited penetration of commercial audits in the reference case. The GHG reductions and associated costs or benefits from the auditing element of this policy are not reduced to account for overlaps with other policies.

Overlaps Between Sectors

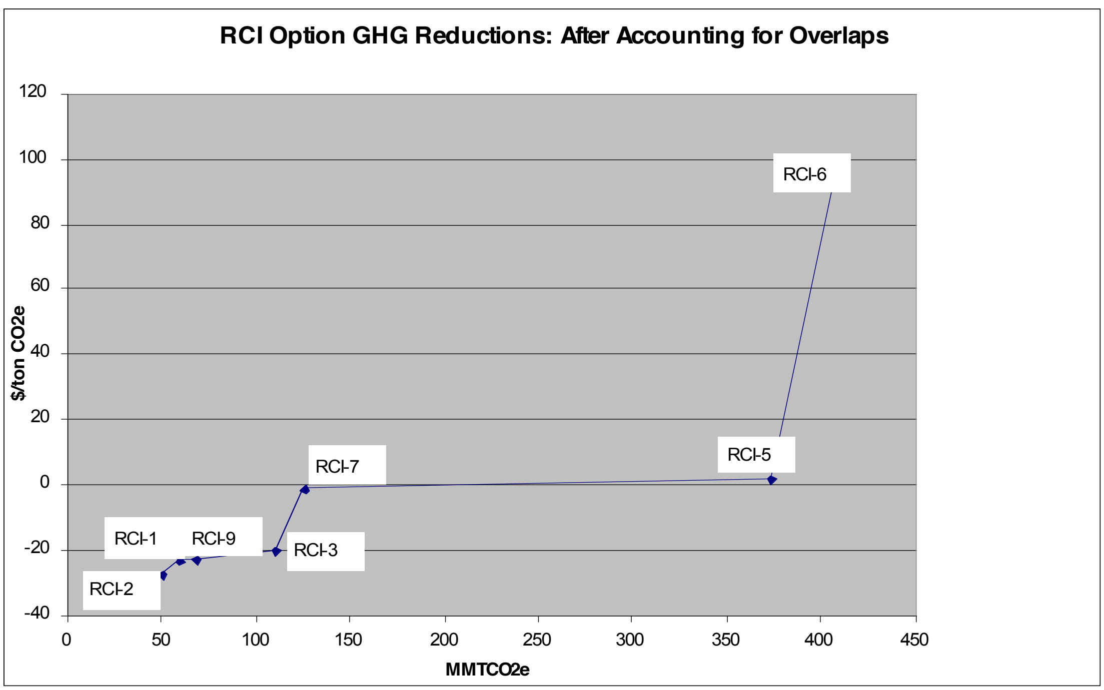
There are several potential overlaps between RCI and other sectors. These potential overlaps are discussed qualitatively here. The first is that electricity energy efficiency investments from the suite of RCI policy recommendations reduce electricity demand. Reducing future electricity sales makes it easier for regulated entities to meet a target for renewable electricity sales as a percentage of total sales. Such a renewable electricity target is being developed under ES-7, and the demand reductions from RCI would likely make compliance with the target more cost-effective and easier to attain.

AFW-3 (On-Farm Energy Production and Efficiency Improvements) targets energy-efficient electric pumps, lighting, and electric drying on farms. We assume that agricultural electric energy efficiency is largely separate from energy efficiency measures in the RCI sector. While there are some potential overlaps in the agricultural building energy efficiency measures of AFW-3 and RCI-2 (Beyond Code Energy Efficiency), we believe that any potential double counting of energy efficiency savings (and associated GHG reductions) are more than adequately accounted for in the 75% decrease in GHG reductions from RCI-3 due to its potential overlaps with RCI-2.

Finally, an additional feedback is that certain Energy Supply policies will have the effect of reducing the GHG emissions associated with electricity generation. In this case, RCI policies that target electricity use will have a reduced ability to deliver GHG emissions. The RCI analysis assumes that current and future electricity generation is largely coal-fired. If considerable fuel switching occurs from coal to cleaner sources of electricity, then the GHG electricity-related reductions from the RCI policies would be reduced. This impact has not been reflected in the analysis.

Figure RCI-1 shows the costs and supplies of GHG reductions from the RCI sector in the summary table above. These estimates are adjusted for overlaps. Figure RCI-1 shows reductions of about 375 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) with cost savings or low costs to the state.

Figure RCI-1. RCI Greenhouse Gas Emission Reduction Supply Curve, 2011–2030



$/ton CO_2e = dollars per metric ton of carbon dioxide equivalents; $MMtCO_2e$ = million metric tons of carbon dioxide equivalents; RCI = Residential, Commercial, and Industrial.

Electricity Savings from Integrated Policy Recommendations

Estimated savings from the combined policies (net of overlaps) for 2030 for electricity are estimated at 10,064 gigawatt-hours (GWh). This includes energy efficiency savings under RCI-1 Improved Building Codes, RCI-2 "Beyond-Code" Efficiency, RCI-3 Electric Energy Efficiency, RCI-7 Government Lead by Example, and RCI-9 Building Commissioning and Recommissioning. This represents about 7.7% of the 130,500-GWh forecasted sales in 2030 according to the Kentucky inventory and forecast.[1] In addition to these demand reductions, RCI-5 CHP switches an estimated 6,300 GWh from central station electricity generation to distributed commercial and industrial CHP electricity generation.

GHG Reductions from Recent State Actions

Recent actions are accounted for in the summary table as policies that have been enacted, but that are not in the reference case Kentucky inventory and forecast. Recent actions are defined as legislative or executive orders that have been enacted in Kentucky by November 2010. The impacts from federal actions are assumed to be included in the reference case forecast.

The first recent action that needs to be included is Kentucky House Bill (HB) 2 of 2009, which requires:

> (1) Beginning July 1, 2009, require that all construction or renovation of public buildings for which fifty percent (50%) or more of the total capital cost is paid by the Commonwealth shall be designed and constructed, or renovated, to meet the high-performance building standards established in Section 5 of this Act….
>
> (2) Require that all building leases entered into by the Commonwealth or any of its agencies on and after July 1, 2018, shall meet the high-performance building standards….
>
> (3) Incorporate ENERGY STAR-qualified products in state agency procurements to the extent economically feasible using a life-cycle cost analysis.[2]

Table RCI-1 presents the assumptions employed to calculate the GHG reductions from HB 2.

Table RCI-1. Assumptions Used to Calculate GHG Reductions from HB 2

Description	Assumption	Rationale
Assumed Efficiency of Green Buildings Under HB 2	30%	More efficient than new construction
Percent of Leases Renewed Each Year	10%	Placeholder: assumes average 10-year lease life
Percent of Government Floor Space that is Leased	7%	From Kentucky Department of Finance
ENERGY STAR Appliance Efficiency Improvement	20%	Estimate
Annual Appliance Turnover	10%	Based on 10-year measure life

GHG = greenhouse gas; HB = House Bill.

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[1] See: http://www.kyclimatechange.us/Inventory_Forecast_Report.cfm.

[2] See: www.lrc.ky.gov/record/08rs/hb2.htm.

We quantify the lease renewal and efficient appliance portions of HB 2 that are not included in RCI-7. Only the GHG reductions associated with the new construction portion of HB 2 are considered to overlap with RCI-7, and thus are eliminated from the RCI-7 quantification. The total GHG reductions associated with HB 2 in Kentucky are listed in Table RCI-2.

Kentucky's utilities have been pursuing limited demand-side management (DSM) programs for some time. For the analysis of RCI-3, we assume that existing residential electric DSM programs are equal to 0.25% of load over the 2010–2030 period and are not in the reference case forecast; therefore, they need to be treated as recent actions.[3] This estimate is based on the activities for one investor-owned utility (IOU), and may not be representative of statewide activities. Nonetheless, the important thing is that potential DSM activities are included in recent actions and are not being double counted in RCI-3. Commercial electric DSM programs are assumed be funded at lower levels. Thus, they are adequately incorporated into the electric utility load growth forecasts used for the Kentucky Inventory and Forecast, and are not treated as recent actions. The fuels forecast for Kentucky is based on growth estimates from the U.S. Energy Information Administration's (EIA's) *Annual Energy Outlook* (AEO) *2009*. The fuels forecast includes historical improvements in energy efficiency, so fuel DSM programs are not treated as recent actions in this analysis. See the RCI-3 quantification results section for the assumptions used to calculate GHG reductions from recent DSM actions in the electric sector.

Table RCI-2. Recent Action Results Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)		
		2020	2030	Total 2011–2030
RCI-7	Government Lead by Example	0.6	1.5	14
RCI-3	Expand Utility DSM Programs for Electricity	0.9	1.7	18

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; DSM = demand-side management; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

[3] Based on a telephone call with Mike Horning at E.ON AG, September 15, 2010.

RCI-1. Improve Building Codes for Energy Efficiency, Coupled with Improved Energy Code Training and Enforcement

Policy Description

Building energy codes specify minimum energy efficiency requirements for new buildings or for existing buildings undergoing a major renovation. Given the lifetime of buildings, amending state building codes to include minimum energy efficiency requirements and periodically updating energy efficiency codes could provide long-term GHG savings. Kentucky can improve energy codes that go beyond HVAC systems to include efficiency gains, such as designs to reduce lighting needs, electric lighting design, building envelope design, and integrated building design strategies.

Building codes, such as fire, structural, and electrical codes, were originally developed to address building conditions and safeguard occupants; building officials have thought of themselves as protectors of the public. Energy codes are a relatively recent addition to the family of building codes and do not have the same immediate connection to public safety. Therefore, many jurisdictions have given them lower priority when allocating resources. Energy codes are increasingly being relied upon to address health issues, energy supply concerns, and climate change. Accordingly, officials will need to put building code enforcement on a par with that of traditional codes.

State and local governments must communicate that energy code enforcement is an equal partner in the family of building codes. They must also allocate sufficient resources to allow code officials to enforce the energy code requirements on a level playing field with fire, life, and safety codes. Building codes are generally funded and enforced by permit fees, which average less than 1% of construction costs.

Adequate training of building plan reviewers and building inspectors is key to the success of building codes, as is appropriate enforcement capability. Unless these functions are adequately funded and staffed with qualified personnel, the full value of building codes will not be realized. Accordingly, the state's building code efforts should include an education and outreach program for building inspectors to encourage incorporation in inspection protocols of energy efficiency and GHG emission reduction considerations.

Policy Design

Goals/Levels

- Expand enforcement of building energy codes.
- Adopt national codes with amendments as appropriate.
- Achieve targeted improvements in energy efficiency through educational programs for building inspectors and code enforcement officials to ensure that the existing codes are implemented and enforced.
- As a longer-term goal (e.g., ~2030), consider the benefits and shortcomings of basing the state's energy codes on units of carbon emitted, rather than units of energy consumed.

Timing

- Expand adoption and enforcement efforts of building energy code requirements immediately.
- Update Kentucky energy codes within one year to coincide with the most recent version of the national codes, and keep them updated to the latest standards.
- Coordinate training of building code officials with the adoption and enforcement of the new codes.

Parties Involved: The Kentucky Department of Housing, Building and Construction (DHBC) and local jurisdictions as applicable, with input from the Kentucky Energy and Environment Cabinet (KEEC) and Finance and Administration Cabinet; building designers; builders and contractors; building inspectors; mortgage lenders.

Other: None.

Implementation Mechanisms

As noted above, implementation would primarily occur through the adoption and enforcement of updated building codes by the involved parties. Training and education efforts would occur in parallel.

Related Policies/Programs in Place

- Training workshops of industry personnel and public awareness efforts are contemplated under a grant administered by DHBC through the Department for Energy Development and Independence (DEDI).
- Compliance with model energy codes (e.g., 2009 International Energy Conservation Code [IECC] and American Society of Heating, Air Conditioning, and Refrigeration Engineers [ASHRAE] 90.1_2007) is scattered in all but a few states. In response, the International Code Council (ICC) and the Building Codes Assistance Project (BCAP) have put forth an initiative and partnership called the Energy Code Ambassadors Program (ECAP). One important barrier to improved code compliance is a general lack of local and state infrastructure and experience in enforcing energy codes. Using national and regional energy code experts as mentors or "ambassadors" to assist state and local code officials in developing and implementing effective enforcement/compliance approaches will provide needed support and technical assistance. The ambassadors will provide support and energy code expertise, including infield guidance and/or training, to the code enforcement community. Further, ambassadors will be adept in using ICC, BCAP, U.S. Department of Energy (DOE), and other resources and will act as grassroots code adoption and implementation representatives, as needed. Further, ambassadors will provide advocacy support in their states for code adoption and updates. Kentucky is one of four states selected to participate in this pilot program, which will be coordinated by DHBC, the state code enforcement authority.
- Kentucky has formed a High-Performance Building Advisory Committee to set aggressive energy consumption standards for state buildings as part of the state's government-lead-by-example efforts.

- By accepting American Recovery and Reinvestment Act of 2009 (ARRA) State Energy Program funding and submitting letters assuring DOE that it will comply with the terms of Section 410, Kentucky has committed to do three things:
  - Adopt a residential building energy code that meets or exceeds the 2009 IECC;
  - Adopt a commercial building energy code that meets or exceeds the American National Standards Institute (ANSI)/ASHRAE/Illuminating Engineering Society of North America (IESNA) Standard 90.1–2007; and
  - Develop and implement a plan, including active training and enforcement provisions, to achieve 90% compliance with the target codes by 2017, including measuring current compliance each year.[4]

Type(s) of GHG Reductions

- Carbon dioxide (CO_2) is the primary gas reduced by avoided electricity generation from fossil fuel sources, but trace amounts of methane (CH_4), and nitrous oxide (N_2O) emissions are also avoided.
- CO_2 is the primary gas reduced by avoided fossil fuel combustion in the RCI sectors, but trace amounts of CH_4 emissions are also avoided.

Estimated GHG Reductions and Costs or Cost Savings

Table RCI-1-1a. Estimated GHG Reductions and Costs or Cost Savings from RCI-1 Applying Direct Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		Annual		Total 2011–2030		
		2020	2030			
RCI-1	Improved Building Codes for Energy Efficiency	0.34	1	8	–$213	–$25

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

[4] See: http://www.usgbc.org/Docs/News/State%20Bldg%20Codes%20White%20Paper%2012-1-09%20REV2-usgbc.pdf.

Table RCI-1-1b. Estimated GHG Reductions and Costs or Cost Savings from RCI-1 Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		Annual		Total 2011–2030		
		2020	2030			
RCI-1	Improved Building Codes for Energy Efficiency	0.36	1.2	9	–$213	–$23

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

Data Sources

- Western Governors' Association. December 2005. The Potential for More Efficient Electricity Use in the Western United States, p. 42. Available at: http://www.naesco.org/resources/industry/documents/2005-11-18.pdf.
- Maggie Eldridge, Steve Nadel, Amanda Korane, John A. "Skip" Laitner, Vanessa McKinney, Max Neubauer, and Jacob Talbot. April 1, 2009. *Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania*. American Council for an Energy-Efficient Economy (ACEEE) et al. Available at: http://www.aceee.org/pubs/e093.htm.
- U.S. Department of Energy, Energy Information Administration. 2005. "Residential Energy Consumption Survey 2005: Consumption and Expenditure Data Tables." Table CE1-1c: Total Energy Consumption in U.S. Households by Climate Zone. Available at: http://www.eia.doe.gov/emeu/recs/recs2001/detailcetbls.html#space.
- U.S. Department of Energy, Energy Information Administration. 2003. Table 3a. Electricity End-Use Consumption by Principal Building Activity, 1999 (Preliminary Estimates) "Commercial Buildings Energy Consumption Survey" (CBECS). Ratio of 1990–1999 buildings to all buildings total energy use. Available at: http://www.eia.doe.gov/emeu/cbecs/enduse_consumption/pba.html.
- U.S. Department of Energy, Energy Information Administration. 2010. *Annual Energy Outlook 2010*. Reference case supplement tables for regional detail. Available at: http://www.eia.doe.gov/oiaf/aeo/aeoref_tab.html.

Quantification Methods: The analysis first calculates gross costs, which include the incremental capital, labor, and fuel (if appropriate) costs of the efficient technology over the assumed baseline technology. Administrative (program, evaluation, marketing, and outreach) costs are also included in the costs of RCI energy efficiency. These cost assumptions are listed in Tables RCI-1-3 and RCI-1-4. Next, gross benefits from avoided energy expenditures are calculated. Net cash flows (costs or benefits) are then calculated, which are gross costs-gross benefits. Finally, the net present value (NPV) of this stream of net cash flows is derived.

Gross Costs

The gross costs in each year are derived as follows:

- The quantity of energy savings (gigawatt-hours [GWh]/billion British thermal units [BBtu]) for each year is determined from the goal and timing sections of each policy recommendation.
- The above costs of the incremental energy-efficient equipment is multiplied times the quantity of energy savings (GWh/BBtu) assumed mitigated in each year. This gives the total gross cost of the policy recommendation in each year.

Gross Benefits

The gross benefits in each year are derived as follows:

- The avoided prices of energy, which are the avoided energy expenditures (or bill savings) from the RCI policies. These avoided prices are listed in Table RCI-1-2.
- The quantity of energy (GWh/BBtu) used to calculate the gross benefits is the same amount of energy as calculated for gross costs above.
- The gross benefit is the avoided energy price multiplied by the quantity of energy assumed mitigated in each year.

Net Costs or Benefits

The net costs or benefits in each year are derived as follows:

- Gross benefits are subtracted from gross costs in each year through 2025 to give a net cash flow for each time period. Negative values represent positive economic cash flows.

Net Present Value

- The NPV of this stream of cash flows is calculated using a 5% real discount rate to estimate a discounted, lump sum cost (benefit) in $2006 to the state from the program in 2010 (assuming the relevant 2012–2030 implementation schedule).

The building code analysis begins with the new construction growth rate for each sector and applies this rate to the relevant electric sales forecast. The percentage of electricity use that falls under code buildings in each year is calculated and then multiplied by the cumulative electricity savings percentage from assumed improvements in efficiency in future energy codes. Electricity savings from major retrofits are then included, and losses from noncompliance are subtracted. Fuel savings from the code policy is derived at the ratio of fuel use to electricity use for each building type.

Key Assumptions

- The direct emissions factor for avoided CO_2 emissions intensity for electricity is approximately 1.03 metric tons per megawatt-hour (t/MWh) for all years, and is derived from a consumption-based carbon dioxide-equivalent (CO_2e) forecast for each year divided by MWh forecasted sales. This approach includes electricity transmission and distribution (T&D) losses in emission intensity. The full-fuel-cycle emissions factor is assumed to be 5% higher than the direct factor. As coal is the source of nearly all electricity generation in Kentucky, the full fuel cycle for coal is used, which is 5% higher than the direct emissions factor.

- Table RCI-1-2 lists the fuel emissions factor assumptions. The direct emission factors come from EIA, and the full-fuel-cycle emissions are in addition to the direct emissions developed for New York from the GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) model.[5]

Table RCI-1-2. CO_2 Emission Factors Used in Kentucky

CO_2 Emission Factors Used in Kentucky (tCO_2/MMBtu)	Direct Emissions	Full-Fuel-Cycle Emissions
Bituminous Coal	0.09346	0.098133
Fuel Oil-Middle Distillate Fuels (No. 1, No. 2, No. 4 fuel oil, diesel, home heating oil)	0.073	0.0914375
Propane (liquefied petroleum gas)	0.062	0.0729261
Natural Gas HHV of 1025–1050 Btu/scf	0.0536	0.06650182
Biomass	0	0.012

Btu/scf = British thermal units per standard cubic foot; CO_2 = carbon dioxide; HHV = high heating value; tCO_2/MMBtu = metric tons of carbon dioxide per million British thermal units.

- Existing code enforcement rates are 50%, rising to 90% by 2019 under ARRA. Residential compliance entails plan reviews and inspections by local officials. This activity is part of the baseline, given it is a condition of ARRA (2009) funding.
- The baseline energy consumption forecast is derived from the 2010 AEO, which assumes a slow adoption of residential and commercial building codes.
- The baseline for this analysis is that Kentucky adopts the 2009 residential and 2007 commercial codes by the start of RCI-1 in 2012. It also assumes that Kentucky updates these codes to the most recent vintage in 2021 as part of the baseline activity.
- Table RCI-1-3 shows forecasted fuel prices for the RCI sectors come from most recent EIA state *retail prices* for each sector. For each year past the base year historical price through 2030, the annual change in fuel prices comes from Table 16 in EIA's 2010 AEO reference case supplementary tables for the East South Central census region.
    - 2008 Kentucky Retail Natural Gas Prices from EIA.[6]
    - 2009 Kentucky Weekly Average Fuel Oil Prices from EIA.[7]
    - 2009 Kentucky Weekly Average Propane Prices from EIA.[8]

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[5] Direct emission factors are from the EIA 1605B program: www.eia.doe.gov/oiaf/1605/excel/Fuel%20Emission%20Factors.xls. The full-fuel-cycle emission factors are from the New York GREET model. The New York Climate Action Plan can be found at: http://www.nyclimatechange.us/ewebeditpro/items/O109F24048.pdf.

[6] 2008 prices were used because 2009 residential gas prices were not available. See: http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_SKY_a.htm.

[7] See: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WHORE304&f=W.

- 2008 Kentucky Commercial and Institutional Coal Price: Average Price of Coal Delivered to End Use Sector by Census Division and State.[9]

Table RCI-1-3. 2010 Avoided Fuel Price Assumptions

Sector	2010 Prices (2005$/MMBtu)				Electricity ($/MWh)
	Natural Gas	Fuel Oil	Propane	Coal	
Residential	$9.33	$12.16	$20.78	—	$79.07
Commercial	$7.99	$12.45	$22.14	$4.10	$67.25
Industrial	$4.86		$18.69	$4.10	$53.50

$/MWh = dollars per megawatt-hour; MMBtu = million British thermal units.

- Forecasted electricity prices start with 2007 retail electricity prices from EIA's State Electricity Profile (p. 107). For 2007–2030, the annual change in electricity price comes from Table 16 in EIA's 2010 AEO reference case supplementary tables for the East South Central census region.
- The levelized cost of building code electric efficiency measures is $47.40/MWh, from the Western Governors' Association (2005) report.[10] The costs of natural gas, fuel oil, propane, and coal efficiency measures are in Table RCI-1-2.

The costs of energy efficiency measures in Tables RCI-1-4 and RCI-1-5 include program and participant costs as is typically used in total resource cost tests.

Table RCI-1-4. Cost of Fuel Efficiency Measures (all years)

Sector	2009$/MMBtu
Residential	$6.08
Commercial	$3.77
Industrial	$2.25

MMBtu = million British thermal units.

Table RCI-1-5. Fuel Efficiency Measures—Fixed-Cost Assumptions

Levelized Cost of Energy Efficiency—Fixed Costs (administrative, marketing, etc.)	% of Capital
Residential	15%
Commercial	15%
Industrial	15%

Table RCI-1-5 shows the fixed-cost assumptions of fuel efficiency measures that are included in Table RCI-1-4. To extract the fixed costs in dollars per million British thermal units ($/MMBtu), the percentages in Table RCI-1-5 are applied to the sectoral capital costs from the American

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[8] See: http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WPRRE304&f=W.

[9] See: http://www.eia.doe.gov/cneaf/coal/page/acr/table34.html.

[10] See: http://www.naesco.org/resources/industry/documents/2005-11-18.pdf.

Council for an Energy-Efficient Economy (ACEEE) (2009). For example, the fixed costs for residential efficiency equal (0.15 * $5.29) = $0.79/MMBtu. Total costs of residential are thus $5.29 + $0.79 or $6.08/MMBtu.

The energy savings assumptions for RCI-1 are listed in Table RCI-1-6. The savings from building energy codes are driven by estimated electric energy demand reductions. Efficiency savings for natural gas, fuel oil, and other fuels are estimated by their usage in each sector relative to electricity. For example, in the residential sector on a total Btu basis approximately 28% more natural gas is used than electricity. Therefore, an improvement in a building energy code cycle that reduced electricity demand by 10% would result in a 12.8% reduction in natural gas for the residential sector and a 6.35% reduction in natural gas for the commercial sector.

Table RCI-1-6. RCI-1 Assumptions

Levelized Cost of Energy Efficiency—Fixed Costs (administrative, marketing, etc.)	**% of Capital**
Residential	13%
Commercial	10%
Industrial	5%
Ratio of Fuel Savings to Electricity Savings: Btu (based on total Btu consumption)	**Ratio**
Residential Sector—Gas	128.2%
Residential Sector—Fuel Oil	30.6%
Residential Sector—Liquefied Petroleum Gas	9.4%
Commercial Sector—Gas	63.5%
Commercial Sector—Fuel Oil	7.3%
Commercial Sector—Liquefied Petroleum Gas	2.3%
Commercial Sector—Coal	4.9%
Industrial Sector—Gas	86.0%
Estimated based on relative usage of electricity and gas by sector. *Residential energy use consists of more natural gas relative to electricity, so efficiency improvements accrue at a higher rate.* *Assumes the same pattern of code improvement for fuels as for electricity use, as described above.* *Table C1. Total Energy Consumption by Major Fuel for Non-Mall Buildings, 2003. Table CE1-1c.Total Energy Consumption in U.S. Households, 2005.*	
Improvements in Building Codes/Year in Baseline	**Rate/Year**
ARRA building code improvements assumed to be in AEO 2010 forecast.	0.0%
Improvements in Building Codes /Year for 2012–2030 Code Cycles	
Assumed per code cycle improvement in electric efficiency.	10.0%
Net New Construction Growth	**Rate/Year**
Residential	1.0%
Commercial	1.2%
2010–2030 average forecasted annual change in number of space heaters, air conditioners, and water heaters for U.S. multiplied times ratio of change in disposable income for census region. Source: Table 32. AEO 2010 Reference Case. *2010–2030 average forecasted change in commercial floor space for U.S. multiplied by the ratio of change in disposable income for census region. Source: Table 31. AEO 2010 Reference Case.*	

Renovated Residential Space	**No. of Units**
Currently set at 1.2 so that for every one new building falling under code, an additional 0.2 units of substantially renovated residential space is included.	1.20
Electricity Use in Buildings That Falls Under Code	**Rate/Year**
Residential (HVAC)	27.1%
Commercial (HVAC and Lighting)	57.1%
Industrial (HVAC and Lighting)	0.0%
Regional Climate Correction Factor	**% Correction**
Commercial	103.0%
Currently set at 1.2 so that for every one new building falling under code, an additional 0.2 units of substantially renovated residential space is included.	1.20
% of Buildings That Comply with Codes	**% Compliance**
All Buildings in 2012	50.0%
All Buildings in 2019	90%
Efficiency Losses from Noncompliance	**% of Loss**
Losses from substandard building practices compared to code/policy. *Placeholder assumption.*	20%

Net present value is calculated in 2005 dollars beginning in 2010.

AEO = *Annual Energy Outlook*; ARRA = American Reconstruction and Recovery Act of 2009; Btu = British thermal unit; HVAC = heating, ventilating, and air conditioning.

Key Uncertainties

None identified.

Additional Benefits and Costs

None identified.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-2. Promote, Encourage, and Provide Incentives for "Beyond-Code" Efficiency in All Building Characteristics and Systems That Impact Energy Consumption

Policy Description

This policy provides incentives and targets to induce the owners and developers of new buildings to improve the efficiency of the use of energy and other resources in those buildings, along with provisions for raising target levels periodically and providing resources to building industry professionals to help achieve the desired building performance. This policy can include elements to encourage the improvement and review of energy use goals over time. Additionally, it can support flexibility in contracting arrangements to encourage integrated energy- and resource-efficient design, construction, and renovation. Incentives could include low-cost loans for investments in energy efficiency, tax credits, expedited plan review permits, and feebates for design professionals. Improving the energy efficiency design of buildings will have an immediate and ongoing impact on reducing GHG emissions.

For the remainder of RCI-2, we will use the base energy use intensities from ANSI/ASHRAE/IESNA Standard 90.1-2004 for various building types in climate zone 4A, as defined by DOE Executive Order (EO) 430.2B.

Policy Design

Goals

- Provide tiered incentives for energy efficiency in new buildings that achieve a reduction in energy use relative to the base established per the DOE EO 430.2B energy standard for commercial buildings and the 2009 IECC for residential buildings through certification by a design professional or a nationally recognized third-party-verified green building certification system for commercial or residential buildings (e.g., Leadership in Energy and Environmental Design (LEED), ASHRAE/U.S. Green Building Council (USGBC)/IESNA Standard 189, or Green Globes New Construction).
- Reward projects where minimum energy efficiency exceeds ANSI/ASHRAE/IESNA Standard 90.1-2004 benchmark levels[11] by the amounts shown in Table RCI-2-1.

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[11] This benchmark applies base energy use intensities from ANSI/ASHRAE/IESNA Standard 90.1-2004 for various building types in climate zone 4A as defined by U.S. DOE Executive Order 430.2B. See https://www.directives.doe.gov/directives/current-directives/430.2-BOrder-b/view?searchterm=None. End user energy intensity targets are located at: http://apps1.eere.energy.gov/buildings/publications/pdfs/commercial_initiative/all_euis.pdf.

Table RCI-2-1. Reductions from Benchmark Energy Use Intensity

Year	New Construction	Existing Building Retrofits
2010	30%	20%
2015	50%	35%
2020	70%	50%
2025	85%	65%
2030	100%	75%

- Provide projects and project teams appropriate incentives for achieving the appropriate levels above. Give projects and project teams that surpass the above goals an additional incentive for every 5% greater efficiency achieved beyond the above goals. In 2025 and 2030, once the team has made the project as energy efficient as possible (i.e., 100%), give the project and project team all aforementioned incentives.
- Require participating organizations or individuals to calculate, monitor, and report the costs and actual performance of energy efficiency improvements, as well as annual GHG emissions. Compare the performance of energy efficiency improvements in existing buildings against a regional average of similar building types.

Timing: Legislation may be required for implementation. Develop any necessary legislation in 2011, and implement the incentives policy in 2012.

Parties Involved: Legislative Research Commission (LRC), Commonwealth of Kentucky Finance Cabinet, DHBC, developers, builders and contractors, building owners, energy service companies, building material suppliers, recycled building material sellers, design professionals, and home improvement stores.

Other: None identified.

Implementation Mechanisms

Examples of potential incentive programs include:

- Commercial Lighting Retrofit Rebate Programs: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=AK09F&re=1&ee=1.
- Commercial and Industrial Energy Efficiency Rebate Programs: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=AR53F&re=1&ee=1.
- Business Energy Efficiency Rebate Programs: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=IL52F&re=1&ee=1.
- Property Tax Exemption for Renewable Energy: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=IN01F&re=1&ee=1.
- State Loan Programs for Rural Business Energy Efficiency Improvements: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MD25F&re=1&ee=1.

- Photovoltaic Rebate Programs: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=MO95F&re=1&ee=1.
- Energy Efficiency Rebates to Nonprofit Organizations: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NC57F&re=1&ee=1.
- Builder Rebate Programs: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=SC43F&re=1&ee=1.
- Green Energy Tax Credits: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=TN66F&re=1&ee=1.
- Expedited Plan Reviews for Green Buildings: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=AZ38F&re=1&ee=1.
- Solar Permit Fee Rebates: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CO184F&re=1&ee=1.
- Building Permit Fee Waivers: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=NC46F&re=1&ee=1.
- Also, the federal Energy Policy Act of 2005 allows architects and engineers to take federal tax deductions for energy-efficient design when the building owner is tax exempt and, therefore, ineligible for tax credits.

Related Policies/Programs in Place

None identified.

Type(s) of GHG Reductions

- CO_2 is the primary gas reduced by avoided electricity generation from fossil fuel sources, but trace amounts of CH_4 and N_2O emissions are also avoided.
- CO_2 is the primary gas reduced by avoided fossil fuel combustion in the RCI sectors, but trace amounts of CH_4 emissions are also avoided.

Estimated GHG Reductions and Costs or Cost Savings

Table RCI-2-2a. Estimated GHG Reductions and Costs or Cost Savings from RCI-2 Applying Direct Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/t$CO_2e$)
		Annual		Total 2011–2030		
		2020	2030			
RCI-2	High-Performance Buildings	2	4	46	–$1,376	–$30

$/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table RCI-2-2b. Estimated GHG Reductions and Costs or Cost Savings from RCI-2 Applying Full-Fuel-Cycle Emission Factors

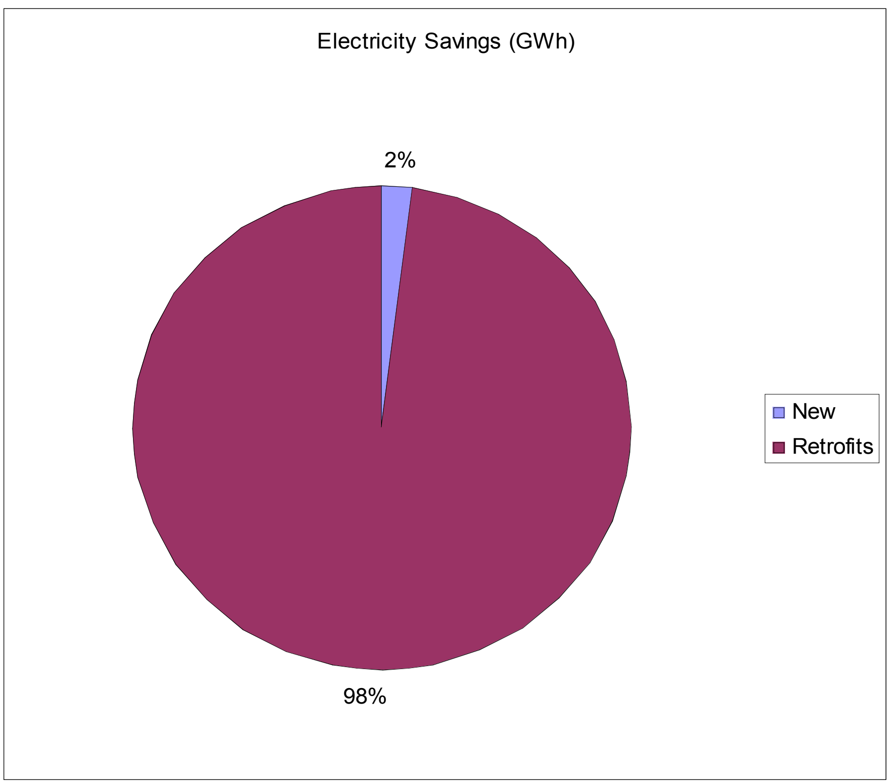
Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/t$CO_2$e)
		Annual		Total 2011–2030		
		2020	2030			
RCI-2	High-Performance Buildings	2	5	50	–$1376	–$27

$/t$CO_2$e = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative $MMtCO_2e$ of GHG reductions (column five).

Figure RCI-2-1 shows the relative contribution of new construction versus retrofits for cumulative electricity reductions in 2030 from RCI-2 totaling approximately 3,300 GWh. Retrofits provide the vast majority of the reductions because of the larger stock of existing buildings, given the assumed penetration rate of high-performance buildings.

Figure RCI-2-1. Cumulative 2030 Electricity Reductions by Program



GWh = gigawatt-hours.

Data Sources: See RCI-1 and sources listed below.

Quantification Methods: Energy efficiency improvements are taken from Table RCI-2-1. These improvements are implemented at the rates shown in the ramp-in assumptions in Table RCI-2-3. Only residential and commercial buildings are included; government reductions are quantified under RCI-7, and industrial building reductions are not quantified under this policy.

Key Assumptions

- Efficiency improvement targets for new and retrofitted buildings are taken from Table RCI-2-1.
- Residential building efficiency improvements are included in the quantification.
- Energy reductions (and associated GHGs) from the policy do not begin until 2011.

Table RCI-2-3. Energy Efficiency Ramp-In Assumptions

Buildings Provided with Incentives	Percentage	Year
New Commercial Buildings	3.0%	2012
Incentives implemented linearly	15.0%	2020
	30.0%	2030
Existing Commercial Buildings	3.0%	2012
Incentives implemented linearly	10.0%	2020
	20.0%	2030
New Residential Buildings	3.0%	2012
Incentives implemented linearly	15.0%	2020
	30.0%	2030
Existing Residential Buildings	3.0%	2012
Incentives implemented linearly	10.0%	2020
	20.0%	2030
Cost of New High-Performance Building	**Electricity**	**Fuel**
Residential $/MWh or $/MMBtu	$29.94	$5.45
Commercial ($/sq ft)	$2.09	$1.91
Commercial (Levelized $/sq ft)	$0.20	$0.18
Expected Life of Measures	15	15
Residential costs are DSM from ACEEE et al. (2009). *Kats (2004).* The Costs and Financial Benefits of Green Buildings*. Available at: http://www.calrecycle.ca.gov/greenbuilding/design/CostBenefit/Report.pdf.* *$4/square foot increased architectural and engineering (A&E) design time. The gross initial capital cost of $4/sq ft is levelized over measure life. Prorated by electric vs. fuel energy consumption.*		
Cost of Retrofit for High-Performance Building	**Electricity**	**Fuel**
Residential $/MWh or $/MMBtu	$29.94	$5.45
Commercial ($/sq ft)	$2.09	$1.91
Commercial (Levelized $/sq ft)	$0.20	$0.18
Expected Life of Retrofit Measures	15	15
Residential costs are DSM from ACEEE et al. (2009). *Kats (2004).* The Costs and Financial Benefits of Green Buildings*. Available at: http://www.calrecycle.ca.gov/greenbuilding/design/CostBenefit/Report.pdf.* *$4/square foot increased architectural and engineering (A&E) design time. The gross initial capital cost of $4/sq ft is levelized over measure life. Prorated by electric vs. fuel energy consumption.*		

Average Existing Household Energy Consumption	kBtu	kWh
kBtu/year Consumption	87	
Electricity Share	32	9497
Fuels Share	55	
For East South Region. Table US14. Average Consumption by Energy End Uses, 2005. Available at: http://www.eia.doe.gov/emeu/recs/recs2005/c&e/summary/pdf/tableus14.pdf.		
Average New Household Energy Consumption	**kBtu**	**kWh**
kBtu/year Consumption	76	
Electricity Share	28	8215
Fuels Share	47	
For U.S. residences built 2000–2005 less 20% for smaller houses and 2009 IECC. Table U.S.14. Average Consumption by Energy End Uses, 2005. Available at: http://www.eia.doe.gov/emeu/recs/recs2005/c&e/summary/pdf/tableus14.pdf.		
Average End User Energy Intensity of New Commercial Building	**kBtu**	**kWh**
kBtu/sq ft Site Energy	51	
Electricity Share	27	7.8
Fuels Share	24	
DOE Commercial Building Benchmarks for Medium Office (Climate Zone 4a). Available at: http://apps1.eere.energy.gov/buildings/publications/pdfs/commercial_initiative/all_euis.pdf.		
Average End User Energy Intensity of Existing Commercial Building	**kBtu**	**kWh**
kBtu/sq ft Site Energy	91	
Electricity Share	48	13.9
Fuels Share	44	
Table C8. Consumption and Gross Energy Intensity by Census Division for Sum of Major Fuels for Non-Mall Buildings, 2003: Part 1. Available at: http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set9/2003html/c8.html.		
Net New Construction Growth	**Rate/Year**	
Residential	1.0%	
Commercial	1.2%	

See RCI-1 for additional assumptions.

ACEEE = American Council for an Energy-Efficient Economy; AEO = Annual Energy Outlook; DOE = U.S. Department of Energy; DSM = demand-side management; EIA = U.S. Energy Information Administration; IECC = International Energy Conservation Code; kBtu = thousand British thermal units; kWh = kilowatt-hour; MMBtu = million British thermal units; sq ft = square foot; MWh = megawatt-hour.

Key Uncertainties

None identified.

Additional Benefits and Costs

None identified.

Feasibility Issues

New legislation may be required for implementation.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-3. Expand Utility DSM Programs for Electricity

Policy Description

Note: This policy recommendation was developed jointly with the Energy Supply TWG as policy ES-2.

Demand-side management (DSM), energy efficiency education, programs, pilots, or goals for reduced electricity consumption call for actions that influence the quantity and/or patterns of use of energy consumed by end users. This policy recommendation focuses on increasing investment in electricity DSM/energy efficiency through innovative actions developed and implemented by utilities, community partners, and customers. The ultimate goal is to provide tools, information, assistance, and knowledge that will help customers manage their energy consumption more efficiently and reduce their consumption.

Policy Design

Given the current cost of electricity in Kentucky and the lack of consensus in the U.S. House and Senate on increasing the costs of electricity through the establishment of a price on carbon, renewable portfolio standards, efficiency standards, or clean energy standards, the most cost-effective method of preparing the Commonwealth for increased energy efficiency and DSM is to increase education and the number of efficiency/DSM programs and pilot projects that provide customers with the tools and information they need to better manage their energy consumption.

The current rate structure for utilities in Kentucky creates a business environment where additional energy efficiency and conservation measures may have a negative financial impact for utilities. Historically, utility rate structures encourage the sale of power. To align energy efficiency and conservation incentives with the utilities' business model, Kentucky should examine alternative rate structures that equalize the incentive for utilities to invest in cost-effective energy efficiency, with the incentive to invest in new supply resources.

Goals

- On a collaborative basis, by June 2011, develop a consortium of IOUs, electric cooperatives, and municipal utilities to work with DEDI and the Public Service Commission (PSC) to develop rate mechanisms and remove regulatory barriers so that utilities are better able to invest in DSM and energy efficiency programs. Considerations for this recommendation could include, but are not limited to, corporate tax incentives, sustainable building tax credits, green building incentives, green building standards for state facilities, energy efficiency bond programs, personal tax incentives, sales tax incentives, lease purchase programs, grant programs, and loan programs.
- By January 2012 have in place a regulatory environment that provides a mechanism and procedure for investment in DSM and energy efficiency. Investment in DSM and energy efficiency may include, but is not limited to:
    - Consumer and member education

- Consumer and member focus groups
- Pilot programs to explore and test creative and innovative opportunities
  - SCADA (supervisory control and data acquisition) systems
  - Communication systems
  - Advanced Volt/Var control
  - Smart feeder switching systems (self-healing grid)
  - Direct-load control systems
  - Smart Home systems, including, but not limited to:
    - In-home displays
    - Smart meters (See RCI-10)
    - Home energy networks and gateways
    - Smart Thermostats
    - Smart Appliances
    - Load management systems
    - Energy Web portals displaying energy use data and comparisons
    - Integrated utility home network, communication, and data transfer
  - Distributed generation pilots, where consumers work collaboratively to implement economic alternative power supply systems, such as:
    - Solar water-heating systems
    - Heat pump water-heating systems
    - Geothermal HVAC and water-heating systems
    - Wind power systems
    - Biomass power supply systems
    - Solar power supply systems
    - Net-zero-energy homes
    - Electric vehicle/utility interconnection systems
  - Energy storage systems
  - Weatherization, HVAC upgrades, and ENERGY STAR appliance upgrade pilot programs in collaboration with finance and community networks to provide innovative funding mechanisms to assist customers to finance their energy efficiency efforts.

- By June 2011, have DEDI in a collaborative effort with the PSC and the state's utilities. Based on empirical studies of nationwide energy efficiency and DSM programs, determine the costs of electricity where participation in energy efficiency and DSM has become commonplace. In addition, determine the impact of DSM on energy consumption in Kentucky as well as nationwide. Charts identifying the aggregated DSM energy savings from filed programs from 1995 through 2015 would provide a good historical basis to assist in determining a reasonable policy going forward.

- By January 2012, have pilot programs and consumer education in place at all utilities in the Commonwealth.
- By January 2014, have advanced the pilot programs to make energy efficiency/DSM opportunities available to all consumers in the Commonwealth. Beginning in 2014 and running to 2030, consider targets for DSM GHG reductions, pending additional research on experience in other states with comparable demographics and energy price points.
- As the cost of electricity increases to the level that causes significant energy efficiency/DSM results, have a strong, viable consumer education program and an energy efficiency/DSM plan in place at all utilities in the Commonwealth.

Timing: See above.

Parties Involved: IOUs, municipals, cooperatives, DEDI, PSC, community action groups, financial organizations, environmental groups, and DSM equipment manufacturers. It is the intent to work in a collaborative process, to properly align the roles of these parties.

Other: None.

Implementation Mechanisms

DEDI will convene a collaborative team made up of all of the stakeholders identified above to work in a consensus decision-making process to achieve these goals. New legislation may be required to implement resulting recommendations, especially any relating to well-established PSC requirements.

Related Policies/Programs in Place

- Many Kentucky utilities have DSM funds and programs in place for residential and commercial customers.
- DSM is a component of Kentucky's Energy Efficiency Resource Standard (EERS), one of four major action items in Kentucky's proposed energy strategy.[12]
- Government Lead by Example (GLE) is also one of the four major action items in Kentucky's energy strategy; the recommended targets are 15% reduction in energy consumption from 2009 levels by 2015 and 25% by 2025.

[12] Gov. Steven L. Beshear, *Intelligent Energy for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008. Available at: http://www.energy.ky.gov/energyplan2008/.

Type(s) of GHG Reductions

CO_2 is the primary gas reduced by avoided electricity generation from fossil fuel sources, but trace amounts of CH_4 and N_2O emissions are also avoided.

Estimated GHG Reductions and Costs or Cost Savings

Table RCI-3-1a. Estimated GHG Reductions and Costs or Cost Savings from RCI-3 Applying Direct Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-3	Expand Utility DSM Programs for Electricity	7	18	161	–$3,340	–$21

Table RCI-3-1b. Estimated GHG Reductions and Costs or Cost Savings from RCI-3 Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-3	Expand Utility DSM Programs for Electricity	8	19	169	–$3,340	–$20

$/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative $MMtCO_2e$ of GHG reductions (column five).

Data Sources: See RCI-1. Also, Maggie Eldridge, Steve Nadel, Amanda Korane, John A. "Skip" Laitner, Vanessa McKinney, Max Neubauer, and Jacob Talbot. April 1. 2009. *Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania*. ACEEE et al. Available at: http://www.aceee.org/pubs/e093.htm.

Quantification Methods: See RCI-1.

Key Assumptions: See RCI-1. Also:

- Assume existing utility DSM programs achieve 0.25% of load-incremental DSM per year.
- DSM and education programs begin in 2012 and reach full implementation by 2015, when they achieve incremental annual load reductions of 1% of the forecasted load. Load reductions occur for all RCI sectors at the same implementation rate. Load reductions from the programs for 2016–2030 are at the 2015 rate. Table RCI-3-2 presents the assumed short-term implementation schedule for load reductions.

Table RCI-3-2. Short-Term Implementation Schedule for Load Reductions

2012	2013	2014	2015
0.1%	0.25%	0.75%	1.0%

- The 1% annual reduction for 2015–2030 is moderate compared to what other states with low electricity prices have implemented for aggressive electricity DSM programs. As a point of reference, Kentucky's all-sector average electricity price for 2007 was $58.40/MWh according to EIA.[13]
    - Iowa's IOUs are scheduled to achieve incremental annual load reductions from DSM of 1.4% of load by 2013, up from 0.8% in 2007.[14] Iowa's all-sector average electricity price for 2007 was $68.30/MWh.
    - Idaho Power spends about 4.7% of revenues on energy efficiency, in spite of low electricity prices.[15] Idaho's all-sector average electricity price for 2007 was $50.07/MWh.
    - The Arkansas Governor's Commission on Global Warming recommended meeting all new electricity load growth (about 1.7%/year) through DSM programs.[16] Arkansas' all-sector average electricity price for 2007 was $69.60/MWh.

Table RCI-3-3. Cost of Electricity Efficiency Measures (all years)

Levelized Cost of Electric Energy Efficiency—Total Cost	2009$/MWh
Residential	$33.42
Commercial	$13.19
Industrial	$22.03
Load Weighted Average	$23.84

$/MWh = dollars per megawatt-hour.

The costs of energy efficiency measures include program and participant costs, as is typically used in total resource cost tests.

Key Uncertainties

Technology Feasibility

- Many technologies required to achieve energy reductions may not be feasible in Kentucky due to geographic location, and others can require significant investment by individuals.

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[13] 2007 State Electricity Profiles. Available at: www.eia.doe.gov/electricity/st_profiles/e_profiles_sum.html.

[14] Iowa Utilities Board. *Energy Efficiency in Iowa's Natural Gas and Electric Sectors*. January 1, 2009. Available at: http://www.state.ia.us/government/com/util/energy/noi072.html.

[15] IdahoStatesman.com. September 7, 2010. "Have your say on Idaho Power's conservation surcharge." Available at: http://www.idahostatesman.com/2010/09/07/1330120/have-your-say-on-utilitys-conservation.html.

[16] Arkansas Governor's Commission on Global Warming. October 2008. *Final Report*. P. 4-10. Available at: http://www.arclimatechange.us/ewebeditpro/items/O94F20338.pdf.

Considerable caution is necessary in development of energy reduction targets. It should be recognized that achieving any level of energy savings requires consumer behavior change and acceptance. The 1% outlined in the current document should be used with caution, as it is unknown what incentives are necessary to motivate Kentuckians to fully participate in energy efficiency programs sufficient to achieve a 1% reduction year-over-year. Thus, this policy recommends that the evaluation process be lengthy enough to thoroughly vet the concerns of all participants, and that the setting of any policy/targets be cautious to allow for adequate time for adoption by Kentucky residents.

Technology Costs

- Technology costs can vary widely, and emerging technology contains risks that are not fully understood.
- Targets must be set while considering market acceptance (consumer behavior changes) and development (to maturity) of technologies.

Rebound Effect

- Depending on price elasticity of demand, the rebound from pricing changes could be substantial, and needs to be understood completely in relation to overall efficiency goals.

Participation

- Out-of-pocket expenses and incentives of consumers should be considered, as they may be the key to successful participation.
- Predicting consumer behavior changes related to energy savings may be difficult.

Regulatory Process/Approval

- The Kentucky PSC is required to adhere to well-established requirements in assessing cost-effectiveness. Modification of these procedures, if needed, may require new statutory authorization.

Additional Benefits and Costs

None identified.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-4. Develop and Implement Comprehensive Education, Outreach, and Marketing, Including Consumer Awareness, School Curriculum, Truth-in-Advertising, Technical Information and Support (e.g., How to Do GHG Inventories, Rationales for Action, etc.)

Note: This policy recommendation bears similarities with Cross-Cutting Issues TWG policy recommendation CCI-2. Consideration and, if appropriate, adoption and implementation of RCI-4 and CCI-2 should take into account these similarities.

Policy Description

Education in this policy recommendation falls under three categories:

- Consumer awareness and education.
- School curriculum.
- Truth-in-advertising campaigns.

The ultimate effectiveness of emission reduction activities depends in many cases on providing information and education to consumers regarding the energy and GHG emission implications of consumer choices. Public education and outreach is vital to fostering a broad awareness of climate change issues and effects (including co-benefits, such as clean air and public health) among the state's citizens. Such awareness is necessary to engage citizens in actions to reduce GHG emissions in their personal and professional lives. Public education and outreach efforts should integrate with and build upon existing outreach efforts involving climate change and related issues in the state. Ultimately, education and outreach will be the foundation for the long-term success of all of the mitigation actions proposed, as well as those that may evolve in the future.

Policy Design

Goals

- Develop consumer education courses and outreach programs for GHG emission reductions.
- Provide information and education to present and future consumers in all levels of education—elementary, secondary, college, university, and community colleges.
- Develop guidelines to ensure that factual and accurate information regarding GHG emission implications is provided to consumers through a truth-in-advertising campaign targeting advertising of energy-consuming products.
- Develop consumer product programs that may include education, incentives, retailer trainer, marketing, and promotion.
- Utilize tools, such as Web-based calculators, to assist residents, businesses, and communities with developing GHG inventories and to evaluate and act upon their GHG inventory results.

Timing: By 2012, put the education awareness programs in place, begin outreach programs, and evaluate school curriculum areas to make sure they include GHG awareness.

Parties Involved: Consumers, retailers, manufacturers, technicians, teachers, professionals in building and related trades, trade schools, community colleges, universities, utility companies, Kentucky National Energy Education Development (NEED) Project, DEDI, Kentucky Energy Efficiency Program for Schools, Kentucky School Plant Management Association, Kentucky Green and Healthy Schools, Kentucky Department of Education, and Kentucky Environmental Education Association.

Other: None.

Implementation Mechanisms

Funding for education programs could come from a variety of sources, including businesses, professional associations, matching grants from federal agencies, regional market energy efficiency organizations, and energy efficiency surcharges paid by energy customers from utilities and non-utilities, among others.

Related Policies/Programs in Place

- Kentucky NEED Project.
- DEDI.
- Kentucky Energy Efficiency Program for Schools.
- Kentucky School Plant Management Association.
- Kentucky Green and Healthy Schools.
- ENERGY STAR for K–12 school districts.
- School Energy Managers Project (Kentucky School Board Association).

Type(s) of GHG Reductions

CO_2 is the primary gas reduced by avoided electricity generation from fossil fuel sources, but trace amounts of CH_4 and N_2O emissions are also avoided.

Estimated GHG Reductions and Costs or Cost Savings

This is a non-quantified policy recommendation.

Data Sources: Not applicable.

Quantification Methods: Not applicable.

Key Assumptions: With more education about GHG emissions and their impact on the environment, consumers will try to find ways to use less electricity and lower GHG emissions.

Key Uncertainties

Consumers may not take the need to reduce GHGs seriously unless there are incentives to encourage such reductions.

Additional Benefits and Costs

None identified.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-5. Financing Programs and Incentives for Energy Efficiency and CHP (PBF, Revolving Loans, etc.)

Note: This policy recommendation bears similarities with recommendation RCI-6 and Cross-Cutting Issues TWG recommendation CCI-7. Consideration and, if appropriate, adoption and implementation of RCI-5, RCI-6, and CCI-7 should take into account these similarities.

Policy Description

Financing programs need to be designed to eliminate a major barrier to private investment in energy efficiency, conservation, or combined heat and power (CHP) measures installed on buildings: the large up-front investment. By removing this barrier, building owners are more likely to pursue building-scale energy efficiency retrofits and/or CHP installations.

A number of programs and incentives that have been successful in other jurisdictions could be designed and implemented in Kentucky as part of this policy recommendation.[17] Green mortgages roll the costs of energy efficiency or CHP measures into new or refinanced mortgages and allow the amortization of the costs of the efficient equipment to better match future utility bill savings from the equipment. Public benefit funds provide a source of financing for all types of sales rebate programs to "buy down" the incremental costs of CHP and/or energy-efficient equipment. State income tax credits and property tax credits can also provide a source of funding to households and firms to purchase energy efficient equipment and/or CHP. Energy loan programs, financed by state issued bonds, provide low-interest loans and can also reduce the large up front investments associated with energy-efficient equipment and/or CHP. Finally, Property Assessed Clean Energy (PACE) financing programs work through the creation of a public loan fund at the municipal level that is directed solely to financing energy efficiency and/or CHP installations. The repayment of the funds takes place annually along with the building owner's property tax bill, giving PACE payments the same treatment as taxes for lien priority purposes.[18]

This policy pairs with RCI-6, which provides for similar financing mechanisms to encourage investments in renewable energy by building owners.

Figures RCI-5-1 and RCI-5-2 show the industries and sectors that are the sources of CHP supply in the state. The estimates for the Southeast region are used for Kentucky.

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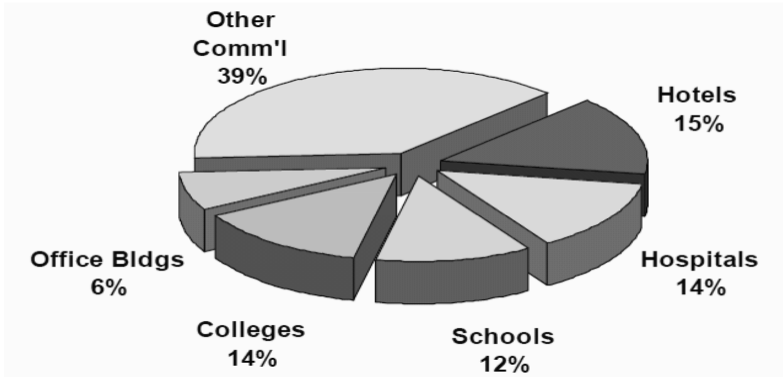
[17] See www.dsireusa.org for examples of funding programs in other jurisdictions.

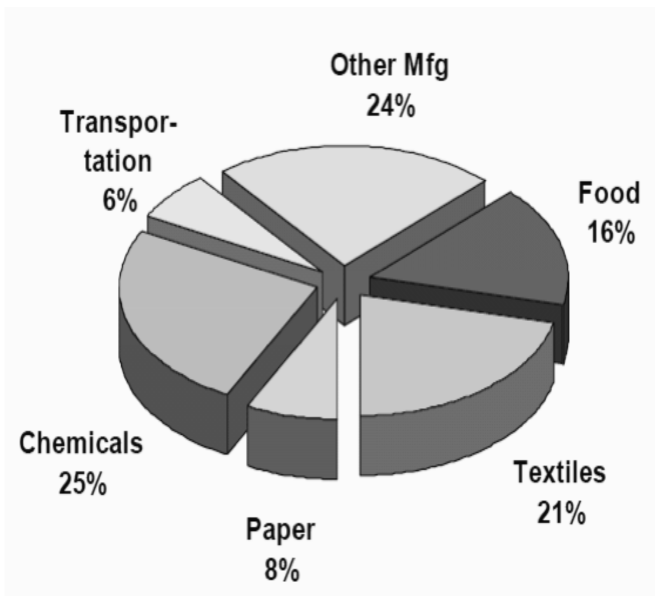
[18] On May 5, 2010, Fannie Mae and Freddie Mac—the U.S. government-chartered entities that collectively back around half of the mortgages in the United States—issued "lender guidance letters," which suggested that PACE programs were incompatible with their mortgages because they were left in a subordinate debt position. As a result, PACE implementation has slowed or stalled nationally (since this policy recommendation was crafted), pending resolution of this issue.

Figure RCI-5-1. Estimates of Commercial CHP Supplies in the Southeast Region[19]



CHP = combined heat and power; Comm'l = commercial.

Figure RCI-5-2. Estimates of Industrial CHP Supplies in the Southeast Region[20]



CHP = combined heat and power; Mfg = manufacturing.

Policy Design

Goals: Address the significant opportunity in Kentucky for increased energy efficiency measures and CHP generation. Numerous ways exist to provide incentives for the adoption of energy efficiency measures, including rebates funded through public benefits funds or other mechanisms, low-cost loans provided through revolving loan funds, providing greater security to lenders through

[19] See http://www.chpcenterse.org/pdfs/EEA-Southeast_Planning_session_7-6-05.pdf.

[20] Ibid.

loan-loss reserve funds, etc. Market penetration will depend on funding levels and decisions concerning what kinds of improvements qualify for funding. For the purposes of quantification, CHP projects in Kentucky are assumed to be financed by a wide range of mechanisms that reduce market barriers to CHP deployment and result in the CHP policy goals being achieved. Sample assumptions, detailed below, illustrate potential GHG reductions and costs/savings.

Timing: See assumptions below.

Parties Involved: Building owners, mortgage lenders, local governments, state and local building officials.

Other: None.

Implementation Mechanisms

A variety of implementation approaches are possible, as discussed above.

Related Policies/Programs in Place

A Public Benefit Fund (PBF) is a component of the EERS proposed as part of Kentucky's 7-Point Strategy for Energy Independence.[21] Tax incentives are cited as a possible component as well.

Type(s) of GHG Reductions

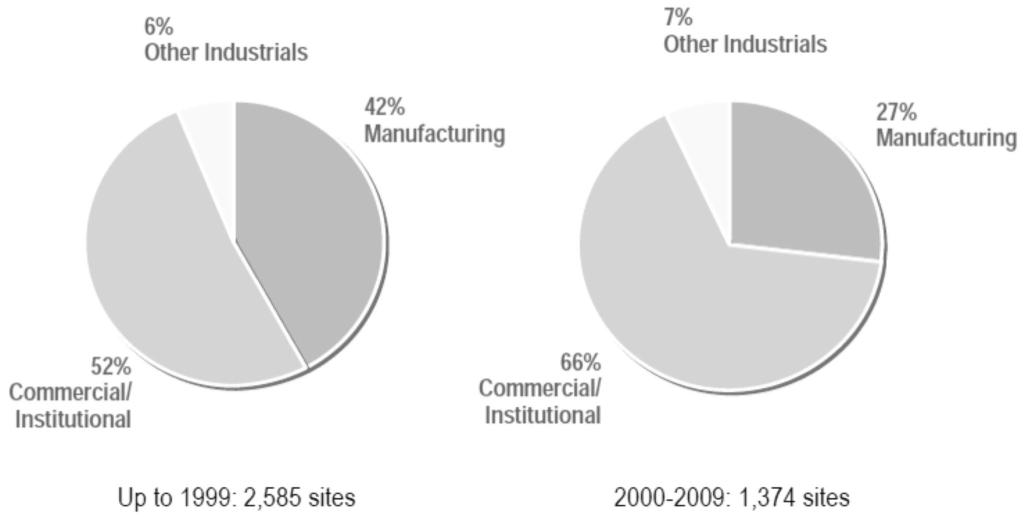
CO_2, N_2O, CH_4: Displaces emissions from fossil-based, central-station, electricity generation. Local emissions of criteria pollutants can increase due to the distributed nature of generation, depending on the efficiency of the avoided boiler and other considerations.

Estimated GHG Reductions and Costs or Cost Savings

This analysis quantifies the GHG impacts from the CHP component of the policy. Commercial and institutional CHP installations have accounted for the majority of new installations in recent years. Figure RCI-5-3 shows the breakdown by sector for the last decade.

[21] Gov. Steven L. Beshear, *Intelligent Energy for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008. Available at: http://www.energy.ky.gov/energyplan2008/.

Figure RCI-5-3. Recent CHP Installations[22]



CHP = combined heat and power.

This analysis models CHP costs and emission reduction opportunities in Kentucky for commercial/institutional and industrial applications. Technology developments have led to the promise of CHP for residential applications as well, but penetration is in its earliest stages. Commercial/institutional applications include facilities with consistent thermal loads, such as hospitals, hotels/motels, and universities. The industrial sector in Kentucky is large and diverse. Tables RCI-5-1a and RCI-5-1b present the estimated emission reductions and costs/savings from RCI-1 using CHP only.

Table RCI-5-1a. Estimated GHG Reductions and Costs or Cost Savings from RCI-1 (CHP only) Applying Direct Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/t$CO_2$e)
		2020	2030	Total 2011–2030		
RCI-5	Combined Heat and Power	13.1	22.8	274	$538	$2

[22] Bruce Hedman. October 1, 2009. "CHP: The State of the Market." Available at: http://www.epa.gov/chp/documents/meeting_100209_hedman.pdf.

Table RCI-5-1b. Estimated GHG Reductions and Costs or Cost Savings from RCI-1 (CHP only) Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/t$CO_2e$)
		2020	2030	Total 2011–2030		
RCI-5	Combined Heat and Power	12	22	259	$538	$2

$/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; CHP = combined heat and power; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

Differences in capital, fuel, and avoided electricity costs between the commercial and industrial sectors result in considerable differences in the program costs. Table RCI-5-2 shows the breakdown between the two sectors. The industrial sector has much larger reduction potentials at lower costs than the commercial sector.

Table RCI-5-2. Sectoral Composition of Reductions

CHP Sector	2010–2030 Cumulative Reductions ($MMtCO_2$)	Net Present Value (Million 2005$)	Cost-Effectiveness ($/ton)
Commercial CHP	53	$558	$11
Industrial CHP	206	–$20	$0

CHP = combined heat and power; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Hedman, B. 2005. The Potential for Additional CHP in the Southeast (first cut estimate). Available at: http://www.chpcenterse.org/12-00_library.html#reports.
- Maggie Eldridge, Steve Nadel, Amanda Korane, John A. "Skip" Laitner, Vanessa McKinney, Max Neubauer, and Jacob Talbot. April 1. 2009. *Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania*. ACEEE et al. Available at: http://www.aceee.org/pubs/e093.htm.
- Kentucky Public Service Commission. 2009. Electric Service Tariffs for Kentucky Utilities Company. Available at: http://psc.ky.gov/Home/Library?type=Tariffs&folder=Electric.

Quantification Methods: A linear deployment for each CHP sector in MWh is multiplied by the $/MWh cost for each CHP technology in each year to derive the cost. The $/MWh cost for each CHP technology is a function of the unit heat rate, operating and maintenance costs, and fuel costs. Benefits are calculated by multiplying the assumed avoided electricity $/MWh cost by the above number of linearly deployed MWh for each CHP sector in each year. Avoided boiler expenditures and capacity charges are also included. The net cost is the difference between costs and benefits, which is then discounted at 5% from 2010 to 2030 to estimate NPV. The NPV value is then divided by the cumulative number of $MMtCO_2$ reduced (net of the CHP unit's emissions) to arrive at the $/tCO_2e$ value. These and other factors and assumptions used in quantifying this policy recommendation are listed in Tables RCI-5-3 and RCI-5-4.

Table RCI-5-3. Avoided Electricity Charges

Avoided Electricity Charges ($2005)	2030		Source
	Commercial	Industrial	
Demand Charge (kW month)	$7.91	$2.89	Commercial: KY PSC Power service load charge sheet 15 for 50–250 kW demand. Industrial: KY PSC industrial demand charge sheet 30 for KY Utilities Co. Average of on and off peak. Assumes power factor of 1.0.
Transmission Charge (customer/kW/month)	$3.55	$3.55	KY PSC retail transmission charge sheet 25 for KY Utilities Co. Average of on and off peak. Assumes power factor of 1.0.
T&D Losses	8.3%	8.3%	Statewide T&D losses from KY Inventory and Forecast.

kW = kilowatt; KY PSC = Kentucky Public Service Commission; T&D = transmission and distribution.

Key Assumptions

- Financing mechanisms are required to fully develop the CHP supplies in the state. The program and administrative costs of these financing mechanisms are not included in the analysis.
- The real financing rate for all CHP projects is assumed to be 8.5%.
- CHP potential for commercial applications in 2025 is assumed to be 917 megawatts (MW), and industrial potential is 3,390 MW. These are the 2005 MW potentials identified in Hedman (2005), and are assumed to be unchanged over the period. This value is consistent with Hedman (2009), which quotes an Oak Ridge National Laboratory study that estimates 3,000–8,000 MW of CHP supply for Kentucky.[23]
- CHP potential is installed in equal annual amounts (linearly) from the start of the program in 2012 until 2025. The 2025–2030 capacities remain constant at 2025 levels.
- The T&D charges for Kentucky Utilities Company are representative of these charges statewide.

[23] Hedman, Bruce. 2009. "CHP: The State of the Market," p. 48. Available at: http://www.epa.gov/chp/documents/meeting_100209_hedman.pdf.

Table RCI-5-4. Other CHP Assumptions

Characteristics	Commercial	Industrial	Source
CHP Characteristics			
Heat Recovered from CHP Power-to-Heat Ratio	70%	90%	*Catalogue of CHP Technologies*, EPA CHP Partnership, Introduction, p. 7.
CHP Unit Size (MW)	0.25	10.00	
CHP Technology	Micro Turbine	Gas Turbine	
Heat Rate (MMBtu/MWh)	10,825	9,950	2016–2020 heat rates from ACEEE (2009), pp. 212, 214.
Capacity Factor	95%	85%	Assumption
Installed Capital Costs ($/kW)	$1,442	$1,165	ACEEE et al. (2009) 2016-2020 Costs for 250 kW, 10 MW units as average for the period. Plus after-treatment costs of $100/kW.
O&M Costs ($/kWh)	$0.01	$0.01	Assumption
Economic Life/Years	25.00	25.00	Assumption
Natural Gas Fuel (%)	100%	100%	Assumption
Net Generation Cost ($/MWh)	$95.77	$46.80	Calculation
Avoided Price of Power ($/MWh)	$65.18	$49.16	Assumption
MW Capacity in 2025	917	3,390	Assumption
MWh Generation in 2030	7,631,274	25,241,940	Calculation
Avoided Boiler Characteristics			
Displaced Boiler Efficiency	75%	85%	Assumption
Fixed O&M $/MMBtu	$0.07	$0.07	Assumption
Variable O&M $/MMBtu	$0.07	$0.07	Assumption

ACEEE = American Council for an Energy-Efficient Economy; $/kWh = dollars per kilowatt-hour; $/MMBtu = dollars per million British thermal units; $/MWh = dollars per megawatt-hour; CHP = combined heat and power; kW = kilowatt; MW = megawatt; MWh = megawatt-hour; O&M = operations and maintenance.

Key Uncertainties

- The costs presented here would be better presented as a range to reflect the uncertainties associated with future capital costs and heat rates of CHP technologies, as well as fuel price forecast uncertainties.
- Kentucky has some of the lowest electricity prices in the country, which hinders market-based deployment of CHP. Kentucky also has relatively expensive natural gas. However, the avoided CO_2 resource assumption in Kentucky is high, due to coal-fired electricity generation. The economic costs and benefits from CHP are heavily reliant on the assumptions of avoided electricity and natural gas costs, as well as CO_2 emissions.
- Some of Kentucky’s key industries (e.g., aluminum) may be less amenable to CHP applications due to the nature of their production processes.
- Public concerns could arise over the use of PACE or PBF funding for private industrial facilities.
- Financing through utilities—and repayment on the utility bill—could also be an option besides the PACE approach. In this case, however, steps to insulate the utility from the financial risk of default would need to be incorporated.

Additional Benefits and Costs

None identified.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-6. Financing Programs, Incentives, Policies, and Research for Conversion to Renewable Energy or Low-Carbon Energy Sources

Note: This policy recommendation bears similarities with recommendation RCI-5 and Cross-Cutting Issues TWG recommendation CCI-7. Consideration and, if appropriate, adoption and implementation of RCI-5, RCI-6, and CCI-7 should take into account these similarities.

Policy Description

A number of programs and incentives could be designed and implemented as part of this policy recommendation. Financing programs need to be designed to eliminate a major barrier to private investment in renewable energy measures installed on buildings: the large up-front investment. By removing this barrier, building owners are more likely to pursue building-scale renewables projects. A number of programs and incentives that have been successful in other jurisdictions could be designed and implemented in Kentucky as part of this policy recommendation.[24] Green mortgages roll the costs of renewable energy measures into new or refinanced mortgages and allow the amortization of the costs of the equipment to better match future utility bill savings from the equipment. Public benefit funds provide a source of financing for all types of sales rebate programs to "buy down" the incremental costs of renewable energy equipment. State income tax credits and property tax credits can also provide a source of funding to households and firms to purchase renewable energy equipment. Energy loan programs, financed by state-issued bonds, provide low-interest loans and can also reduce the large up front investments associated with renewable energy. Finally, PACE financing programs work through the creation of a public loan fund at the municipal level that is directed solely to financing renewable energy installations. The repayment of the funds takes place annually along with the building owner's property tax bill, giving PACE payments the same treatment as taxes for lien priority purposes.[25]

This policy pairs with RCI-5, which provides for similar financing programs to encourage investments in energy efficiency measures and CHP installations by building owners.

Policy Design

Goals: Address the significant opportunity in Kentucky for increased investments in renewable energy by building owners. Numerous ways exist to encourage adoption of renewable energy options, including rebates funded through public benefits funds or other mechanisms, low-cost loans provided through revolving loan funds, providing greater security to lenders through loan-loss reserve funds, etc. Funding may also be available through U.S. DOE programs. Market penetration

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[24] See www.dsireusa.org for examples of funding programs in other jurisdictions.

[25] On May 5, 2010, Fannie Mae and Freddie Mac—the U.S. government-chartered entities that collectively back around half of the mortgages in the United States—issued "lender guidance letters," which suggested that PACE programs were incompatible with their mortgages because they were left in a subordinate debt position. As a result, PACE implementation has slowed or stalled nationally (since this policy recommendation was crafted), pending resolution of this issue.

will depend on funding levels and decisions concerning what kinds of improvements qualify for funding. For the purposes of quantification, renewable energy projects in Kentucky are assumed to be financed by a wide range of mechanisms that reduce market barriers to their deployment and result in the renewable energy policy goals being achieved. Sample assumptions, detailed below, illustrate potential GHG reductions and costs/savings.

Timing: See assumptions below.

Parties Involved: Building owners, mortgage lenders, local governments, state and local building officials.

Other: None.

Implementation Mechanisms

A variety of implementation approaches are possible, as discussed above.

Related Policies/Programs in Place

A PBF is a component of the EERS proposed as part of Kentucky's 7-Point Strategy for Energy Independence.[26] Tax incentives are cited as a possible component as well.

Type(s) of GHG Reductions

CO_2 is the primary gas reduced by avoided electricity generation from fossil fuel sources, but trace amounts of CH_4 and N_2O emissions are also avoided.

Estimated GHG Reductions and Costs or Cost Savings

The GHG reductions in Tables RCI-6-1a and RCI-6-1b are from solar photovoltaics (PV) (crystalline and thin film) only. Kentucky has very limited distributed wind resources, so these were not quantified.[27]

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[26] Gov. Steven L. Beshear, *Intelligent Energy for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence,* November 2008. Available at: http://www.energy.ky.gov/energyplan2008/.

[27] The National Renewable Energy Laboratory shows a total of 12 square kilometers of "windy" areas (at 80 meters). Available at: http://www.windpoweringamerica.gov/wind_maps.asp.

Table RCI-6-1a. Estimated GHG Reductions and Costs or Cost Savings from RCI-6 Applying Direct Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/$tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-6	Renewable Energy	1.3	4.2	33	$3,397	$104
RCI-6	Residential Biomass	0.02	0.0	0.4	–$24.59	–$66
Total		**1.3**	**4.2**	**33**	**$3,372**	**$102**

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

Table RCI-6-1b. Estimated GHG Reductions and Costs or Cost Savings from RCI-6 Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/$tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-6	Renewable Energy	1.3	4.4	35	$3,397	$98
RCI-6	Residential Biomass	0.02	0.0	0.4	–$25	–$62
Total		**1.4**	**4.4**	**35**	**$3,372**	**$96**

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

Data Sources: See below. Also:

- S. Haase. 2010. *Assessment of Biomass Pelletization Options for Greensburg, Kansas. Executive Summary*. Technical Report, NREL/TP-7A2-48073. Table 18. Available at: www1.eere.energy.gov/buildings/greensburg/pdfs/45843.pdf.

Quantification Methods: See RCI-1. Also, penetration of solar PV for new and existing residential and commercial buildings is assumed to occur as described in the assumptions section below. New and existing residential buildings are assumed to install a 2-kilowatt (kW) crystalline PV system, while commercial new and existing buildings are assumed to install a 25-kW thin-film PV system.

These MW installations in each year are converted to MWh based on each technology's capacity factor. The costs of the policy recommendation are the generation costs of each type of solar PV. The benefits from the policy recommendation are the avoided electricity expenditures ($/MWh forecasted avoided cost of electricity multiplied by the distributed generation in MWh) for the residential and commercial sectors in each year. The NPV of the costs less benefits is then calculated.

Key Assumptions: See RCI-1 and Table RCI-6-2.

Table RCI-6-2. Key Assumptions for RCI-6

Penetration of PV in New Buildings	**Rate/Year**	
Residential and Commercial	5% in 2012, increasing linearly to 15% in 2030	
Penetration of PV in Existing Buildings	**Rate/Year**	
Residential	1.0%	
Commercial	1.0%	
Technology and Size of PV Installations	**kW**	
Residential Crystalline PV	2.00	
Commercial Thin Film	25.00	
Calculated Installed MW Given Above Assumptions	**MW in 2030**	
Residential Crystalline PV	994	
Commercial Thin Film	1,953	
Capacity Factor	**Percent**	
Residential Crystalline PV	18%	
Commercial Thin Film	14%	
Residential capacity factor based on 4855 kWh annual AC output for 3.08 AC fixed-tilt system for Louisville from PV Watts. Available at: http://www.pvwatts.org/. *Commercial capacity factor reduced by approximately 25% for lower efficiencies from thin-film technology.*		
Installed Capital Costs ($2005/MW)	**2010**	**2025**
Residential Crystalline PV	$6,500	$4,196
Commercial Thin Film	$5,530	$3,332
Note: Costs for 2010 and 2025 are assumed; costs for 2030 are calculated. 2010 costs are from recent Kentucky PV installation experience provided by RCI TWG member Jeremy Smith and are adjusted to $2005. Future cost declines come from ICF, 2010, Photovoltaic (PV) Cost and Performance Characteristics for Residential and Commercial Applications*, prepared for Office of Integrated Analysis and Forecasting, EIA. (No Web link available.)*		
Costs of Electricity ($2005/MWh)	**2010**	**2025**
Residential Crystalline PV	$249	$161
Commercial Thin Film	$272	$177
Note: Calculated from above based on capital costs and capacity factors. Assumes 7.0% real financing rate and 30-year equipment life.		
Net New Construction Growth (as described in RCI-1)	**Rate/Year**	
Residential	1.0%	
Commercial	1.2%	

Average Size of Commercial Building (square feet)	13,233
Table B3. Census Region, Number of Buildings and Floor Space for Non-Mall Buildings, 2003. *For South Region—All Buildings, See: http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set2/2003html/b3.html.*	

AC = alternating current; kW = kilowatt; MW = megawatt; MWh = megawatt-hour; EIA = U.S. Energy Information Administration; MW = megawatt; MWh = megawatt-hour; PV = photovoltaics.

Table RCI-6-3. Key Assumptions for RCI-6—Solar Water Heating

Additional Inputs to/Intermediate Results of Costs Analyses		
Incremental Capital Cost of Solar Water Heater (Relative to Electric or Gas Unit) (2005$)	**2012**	**2025/All**
	$5,000	$3,500
Assumption for residential system, and assumes costs will decrease over time. This is consistent with recent cost experience. Commercial systems are estimated at $3,600–$4,000 per collector. See: http://www.ncpublicpower.com/.../Solar.../Large_Commercial_Case_Study.sflb.ashx.		
Percent of Household Hot Water Needs Provided by Solar Hot Water Units	**2012**	**2025/All**
Rough Estimate, but consistent with rule of thumb from Puget Sound Solar, Inc. (http://www.pugetsoundsolar.com/starthere.html) for Seattle area installation.	65.0%	70.0%
Average Annual Water Heating Energy Used per Household (Hot Water Output in MMBtu)		**12.7**
Based on assumption of household with electric water heater using 4000 kWh/yr at average efficiency (EF) of 93% heat in hot water/electrical energy input. Solar industry claims average thermal output at 11.68 MMBtu/yr. See: http://www.solar-estimate.org/index.php?verifycookie=1&page=solar-calculations&subpage=&external_estimator=r.		
Average Annual Water Heating Output per Solar Hot Water System (MMBtu) *Calculation based on household hot water demand.*		**8.6**
Average Annual Water Electrical Output per Solar Hot Water System (MWh) *See: http://www.solar-rating.org/solarfacts/solarfacts.htm*		**3.4**
Number of SHW Collectors per Commercial Building *Placeholder assumption.*		**8.00**
Water Heating by Fuel Type		**Percent**
Electricity		65%
Natural Gas		32%
Fuel Oil		0%
Liquefied Petroleum Gas		3%
Total		**100%**
Table CE4-11c. Water-Heating Energy Consumption in U.S. Households. Available at: http://www.eia.doe.gov/emeu/recs/recs2001_ce/ce4-11c_so_region2001.html.		
Factors for Annualizing Capital Costs (Residential and Commercial PV and Solar Hot Water Systems)		
Interest Rate (Real)		7%/year
Economic Life of System		20 years
Implied Annualization Factor		9.44%/year
Marginal Federal Tax Rate, Residential and Commercial		0%
Federal Solar Tax Credits	**2012**	**2025/All**
Residential	30%	30%
Commercial	30%	30%
Capital Cost per Unit Capacity (and Output) of Solar Hot Water Heaters		**Percent**
Residential		100%
Commercial		70%
Placeholder assumption. Assumes economies of scale for materials and installation for commercial units relative to (significantly smaller, on average) residential units.		

Estimated Annual Levelized Cost of Solar Hot Water per Unit Output ($2005)	2012	2025/All
Residential ($/MMBtu)	$40	$31
Commercial ($/MMBtu)	$28	$22
Calculated based on inputs above.		
Implied per Unit Cost of Electricity Avoided by Solar WH/SH/Cooling ($2005)	**2012**	**2025/All**
Implied Per Unit Cost Electricity Avoided by Solar WH/SH/Cooling (Residential)	$127	$99
Implied Per Unit Cost Electricity Avoided by Solar WH/SH/Cooling (Commercial)	$89	$69
Implied Per Unit Cost Natural Gas Avoided by Solar WH/SH/Cooling (Residential)	$28	$22
Implied Per Unit Cost Natural Gas Avoided by Solar WH/SH/Cooling (Commercial)	$20	$15
Assumes delivered solar WH/SH/cooling replaces electric with EF of 0.93, gas with EF of 0.70 (and therefore 1 MMBtu of delivered solar heat is the equivalent of more than one MMBtu of each fuel).		

$/MMBtu = dollars per million British thermal unit; $/MWh = dollars per megawatt-hour; EF = efficiency; HW = hot water; kWh/yr = kilowatt-hours per year; MMBtu = million British thermal units; MW = megawatt; MWh = megawatt-hour; PV = photovoltaic; SH = space heating; WH = water heating.

Table RCI-6-4. Key Assumptions for RCI-6—Residential Wood Stoves

Additional Inputs to/Intermediate Results of Costs Analyses		
Incremental Capital Cost of Residential Woodstoves (Relative to Electric or Gas Unit) ($2005)	**2012**	**2025/All**
	$500	$500
Average Annual Water Heating Energy Used per Household	85.0%	85.0%
Assumes that wood-burning fireplace provides most of the heating requirements for households with the exception of very cold days or early mornings when a fire has not been started.		
Average Annual Heating Energy Used per Household Year (MMBtu)		**28.00**
Average all fuel energy used by households in the East South Central census region. From the 2005 Residential Building Energy Consumption Survey. Table SH8. See: http://www.eia.doe.gov/emeu/recs/recs2005/c&e/spaceheating/pdf/tablesh8.pdf.		
Average Annual Heating Output per Residential Woodstove System (MMBtu)		**23.8**
Calculation based on household heating demand.		
Factors for Annualizing Capital Costs (Residential Photovoltaic and Solar Woodstove Systems)		
Interest Rate (Real)		7%/year
Economic Life of System		20 years
Implied Annualization Factor		9.44%/year
Marginal Federal Tax Rate, Residential and Commercial		0%
Cost of Residential Woodstoves (2005$/MMBtu)	**2012**	**2025/All**
Estimated Annual Levelized Cost per Unit Output	$2	$2
Fuel Costs of Woodstoves	$12	$12
Total Costs of Woodstoves	**$14**	**$14**
Calculated based on inputs above.		
Cost of Woodstove Fuel (2005$/tonne)	**$90**	**$90**
Average of pellets and solid fuel biomass. Pellets are assumed to cost $150/ton and cord wood $60/ton. See: http://www.fireplacesandwoodstoves.com/all-about-fireplaces/price-comparisons/fuel-price-comparison.aspx.		

Heat Content of Wood (MMBtu/tonne)	**12.00**
Values assumed by the Agriculture, Forestry, and Waste Technical Work Group.	
Percent Efficiency of Fireplace	**65%**
Average of "high-tech" stove and advanced combustion fireplace in: Natural Resources Canada. 2010. Advanced Combustion Wood Fireplaces. Available at: http://oee.nrcan.gc.ca/publications/infosource/pub/Heat_and_Cool/Wood_Fireplaces_Section3.cfm.	

MMBtu = million British thermal units.

Table RCI-6-5 shows the supply of residential biomass assumed.[28]

Table RCI-6-5. Supply of Residential Biomass Assumed

Year	MMBtu Available to RCI
2011	478,571
2012	478,806
2013	473,275
2014	463,017
2015	444,313
2016	424,553
2017	403,185
2018	376,827
2019	349,158
2020	329,135
2021	280,994
2022	238,133
2023	213,856
2024	188,136
2025	161,086
2026	132,560
2027	102,530
2028	70,969
2029	36,434
2030	110

MMBtu = million British thermal units; RCI = residential, commercial, and industrial.

Full-fuel-cycle emissions for aggregate residential biomass are assumed to be 0.012 tCO_2/MMBtu. This is the simple average of the estimation by the Agriculture, Forestry, and Waste (AFW) TWG for transportation-related GHGs for cordwood (0.001 tCO_2/MMBtu) plus residential wood pellets (0.023 tCO_2/MMBtu). The cord wood estimate includes the emissions from transporting the

[28] Agriculture, Forestry, and Waste Technical Work Group assumption, which allocates surplus biomass supplies from the other sectors to the RCI sector to use for residential biomass. File: KY Biomass Demand.xls emailed 11/29/10 by Rachel Anderson.

biomass 50 miles (100 miles round trip), as well as N_2O emissions and CH_4 emissions from burning the biomass. This estimate does not include the energy inputs to grow, harvest, or process the biomass. The processing-related GHGs calculations for wood pellets are presented in Table RCI-6-6.

Table RCI-6-6. Full-Fuel-Cycle Calculations for Residential Wood Pellets

Residential Pellets Full-Fuel-Cycle GHG Table		Source
MWh Electricity/Ton Pellets	0.25767	S. Haase. 2010. Assessment of Biomass Pelletization Options for Greensburg, Kansas.
tCO_2/MWh	1.083	RCI assumption from RCI-1
tCO_2/Ton Pellets	0.279	Product of MWh/ton multiplied by CO_2 intensity
tCO_2//MMBtu	0.023	Assumes 12 MMBtu/ton pellets

CO_2 = carbon dioxide; MMBtu = million British thermal units; MWh = megawatt-hour; tCO_2= metric tons of carbon dioxide.

Key Uncertainties

- The costs of this policy recommendation would be better presented as a range to reflect the uncertainties associated with future capital costs, performance of renewable energy technologies, and fuel price forecast uncertainties.
- Kentucky has some of the lowest electricity prices in the country, which hinders market-based deployment of renewable energy. However, the avoided CO_2 resource assumption in Kentucky is high due to coal-fired electricity generation. The economic costs and benefits from renewable energy are heavily reliant on the assumptions of avoided electricity costs, as well as CO_2 emissions.
- The federal 30% investment tax credit is scheduled to run through 2018. It may not be extended to 2030.
- Biomass production could also be included as a renewable energy policy, but this technology is being assessed as part of the AFW-2 policy recommendation.
- Financing through utilities—and repayment on the utility bill—could also provide a financing mechanism. In this case, however, steps to insulate the utility from the financial risk of default would need to be incorporated.

Additional Benefits and Costs

- Increased residential wood burning could lead to increases in emissions of criteria and other pollutants, especially particulate matter.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Super-majority. One member objected to the policy. Another KCAPC member abstained from voting due to his professional affiliation in order to avoid any appearance of conflict.

Barriers to Consensus

One KCAPC member objected to approval of this policy based on its comparatively high cost-per-ton of GHG emissions reduced.

RCI-7. Government Lead by Example (GLE) in Highly Efficient State and Local Government Buildings

Policy Description

This policy provides energy efficiency targets for new construction of state and local government buildings and renovation of existing state and local government buildings that are much higher than code standards.

The Kentucky state government is a significant consumer of energy. The state owns about 66.9 million square feet of building space and leases an additional 5.2 million square feet.[29] Further, local government buildings, such as courthouses, city halls, K–12 schools, and other facilities, are not included in these figures. This policy recommendation estimates local government building square footage at 60 million square feet, based on the 2003 U.S. EIA Commercial Building Energy Consumption Survey.[30]

The Kentucky General Assembly has made great strides in the maintenance of public buildings. However, the potential for significant improvements and upgrades remains, reflecting opportunities for more energy savings through more energy-efficient equipment and practices.

This policy requires the Kentucky Finance and Administration Cabinet (FAC) to improve the efficiency of energy and other resources in public buildings that receive 50% or more of their construction funding from the Commonwealth. Improving the energy efficiency of buildings will provide immediate and ongoing energy savings and reduce GHG emissions.

The remainder of RCI-7 uses the base energy use intensities from ANSI/ASHRAE/IESNA Standard 90.1-2004 for various building types in climate zone 4A, as defined by DOE EO 430.2B.

Policy Design

Goals

- Require new buildings to achieve a reduction in energy use relative to the base established per the DOE EO 430.2B energy standard for commercial buildings and the 2009 IECC for residential buildings through certification by a design professional or a nationally recognized third-party-verified green building certification system for commercial or residential buildings (e.g., LEED, ASHRAE/USGBC/IESNA Standard 189, or Green Globes New Construction).

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[29] E-mail from Traci Walker at Kentucky Department of Finance. November 15, 2010. These include space-conditioned and occupied buildings.

[30] U.S. EIA. 2003. Commercial Building Energy Consumption Survey. Table B5, Non-mall Buildings in "East South Central" Region. Available at: http://www.eia.doe.gov/emeu/cbecs/census_maps.html.

- Increase the minimum energy efficiency standard beyond Standard 90.1-2004 benchmark levels[31] by the amounts shown in Table RCI-7-1.

Table RCI-7-1. Reductions from Benchmark Energy Use Intensity

Year	New Construction	Existing Building Retrofits
2010	30%	20%
2015	50%	35%
2020	70%	50%
2025	85%	65%
2030	100%	75%

- Require participating organizations or individuals to calculate, monitor, and report the costs and actual performance of energy efficiency improvements, as well as annual GHG emissions. Compare the performance of energy efficiency improvements in existing buildings against a regional average of similar building types.
- This policy recommendation closely parallels RCI-2, but unlike that policy, it does not provide for incentives to government, thereby raising the bar and establishing government leadership by example.

Timing: Legislation may be required for implementation. Develop any necessary legislation in 2011, and implement the incentives policy in 2012.

Parties Involved: LRC, FAC, DHBC, developers, builders and contractors, building owners, building material suppliers, recycled building material sellers, design professionals, and home improvement stores.

Other: None.

Implementation Mechanisms

Public buildings that receive 50% or more of their construction funding from the Commonwealth would be required, as a condition of receiving that funding, to meet the specified reductions from benchmark energy use intensity.

Related Policies/Programs in Place

HB 2 (2008) also addresses state-owned, high-performance buildings.

Type(s) of GHG Reductions

CO_2 is the primary gas reduced by avoided electricity generation from fossil fuel sources, but trace amounts of CH_4 and N_2O emissions are also avoided.

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[31] This benchmark applies base energy use intensities from ANSI/ASHRAE/IESNA Standard 90.1-2004 for various building types in climate zone 4A, as defined by DOE Executive Order 430.2B.

Estimated GHG Reductions and Costs or Cost Savings

Table RCI-7-2a. Estimated GHG Reductions and Costs or Cost Savings from RCI-7 Applying Direct Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-7	Government Lead by Example	0.7	1.5	14	–$15.7	–$1.1

Table RCI-7-2b. Estimated GHG Reductions and Costs or Cost Savings from RCI-7 Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-7	Government Lead by Example	0.7	1.6	15.2	–$15.7	–$1.1

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

Data Sources: See Tables RCI-7-3 through RCI-7-5.

Quantification Methods: Energy efficiency improvements are taken from Table RCI-2-1. These improvements are implemented at the rates shown in the ramp-in assumptions in Table RCI-7-3. Only government buildings are included; residential and commercial reductions are quantified under RCI-2.

Key Assumptions: See Tables RCI-7-3 through RCI-7-5.

Table RCI-7-3. Energy Efficiency Ramp-In Assumptions

Buildings Provided with Incentives	Percentage	Year
New Government Buildings	75.0%	2012
Incentives implemented linearly	90.0%	2020
	100.0%	2030
Existing Government Buildings	5.0%	2012
Incentives implemented linearly	50.0%	2020
	75.0%	2030

Table RCI-7-4. Cost and Energy Efficiency Assumptions

Cost of New High-Performance Buildings	Electricity	Fuel
Commercial/Government ($/sq ft)	$2.09	$1.91
Commercial/Government (levelized $/sq ft)	$0.20	$0.18
Expected Life of Measures	15	15
Kats (2004). The Costs and Financial Benefits of Green Buildings. • *$4/square foot increased architectural and engineering design time.* • *Prorated by electric vs. fuel energy consumption.* • *The gross up-front cost $4/sq ft is levelized over assumed life.* *See:* http://www.calrecycle.ca.gov/greenbuilding/design/CostBenefit/Report.pdf.		
Cost of Retrofit for High-Performance Buildings	**Electricity**	**Fuel**
Commercial/Government ($/sq ft)	$2.09	$1.91
Commercial/Government (levelized $/sq ft)	$0.20	$0.18
Expected Life of Retrofit Measures	15	15
Kats (2004). The Costs and Financial Benefits of Green Buildings. • *$4/square foot increased architectural and engineering design time.* • *Prorated by electric vs. fuel energy consumption.* • *The gross up-front cost $4/sq ft is levelized over assumed life.* *See:* http://www.calrecycle.ca.gov/greenbuilding/design/CostBenefit/Report.pdf.		
Commercial/Government Share of Building Energy Consumption	**Electricity**	**Fuel**
Commercial/Government	52%	48%
Table CE1-1c. Total Energy Consumption in U.S. Households, 2005. Available at: http://www.eia.doe.gov/emeu/recs/recs2001/ce_pdf/enduse/ce1-1c_climate2001.pdf. *Table C1. Total Energy Consumption by Major Fuel for Non-Mall Buildings, 2003. Available at:* http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#consumexpen03.		
Government Share of Total Commercial Building Energy Consumption	**Sq. Ft.**	**Percentage**
State	80,000,000	14%
Local	60,000,000	10%
Table B5, for Non-mall Buildings in "East South Central" Region. Available at: file://localhost/CBECS http/::www.eia.doe.gov:emeu:cbecs:census_maps.html.		
Net New Construction Growth		**Rate/Year**
Government		1.2%

$/sq ft = dollars per square foot; CBECS = Commercial Buildings Energy Consumption Survey.

Table RCI-7-5. Distributed Generation Assumptions

Government PV Penetration	Percentage	Year

Percentage of New Government Buildings with Solar Photovoltaic	10.0%	2012
Incentives implemented linearly	50.0%	2020
	100.0%	2030
Percentage of Existing Retrofitted Commercial Buildings with Solar Photovoltaic	5.0%	2012
Incentives implemented linearly	25.0%	2020
	50.0%	2030

- See RCI-6 (Renewables) for solar PV cost and performance assumptions (25-kW thin-film solar).
- Energy reductions (and associated GHGs) from the policy do not begin until 2011.

Key Uncertainties

The costs of this policy recommendation would be better presented as a range to reflect the uncertainties associated with future capital costs, performance of renewable energy technologies, and price forecast uncertainties.

Kentucky has some of the lowest electricity prices in the country, which hinders market-based deployment of renewable energy. However, the avoided CO_2 resource assumption in Kentucky is high due to coal-fired electricity generation. The economic costs and benefits from renewable energy are heavily reliant on the assumptions of avoided electricity costs, as well as CO_2 emissions.

Additional Benefits and Costs

None identified.

Feasibility Issues

New legislation may be required for implementation.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-8. Training and Education for Builders, Contractors, and Building Operators

Policy Description

Providing training, education, and outreach for builders, contractors, building operators, and code officials encourages these building professionals to incorporate energy efficiency and GHG emission reduction considerations in the conduct of their work. Education and training should be mandatory and available to builders, contractors, and others involved in the construction of new buildings and the retrofitting and renovation of existing buildings.

Policy Design

Goals

- Develop technical/professional education courses and outreach programs for GHG emission reductions to increase the number of professionals trained in energy efficiency.
- Achieve targeted improvements in energy efficiency through educational programs for builders, building inspectors, and other building industry professionals to help ensure that the existing codes are implemented and enforced.

Timing: By 2012, put the education/training policy in place and begin outreach programs.

Parties Involved: Consumers, retailers, manufacturers, technicians, and professionals in building and related trades, code enforcement agencies and other government agencies (e.g., DBHC), trade schools, and community colleges.

Other: None.

Implementation Mechanisms

Funding for education programs could come from a variety of sources, including professional associations, matching grants from federal agencies, regional market energy efficiency organizations, and energy efficiency surcharges paid by energy customers of from utilities and non-utilities.

Related Policies/Programs in Place

- Kentucky Building Energy Code: http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=KY09R&re=1&ee=1.
- Kentucky Renewable Energy Consortium: https://louisville.edu/kppc/krec.
- Environmental Sustainability Program: https://louisville.edu/kppc/es.
- Green Bank of Kentucky: http://finance.ky.gov/greenbank/.

Type(s) of GHG Reductions

CO_2, CH_4, and N_2O emissions are reduced by avoided electricity generation from fossil fuel sources.

Estimated GHG Reductions and Costs or Cost Savings

This is a non-quantified policy recommendation.

Data Sources: Not applicable.

Quantification Methods: Not applicable.

Key Assumptions: Not applicable.

Key Uncertainties

None identified.

Additional Benefits and Costs

None identified.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-9. Building Commissioning and Recommissioning, Including Energy Tracking and Benchmarking, and Implement a Building Energy Labeling Program

Policy Description

Building commissioning is the process of verifying that systems perform as required for such areas as energy consumption, system function, system operations, and systems maintenance. Commissioning is the process applied to new construction projects or major renovations involving capital expenditures. Existing building commissioning is the process applied to facilities in operation to ensure proper operation and mitigate the impact of system degradation. Ongoing commissioning is the continued implementation of preventive maintenance and performance reviews in order to keep building systems operating efficiently, involving energy tracking and benchmarking, system tune-ups, equipment and sensor calibrations, and staff retraining, among other program elements.

The benefit of commissioning is to not only identify, but also address, operational issues that impact energy consumption and system performance. The effort goes beyond energy analysis to assess parameters, such as indoor environmental quality, equipment longevity, and system maintenance, among others, as needed for the use and occupants of a given facility.

This policy recommendation would initiate commissioning efforts for publicly owned buildings. The efforts would extend the scope of facilities to not only include capital construction, but also systematically address existing buildings and facility management processes. The recommendation would look at possible incentives for private facility owners who implement commissioning efforts for new construction and renovations, existing buildings, and/or facility management processes.

This recommendation would require that findings related to commissioning identified in new construction and renovation projects be addressed within the construction contract. For existing building commissioning, the policy will require no- and low-cost findings to be addressed within the project, while developing a plan to implement recommendations requiring capital expenditure within a reasonable time period.

The integrity of the process will be defined by one of the following: the Building Commissioning Association, ASHRAE, the Associated Air Balance Council Commissioning Group, the National Environmental Balancing Bureau, or equivalent. Commissioning will be implemented by an independent third-party commissioning authority certified by the associations listed above.

The minimum systems that will be commissioned include those that impact the energy consumption of the facility, namely: HVAC, domestic hot water, lighting, renewable energy, building envelope, all controls associated with listed systems, and additional systems as desired by the facility owner.

This recommendation would also initiate a program to inform building owners and operators, tenants, and prospective buyers on the energy use of buildings, similar to a nutrition label on food or miles-per-gallon ratings on cars. Examples include the Building Energy Quotient (or "Building

EQ") program administered by ASHRAE[32] and Seattle's Energy Use Benchmarking ordinance #123226.[33]

Energy Tracking and Benchmarking

Tracking and benchmarking the energy used in a building provides valuable information, not only for comparative purposes between buildings of similar use classification, but also for identification of buildings that have high and/or low performance, in order to determine efficient utilization of energy and where resources need to be spent to reduce the energy costs. Benchmarking is commonly used to identify the minimally acceptable performance of buildings.

Building Energy Labeling

Building energy labels provide information on the potential and actual energy usage of buildings, give feedback to building owners and operators on how their buildings are performing, provide insight into the value and potential long-term costs of a building and market-based forces to influence energy efficiency investment opportunities, and can serve as a tool to provide for differentiation in the marketplace.

Building energy disclosure benefits the Commonwealth by providing a mechanism for uniformly measuring all building consumption, assists in the enforcement of building energy codes, demonstrates responsible use of taxpayer funds when used in public buildings, protects consumers from unknown future energy costs, and reduces energy use while allowing building owners to make decisions about their property. One analysis[34] identified building energy disclosure as a more cost-effective means for reducing energy use than codes. Mandatory labeling requirements are already in place in the European Union, California, and Washington, DC.

Policy Design

Goals

Commissioning

- Commence implementation of commissioning for new construction and major renovations immediately for all publicly owned facilities.

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[32] See: http://www.ashrae.org/pressroom/detail/17380.

[33] See: http://clerk.ci.seattle.wa.us/~scripts/nph-brs.exe?s1=energy&s3=&s4=&s2=&s5=&Sect4=AND&l=20&Sect2=THESON&Sect3=PLURON&Sect5=CBORY&Sect6=HITOFF&d=ORDF&p=1&u=%2F~public%2Fcbory.htm&r=2&f=G.

[34] Interlaboratory Working Group on Energy-Efficient and Clean Energy Technologies. November 2000. *Scenarios for a Clean Energy Future*. ORNL/CON-476 and LBNL-44029. Oak Ridge, TN, and Berkeley, CA: Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory. Available at: http://www.ornl.gov/sci/eere/cef/.

Existing Building Commissioning and Ongoing Commissioning

- Require publicly owned existing building inventory subject to the 2009 *Intelligent Energy Choices for Kentucky's Future*[35] (Kentucky Energy Plan) to incorporate existing building commissioning and ongoing commissioning measures to achieve the plan's energy efficiency reduction targets.
- Require existing building inventory owned by local governments to incorporate existing and ongoing building commissioning measures in the same time frame as established in the Kentucky Energy Plan plus 3 years.
- Require privately owned facilities to have incentives in place as soon as funding and mechanisms are feasibly available.

Energy Tracking and Benchmarking

- Create a uniform method of reporting the energy use of a building, to enable comparable evaluations of the building's energy performance.
- Aggregate sufficient building energy and operational data to determine values that would identify buildings in the upper (low performers) and lower (high performers) quartiles of energy use.

Building Energy Labeling

- Require all buildings to have a comparable metric or an estimate of the energy required to operate the building.
- Require all new state-owned buildings and buildings rented by the state government to include the building label as part of the design documents.
- Require all existing buildings to collect information needed to produce an "In Operation" rating.
- Develop the tools and resources necessary to support utilization of the program.
- Require all new buildings designed under the 2013 code and later to have a building label.

Timing

Commissioning

- Commissioning for Publicly Owned Capital Projects—Immediate implementation.
- Existing Building Commissioning and Ongoing Commissioning—Publicly owned subject to the Kentucky Energy Plan.
    - 2015—Incorporated into measures to achieve 15% reduction in energy per square foot reduction over 2004 baseline.

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[35] Gov. Steven L. Beshear, *Intelligent Energy for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008. Available at: http://www.energy.ky.gov/energyplan2008/.

- o 2025—Incorporated into measures to achieve 25% reduction in energy per square foot reduction over 2004 baseline.

- Existing Building Commissioning and Ongoing Commissioning and Facilities Owned by Local Governments
  - o 2018—Incorporated into measures to achieve 15% reduction in energy per square foot reduction over 2004 baseline.
  - o 2028—Incorporated into measures to achieve 25% reduction in energy per square foot reduction over 2004 baseline.

- Privately Owned Facilities Commissioning
  - o 2011–2012—Implementation of incentive programs for owners engaging in commissioning, existing building commissioning, and ongoing commissioning programs.

Building Energy Tracking, Benchmarking, and Labeling

- Develop energy tracking metric: Fourth quarter (4th Q) of 2011.
- Develop benchmarks for the 15 building types in Kentucky climates: 4th Q of 2011.
- Develop building labeling requirements: 4th Q of 2011.
- Implement energy tracking and building labeling for state buildings: 4th Q of 2013
- Require energy tracking and building labeling for all new construction: 4th Q of 2014.
- Require energy tracking and building labeling for all building transfers: 2015.

Parties Involved

- *Commissioning*—Facility owners, facility managers, architecture and engineering community, commissioning professional community, contracting community.
- *Building Energy Tracking, Benchmarking, and Labeling*—Building owners and operators, designers, construction industry, utilities, building sales, energy managers.

Implementation Mechanisms

Technical assistance would likely be required from DHBC and possibly other agencies. Implementation for publicly owned facilities would occur largely through executive order and/or governing council orders. Implementation for privately owned facilities may require adoption of corresponding regulations.

Related Policies/Programs in Place

HB 2 (2008) requires state buildings that are leased or that receive 50% or more of their total capital cost from the state must meet high-performance building requirements that include building commissioning.[36]

Type(s) of GHG Reductions

- CO_2 is the primary gas reduced by avoided electricity generation from fossil fuel sources, but trace amounts of CH_4 and N_2O emissions are also avoided.

- CO_2 is the primary gas reduced by avoided fossil fuel combustion in the RCI sectors, but trace amounts of CH_4 emissions are also avoided in Tables RCI-7-2a and RCI-7-2b.

Estimated GHG Reductions and Costs or Cost Savings

Table RCI-9-1a. Estimated Costs or Cost Savings from RCI-9 Applying Direct Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-9	Building Commissioning, Benchmarking, and Labeling	2	4	46	–$1,117	–$24

Table RCI-9-1b. Estimated Costs or Cost Savings from RCI-9 Applying Full-Fuel-Cycle Emission Factors

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value 2011–2030 (Million 2005$)	Cost-Effectiveness 2011–2030 ($/tCO_2e$)
		2020	2030	Total 2011–2030		
RCI-9	Building Commissioning, Benchmarking, and Labeling	3	5	50	–$1,117	–$23

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG reductions are calculated for each year (columns three and four above) and the cumulative for 2010–2030 (column five). The cost per tCO_2e (column seven) over 2010–2030 is the discounted, net present value of the 2010–2030 cash flows in millions of dollars (column six) divided by the cumulative MMt of GHG reductions (column five).

Data Sources: See below.

[36] The full text of HB 2 can be found at http://www.lrc.ky.gov/record/08rs/hb2.htm.

Quantification Methods: See RCI-1. This policy is applied to the residential, commercial, and government sectors. Industrial buildings are not included.

Key Assumptions: See Table RCI-9-2.

Table RCI-9-2. Key Assumptions for RCI-9

Buildings Commissioned	Percentage	Year
New Private Sector-Buildings Commissioned	5.0%	2012
Commissioning implemented linearly and capped at:	90.0%	2020
Existing Private-Sector Buildings Commissioned	5.0%	2012
Commissioning implemented linearly and capped at:	66.0%	2020
New State-Owned Building Commission Rate	25.0%	2012
Commissioning implemented linearly and capped at:	90.0%	2020
New Local-Owned Building Commission Rate	25.0%	2012
Commissioning implemented linearly and capped at:	90.0%	2020
Source: Policy option timing section above as well as professional judgment.		
Maximum Auditing/Labeling Penetration	**Percentage**	**Year**
Existing building auditing/labeling implemented linearly over 4 years and capped at:	90.0%	2020
New buildings implemented immediately at:	90.0%	2020
Levelized Cost of Building Label (Investment Audit)	**Electricity ($/MWh)**	**Fuel ($/MMBtu)**
Residential	$63.94	$6.25
Commercial and Government	$11.81	$3.38
Interstate Power and Light Energy Efficiency Plan. 2008. pp. 67-68. http://www.alliantenergy.com/wcm/groups/wcm_internet/@int/documents/contentpage/007810.pdf. Commercial costs of EE from RCI-3 (ACEEE, 2009).		
Energy Savings from Commercial Building Label	**Electricity (kWh/SF-yr)**	**Fuel (kWh/SF-yr)**
Residential (From Interstate Power and Light above)	1242	10
Commercial and Government	0.7	0.002
Assumed energy savings from audits for commercial buildings	5%	5%
Commercial Buildings: Gordon et al. (1996). Low Cost Energy Efficiency Programs. Available at: http://www.raponline.org/docs/PEA_Gordon_LowCostEEPrograms_1996_02.pdf. Also assumed 52% site electricity and 48% fuels.		
Cost of Commercial Building Commissioning and Recommissioning	**Levelized Electricity ($/MWh)**	**Levelized Fuel ($/MMBtu)**
Commercial Building Commissioning	$50.10	$12.81
Cost of Commercial Recommissioning	$23.68	$9.45
Source: SBW Consulting, 2003, for Northeast Energy Efficiency Alliance ("Cx C-B Final Report (June 2003).doc").		
Percentage of housing stock sold per year (based on 2007–2009 U.S. data)		4%
Existing U.S. home sales from National Association of Realtors divided by census housing stock. Available at: http://www.census.gov/popest/housing/HU-EST2007.html.http://www.realtor.org/wps/wcm/connect/acfd450043b03013825aeb34cafa6d66/REL1007EHS_rev.pdf?MOD=AJPERES&CACHEID=acfd450043b03013825aeb34cafa6d66.		

Turnover Rate of Existing Residential Buildings		Percentage
Percentage of housing stock sold per year (based on 2007–2009 U.S. data)		4%
Existing U.S. home sales from National Association of Realtors divided by census housing stock. Available at: http://www.census.gov/popest/housing/HU-EST2007.html.http://www.realtor.org/wps/wcm/connect/acfd450043b03013825aeb34cafa6d66/REL1007EHS_rev.pdf?MOD=AJPERES&CACHEID=acfd450043b03013825aeb34cafa6d66.		
Turnover Rate of Existing Commercial Buildings		**Percentage**
Assumed percentage of floor space sold or entered into a long term contract in each year		2.5%
Commercial Share of Building Energy Consumption	**Electricity**	**Fuel**
Commercial	52%	48%
Table C1. Total Energy Consumption by Major Fuel for Non-Mall Buildings, 2003. Available at: http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003.html#consumexpen03.		
Government Share of Total Commercial Building Energy Consumption	**Sq. Ft.**	**Percentage**
State	80,000,000	14%
Local	60,000,000	10%
Table B5, for Non-mall Buildings in "East South Central" Region. Available at: file://localhost/CBECS http/::www.eia.doe.gov:emeu:cbecs:census_maps.html.		
Net New Construction Growth		**Rate/Year**
Residential		1.0%
Commercial and Government		1.2%
2010–2030 average forecasted annual change in # of space heaters, A/C, and water heaters for U.S. multiplied by ratio of change in disposable income for census region. Source: Table 32. AEO 2010 Reference Case. *2010–2030 average forecasted change in commercial floor space for U.S. multiplied by ratio of change in disposable income for census region. Source: Table 31. AEO 2010 Reference Case.*		

\$/MMBtu = dollars per million British thermal unit; \$/MWh = dollars per megawatt-hour; kWh/SF-yr = kilowatt-hours per square-foot per year; sq. ft. = square feet.

The costs of new building labeling and benchmarking are assumed to be the same as an investment grade audit. These costs include building energy simulation and certification. The savings from new-building labeling and benchmarking is assumed to be 5%, which results from more efficient equipment installations due to the labeling, as well as reduced market failures from landlord/tenant and builder/operator agency problems.

Key Uncertainties

The costs of this policy recommendation would be better presented as a range to reflect the uncertainties associated with future capital costs and performance of renewable energy technologies, as well as fuel price forecast uncertainties.

Kentucky has some of the lowest electricity prices in the country, which hinders market-based deployment of renewable energy. However, the avoided CO_2 resource assumption in Kentucky is high due to coal-fired electricity generation. The economic costs and benefits from renewable energy are heavily reliant on the assumptions of avoided electricity costs, as well as CO_2 emissions.

Additional Benefits and Costs

None identified.

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

RCI-10. Implement Advanced Metering Technologies and Associated Policies for Greater Load Management, Customer Control, Awareness, Price Signaling, etc.

This policy duplicates Energy Supply TWG recommendation ES-11. Thus, it was deleted by the KCAPC as being unnecessary here.

Appendix H
Transportation and Land Use Sectors Policy Recommendations

Summary List of Policy Recommendations[1]

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/t$CO_2$e)	Energy Savings (Million gallons) 2011–2030
		2020	2030	Total 2011–2030			
TLU-1	Bicycle and Pedestrian Comprehensive Plan and Infrastructure Development	0.055	0.087	1.049	–$445	–$424	–87
TLU-2/6	Livability, Brownfield Redevelopment, Downtown Revitalization, Location-Efficient Strategies, Land Use, Building Code Reform and Connectivity	*Not Quantified*					
TLU-3A	Transportation System Management	0.32	0.38	5.32	–$1,070	–$201	–604
TLU-3B/4	Transit Management and Infrastructure	0.07	0.15	1.56	$110	$71	–143
TLU-5	Education and Outreach for Vehicle Maintenance, Idle Reduction, and Co-Driving, and Promote Alternative Modes of Travel	*Not Quantified*					
TLU-7	Parking Management and Ride Sharing	0.204	0.345	4.032	–$2,327	–$554	–335
TLU-8	Strategies to Move Freight in More GHG-Efficient Ways	0.463	1.079	10.31	–$424	–$41.16	–2,786
TLU-9	Promote Consumption of Locally Produced Goods and Services	0.31	0.55	6.36	–$769	–$120.87	–472
TLU-10	Promote the Use of Alternative Transportation Fuels	0.312	1.015	8.475	$30.7	$3.63	–1,880.9
TLU-11	Promote the Use of Clean Vehicles	1.36	3.41	31.34	–$3,581	–$114.30	–2,330
	Sector Total After Adjusting for Integration	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**–7,980**
	Reductions from Recent Actions	**0**	**0**	**0**	**$0**	**$0**	**0**

[1] The cost analysis provides figures that represent the net of both positive up-front costs and cost savings over time. Data results that indicate the potential for net cost savings should be viewed with an understanding that in some cases, initial up-front costs may be necessary in order to achieve the net cost savings over time.

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$)			Net Present Value (Million $)	Cost-Effective-ness ($/t$CO_2$e)	Energy Savings (Million gallons) 2011–2030
		2020	2030	Total 2011–2030			
	Sector Total Plus Recent Actions	**2.84**	**6.30**	**62.41**	**–$7,877**	**–$126**	**7,980**

$/t$CO_2$e = dollars per metric ton of carbon dioxide equivalent; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; NQ = not quantified.

Notes: The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important recommendations.

Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings. Negative net present value represents positive net cash flows from the policy recommendation (i.e., the costs of the policy recommendation, when levelized over their expected lifetimes, are less than expected expenditures). Policy recommendations with estimated costs savings still are likely to require significant up-front capital investments.

TLU-1. Bicycle and Pedestrian Comprehensive Plan and Infrastructure Development

Policy Description

This policy would improve, construct, and promote sidewalks, bicycle lanes, and shared-use paths to increase pedestrian and bicycle travel and thus reduce energy demands and GHG emissions from automobile use.

Not so many years ago, most urban and suburban communities had sidewalks and many low-volume, low-speed roads. Many rural communities had few sidewalks, but traffic was sparse and moved at lower speeds than today. Increases in population and automobile use have resulted in complex transportation systems that accommodate more traffic, while often ignoring the needs of non-drivers. In response to a growing interest in walking and bicycling, planners and engineers have developed sound guidance, which should be applied to all future bicycle and pedestrian planning in the Commonwealth of Kentucky. The following principles of this guidance ensure maximum utilization of bicycle and pedestrian systems.

Principle #1: Local bicycle and pedestrian systems should provide safe and comfortable facilities.

Research has contributed to our understanding of the needs of bicyclists and pedestrians. For instance, there is unequivocal evidence that sidewalks protect pedestrians and contribute to overall traffic safety.[2] Other research indicates that bicycle lanes increase the safety of bicyclists on roadways between intersections and enhance a bicyclist's sense of comfort in traffic.[3] Research is inconclusive as to whether bicycle lanes help or complicate movements at intersections. To increase the perception of safety, careful design judgment is required for the best application of many bicycle and pedestrian improvements. Areas that are inherently unfriendly to bicyclists and pedestrians can be improved with practical design treatments, such as with the addition of refuge islands and recessed stop lines at multi-lane crosswalks. The addition of landscaping and well-maintained facilities also increases the sense of personal comfort and safety for pedestrians and bicyclists.

Principle #2: Direct access to destinations and continuity through connected facilities encourage the use of bicycle and pedestrian facilities.

Higher-density environments that provide sidewalks and Bicycle paths with short distances between residential and commercial areas encourage walking and biking. Therefore, local facilities should be connected with adjacent communities and state and regional trails. Pedestrians and bicyclists need a continuous system of sidewalks/paths, Bicycle lanes, and crossing opportunities that connect residential areas to schools, jobs, shopping, and other

[2] B.J. Campbell, Charles V. Zegeer, Herman H. Huang, and Michael J. Cynecki. 2003. *A Review of Pedestrian Safety Research in the United States and Abroad*. Federal Highway Administration, Office of Safety Research and Development.
[3] B.E. Saelens, J.F. Sallis, and L.D. Frank. 2003. "Environmental Correlates of Walking and Cycling: Findings from the Transportation, Urban Design, and Planning Literatures." *Annals of Behavioral Medicine* 25(2): 80-91.

services. There should be a proactive approach by government that will require sidewalks and Bicycle paths in new developments and in-fill of missing links.

Additional considerations include:

- Signing and re-striping of existing roadways and building off-road trails.
- Accommodating the highest-priority destinations of local pedestrians and cyclists through connected facilities.
- Providing walkways and Bicycle paths to and within large developments and shelters for transit users.
- Implementing "Bicycles-on-Buses" programs, with bicycle parking available at transit stations, shopping areas, schools, libraries, and parks.

Principle #3: The design and extent of a bicycle and pedestrian system should reflect the needs of the community.

Communities differ in the type of bicycle and pedestrian facilities they require. The character of a community, its existing infrastructure, and the needs of local bicyclists and pedestrians determine the opportunities and constraints that define a reasonable approach to planning. Rural communities that are characterized by relatively narrow roads with shoulders, limited public land holdings, and long distances between farms and towns are quite different from urban areas with high traffic volumes, curbed streets, and compact land uses. University and college towns, as well, have special needs.

Opportunities for off-road trail facilities also vary by community location and type. Suburban communities often fare well, especially if they have actively planned for open-space preservation along rivers and abandoned railroad rights of way. They can develop inter-urban trails, create local Bicycleway networks, and include sidewalks in new development.

Opportunities to create linear trails in urban areas are sometimes constrained by dense land use and intense development pressure. However, in many cities, river walks and railroad corridors have been developed as important public spaces. Cities usually have the advantage of a grid street pattern and a relatively complete sidewalk system that offer alternatives for bicycle travel and places to walk.

Principle #4: A bicycle and pedestrian plan should be implemented in phases over a reasonable period of time.

The development of a bicycle system network and pedestrian circulation system will be determined, in part, by input from the public, the configuration of the existing infrastructure and linear corridors, and the availability of funding. It is important to select popular initial projects that can be readily implemented. In addition, early projects should include low-cost items that will make a difference to the community. Subsequent projects will include those that require more coordination and a longer funding horizon.

It is advantageous to secure local funding from a variety of sources. Demonstrating that a plan can be executed through a combination of already-planned transportation projects, various grant programs, and local volunteer efforts builds support for allocating needed matching funds and accessing local budgets.

Policy Design

Bicyclists want access to most of the same places as motorists, and they can legally use any roads from which they are not officially banned. Many roads are usable for local bicycling, but others are undesirable because of such factors as excessive traffic and high speeds. Bicyclists have varying levels of comfort in traffic, depending on skill levels and aversion to risk. The average adult bicyclist is uncomfortable in heavy, fast traffic and prefers an improved designated bicycle facility system.

Pedestrian planning differs from bicycle planning partly because almost everyone walks. Individuals from every age group and ability level use the pedestrian environment, and most destinations need to be accessible by walking. People may be walking less these days, especially in environments that lack pedestrian accommodations. However, many communities are beginning to reverse this trend through pedestrian infrastructure improvements.[4] This promotes health, brings people in contact with their neighbors, and offers mobility to those who cannot or choose not to drive.

A bicycle- and pedestrian-friendly community must provide facilities that allow people to bicycle and walk safely. In some circumstances, roadways and developments must be retrofitted to make bicycling and walking easier and more inviting. Facilities alone will not encourage a change in behavior. Revitalizing downtowns and planning for density and mixed-use development are equally important.

Goals

- Increase walking and bicycling by making it a fun, comfortable, and accessible mode of travel.
    - 10% of all trips by walking and 2% of all trips by bicycle by 2020.
    - 13% of all trips by walking and 3% of all trips by bicycle by 2030.
    - Walking and bicycling account for 1% of person miles traveled by 2020, and 1.5% by 2030.

Timing: See the Goals section, above.

Parties Involved: State government agencies, such as numerous departments of the Kentucky Transportation Cabinet (KYTC), local community pedestrian/bicycle program managers, and educational institutions.

Other: None identified.

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[4] B.E. Saelens and S.L. Handy. 2008. "Built Environment Correlates of Walking: A Review." *Medicine & Science in Sports & Exercise* 40 (7 Suppl): S550-S566.

Implementation Mechanisms

Mechanism 1: Provide accessible, safe, and well-maintained bicycle and pedestrian facilities along and across all streets.

- Create a list of projects with a defensible, data-driven prioritization process that incorporates public input, current and future demand, socioeconomic measures, and land use in order to make the most of limited funds and to ensure that improvements best meet needs.
- Involve pedestrians and cyclists in the identification of local land use needs by appointing community pedestrian/cyclist advisory committees that meet regularly with local community pedestrian/bicycle program managers to review progress and update land use plans.
- Accommodate and improve bicycle and pedestrian access to and across bridges, railroads, and state highways and through interchanges.

Mechanism 2: Institute policies and practices to ensure that Kentucky accommodates the needs of bicyclists and pedestrians.

- Adopt a statewide "complete streets" policy establishing the inclusion of bicycle and pedestrian facilities in all new construction and reconstruction projects within the public right of way.
- Modify the annual KYTC traffic survey to collect data on pedestrian and bicycle traffic that allow monitoring of behavioral change.
- Prepare an expanded set of KYTC standard drawings and specifications related to bicycle and pedestrian facilities.
- Coordinate bicycle and pedestrian improvements with construction projects, such as roadway maintenance, repaving, painting, sewer and water works, and utility corridors.

Mechanism 3: Establish education, encouragement, and enforcement programs that support safe bicycle and pedestrian travel.

- Design and implement a data-driven safety education campaign that targets drivers, bicyclists, and pedestrians.
- Develop a social marketing campaign to promote bicycling and walking.
- Develop health improvement incentive programs related to biking and walking.
- Review and update legislation regulating pedestrian and bicycle travel to incorporate recent research findings and proven programs from other regions.
- Train police officers to consistently enforce laws that promote safe bicycle and pedestrian travel.
- Expand auto trip reduction programs to encourage more people to travel by means other than the private automobile (including bicycling and walking).
- Encourage employer-based programs that offer incentives to bicycle and use transit with disincentives to drive.

- Develop a strong safety education program that includes videos for children and mandatory street-crossing education and bicycle education programs as part of the physical education/ practical living curriculum.
- Develop bicycle education programs targeting adult males, who suffer higher bicycle injury and fatality rates than women or children. Discourage drinking and bicycling, recognizing that alcohol is a factor in more than a third of bicycle fatalities.
- Expand bicycle way-finding efforts statewide, to include maps, signage in the right of way, and Web-based tools.

Related Policies/Programs in Place

- Share the Road: http://sharetheroad.ky.gov/.
- Kentucky Bicycle and Pedestrian Program
- Bicycle Louisville: http://www.louisvilleky.gov/Bicyclelouisville/.
- 2010 Bicycle Master Plan: http://www.louisvilleky.gov/BicycleLouisville/Bicyclefriendly/ 2010Bicyclemasterplan.htm.

Type(s) of GHG Reductions

Predominantly carbon dioxide (CO_2) emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

Table TLU-1-1 summarizes the estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-1.

Table TLU-1-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-1

Quantification Factors	2020	2030	Units
GHG Emission Savings	0.055	0.087	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	1.049		$MMtCO_2e$
Energy Savings (2011-2030)	87		Millions of gallons
Net Present Value (2011–2030)	–$445		Millions of 2005$
Cost-Effectiveness	–$424		$/$tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

Quantification Methods

For the increase in walking and biking, the projected goal is identified in the POD and was used to calculate the associated emission reductions:

- Walking and bicycling account for 1% of person miles traveled by 2020, and 1.5% by 2030.

- The participation in increased walking and biking was assumed to apply to all central business districts (CBDs) in the state with employment and population rates greater than 20,000 people. These cities include:
    - Louisville
    - Lexington
    - Bowling Green
    - Owensboro
    - Covington
    - Richmond
    - Hopkinsville
    - Florence
    - Henderson
    - Frankfort
    - Nicholasville
    - Jeffersontown
    - Paducah
    - Elizabethtown
    - Radcliff
    - Independence
    - Georgetown
    - Ashland

Cities and rural areas with employment and populations below 20,000 were not considered in the analysis. The analysts created a forecast to the year 2030 for employment using historic data from 2005 to 2009 from the Workforce Kentucky Web site[5] for the following cities:

- Louisville
- Lexington
- Bowling Green
- Elizabethtown
- Frankfort

The growth rates used for forecasting the employment to 2030 were taken from the Workforce Kentucky Web site. The rest of the analysis was completed using the EPA COMMUTER Model,

[5] Kentucky Workforce Web site: http://www.workforcekentucky.ky.gov/cgi/databrowsing/localAreaProfileQSMoreResult.asp?viewAll=yes&viewAllUS=&currentPage=&currentPageUS=&sortUp=&sortDown=&criteria=Unemployment+Rate&categoryType=employment&geogArea=2101000000&timeseries=&more=More+Areas&h

as well as spreadsheet-based analysis. Individual runs using the employment baseline in 2005 and the employment forecast to 2030 for metropolitan areas, such as Louisville, Lexington, Bowling Green, Elizabethtown and Frankfort, were completed using the EPA COMMUTER Model. The EPA COMMUTER Model allows for local inputs, such as average time of driving to work in a single-occupancy vehicle (SOV), and the user can specify local mode share inputs.

The EPA COMMUTER Model created a baseline daily VMT estimate. This baseline was converted to daily PMT (person miles traveled) using the DOE person miles multiplier.[6] For the scenario, the target total PMT decrease was assumed to be 0.78% by 2020 and 1.28% by 2030. This scenario assumes that some activity in biking and walking is part of the baseline. In addition, the scenario analysis was completed in a separate spreadsheet, since the COMMUTER Model does not take into account that only trips below a certain travel distance threshold can be considered for shifting away from using an SOV to bicycling and walking.

The daily PMT savings of increased participation in walking and biking were converted to reflect yearly estimates assuming 240 work days per year. Emission factors and full fuel factors from the most recent AEO were applied to the yearly VMT savings to create estimates for million metric tons of carbon dioxide equivalent ($MMtCO_2e$) emissions saved as well as fuel savings. These steps were completed for the five cities mentioned above.

Since workforce data were not readily available for the cities with populations between 20,000 and 40,000 employees, a factor for estimating the impacts was created using the Frankfort data as a basis. A ratio of employment to population was created for Frankfort, and was applied to the population data available for the remaining 13 small cities to estimate the total affected employment in that area. The sum of the estimated number of employees for the small cities was then used to estimate total emission savings by extrapolating from the Frankfort example.

The same process was repeated to estimate the impacts of increased carpool participation in the city of Owensboro with a population between 50,000 and 60,000 using Bowling Green as the example.

In addition to GHG emission savings, the analysts considered vehicle cost savings of 41 cents (2005$) per mile from the AAA Web site.[7] Cost estimates include the following: Louisville, with a population of 720,000, would spend $360,000 per year on Bicycle/pedestrian coordination; Lexington, with a metropolitan population of 470,000, would spend $235,000 per year; and Frankfort, with a population of 28,000, would spend $14,000 per year. A $20 million initial construction cost and $1.5 million annual maintenance costs for the cities of Louisville, Lexington, Elizabethtown, Bowling Green, and Owensboro were also implemented. This allows for the construction of 25 miles of bicycle lanes per city. The region of the 14 smaller cities was assumed to have an initial construction cost of $40 million and annual maintenance costs of $3 million.[8] Finally, the cost and GHG reduction estimates for the 14 small cities were added to the individual estimates for Louisville, Lexington City, and Elizabethtown, as well as to the

[6] DOE Person Miles Multiplier. Available at: http://www1.eere.energy.gov/vehiclesandfuels/facts/2003/fcvt_fotw257.html.
[7] AAA Operating Cost. Available at: http://www.carbuyersnotebook.com/archives/2007/03/driving_cost_pe.htm.
[8] Bicycle Lane Project Construction and Maintenance Cost. Available at: http://ladotBicycleblog.wordpress.com/Bicycle-path-projects/.

estimates of Bowling Green and Owensboro. The final results are summarized in the Table TLU-1-2.

Table TLU-1-2. City-Specific, Regional, and Total GHG Emission Savings from TLU-1 Increases in Biking and Walking ($MMtCO_2e$)

Year	Louisville	Lexington	Bowling Green	Rest of the Region (14 Small Cities)	Total
2020	0.026	0.010	0.002	0.016	0.055
2030	0.044	0.015	0.003	0.024	0.087

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Emission factors are taken from the 2009 AEO (http://www.eia.doe.gov/forecasts/aeo/).
- Employment data are from the Kentucky Workforce Web site.[9]

Key Assumptions

- Assumes 240 commute days per year.
- AAA assumes a 41-cent (2005$) vehicle operating cost per mile.[10]
- Adjustments for inflation were made using the CPI. All dollar values are represented in 2005 dollars.

Key Uncertainties

None noted.

Additional Benefits and Costs

None noted.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

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[9] Kentucky Workforce Web site. Available at: http://www.workforcekentucky.ky.gov/cgi/databrowsing/localAreaProfileQSMoreResult.asp?viewAll=yes&viewAllUS=&currentPage=&currentPageUS=&sortUp=&sortDown=&criteria=Unemployment+Rate&categoryType=employment&geogArea=2101000000&timeseries=&more=More+Areas&menuChoice=localAreaPro&printerFriendly=&BackHistory=-1&goTOPageText=.

[10] AAA Operating Cost. Available at: http://www.carbuyersnotebook.com/archives/2007/03/driving_cost_pe.htm.

Barriers to Consensus

None.

TLU-2/6. Livability, Brownfield Redevelopment, Downtown Revitalization, Location-Efficient Strategies, Land Use, Building Code Reform, and Connectivity

Policy Description

The Livability/Land Use bundle includes policies that will align growth and/or development in Kentucky with the Commonwealth's energy plan[11] and GHG reduction goals. Livability means different things to different people. One common theme of livability is a high quality of life encouraged by walkable, compact, and mixed-use development, which, among other things, has the co-benefits of improving public health and reducing GHG emissions. An integral part of livability is sustainability in using resources in a way that does not deplete nor permanently damage them. Livability used here is a high quality of life lived in a sustainable manner.

These policies are intended to increase the number of walkable, bikable, compact, and mixed-use communities in the Commonwealth, provide incentives for their development, and extend theses concepts wherever feasible. In addition, these policies strive to encourage infill development, increase density in support of transit services, and thus promote preservation of undeveloped land outside urbanized areas. These policies are proven to reduce VMT and resulting GHGs.

Additional co-benefits of these development practices are less infrastructure to support a given population/employment base, resulting in lower costs for water, sewer, and utility services and reduced service distances as well as reduced maintenance costs; all sustainable development practices.

In 2009, the U.S. Department of Transportation (DOT), U.S. Environmental Protection Agency (EPA), and U.S. Department of Housing and Urban Development (HUD) formed a partnership to move our nation toward a livable and sustainable future. Through this partnership, six principles were developed that describe livable, sustainable communities as places where transportation, housing, and commercial development investments are coordinated to better serve the people living in those communities:

1. Providing more transportation choices.
2. Expanding access to affordable housing.
3. Enhancing economic competitiveness-–giving people access to jobs, education, and services, as well as giving businesses access to markets.
4. Targeting federal funds toward existing communities to spur revitalization and protect rural landscapes.
5. Target federal funding toward existing communities—through strategies like transit oriented, mixed-use development, and land recycling. Increasing collaboration among federal, state, and local governments to better target investments and improve accountability.
6. Valuing the unique qualities of all communities, whether urban, suburban, or rural.

[11] Gov/ Steven L. Beshear, *Intelligent Energy for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008. Available at: http://www.energy.ky.gov/energyplan2008/.

Upon consideration of these principles, the desired outcome for our communities is a "completeness" of economic, cultural, and environmental resources. Only then will our policies result in a sustainable, positive impact on the issue of climate change. In an effort to achieve "complete communities" for the citizens of the Commonwealth, the policies described in this section will promote more location efficient growth and will align growth and/or development in Kentucky with greenhouse gas reduction goals.

Implementation of such policies and strategies will enable more Kentuckians to conveniently travel on foot, by bicycle, by transit, or with shorter driving trips; thereby, reducing VMT. Improving the availability of planning tools and other resources will enable implementation. This Livability/Land Use Planning bundle of policies includes the following elements:

- Coordinated Transportation and land-use planning;
- Livability Tools for Planning and Measuring Performance;
- Bicycle and pedestrian infrastructure;
- Transit-oriented development;
- Revitalization in urban and rural communities, including infill, greyfield, and brownfield redevelopment;
- Educational resources and technical support for local and regional agencies;
- Incentives and financial support to local and regional agencies; and
- Evaluation of property tax assessment and zoning policies.

The combination of these policies and strategies will ensure maximum impact on attaining a reduction of GHGs.

Policy Design

Goals: The Kentucky Chapter of the American Planning Association (KAPA) in consultation with related industry, would explore how comprehensive planning documents (comprehensive plans, metropolitan transportation plans (MTPs), Statewide Long Range Plans (SLRPs), Statewide Transportation Improvement Program (STIPs), Metropolitan Transportation Improvement Programs (MTIPs), and local land use plans can be coordinated to meet the Commonwealth of Kentucky's GHG reduction goals.

Timing:

- By 2012, initiate partnership with the Kentucky American Planning Association (KAPA);
- By 2012, disseminate to all local governments the EPA assessment tool, "Green Buildings for Local Governments", to assess current codes/ordinances and determine if barriers exist for sustainable design and green buildings;
- By 2015, all counties will have a comprehensive mapping of existing land uses that identifies opportunities for development, redevelopment, and preservation;

- By 2015, all incorporated cities with a population greater than 5,000 will adopt site planning and urban design standards that help reduce VMT and GHG emissions;
- By 2015 all counties will have a pedestrian/bicycle plan in place that will include "complete street" policies;
- By 2020, create a statewide incentive package that promotes compact urban and mixed use development; and
- By 2020, create a statewide incentive package that promotes brownfield, greyfield, and infill development.

Implementation Mechanisms

The following implementation mechanisms all involve public outreach and input. All implementation mechanisms will be coordinated through the proposed virtual State Planning Resource Office.

Creation of a "Kentucky State Planning Resource Office"

Implementation of the following recommendations would be greatly facilitated by the creation of a Kentucky State Planning Resource Office. The mission of this virtual office would be to facilitate communication and collaboration among state agencies in the planning and delivery of sustainable infrastructure investments across the Commonwealth of Kentucky. At a minimum, this office would provide education, technical assistance, and links to funding resources for both rural and urban communities. The three chief functions of the proposed Kentucky State Planning Resource Office would be to:

- Develop a compendium of best practices;
- Help coordinate the policies and activities of state agencies;
- Provide technical assistance and serve as an informational resource; and
- Provide training and public awareness.

In 2008, considerable work was done creating specifications for a state planning office. The results of this effort are available as attachments to this document.

Study of Best Practices (Part 1)

Identify potential best Sustainable Urban Development Practices (inventory) including ideal development densities, GHG projection techniques, and energy efficiency. In addition, transportation authorities should be given authority to prioritize projects that reduce VMT and consider the GHG impact of constructing new roads. All practices should include specific measurable results to permit evaluation of progress over time.

Ongoing Survey of Best Practices (Part 2)

Develop a continuous survey of Sustainable Urban Development Best Practices (SDBPs) in and around Kentucky to assess their feasibility and profitability. The survey would serve as a resource for the development community and related industries in identifying successful and profitable SBDP programs (e.g., speakers bureau, Web site, public service announcements, etc.).

The close proximity of these case studies would permit interested Kentuckians to visit these locations with minimal time and expense. This would be a continuous monitoring system of SDBPs in Kentucky and surrounding states that would monitor performance and profitability, emphasizing measurable and trackable results.

The survey would begin with a study setting up the system, collection of the initial data, and design of updating procedures and public education program. The established system would be assigned to an appropriate agency (State Planning Resource Office) to periodically update the data; identify new, emerging SBDP programs; and to publicize findings. The underlying assumption for continuous updating of the material is that the national economy is entering a new paradigm challenged by future energy shortages and changing climate; and that this may result in a long period of rapidly changing/ evolving SDBP programs that Kentucky could learn from and prosper by with implementation

Coordination of Land Use and Transportation Planning

Effective coordination of state, regional, local land use and transportation plans will be necessary to develop realistic GHG reduction targets. At the same time, individual communities need the flexibility to choose the specific policies that help them meet those targets. Many communities have used scenario planning as an effective way to quantify land use and transportation planning decisions in their efforts to reduce VMT and GHGs.

Scenario planning matches alternative future land use plans with alternative future transportation plans. These plans are evaluated and/or run through a simulation model (e.g., TransCad, ICLEI, Motor Vehicle Emission Simulator [MOVES], etc.) to project impacts on VMT, land consumption rates, air pollution, GHGs, infrastructure costs, and other outcomes. When technical modeling is not feasible, qualitative assessments can be performed. GHG projections from alternative land use and transportation proposals should be incorporated into state and local plans.

In October 2010, the FHWA released a scenario planning guidebook to assist government agencies in implementing the scenario planning process from start to finish.

Livability Tools for Planning and Measuring Performance

The KYTC and the FHWA–Kentucky Division will develop a "livability matrix" to assist communities to determine their current livability status and the status of proposed development.

Bicycle and Pedestrian Infrastructure

Complete Streets are streets that provide transportation facilities for all users, including pedestrians, bicyclists, transit users and motorists, to the extent appropriate for the land use or the context of the street. The Commonwealth of Kentucky should develop a statewide policy that requires "complete street" design be considered for all state and federal projects. (This is similar to the existing "bike/ped" policy that the KYTC currently has in existence.")

An extra component should be added to the KYTC's Project Identification Form (PIF) that indicates whether a project is a complete street. Projects that are "complete streets" should rise higher in the ranking process for the STIP and receive priority funding. Metropolitan planning organizations (MPOs) should also follow suit when ranking projects for their MTPs and TIPs.

This requirement would apply to all roads that will receive state or federal funding. It would require support from the FHWA, the KYTC, and local governments. For neighborhood developments it would involve planners, builders, electricians, architects, developers, utilities, and retailers of energy-efficient products. All efforts would involve the general public. In addition to supporting a statewide complete streets policy, KYTC should:

- Work to implement KYTC's access management guidelines where feasible by developing Memorandums of Understanding (MOUs) with local communities;
- Develop "road diet" guidelines and will work with local communities to implement guidelines where feasible; and
- Continue to support the maintenance and development of the rural and urban transit systems.

Transit-Oriented Development

A transit-oriented development (TOD) is mix of land uses—residential, office, shopping, civic uses, and entertainment—within easy walking distance of a transit station. TODs can reduce VMTs and GHGs emissions by promoting the use of multimodal and mass transit. This development concept is similar to development that occurred throughout the United States prior to the 1950s and can be seen in many of Kentucky's historic districts near rail lines. State, regional, and local governments should plan transit-ready corridors and provide incentives for TODs. Transit-ready corridors would improve the feasibility of future transit service throughout the state.

Revitalization, Including Infill, Greyfield, and Brownfield Redevelopment

The Kentucky Cabinet for Economic Development (KCED) and the Kentucky Department for Environmental Protection will work together to facilitate the cleanup and redevelopment of brownfields and greyfields. In particular, they will work with company representatives and local officials when facilities are initially closing, which in turn will expedite the cleanup and redevelopment of the facility. Earlier coordination enables the placement of the property on the market before the facility deteriorates due to lack of maintenance or vandalism.

State government will lead by example in promoting infill and redevelopment of brownfields and greyfields. The High-Performance Building Committee, established in House Bill 2 (2008 regular session), should consider the effect on VMT and community sustainability as it assists the Finance and Administration Cabinet (FAC) in the review of state building projects. These issues should be included in professional development programs for state and local building designers, construction companies, school districts, building managers, and the general public.

KCED should create a statewide package of sustainable growth incentives and promote them in coordination with local governments. Such incentives should include, but not be limited to, contracting based on measurable GHG reduction and utilizing such devices as fast-tracking permits, tax reductions, "green" certification designations, awards programs, etc.

School Siting Considerations

The location of a school has a major impact on a community's land use and development patterns. The state should encourage the Kentucky Board of Education to support the concept of sustainability for school facility planning, including the renovation and reuse of existing school buildings. To accomplish this, the board could:

- Eliminate minimum acreage standards in order to preserve community-centered schools.
- Eliminate the guideline that suggests a new school should be built if the renovation costs exceed 80% of building a new school.
- Ensure a complete analysis is conducted, taking into consideration all consequences, before a decision is made concerning school consolidation. The analysis should consider the number of students for whom school location makes walking or biking to school feasible.
- Adopt revised policies and regulations that encourage restoration and rehabilitation of community schools over new construction of school buildings.
- Encourage renovation projects with a sustained, substantial, and dedicated funding commitment through an "Aging Schools Construction Fund."
- Amend state law to allow local governments and school boards to sell surplus property for a nominal fee if the property is to be used for public purposes.
- Expand local school planning committees to include a representative from the local government office that is responsible for planning and development.
- Explore the possibility of obtaining supplemental funding for historic schools to assist with adaptive reuse projects, such as senior housing and community centers. Funding from the Main Street and Renaissance Kentucky programs could be used in those locations.

Educational and Technical Support for Local and Regional Agencies

Develop a related public sector educational program for local mayors, county judge executives, and city planners. Work with KAPA, MPOs, and area development districts (ADDs) to provide training on scenario planning, complete streets programs, livability assessments, and the EPA assessment tool for analyzing current codes and ordinances.

State agencies will collaborate on providing educational and technical assistance to Kentucky communities about the "complete communities" strategies. Sample policies and strategies and best practices will be provided for local consideration through the Kentucky State Planning Resource Office. Not every community will be expected to use the exact same tools or strategies. Communities will be given flexibility and choices to achieve VMT reduction goals through their ideal growth and development. Local governments and other stakeholders, such as developers and private lending institutions, will be provided technical assistance that will include diverse strategies for communities to consider using in reaching their VMT reduction goals.

Educational and technical assistance will include:

- The capabilities for communities to examine their current level of livability and sustainability, and to plan toward increasing that current level.

- The capabilities for local governments to adopt comprehensive plans, zoning regulations, and urban design standards that help reduce VMT and GHG emissions, such as:
    - Implementing design standards that increase street network density and connectivity in new development and redevelopment projects (i.e., reduce cul-de-sacs and increase street network densities);
    - Implementing community development that is compact and mixed-use, and includes adaptive re-use of existing resources;
    - Developing a pedestrian- and bicycle-friendly environment by creating design guidelines that require connectivity and accessibility within the community, especially to "basic needs" services (food, clothing, healthcare, education, etc.);
    - Implementing TOF that includes "basic need" services; and
    - Providing incentives for greater sidewalk coverage in all future residential, commercial, and retail developments (meaning that all streets within such developments should have sidewalks);
    - Providing incentives to design or locate residential projects to encourage a greater proportion of dwelling units to be developed within a one-half mile walking distance of at least two or more commercial, retail, or entertainment centers; and
    - Providing incentives for the preservation of rural landscapes.

Education will be provided to the general public and state legislators, as well as to local officials and developers, as appropriate. Education and technical assistance will be developed with the advice of federal, state, and local governments, academics, and other stakeholders and will focus on bridging the gap between transportation planners and land-use planners. State agencies will share responsibility in implementing cooperative strategies, where deemed appropriate.

Incentives and Financial Support to Local and Regional Agencies

Existing incentives, funding, and loan programs administered by the state that are applicable to growth and development should be assessed and realigned to support the elements of this Livability/Land-Use Planning bundle of policies. Rating systems and prioritization of funding will be reviewed and improved to meet livability/sustainability objectives. New programs will be developed, and existing programs will be revised to fill in gaps where no program exists to meet needs that cannot be achieved, or are far less likely to be achieved, without funding assistance (e.g., improved brownfields and greyfields incentives, increased technical assistance funding).

Evaluation of Property Tax Assessment and Zoning Policies

Local governments should utilize the EPA toolkit for sustainable design, "Green Building for Local Governments." This toolkit is designed to help local governments identify and remove barriers to sustainable design and green building within their permitting process. It addresses the local codes and ordinances that would affect the design, construction, renovation, and operation and maintenance of a building and its immediate site. For example, it is common for zoning ordinances to have minimum parking requirements, minimum setbacks, land use segregation, and maximum densities. In many cases, these ordinances prevent sustainable development and should be revised to allow flexibility.

In addition to revising local ordinances to provide flexibility, local governments should work with state and federal agencies to create incentive packages for transit oriented, infill, brownfield, greyfield, and rehab developments. Local governments need to be aware of existing tax incentives and new ones as they become available. The Kentucky State Planning Resource Office would be able to provide this information and examples of their implementation. At the local level, tax incentive packages should be targeted to areas identified for sustainable development. This would provide developers with multiple sources of financing for projects in those locations. Examples of tax incentive tools for funding include but are not limited to:

- Brownfield redevelopment tax credits,
- Energy-efficient construction tax credits,
- Low-income housing tax credits;
- New markets tax credits,
- Historic preservation tax credits,
- Rehabilitation tax credits, and
- Tax Increment Financing Districts.

Related Policies/Programs in Place

No major policies or programs are in place. Some programs that relate somewhat to livability include:

- KYTC Bike/Ped Policy,
- Safe Routes to School program, and
- "Healthy Communities" initiative partnership between KYTC and the Kentucky Cabinet for Health and Family Services (CHFS),

Louisville Metro has several programs and initiatives in place that are consistent with these policies, including:

- Bicycle and Pedestrian Plan,
- Complete Street Policy,
- Healthy Hometown Movement,
- Partnership for a Green City, and
- Step Up Louisville.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The policy description and policy design establish process-oriented goals. Meeting a process-oriented goal will not by itself result in energy savings and GHG savings. Meeting such process-oriented goals has the potential to increase the effectiveness of other related programs. As a result, the GHG emission reductions that may be associated with these programs are incorporated into the estimates for other TLU policies, including TLU -1.

Table TLU-2/6-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-2/6

Quantification Factors	2020	2030	Units
GHG Emission Savings	Not quantified		$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	Not quantified		$MMtCO_2e$
Energy Savings (2011-2030)	Not quantified		Millions of gallons
Net Present Value (2011–2030))	Not quantified		Millions of 2005$
Cost-Effectiveness	Not quantified		$\$/tCO_2e$

$\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Key Uncertainties

There is a strong feeling that it is not the state's responsibility to dictate land use to local communities. And, there is concern that any effort to "educate" not be interpreted as "dictating." As stated, a Kentucky State Planning Resource Office—virtual or otherwise—was seen by the Livability/Land Use team as critical for the implementation of most of these recommendations.

- Will there be inter-cabinet support for the concept of a Kentucky State Planning Resource Office?
- If so, who will take the lead to implement a Kentucky State Planning Resource Office?
- Will necessary resources, including staff time, be made available?

In addition, these policies are not recommending the restriction of any form of development. Rather, they are promoting development that will create more transportation choices for Kentucky residents.

Additional Benefits and Costs

Statewide policies to foster complete communities will have significant economic, social, and ecological benefits for communities across Kentucky. Implementation of such policies and strategies will enable more Kentuckians to conveniently travel on foot, by bicycle, by transit, or with shorter driving trips. Proven co-benefits to these policies include:

- Reduced cost for building and maintaining infrastructure,
- More transportation choices for residents, and
- More opportunities for residents to have physically active lifestyles.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

TLU-3A. Transportation System Management

Policy Description

This policy is designed to align Kentucky's transportation system with the Commonwealth's energy plan[12] and GHG reduction goals. Transportation system management (TSM) is the concept of pairing transportation demand with transportation supply to help transportation networks serve the demand effectively and efficiently. TSM strategies are relatively low in cost but effective in nature. Each strategy alone provides a relatively small benefit to energy demands and GHG reduction, but when applied in concert, substantial gains can be achieved.

TSM strategies attempt to reduce the number of trips taken by SOVs, shorten trip lengths, reduce delay, increase the reliability of the network, and reduce idling (and/or other transportation actions that increase GHG emissions). The goal of TSM is to reduce the daily VMT per capita on the transportation network. An added benefit of effective TSM is reduced vehicle hours traveled (VHT) per capita, which measures the amount of traffic congestion delay. Reduced VMT or VHT is highly correlated with reduced GHG emissions.

TSM attempts to both improve transportation system performance and alter travel behavior through a combination of technological improvements, incentives, design, and restrictions. Technological improvements include traffic signal coordination, traveler information displays, lane management, real-time monitoring of traffic conditions to adapt/improve operations, and other intelligent transportation system (ITS) applications. Incentives can include policies that financially favor desired behavior or allow users to gain a time advantage and include value pricing and smart parking strategies. System design is also important, since infrastructure and technology can be adapted to encourage less driving, and it includes access management; intersection improvements; bottleneck removal; and integrated, interconnected, intermodal systems to serve the mobility needs of people and goods and foster economic growth. Finally, users can be barred from performing certain actions that would negatively impact the efficiency of the transportation system.

TSM policies can be instituted at every level of government. Some can have a virtually instant effect, while others require many decades to realize full benefits.

Policy Design

Goals: The overarching goal is to reduce urban per-capita VMT in the range of 10%–15% by 2030.

- Develop and implement policies and strategies that include program funding, financial and development incentives, infrastructure investment, and regulatory requirements to promote transportation system management improvements that result in reduced VMT and/or VHT which, in turn, result in reduced GHG emissions. These actions, taken in concert with other aggressive TLU policy actions, should be designed to reduce urban per-capita VMT in the

[12] Gov. Steven L. Beshear, *Intelligent Energy for Kentucky's Future: Kentucky's 7-Point Strategy for Energy Independence*, November 2008. Available at: http://www.energy.ky.gov/energyplan2008/.

range of 10%–15% by 2030; VHT can be reduced by amounts that are associated with these VMT reductions. VHT reduction is recognized as a means of reducing driver delay, while also reducing excess fuel consumption in congested traffic.

- Reduce existing and future trips and trip lengths in an effort to reduce both VMT and VHT. Driving less, in terms of both hours and miles driven, will decrease GHG emissions. This can be achieved through the aggressive implementation of specific transportation demand management (TDM) strategies and coordinated TLU planning and decision making.
- Distribute existing and future trips in terms of both time and geography—when trips are taken and where trips are taken—to reduce congestion and smooth traffic flow. Reducing congestion and smoothing flow by changing people's driving patterns—by changing either the time of day they drive or the route they take—will result in less idling and stop-and-go driving. This will reduce VHT and GHG emissions and can be achieved through increased investment in supporting transportation infrastructure, implementation of specific TSM strategies, and the aggressive implementation of specific TDM strategies.
- Improve transportation system operations to improve travel conditions on the transportation network. This includes traffic signal coordination and remote communication, real-time traveler information and traffic monitoring and analysis, advanced computerized lane and parking space management, value pricing at future toll locations, intersection improvements such as roundabouts, diverging diamond,[13] grade separations, advanced incident management, and other traffic operation applications. This will reduce the frequency of transportation actions that contribute to high levels of GHG emissions (for example, quick starts, idling, and excessive braking). It will require an increased investment in TSM-related capacity/infrastructure and aggressive implementation of non-capacity operational strategies that improve the flow of vehicles (including smart/efficient integrated transit, Bicycle, and pedestrian facilities) on the transportation network.

Timing: 2010–2030—Various TSM strategies have a variety of implementation time frames. Some, such as workplace-based strategies, can begin implementation almost immediately. Others that are based on infrastructure construction will have an implementation timeline of 4–10 years. Systemic changes to the urban landscape have the longest horizon—up to 25 years.

Parties Involved: Federal transportation agencies (FHWA, Federal Transit Administration); state government agencies (many departments of KYTC and District Highway Offices, economic development agencies); state and local community affairs agencies; selected Kentucky environmental protection agencies; regional government agencies (metropolitan planning organizations [MPOs], area development districts [ADDs)] regional planning councils); regional transportation authorities; local transportation providers (public transit agencies, airports, river ports, expressway/bridge authorities; local governments and agencies.

Other: None identified.

[13] A diverging diamond interchange is a rare form of diamond interchange in which the two directions of traffic on the non-freeway road cross to the opposite side on both sides of the bridge at the freeway. It is unusual in that it requires drivers on the freeway overpass (or underpass) to briefly drive on the side of the road opposite than what they are accustomed to.

Estimated GHG Reductions and Net Costs or Cost Savings

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-3A are summarized in Table TLU-3A-1.

Table TLU-3A-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-3A

Quantification Factors	2020	2030	Units
GHG Emission Savings	0.32	0.38	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	5.32		$MMtCO_2e$
Energy Savings (2011-2030)	604		Millions of gallons
Net Present Value (2011–2030)	–$1,070		Millions of 2005$
Cost-Effectiveness	–$201		$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

Implementation Mechanisms

Collectively, the implementation mechanisms recommended under this policy attempt to reduce GHG emissions by enhancing system efficiency and modifying travel behavior and conditions through TSM strategies. Those strategies will require a combination of program funding, financial and development incentives, infrastructure and technology investment, and regulatory requirements implemented at local, state, and regional levels.

Reduce existing and future trips and trip lengths.

These implementation mechanisms are intended to result in either the reduction of trip lengths or the complete elimination of certain trips. This can reduce both VMT and VHT, which in turn will reduce GHG emissions. Implementation mechanisms intended to reduce trips and trip lengths include:

- Encourage and/or incentivize public- and private-sector employers to implement telework programs for eligible employees. This can result in fewer work-based vehicle trips.
- Encourage and/or incentivize public- and private-sector employers to implement job-sharing programs for eligible employees. This can result in fewer work-based vehicle trips.
- Encourage and/or incentivize public- and private-sector employers to fund and implement regional and local carpooling and vanpooling programs. This can result in fewer work-based vehicle trips.
- Encourage and/or incentivize enhanced coordination between land use and transportation planning and decision making to reduce distances between clusters of affordable housing, employment opportunities, and people supplies/services.

Distribute existing and future trips in terms of both time (when a trip is taken) and geography (where a trip is taken).

These implementation mechanisms are intended to change people's driving patterns and behaviors (by changing either the time of day they drive or the route they take), resulting in reduced congestion and smoother traffic flows. Reducing congestion will result in less idling and stop-and-go driving which, in turn, can result in fewer GHG emissions. Implementation mechanisms intended to change people's driving patterns and behaviors include:

- Encourage and incentivize transportation facility operators to implement value-pricing (variable-pricing) policies. This can encourage travelers to change the time of day they make various types of trips and result in fewer vehicle trips during peak periods. Alternatively, this will encourage travelers to change the routes they take for various types of trips and will result in a more even distribution of vehicle trips across the transportation network.
- Encourage and incentivize public and private parking facility operators to implement smart parking policies. This can encourage travelers to change the time of day they make various types of trips and will result in fewer vehicle trips during peak hours.
- Encourage and incentivize local governments and private developers to build up the supporting transportation network (e.g., lower functional class street network), improve local transit routes that support express bus routes and premium transit options, and construct more sidewalks and Bicycle pathways. This can encourage/enable travelers to make appropriate route and mode choices and result in a more even distribution of vehicle trips across the transportation network.
- Encourage and/or incentivize public- and private-sector employees to implement flex-time and compressed time programs for eligible employees. This can result in fewer work-based vehicle trips during peak periods and, in cases of compressed time programs, fewer work-based trips overall.

Improve transportation system operations to reduce occurrences of transportation actions that contribute to high levels of GHGs (e.g., "jack rabbit" starts, idling, and excessive braking).

These implementation mechanisms are intended to maximize the efficiency of the transportation system through the application of technology and advanced design. Management of the supply of transportation capacity through the application of various technologies and design strategies will result in reduced congestion and smoother traffic flows, which, in turn, can result in less idling and stop-and-go driving and reduced GHG emissions. Implementation mechanisms intended to change people's driving patterns and behaviors and reduce VMT and VHT include:

- Increase investment in ITS technologies at all levels (including ITS systems already in operation/installed), particularly those that can help smooth traffic flow.
- Increase investment in traffic monitoring and analysis systems to support TSM, ITS, incident management, congestion management, systems maintenance, sustainability, etc.
- Increase investment in incident management programs and technologies (e.g., roadside assistance) that can smooth traffic flow and reduce delay.
- Increase investment in traffic signal systems to smooth traffic flow and reduce delay through traffic signal timing, such as coordination, prioritization, and installing/upgrading/ maintaining remote communications.

- Encourage and/or incentivize access management programs at all levels, particularly those that coordinate land use and transportation decision making. This can reduce conflicts among other positive impacts.
- Increase investment in traveler information technologies that can maximize efficient use of the network.
- Increase investment in managed-lane technology to maximize available capacity and smooth traffic flow.

Other TSM implementation mechanisms (not specifically mentioned above) that have proven to reduce VMT, VHT, and GHGs and fall into the strategies mentioned above include:

- Special-events management strategies.
- Installation, upgrades, and maintenance of traffic signal hardware, such as controllers, cabinets, and vehicle and pedestrian detection hardware.
- Turning lanes.
- Acceleration, deceleration, and weaving sections (e.g., lanes and ramps).
- Ramp metering.
- Lane assignment changes.
- Building high-occupancy vehicle (HOV) lanes (where and when appropriate).
- Pavement striping/re-striping.
- Signage and lighting.
- Roundabouts and other traffic-calming/smoothing measures.
- Network interconnectivity.
- Innovative and broad TSM initiatives to reduce future GHG emissions within the transportation planning process.
- Transit management (improved, expanded transit service; TOD; transit system priority—e.g., signal prioritization or preemption, bus lanes resulting in improved level of service).
- Road diets (or re-designs).

Related Policies/Programs in Place

KYTC supports and advocates the use of ITS technology. Local plans also propose TSM measures.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

Quantification Methods

This analysis examines potential GHG reductions from TSM strategies. Within this broad category are three strategies:

- Reduce Existing and Future Trip Lengths
- Distribute Existing and Future Trips Across Time and Geography
- Improve Transportation System Operations

The goal for the TSM strategy is to reduce LDV GHG emissions by 3.05%. The target is based on DOT's estimate of the GHG reduction potential of strategies to improve transportation systems.[14] DOT estimates strategies to improve transportation system efficiency may reduce GHG emissions by 3%–6% compared to the BAU scenario. However, 1.1%–1.8% of the 3%–6% emission reduction is attributed to reduced speed limits. Since states may not be able to influence speed limits as easily as other aspects of transportation system efficiency, for the purposes of this analysis speed limit reduction was not included in the analysis. After factoring out speed limit reduction strategies, the estimated midpoint of the range of potential GHG emission reduction achievable from TSM is 3.05%.

Each of the three strategies will contribute to the total emissions reduction goal. Reducing existing and future trip lengths, distributing existing and future trips, and improving transportation system operations were assumed to each reduce GHG emissions by 1.016%. Combined, these three strategies would reduce per GHG emissions by about 3.05%.

Each strategy was assumed to take 10 years to fully implement and had a 10-year linear ramp up. After the ramp-up period, the strategy was assumed to be fully implemented and held constant for the remainder of the period of analysis. The 10-year implementation estimate is consistent with DOT estimates. DOT estimates transportation system strategies may take 5–10 years to fully deploy.[15] This analysis assumes the more conservative 10-year strategy implementation period.

The reduction in GHG emissions was calibrated with the Kentucky Inventory's total VMT estimates. The difference between the baseline total VMT and the scenario with the GHG emission reduction strategies is used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and vehicle ownership and operation cost savings. The projected fuel cost estimates are from the most recent AEO projected cost estimates. The vehicle ownership and operation costs are estimated using AAA estimates of the cost to own and operate a vehicle per mile. The capital costs of the TSM strategy were estimated to be about $13 million per year based on Kentucky's average annual expenditure on ITS between 2001 and 2007.[16]

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[14] U.S. DOT. 2010. *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*. Volume 1. Available at: http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf.
[15] Ibid.
[16] Kentucky Transportation Center, University of Kentucky. 2001. *Intelligent Transportation Systems: Business Plan for Kentucky*. Available at: http://transportation.ky.gov/traffic/systemoperations/BPFINALREPORT.pdf.

The statewide average annual expenditure on ITS was checked against city-level expenditure estimates to ensure the reasonableness of the statewide estimate. The statewide average annual expenditure on ITS is about 3.5 times larger than TRIMARC's average annual expenditure on ITS. Kentucky's average annual expenditure on ITS was about $13 million per year between 2001 and 2007, whereas TRIMARC's average annual expenditure on ITS was about $3.7 million per year between 1997 and 2007.[17] These state and local estimates from two different studies corroborate one another.

Table TLU-3A-2 shows Kentucky's projected baseline VMT based on the Kentucky Inventory and the projected VMT after the implementation of the TSM strategies.

Table TLU-3A-2. Baseline and Reduction Scenario Estimates of per-Capita VMT

Year	Total Baseline VMT	Total VMT After GHG Emission Reduction Scenarios	Emission Reduction Achieved off Baseline (%)	Strategy Implementation Rate (%)
2010	25,233	25,233	0.00	0
2011	25,195	25,118	0.31	10
2012	25,627	25,471	0.61	20
2013	26,719	26,475	0.92	30
2014	27,951	27,610	1.22	40
2015	28,520	28,085	1.53	50
2016	29,252	28,717	1.83	60
2017	30,320	29,673	2.14	70
2018	31,614	30,843	2.44	80
2019	32,165	31,282	2.75	90
2020	**33,639**	**32,613**	**3.05**	**100**
2021	35,213	34,139	3.05	100
2022	38,062	36,901	3.05	100
2023	39,598	38,390	3.05	100
2024	39,822	38,607	3.05	100
2025	41,095	39,842	3.05	100
2026	42,586	41,287	3.05	100
2027	43,520	42,193	3.05	100
2028	44,895	43,526	3.05	100
2029	46,445	45,028	3.05	100
2030	**46,803**	**45,376**	**3.05**	**100**

GHG = greenhouse gas; VMT = vehicle miles traveled

Key Assumptions

Each of the strategies will contribute to the total emissions reduction goal. Reducing existing and future trip lengths, distributing existing and future trips, and improving transportation system operations were assumed to each reduce GHG emissions by 1.016%.

[17] Kentucky Transportation Cabinet. 2009. Evaluation of TRIMARC.

The strategies were assumed to take 10 years to fully implement and have a straight linear ramp up. DOT estimates transportation system strategies may take 5–10 years to fully deploy. This analysis assumes the more conservative 10-year strategy implementation period.

The capital costs of the TSM strategy were estimated to be about $13 million per year based on Kentucky's average annual expenditure on ITS between 2001 and 2007.[18]

Data Sources

- A key cost data source is the Kentucky Transportation Center's *Intelligent Transportation Systems: Business Plan for Kentucky*, 2001. Available at: http://transportation.ky.gov/traffic/systemoperations/BPFINALREPORT.pdf.
- DOT's *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions,* Volume 1, study was used to set the 3.05% GHG emission reduction goal for the strategy. Available at: http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf.

Key Uncertainties

- A key uncertainty is future fuel prices. Fuel prices may fluctuate unpredictably, and their fluctuations affect VMT significantly.
- Another uncertainty is the degree to which people will respond to incentives and disincentives to reduce existing and future trip lengths, distribute existing and future trips across time and geography, and improve transportation system operations. This sort of effort requires buy-in and some coordination between employers, employees, homebuyers, car and technology manufacturers, car purchasers, and transportation planning officials.

Additional Benefits and Costs

Additional benefits include enhanced freight movement, accessibility, and safety.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

[18] Kentucky Transportation Center, University of Kentucky. 2001. *Intelligent Transportation Systems: Business Plan for Kentucky*. Available at: http://transportation.ky.gov/traffic/systemoperations/BPFINALREPORT.pdf.

TLU-3B/4. Transit Management and Infrastructure

Policy Description

This policy presents objectives and strategies intended to make public transit a legitimate transportation choice for the citizens of Kentucky, which will reduce energy demand and the GHG emissions associated with transportation. DOT recently announced that the national average CO_2 emissions per passenger-mile for bus transit is just two-thirds that of the average private automobile. When buses operate with all seats occupied, that fraction is reduced to less than one-fifth. The following additional data support this policy recommendation:

- EIA forecasts that oil prices could rise to $210 per barrel from their current level (approximately $75/barrel) by 2035.[19] The rising cost of fuel will cause more Kentuckians to rely on public transit for travel needs.
- Public transit is the safest form of transportation in America today. In 2007, 864 people were killed on Kentucky roads, and 38,786 people were injured.[20]
- Kentucky has one of the lowest per-capita funding rates for public transportation in the country. Currently, that rate is less than $ 0.30 per person annually.
- During 2008, Kentucky's three urban transit agencies (Lextrans, Transit Authority of River City, and Transit Authority of Northern Kentucky) provided 25,487,600 trips to passengers.
- Greater use of public transit and reduction in automobile travel can be achieved by expanding public transit infrastructure, both within and among Kentucky's communities. Infrastructure improvements, such as conversion of mixed-traffic lanes to dedicated bus or light-rail lanes, can significantly aid level-of-service measures.

Public transportation improvements are critical to support livability initiatives (as referenced in TLU-2/6), and are essential to an ongoing effort to reduce VMT. As an example, a 2008 Transportation Research Board study found that households in 17 TODs the country took 44% fewer car trips than the Institute of Transportation Engineers' manual suggests for a typical housing development

This policy includes four recommended components of change that are needed on the state level to expand and improve transit infrastructure:

- *Funding*—Increase funding for transit at the state level. Current levels and allocation formulas of state funding for transit are inadequate to maintain—let alone substantially expand and improve—transit infrastructure to reduce VMT.
- *Studies and Planning*—Provide local governments and MPOs the leadership and assistance needed to initiate transportation corridor studies. Partner with local governments and MPOs to study how we might provide more transit opportunities within and between rural areas of the state, as well as between our urban centers.

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[19] U.S. Energy Information Administration Oil Forecast. Available at: http://www.eia.doe.gov/oiaf/forecasting.html.
[20] Also see: http://highwaysafety.ky.gov/files/strategic_plan/HSP_FY2009.PDF.

- *Technical Assistance*—Provide technical assistance, where needed, to promote the coordination of land use and transportation infrastructure planning, with the goal of increasing transportation options and decreasing transportation costs.
- *Transit Marketing and Promotion*—Provide incentives and marketing strategies aimed at increasing awareness regarding the benefits of mass transit in a community.

The goals and strategies outlined in this policy recommendation will support transit as a viable transportation choice for the citizens of Kentucky, and will help the state realize the potential for GHG emission reductions associated with transportation. At the same time, the policy will encourage growth and development that make the most effective and efficient use of the state's resources by supporting cost-effective transportation mode choices. The policy will:

- Support desired shifts in passenger transportation mode choice to lower-carbon options.
- Encourage growth and development in Kentucky that make effective and efficient use of expenditures on transportation infrastructure by supporting cost-effective mode choices.
- Partner with existing transit agencies to improve the level of service (travel time, reliability, and convenience) through support of transit operating and capital programs.
- Encourage and facilitate "buy-in" among affected agencies and stakeholders.

Policy Design

An important strategy in reducing GHG emissions produced from transportation sources is reducing the growth rate in per-capita VMT. Providing alternatives to the SOV has been shown to reduce the number of trips and VMT on the highway system. Modal alternatives can include bus transit and paratransit, rail transit, ridesharing, and vanpools (in addition to bicycling and walking, which are not addressed here).

Increased transit use is key to reducing the growth rate of VMT. A higher rate of transit use can be achieved by improving transit's competitiveness with other modes, expanding transit services, ensuring the safety and security of transit systems, and educating the public about transit options available in their community. Transit's competitiveness will be enhanced by providing the livable, walkable, complete streets context in which transit can be cost-effective. (See TLU-2/6.)

Goals: Increase transit ridership statewide by 100% from 2010 levels by 2020, and an additional 150% by 2030. (Ridership will be measured on a per-capita basis, in order to prevent population demographics from affecting the goal.)

Timing: See the Goals section, above.

Parties Involved: The Kentucky Public Transportation Association (KPTA), public transit agencies, MPOs, local governments, and KYTC all have a place in implementing this policy. Communities that currently have public transit will be positively affected by the policy.

Other: None identified.

Implementation Mechanisms

- Enact complete streets legislation. In the context of the Kentucky's Complete Streets Ordinance, encourage local governments and developers to provide and expand bicycle and pedestrian facilities. Complete streets provide the context for transit to be successful. Improved pedestrian access to Kentucky's transportation infrastructure promotes transit use, since all transit trips begin and end as pedestrian trips.
- Establish a dedicated source of funding to fully match federal transit funds allocated to Kentucky, and to support transit capital investments in Kentucky's communities.
- Increase capital investment in transit infrastructure to ensure reliability (vehicle location and next-bus systems increase on-time performance and, therefore, reliability); improve safety (lighting and surveillance at stops and stations, improved signage); and increase the competitiveness of transit (e.g., bus-only lanes and signal prioritization).
- Increase investment in public transit systems to provide more frequent service and longer service hours, which will make transit more competitive with SOV travel. More frequent service is more convenient service.
- Support the creation of new public transportation systems and options, including bus rapid transit and commuter rail.
- Provide preferential and discounted parking to vanpool vehicles at all state-owned parking facilities.

Related Policies/Programs in Place

KPTA addresses issues with public transportation and seeks to attain funding from the Kentucky General Assembly to match all federal funds for transit programs.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-3B/4 are summarized in Table TLU-3B/4-1. Transit management and infrastructure strategies have a net positive cost. Transit systems often have significant capital costs, but the share of system expansion costs allocated to transit-displaced GHG emissions activities are mostly offset by fuel cost savings and vehicle ownership and operation cost savings from mode shift, congestion relief, and land use leverage.

Table TLU-3B/4-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-3B/4

Quantification Factors	2020	2030	Units
GHG Emission Savings	0.07	0.15	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	1.56		$MMtCO_2e$
Energy Savings (2011-2030)	143		Millions of gallons
Net Present Value (2011–2030)	$110		Millions of 2005$
Cost-Effectiveness	–$71		$/$tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

Quantification Methods

This analysis examines potential GHG reductions for a transit management and infrastructure strategy. Based on the POD goal language from above, the goal for the strategy is to increase transit ridership in the state by 100% from 2010 levels by 2020, and an additional 150% by 2030. The scenario was modeled by increasing transit passenger revenue miles by 100% between 2011 and 2020 and 150% between 2011 and 2030.

Using the strategy goal, the associated GHG emission reductions were estimated using analytical methods developed by the American Public Transportation Association (APTA).[21] According to APTA, transit service provision reduces total VMT and GHG emissions in three ways: mode shift, congestion relief, and land use leverage. Mode shift occurs when transit service reduces total VMT as some people switch from private vehicle trips to transit trips and fewer vehicles are used to transport people. Congestion relief occurs when the reduction in total VMT from mode shift decreases congestion, which improves overall transportation system flow and fuel economy. Land use leverage occurs because transit service often facilitates denser land use and planning options. Communities with compact development patterns tend to have lower demand for private vehicle trips relative to communities with less compact development.

The analysis was performed using Jack Faucett Associates' TARGGET (Transit Associated Reduced Greenhouse Gas Emissions Tool) program. TARGGET develops historic, current, and projected displaced GHG emissions from transit, as well as fuel savings and vehicle ownership and operation savings on an annual basis. TARGGET fully adheres to APTA's guidance on measuring transit-displaced GHG emissions. However, instead of using APTA's default land use leverage factor of 1.9, TARGGET calculates a unique land use leverage factor based on transit agency passenger revenue miles and service area population and density. This allows the analysis to develop Kentucky-specific estimates.

Current transit passenger revenue mile estimates were taken from the National Transit Database, which is maintained by the Federal Transit Administration (FTA).[22] Using APTA's guidance, the quantity of statewide VMT that transit systems displace can be estimated. Displaced VMT is then used to estimate fuel and vehicle operation cost savings. The VMT reduction estimate is also used to estimate gallons of fuel saved and the associated reduction in GHG emissions. The

[21] APTA. 2009. Quantifying Greenhouse Gas Emissions from Transit.
[22] FTA. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/ntdprogram/.

capital costs of the transit management and infrastructure were estimated using GHG emission reduction strategy cost estimates in the *Moving Cooler* report and a joint product cost allocation estimate.[23]

Joint product cost allocation is a process by which a share of a program's overall cost is applied to one specific benefit, rather than the entire cost. Transit produces many benefits in addition to GHG reduction. These include improved transportation services, easier access to a variety of work, leisure, family, and commercial destinations. GHG reduction is one of several benefits purchased with the expenditure on increased transit, and it was allocated to only part of the capital cost estimate. For the purpose of this analysis, a joint product cost allocation of 20% was applied to the capital cost estimates from the *Moving Cooler* report.

Mode shift was estimated by taking current and projected transit passenger revenue miles and multiplying them by APTA's mode shift factor based on transit service region population. Congestion relief was estimated by taking current and projected transit passenger revenue miles and multiplying them by APTA's congestion relief factor, which is derived from the Texas Transportation Institute's 2009 Annual Urban Mobility Report.[24] The Urban Mobility Report provides congestion profiles and factors for cities based on size. Land use leverage was estimated using the TARGGET tool, instead of APTA's national default land use leverage factor. TARGGET uses transit service area population, density, and passenger revenue miles to develop unique, Kentucky-specific land use leverage factors for each year and for each local transit agency to account for changes in population, density, and passenger revenue miles.

Table TLU-3B/4-2 provides transit-displaced VMT, GHG emissions, and fuel use. The table also compares the expected VMT reduction against the Kentucky Inventory's statewide VMT estimates.

Table TLU-3B/4-2. Transit-Displaced VMT, GHG Emissions, and Fuel Use

Year	VMT Reduced	Emissions Saved (tCO_2e)	Gallons of Fuel Saved	Kentucky Inventory VMT Baseline (Millions)	Scenario's VMT Reduction off KY Inventory Baseline (%)
2011	11,200,183	7,373	672,396	48,651	0.0
2012	22,813,330	14,831	1,351,613	49,024	0.0
2013	34,946,514	22,355	2,036,488	49,396	0.1
2014	47,711,999	29,932	2,724,987	49,768	0.1
2015	61,251,000	37,543	3,416,208	50,141	0.1
2016	75,380,349	45,021	4,097,104	50,513	0.1
2017	90,094,894	52,383	4,769,424	50,885	0.2
2018	105,452,289	59,701	5,441,770	51,256	0.2
2019	121,426,254	66,987	6,115,658	51,627	0.2
2020	**138,061,123**	**74,252**	**6,785,369**	**51,998**	**0.3**

[23] Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.
[24] Available at: http://mobility.tamu.edu/.

Year	VMT Reduced	Emissions Saved (tCO_2e)	Gallons of Fuel Saved	Kentucky Inventory VMT Baseline (Millions)	Scenario's VMT Reduction off KY Inventory Baseline (%)
2021	155,472,060	81,471	7,458,900	52,369	0.3
2022	173,519,414	88,768	8,143,803	52,739	0.3
2023	191,791,275	96,186	8,821,968	53,108	0.4
2024	210,481,699	103,651	9,501,866	53,477	0.4
2025	229,650,727	111,161	10,187,603	53,846	0.4
2026	249,109,992	118,715	10,875,027	54,214	0.5
2027	268,736,683	126,321	11,564,553	54,581	0.5
2028	288,747,387	133,943	12,262,778	54,947	0.5
2029	309,370,322	141,545	12,978,268	55,312	0.6
2030	**329,735,817**	**149,313**	**13,685,396**	**55,677**	**0.6**
Total	**3,114,953,312**	**1,561,454**	**142,891,178**	**1,043,529**	**0.3**

GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent; VMY = vehicle miles traveled.

Key Assumptions

An important assumption is that transit passenger revenue miles will increase by 100% between 2011 and 2020 and 150% between 2011 and 2030. This is the goal of the strategy and the primary assumption the reduction scenario is modeled upon.

Data Sources

- American Public Transportation Association. 2009. *Quantifying Greenhouse Gas Emissions from Transit*.
- Federal Transit Administration. 2010. National Transit Database. Available at: http://www.ntdprogram.gov/.
- Cambridge Systematics. 2009. *Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*. Available at: http://www.movingcooler.info/.
- Texas Transportation Institute. 2010. 2009 Annual Urban Mobility Report. Available at: http://mobility.tamu.edu/.

Key Uncertainties

- Funding availability for the provision of additional transit service.
- A key uncertainty is future fuel prices. Fuel prices may fluctuate unpredictably, and their fluctuations affect VMT significantly.
- Another uncertainty is the degree to which land use leverage will occur. Aside from transit service provision, land use planning and zoning influence how much density and decreased demand for private vehicle trips is achieved in a region when transit service is provided. For example, mixed-use zoning may facilitate less demand for vehicle trips by locating residential units, grocery stores, community centers, retail and services, and businesses within walking distance of one another. Therefore, land use planning and transit service

provision influence one another when strategies are implemented to reduce private vehicle trip demand.

Additional Benefits and Costs

The provision of transit service results in other more direct benefits and cost impacts. Most important are travel time benefits that accrue to transit users, reduced air pollution, and congestion relief that affects road users on parallel routes.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

TLU-5. Education and Outreach for Vehicle Maintenance, Idle Reduction, and Co-Driving, and Promote Alternative Modes of Travel

Policy Description

This policy is designed to inform Kentucky's citizens of how they can save energy, reduce costs and protect the environment through their daily activities can influence the ability of the Commonwealth to meet its objectives of reducing energy demand and GHG emissions. Slight modifications in behavior and habit can result in significant energy demand and GHG reductions. Therefore, to achieve the objective of a more informed citizenry, a comprehensive and coordinated education outreach program is required. While education and outreach efforts need to address numerous topics, these key areas have been identified as critical for raising awareness on this issue:

- Energy demand and GHG emissions are reduced by improving fuel efficiency, using such measures as:
  - Improved driving habits, including moderating acceleration, shifting at lower revolutions per minute, using cruise control, and reducing idling.
  - Maintaining proper tire pressure and appropriate levels of engine lubricants.
  - Encouraging use of replacement vehicles that have higher fuel efficiency.
- Alternative transportation modes that do not contribute to energy demands and GHG emissions are promoted by:
  - Campaigns to promote use of transit riding, walking, and cycling, rather than vehicle use.
  - Educating drivers to "share the road" and cyclists to obey traffic laws.

Educational opportunities can come in many forms. Opportunities to cooperate and partner with existing promotional campaigns and public outreach should be sought. Development and implementation of a focused multimedia campaign will be a cornerstone of the educational program. Incorporating a GHG message into existing educational venues, such as the Kentucky Driver Manual and licensing exam for new drivers and the driver education classes provided by many Kentucky high schools should be considered. Mandating that driver education be offered as part of all Kentucky high school curricula may also be considered. Establishing a "Drive Smart–Drive Green" or other similarly monikered license plate may raise not only awareness but also funding for other education initiatives. Efforts to reach existing drivers can be made by distributing information when motor vehicle licenses or vehicle registrations are renewed. Partnerships with the insurance industry could result in reduced insurance rates for drivers who have completed "green drivers training" and pledged to follow the guidelines.

Promotion of the Smart Cycling program, a set of curricula for adults and children and the certified instructors who teach it, will be important for expanding the use of alternative modes of travel. Smart Cycling classes are taught across the United States by League Cycling Instructors (LCIs), certified by the League of American Bicyclists, to provide the tools, tips, and techniques to safely ride a Bicycle, to be confident enough to share the road with vehicles, and to teach children to ride cautiously and conspicuously on their own. Simply knowing how to ride a Bicycle is not the same as knowing how to operate a Bicycle safely and legally. This training, in addition to Share the Road training for drivers, will be important as initiatives begin to show results and the number of cyclists on the road increases.

Policy Design

This CAP policy is intended to increase awareness of the general public of personal transportation-related behaviors, within their control, that may positively or negatively impact energy use and GHG emissions. An effective multimedia campaign can be developed that promotes improved driving habits and behavior, encourages use of alternative or more efficient means of transportation, emphasizes the benefits of proper vehicle maintenance, and explains the interconnection between land use decisions and the consumption of resources. Developing educational opportunities for both the driving and the cycling public will promote harmonious use of existing facilities and reduction in conflict between vehicles and people traveling along the roadside.

Measures developed will have the intent of promoting positive change through education statewide. These measures should appeal to the good will and common sense of the citizens statewide, resulting in behavioral changes that will improve community livability, which can be a source of pride for all Kentuckians.

Goals

- The objective will be to increase public awareness of these issues by 10% by 2020 and an additional 10% by 2030. The goal of the education and outreach program will be to raise awareness of the public to issues that may directly or indirectly influence GHG production and its implications for corresponding climate change. The level of public understanding will be measured through a statewide survey at the outset of the program to establish baseline conditions. The survey will be designed to measure awareness through numerical scoring of responses.
- The Smart Cycling initiative will be intended to reduce bicycle/vehicle conflicts and will be measured by doubling the number of counties where there are certified LCIs by 2020. Additional goals related to bicyclists' fatality and injury rates resulting from vehicle conflict may also be considered.

Timing: Early development and execution of the baseline survey will be critical to establish existing conditions. Frequency of follow-up surveys will be determined by the implementing agency at an interval sufficient to develop meaningful feedback and support an iterative approach to program modification and improvement.

There currently are five counties with at least one certified LCI. Expansion of this population would likely be influenced by the ability to secure training at localities statewide.

Parties Involved: To develop and manage a statewide educational program, the Governor's Office may establish a focus group, task force, advisory commission, or advisory committee that will consist, at a minimum, of representatives from KYTC, the Kentucky Energy and Environment Cabinet (KEEC), CED, and the Kentucky Education and Workforce Development

Cabinet. A Key Stakeholders Group may also include representatives of the Kentucky Broadcasters Association (KBA), Kentucky print media, the auto insurance industry, KPTA, and the Kentucky State Police (KSP), as well as other public or private organizations that may be identified as key to the success of the education program. The purpose of the group will be to oversee and administer a public education program to modify behaviors and promote change to reduce GHG emissions. KYTC will be responsible for the execution of the program.

The program developers may seek the involvement of the Kentucky Environmental Education Council for its skill in delivering educational programs to schools and the public in general, as well as its experience conducting statewide surveys regarding public knowledge. Partnering of the program with other existing programs having similar or related messages, such as the KSP Click-It or Ticket and the KYTC Highway Safety program will also be advantageous. Measures addressing education of new drivers through modification of the Kentucky Driver Manual would also require the involvement and cooperation of the KSP.

To advance and promote bicycling education, the League of American Cyclists, area cycling clubs, and the public may be involved.

Other: None identified.

Implementation Mechanisms

The Governor's Office may establish a focus group, task force, advisory commission, or advisory committee that will address implementation of a public education program to inform citizens on this complex issue. A Key Stakeholders Group consisting, at a minimum, of representatives from KYTC, KEEC, CED, and the Education Cabinet should be empanelled to specifically address educational needs related to transportation and land use. Recommendations of this panel should be considered and coordinated with other educational initiatives being conducted on the climate change issue. A Key Stakeholders Group may also include representatives of KBA, Kentucky print media, the auto insurance industry, KPTA, and the KSP as well as other public or private organizations that may be identified as key to the success of the education program. The purpose of the Key Stakeholders Group will be to oversee and administer a public education program to modify behaviors and promote change to reduce GHG emissions and climate change.

The Key Stakeholders Group will commission the development and implementation of a statewide survey that assesses the understanding of the general public regarding personal behavior and decisions that influence GHG production and climate change, as well as knowledge of the effects of land use decisions on resource consumption. This may be incorporated within an existing surveying effort conducted by the Kentucky Environmental Education Council or may be conducted independently. Additional surveys will be conducted in future years to gauge the effectiveness of the proposed educational campaigns.

The Key Stakeholders Group will consider effective means for addressing desired modification to public behavior, including:

- Mass media campaigns using print, radio, and television media. KBA may be a key partner in this initiative.

- Modification of the materials studied for the driver licensing examination to include benefits of eco-driving and a "share the road" message. The KSP will be integral to this objective.
- Partnering with existing organizations with similar goals and objectives to the extent practicable to make the best possible use of available funds.
- Establishing a driver education requirement in the public school curriculum that would provide education on the benefits of using eco-friendly driving techniques and the importance of proper maintenance to reduce fuel consumption and emissions, in addition to addressing the rules of the road. An emphasis on the corresponding safety benefits of these measures should also be incorporated.
- Working with the County Clerks Association to disseminate information on the benefits of green driving when drivers' licenses or vehicle tags are renewed.
- Working with the auto insurance industry to develop cost incentives or discounts for people who have completed eco-friendly driving and Share the Road training that should both reduce emissions and improve safety.
- Establishing a Smart Cycling program that will expand bicycling education opportunities throughout the state, and promoting a Share the Road educational program for drivers.

The source of funding for the educational program should be established by the Governor's Office. The Key Stakeholders Group will identify and make best use of other available funding opportunities, including public–private partnerships, grants, and other related federal funding sources to promote its message of change. One possible revenue stream for this program is the creation of a "Drive Smart–Drive Green" specialty license plate, similar to those benefiting the Share the Road program and the Kentucky Heritage Land Conservation Fund.

Related Policies/Programs in Place

- The Kentucky Drivers Manual prepared by the KSP.
- "Healthy Communities" initiative partnership between KYTC and CHFS.
- Kentuckiana Air Education—KAIRE—is the Louisville Metro Air Pollution Control District's community outreach and education program for the Louisville metro area. KAIRE's primary goal is to increase public awareness of the impact individual choices can have on local air quality, particularly as related to vehicle use (http://www.helptheair.org/).

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The policy description and policy design establish process-oriented goals. Meeting a process-oriented goal will not by itself result in energy and GHG savings. Meeting such process-oriented goals has the potential to increase the effectiveness of other related programs.

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-5 are summarized in Table TLU-5-1.

Table TLU-5-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-5

Quantification Factors	2020	2030	Units
GHG Emission Savings	Not quantified		$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	Not quantified		$MMtCO_2e$
Energy Savings (2011-2030)	Not quantified		Millions of gallons
Net Present Value (2011–2030)	Not quantified		Millions of 2005$
Cost-Effectiveness	Not quantified		$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

Key Uncertainties

Availability of funding.

Additional Benefits and Costs

None noted.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

TLU-7. Parking Management and Ride Sharing

Policy Description

This strategy will reduce GHG emissions and lower fuel consumption by reducing the number of SOV trips, resulting in reduced VMT. Parking management refers to policies and programs that result in more efficient use of parking resources. Reserved and preferential parking for HOVs near places of employment will further provide incentives to reduce SOV trips. HOV parking may be reserved at preferential locations, such as near building entrances or parking garage exits. Free or reduced-fee parking for HOVs may also be provided. Similarly, preferential parking and incentives can also be offered to drivers of vehicles with low GHG emission rates. Depending on effectiveness, these incentives could include preferential vehicle access to metered parking spaces or HOV lanes.

Providing safe, convenient park-and-ride lots will facilitate the use of carpooling, vanpooling, and transit. The most utilized park-and-ride lots are those that are in highly visible locations, are police-patrolled, and have direct access to transit if available. Locating park-and-rides near HOV-only highway lanes would complement this strategy. Promoting carpooling and vanpooling through rideshare matching, marketing, and public awareness increases the success of shifting to HOVs for work trips. Regional ride-matching programs provide a centralized database for matching drivers with others with similar commute schedules, origins, and destinations.

Policy Design

An effective policy for parking management and carpooling will encourage more efficient travel choices. This is accomplished by facilitating the shift to HOVs, providing for the safety and security of HOV travelers, and encouraging the use of low-GHG-emitting vehicles.

Goals: Goals for this policy are as follows (from a 2005 baseline):

- Provide additional state funding for studies/plans and for design and construction of park-and-ride lots.
- Increase the number of park-and-ride spaces by 50% by 2030.
- Increase the utilization of existing park-and-ride facilities.
- Increase the number of carpool and vanpool participants by 75% by 2030.
- Increase funding for regional and state ride-matching programs.
- Recommend standards for local jurisdictions to reserve parking spaces, provide transit or park-and-ride facilities, or offer free or reduced parking rates for HOVs and low-GHG vehicles.

Timing: 2010–2030.

Parties Involved: Kentucky legislature, KYTC, parking authorities and parking departments, local transit operators, local governments, MPOs, ADDs, other community agencies, commuters, and large employers.

Other: None identified.

Implementation Mechanisms

- Conduct studies and develop plans to locate and build additional park-and-ride lots to encourage and enable increased carpooling, vanpooling, and transit ridership.
- Improve the security and accessibility of existing park-and-ride facilities.
- Fund and conduct studies to develop efficient successful methods to facilitate the use of HOVs (e.g., preferential parking facilities and monitoring systems for enforcement).
- Develop and fund marketing strategies and incentives to promote the use of HOVs and ridesharing.
- Provide additional funding for regional ride-matching services.
- Build regional rideshare matching databases on the same platform to ensure accurate and easier tracking of participation goals.
- Improve the existing state ride-matching system.
- Fund regional guaranteed-ride-home programs. Such programs typically offer registered carpool and vanpool commuters a partial reimbursement of the cost of cab fare or transit fare home.
- Provide incentives and fund associations or networks for transit or transportation coordination and management.
- Provide various effective incentives and strategies to businesses/employers and individuals to encourage or use ridesharing, carpools and vanpools, and transit.
- Provide employer outreach, education, and technical assistance, especially for large employers. Employer outreach may include information on tax incentives and providing reserved/preferred parking for HOV and low-GHG vehicles, as well as parking cash-out options.
- Encourage text amendments to ordinances and regulations that promote or require new developments and redevelopments to include transit and park-and-ride facilities and reserved/preferred parking for HOV and low-GHG vehicles.

Related Policies/Programs in Place

Rideshare, vanpool, and mobility programs exist in some of the larger MPOs operating in Lexington, Louisville, and northern Kentucky. There is also an existing state ride-matching system. This policy would support these programs already in place. An education and outreach component of this policy should be combined with promoting better vehicle maintenance, idle reduction, eco-driving, and alternative modes of travel (TLU-5). Where public transportation is available, the addition of park-and-ride lots is to be coordinated with public transit agencies.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-7 are summarized in Table TLU-7-1.

Table TLU-7-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-7

Quantification Factors	2020	2030	Units
GHG Emission Savings	0.204	0.345	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	4.032		$MMtCO_2e$
Energy Savings (2011-2030)	335		Millions of gallons
Net Present Value (2011–2030)	–$2,327		Millions of 2005$
Cost-Effectiveness	–$554		$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

Quantification Methods: This policy includes multiple components; however only the increased participation in carpooling and vanpooling for work trips with the help of employee support programs has been quantitatively analyzed. While other elements are mentioned as sub-components, they are not addressed explicitly in this analysis. The quantitative analysis is a conservative estimate because it only includes a subset of implementation strategies. As a result, the potential for GHG emission reductions and energy savings may be larger than the conservative estimates provided indicate.

For the carpool components, the following projected goal is identified in the POD and was used to calculate the associated emission reductions: Increase the number of carpool and vanpool participants by 75% by 2030 for work trips. The participation in carpooling and vanpooling and preferential parking was assumed to apply to all CBDs in the state with employment and population rates greater than 20,000 people. These cities include:

- Louisville
- Lexington
- Bowling Green
- Owensboro
- Covington
- Richmond
- Hopkinsville
- Florence
- Henderson

- Frankfort
- Nicholasville
- Jeffersontown
- Paducah
- Elizabethtown
- Radcliff
- Independence
- Georgetown
- Ashland

Cities and rural areas with employment and populations below 20,000 were not considered in the analysis. The analysts created a forecast to the year 2030 for employment using historic data from 2005 to 2009 from the Workforce Kentucky Web site[25] for the following cities:

- Louisville
- Lexington
- Bowling Green
- Elizabethtown
- Frankfort

The growth rates used for forecasting the employment to 2030 were taken from the Workforce Kentucky Web site. The rest of the analysis was completed using the EPA COMMUTER Model,[26] as well as spreadsheet-based analysis. Individual runs using the 2005 employment baseline and the employment forecast to 2030 for metropolitan areas, such as Louisville, Lexington, Bowling Green, and Frankfort, were completed using the EPA COMMUTER Model. The rate of increased participation in ridesharing was assumed to be 75% by 2030 from a 2005 baseline, with carpool programs being implemented in 2011. The EPA COMMUTER Model allows for local inputs, such as average time of driving to work in an SOV or in a carpool arrangement, and the user can specify local mode-share inputs.

The EPA COMMUTER Model created a baseline daily VMT estimate, and a scenario ramp-up of daily VMT was also created. The daily VMT savings of increased carpool participation were converted to reflect yearly estimates assuming 240 work days per year. Emission factors and full fuel factors from AEO 2009 were applied to the yearly VMT savings to create estimates for

[25] Workforce Kentucky Web site. Available at: http://www.workforcekentucky.ky.gov/cgi/databrowsing/localAreaProfileQSMoreResult.asp?viewAll=yes&viewAllUS=&currentPage=&currentPageUS=&sortUp=&sortDown=&criteria=Unemployment+Rate&categoryType=employment&geogArea=2101000000&timeseries=&more=More+Areas&h.

[26] An EPA assessment tool that provides estimates on how commuter benefits can impact nitrogen oxide, particulate matter, and air toxic emissions, and fuel use and costs. Available at: http://www.epa.gov/otaq/stateresources/policy/pag_transp.htm.

$MMtCO_2e$ emissions saved as well as fuel savings. These steps were completed for the five cities mentioned above.

Since workforce data were not readily available for the cities with a population between 20,000 and 40,000 employees, a factor for estimating the impacts was created using the Frankfort data as a basis. A ratio of employment to population was created for Frankfort and was applied to the population data available for the remaining 13 small cities to estimate the total affected employment in that area. The sum of the estimated number of employees for the 13 small cities was then used to estimate total emission savings by extrapolating from the Frankfort example.

The same process was repeated to estimate the impacts of increased carpool participation in the city of Owensboro with a population between 50,000 and 60,000 using Bowling Green as the example.

In addition to GHG emission savings, the analysts also considered vehicle cost savings of 41 cents (2005$) per mile from the AAA Web site.[27] Additional costs were assumed to be an annual program administration cost of $2,600 (2005$) per employer for carpool programs. The analysts used data from city-specific Web sites to consider the number of employers with more than 100 employees that would implement a carpooling program for their employees. Only employers with more than 100 employees were assumed to implement a carpooling program.

Finally, the cost and GHG reduction estimates for the small cities was added to the individual estimates for Louisville and Lexington City, as well as to the estimates of Bowling Green and Owensboro. Table TLU-7-2 summarizes the final results for a 75% increase in carpooling and vanpooling.

Table TLU-7-2. Summary of Results from Increasing the Number of Carpool and Vanpool Participants by 75% by 2030

GHG Emission Reductions per City, Region, and Total ($MMtCO_2e$)					
Year	**Louisville**	**Lexington**	**Bowling Green**	**Rest of the Region**	**Total**
2020	0.102	0.036	0.011	0.054	0.204
2030	0.173	0.062	0.018	0.092	0.345

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Data Sources

- Emission factors are taken from AEO 2009. Available at: http://www.eia.doe.gov/forecasts/aeo/.
- The mode share and trip length information is from the 2000 U.S. Census and the 2001 Nationwide Household Transportation Survey.[28]
- Employment data are from the Kentucky Workforce Web site.[29]

[27] AAA Operating Cost. Available at: http://www.carbuyersnotebook.com/archives/2007/03/driving_cost_pe.htm.
[28] Census Bureau Survey. Available at: http://www.census.gov/acs/www/Products/Ranking/2002/R04T160.htm.
[29] Kentucky Workforce Web site. Available at: http://www.workforcekentucky.ky.gov/cgi/databrowsing/localAreaProfileQSMoreResult.asp?viewAll=yes&viewAllUS=&currentPage=&currentPageUS=&sortUp=&sortDo

- Employer information about the number of firms with more than 100 employees was taken from local Web sites.[30]

Key Assumptions

- Assumes 240 commute days per year.
- Assumes an annual program administration cost of $2,600 (2005$) per employer based on the Best Workplaces for Commuters Web site (http://www.bestworkplaces.org/).
- AAA assumes a 41-cent (2005$) vehicle operating cost per mile.[31]
- Adjustments for inflation were made using the CPI. All dollar values are represented in 2005 dollars.
- The average commute time according to the U.S. Census Bureau for Louisville is 19.2 minutes,[32] the average commute time for Lexington is 17.3 minutes, and the average commute time for Frankfort is 16 minutes. The national average is 12.2 minutes.[33]

Key Uncertainties

- The price of fuel will have a significant impact on the attractiveness of ridesharing as an alternative mode.
- The success of a parking management policy is dependent on the participation of local governments and large employers.

Additional Benefits and Costs

None noted.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

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wn=&criteria=Unemployment+Rate&categoryType=employment&geogArea=2101000000&timeseries=&more=More+Areas&menuChoice=localAreaPro&printerFriendly=&BackHistory=-1&goTOPageText=.

[30] Employer and Company Information per City. Available at: http://www.manta.com/mb_51_ALL_7GW/louisville_ky?refine_company_emp=E06&refine_company_emp=E07&refine_company_emp=E08&refine_company_emp=E09&refine_company_emp=E10&refine_company_emp=E11.

[31] AAA Operating Cost. Available at: http://www.carbuyersnotebook.com/archives/2007/03/driving_cost_pe.htm.

[32] Ibid.

[33] City Data for each city. Available at: http://www.city-data.com/city.

Barriers to Consensus

None.

TLU-8. Strategies to Move Freight in More GHG-Efficient Ways

Policy Description

Trucking continues to deliver a majority of the freight in the United States and Kentucky. On a national level, the trucking industry delivers over 70% (by weight) of all the freight transported. In Kentucky, over 72% of the freight tonnage and over 90% of all commodities are delivered by truck. Existing infrastructure makes it unlikely that this distribution will be significantly changed at any point in the near future. According to the ATA, the freight forecast predicts freight tonnage being moved by truck will continue to increase over the next several years. Kentucky can make significant strides in improving the efficiency and environmental impact of the necessary freight movements within its boundaries and current infrastructure.

Shifting freight from trucks to river and rail will decrease impacts on highway infrastructure, and will reduce GHG emissions and particulate matter.

The development of warehouses or distribution in the rural areas surrounding the larger cities in Kentucky is needed to improve inefficiencies within the supply chain. With additional square footage of distribution space, the ability to coordinate freight movements in non-peak times will increase, resulting in a reduction of congestion and emissions.

Policy Design

These latest efforts to improve air quality continue a nearly quarter-century trend of reducing truck emissions. In 2002 (the most current year for which data are available), on-road diesel engines contributed approximately 1% of the nation's total emissions of volatile organic compounds, carbon monoxide, and sulfur dioxide; less than 1.5% of the nation's total emissions of fine particulate matter; and approximately 16% of the nation's total emissions of nitrogen oxides.[34] Fine particulate emissions from on-road diesel engines have been cut by more than half over the past decade.

Even with all the improvements in emission control systems, the challenge of significantly improving GHG emissions in the trucking industry is still very difficult. The vast majority (97%) of the motor carriers across the United States have 20 or fewer trucks. Many smaller trucking companies are unable to afford the upgrades and add-ons that would make a significant impact on their fuel efficiency and consumption. The bottom line is that most of these small companies that are operating on-road or off-road equipment have no capital, and their ability to obtain credit is limited.

Intermodal freight transportation is expanding across the United States every year. The ATA projects the largest increases in tonnage hauled will occur over the next 20 years. Intermodal freight movement can be more efficient than moving that same freight by a single mode of transport, depending on the distance, weight, and time sensitivity of the shipment. The tonnage of freight moved by intermodal transportation in Kentucky is well below the national average.

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[34] U.S. Environmental Protection Agency. 2005. Available at: http://www.epa.gov/otaq/hwy.htm.

Kentucky needs to develop a strong intermodal infrastructure by improving intermodal connectors to increase rail and river capacity.

This policy recommendation should focus on reducing the carbon footprint for all modes of transportation.

Goals

- Reduce congestion in urbanized areas by 20%.
- Reduce carbon emissions by 5% from railroads through increased deployment of innovative EPA-approved carbon emissions from hybrid and GenSet locomotives.
- Increase participation in the EPA SmartWay program by 10%.
- Reduce carbon emissions from commercial trucks by 10%.
- Encourage trucking companies to purchase carbon emission technology.
- Move freight more efficiently in certain transportation segments. Seek to increase road funding by 10% through increased overweight permit fees.
- Issue transponders to all commercial trucks based in Kentucky. Eliminate the need for slowing or stopping at the scales by trucks that are in compliance with the weight standard. Reduce carbon emissions by 2%.
- Reduce unnecessary idling at various locations that have large truck traffic. Reduce carbon emissions by 20% at these locations.
- Expand rail and river freight transport capacity by 10%.
- Reduce carbon emissions by 20% from rail, truck, terminal equipment, and water-going vessels.
- Reduce carbon emissions by 20% from the light-to-medium truck new vehicle market.
- Reduce unnecessary idling by 10% in the truck and rail industries.

Timing: 2010–2030.

Parties Involved: KYTC, local governments, Kentucky General Assembly, the Kentucky Motor Transport Association, river ports, railroads, shippers, developers, Kentucky DOT, and MPOs.

Other: None identified.

Implementation Mechanisms

- Reduce road freight bottlenecks in known urbanized, congested areas, and assess the feasibility and cost associated with increased and appropriately sited river and rail port development in Kentucky.

  Mechanism: Kentucky will identify key urbanized, congested areas, and will then work with public and private stakeholders in determining the need, scope, and size of projects. The state will work with federal agencies, local authorities, citizen groups, and other stakeholders on the best way to develop and fund the project.

Goal: Reduce congestion in urbanized areas by 20%.

- Support the reduction of emissions by railroads through increased deployment of innovative EPA-approved carbon emissions from hybrid and GenSet locomotives.

  Mechanism: Kentucky, MPOs, private financing groups, the goods movement industry, and research institutes will work together to encourage public–private partnerships to develop and test new technologies. Tax incentives and penalties, tariffs, performance standards, and freight fees will encourage private investment. Kentucky will lobby for more federal grants and incentive funding.

  Goal: Reduce carbon emissions by 5%.

- Increase and improve rail interconnectors.

- Expand intermodal service.

- Encourage increased participation in the EPA SmartWay program for both truck and rail industries.

  Mechanism: Kentucky will work with industry representatives on educating companies about the value of being part of the SmartWay program. Kentucky will encourage shippers to work with transportation companies on joining the SmartWay program.

  Goal: Increase participation in the SmartWay program by 10%.

- Provide tax incentives and rebates to trucking companies to encourage:
  - The purchase and installation of devices that eliminate the need to idle, including battery electric auxiliary power systems, vehicle battery systems, thermal energy storage systems, fueled auxiliary power systems, automatic tire-inflation systems, diesel oxidation catalysts, diesel particulate filters, on-board plug-in systems, hydrogen systems, and trailer fairings.
  - Investment in hybrid truck and alternative fuel technologies as they become available in class 7 and class 8 trucks over the next 3 years and beyond.

  Mechanism: Kentucky will work with legislators at the state and federal levels to encourage legislation that includes tax incentives and rebates. Industry will advocate for the need of public involvement in the area of air quality technology.

  Goal: Reduce carbon emissions in commercial trucks by 10%.

- Seek weight exemption for companies that install air quality technologies on equipment.

  Mechanism: KYTC and the trucking industry will work with the general assembly, the KSP, and other stakeholders on proposing legislation.

  Goal: Encourage trucking companies to purchase carbon emission technology.

- Research the possibility of changes in truck weight and configuration restrictions to maximize trip efficiency.

  Mechanism: Kentucky/Local Federal Motor Carrier Safety Administration/KSP will research the possibility of increasing weight restrictions in Kentucky. Research should examine different modes of truck transport and routes where additional weight creates no harmful effects to safety or highway maintenance. Increasing overweight permit fees should also be explored.

  Goal: Move freight more efficiently in certain transportation segments. Seek to increase road funding by 10% through increased overweight permit fees.

- Authorize the Kentucky Commercial Vehicle Information Systems and Networks (CVISN) team to develop a plan to convert all weigh stations in Kentucky to a wireless screening station. Provide all carriers at registration a transponder.

  Mechanism: The Kentucky Transportation Center continues to research the possibility of replacing manual truck screening. Use CVISN funding to create a completely wireless e-screening process for commercial trucks.

  Goal: Issue transponders to all commercial trucks based in Kentucky. Eliminate trucks that are in compliance with the weight standard from slowing or stopping at the scales. Reduce carbon emissions by 2%.

- Kentucky and private freight carriers will evaluate installing truck stop electrification at truck stops, weigh stations, and electric trailer refrigeration units (eTRUs) at distribution centers.

  Mechanism: KYTC will conduct a cost/benefit analysis of installing electrification at truck stops, weigh stations, and eTRUs at distribution centers. Congestion Mitigation Air Quality (CMAQ) Program funds will be used for the analysis.

  Goal: Reduce unnecessary idling at various locations that have heavy truck traffic. Reduce carbon emissions by 20% at these locations.

- Encourage and implement incentive programs for the development and operation of more localized truck delivery/parking facilities (preferably facilities using technology to cut down idling and GHG emissions, such as electrification).

  Mechanism: Conduct research to develop effective incentives for the development and operation of more privately owned and operated truck layover/parking facilities.

  Goal: Reduce unnecessary truck/freight VMT and idling by providing more privately owned/operated truck delivery/parking facilities. Locate these facilities close to delivery points to enable drivers and carriers to more efficiently deliver freight and meet required rest periods, therefore reducing VMT, idling, and GHG emissions.

- Encourage railroad and river capital investment to increase capacity and efficiency. KYTC will continue to support and expand such initiatives as:

  - Federal tax credit to Class 1 railroads, short-line railroads, river transport operators, and intermodal terminals.

- Public–private partnerships to expand freight river and rail capacity.
- State tax credits to Class 2 and Class 3 railroads.
- Protect future funding.

Mechanism: Kentucky will work with all the stakeholders on developing ways to expand railroad and river capacity. Kentucky will explore different funding opportunities and work with KYTC on areas of development, and with the goods movement industry on defining and increasing opportunities. Kentucky should support federal funding of the U.S. Army Corps of Engineers to find ways to maintain and improve the locks and dams in the inland waterway system.

Goal: Expand rail and river freight transport capacity by 10%.

- Adopt progressive performance standards for rail, truck, terminal equipment, and water-going vessels.

  Mechanism: Kentucky will adopt progressive performance standards for rail, truck, terminal equipment, and water-going vessels. Possible other sources of funding include CMAQ funding.

  Goal: Reduce carbon emissions by 20% at these locations.

- Kentucky, MPOs, private financing companies, Class I railroads, local switcher rail services, and research institutes/groups will collaborate on low-to-zero emissions rail technology and alternative transportation technology, such as hybrid engines, electrified rail, linear induction, RailRunner, Maglev, and virtual container yards. Collaboration could include state grant funding, tax incentives, and public–private partnerships.

  Mechanism: Kentucky, MPOs, private financing groups, the goods movement industry, and research institutes will work together to encourage public–private partnerships to develop and test new technologies. Tax incentives and penalties, tariffs, performance standards, and freight fees will encourage private investment. Kentucky will lobby for more federal grants and incentive funding.

  Goal: Reduce carbon emissions by 20% at these locations.

- Kentucky, MPOs, private financing companies, and trucking companies will collaborate on low-to-zero emissions truck technology, including hybrid and electric engines. Collaboration could include state grant funding, tax incentives, and public–private partnerships.

  Mechanism: Kentucky, MPOs, private financing groups, the goods movement industry, and research institutes will work together to encourage public–private partnerships to develop and test new technologies. Tax incentives and penalties, tariffs, performance standards, and freight fees will encourage private investment. Kentucky will lobby for more federal grants and incentive funding.

  Goal: Reduce carbon emissions by 20% in the light-to-medium truck market.

- Kentucky will adopt and/or enforce anti-idling regulations for trucks and trains where appropriate.

Mechanism: Kentucky, MPOs, private financing groups, the goods movement industry, and research institutes will work together to encourage public–private partnerships to develop policies, ordinance, or laws. Land use policies, tax incentives and penalties, tariffs, performance standards, and freight fees will encourage private investment. Kentucky will lobby for more federal grants and incentive funding.

Goal: Reduce unnecessary idling by 10% in the truck and rail industries.

- Kentucky, MPOs, and community groups will develop a green port strategy, including:

  Mechanism:

  - Establishing marine vessel efficiency improvements programs with the maritime shipping industry.
  - Developing marine, rail, and air terminal electrification projects.
  - Creating a Clean Truck Program, with eventual move to electric trucks/zero-emissions container movers.

  The strategy will be administered through leases, incentives, and tariffs, and financed through grants, freight fees, and public–private partnerships.

  Goal: Reduce carbon emissions by 20%.

- Kentucky will encourage clean diesel retrofits. Diesel vehicles are often more fuel efficient than their gasoline-powered counterparts, but have traditionally been higher emitters of other air pollutants, including black carbon, a potential GHG. New diesel vehicles, however, are manufactured to meet much more stringent emissions standards. Additionally, retrofit technologies are available for almost all older diesel applications that can reduce harmful air pollution. These retrofits allow the owner to enjoy the fuel efficiency benefits and reduced emissions from clean diesel technologies, without having to replace the diesel vehicle. Different approaches from those that would be used to encourage new clean vehicle purchase may be needed to incentivize the application of retrofit technologies.

  Mechanism:

  - *Outreach and Education*—Raising awareness of the emission reduction possibilities of retrofits and the resulting health benefits may encourage owners to retrofit existing diesel vehicles and equipment.
  - *Grant Programs*—These types of programs provide a financial incentive to retrofit, repower, or replace equipment by covering the cost of the new technology. For an example, see: http://www.air.ky.gov/homepage_repository/Kentucky+Clean+Diesel+Grant+Program.htm.
  - *Financing Assistance*—These types of programs provide a financial incentive to retrofit, repower, or replace equipment by lowering the cost of the new technology. For an example, see: http://www.louisvilleky.gov/economicdevelopment/businessdevelopment/GreenIncentives.htm (POWER Loan).

Related Policies/Programs in Place

The SmartWay program is a voluntary partnership between EPA and the freight industry. It is intended to increase energy efficiency while trimming GHG emissions and air pollution.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-8 are summarized in Table TLU-8-1.

Table TLU-8-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-8

Quantification Factors	2020	2030	Units
GHG Emission Savings	0.463	1.079	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	10.31		$MMtCO_2e$
Energy Savings (2011-2030)	2,786		Millions of gallons
Net Present Value (2011–2030)	$424		Millions of 2005$
Cost-Effectiveness	$41.16		$/$tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

This analysis focused on four specific efficiency and emissions-reduction strategies discussed in the "Implementation Mechanisms" section. Three are under the umbrella of technologies approved and promoted as part of the EPA's SmartWay program. Those four strategies are as follows:

SmartWay strategies:

- Trailer fairings to reduce wind resistance.
- Auxiliary power units (APUs) to reduce demand for engine idling.
- On-board automatic tire-inflation units.

Other strategy:

- Weigh-in-motion (WIM) technology allowing truck weight compliance checks without stopping vehicles at weigh stations.

Each technology has a different level of impact on emissions. Trailer fairings were found by one study to achieve an average fuel efficiency gain of approximately 6%. APUs, which do not affect efficiency on the road, reduce idling by several hours a night on average, and result in a similarly large overall efficiency improvement. Tire-inflation units have a smaller impact, and WIM technology achieves idling reduction on a per-transaction basis, rather than on a per-vehicle basis.

The efficiency gains from SmartWay strategies are summarized in Table TLU-8-2.

Table TLU-8-2. Fuel Consumption Reductions from SmartWay Strategies (% below BAU)

	2010	2015	2020	2025	2030
Fairings	0%	1.4%	2.7%	4.0%	5.3%
Tire Inflation	0%	0.1%	0.2%	0.25%	0.33%
APUs	0%	1.1%	2.1%	3.2%	4.2%
Total	**0%**	**2.5%**	**5.0%**	**7.4%**	**9.8%**

APUs = auxiliary power units; BAU = business as usual.

WIM impacts, summarized in Table TLU-8-3, were measured per transaction, assuming that more truck stops would install and utilize the technology each year.

Table TLU-8-3. Weigh-in-Motion Emissions Reduction

	2010	2015	2020	2025	2030
# of WIM Locations	0	3	7	12	17
# of WIM transactions per day	0	200	200	200	200
GHG Reduction ($MMtCO_2e$)	0	0.00073	0.00169	0.00290	0.00411

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; WIM = weigh-in-motion.

The overall emissions reductions from the four strategies are summarized in Table TLU-8-4.

Table TLU-8-4. GHG Emissions Reduction from All Technologies

	2010	2015	2020	2025	2030
SmartWay	0	0.219	0.461	0.742	1.075
WIM	0	0.00073	0.00169	0.00290	0.00411
Total	0	0.220	0.463	0.745	1.079

WIM = weigh-in-motion.

With regard to costs, each achieves fuel savings, but also involves expenses for equipment. The following equipment costs were estimated:

- *Trailer Fairings:* Fairings vary widely in cost, but two different estimates placed typical costs at approximately $2,200 to upgrade a single trailer.
- *APUs:* Three sources put the cost of APUs at between $6,000 and $7,000 per unit. These units are capable of providing cabin heat, cabin air conditioning, and electricity to both the vehicle's electrical system and other devices. Smaller units, capable only of producing cabin heat, were not considered for this analysis.
- *On-Board Tire-Inflation Units:* Two estimates averaged to a cost of $545 per unit. The unit is attached to the trailer and regulates tire pressure on the trailer tires, or to the non-steering tires of a single-unit truck.
- *WIM Equipment:* Several sources established an average cost of approximately $6,200 to install necessary equipment at a single weigh station. Kentucky already provides transponders for such a program free of charge to heavy-duty vehicle (HDV) owners, at an estimated cost of $40 per transponder. Additionally, private contracts to operate WIM systems average approximately $400,000 per year.

Fairings and APUs achieved significant fuel and emission savings, resulting in a net cost savings from the reduced fuel expenditure that overwhelms the equipment cost. Tire-inflation units and WIM technology achieved smaller impacts, resulting in less of an offset against their costs. As shown in Table TLU-8-5, annual costs stay fairly stable, while fuel savings each year climb with adoption rates.

Table TLU-8-5. Equipment Costs (Single Year) of All Technologies (millions of 2007$)

	2010	2015	2020	2025	2030
Fairings	$0	$15.75	$16.50	$17.30	$18.30
Tire Inflation	$0	$3.88	$4.07	$4.27	$4.51
APUs	$0	$46.30	$48.48	$50.89	$53.79
WIM	$0	$0.48	$0.48	$0.48	$0.48
Total Equipment Cost	$0	$66.39	$69.52	$72.96	$77.09
Total Fuel Savings	$0	–$47.34	–$111.09	–$188.09	–$288.19
Total Net Cost	**$0**	**$19.05**	**–$41.57**	**–$115.13**	**–$211.10**

APUs = auxiliary power units; WIM = weigh-in-motion.

Data Sources

- *Trailer Fairings:* Costs and emission impacts from a Transport Canada study, found at: http://www.tc.gc.ca/eng/programs/environment-ecofreight-road-tools-casestudies-freightwing-554.htm.
- *APUs:* Costs and emission impacts from Argonne National Laboratory (AN)L, Mid-Atlantic Regional Air Management Association, and EPA. See: http://www.marama.org/diesel/frieght/Wachovia_%20SmartWay_Concept_%20Document.pdf; http://www.epa.gov/smartwaylogistics/transport/partner-resources/resources-glossary.htm; and http://www.nrel.gov/docs/fy00osti/26751.pdf.
- *On-Board Tire-Inflation Units:* Costs and emissions impacts from Arvin Meritor, AirGo, and EPA. See: http://www.meritorhvs.com/PBCTireInflationSystem.aspx; http://tireinflation.com/store/magento/system/gold-series/gold-tandem-axle-kit.html; and http://www.epa.gov/smartwaylogistics/transport/documents/tech/tireinflate.pdf
- *WIM Equipment:* Costs, operating parameters, fuel savings data, and weigh station data from State of Oregon, truck driver resources. See: http://www.oregon.gov/ODOT/MCT/GREEN.shtml and http://www.coopsareopen.com/kentucky-weigh-stations.html.

Quantification Methods

The quantitative analysis is a conservative estimate because it only includes a subset of implementation strategies. As a result, the potential for GHG emission reductions and energy savings may be larger than the conservative estimates provided indicate.

The strategy sought to achieve 10% reduction in GHG emissions from the BAU projection by 2030. When considering that the potential of all four technologies summed together reaches approximately 13% improvement in vehicle efficiency, the strategy design was made very aggressive. WIM technology was assumed to reach installation at all 17 of Kentucky's weigh stations, and to be in operation every day of the year. SmartWay technologies were assumed to reach 100% rates of installation on the HDVs registered in Kentucky.

The quantification method for this analysis relies on the VISION model, which is a transportation energy and emissions model developed and updated every year by ANL. The model is built around a detailed perpetual-inventory model of the national vehicle fleet. A great deal of detail can be customized in this tool with regard to fleet size and makeup, driver behavior, fuels characteristics and levels of use, and emission factors.

This model is first adjusted to represent only Kentucky's share of fuel use and VMT in the heavy-duty sector, using FHWA historical data, and is then calibrated for this analysis with data from the Kentucky CAP inventory and forecast. HDV-specific baselines for emissions, energy use, and VMT were developed in this process.

The efficiency gains from SmartWay technologies were developed by assuming gradual ramp-ups of application to the HDV fleet registered in Kentucky. This produced a fleetwide average impact on vehicle efficiency from each technology. The impacts grew at different rates as the ramp-ups assumed were different. The average impacts for each year of the scenario (2011–2030) were combined and applied to the model. Emissions and energy savings were extracted from the model, and converted to fuel savings and fuel costs using AEO 2009 data and full fuel-cycle energy-content estimates developed by DOE.

The efficiency gains for WIM technology adoption were developed independently, utilizing cost and emission numbers and estimates for technology adoption rates.

Key Assumptions

- The rate of adoption for the three SmartWay technologies was assumed to be equal. For each APU installed on a truck, one other truck was assumed to install fairings, and one truck was assumed to install automatic tire-inflation technology. The analysis was not weighted in favor of or against technologies based on either emissions impact or cost.
- Approximately 12.5% of HDVs registered in Kentucky, or one of every eight, is assumed to have the SmartWay technologies in place. The scenario involves increasing adoption, reaching full adoption by all Kentucky-registered trucks in 2030.

Key Uncertainties

- The impact on truck tonnage is uncertain. Even with increasing the freight tonnage transported by intermodal, rail, or river, the overall impact in Kentucky is minimal.
- The efficiency equipment considered in this strategy analysis undergoes significant environmental forces, and is likely to incur wear and tear, requiring eventual replacement. Without data on scrappage rates or life spans, no replacement costs were included in this analysis; however, most of the equipment considered for this analysis is likely to eventually need replacement.

Additional Benefits and Costs

This policy will also decrease impacts on highway infrastructure and reduce emissions of particulate matter, including black carbon. The improvement in efficiencies in the movement of freight within Kentucky's boundaries and current infrastructure will reduce the impact of harmful emissions.

Improvements in HDV efficiency, as well as reductions in idling, will also mitigate the negative consequences that result from the emissions of criteria pollutants. Although these pollutants, such as black carbon and carbon monoxide, are not always considered to be GHG pollutants, they do have other negative impacts, particularly on public health. Reductions in these pollutants will have significant positive impacts on health issues and air quality outside of the reductions in GHG emissions.

The improvement in efficiencies in the movement of freight within Kentucky's boundaries and a decrease in unnecessary idling will also lessen the freight sector's impact on highway infrastructure. These policies will also reduce emissions of criteria air pollutants. Criteria air pollutants are ones for which the EPA has set National Ambient Air Quality Standards and are those generally associated with regulated emission standards. These pollutants, such as ozone, particulate matter, and carbon monoxide, have adverse effects on human health. Strategies that reduce criteria pollutant emissions will also result in significant public health benefits and air quality improvements in addition to GHG reductions.

Diesel particulate matter (PM) contains significant amounts of black carbon,[35] which has been increasingly implicated as a contributor to climate change. Diesel PM is also listed by EPA as a mobile source air toxic due to its cancer and noncancer health effects, making diesel PM an even greater concern to public health. As evidenced by the SmartWay program, several years of continued funding for diesel emission reduction grant programs, and an increasing number of idle reduction mandates nationwide, addressing diesel PM emissions has become a pressing public health priority.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

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[35] Black carbon (BC) particles[2] strongly absorb sunlight and give soot its black color. BC is produced both naturally and by human activities as a result of the incomplete combustion of fossil fuels, biofuels, and biomass. Primary sources include emissions from diesel engines, cook stoves, wood burning and forest fires. Available at: http://www.pewclimate.org/global-warming-basics/blackcarbon-factsheet.

TLU-9. Promote Consumption of Locally Produced Goods and Services

Policy Description

Today it is often more convenient to buy distantly produced goods (including food), which at face value appear to be cheaper. Indeed, most produce in the United States is picked four to seven days before being placed on supermarket shelves, and is shipped for an average of 1,500 miles before being sold. However, these "cheaper" goods are not always less expensive, as there are hidden economic, environmental, and societal costs related to transporting distant products. This policy supports "buy local" programs, like the Kentucky Proud marketing campaign, which promotes local cycling of dollars and resources, and reduces the need to haul freight. While "local" is a relative term, for the purpose of this policy we are considering local to mean made in Kentucky, since this is a statewide CAP.[36]

Policy Design

This policy will work by promoting and facilitating the purchase of local goods (particularly agriculture) and services produced in Kentucky. It will build on current initiatives wherever possible, such as the Kentucky Department of Agriculture's (KDA's) Kentucky Proud program, and may also entail creating new partnerships and initiatives.

Goals: The overarching goal is to reduce heavy-duty freight VMT by 5% below current projected levels by 2025.

The methodological approach will first involve developing estimates for the economic volume of the shift from foreign products and food to Kentucky-produced products and food. Once the amount of this shift is established, a factor will be established to allow the economic shift to indicate a reduction in imported freight transportation and an increase in intrastate freight transportation. From this change, an estimate of total heavy-duty and medium-duty VMT avoided as a result of the policy will be established. Once an estimate of the VMT reduction from the freight sector is established, use of the Kentucky VISION tool and emission factors from GREET will allow for estimation of the GHG reduction potential of these strategies.

Schools

Goal #1

- Increase the number of public school districts participating in the "Farm to School" program to promote the use of locally grown foods in all K–12 public school lunch programs. Currently, 39 counties are participating per the KDA Web site. The aim is to have 50 counties participating by 2015 and all 120 counties participating by 2030.

Timing: The project would begin in 2012. It would be partly implemented by 2015 and fully implemented by 2030.

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[36] For more information, see: http://www.sustainabletable.org/issues/eatlocal/; http://www.time.com/time/business/article/0,8599,1903632,00.html; and http://www.leopold.iastate.edu/pubs/staff/files/food_travel072103.pdf.

Parties Involved: Kentucky Education Cabinet, KDA, local school districts, teachers, local farmers. *Affected parties:* Students, cafeteria staff.

Implementation Mechanisms: Work with stakeholders in a concerted effort to ensure agriculture is incorporated into school curriculum. Identify and expand opportunities for students to obtain hands-on educational experience by touring local farms.[37]

Key Uncertainties: The level of support/funding, the ability of local farmers to supply the amount of food needed on consistent basis, and the lack of facilities (infrastructure) to prepare food.

Related Policies and Programs in Place: Farm to School program.

Goal #2

- Incorporate agriculture into the K–12 curriculum.

Timing: The project would begin in 2012 and would be fully implemented by 2015.

Parties Involved: Kentucky Education Cabinet, KDA, local school districts, teachers. *Affected parties:* Students.

Implementation Mechanisms: Clark County is Kentucky's model program for integrating Farm to School with nutrition and health education. The county is developing and piloting the Clover CAT (Cooking, Activity, and Time to be well) curriculum, which includes nutrition, time management, exercise, and self-esteem. The curriculum is being piloted in the 5th, 7th, and 9th grades with respective introductory, intermediate, and advanced levels. The implementation strategy would be to replicate this model program into additional Kentucky schools and to expand this curriculum to include agriculture education and gardens located on school grounds.[38]

Key Uncertainties: The level of support/funding, the ability of educators to allot classroom time for this effort, and whether the program developed would support and be integrated into required curriculum.

Related Policies and Programs in Place: Clover CAT curriculum.

Economic Development

Goal #3

- Encourage local governments to buy locally produced products by 2012. This project would build upon the mandates for state agencies to buy locally grown agricultural products, including wood products, under HB 669.

Timing: The project would begin in 2012, with a goal of having local governments increase purchasing up to 5% of goods/services locally by 2020 and 10% by 2030.

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[37] For more information, see: http://www.foodroutes.org/doclib/243/FarmtoSchoolSuccess.pdf, http://www.farmtoschool.org/KY/, and http://www.ca.uky.edu/news/?c=n&d=614.
[38] See: http://www.foodroutes.org/doclib/243/FarmtoSchoolSuccess.pdf.

Parties Involved: Kentucky legislature, FAC, and local governments. *Affected parties:* Citizens.

Implementation Mechanisms: Educate local purchasing coordinators regarding the benefits of buying locally (through workshops, etc.), and remove barriers to buying locally. Identify Kentucky-made products and services on the state master price contract, so that municipalities can use this information during their selection of vendors.[39] Also ask the legislature to pass legislation specifically allowing city and county governments to consider "local" when determining best bids.

Key Uncertainties: The availability of locally produced products, and whether buying local products would significantly increase costs to local governments.

Related Policies and Programs in Place: HB 669 and amendment to *KRS 45A.645*: "Agencies to purchase Kentucky-grown products meeting quality standards and pricing requirements if available." Also climate protection plans and transportation plans that use similar initiatives to lower VMT.

Goal #4

- Create a "Made in Kentucky" logo/brand for nonagricultural products to complement the Kentucky Proud brand, or expand the Kentucky Proud brand to more nonagricultural products if practical.

Timing: The project would build upon current KDA and CED efforts. Implementation would begin in 2013 and continue annually.

Parties Involved: Producers, Kentucky legislature, KDA, CED, and Kentucky Department of Tourism. *Affected parties*: Citizens.

Implementation Mechanisms: Create branding similar to Kentucky Proud to denote products that are made in Kentucky for nonagricultural products. An alternate mechanism would be to use Kentucky Proud for nonagricultural products. Develop an outreach strategy to educate the public about the benefits of buying locally. Have CED and KDA identify additional products made in Kentucky, and post this information on their Web sites.

Key Uncertainties: Possible concern for watering down/competing with the Kentucky Proud brand.

Related Policies and Programs in Place: Kentucky Proud. Also climate protection plans and transportation plans that use similar initiatives to lower VMT.

Resources: http://www.uky.edu/Ag/CLD/lcfa/.

Goal #5

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[39] For more information, see: http://www.farmtoschool.org/KY/policy.htm, http://www.sustainabletable.org/issues/eatlocal/, and http://www.kyagr.com/buyky/index.aspx.

- Ask CED and KDA (with the assistance of universities) to study and contrast the economic benefits of buying locally versus distantly produced foods and products (if this has not been done already), to include identifying distances that food typically travels, quantifying carbon emissions, cycling of dollars, and similar issues.

Timing: The project would begin in 2012 and would be completed by 2013.

Parties Involved: Kentucky legislature, CED, KDA. *Affected parties:* Citizens.

Implementation Mechanisms: Work with the legislature to request such a study and provide funding to conduct the study (possibly to universities).

Key Uncertainties: The availability of funding/resources to complete the study.

Related Policies and Programs in Place: HB 669.

Resources: http://www.time.com/time/business/article/0,8599,1903632,00.html.

Goal #6

- Identify needs and facilitate the establishment of infrastructure needed for efficient transport, storage, and processing of local foods throughout Kentucky.

Timing: The project would be implemented by 2015.

Parties Involved: KDA, Kentucky Agriculture Extension Service, farmers. *Affected parties:* Citizens.

Implementation Mechanisms: Ask KDA to use its resources and university resources to study and identify problem areas and bottlenecks that hinder access to locally grown foods, if these issues have not already been examined. The study would also investigate whether community kitchens could be established to allow local foods to be prepared in a centralized location and then distributed to nonprofit organizations and community groups, as well as for-profit organizations (for a fee). This could reduce kitchen labor significantly and achieve economies of scale that would result in more local produce being distributed. As an example, Jefferson County Public Schools has established a central kitchen that prepares food that is subsequently transported to individual schools.

Key Uncertainties: The availability of funds to establish the required infrastructure.

Related Policies and Programs in Place: Homeland security (food security) and economic development.

Food Equity/Food Security

Goal #7

- Encourage communities to include community and regional food planning in their five-year comprehensive plan reviews/updates.

Timing: The project would be implemented by 2013.

Parties Involved: Kentucky legislature, local governments. *Affected parties:* Citizens.

Implementation Mechanisms: Work with the state legislature to facilitate adoption of this legislation.[40]

Key Uncertainties: The acceptance of this requirement by local governments, and the availability of resources to meet this requirement.

Related Policies and Programs in Place: Five-year comprehensive plan. Also climate protection plans and transportation plans that use similar initiatives to lower VMT.

Goal #8

- Encourage gleaning of fresh produce for nonprofits by expanding gleaning networks and identifying gleaning sponsors. Reduce food waste in Kentucky from the current 20% to 10% by 2030.

Timing: The project would be implemented by 2012.

Parties Involved: KDA, local governments, community organizations, houses of worship. *Affected parties:* Citizens.

Implementation Mechanisms: The U.S. Department of Agriculture (USDA) estimates that 20% of all food grown in the United States is wasted. Work with houses of worship and nonprofits to implement this grassroots effort. Provide Web support (hosting) of gleaning resources and initiatives on the KDA Web site.[41]

Key Uncertainties: Being able to "drive" traffic to the KDA Web site.

Related Policies and Programs in Place: Gleaning networks, such as the Lexington Urban Gleaning Network, food banks, churches, and community garden groups.

Goal #9

- Increase the availability of fresh produce to underserved populations (food equity) by increasing the number of farmers' markets that accept Electronic Benefit Transfer (EBT), etc., by 2012, and to have all farmers' markets accept EBT by 2020. In 2008, 11 markets reported they accepted EBT cards, and 9 reported they accepted credit and debit cards.

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[40] See: http://www.planning.org/policy/guides/adopted/food.htm.
[41] See: http://home.insightbb.com/~igrowfood/LUGN/.

Timing: Ongoing efforts would be expanded.

Parties Involved: KDA, CHFS. *Affected parties:* Citizens.

Implementation Mechanisms: Provide additional outreach to the 102 farmers' markets to increase acceptance of EBT.[42] Also investigate whether a statewide farmers' market EBT program could be established. Technology advancements will also have to be monitored (for example, if the ability to conduct transactions using a cell phone becomes common, then EBT may not be necessary).

Related Policies and Programs in Place: Farmers' markets, community-supported agriculture (CSA) farms.

Goal #10

- Provide local health departments with literature and training on gardening and gardening resources, as well as locations of farmers' markets, food banks, and area stores where locally grown produce can be obtained for dissemination to the public.

Timing: The project would be implemented by 2012.

Parties Involved: KDA, CHFS, local health departments, Agriculture Extension Service (Ag Extension), community organizations. *Affected parties:* Citizens.

Implementation Mechanisms: Develop a coordinated, uniform educational and outreach campaign that could be used by health departments throughout the state to encourage more people to grow their own food, and educate them about where to find fresh produce. Partner with the Ag Extension and universities on this initiative.

Key Uncertainties: The availability of resources/funding to conduct this outreach.

Related Policies and Programs in Place: Ag Extension.

Goal #11

- Establish legislation that would encourage local governments to establish community gardens. Specifically, exempt local governments from liability associated with use of municipal land for community gardens to make establishing community gardens on public lands more attractive. The goal would be to have a community garden for every 10,000 urban residents by 2020 and one for every 5,000 urban residents by 2030.

Timing: The project would begin being implemented by 2012 and would continue through 2030.

Parties Involved: Kentucky state legislature, local governments. *Affected parties:* Citizens.

Implementation Mechanisms: Work with the state legislature to encourage adoption of this legislation. Inventory the number of existing urban community gardens, and post this

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[42] See: http://www.kyagr.com/consumer/food/ and http://www.kyagr.com/marketing/farmmarket/index.htm.

information on a central Web site.[43] Model Kentucky efforts after municipalities and states that already have extensive community garden programs and procedures in place.

Key Uncertainties: The availability of land in urban environment, potential liability issues, the protocol for ensuring garden space is allotted fairly, preventing use of contaminated properties for gardening, the maintenance of gardens at end of the year, the application of pesticides near waterways.

Related Policies and Programs in Place: Homeland security (food security); gleaning networks, such as the Lexington Urban Gleaning Network; food banks, churches, and community garden groups.

Goal #12

- Facilitate establishment of local Food Policy Councils (FPCs) throughout Kentucky as well as a statewide FPC. FPCs bring together stakeholders from diverse food-related sectors to examine how the food system is operating and to develop recommendations on how to improve it. FPCs may take many forms, but typically either are commissioned by state or local government, or are predominately a grassroots effort. FPCs would in all likelihood be supportive of and facilitate the other goals outlined in TLU-9.

Timing: The project would be started in 2012 and completed by 2020.

Parties Involved: KDA, Ag Extension, community organizations. *Affected parties:* Farmers, citizens.

Implementation Mechanisms: Ask KDA to use its resources and networking to establish FPCs (beginning in larger communities and then progressively smaller communities).[44]

Key Uncertainties: The level of acceptance/support, resources, ability to implement policies/effect change (particularly across county lines).

Related Policies and Programs in Place: Homeland security (food security); gleaning networks, such as the Lexington Urban Gleaning Network; food banks, churches, and community garden groups.

Related Policies/Programs in Place

- Kentucky Proud
- Lexington Urban Gleaning Network
- HB 669
- Resources: http://www.time.com/time/business/article/0,8599,1903632,00.html.
- Clover CAT

[43] See: http://communitygarden.org/learn/resources/articles.php.
[44] See: http://www.foodsecurity.org/FPC/.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-9 are summarized in Table TLU-9-1.

Table TLU-9-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-9

Quantification Factors	2020	2030	Units
GHG Emission Savings	0.31	0.55	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	6.36		$MMtCO_2e$
Energy Savings (2011-2030)	472		Millions of gallons
Net Present Value (2011–2030)	–$769		Millions of 2005$
Cost-Effectiveness	$120.87		$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

This GHG reduction strategy, focusing on several efforts to encourage consumption of Kentucky-produced goods and services, was envisioned as an overall effort seeking to reduce VMT from heavy-duty trucks within Kentucky by 5% below the BAU projection by 2025.

Because the period of analysis for the Kentucky CAP process is 2011 through 2030, analysts extended the impact of the policy beyond 2025 (the stated year by which the target would be reached) to 2030. This produced a VMT reduction scenario that grows from no change in 2010 to 5% in 2025, and continues to achieve 5% reductions from BAU VMT in 2026 through 2030.

GHG reductions track very closely with VMT reductions in the analysis results, as was expected. Emissions fell almost exactly 5% from BAU in 2025, and remained there as the 5% target remained in place for the last five years of the analysis. The total number of tons avoided grew in that time, as the BAU scenario projects greater and greater heavy-duty VMT throughout the next 20 years. As a consequence, a constant percentage reduction off of a growing baseline results in a reduction that grows when measured in total tons. Table TLU-9-2 shows the projected scenario impacts expected every five years, and demonstrates that reductions grow from 2025 and 2030, despite a constant percentage reduction in VMT.

Table TLU-9-2. GHG Reductions from Buy-Local Scenario

Quantification Factors	2010	2015	2020	2025	2030	Total (2011–2030)
% VMT Reduction	0%	1.67%	3.33%	5%	5%	
GHG Reduction ($MMtCO_2e$)	0	0.14	0.31	0.50	0.55	6.36
Fuel Savings (millions of gallons)	0	10.6	22.7	37.2	40.9	472

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; VMT= vehicle miles traveled.

Cost savings also track closely with VMT. Fuel savings exceed $30 million per year by 2015 (measured in 2007 dollars). They grow to $126 million by 2025, and grow further to $147 million by 2030.

Data Sources

- Heavy-duty VMT volumes, both historical and projected, were taken from the inventory and forecast developed as part of this CAP.
- Fuel price projections for all fuels related to this strategy were drawn from DOE's AEO 2009, which was released in early 2010.
- Assumptions regarding the fuel efficiency of various truck classes, scrappage rates for aging vehicles, and VMT changes corresponding to vehicle age were taken from projections developed by DOE and ANL.

Quantification Methods

The quantification method for this analysis relies on the VISION model, which is a transportation energy and emissions model developed and updated every year by ANL. The model is built around a detailed perpetual-inventory model of the national vehicle fleet. A great deal of detail can be customized in this tool with regard to fleet size and makeup, driver behavior, fuels characteristics and levels of use, and emission factors.

This model is first adjusted to represent only Kentucky's share of fuel use and VMT in the heavy-duty sector, using FHWA historical data and then calibrated for this analysis with data from the Kentucky CAP inventory and forecast. HDV-specific baselines for emissions, energy use, and VMT were developed in this process.

The scenario assumptions regarding VMT reduction were applied within the model to both medium-duty vehicles (representing truck classes three through six) and HDVs (representing classes seven and eight). Energy and GHG impacts were assessed by comparison of new projections to the HDV-specific baseline projections. Energy impacts were converted to fuel savings, both in gallons and in dollars of expenditure.

Key Assumptions: The fuel efficiency of the heavy-duty fleet is projected to improve slightly but steadily over the next 20 years.

Key Uncertainties

Key uncertainties include the level of support/involvement in these programs. Further, the potential program costs are uncertain and depend on the levels of support. While some programs have relatively fixed and minor costs, such as outreach campaigns, other programs (such as subsidies or regulations requiring enforcement) may have high and varying costs that are subject to change as legislative and agency priorities evolve.

Additional Benefits and Costs

There can be hidden economic, environmental, and societal costs in terms of transportation, packaging, reliance on pesticides, loss of local jobs, cycling of money outside the local community, loss of sense of community and community fabric, health impacts, and climate change.

Although buy-local initiatives are sometimes viewed as “protectionism,” in many respects buying locally allows communities to preserve and protect their heritage and way of life and to become more sustainable. The New Economics Foundation, an independent economic think tank based in London, compared what happens when people buy produce at a supermarket versus a local farmers’ market or CSA program, and found that twice the money stayed in the community when people bought locally.[45]

Reduced heavy-duty VMT, particularly around large cities, can reduce congestion, saving both time and fuel otherwise wasted when idling or driving at low speeds.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

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[45] For more information, see: http://www.sustainabletable.org/issues/eatlocal/; http://www.time.com/time/business/article/0,8599,1903632,00.html; and http://www.leopold.iastate.edu/pubs/staff/files/food_travel072103.pdf.

TLU-10. Promote the Use of Alternative Transportation Fuels

Policy Description

Increasing use of alternative transportation fuels has the potential to result in savings of imported petroleum-based fuels, and also reduce GHG emissions. State and local governments have the potential to "lead by example" by increasing use of alternative transportation fuels in fleet vehicles.

Alternative-Fuel Production Incentives

Adopt standards that require a certain amount or percentage of fuel sold within the state to be a low-carbon fuel (e.g., ethanol or biodiesel). This percentage can gradually increase over time. The state can help facilitate transition to low-carbon fuels by regulating quality standards for fuel blends. This recommendation could also promote research and development related to biofuel production, such as the use of enzymes for breaking down cellulose to produce ethanol (as opposed to corn-based ethanol, which has a lower life-cycle benefit).

Targeted State Fuel Procurement to Encourage Alternative Fuel Production

This might require minimum volumes of cellulosic ethanol and biodiesel to be blended into gasoline and diesel fuel commensurate with specified in-state production of these biofuels. This would be designed to ensure that biofuel produced will be blended and sold in the state—ensuring a market for biofuel producers.

Alternative-Fuel Infrastructure Development

Directly or indirectly provide incentives to private providers of alternative-fuel infrastructure. The development of an alternative-fuel infrastructure can aid in the promotion of alternative-fuel use and offset the expense of equipment and installation costs. The convenient locations of stations offering alternative fuels at competitive prices can increase the use of the fuels. In addition, it is important to increase the availability, accessibility, and use of alternative fuels and low-sulfur diesel for off-road vehicles. Expand low-carbon fuel use to off-road and recreational marine vehicles. Provide incentives and support for low-carbon fuel infrastructure development.

Policy Design

Goals: Consistent with the Renewable Fuel Standard (RFS) promulgated in the federal Energy Information and Security Act (EISA), Kentucky's share of the RFS2 requirement is projected to be 335 million gallons of advanced biofuels, based upon Kentucky's 1.6% share of the nation's motor fuel use in 2022. The goal of 20% of Kentucky's motor fuels demand may be met in 2030 from Kentucky feedstocks, while continuing to produce safe, abundant, and affordable food, feed, and fiber. Additional biofuels estimated to be produced in AFW-4 beyond the level of in-state consumption would be expected to be exported for out-of-state consumption.

Timing: Current levels are approximately 6%, primarily from E-10 and B-2. Assume growth as B-10 and E-85 use increases.[46] Additional increases can be achieved by incorporating plug-in hybrid vehicles and compressed natural gas. Technology and research advances will also increase the use and availability of alternative fuels.

Parties Involved: Meeting these goals would benefit citizens of the Commonwealth of Kentucky by generating new jobs and reducing net per capita carbon emissions, while ensuring Kentucky's economic viability and assisting Kentucky in gaining energy independence from imported oil. Parties involved in implementation include the General Assembly and state agencies, including departments in KEEC, KYTC, KDA Facilities Services, Fleet Management, and the FAC. Any state agencies with sizable fleets, such as elementary and secondary schools, colleges and universities, and the KPS, should also be involved. Affected parties who are also involved in implementation include private industry developers, commercial and retail distributors, post-secondary institutions, agriculture producers, low-carbon fuel producers, and technology innovators.

Other: The current largest deterrent for achieving this goal beyond current economic conditions is the limited availability of alternative fuel products for consistent consumption.

Implementation Mechanisms

- Develop purchasing criteria for the Commonwealth to increase the overall fuel efficiency of the vehicles in the state fleet.
- The General Assembly should enact a tax credit of the income tax and the limited liability entity tax owed by a company installing or locating blender pumps in an amount equal to no greater than 50% of the capital expenditure costs of the required equipment. This type of incentive will exponentially increase the availability of alternative fuels.
- The Commonwealth will establish an escalating renewable fuel standard (RFS) for the state vehicle fleet. The state will establish an initial RFS of 10%, or 560,000 gallons (10% of an estimated 5.6 million gallons consumed annually by all state fleet vehicles) for E-10 gasoline.
- The state will require all eligible fueling stations under government contract to provide, at a minimum, E-10 gasoline and B-2 biodiesel by 2012.

Related Policies/Programs in Place

Kentucky Energy Plan Scenarios 1, 2, 3, and 4, and HB 2 (2008), which include goals for the state vehicle fleet.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

B-2 is a fuel blend of 2% biodiesel and 98% diesel. B-10 is a fuel blend of 10% biodiesel and 90% diesel. E-10 and E-85 are fuel blends of 10% ethanol and 90% gasoline and 85% ethanol and 15% gasoline, respectively.

Estimated GHG Reductions and Net Costs or Cost Savings

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-10 are summarized in Table TLU-10-1. The scenario analyzed and shown with results may be summarized as a scenario consistent with 20% biofuels goal in the year 2030, as discussed and recommended by the TLU Technical Work Group (TWG) and approved by KCAPC at Meeting #6.

Table TLU-10-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of Scenario with 20% Biofuels Share by 2030

Quantification Factors	2020	2030	Units
GHG Emission Savings	0.312	1.015	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	8.475		$MMtCO_2e$
Energy Savings (2011–2030)	1,880.9		Millions of gallons
Net Present Value (2011–2030)	$30.7		Millions of 2005$
Cost-Effectiveness	$3.63		$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

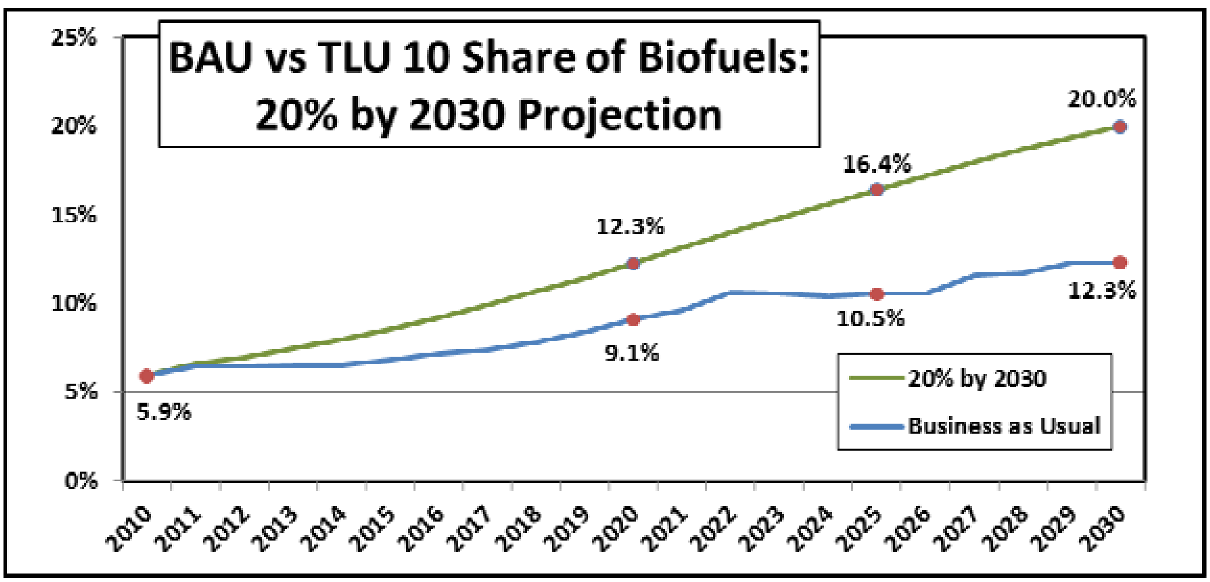
Quantification Methods: The policy analyzed is a scenario consistent with a goal level for biofuel consumption that may be summarized as a 20% biofuels share by 2030 ("20-by-'30") goal. To achieve this goal, the policy seeks to utilize a combination of incentives for increased production of biofuels from in-state feedstock sources and for expansion of biofuel infrastructure. Biofuel usage is expected to rise significantly, even in the absence of any policy. Kentucky's 20%-by-2030 goal is best understood in light of how it differs from those projections. U.S. Department of Energy (DOE) official baseline projections indicate that biofuel consumption is expected to reach more than 10% of total fuel demand in 2025. Further, by 2030, biofuel consumption is expected to exceed the 12% share stated by Kentucky's goal. Table TLU-10-2 shows the projected growth of the role of biofuels as an energy source for LDVs under the baseline scenario, and the 20-by-'30 scenario. Figure TLU-10-1 shows the baseline and scenario trends for the 20-by-'30 scenario.

Table TLU-10-2. Business-as-Usual Compared with "20 by '30" Scenario Projection: Biofuel Use as Share of Light-Duty Vehicle Fuel Supply

Year	Baseline Biofuels Energy Share	20% by 2030 Biofuels Energy Share	Difference: 20% Scenario vs. Baseline
2010	5.9%	5.92%	0%
2011	6.5%	6.59%	0.1%
2012	6.5%	6.99%	0.5%
2013	6.5%	7.44%	0.9%
2014	6.5%	7.97%	1.5%
2015	6.8%	8.57%	1.8%
2016	7.2%	9.22%	2.0%

Year	Baseline Biofuels Energy Share	20% by 2030 Biofuels Energy Share	Difference: 20% Scenario vs. Baseline
2017	7.4%	9.92%	2.5%
2018	7.8%	10.68%	3.0%
2019	8.4%	11.46%	3.1%
2020	9.1%	12.27%	3.2%
2021	9.6%	13.13%	3.5%
2022	10.6%	14.01%	3.4%
2023	10.6%	14.84%	4.2%
2024	10.5%	15.63%	5.1%
2025	10.5%	16.42%	5.9%
2026	10.6%	17.20%	6.8%
2027	11.5%	17.97%	6.5%
2028	11.7%	18.69%	7.0%
2029	12.3%	19.36%	7.1%
2030	12.3%	19.98%	7.7%

Figure TLU-10-1. Biofuels Share of Fuel Supply under 20%-by-2030 Scenario



The baseline scenario, or "business as usual" scenario, shows a significant growth in biofuel use. Biofuels, which currently represent only about 6% of the volume of fuel consumed by on-road vehicles, are projected to represent over 12% of the volume by 2030, even without any state-level policy intervention. This increase results from projections that show that the U.S. transportation sector will make significant strides toward meeting the goals of the federal RFS established in 2007, which calls for the national fleet to utilize 36 million gallons of biofuels by 2022. Because the baseline itself contains significant growth in consumption of biofuels, the

20% by 2030 goal has a significant effect, as Figure TLU-10-1, above, shows. Under the scenario recommended, biofuel use would grow by 60% above the baseline in 2025, and by almost 80% above the baseline in 2030.

The quantification method for this analysis relies on the VISION model, which is a transportation energy and emissions model developed and updated every year by DOE's ANL. The VISION model is built around a detailed perpetual-inventory model of the national vehicle fleet. A great deal of detail can be customized in this tool with regard to fleet size and makeup, driver behavior, fuels characteristics and levels of use, and emission factors.

For these analyses, the VISION model is first adjusted to represent only Kentucky's share of fuel use and VMT, using FHWA historical data and the officially accepted Kentucky KCAPC baseline inventory and forecast. The VISION model is then manipulated to analyze scenarios for different policies' goal levels, by adjusting volumes of E-85 and B-10 consumption, overall ethanol and biodiesel consumption, and rates of biofuel blend purchases by drivers with compatible vehicles (flex-fuel vehicles).

The TLU-10 policy is not expected to have a significant impact on prices of biofuels, though some impact is possible. The total projection for U.S. biofuel consumption for 2011–2030 is projected to exceed 450 billion gallons (according to DOE estimates). In the absence of actions by other states or the federal government, this strategy would increase national biofuel use by approximately 2% of the expected use over that time. Taking into account analyses suggesting that ethanol prices can be sensitive to changes in supply and demand, the price change due to a shift in consumption of this scale would be, at most, a few cents per gallon. The effects on gasoline prices, which are based on a much larger volume of consumption, are not likely to be noticeable.

Key Uncertainties

Prices of fuels, both petroleum-based and biomass-based, are unreliable even over periods of two to three years. Projections 20 years out should not be taken as reliable. The costs, and cost-effectiveness, of this strategy turn on the relative prices of biofuels and petroleum fuels, and the biggest impacts occur after 2020. If petroleum prices rise above biofuel prices, this strategy will be much more cost-effective; if they fall below biofuel prices, however, this policy will impose significant direct costs on consumers.

Additional Benefits and Costs

None noted.

Feasibility Issues

Much of the increased use of alternative transportation fuels will depend on both state and federal regulations. Reinstating the federal biodiesel incentive will help ensure the continued viability of the biodiesel industry. The state can help facilitate transition to low-carbon fuels by regulating quality standards for fuel blends. Targeted state fuel procurement might require minimum volumes of cellulosic ethanol and biodiesel to be blended into gasoline and diesel fuel commensurate with specified in-state production of these biofuels. Directly or indirectly providing incentives to private providers of alternative-fuel infrastructure will aid in the promotion of the use of alternative fuels.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

TLU-11. Promote the Use of Clean Vehicles

Policy Description

Increasing use of cleaner vehicles has the potential to result in savings of imported petroleum-based fuels, and also reduce GHG emissions. State and local governments have the potential to "lead by example" by increasing use of alternative transportation fuels in fleet vehicles.

By promoting the use of clean vehicles, this policy is designed to reduce Kentucky's energy demands, as well as GHG emissions from the transportation sector. Clean vehicles reduce GHG emissions through fuel efficiency, advanced vehicle technologies, and/or use of low-carbon fuels. The use of clean vehicles should be promoted through incentives and education. These vehicles include plug-in hybrids, natural gas vehicles, high-efficiency vehicles, hybrid-electric vehicles, electric vehicles, clean diesel vehicles, and clean diesel hybrid vehicles. Diesel vehicles have excellent fuel economy, and when paired with up-to-date pollution reduction devices either by retrofitting older vehicles or as required for new models (collectively referred to as "clean diesel" technologies), they can be an effective means to reduce GHGs.

Policy Design

To meet a goal for fuel efficiency improvement, the current baseline fuel economy must be identified. This information would need to be compiled by a state agency charged with implementing this policy. Once a baseline for Kentucky's fuel economy is established, the state could then establish goals for improving the fuel economy of the entire fleet as a basis for reducing GHG emissions.

In setting this goal, it is important to account for emission reductions that will occur as a result of national regulations. Recently, EPA and DOT's National Highway Traffic Safety Administration finalized new corporate average fuel economy (CAFÉ) standards for model year 2012 through 2016 LDVs. In total, the new CAFE standards will reduce GHG emissions from the U.S. light-duty fleet by approximately 21% by 2030 over the level that would occur in the absence of new standards.

Diesel fuel and engine standards have also been strengthened in recent years. In January 2001 and June 2004, EPA finalized the Highway Diesel and Non-road Diesel Rules, respectively, which set more stringent standards for new diesel engines and fuels. The rules mandated the use of lower-sulfur fuels in diesel engines (ULSD), which enabled the use of after-treatment technologies, such as diesel particulate filters on new and retrofitted diesel engines that can reduce harmful emissions by 90% or more. This includes reductions of diesel particulate matter, comprised largely of black carbon, a potential GHG.

After-treatment technologies control emissions by removing pollutants from vehicle exhaust (i.e., filters) or converting those pollutants into less harmful components (i.e., catalysts). These technologies can be retrofitted onto older engines, and requirements have already begun being phased into new diesel vehicles and equipment, beginning in 2007 for highway and 2011 for non-road vehicles and equipment.

On average, diesel vehicles have longer useful lives than gasoline vehicles. Consequently, the in-use fleet will take much longer to turn over than the in-use LDV (gasoline) fleet. However, with the use of cleaner diesel fuel, there are retrofit technologies available for most applications. These retrofits reduce emissions of air pollutants, allowing for the fuel efficiency benefits of diesel engines with fewer negative impacts on air quality than older, dirtier diesel engines. In fact, "when ULSD fuel and diesel particulate filters are used, light duty diesel vehicles have a 17 percent CO_2-equivalent emissions benefit over gasoline powered vehicles."[47]

Goals

- By 2025, increase the average fuel efficiency of Kentucky's new-vehicle fleet by 12%–25% over and above the projected fuel efficiencies of the federal 2016 CAFE standards. This improvement in fuel efficiency would be achieved by implementing a policy that would result in an increased number of fuel-efficient vehicles being placed into operation in Kentucky that is above the number projected to occur under the federal accelerated CAFE standards alone. This would be achieved through monetary incentives, such as tax credits, feebates, or reduced registration fees, with the eligibility requirements for vehicle purchasers to receive the incentive determining the ultimate impact on new-vehicle fleet efficiency.
- By 2015, improve the state-owned vehicle fleet fuel economy by 30%, to 21.7 mpg, as compared to a 2007 baseline of 16.7 mpg.
- By 2025, improve the state-owned vehicle fleet fuel economy by 50%, to 25 mpg, as compared to the 2007 baseline of 16.7 mpg.
- By 2025, increase the number of clean diesel vehicles registered in Kentucky (either new or retrofitted) by 50%.

Timing: The timing for implementing these goals should align with Kentucky's overall energy plan and GHG reduction targets.

Parties Involved: The KEEC Department for Energy Development and Independence (DEDI), KYTC Division of Motor Vehicle Licensing, FAC, Kentucky Department of Revenue, county clerks, automobile dealer associations, automobile manufacturers.

Other: The design and implementation of measures intended to achieve this policy goal should be spearheaded by DEDI, but will need to be administered in partnership with state and local agencies.

Implementation Mechanisms

The proposed policies and programs in this policy recommendation will need to be passed through the legislative process and implemented by state and local government agencies in partnership with affected parties. These policies will need to be evaluated by DEDI for feasibility and effectiveness in Kentucky, as well as the impact on revenue streams supporting other state programs. Following is a list of possible mechanisms to encourage the purchase of clean vehicles and achieve the goals set for this policy recommendation.

[47] Diesel Technology Forum, "Climate Change, Black Carbon & Clean Diesel" (visited Oct. 1, 2010). Available at: http://www.dieselforum.org/news-center/pdfs/Black%20Carbon_FINAL.pdf.

- *Outreach and Education*—Raising awareness of the importance of fuel efficiency and low-GHG fuels, to both the environment and the consumer's pocketbook, can encourage the purchase of these vehicles. Along with the awareness, access to information about vehicle fuel economy and consumer benefits of higher fuel economy should be readily available.
- *Feebates*—Feebates are a market-based alternative in which vehicles with fuel consumption rates above a "pivot point" are charged fees, while vehicles below receive rebates.
- *Tax Credits for Low-GHG Vehicles*—A tax credit program has been implemented at the federal level. The results of this program should be studied for effectiveness and impact on the state revenue stream.
- *Operating Incentives for Low-GHG Vehicles*—This could include access to preferred or reduced-rate parking, HOV lane access, and other benefits on state or local government-owned or -controlled properties.
- *Vehicle Registration Fees*—This may be similar to a feebate system, but rather than provide a rebate for low-GHG cars, low-emitting vehicles would simply pay a lower registration fee than high-emitting vehicles.
- *Grant Programs (Likely for Fleets)*—These types of programs provide a financial incentive to retrofit, repower, or replace equipment by covering the cost of the new technology.

Related Policies/Programs in Place

- Energy Plan Programs 1, 2, 3, and 4, and HB 2 (2008), which include goals for the state vehicle fleet.
- Kentucky Clean Diesel Grant Program—http://www.air.ky.gov/homepage_repository/Kentucky+Clean+Diesel+Grant+Program.htm.
- Louisville Metro POWER Loan program—http://www.louisvilleky.gov/economicdevelopment/businessdevelopment/GreenIncentives.htm.

Type(s) of GHG Reductions

Predominantly CO_2 emissions.

Estimated GHG Reductions and Net Costs or Cost Savings

The estimated GHG reductions, energy savings, net present value, and cost-effectiveness of TLU-11 are summarized in Table TLU-11-1.

Table TLU-11-1. Estimated GHG Reductions, Energy Savings, Net Present Value, and Cost-Effectiveness of TLU-11

Quantification Factors	2020	2030	Units
GHG Emission Savings	1.36	3.41	$MMtCO_2e$
Cumulative Emissions Reductions (2011–2030)	31.34		$MMtCO_2e$
Energy Savings (2011-2030)	2,330		Millions of gallons
Net Present Value (2011–2030)	–$3,581		Millions of 2005$

Cost-Effectiveness	–$114.30	$/t$CO_2$e

GHG = greenhouse gas; MMtCO_2e = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

This analysis examines the GHG reductions possible under a series of strategies pursuing a significantly more efficient statewide vehicle fleet by 2025, as well as a much more efficient state-owned LDV fleet. The targets are a statewide fleet that is 12%–25% more efficient than required under recent federal CAFE standard legislation and regulations, and a government fleet that achieves 30% greater efficiency by 2015 and 50% greater efficiency by 2025. The selected policy approach to achieving these goals is the application of financial incentives and disincentives, such as fees and rebates assessed at vehicle purchase, differential registration fee rates, and other financial incentive mechanisms. The approach to modeling the impacts of financial incentives is literature-based, relying primarily on targeted incentives research by Greene et al.[48] and Davis et al.[49] working out of Oak Ridge National Laboratory and DOE's Office of Policy, respectively.

Review of this research identified fee and incentive scenarios that would achieve a fuel-efficiency improvement in new vehicles of 17% over the 14-year range of 2011–2025, or almost exactly in the middle of the 12%–25% range described in the TLU POD.

The quantification method for this analysis relies on the VISION model, which is a transportation energy and emissions model developed and updated every year by experts at ANL. The VISION model is built around a detailed perpetual-inventory model of the national vehicle fleet. A great deal of detail can be customized in this tool with regard to fleet size and makeup, driver behavior, fuels characteristics and levels of use, and emission factors.

This model is first adjusted to represent only Kentucky's share of fuel use and VMT using FHWA historical data. Alternate prices representing the impacts of the relevant fees and rebates on the price facing the consumer of new vehicles are then used to modify the model, and alternate projections for fuel efficiency are introduced to represent the impact of both changes in consumer choice and changes by manufacturers to vehicles to take advantage of the policy.

Table TLU-11-2. Estimated GHG Reductions and Net Costs/Savings from TLU-11

Year	Emissions Reductions (MMtCO_2e)	Total Cost (million 2005$)	Total Gas & Diesel Savings (million gallons)
2020	1.36	–$184.2	102.2
2025 (Policy Goal Year)	2.51	–$276.8	187.0
2030	3.41	–$316.6	250.2
Cumulative (2011–2030)	31.34	–$3,581.9	2,330.0

GHG = greenhouse gas; MMtCO_2e = million metric tons of carbon dioxide equivalent.

[48] D.L. Greene et al., "Feebates, Rebates and Gas-Guzzler Taxes: A Study of Incentives for Increased Fuel Economy." *Energy Policy* 33 (2005): 757-775.
[49] W.B. Davis et al., "Effects of Feebates on Vehicle Fuel Economy, Carbon Dioxide Emissions and Consumer Surplus." DOE/PO 0031, Office of Policy, U.S. DOE, 1995.

This policy is estimated to have a cost-effectiveness of –$114.30 per ton of emissions avoided over the 2011–2030 period, representing a net savings from fuel use reduction that overwhelms a projected increase in new-vehicle purchase costs. Expected fuel savings are approximately six or seven times the increased costs expected in the prices of new vehicles.

Key Uncertainties

Fuel prices, which can be wildly unpredictable, can affect consumer demand for fuel-efficient vehicles.

Additional Benefits and Costs

None noted.

Feasibility Issues

None noted.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

Appendix I
Cross-Cutting Issues
Policy Recommendations

Summary List of Policy Recommendations

Policy No.	Policy Recommendation	GHG Reductions ($MMtCO_2e$) 2020	2030	Total (2011–2030)	Net Present Value (Million $)	Cost-Effective-ness ($/tCO_2e$)
CCI-1	Greenhouse Gas (GHG) Emission Inventories, Forecasts, Reporting, and Registry	*Not Quantified*				
CCI-2	Public Education and Outreach	*Not Quantified*				
CCI-3	Adaptation and Vulnerability	*Not Quantified*				
CCI-4	Statewide GHG Emission Reduction, Energy Intensity, and Energy Efficiency Goals, Targets, and Metrics	*Not Quantified*				
CCI-5	State and Local Government GHG Emission Reduction, Energy Intensity, and Energy Efficiency Activities (Lead by Example)	*Not Quantified*				
CCI-6	Local GHG Emission Reduction, Energy Intensity, and Energy Efficiency Actions	*Not Quantified*				
CCI-7	Financial Policies	*Not Quantified*				
CCI-8	Conduct an Impact Analysis of Federal GHG Constraints on Kentucky	*Not Quantified*				

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

Note: The numbering used to denote the above policy recommendations is for reference purposes only; it does not reflect prioritization among these important policies.

CCI-1. Greenhouse Gas (GHG) Emission Inventories, Forecasts, Reporting, and Registry

Policy Description

Inventories inform state leaders and the public on statewide trends, opportunities for mitigating greenhouse gas (GHG) emissions or enhancing sinks, and verifying GHG reductions associated with implementation of all future regulatory and reporting requirements. GHG emission inventories are a critical component of all GHG policy development. This should also be the case in the Commonwealth of Kentucky.

Emission inventories serve as a regulatory platform by establishing a baseline rate of annual GHG emissions. A comprehensive GHG inventory of all direct emission sources within the borders of the Commonwealth, both point and fugitive sources, should be developed and updated annually.[1] An effective inventory is comprised of specific components:

- This GHG inventory should serve as the official GHG emissions inventory of anthropogenic sources and sinks within the borders of the Commonwealth.
- The inventories should be transparent and consistent with the GHG inventory reporting guidelines and requirements of the U.S. Environmental Protection Agency (EPA).[2]
- GHG emission factors should be consistent with national and international guidance documents.
- Threshold reporting levels should be determined by the Commonwealth to adequately and accurately compile a comprehensive inventory of GHG emission sources and sinks.
- State emission inventories should serve as a compilation tool for organizing city and county GHG emission inventory efforts.
- Emission inventories should be verified by certified independent third-party verifiers.
- Direct emissions (Scope 1) and indirect emissions (Scope 2) should be included in the GHG emissions inventory. Emission sinks and carbon sequestration credits should only occur within the physical boundaries of the Commonwealth of Kentucky.
- GHG emission projections should be transparent, and all assumptions should be clearly disclosed.
- The inventory will include six GHGs—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6)—and will weight these gases according to global warming potentials reported by EPA.

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[1] The U.S. Environmental Protection Agency (EPA) has demonstrated the importance of GHG inventory reporting as a precursor to policy making with the General Provisions of 40 CFR Part 98. The Final Rule requires affected source categories to begin tracking GHG emissions on January 1, 2010, and report annual emissions for calendar year 2010 by April 2011.

[2] See: http://unfccc.int/national_reports/annex_i_ghg_inventories/reporting_requirements/items/2759.php.

Policy Design

The comprehensive GHG emissions inventory will serve as a foundation for developing emission projections and all future GHG emission regulatory requirements. An effective inventory system is aligned with national protocols and tailored to specific sources and sinks found in Kentucky. Two essential mechanisms of an inventory are reporting and registry functions.

Reporting

GHG reporting reflects the measurement and reporting of GHG emissions to support goal development, tracking of GHG emissions, and efficient management of resources. GHG reporting can help sources identify GHG emission reduction opportunities, reduce risks, and potentially develop revenue associated with future GHG mandates by developing the required infrastructure in advance. GHG reporting is a precursor for sources to participate in GHG reduction programs, opportunities for recognition, and a GHG emission reduction registry, as well as to secure "baseline protection" (i.e., credit for early reductions).

Registry

A GHG registry enables recording of GHG emission reductions in a central repository with "transaction ledger" capacity to support tracking, management, and "ownership" of emission reductions; establish baseline protection; enable recognition of environmental leadership; and/or provide a mechanism for regional, multistate, and cross-border cooperation. Properly designed registry structures also provide a foundation for possible future trading programs. The reporting protocol and format must be aligned with the requirements of the registry provider.

Goals

- Gather all inventory-related information for calendar years (CY) 2005 and 2010; 2010 will serve as the inventory base, with 2005 being used to develop trends. For 2011 and beyond, a GHG emissions inventory should be compiled by the Commonwealth on a biennial basis. These biennial inventories should be compiled in a biennial report that shows trends and includes recommendations for improvements.
- Coordinate with federal agencies to ensure consistency in GHG reporting rules. Follow the U.S. EPA's requirements for stationary sources as they relate to GHG emissions.
- Strive to avoid duplication of reporting requirements on GHG emission sources. Rely on the use of data that GHG emission sources already report under existing and future state and federal programs to avoid duplication of reporting burden on the sources. Utilize existing air pollution reporting systems and processes where applicable. Utilize existing government structures to identify an appropriate home for this work.
- Facilitate and encourage voluntary participation in an approved registry program.
- Encourage cross-departmental collaboration at the local and state levels.
- Educate and engage key private and public stakeholders in understanding the benefits of GHG emission measurement and stabilization.
- Develop a forecasting protocol based on CY 2010. Generate projections of future GHG emissions in 5-year increments extending to 2050.

- Create the institutional capacity for continued broad stakeholder involvement in the climate action planning process.
- Include all anthropogenic GHG emission sources and sinks.

Timing: Encourage state participation as quickly as possible.

Parties Involved

- Place the responsibility for this requirement within the Kentucky Energy and Environment Cabinet (KEEC).
- Coordinate with all relevant departments within the Commonwealth of Kentucky.
- Local governments, academic, nonprofit institutions, businesses, and regulated industries.

Other: None identified.

Implementation Mechanisms

- Establish an entity within KEEC as the lead on this project. This entity will be responsible for coordinating with local governments and other departments within Kentucky state government, as well as federal entities. This entity will have responsibility for:
- Collecting all inventory-related information for all GHG emissions for CY 2005 and 2010; 2010 will serve as the inventory base, with 2005 being used to develop trends. For 2011 and beyond, a GHG emissions inventory should be compiled by the Commonwealth biennially. These inventories should be compiled in a biennial report that shows trends and includes recommendations for improvements.
    - Encouraging cross-departmental collaboration at the local and state levels.
    - Educating and engaging key private and public stakeholder in understanding the benefits of GHG emission measurement and stabilization.
    - Developing a forecasting protocol based on CY 2010, and generating projections of future GHG emissions in 5-year increments extending to 2050.
    - Creating the institutional capacity for continued broad stakeholder involvement in the climate action planning process.

Related Policies/Programs in Place

- Kentucky is a member of the Climate Registry.
- The Kentucky Division for Air Quality is implementing the EPA reporting requirements for GHG emissions.
- Several local governments have completed inventories or climate action plans, or are in the process of doing so.

Type(s) of GHG Reductions

Not applicable.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

Whether or not Kentucky can avoid duplication and take advantage of federal, state, and local efforts.

Additional Benefits and Costs

None identified.

Feasibility Issues

The cost of implementation within KEEC.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

CCI-2. Public Education and Outreach

Policy Description

The Kentucky Climate Action Plan Council (KCAPC) recognizes the importance of public involvement and education regarding the issues of climate change to enhance communication and dialogue about climate issues. An essential element of addressing climate change for Kentucky is education and outreach. An effective process must be developed that increases understanding and awareness of the issue and the potential impact of climate change on the economy, environment, and lifestyle of present and future generations of Kentuckians. This process must involve a broad range of stakeholders and interest groups in implementing strategies to address climate change. The outreach and education component will target six specific groups of stakeholders. The process should be initiated early in the planning stages and should continue through the development and implementation of a Climate Action Plan.

The purpose of an education and outreach policy is to raise understanding of the technical and policy issues surrounding climate change, open lines of communication with stakeholders, and involve those stakeholders in the implementation process. Each identified group may have a different level of understanding of and stake in the impact(s) of climate change and may be affected differently by strategies to address climate change. Effective environmental education involves listening to multiple perspectives, sharing information, and addressing concerns through proactive community engagement.

Public outreach and environmental education can be used to help identify the main concerns of a host community, as well as the perceived benefits of an action plan. This process will help the KCAPC to address the issues of relevance to a particular community. The involvement through outreach and education of these groups will assist in developing lasting commitments to improving Kentucky's environment and economy through methods that minimize negative impacts and enhance positive outcomes. An additional goal of this policy is to facilitate funding for climate change and carbon mitigation research, and ensure the results of this research are used when developing new policies and regulations. Funding will target research in Kentucky that focuses on these main areas: climate science; energy efficiency enhancement; development and implementation of low-carbon technologies for industrial, residential, and transportation sectors; carbon capture technology; and carbon storage technology. Outreach and technology transfer will be an important part of this research, to help inform, educate, and engage the public.

Policy Design

Goals: The goals of the public education and outreach policy recommendation are to increase awareness of the issues and understanding of the costs of and benefits from adopting new policies and/or goals for current and future generations, to involve stakeholders in ongoing dialogue, and to effect behavioral change in a way that minimizes the negative impacts of climate change. Education of Kentucky's citizens, business leaders, and policymakers is integral to the successful implementation of behavioral and infrastructural changes necessary to minimize potential negative effects of climate change on the state's environment, economy, and lifestyle. The components of this policy should build upon and be linked to the activities, programs, and funding currently in place in the state. The four major elements of the education and outreach component are:

- Improve communication and dialogue about climate change.
- Provide education about climate and climate change.
- Involve multiple stakeholders in the process, and understand their concerns and awareness of climate change.
- Facilitate research funding opportunities within Kentucky, and leverage federal funding in the areas of climate science and carbon capture and storage technologies, energy efficiency, and diversification of energy sources. Communicate research results to the public, policymakers, legislators, stakeholders, and interest groups.

The steps of the public education and outreach policy are:

1. Appoint a Public Education and Outreach Team. The team would be selected by the KEEC Secretary or his or her designee. Individuals with experience in environmental education, communications, and technical fields (energy production, conservation, and management; climate science; or environmental sciences) are preferred. The team should have a broad representation of these fields from state agencies and public/private and educational/industrial/environmental interests, and would develop a plan for public education and outreach to the stakeholder groups. A KEEC representative will be designated as a member and staff coordinator for the team.
2. Identify key stakeholders and develop balanced outreach messages related to the Climate Action Plan and associated policies. The Public Education and Outreach Team should first establish a baseline of public understanding of the impacts of climate change and variability of proposed state-specific actions to deal with climate change. Second, the group should identify key messages for each party involved, by conducting a series of public forums and interviews.
3. Develop outreach materials based on identified outreach messages for specific stakeholders. Transfer information to the stakeholders, and allow for feedback. While the goal of the group should be education-based—that is, showing all sides of the issue and teaching how to think critically about this issue, rather than telling people what to think about the issue—it may also be necessary for the group to identify and utilize social marketing techniques to encourage energy conservation and a lower-energy lifestyle.
4. Evaluate the effectiveness of the materials through implementation of the Climate Action Plan, and monitor levels of understanding and changes in public perception and concerns. Refine the materials based on the evaluation.

Timing

- Year 1, first 6 months:
    - Appoint and train group members.
    - Evaluate existing surveys conducted by the Kentucky Environmental Education Council, and conduct a baseline survey about Kentuckians' attitudes, understanding, and behavior related to climate change.

- Year 1, second 6 months:
  - Identify existing outreach and educational materials and processes that are already in place or that could be easily adapted for use.
  - Develop a detailed policy and plan for public outreach and education.
- Year 2:
  - Coordinate with existing forums to conduct teacher workshops.
  - Conduct outreach to public officials in collaboration with state and local government agencies.
  - Assist with outreach activities at conferences for involved parties.
- Periodic resurvey:
  - Conduct periodic follow-up surveys to gauge changes in behavior and understanding.
  - Refine the strategy as needed.

Parties Involved: The following entities are targeted for education and outreach**:** state government agencies and employees, local and state policymakers, educators (K–12 and university staff) and future generations, community leaders and community-based organizations, business and industry representatives, general public, stakeholders, interest and advocacy groups, and Climate Change and Solution Research Funding Panel.

Other: None identified.

Implementation Mechanisms

The methods of and messages for communication and outreach will be specific to the following targeted audiences.

State Government Agencies and Employees

State government agencies and their employees will be targeted through CCI-5: State Lead by Example. Education of state government leadership and individual agencies and their employees will be needed regarding key understandings related to climate change and strategies for GHG emission reduction, energy intensity, and energy efficiency activities. The key activities needed to engage the agencies include, but are not limited to, the following:

- **Initial assessment.** Assess the level of understanding of the impacts of climate change and state-specific actions to deal with climate change.
- **Message.** Encourage agency actions and leadership in energy efficiency and intensity in state government agencies.
- **Methods.** Create posters and other outreach materials for distribution to state agencies. Develop optional brown-bag discussion courses about the issue, with a take-home reading component for state employees, perhaps requiring participation for leaders of these agencies. Establish model greening language for adoption in agency policies. Strive to reduce and/or eliminate barriers to green purchasing in state government.

- **Incentives and recognition.** Establish a recurring awards program to recognize leadership and attainment of the goals and objectives of the Kentucky Climate Action Plan.

Local and State Policymakers

Education and outreach efforts with state and local elected officials will provide education about issues surrounding climate change and implications for public officials.

- Partner with the Department of Local Government, the Kentucky Association of Counties, and the Kentucky League of Cities through existing forums and outreach materials to spread the message.
- Utilize the county officials training program in the Department of Local Government.
- Provide information to help officials better understand the issues and the impact of local, state, and federal actions on their areas (state or local government).
- Identify key officials who should be involved initially.
- Assist with developing new materials and training to inform local and state officials.
- Include sharing of climate strategies and implementation as part of interactions with Sister Cities programs.

Future Generations

Materials will be developed and existing materials and forums will be used to inform primary, secondary, and post-secondary students and teachers about key understandings related to climate change, and efforts to address climate change in public policy. Curriculum will be developed with input from educators and correlated to the Kentucky Department of Education (KDE) Core Content, and the KDE Program of Studies. Focus will be first on core climate concepts, such as how carbon cycles through Earth's systems, the difference between weather and climate, sources and sinks of carbon and other GHGs, what GHGs are and how they relate to the greenhouse effect, etc.

The second half of the curriculum should focus on sustainability and steps that students and schools can take to minimize impacts through reducing consumption and promotion of a low-carbon lifestyle. Methods and programs for developing implementation of these "best practices" and principles in schools will be identified and utilized, and any additionally necessary programs will be developed as needed. These best practices will need to be integrated into public school design and construction, and used as a means to educate students (and parents) and the general public firsthand in their communities and colleges.

- **Initial assessment.** Assess the level of understanding of the concept of climate change and key understandings related to that concept. Assess the level of understanding of the impacts of climate change.
- **Message.** Communicate core climate and climate change concepts and personal and district-level actions that can help reduce the carbon footprints of individuals and school districts.

- **Methods.** Develop curriculum, conduct teacher curriculum workshops, and give presentations at key teacher professional development conferences, including Kentucky Association for Environmental Education, Kentucky Science Teachers Association, etc.
- **Incentives and recognition.** Establish a recurring awards program to recognize leadership and attainment of the goals and objectives of the Kentucky Climate Action Plan.

Community Leaders and Community-based Organizations

Materials and efforts for community leaders will give an introduction to climate change and facilitate a better understanding of the policy implications of climate change. Materials will focus on reducing consumption, encouraging sustainable decision making, and planning for reducing environmental impacts and promoting a low-carbon lifestyle. Identify existing forums and activities for outreach to local communities and community leaders, such as KY EXCEL. Collaborate with local groups, like the Center for Nonprofit Excellence and Chambers of Commerce, to help community leaders and community-based organizations provide information about climate activities and implications for local communities.

Business and Industry Representatives

Work with existing business outreach efforts to customers to enhance awareness of climate change issues and opportunities. Develop market-based incentives for reducing their carbon footprint.

- **Initial assessment.** Assess the level of understanding of the core concepts associated with climate change, the impacts of climate change, and state-specific actions to deal with global warming. Assess the level of integration that business and industry have with existing programs designed to increase energy efficiency and green internal operations.
- **Message.** Reduce business costs and overhead by conserving resources, building green, and finding methods to recycle waste within industry.
- **Methods.** Utilize workshops and member organizations to deliver the message and increase enrollment.
- **Incentives and recognition.** Establish a recurring awards program to recognize leadership and attainment of the goals and objectives of the Kentucky Climate Action Plan. General Public

Strategies for educating and involving the general public will focus on general information and understanding about climate change, voluntary efforts to reduce consumption of goods and corresponding emissions, promotion of a low-carbon lifestyle, and participation in organized programs and incentives where available.

- Educate broadcasters, reporters, editorial boards, etc., about climate change and the risks it imposes, and provide solutions in the Kentucky Climate Action Plan. Work with state broadcasters and print media associations to develop and run climate change public service announcements.
- Develop and maintain a state climate change Web site for the public, including a clearinghouse of Kentucky-specific climate change information and resources.

- Utilize social media, including Facebook, Twitter, and LinkedIn to reach the public.

Interest and Advocacy Groups

Groups involved in advocacy from all viewpoints (environmental, groups supporting coal mining, or business and industrial interests) will be targeted through focus groups and educational materials. The purpose and focus will be to provide information on core climate concepts, including sources and sinks of carbon and other GHGs, what GHGs are and how they relate to the greenhouse effect, reducing energy use, controlling carbon emissions, and enhancing Kentucky's use of energy efficiency systems. Along with providing education, conducting focus groups with these groups will allow better understanding of their concerns and viewpoints.

Climate Change and Solution Research Funding Panel

Designate a Climate Change and Solution Research Funding Panel that will facilitate technical, business, and social research funding in Kentucky universities and industry. This panel will:

- Coordinate research on climate science, energy efficiency enhancement, development and implementation of low-carbon technologies for industrial, residential, and transportation sectors, carbon capture technology, and carbon storage technology by establishing a database of pertinent research projects in Kentucky. This database will be made available on the Web so other researchers and the general public can keep informed on research topics, progress, and final results.
- Work with KEEC to identify important research areas and obtain state funding for projects.
- Identify state and federal funding opportunities, and communicate to researchers who may want to respond to specific solicitations. Coordinate state matching funds to leverage federal funds.

Related Policies/Programs in Place

KDE and the KEEC are essential partners in developing education and outreach materials and processes.

Kentucky NEED is the state affiliate of the National Energy Education Development (NEED) Project, a nonprofit education association, dedicated since 1980, to equipping students and teachers with a realistic understanding of the scientific, economic, and environmental impacts of energy. Kentucky NEED provides core content-aligned curriculum for students, professional development for teachers, energy management programs for school operations and maintenance staff, and professional development and workshops for teachers.

Project Lead the Way (PLTW) is a program that works with middle schools and high schools and involves partnering schools and industry to prepare an increasing and more diverse group of students for success in engineering and engineering technology programs. PLTW focuses on science, technology, engineering, and mathematics. In the engineering curriculum, students investigate the importance of energy in our lives and the impact of energy use on the environment. Students design and model alternative energy sources and participate in an energy expo to demonstrate energy concepts and innovative ideas. They also evaluate ways to reduce energy consumption through energy efficiency and waste management techniques.

Green Bank of Kentucky is part of the Kentucky Finance Cabinet. It promotes energy efficiency in state buildings through competition for low-interest loans to reduce operating costs and energy use, protect the environment, save taxpayer dollars, promote economic development, and create new “green collar” jobs by means of education, engineering analyses, and building improvements. Green Bank of Kentucky is active in public outreach efforts and is an essential part of a comprehensive outreach and education process.

In the Kentucky Green and Healthy Schools program, students implement projects to improve the health, safety, or sustainability of their schools in nine different categories: Energy, Green Spaces, Hazardous Chemicals, Health & Safety, Indoor Air Quality, Instructional Leadership, Solid Waste, Transportation, and Water Quality. These efforts provide a forum for increasing environmental literacy and raising awareness of climate issues.

Through the Safe Routes to Schools program, students learn the value of exercise by walking or riding their bicycle to school. The program could be used as a forum for discussing the additional benefit of walking and riding instead of driving vehicles, including reduced vehicle exhaust and improved air quality.

KDE’s Regional Resource Centers (RRCs) also provide educational assistance. The RRC Program assists state education agencies in the systemic improvement of education programs, practices, and policies that affect children and youth with disabilities. By working across regions, RRCs facilitate networking and information sharing among states and U.S. jurisdictions.

Type(s) of GHG Reductions

Not applicable.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

The effectiveness of the education and outreach efforts is contingent upon adequate funding, coordination among partners to reduce duplication of effort, and recruitment of partners to capitalize on existing efforts. Obtaining additional funding and adding new programs or efforts must compete for limited resources and staff in government agencies. Having central coordination among the variety of targeted audiences and partners may present a challenge.

Additional Benefits and Costs

- Increasing public education and outreach will likely require additional funding.

- There are often ancillary benefits of public education resulting from increased awareness about how to lower energy consumption (e.g., health benefits from increased walking and biking, and environmental benefits from car pooling, using public transportation and consumption of local goods and services.)

Feasibility Issues

None identified.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

CCI-3. Adaptation and Vulnerability

Policy Description

The Commonwealth of Kentucky should undertake a comprehensive planning effort to assess the state's vulnerability to the physical impacts of climate change on the natural environment and human health, and then to identify and evaluate adaptation opportunities. Various organizations and agencies in the state are already collecting some of the information needed to make such an assessment, and efforts should be made to coordinate and consolidate these information-gathering activities.

Policy Design

Goals

- Undertake a comprehensive planning effort to assess the impact of climate change on Kentucky, including, but not limited to, impacts on water quality and quantity, agriculture, recreation, fish and wildlife habitat, industry, and human health. The analysis, to the extent possible, will include the economic impacts on these sectors.
- Suggest adaptation strategies to minimize the effects of climate change on the above sectors within the Commonwealth.

Timing: As part of the Kentucky Climate Action Plan, KEEC should begin to coordinate collection of existing information and identification of data gaps in 2010, and continue in 2011. Assessment of the state's vulnerability to climate change impacts in the above sectors will begin in 2011.

Parties Involved: Kentucky Department for Environmental Protection (DEP), Department for Energy Development and Independence (DEDI), Department for Natural Resources (DNR); Kentucky Fish and Wildlife; Kentucky Water Resources Research Institute; Kentucky Geological Survey (KGS); Kentucky Department of Agriculture (KDA), Governor's Office of Agricultural Policy; Kentucky Cabinet for Health and Family Services; Kentucky Tourism, Arts and Heritage Cabinet; U.S. Army Corps of Engineers (USACE), U.S. Fish and Wildlife Service (FWS), U.S. Department of Homeland Security (DHS); state and regional universities.

Other: None identified.

Implementation Mechanisms

Identify resources to support this analysis and establish an entity within KEEC as lead on this project. This entity will be responsible for coordinating with DEP, DEDI, DNR; Kentucky Fish and Wildlife; Kentucky Water Resources Research Institute; KGS; KDA, Governor's Office of Agricultural Policy; Kentucky Cabinet for Health and Family Services; Kentucky Tourism, Arts and Heritage Cabinet; USACE, FWS, DHS; state and regional universities. This group with the designated entity as lead will collect and analyze all available data to assess the impact upon each potentially vulnerable sector within Kentucky.

Related Policies/Programs in Place

There are no known directly related programs in place, but the initial comprehensive analysis would identify any related programs.

Type(s) of GHG Reductions

Not applicable.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

Funding and level of participation from relevant stakeholders.

Additional Benefits and Costs

Ancillary benefits can result from communities enhancing their emergency preparedness and response capacities.

Feasibility Issues

Funding.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

CCI-4. Statewide GHG Emission Reduction, Energy Intensity, and Energy Efficiency Goals, Targets, and Metrics

Policy Description

Kentucky is the third-largest coal producer in the United States and has an electricity generation fleet that is more than 90% coal-fired. Approximately 49% of that power is delivered to an industrial sector that produces automobiles, appliances, aluminum, stainless steel, chemicals, and other products. With its high reliance on coal to meet its electric energy needs, Kentucky may be subject to disproportionally large economic and infrastructure impacts as a result of federal action to limit GHG emissions, relative to states with more options available to them (see CCI-8). Simultaneously, Kentucky is also a developing economy, depending heavily on manufacturing and production for a significant majority of gross state product (GSP). Therefore, any implementation plan must be Kentucky-specific.

In November 2008 Governor Steven Beshear's office published *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence*.[3] The Kentucky Energy Strategy includes outcome-based goals that are anticipated to result from implementation of the seven strategies. They are described in the Policy Design section, below.

Policy Design

Goals: The following GHG emission reduction goals are from the 7-Point Energy Strategy were used as a starting point for the analysis of potential statewide GHG emission reduction goals for the Kentucky Climate Action Plan being developed by the KCAPC.

- "GHG emissions will be more than 50% lower in 2025 than they would otherwise be."
- "GHG emissions in Kentucky will be 20% lower in 2025 than were our 1990 emissions."[4]

After analysis of the above GHG reduction goals from the 7-Point Energy Plan, it became evident that significant reductions would result from implementation of several options in the latter part of the planning period between 2025 and 2030. Therefore, the following GHG reduction goal is recommended for Kentucky: Reduce GHG emissions in Kentucky to 20% below 1990 levels by 2030.

In addition to formulating proposed GHG emission reduction goals as part of the KCAPC process, the Council has indicated an interest in metrics for energy intensity and energy efficiency. Therefore, three elements are proposed in this policy:

- *GHG Emission Reductions*— Reduce GHG emissions in Kentucky to 20% below 1990 levels by 2030.

[3] Governor Steven Beshear, *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence*, page v, November 2008.

[4] Ibid.

- *Energy Intensity*—Development of a metric and possibly standards or goals for evaluating the energy intensity, or CO_2 emissions, per unit of product or service provided (e.g., 1 metric ton of CO_2 per megawatt-hour (MWh) of power delivered, or 3 MWh used per $1 million of product value). This is also sometimes called carbon intensity. These values are determined by comparison to regional or national averages within the same sector and industry.
- *Energy Efficiency*—Development of a metric and possibly standards or goals for GSP per unit of power consumed (industrial), or less overall energy use per hour of operation (homes, buildings, etc.). This is a means of maintaining current energy use, while reducing overall emissions through improvements that allow more energy use or more GSP for the same amount of fuel consumed in the process.

Timing: Initiate in 2011 and ramp up by 2015.

Parties Involved: KEEC, the Public Service Commission (PSC), and the Cabinet for Economic Development (CED) will be primarily responsible for implementation of the goals. The legislature, representative organizations from within each of the economic sectors, citizen groups, regional and national partnerships, etc., must be consulted during this process.

Other: The goals and targets must be reviewed within each sector periodically, with standards or targets adjusted accordingly as regional and national equivalencies change. For that reason, implementation of this strategy will require a long-term commitment by the Commonwealth to fund and enforce reporting, monitoring, and special tariff enactments.

Implementation Mechanisms

To implement this strategy, the following actions should be undertaken:

- Establish a responsible entity for this activity. This may be enacted within an existing agency or formulated as an independent commission overseeing existing agency activity.
- Evaluate Kentucky's key economic sectors, and determine baseline productivity within each of those sectors with respect to GSP or productivity per unit of relevant GHG emissions.
- Determine applicable regional or national emission profiles for equivalent sectors on the same basis.
- Develop an economic model to determine which of the three options (or combinations of options) within this strategy will have the most significant positive benefit in terms of sector GSP while meeting national GHG goals. Not all sectors may have the same options (e.g., manufacturing based on intensity and home energy use based on efficiency).
- Create the institutional capacity for continued broad stakeholder involvement in the energy intensity and energy efficiency metric- and goal-setting process. Include entities not currently represented on the KCAPC, both geographically and economically, such as small and medium-size manufacturing companies and local Chambers of Commerce.
- Using a stakeholder process, develop a metric for measuring energy intensity and energy efficiency. Propose specific energy intensity and efficiency targets (in terms of appropriate units) for each sector.

- The responsible entity will begin study of economic sectors once authorized (July 2011 or thereafter), utilizing as many existing mechanisms as possible (such as CCI-1).
- The responsible entity will begin negotiated goals or targets determination with appropriate stakeholders (July 2012 or thereafter).
- The responsible entity will propose goals or targets for each identified economic sector to the Secretary of the KEEC prior to January 2014.
- The responsible entity will report to the Secretary of the KEEC the progress of GHG emission reductions, as well as the relevant energy efficiency and energy intensity goals, in accordance with the implementation of the CCI-1 reporting requirements. The Secretary may review and adjust goals or targets for each sector.

This strategy will intertwine with CCI-1 and CCI-8 across many areas. For this reason, the initial determination of regulated sectors and regional and national equivalences will be of paramount importance. Any GHG mitigation plan ultimately adopted by Kentucky should ensure the cost-effective reduction of GHG emissions in a manner that maximizes public benefits; sustains and improves Kentucky's economy; mitigates adverse socioeconomic impacts; encourages innovation in energy production technologies, energy efficiency, and sustainable energy technologies; and avoids inequitable interstate and interregional impacts.

Related Policies/Programs in Place

- *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence*.
- The programs within the Finance and Administration Cabinet (FAC), DEDI, CED, the Governor's Office of Agricultural Policy, DNR, and research at state and regional universities that are focused upon the energy-related economic development that results from the diversification of Kentucky's energy supply, using Kentucky's vast resources. In addition, programs within these agencies and others that are focused on increased energy efficiency.

Type(s) of GHG Reductions

The six types of gases included in the U.S. Greenhouse Gas Inventory: CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

Regulatory issues associated with diversification of the electricity-generating fleet.

Additional Benefits and Costs

- There are increased economic opportunities associated with energy-related economic development alternatives focused on diversification of Kentucky's energy supply, using Kentucky's vast resources.
- Cost impacts of implementation of these policies in Kentucky.

Feasibility Issues

- Availability of alternative or lower-GHG sources of energy in Kentucky.
- Infrastructure needed to diversify energy supply, both transportation fuels and electricity generation.
- Cost of alternatives, and impact upon Kentucky's economy.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

CCI-5. State and Local Government GHG Emission Reduction, Energy Intensity, and Energy Efficiency Activities (Lead by Example)

Policy Description

To effectively reduce GHG emissions, improve energy intensity and energy efficiency results, and enhance air quality throughout the state, the Commonwealth will lead by example and will encourage and support local governmental entities to take similar actions. Kentucky has already undertaken numerous initiatives to enhance energy efficiency in state buildings and in public schools and will further build on these initiatives.

The state will adopt policies, goals, benchmarks, and reduction targets for energy efficiency and intensity strategies for state-owned or state-operated buildings, facilities, and vehicle fleets. To encourage broad adoption of and compliance with these new policies, the state will develop incentives for agencies, offices, and organizations that meet or exceed these established state benchmarks. To implement these new policies, the Governor should assign or create a multi-agency governmental body represented by staff from the Governor's Office and all three branches of government (legislative, executive, and judicial), to direct ongoing state climate efforts, including coordination with local government activities. Additionally, all programs and capital development funded through state bonding mechanisms should be required to meet these new policies.

Kentucky's adherence to its own policies, goals, and targets will inform and encourage local governmental entities to adopt similar policies, goals, and targets by highlighting the financial, social, and environmental benefits inherent in these policies. Development of the goals in this policy will help make energy efficiency practices available and accessible to Kentucky's cities and smaller communities.

Policy Design

Goals

- Implement legislative mandates with regard to state-owned and -operated buildings, renovations, and transportation options.
- Appoint and organize the multi-agency body by June 30, 2011.
- By December 31, 2011, the agency will establish goals and targets to accomplish the following:
    - The Commonwealth will increase its use of alternative fuel in the state fleet. This effort may include increased use of electric and hybrid cars and alternative fuels like biodiesel, ethanol, and natural gas, preferably from in-state sources. These changes will be implemented to the maximum extent possible throughout all branches of state government.
    - The Commonwealth will identify roadblocks to the development of alternative-fuel stations or access to recharge points, and will implement a plan to increase the number and accessibility of recharge and refueling stations for alternative fuels.

- The state will identify ways to design, encourage, and provide incentives for regional interconnected energy systems (e.g., smart grid, building management systems, energy mapping, energy data collection, customer utility demand management, decentralized energy production, transmission line upgrades for intermittent power sources) needed to improve state and local government energy use and encourage innovative approaches to energy supply and use. While many of these initiatives are not within the state's power, the state can serve as abettor, facilitator, and the coordinator in ways no individual community, organization, agency, or company can.
- All new building and renovation projects funded by state dollars and bonding will be required to incorporate energy efficiency aspects in the design, construction, or renovation. Where feasible, projects should strive to achieve Leadership in Energy and Environmental Design (LEED) standards.
- All state building and renovation projects that include new or substantial revision to heating, ventilating, and air conditioning (HVAC) and building systems will utilize commissioning to maximize energy-efficient operation.
- The state purchasing practices will include the use of energy-efficient products where feasible, especially in areas of lighting, HVAC units, etc.
- Accomplish culture change within state agencies, including educational institutions at all levels, to continually identify efficiency measures that can reduce energy use without damage to the institution's essential functions.
- As part of the culture change, promulgate and enforce a no-idling policy for state vehicles, except in traffic or required for health or safety. The state has probably the largest fleet in Kentucky; this is a great opportunity to lead by example.

- The multi-agency body will issue challenges to local governmental entities to address their energy use and attitudes in the same manner.

Timing: The multi-agency entity should be established by the Governor by the end of June 2011, and will immediately begin to design and develop specific goals and targets for state government. The goals and targets for state-owned and state-operated buildings will be more aggressive than those for buildings owned and operated by private entities. These goals and targets will be adopted no later than December 2012, and implementation will begin immediately.

Parties Involved: The multi-agency entity will include representatives from each cabinet and a representative from the Governor's Office, the state court system, and the legislature.

Other: State government efforts to reduce GHG emissions and improve energy efficiency and energy intensity will have direct ancillary benefits of improving air quality by reducing corresponding emissions to the ambient air.

Implementation Mechanisms

- Public education and outreach team established under CCI-2.

- Work with the responsible authority established under CCI-4 to establish goals and targets for state-owned and -operated buildings and state transportation mechanisms and policies.
- Legislative action to identify, fund, and implement actions to fulfill "lead by example" policy options.
- Identify opportunities using state-owned property, such as state parks and reserves, to increase biological sinks with a goal of offsetting state GHG emissions.
- Performance contracting/Green Bank ($14.2 million) for energy efficiency in state buildings.
- Leasing of solar/wind equipment to lower costs.
- Invest in programs, such as PACE (Property Assessed Clean Energy), that assist municipalities with energy efficiency and renewable energy projects.
- Formulate criteria and evaluation mechanisms to gauge the effectiveness of these initiatives.

Related Policies/Programs in Place

- NEED Project—With network of regional coordinators across the state, do teacher training, supply materials, help develop school energy teams, projects, and awards (http://www.need.org/).
- Green and Healthy Schools—Students do inventories on various environmental topic areas (energy, waste, indoor air quality, stormwater runoff, etc.), devise plan, and implement projects (http://www.greenschools.ky.gov/).
- Kentucky Energy Efficiency Program for Schools—Engineering and technical assistance to implement the ENERGY STAR 7-step process toward energy efficiency (http://louisville.edu/kppc/keeps).
- School Energy Managers Program—An American Recovery and Reinvestment Act of 2009 (ARRA)-funded program to place 36 energy managers in clusters of schools across the state to help them implement the 7-step energy efficiency program. Its goal is to have energy managers produce enough cost (and energy) savings to earn their salary when ARRA funding goes away (http://www.ksba.org/energy-management).
- Hybrid School Bus Program—$13 million to deliver 213 hybrid school buses across the state.
- Green Bank of Kentucky—An approximately $14 million loan fund for state government buildings (http://finance.ky.gov/greenbank/).
- KY Home Performance—$6.1 million to implement an energy efficiency retrofit program for residential property—sets standards, training, certification for building energy auditors (Building Performance Institute) and installers, audit software and database to track savings, and revolving loan/rebate program (kyhomeperformance.org).
- See all programs at: http://energy.ky.gov/StimulusPrograms/Pages/default.aspx.

Type(s) of GHG Reductions

Not applicable.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

- Funding available to accomplish the goals.
- Potential legal challenges.
- Continued commitment within all branches and departments of state government.
- Effectiveness of education effort to align state employee interests with policy options.
- Sustainability of ARRA-funded programs—most are designed to have some longevity beyond funding periods (e.g., revolving loan fund, installations in buildings last), but funding depends upon the success of design and implementation.

Additional Benefits and Costs

- Increasing the energy efficiency of state and local government properties saves money.
- Policies to reduce GHG emissions often reduce emissions of other air pollutants, thereby improving overall air quality and public health.

Feasibility Issues

Availability of funding to accomplish the goals.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

CCI-6. Local GHG Emission Reduction, Energy Intensity, and Energy Efficiency Actions

Policy Description

Many communities across Kentucky are actively engaged in developing GHG emission reduction strategies, are seeking energy savings through energy intensity and energy efficiency initiatives, and are striving to achieve effective air quality improvements. These communities' existing efforts will be encouraged and supported by the Commonwealth. Additional communities interested in evaluating the vulnerabilities and opportunities posed by pending state and federal legislative changes and by predicted climate change will be provided encouragement and tools for developing a local plan of action.

To leverage these efforts, the state will develop a tool kit for local governments, institutions, and individuals to assist in planning and implementing effective strategies. The tool kit will utilize nationally recognized best practices (ICLEI–Local Governments for Sustainability, ENERGY STAR, LEED, etc.) to provide assistance with GHG emission reduction, energy intensity, and energy efficiency actions, and will collect "best lessons learned" by entities throughout the Commonwealth. It is not the intent of the state to utilize this policy to mandate how local governments or organizations should address this planning process. Rather, the state will be a partner to local communities by supporting, assisting, and coordinating these efforts where appropriate or beneficial.

The Commonwealth also recognizes that its communities need assistance with implementing their plans. The state will establish a "help desk" to share information and resources with its communities.

Policy Design

Goals: The state will make available to local communities the necessary tools for planning for potential climate change and associated legislative changes. These tools will be designed to include educational materials, coordination with state and other communities, facilitation of planning sessions, and information about potential economic impacts and opportunities ahead.

Local government units, whether county, city, or otherwise, will have the opportunity to participate in learning about and commenting on the state's plan of action. This opportunity will help local planners better coordinate with planning activities already underway and use and learn from work already completed.

The state will establish a help desk to provide assistance to communities in preparing and implementing plans through actions to reduce energy use, educate their communities, and lead in efficiency, reduction, and intensity. This help desk can provide technical assistance with questions like:

- How do I get an energy audit done?

- What materials are available to use for education and outreach to commercial and industrial businesses and organizations in my community?
- How can I get help with writing a bid specifications proposal for procuring energy-efficient equipment?
- How do I identify and apply for available grant funding to tackle our projects?

Timing: As the state, through its many initiatives developed under the Kentucky Climate Action Plan, learns about and identifies processes or actions that are effective in increasing energy efficiency, reducing GHG emissions, and addressing energy intensity, it will make those tools available to local governments. This process will be ongoing and will begin with development of the first climate action plan. The statewide process to develop consensus on targets and goals for GHG reduction, energy efficiency, and energy intensity will serve as a means to communicate the tools under development by the state, and most important, as a means to listen to the needs of the local communities across the state to guide further development, both of helpful tools and of the goals and targets themselves.

Parties Involved: This effort should be coordinated by the multi-agency body established by the Governor to direct the state “lead by example” policy. Other participants will be representatives of local governmental bodies and interested citizens engaged in local planning and implementation actions.

Other: None identified.

Implementation Mechanisms

- League of Cities, Department for Local Government, Kentucky Association of Counties, Kentucky Area Development Districts, etc., share message.
- NEED.
- KEEC.
- Programs, such as PACE, that assist municipalities with energy efficiency and renewable energy projects.
- Newsletters, Kentucky Energy Watch, Web sites, workshops, conferences.

Related Policies/Programs in Place

Kentucky received $69 million in ARRA funding for the energy sector. DEDI has funded 40 projects, some of which are listed at http://energy.ky.gov/StimulusPrograms/Pages/default.aspx.

Type(s) of GHG Reductions

Not applicable.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

Factors that drive demand, interest, and affordability, such as:

- Economy.
- Price of power and fuel.
- Interest of partners to help promote and share information.
- Level and type of incentives available, especially to local governments.
- Availability of funding to accomplish the goals at the state and local government levels.

Additional Benefits and Costs

- Increasing the energy efficiency of state and local government properties saves money.
- Policies to reduce GHG emissions often reduce emissions of other air pollutants, thereby improving overall air quality and public health.

Feasibility Issues

Funding availability to accomplish the goals.

Status of Group Approval

Approved.

Level of Group Support

Unanimous.

Barriers to Consensus

None.

CCI-7. Financial Policies

Policy Description

Recognizing that some policy decisions to reduce GHG emissions will have costs, Kentucky must develop long-term funding to implement KCAPC-adopted actions. This will require that a framework be established and funding sources be identified that will be available to public–private partnerships focused on improving energy efficiency and intensity. To accomplish this policy, Kentucky will formulate a financial and regulatory structure that promotes investments in cost-effective initiatives to promote improvements in energy efficiency and intensity.

Policy Design

Goals: In order to secure financing required to implement KCAPC-adopted actions in the long term, to ensure efficient allocation of limited resources, and to deploy efficiency, emission- and intensity-reduction strategies at scales across the Commonwealth, Kentucky will strive to achieve the following goals:

- Establish a revolving loan program, initially funded by the legislature and supported by receipt of low-interest payments, to fund required changes that improve energy efficiency and intensity, potentially structured as a performance savings contract.
- Identify and aggressively pursue available grants, loans, and other funding to provide capital funding and operational assistance for changes within the public and private sectors in adapting to climate change and related policy changes.
- Provide for an economic analysis that identifies the least-cost and most effective alternative to improve energy efficiency and energy intensity for each goal in the Climate Action Plan.
- Develop a marketing plan to attract appropriate investment by existing companies and new investors in Kentucky's resources, taking into consideration the potential for increased energy costs.
- Identify streamlining actions that can be implemented for permitting new businesses or adopting revised permits for existing businesses, in order to best address changes in policy, law, and regulation.
- Take advantage of existing programs as vehicles for funding (e.g., Kentucky Bluegrass Turns Green, Green Bank of Kentucky).

Timing

- The legislature should consider and adopt a revolving loan fund during the 2011 or 2012 session to be administered by the appropriate entity of state government, and should identify the source and amount of funding to initiate and support the loan fund.
- The state will immediately create a point of contact within each appropriate cabinet to aggressively seek and pursue funding from sources outside the state. All state employees charged with this goal will coordinate with each other to ensure efficient use of resources.

- The KCAPC will include the requirement for the economic analysis in its Climate Action Plan and will recommend the means for implementing this plan.
- The Climate Action Plan will immediately be reviewed by CED, with appropriate assistance from DEDI, and will develop a plan of action during 2011.
- KEEC will develop a plan to streamline permitting processes likely to be impacted by changes in policy, law, and regulation during 2011, and will then provide that proposed plan to stakeholders throughout the Commonwealth for input and final plan development during 2011 or 2012.

Parties Involved: The appropriate entity of state government will be primarily responsible for implementing the goals, and will seek the input of stakeholders in business, local government, and the higher education community. The Kentucky Science & Technology Corporation will play a vital implementation role in providing financing for economic development opportunities related to the Climate Action Plan.

Other: The Attorney General and PSC may be involved in addressing regulatory barriers to implementation of efficiency improvements and emission reduction projects.

Implementation Mechanisms

- Conduct an assessment of existing financing programs throughout the state, identifying successful models and approaches, as well as assessing the needs of current programs.
- Provide for an economic analysis that identifies the least-cost and most effective alternative to improve energy efficiency, emission reductions, and energy intensity for each goal in the Climate Action Plan for the purposes of guiding investment decisions.
- Establish the requisite framework to establish financing vehicles, including a revolving loan fund, a guarantee fund, and bond authorities where appropriate.
- Coordinate with existing state agencies and public entities supporting relevant projects, and pursue available federal and international assistance where possible.
- Build upon the success of existing programs as vehicles for funding (e.g., Kentucky Bluegrass Turns Green, Green Bank of Kentucky), and partner with established private and nonprofit efforts already underway in this sector.
- Develop a marketing plan to attract appropriate investment by existing companies and new investors in Kentucky's resources, taking into consideration the potential for increased energy costs.
- Develop clear partnerships with private business, local government, and community groups to identify and attract economic development that will benefit from and contribute to Kentucky's resources.
- Choose the most cost-effective alternative in making decisions about climate change adaptation, considering investment and operating costs as well as potential savings from improved energy efficiency and energy intensity.

- Identify ways Kentucky can shorten regulatory time frames for new permitting or revised permitting occasioned by changes in law and policy, in order to conserve both time and money in making required changes, while continuing to provide appropriate protections of Kentucky's natural resources and the health of its citizens.
- Identify regulatory hurdles to implementation of energy efficiency and energy intensity improvements across all sectors from energy production, use, transportation, and manufacturing.

Related Policies/Programs in Place

- The Bluegrass Turns Green program established by HB 2 allows for both a public-sector grant fund and a private-sector loan fund subject to specific stipulations identified by the legislature. Lack of capital has prevented this program from making progress.
- The Green Bank of Kentucky, initially capitalized through ARRA, provides financing to state entities for the purpose of carrying out construction upgrades or retrofits intended to reduce energy use and costs. The capital is then paid back through the realization of energy savings, replenishing the fund. Following the expenditure of ARRA funding, tax-exempt bonds may be issued to capitalize the program.
- The Kentucky Science and Technology Corporation administers several existing funds, including the Kentucky Enterprise Fund, Rural Innovation Fund, and New Energy Ventures, that provide financing for projects throughout Commonwealth. Additionally, the Kentucky Science and Engineering Foundation administers the Commercialization Fund Program. These examples can serve as models for the development of economic development-oriented funds to support projects in line with the Climate Action Plan.

Type(s) of GHG Reductions

Not applicable.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

- The financial resources able to be committed by the state for initial capitalization.
- The ability to partner with private-sector and public-sector organizations.
- The ability to raise private capital to supplement state financing.
- The cost of conducting a due-diligence process and developing criteria and funding guidelines.

- The timeline for legislative action and implementation of the Climate Action Plan.

Additional Benefits and Costs

- Reduce upfront costs for implementation of emission reduction and energy efficiency measures.
- Allow for scaled response to opportunities beyond the reach of state-administered agency programs.
- Enable broad access to financing resources across the state by working through partners.
- Provide consistent financial support for efficiency and economic development programs that can be targeted to benefit low-income Kentuckians.

Feasibility Issues

Availability of adequate funding.

Status of Group Approval

Approved.

Level of Group Support

Unanimous, with one abstention by the PSC representative, due to a potential conflict with a pending case.

Barriers to Consensus

None.

CCI-8. Conduct an Impact Analysis of Federal GHG Constraints on Kentucky

Policy Description

Kentucky is the third-largest coal producer in the United States and has an electricity generation fleet that is more than 90% coal-fired. Approximately 49% of that power is delivered to an industrial sector that produces automobiles, appliances, aluminum, stainless steel, chemicals, and other products. With its high reliance on coal to meet its electric energy needs, Kentucky may be subject to disproportionally large economic and infrastructure impacts as a result of federal action to limit GHG emissions, relative to states with more options available to them, or relative to states with less industrial development. It is therefore imperative for Kentucky to make its voice and the voice of similar states heard in the national dialogue, to have a thorough understanding of its vulnerability, and to have in place an adaptation plan if and when such legislation or regulation is adopted (see CCI-3). It is also critical that Kentucky analyze the impacts of higher electricity rates upon its economy, beginning with the industrial sector (see CCI-3). In addition to vulnerability analysis associated with federal action and increased electricity costs, it is critical that Kentucky evaluate opportunities that may have a positive impact upon its economy.

Federal legislation and regulations tend to assume that one size fits all, which is not the case for Kentucky and several of its neighbors. Because the execution of policies designed to reduce climate change affects regions of the country differently, and the availability and feasibility of energy solutions vary between regions, the one-size-fits-all approach can result in inequitable regional impacts. For this reason, collaborative regional and multistate reduction efforts offer promising possibility for developing compliance strategies that provide for greater opportunities for effective and sustainable successes. Kentucky and several of its neighboring states rely heavily on coal for their current energy supply, and coal is a major part of their economies. Utilizing alternative energy resources, clean coal technology, energy efficiency, and renewable resources through blended energy portfolios can result in a more diverse energy economy with acceptable economic costs.

Any regulatory framework on emissions must be constructed in a way that does not arbitrarily punish a Kentucky manufacturer for GHG emissions if that manufacturer is producing a greater amount of product for equal or lesser emission levels than equivalent activities elsewhere when adjusted for the regional energy portfolio. To avoid this disparity, a normalization approach, taking into account the amount of energy required and the value of the products produced, should be implemented.

Kentucky should take the leadership role in forming a regional group or consortium with similar states, to ensure regional interests are represented and protected while meeting the overarching goal of reducing GHGs.

Policy Design

Goals

- Have a clear understanding of the sources of GHGs, and analyze the potential effects of federal climate change policy, including legislation and/or regulations affecting these sources.
- Work to form and develop partnerships with states with similar interests to attempt to influence federal regulation or legislation, so as to maximize the opportunity to Kentucky and to minimize the negative impacts.
- Evaluate available alternatives and their costs for mitigating GHG emissions required by various federal proposals, as well as the economic benefits associated with increased efficiency or the development of energy resources in Kentucky. Such strategies would propose to mitigate GHG emissions in various sectors, including energy supply, residential, commercial, industrial, transportation, land use, agriculture, forestry, and waste management.
- Develop estimates of the impact of federal GHG actions on Kentucky's economy, initially by focusing on the impact of increased electricity prices on the industrial sector.
- Present and inform Kentucky's government, business leaders, and the public about the results of these analyses and adaptation plans.

Timing: The KCAPC effort will result in a suite of options for GHG mitigation, including discussion of any limitations (technological or economic), and will provide an estimated cost per ton mitigated. In addition, DEDI is building capacity to model the effects of diversification of electricity generation on prices of electricity and on emission levels, as well as on economic development within the Commonwealth. By June 2011, Kentucky will have an estimate of the impact of increased electricity rates on the industrial sector.

Independently, Kentucky will take on a leadership role in the identification of partner states with similar interests regarding federal GHG mitigation policies, and will work to develop partnerships that protect the state's interests. Initial contact and discussions among potential partner states will be undertaken during fiscal year 2010–2011. DEDI will periodically report progress and issues.

Parties Involved: DEDI, CED, PSC, the University of Kentucky, and other stakeholders identified within the evaluation.

Other: None.

Implementation Mechanisms

- Kentucky will take a leadership role in developing a partnership with similar states to evaluate both costs and opportunities and to attempt to influence regulations and legislation. This effort will be carried out by the Governor's Office and KEEC.
- DEDI will evaluate research conducted by federal agencies and others on the impact of mitigating GHG and other emissions.

- DEDI will continue to build capacity for evaluation of the diversification of electricity generation portfolios.
- Research at the University of Kentucky's Center for Business and Economic Research is underway to evaluate the effects of increases in electricity rates within the Commonwealth upon the industrial sector.
- Research continues in several areas in the evaluation of lower-carbon alternative energy resource opportunities in Kentucky.

Related Policies/Programs in Place

- DEDI modeling efforts.
- Research at the University of Kentucky and other state and regional universities.
- CED's evaluation of energy projects for incentives.
- Regional organizations, such as the Southern Governors' Association.

Type(s) of GHG Reductions

Not applicable.

Estimated GHG Reductions and Net Costs or Cost Savings

Not applicable.

Data Sources:

Quantification Methods:

Key Assumptions:

Key Uncertainties

Availability of funds to continue the research and analysis.

Additional Benefits and Costs

This analysis may show benefits or costs to diversification of energy supply.

Feasibility Issues

- Data needs.
- Availability of funds to perform additional work.

Status of Group Approval

Approved.

Level of Group Support

Unanimous, with one abstention by the PSC representative due to a potential conflict with a pending case.

Barriers to Consensus

None.

Appendix J
Comments on the Draft Final Report from KCAPC Members and Agency Staff

Talina Mathews, Kentucky Public Service Commission (10-6-11)

Anywhere that my name is in the final draft, it should refer to me with the notation of "formerly…" so that it is clear that the work was done as a part of my role at DEDI/EEC.

John Voyles, LG&E and KY Energy LLC (10-14-11)

Thanks for the opportunity to comment on the draft report. As I stated at more than one of the KCAPC meetings, this work served as a starting point for future conversations with policymakers and will require continued evaluation prior to any implementation of the recommendations in the report. Clearly, it should be noted this report is a "snapshot" in time and would need to be further refined, challenged, verified and validated. While I provided votes on the recommendations to accept most of the information in this effort and this report, those votes did not represent endorsement of a plan, which should be implemented. This plan serves as a document from which our policy makers can use in their future deliberations, should those occur.

Below find my specific comments and suggestions on the draft report:

- Page iii – please change the company name under Vic Staffieri to read **"LG&E and KU Energy, LLC"** instead of E.ON U.S. (if you need to leave this as originally selected then I suggest you say "formerly E.ON U.S."
- Page ExS2 – first bullet under Key Elements and Recommendations – Make the first sentence read "The KCAPC took into account Governor Steven Beshear's *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence* in proposing GHG reduction goals for Kentucky to achieve a 20% reduction of GHGs below 1990 levels by 2030….. "
- Page ExS2 – add to the closing paragraph of the Key Elements and Recommendations section the following sentences – "The data and costs presented in this report are based on the information and assumptions available at the time of the analyses. Data at a future point in time may produce different results and as such policy recommendations chosen for action at a future date should be updated accordingly."
- Page ExS4 – add a sentence to the third bullet – "Those energy intensive industries provide valuable goods and services to many states beyond the borders of Kentucky."
- Page ExS-8 – add the following words to begin the first sentence last paragraph - **"Based on the assumptions used in 2010, Table ExS-2 depicts….."**
- Page ExS-9 – add a sentence at the end of the paragraph before Table ExS-3 – "For the column labeled Level of Support, it is important to note Unanimous Approval applies only to those KCAPC members present at the time of the approval vote."

- Page 1-2 – add the following to the end of the first sentence in the second bullet – "….below 1990 levels by 2030, consistent with Governor Steven Beshear's *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence*."
- Page 1-4 – in the next to last paragraph which describes the voting and begins with "The KCAPC process employed…" – I suggest adding the following to the end of the paragraph – **"It is important to note that not all KCAPC members were available to attend all meeting where voting was conducted, so the results reflect only votes from those present at the meetings."**
- Page 1-6 – section titled Estimates of Costs/Cost Savings – the third bullet is not a complete sentence, so I don't know what was intended to be written there.
- Page 1-6 – section titled Estimates of Costs/Cost Savings – I believe the first paragraph needs to have a qualifying sentence added – **"The estimated costs used in the analyses of the policy options were based on the assumptions and data from 2010 which should be revisited if any future actions are considered for implementation."**
- Page 1-8 – add the following to the last bullet, consistent with the comment above - "Those energy intensive industries provide valuable goods and services to many states beyond the borders of Kentucky."
- Page 1-10 – last bullet – add to the end of the first sentence – "(Consistent with Governor Steven Beshear's *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence*.)"
- Pages 1-13 through 1-20 – add a footnote to the Level of Support column in each table – **"Unanimous Approval received from the KCAPC members present at the time of the approval vote."**
- Page 1-20 – in the first paragraph under the Perspectives on Policy Recommendations, add to the end of the first sentence – **"… based on the assumptions and data from 2010."**
- Page 4-1 – add to the end of the first paragraph - "Those energy intensive industries provide valuable goods and services to many states beyond the borders of Kentucky."
- Page 4-5 – second paragraph – add to the end of the first sentence – **", but can come with substantial costs."**
- Page 4-6 – top partial paragraph – delete the following text from the end of the first and second lines on the page – **"…when combined with the presumed increased costs for fossil fuel generated electricity."** (this text it is not needed to make the point and it is also possible that fossil fuel generated technology costs could come down over time with technological advances as well.)
- Page 4-9 – add to the third bullet – **"advanced natural gas combined cycle (NGCC)"** (as this technology was included in the policy descriptions.)
- Page 4-11 and page 4-12 – shouldn't both the FIT and the RPS paragraph descriptions have a sentence to indicate that both are not necessarily required (it could be either one?) – suggest adding at least a footnote to that affect.

- Page 5-2 – the paragraph under Figure 5-1 quotes growth rates of 1.6% and 1.4% - add to the first sentence at the end – **“based on the assumptions and data from 2010.”**
- Page 5-4 – first paragraph under Key Challenges and Opportunities – suggest deleting the word **“abundant”**
- Page 5-4 – first paragraph under Key Challenges and Opportunities – what is the definition of **“green collar jobs”** and who determines what those are? I suggest the reference to green collar be deleted and we just refer to them as the jobs created by the energy efficiency opportunities.
- Page 5-9 – last sentence of the top paragraph – again the reference to **“green collar jobs”** should be deleted and reworded.
- Page 5-11 – last paragraph under RCI-5 – the term **“Green Mortgages”** appears here and in the RCI appendix as well - I did not see this term used in any previous drafts of the policy options from the TWGs work. It is not in the last set of options posted on the web. What is a “green mortgage” and why is it here? Suggest it be removed from both places.
- Page 7-1 – the first sentence in the second paragraph speaks to adoption of policy recommendations by the KCAPC members present. Why is this sentence not utilized in each of the policy sections?

Please let me know if these comments need further explanation.

Bob Amato, Kentucky Energy and Environment Cabinet (10-17-11)

- In Chapter 1, page 1-7 has an omission: “individuals, companies, and/or government agencies. In contrast, conventional cost-benefit analysis takes the “societal perspective,” and tallies every conceivable impact on every entity in society (and quantifies these wherever possible).” is omitted from the top of the page. (the last line of page 1-6 is left hanging.
- Remove the “Level of Support” column from all of the Policy Recommendation tables in the report.
- P ExS-11, In Table ExS-3: the ES-1 row I think that an asterisk should be next the “Total” row; In the ES-3 row the asterisk should be next to the Scenario 3, 1600 MW.
- ES-12 should be deleted from Table Exs-3 since it was not approved by the Council.
- ES-12 should be deleted from Table 1-4 since it was not approved by the Council.
- The asterisks in Table 1-4 should be consistent with those in Table ExS-3 and Table 4-2.
- P 4-6 under “Overview of Policy Recommendations and Estimated Impacts” the second sentence should begin: “The policies analyzed and approved…”
- ES-12 should be deleted from Table 4-2 since it was not approved by the Council.

Kentucky Public Service Commission Comments (submitted on 10-19-11 by Bob Amato, compiled from notes taken on 10-17-2011)

- "Level of Support" column—Throughout the report: Remove the "Level of Support" column from all of the Policy Recommendation tables in the report.
- Page ii – 3rd paragraph: Many thanks to Dr. Talina Mathews, who during much of this process was the Assistant Director of ….
- Page ExS-2 (beneath bullets) bold the entire paragraph: **It is important to note that this set of recommended policies is presented to Secretary Peters for consideration. It is acknowledged that these recommendations would require further review and analysis prior to any action. It is also acknowledged that many of these recommendations would require action by other entities, ~~such as~~including the Kentucky General Assembly and the Kentucky Public Service Commission.**
- Page ExS-3: …final I&F report, which was approved by the KCAPC at its meeting on June 2, 2010, is summarized in Chapter 2 of this report and is available in its entirety at: http://www.kyclimatechange.us/ewebeditpro/items/O122F23537.pdf. It is important to note that the analysis was done in 2009–2010 and recent announcements by utilities and more recent actions by USEOA are not included.
- Page ExS-18: Figure ExS-6 presents the estimated dollars-per-ton cost (or cost savings, depicted as a negative number) for each policy recommendation for which cost estimates were quantified, expressed as a cumulative figure for the period 2011–2030. This measure is calculated by dividing the net present value of the cost of the policy recommendation by the cumulative GHG reductions, all for the period 2011–2030. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments. *Comment from PSC: The highlighted sentence above needs to be repeated in all instances when discussing negative net present value.*
- Page ExS-19: Figure ExS-7 …. Note that recommendation steps appearing below the "$0" line near the middle of the graph (on the vertical axis) are cost-saving measures, while the recommendations above this line have positive net direct costs. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.
- Page ExS-20:
  - $/tCO2e = dollars per metric ton of carbon dioxide equivalent; BAU = business as usual; GHG = greenhouse gas; KY = Kentucky; AFW = Agriculture, Forestry, and Waste Management; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply.
  - Negative values represent net cost savings, and positive values represent net costs associated with the policy recommendations. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.
  - Note: Results have been adjusted to remove overlaps between policies.

- Page 1-1: Page ExS-2 (beneath bullets) bold the entire paragraph: It is important to note that this set of recommended policies is presented to Secretary Peters for consideration. It is acknowledged that these recommendations would require further review and analysis prior to any action. It is also acknowledged that many of these recommendations would require action by other entities, ~~such as~~including the Kentucky General Assembly and the Kentucky Public Service Commission.

The KCAPC's Response to the Kentucky Public Service Commission's Comments
(submitted on 10-19-11 by Bob Amato)

- Page 1-2: ~~The KCAPC members present and voting approved 40 policy actions unanimously, approved 5 by a super majority (five objections or fewer), approved 1 by a majority (fewer than half object), and rejected 1 option.~~ Of the 46 policy recommendations, 33 were analyzed quantitatively to have a cumulative effect of reducing GHG emissions by about 63.7 million metric tons of carbon dioxide equivalent (MMtCO2e) in 2020 and 128.3 MMtCO2e in 2030. Explanations of all policies and any objections are in Appendices E through I of this report, which contain detailed accounts of the KCAPC's recommendations.
    - Recommendation that Kentucky ~~adopt~~ evaluate a statewide … process.
    - Evaluation of … cost-saving opportunities for Kentucky, but may have significant initial costs. Other policies will incur net costs.
- Page 1-6: *Cost savings*—Total net costs … (typically through fuel savings and electricity savings associated with new policy actions). It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.
- Page 1-7:

  Kentucky GHG Emissions Inventory and Reference Case Projections

  In January 2010 … at its third meeting on June 2, 2010. It is important to note that the analysis was done in 2009–2010 and recent announcements by utilities and more recent actions by USEOA are not included.

- Page 1-12: Table 1-3 depicts … overlaps. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments. For the policies recommended by the KCAPC to yield the levels of estimated emission reductions shown in Table 1-3, they must be implemented in a timely, aggressive, and thorough manner.
- Page 1-22:
    - CO2 = carbon dioxide; GHG = greenhouse gas; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply; AFW = Agriculture, Forestry, and Waste Management.
    - Negative values represent net cost savings, and positive values represent net costs associated with the policy recommendations. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.

- Page 1-23: $/tCO2e = dollars per metric ton of carbon dioxide equivalent; BAU = business as usual; GHG = greenhouse gas; KY = Kentucky; AFW = Agriculture, Forestry, and Waste Management; RCI = Residential, Commercial, and Industrial; TLU = Transportation and Land Use; ES = Energy Supply. Negative values represent net cost savings, and positive values represent net costs associated with the policy recommendations. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.
- Page 2-1: Historical GHG … Inventory and Projections report. It is important to note that the analysis was done in 2009–2010 and recent announcements by utilities and more recent actions by USEOA are not included.
- Page 2-10:

  Electricity Supply:

  The electricity sales forecast was changed from ~~reliance~~ relying solely on the Energy Information Administration's Annual Energy Outlook 2009 (AEO 2009) forecast ~~to that of the most~~but was enhanced with recent Kentucky utility forecasts provided to the Kentucky Public Service Commission. On average, this resulted in an increase in the electricity sales growth rate from about 0.5%/year to about 1.5%/year over the 2007–2030 period. The projections do not account for utility actions to comply with new or pending USEPA regulations.
- Page 4-1:

  Chapter 4 Energy Supply

  It is acknowledged that the Kentucky Public Service Commission participated in discussing the policy recommendations in this chapter. However, the Kentucky Public Service Commission did not take a position for or against any policy recommendation that could come before it in an adjudicated proceeding. It is also acknowledged that the KPSC may need additional statutory authority to consider some of the policy recommendations should they be proposed by a regulated utility.
- Page 4-5 and 4-6:

  Overview of Energy Supply Emissions

  Renewable energy generation is another opportunity. ~~While there remains some uncertainty about the~~The availability of adequate wind and solar resources ~~and thus~~as well as the current cost-effectiveness of these generation technologies in Kentucky is uncertain. The cost-effectiveness will improve over time with technological and fabrication advances when combined with the presumed increased costs for fossil fuel generated electricity. ~~Providing incentives for wind and solar~~

  ~~power development~~ Studying and testing ~~and studying~~ how and where ~~these~~ wind and solar technologies might be best applied and then providing incentives will help ensure that renewable energy opportunities are not missed.
- Page 4-6:

  Overview of Policy Recommendations and Estimated Impacts

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The Kentucky Climate Action Plan Council (KCAPC) analyzed and is recommending for the secretary's consideration multiple policies and sub policies for the ES sector that offer the potential for significant GHG emission reductions. The policies analyzed are summarized…

- Page 4-9—First Paragraph, last sentence:

Some lacked data upon which to reasonably base analysis, ~~and~~ while others were enabling policies that allow ~~other~~ subsequent policies to operate, but do not offer measurable reductions on their own.

- Page 4-11:
  - Second sentence under ES-5:

Pricing strategies can be used to encourage energy efficiency, conservation, and demand response. Some pricing mechanisms encourage utilities to facilitate their customers' reduction in consumption, while others encourage customers to reduce consumption directly. Three pricing strategies were analyzed. With ~~a~~ time-of-use pricing customers are charged a different rate for electricity during different time blocks during the day corresponding to the utility's cost to produce electricity during that time.

  - Second Paragraph under ES-5:

Interconnection rules and net metering policies can facilitate the cost-effective interconnection and expansion of renewable and distributed energy resources onto the power grid. ~~, supporting the expansion of the supply of renewable electricity.~~ The goal of this policy is to establish effective net metering and interconnection rules to facilitate the connection of renewable or distributed energy resources to the grid.

  - Third Paragraph under ES-5:

A feed-in tariff (FIT) establishes above market rates for renewable power and mandates electric utilities to purchase that renewable power under long-term contracts ~~at these above market rates~~. A Kentucky FIT should apply to the following renewable energy technologies: solar, wind, low-impact biomass/biogas, and hydroelectric. Utilities would be mandated to purchase power from any renewable energy generator within the state who meets the technical requirements. Residential and small commercial systems would all be eligible to participate.

- Page 4-12:

ES-7. Renewable Energy Incentives and Barrier Removal, Including ~~CHP~~Combined Heat and Power

gradually increasing percentages of renewable energy resources or energy efficiency demand reductions ranging from 3% of sales ~~through~~ in 2013 to 15% beginning in 2021. The

- Page 5-1:

Chapter 5 Residential, Commercial, and Industrial Sectors

It is acknowledged that the Kentucky Public Service Commission participated in discussing the policy recommendations in this chapter. However, the Kentucky Public Service Commission did not take a position for or against any policy recommendation that could *come before it in an adjudicated proceeding. It is also acknowledged that the KPSC may need additional statutory authority to consider some of the policy recommendations should they be proposed by a regulated utility.*

- Page 5-1, 3rd paragraph:

  Overview of Sectoral Greenhouse Gas Emissions

  Historical and projected … and coal (3%). The projections do not account for utility actions to comply with new or pending USEPA regulations.

- Page 5-5, last full paragraph:

  The KCAPC recommends for the secretary's consideration a set of nine policy options for the RCI sectors, …

- Page 5-7, top of page:

  GHG = greenhouse gases; MMtCO2e = million metric tons of CO2 equivalent; UC = unanimous consent; NA = not applicable; TWG = technical work group

  Negative cost effectiveness values reflect economic savings. It is important to note that some of the policy options with an estimated cost savings still are likely to require significant up-front capital investments.

- Page 5-10 through 5-13:

  Overlaps within RCI

  Delete "By unanimous vote" from the beginning of each policy option description.

- Page 6-3, bottom of page:

  Table 6-1 on the next page provides…by the Kentucky Climate Action Council (KCAP). It is important to note that the analysis was done in 2009–2010 and recent announcements by utilities and more recent actions by USEPA are not included. The KCAP recommends for the secretary's consideration …

- Page 7-1:

  The CCI TWG developed eight policy recommendations for the secretary's consideration ~~eight policies~~ (see Table 7-1) that were then reviewed, revised, and ultimately adopted by the KCAPC members present and voting. Seven of the recommendations are focused on enabling GHG emission reductions and mitigation activities, while one (CCI-3–Adaptation and Vulnerability) addresses adaptation to the changes expected from the effects of GHGs that will remain in the atmosphere for decades.

- Page 7-5

  CCI-4. Statewide GHG Emission Reduction, Energy Intensity, and Energy Efficiency Goals, Targets and Metrics

  The KCAPC recommends for the secretary's consideration the following goals, taking into account Governor Steven Beshear's *Intelligent Energy Choices for Kentucky's Future, Kentucky's 7-Point Strategy for Energy Independence:*[2]

Rocky Adkins, Kentucky House of Representatives (10/21/11)

16470

Commonwealth of Kentucky

HOUSE OF REPRESENTATIVES

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Bob Amato

HOUSE MAJORITY FLOOR LEADER

Received
OCT 2 1 2011
Office of the Secretary
Energy & Environment Cab

October 19, 2011

Mr. Len Peters
Secretary
KY Energy and Environment Cabinet
500 Mero Street
Frankfort, KY 40601

Dear Secretary Peters:

Thank you for your leadership and efforts to move Kentucky's energy future forward. While I appreciate your inclusion of the Legislative branch in the process to develop a Climate Action Plan for the Commonwealth, I was able to attend only one of the working meetings due to conflicts with my Legislative calendar.

Since I have been unable to participate and because some recommendations of the plan may come before the General Assembly for action, I would like the record of Climate Action Plan proceedings to reflect that I am not endorsing or supporting the final report of the Climate Action Plan.

Sincerely,

Rocky Adkins

Rep. Rocky Adkins
Majority Floor Leader

J. Dorsey Ridley, Kentucky State Senate (10/31/11)

16485

Commonwealth of Kentucky

STATE SENATE

STATE SENATOR
DISTRICT 4
CALDWELL, CRITTENDEN,
HENDERSON, LIVINGSTON,
UNION & WEBSTER COUNTIES

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J. DORSEY RIDLEY

October 31, 2011

Received
NOV 02 2011
Office of the Secretary
Energy & Environment Cab

Mr. Len Peters
Secretary
KY Energy and Environment Cabinet
500 Mero Street
Frankfort, KY 40601

Dear Secretary Peters:

Thank you for your leadership and efforts to move Kentucky's energy future forward. While I appreciate your inclusion of the Legislative branch in the process to develop a Climate Action Plan for the Commonwealth, I was unable to attend the working meetings due to conflicts with my Legislative calendar.

Since I have been unable to participate and because some recommendations of the plan may come before the General Assembly for action, I would like the record of Climate Action Plan proceedings to reflect that I am neither endorsing nor opposing the final report of the Climate Action Plan.

Sincerely,

J. Dorsey Ridley

J. Dorsey Ridley
Kentucky State Senate