DRAFT Kansas Greenhouse Gas Inventory and Reference Case Projections 1990-2025

Center for Climate Strategies
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Executive Summary

The Center for Climate Strategies (CCS) prepared this report for the Kansas Department of Health and Environment (KDHE). The report presents a preliminary assessment of the State's greenhouse gas (GHG) emissions from 1990 to 2025. The inventory and forecast estimates serve as a starting point to assist the State, as well as the Kansas Energy and Environmental Planning Advisory Group (KEEP) and technical work groups, with an initial comprehensive understanding of Kansas' current and possible future GHG emissions, and thereby inform the upcoming identification and analysis of policy options for mitigating GHG emissions. This preliminary draft report will be provided to KEEP and technical work groups for review and will be revised, as needed, to address comments approved by KEEP.

Kansas' anthropogenic GHG emissions and anthropogenic sinks (carbon storage) were estimated for the period from 1990 to 2025. Historical GHG emission estimates (1990 through 2005)[1] were developed using a set of generally accepted principles and guidelines for State GHG emissions, relying to the extent possible on Kansas-specific data and inputs when it was possible to do so. The initial reference case projections (2006-2025) are based on a compilation of various projections of electricity generation, fuel use, and other GHG-emitting activities for Kansas, 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 US 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 equivalents (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.[2]

As shown in Table ES-1, activities in Kansas accounted for approximately 103 million metric tons (MMt) of *gross*[3] CO_2e emissions (consumption basis) in 2005, an amount equal to about 1.4% of total US gross GHG emissions in 2005.[4] Kansas' gross GHG emissions are rising slower than those of the nation as a whole (gross emissions exclude carbon sinks, such as forests). Kansas' gross GHG emissions increased by about 8% from 1990 to 2005, while national emissions rose by 16% from 1990 to 2005. The growth in Kansas' emissions from 1990 to 2005 is primarily associated with the electricity consumption, industrial process, and agriculture sectors.

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[1] The last year of available historical data varies by sector; ranging from 2000 to 2005.

[2] 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, 1996). 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), http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

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

[4] 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.

Estimates of carbon sinks within Kansas' forests, including urban forests and land use changes as well as cultivation practices related to agricultural soils, have also been included in this report. The current estimates indicate that about 10 $MMtCO_2e$ were stored in Kansas forest and agricultural biomass in 2005. This leads to *net* emissions of 93 $MMtCO_2e$ in Kansas in 2005.

Figure ES-1 illustrates the State's emissions per capita and per unit of economic output.[5] On a per capita basis, Kansas residents emitted about 38 metric tons (t) of gross CO_2e in 1990, higher than the1990 national average of 25 tCO_2e. Since 1990, Kansas' per capita emissions have declined slightly to about 37 tCO_2e in 2005. National per capita emissions for the US also decreased slightly to about 24 tCO_2e in 2005. The higher per capita emission rates in Kansas are driven by a lower population density (due to a larger rural area) in Kansas relative to the US as a whole and by emissions in the agricultural industry (agricultural industry emissions are much higher than the national average).[6] Like the nation as a whole, Kansas' 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 26% in Kansas, which is the same decline nationally.[7]

The principal sources of Kansas' GHG emissions in 2005 are electricity consumption; residential, commercial, and industrial (RCI) fuel use; transportation; and agriculture accounting for 34%, 18%, 17%, and 17% of Kansas' gross GHG emissions in 2005, respectively.

As illustrated in Figure ES-2 and shown numerically in Table ES-1, under the reference case projections, Kansas' gross GHG emissions continue to grow, and are projected to climb to about 126 $MMtCO_2e$ by 2025, reaching 33% 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 Kansas, followed by emissions associated with the transportation, industrial processes, and RCI direct fuel use sectors.

Some data gaps exist in this analysis, particularly for the reference case projections. Key tasks in resolving the data gaps include review and revision of key emissions drivers that will be major determinants of Kansas' future GHG emissions (such as the growth rate assumptions for electricity generation and consumption, transportation fuel use, industrial processes, 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.

[5] Kansas population statistics for 1990-2027 from Kansas Budget Office, available at http://budget.ks.gov/ecodemo.htm

[6] Based on information from the US Census Bureau (http://quickfacts.census.gov/qfd/states/20000.html), Kansas has 81,814.88 square miles, which is 2.3% of the nation's 3,537,438 square miles. In 2005, Kansas had an average population density of 33.7 persons per square mile, as compared to 84.7 persons per square mile for the US.

[7] 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 the 2008 version of EPA's GHG inventory report (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

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

$MMtCO_2e$	1990	2000	2005	2010	2020	2025	Explanatory Notes for Projections
Energy Use (CO_2, CH_4, N_2O)	**74.7**	**78.1**	**78.3**	**82.5**	**90.5**	**96.7**	
Electricity Use (Consumption)	**25.4**	**31.8**	**35.3**	**36.5**	**41.5**	**45.5**	Totals include emissions for electricity production plus emissions associated with net imported/exported electricity.
Electricity Production (in-state)	28.9	37.1	38.5	38.9	41.4	47.9	*See electric sector assumptions*
Coal	27.2	34.8	36.8	37.7	40.1	46.6	*in appendix A.*
Natural Gas	1.65	1.87	0.78	1.11	1.22	1.20	
Oil	0.09	0.39	0.91	0.06	0.06	0.06	
MSW/Landfill Gas	0.0000	0.0000	0.0013	0.0005	0.0005	0.0005	
Imported/Exported Electricity	-3.58	-5.23	-3.27	-2.34	0.10	-2.38	Negative values represent net exported electricity
Residential/Commercial/Industrial (RCI) Fuel Use	**23.3**	**21.3**	**18.3**	**20.6**	**21.4**	**22.0**	
Coal	0.35	0.33	0.47	0.46	0.45	0.45	Based on US DOE regional projections
Natural Gas	15.0	13.1	11.2	14.2	15.0	15.6	Based on US DOE regional projections
Petroleum	7.96	7.75	6.55	5.96	5.92	5.88	Based on US DOE regional projections
Wood (CH_4 and N_2O)	0.06	0.04	0.05	0.06	0.06	0.06	Based on US DOE regional projections
Transportation	**17.6**	**17.7**	**17.3**	**18.0**	**20.4**	**22.1**	
Onroad Gasoline	10.7	11.9	10.7	10.7	11.7	12.5	Based on VMT projections from KDOT and US DOE regional projections
Onroad Diesel	2.95	3.52	4.05	4.77	6.16	7.00	
Marine Vessels	0.08	0.07	0.09	0.09	0.11	0.12	Based on historical trends in activity
Rail, Natural Gas, LPG, other	2.33	0.81	1.67	1.67	1.67	1.67	Based on historical trends in activity
Jet Fuel and Aviation Gasoline	1.54	1.39	0.79	0.78	0.79	0.81	Based on FAA operations projections
Fossil Fuel Industry	**8.45**	**7.33**	**7.41**	**7.36**	**7.11**	**7.09**	
Natural Gas Industry	7.69	6.86	6.90	6.87	6.66	6.66	Based on historical trends in activity or US DOE regional projections (when these forecasts are in-line with past state trends)
Oil Industry	0.74	0.46	0.51	0.48	0.44	0.42	Based on historical trends in activity or US DOE regional projections (when these forecasts are in-line with past state trends)
Coal Mining	0.023	0.006	0.006	0.005	0.004	0.003	Based on historical emissions trend
Industrial Processes	**2.79**	**3.44**	**5.74**	**6.42**	**8.31**	**9.49**	
Cement Manufacture (CO_2)	0.79	0.93	1.44	1.42	1.73	1.91	National cement consumption forecast from the Portland Cement Association
Limestone and Dolomite Use (CO_2)	0.03	0.03	0.02	0.02	0.02	0.01	Historical annual decrease in State production from 1994-2004
Soda Ash (CO_2)	0.03	0.03	0.02	0.02	0.02	0.02	Historical annual decrease in State consumption from 1990-2005
Ammonia and Urea (CO_2)	0.78	0.73	1.74	1.74	1.74	1.74	Assumed no growth
Iron and Steel (CO_2)	0.000	0.000	0.001	0.001	0.002	0.003	Historical annual increase in State production from 1995-2005
Glass Manufacture (CO_2)	0.03	0.04	0.05	0.05	0.07	0.08	Historical annual increase in State production from 1990-2005
Ceramics Manufacture (CO_2)	0.01	0.01	0.02	0.02	0.03	0.03	Historical annual increase in State production from 1990-2005
Carbon Black Production (CO_2 and CH_4)	0.09	0.13	0.14	0.15	0.17	0.18	Historical annual increase in State production from 2000-2005

$MMtCO_2e$	1990	2000	2005	2010	2020	2025	Explanatory Notes for Projections
Nitric Acid (N_2O)	0.75	0.62	1.02	1.13	1.39	1.55	Historical annual increase in State production from 1990-2005
ODS Substitutes (HFC, PFC)	0.00	0.77	1.14	1.73	3.01	3.85	National emissions projections (US EPA)
Electric Power Transmission and Distribution (T&D) (SF_6)	0.27	0.16	0.14	0.13	0.12	0.12	National emissions projections (US EPA)
HCFC-22 Production (HFC)	0.00	0.00	0.00	0.00	0.00	0.00	Emissions estimated for one plant that operated from 1990-2002. Emissions estimated to be about 0.001% of total industrial process emissions.
Waste Management	**1.78**	**1.50**	**1.41**	**1.47**	**1.59**	**1.66**	
Waste Combustion	0.06	0.08	0.10	0.10	0.10	0.11	Used growth rate calculated for 1995-2005 emissions growth
Landfills	1.41	1.07	0.95	0.99	1.08	1.12	Used growth rate calculated for 1990-2005 emissions growth
Wastewater Management	0.32	0.35	0.36	0.38	0.41	0.43	Used growth rate calculated for 1990-2005 emissions growth
Agriculture	**15.3**	**16.7**	**17.1**	**17.1**	**17.7**	**18.0**	
Enteric Fermentation	5.52	6.14	6.03	6.21	6.65	6.87	Based on projected livestock population
Manure Management	1.36	1.78	2.00	2.06	2.22	2.29	Based on projected livestock population
Agricultural Soils	8.36	8.68	9.04	8.75	8.74	8.74	Used growth rate calculated for 1990-2005 emissions growth
Agricultural Burning	0.05	0.05	0.07	0.07	0.07	0.07	Assumed no growth after 2005
Rangeland Burning (N_2O and CH_4)	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**	Assumed no change after 2005
Gross Emissions (Consumption Basis, Excludes Sinks)	**95.3**	**100.4**	**103.2**	**108.2**	**118.8**	**126.5**	
increase relative to 1990		*5%*	*8%*	*14%*	*25%*	*33%*	
Emissions Sinks	**-9.80**	**-9.97**	**-10.01**	**-10.01**	**-10.01**	**-10.01**	
Forested Landscape	-4.10	-6.07	-6.07	-6.07	-6.07	-6.07	Based on estimates from the USFS
Urban Forestry and Land Use	-2.33	-0.53	-0.56	-0.56	-0.56	-0.56	Assumed no change after 2005
Agricultural Soils (Cultivation Practices)	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37	Based on 1997 USDA calculations.
Net Emissions (Includes Sinks)	**85.5**	**90.4**	**93.2**	**98.2**	**108.8**	**116.5**	
increase relative to 1990		*6%*	*9%*	*15%*	*27%*	*36%*	

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

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

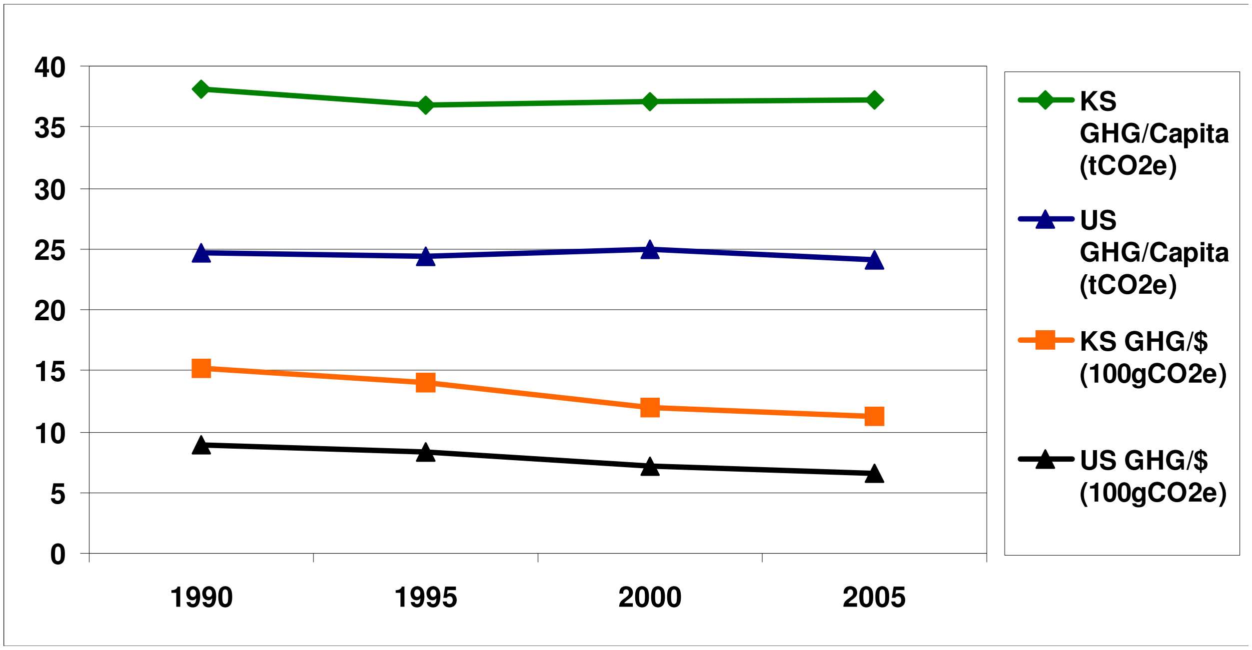
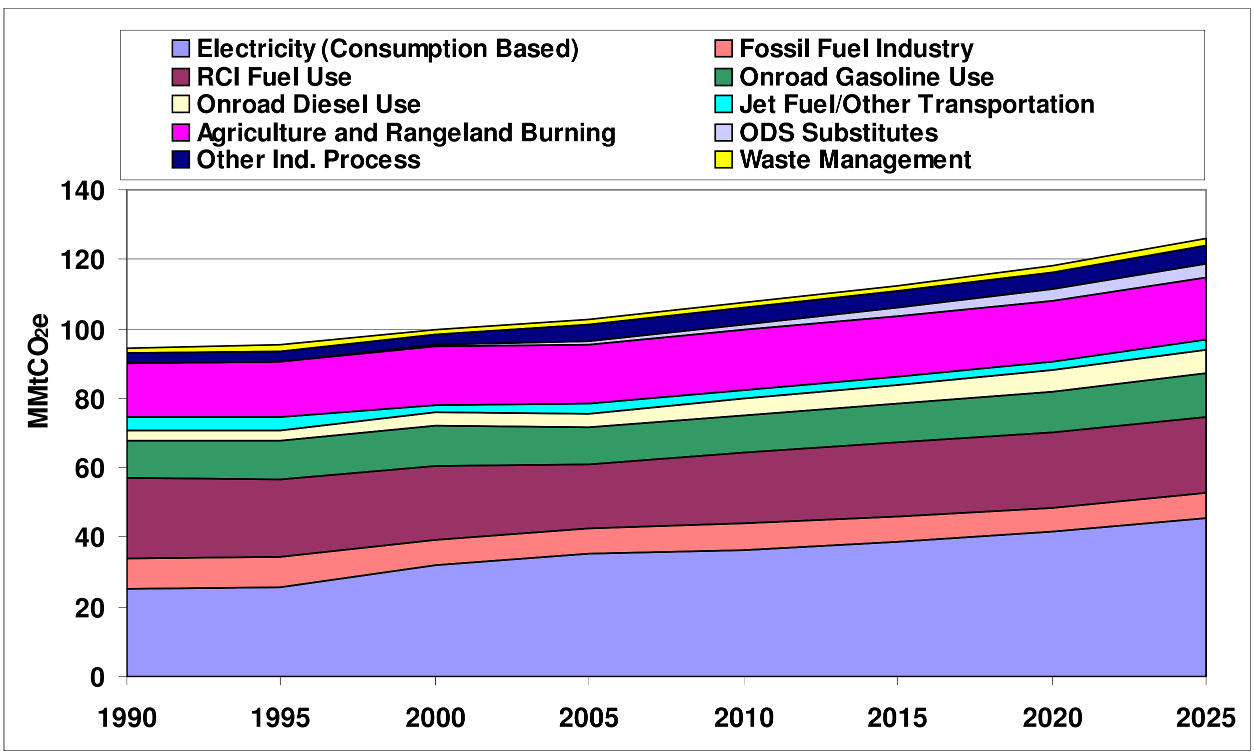
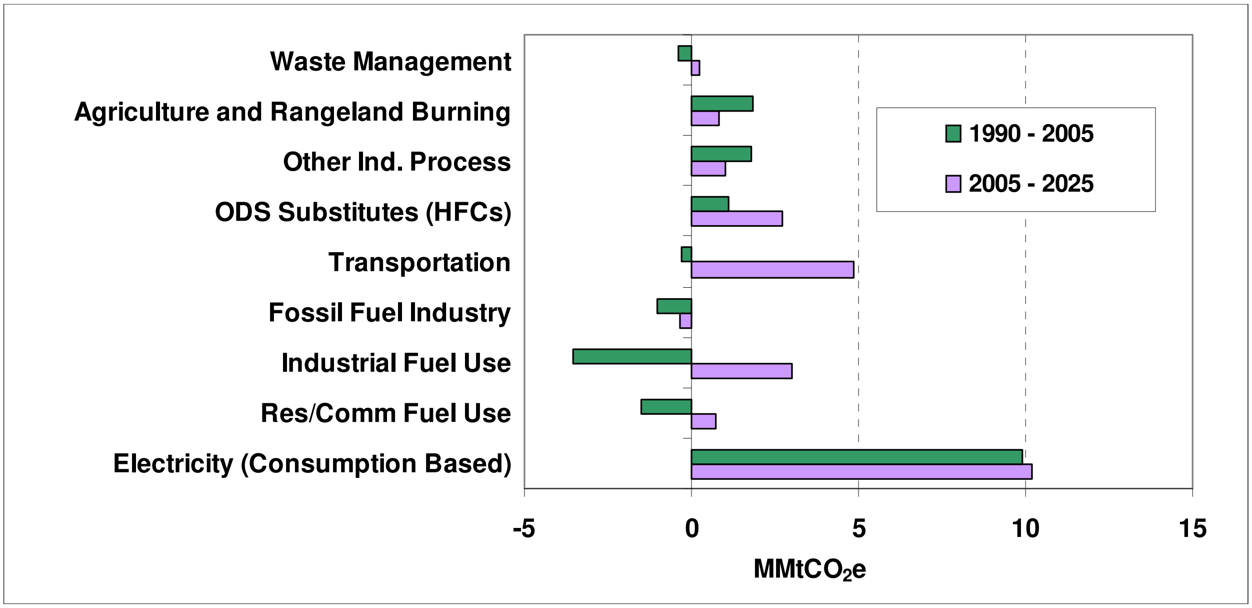


Figure ES-2. Kansas Gross GHG Emissions by Sector, 1990-2025: Historical and Projected



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

Figure ES-3. Sector Contributions to Gross Emissions Growth in Kansas, 1990-2025: 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.

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Acronyms and Key Terms

AEO2007 – EIA's Annual Energy Outlook 2007

bbls – Barrels

BOD – Biochemical Oxygen Demand

Btu – British Thermal Unit

C – Carbon

$CaCO_3$ – Calcium Carbonate

CCS – Center for Climate Strategies

CCT – Carbon Calculation Tool

CFCs – Chlorofluorocarbons

CH_4 – Methane

CHP – Combined Heat and Power

CO_2 – Carbon Dioxide

CO_2e – Carbon Dioxide equivalent

CRP – Federal Conservation Reserve Program

DOE – Department of Energy

DOT – Department of Transportation

EAF – Electric Arc Furnace

EFMA – European Fertilizer Manufacturers Association

EIA – US DOE Energy Information Administration

EIIP – Emission Inventory Improvement Program

FAA – Federal Aviation Administration

FAPRI – Food and Agricultural Policy Research Institute

FERC – Federal Energy Regulatory Commission

FHWA – Federal Highway Administration

FIA – Forest Inventory Analysis

Gg – Gigagram

GHG – Greenhouse Gas

GWh – Gigawatt-hour

GWP – Global Warming Potential

H_2CO_3 – Carbonic Acid

HCFCs – Hydrochlorofluorocarbons

HFCs – Hydrofluorocarbons

HNO_3 – Nitric Acid

HWP – Harvested Wood Products

IPCC – Intergovernmental Panel on Climate Change

KCC – Kansas Corporation Commission

KDHE – Kansas Department of Health and Environment

KEEP – Kansas Energy and Environmental Planning Advisory Group

KGS – Kansas Geological Survey

kg – Kilogram

kWh – Kilowatt-hour

lb – Pound

LF – Landfill

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

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)

N_2O – Nitrous Oxide

NASS – National Agriculture Statistical Service

NEI – National Emissions Inventory

NEMS – National Energy Modeling System

NERC – North American Electric Reliability Corporation

NF – National Forest

NH_3 – Ammonia

ODS – Ozone-Depleting Substance

OPS – Office of Pipeline Safety

PFCs – Perfluorocarbons

ppb – parts per billion

ppm – parts per million

ppt – parts per trillion

ppmv – parts per million by volume

RCI – Residential, Commercial, and Industrial

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.

SPP – Southwest Power Pool

t – Metric ton (equivalent to 1.102 short tons)

T&D – Transmission and Distribution

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

WW – Wastewater

yr – Year

Acknowledgements

We appreciate all of the time and assistance provided by numerous contacts throughout Kansas, as well as in neighboring States, and at federal agencies. Thanks go to in particular the staff at KDHE and other Kansas agencies for their inputs, and in particular to KDHE Bureau of Air and Radiation staff who provided key guidance for and review of this analytical effort, and other state agencies, including Kansas Department of Transportation and Kansas Corporation Commission, who provided additional data.

Preliminary Findings

Introduction

The Center for Climate Strategies (CCS) prepared this report for the Kansas Department of Health and Environment (KDHE). This report presents a preliminary assessment of the State's greenhouse gas (GHG) emissions and anthropogenic sinks (carbon storage) from 1990 to 2025. The inventory and forecast estimates serve as a starting point to assist the State, as well as the Kansas Energy and Environmental Planning Advisory Group (KEEP) and technical work groups, with an initial comprehensive understanding of Kansas' current and possible future GHG emissions, and thereby inform the upcoming identification and analysis of policy options for mitigating GHG emissions.

Historical GHG emission estimates (1990 through 2005)[8] 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 Kansas-specific data and inputs. The initial reference case projections (2006-2025) are based on a compilation of various projections of electricity generation, fuel use, and other GHG-emitting activities for Kansas, along with a set of simple, transparent assumptions described in the appendices of this report.

This report covers the six gases included in the US 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 equivalents (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.[9]

It is important to note that the preliminary emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Kansas' 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.*

[8] The last year of available historical data varies by sector; ranging from 2000 to 2005.

[9] 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, 1996). 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), http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

Kansas Greenhouse Gas Emissions: Sources and Trends

Table 1 provides a summary of GHG emissions estimated for Kansas by sector for the years 1990, 2000, 2005, 2010, 2020, and 2025. Details on the methods and data sources used to construct these draft 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 2005) followed by a summary of the reference-case projection-year emissions (2006 through 2025) 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.

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

$MMtCO_2e$	1990	2000	2005	2010	2020	2025	Explanatory Notes for Projections
Energy Use (CO_2, CH_4, N_2O)	**74.7**	**78.1**	**78.3**	**82.5**	**90.5**	**96.7**	
Electricity Use (Consumption)	**25.4**	**31.8**	**35.3**	**36.5**	**41.5**	**45.5**	Totals include emissions for electricity production plus emissions associated with net imported/exported electricity.
Electricity Production (in-state)	28.9	37.1	38.5	38.9	41.4	47.9	*See electric sector assumptions*
Coal	27.2	34.8	36.8	37.7	40.1	46.6	*in appendix A.*
Natural Gas	1.65	1.87	0.78	1.11	1.22	1.20	
Oil	0.09	0.39	0.91	0.06	0.06	0.06	
MSW/Landfill Gas	0.0000	0.0000	0.0013	0.0005	0.0005	0.0005	
Imported/Exported Electricity	-3.58	-5.23	-3.27	-2.34	0.10	-2.38	Negative values represent net exported electricity
Residential/Commercial/Industrial (RCI) Fuel Use	**23.3**	**21.3**	**18.3**	**20.6**	**21.4**	**22.0**	
Coal	0.35	0.33	0.47	0.46	0.45	0.45	Based on US DOE regional projections
Natural Gas	15.0	13.1	11.2	14.2	15.0	15.6	Based on US DOE regional projections
Petroleum	7.96	7.75	6.55	5.96	5.92	5.88	Based on US DOE regional projections
Wood (CH_4 and N_2O)	0.06	0.04	0.05	0.06	0.06	0.06	Based on US DOE regional projections
Transportation	**17.6**	**17.7**	**17.3**	**18.0**	**20.4**	**22.1**	
Onroad Gasoline	10.7	11.9	10.7	10.7	11.7	12.5	Based on VMT projections from KDOT and US DOE regional projections
Onroad Diesel	2.95	3.52	4.05	4.77	6.16	7.00	
Marine Vessels	0.08	0.07	0.09	0.09	0.11	0.12	Based on historical trends in activity
Rail, Natural Gas, LPG, other	2.33	0.81	1.67	1.67	1.67	1.67	Based on historical trends in activity
Jet Fuel and Aviation Gasoline	1.54	1.39	0.79	0.78	0.79	0.81	Based on FAA operations projections
Fossil Fuel Industry	**8.45**	**7.33**	**7.41**	**7.36**	**7.11**	**7.09**	
Natural Gas Industry	7.69	6.86	6.90	6.87	6.66	6.66	Based on historical trends in activity or US DOE regional projections (when these forecasts are in-line with past state trends)
Oil Industry	0.74	0.46	0.51	0.48	0.44	0.42	Based on historical trends in activity or US DOE regional projections (when these forecasts are in-line with past state trends)
Coal Mining	0.023	0.006	0.006	0.005	0.004	0.003	Based on historical emissions trend
Industrial Processes	**2.79**	**3.44**	**5.74**	**6.42**	**8.31**	**9.49**	
Cement Manufacture (CO_2)	0.79	0.93	1.44	1.42	1.73	1.91	National cement consumption forecast from the Portland Cement Association
Limestone and Dolomite Use (CO_2)	0.03	0.03	0.02	0.02	0.02	0.01	Historical annual decrease in State production from 1994-2004
Soda Ash (CO_2)	0.03	0.03	0.02	0.02	0.02	0.02	Historical annual decrease in State consumption from 1990-2005
Ammonia and Urea (CO_2)	0.78	0.73	1.74	1.74	1.74	1.74	Assumed no growth
Iron and Steel (CO_2)	0.000	0.000	0.001	0.001	0.002	0.003	Historical annual increase in State production from 1995-2005
Glass Manufacture (CO_2)	0.03	0.04	0.05	0.05	0.07	0.08	Historical annual increase in State production from 1990-2005
Ceramics Manufacture (CO_2)	0.01	0.01	0.02	0.02	0.03	0.03	Historical annual increase in State production from 1990-2005
Carbon Black Production (CO_2 and CH_4)	0.09	0.13	0.14	0.15	0.17	0.18	Historical annual increase in State production from 2000-2005

MMtCO$_2$e	1990	2000	2005	2010	2020	2025	Explanatory Notes for Projections
Nitric Acid (N_2O)	0.75	0.62	1.02	1.13	1.39	1.55	Historical annual increase in State production from 1990-2005
ODS Substitutes (HFC, PFC)	0.00	0.77	1.14	1.73	3.01	3.85	National emissions projections (US EPA)
Electric Power Transmission and Distribution (T&D) (SF_6)	0.27	0.16	0.14	0.13	0.12	0.12	National emissions projections (US EPA)
HCFC-22 Production (HFC)	0.00	0.00	0.00	0.00	0.00	0.00	Emissions estimated for one plant that operated from 1990-2002. Emissions estimated to be about 0.001% of total industrial process emissions.
Waste Management	**1.78**	**1.50**	**1.41**	**1.47**	**1.59**	**1.66**	
Waste Combustion	0.06	0.08	0.10	0.10	0.10	0.11	Used growth rate calculated for 1995-2005 emissions growth
Landfills	1.41	1.07	0.95	0.99	1.08	1.12	Used growth rate calculated for 1990-2005 emissions growth
Wastewater Management	0.32	0.35	0.36	0.38	0.41	0.43	Used growth rate calculated for 1990-2005 emissions growth
Agriculture	**15.3**	**16.7**	**17.1**	**17.1**	**17.7**	**18.0**	
Enteric Fermentation	5.52	6.14	6.03	6.21	6.65	6.87	Based on projected livestock population
Manure Management	1.36	1.78	2.00	2.06	2.22	2.29	Based on projected livestock population
Agricultural Soils	8.36	8.68	9.04	8.75	8.74	8.74	Used growth rate calculated for 1990-2005 emissions growth
Agricultural Burning	0.05	0.05	0.07	0.07	0.07	0.07	Assumed no growth after 2005
Rangeland Burning (N_2O and CH_4)	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**	**0.68**	Assumed no change after 2005
Gross Emissions (Consumption Basis, Excludes Sinks)	**95.3**	**100.4**	**103.2**	**108.2**	**118.8**	**126.5**	
increase relative to 1990		*5%*	*8%*	*14%*	*25%*	*33%*	
Emissions Sinks	**-9.80**	**-9.97**	**-10.01**	**-10.01**	**-10.01**	**-10.01**	
Forested Landscape	-4.10	-6.07	-6.07	-6.07	-6.07	-6.07	Based on estimates from the USFS
Urban Forestry and Land Use	-2.33	-0.53	-0.56	-0.56	-0.56	-0.56	Assumed no change after 2005
Agricultural Soils (Cultivation Practices)	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37	Based on 1997 USDA calculations.
Net Emissions (Includes Sinks)	**85.5**	**90.4**	**93.2**	**98.2**	**108.8**	**116.5**	
increase relative to 1990		*6%*	*9%*	*15%*	*27%*	*36%*	

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

Historical Emissions

Overview

Preliminary analyses suggest that in 2005, activities in Kansas accounted for approximately 103 million metric tons (MMt) of CO_2e emissions, an amount equal to about 1.4% of total US GHG emissions in 2005.[10] Kansas' gross GHG emissions are rising slower than those of the nation as a whole (gross emissions exclude carbon sinks, such as forests). Kansas' gross GHG emissions increased 8% from 1990 to 2005, while national emissions rose by 16% from 1990 to 2005.

[10] 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 illustrates the State's emissions per capita and per unit of economic output.[11] On a per capita basis, Kansas residents emitted about 38 metric tons (t) of CO_2e annually in 1990, higher than the 1990 national average of 25 tCO_2e. Since 1990, Kansas' per capita emissions have declined slightly to about 37 tCO_2e in 2005. Kansas' per capita emissions declined slightly to about 37 tCO_2e in 2005. National per capita emissions for the US also decreased slightly to 24 tCO_2e in 2005. The higher per capita emission rates in Kansas are driven by a lower population density (due to a larger rural area) in Kansas relative to the US as a whole and by emissions in the agricultural industry (agricultural industry emissions are much higher than the national average).[12] Like the nation as a whole, Kansas' 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 26% in Kansas, which is the same decline nationally.[13]

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

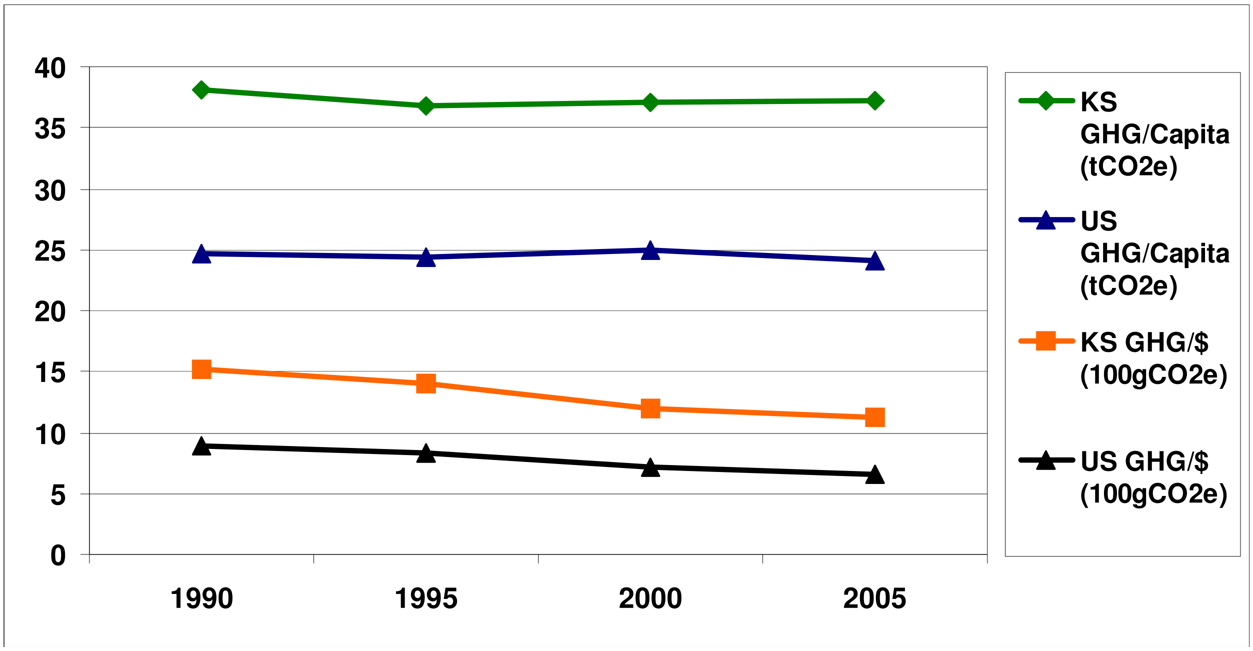
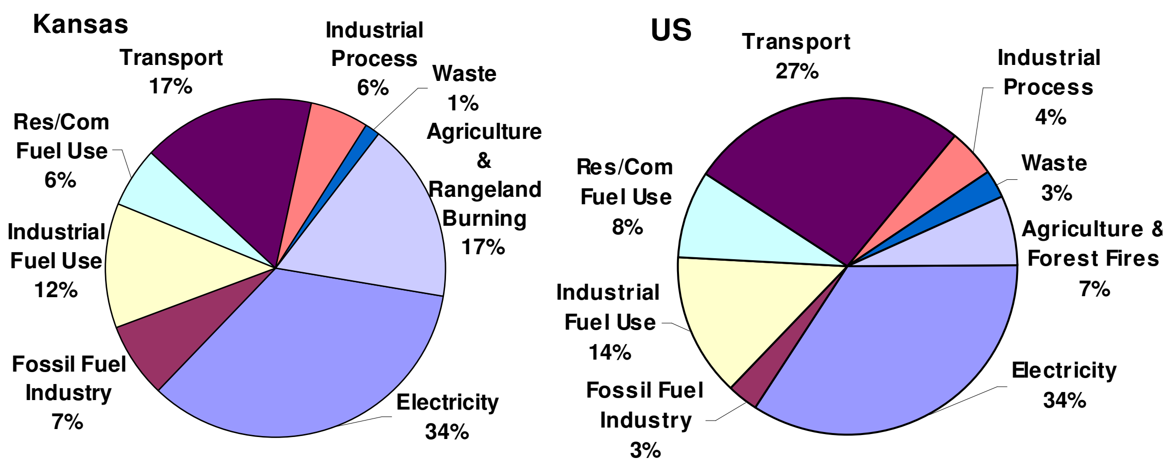


Figure 2 compares gross GHG emissions estimated for Kansas to emissions for the U.S. for 2005. Principal sources of Kansas' GHG emissions are electricity consumption; residential, commercial, and industrial (RCI) fuel use; transportation; and agriculture accounting for 34%, 18%, 17%, and 17% of Kansas' gross GHG emissions in 2005, respectively.

[11] Kansas population statistics for 1990-2027 from Kansas Budget Office, available at http://budget.ks.gov/ecodemo.htm.
[12] Based on information from the US Census Bureau (http://quickfacts.census.gov/qfd/states/20000.html), Kansas has 81,814.88 square miles, which is 2.3% of the nation's 3,537,438 square miles. In 2005, Kansas had an average population density of 33.7 persons per square mile, as compared to 84.7 persons per square mile for the US.
[13] 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 (The national emissions used for these comparisons are based on 2005 emissions from the 2008 version of EPA's GHG inventory report. (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

Methane and CO_2 emissions associated with natural gas production, processing, transmission and distribution (T&D), and flaring, as well as with oil production and refining (included under the fossil fuel industry category), accounted for about 7% of the State's gross GHG emissions in 2005.

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



Notes: Res/Comm = 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 exclude emissions included in the industrial fuel use sector. The transportation sector accounts emissions associated with fuel consumption by all on-road and non-highway vehicles. Non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, agricultural and construction equipment, railway locomotives, boats, and ships. Emissions associated with rangeland burning are low (~4% of total agricultural emissions in 2005). Electricity = electricity generation sector emissions on a consumption basis (depending on the year, consumption-based emissions either exclude emissions associated with net exports of electricity by Kansas generators to other states, or include emissions associated with net imports of electricity produced by generators in other states and consumed in Kansas).

While the industrial processes sector accounted for 6% of gross GHG emissions in 2005, emissions in this sector are increasing rapidly relative to other sectors. Industrial process emissions are rising due to the increasing use of HFCs as substitutes for ozone-depleting chlorofluorocarbons (CFCs), and their overall contribution is estimated to be 8% of Kansas' gross GHG emissions in 2025.[14] Other industrial process emissions result from CO_2 released during the production of cement, ammonia and urea, iron and steel, glass, and ceramics and the use of soda ash, limestone, and dolomite in manufacturing processes; CO_2 and CH_4 released during the production of carbon black; and N_2O released during the production of nitric acid. In addition, SF_6 is released in the use of electric power transmission and distribution (T&D) equipment, and HFC-23 is released during the production of HCFC-22.[15]

[14] CFCs are also potent GHGs; they are not, however, included in GHG estimates because of concerns related to implementation of the Montreal Protocol. 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.
[15] One plant produced HCFC-22 from 1990 through 2002; emissions associated with HCFC-22 production are very low compared to emissions for other industrial processes (~0.00004 $MMtCO_2e$).

Waste management accounted for about 1% of Kansas' gross GHG emissions in 2005. The N_2O and CH_4 emissions associated with rangeland burning are also included in the inventory as a source of GHG emissions; however, these emissions are low (0.68 $MMtCO_2e$).

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

Electricity Supply Sector

Electricity generation in Kansas is dominated by steam units, which are primarily based on coal and nuclear fuel. Part of the total gross generation by Kansas power plants has helped to meet demand for electricity outside of the state (with annual exported electricity ranging from 6% to 15% of total gross generation from 1990 to 2005 depending on the year). As shown in Figure 2, electricity consumption accounted for about 34% of Kansas' gross GHG emissions in 2005 (about 35 $MMtCO_2e$), which was about the same as the national average share of emissions from electricity consumption (34%).[16] The GHG emissions associated with Kansas' electricity consumption sector increased by 10 $MMtCO_2e$ between 1990 and 2005, greater than the total growth in GHG emissions over this period. This is possible because some other sectors, notably the industrial fuel use, decreased their emissions between 1990 and 2005.

In 2005, emissions associated with Kansas' electricity consumption (35.3 $MMtCO_2e$, see Table 1) were about 3 $MMtCO_2e$ (i.e., about 8.5%) lower than those associated with electricity production (38.5 $MMtCO_2e$, see Appendix A). The higher level for production-based emissions reflects GHG emissions associated with net exports of electricity to other states to meet their electricity demand.[17] Projections of electricity sales for 2005 through 2025 indicate that Kansas will remain a net exporter of electricity for most of the period, though there is a period around 2020 where Kansas is projected to be importing a small amount of electricity. For the period from 2005 through 2025, the reference case projection assumes that production-based emissions (associated with electricity generated in-state) will increase by about 9 $MMtCO_2e$, and consumption-based emissions (associated with electricity consumed in-state) will increase by about 10 $MMtCO_2e$.

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

Residential, Commercial, and Industrial (RCI) Fuel Use Sectors

Activities in the RCI[18] sectors produce GHG emissions when fuels are combusted to provide space heating, process heating, and other applications. In 2005, combustion of oil, natural gas,

[16] 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.
[17] 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.
[18] The industrial sector includes emissions associated with agricultural energy use and fuel use associated with leased and plant fuel in the fossil fuel production industry.

coal, and wood in the RCI sectors contributed about 18% (about 18 MMtCO_2e) of Kansas' gross GHG emissions, somewhat lower than the RCI sector contribution for the nation (22%).

The residential sector's share of total RCI emissions from direct fuel use was 22% (4.0 MMtCO_2e) in 2005, the commercial sector accounted for 10% (1.8 MMtCO_2e), and the industrial sector's share of total RCI emissions from direct fuel use was 68% (12.4 MMtCO_2e). Overall, emissions for the RCI sectors (excluding those associated with electricity consumption) are expected to increase by 20% between 2005 and 2025. Emissions from the industrial and commercial sectors are projected to increase more rapidly than the residential sector, with a 24% and 25% increase, respectively, from 2005 to 2025. In contrast, emissions from the residential sector are expected to increase by only 7%, from 2005 to 2025, which is relatively close to the projected increase in population (8%) over this same time period.

Agricultural Sector

The agricultural sector accounts for 17% of the gross GHG emissions in Kansas in 2005. This is significantly higher than the national average for agricultural emissions in that year (7%). However, this is not at all surprising considering the importance of the agricultural sector to the economy in Kansas.

These emissions primarily come from enteric fermentation and agricultural soils. Enteric fermentation is the result of normal digestive processes of livestock, and this results in CH_4 emissions. Agricultural soils can have GHG emissions from nitrogen fertilizers and manure as well as decomposition of crop residues. All of these processes can result in emissions of N_2O. Emissions from the agricultural sector are projected to increase by about 5% between 2005 and 2025, with the majority of this increase coming through enteric fermentation and manure management.

Transportation Sector

As shown in Figure 2, the transportation sector accounted for about 17% of Kansas' gross GHG emissions in 2005 (about 17 MMtCO_2e), which was lower than the national average share of emissions from transportation fuel consumption (27%). The GHG emissions associated with Kansas' transportation sector declined slightly by about 0.3 MMtCO_2e between 1990 and 2005.

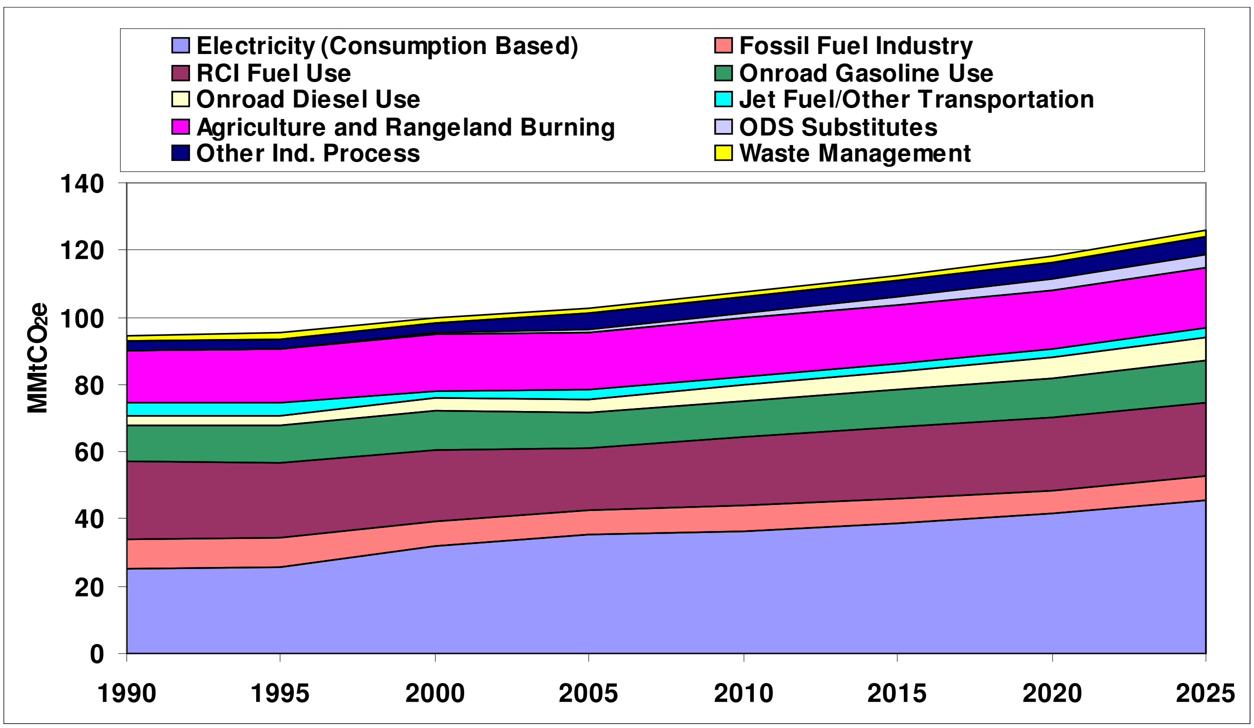
From 1990 through 2005, Kansas' GHG emissions from transportation fuel use have decreased at an average rate of about 0.1% annually. In 2005, onroad gasoline vehicles accounted for about 62% of transportation GHG emissions. Onroad diesel vehicles accounted for another 23% of emissions. Air and marine travel, rail, and other sources (natural gas- and liquefied petroleum gas- (LPG-) fueled-vehicles used in transport applications) accounted for the remaining 15% of transportation emissions. GHG emissions from onroad gasoline use decreased 0.1% between 1990 and 2005. Meanwhile, GHG emissions from onroad diesel use rose 37% during that period, suggesting rapid growth in freight movement within or across the State. Emissions associated with rail use decreased by about 28% from 1990 to 2005, while emissions associated with aviation fuel consumption decreased by 49% in the same period.

Reference Case Projections

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 2025. As illustrated in Figure 3 and shown numerically in Table 1, under the reference case projections, Kansas gross GHG emissions continue to grow steadily, climbing to about 126 $MMtCO_2e$ by 2025, 33% above 1990 levels. This equates to an annual rate of growth of 1.0% per year from 2005 to 2025. Relative to 2005, the share of emissions associated with electricity consumptions increases to 36% in 2025. The share of emissions from the RCI fuel use and agriculture sectors both decrease to 17% and 15%, respectively, of Kansas' gross GHG emissions in 2025. In contrast, the share of emissions from the transportation is projected to remain constant at 17% of total GHG emissions in 2025, the industrial processes sector is projected to increase to 8% by 2025, and the share of waste sector emissions remains at 1%..

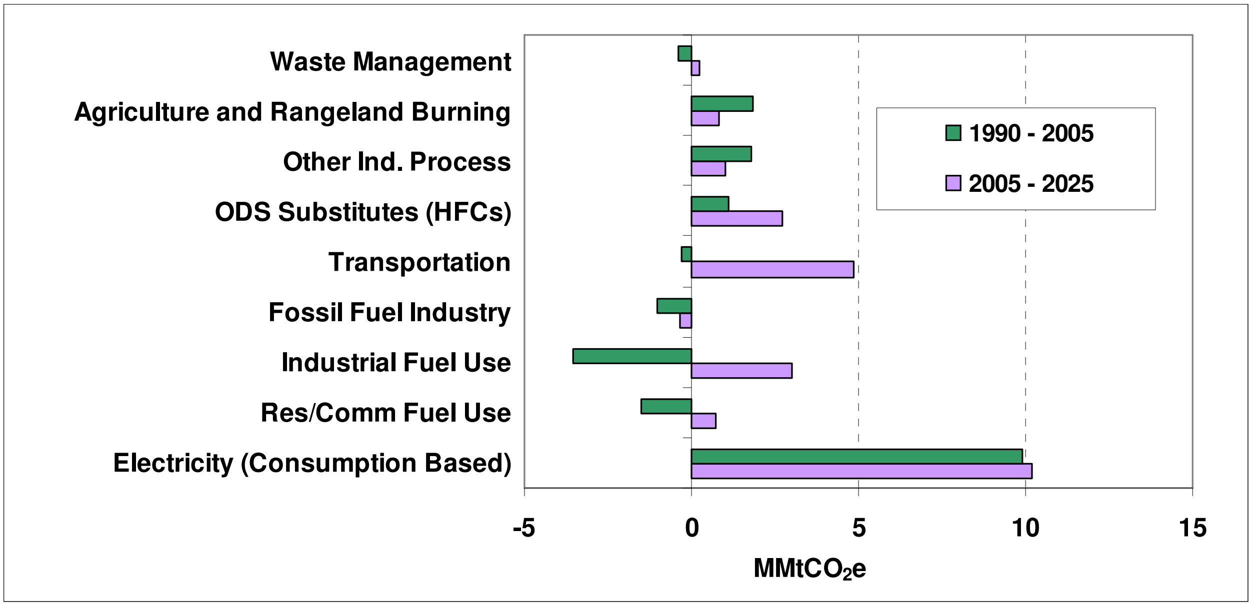
The electricity supply sector is projected to be the largest contributor to future emissions growth, followed by emissions associated with the transportation sector, mainly from onroad fuel combustion, as shown in Figure 4. Other sources of emissions growth include emissions associated with the RCI fuel use sector, industrial processes sector, particularly by ODS substitutes (HFCs), the agriculture sector, and the waste management sector. Emissions from the fossil fuel industry decrease between 2005 and 2025. Table 2 summarizes the growth rates that drive the growth in the Kansas reference case projections as well as the sources of these data.

Figure 3. Kansas Gross GHG Emissions by Sector, 1990-2025: 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 Kansas, 1990-2025: Historic 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 Kansas, Historical and Projected

	1990-2005	2005-2025	Sources
Population	0.70%	0.40%	Kansas population statistics for 1990 through 2025, compiled by Kansas Budget Office, http://budget.ks.gov/ecodemo.htm
Electricity Sales **Total Sales**[a] **KS Sales**[b]	 2.0% 2.4%	 1.1% 1.3%	For 1990-2005, annual growth rate in total electricity sales for all sectors combined in Kansas calculated from EIA State Electricity Profiles (Table 8) and sales by Kansas generators calculated from EIA State Electricity Profiles (Table 5) http://www.eia.doe.gov/cneaf/electricity/st_profiles/kansas.html. For 2005-2025, annual electricity sales and generation are assumed to grow at the same rate as the Southwest Power Pool (SPP) North American Electric Reliability Corporation (NERC) region.
Vehicle Miles Traveled	1.8%	1.6%	Based on projected VMT provided by KDOT

[a] Represents annual growth in total sales of electricity by generators in Kansas to RCI sectors located within and outside of Kansas.
[b] Represents annual growth in total sales of electricity by generators in Kansas to RCI sectors located within Kansas.

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 electricity demand, transportation, RCI fuel use, and industrial processes growth rates that will be major determinants of Kansas' 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 Kansas with a general understanding of Kansas' 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 Kansas.

General Methodology

We prepared this analysis in close consultation with Kansas agencies, in particular, with the staff at KDHE. 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[19] and its guidelines for States.[20] These inventory guidelines were developed based on the guidelines from the IPCC, the international organization responsible for developing coordinated methods for national GHG inventories.[21] The inventory methods provide flexibility to account for local conditions. The key sources of activity and projection data used are shown in Table 3. Table 3 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*.

[19] *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.
[20] http://yosemite.epa.gov/oar/globalwarming.nsf/content/EmissionsStateInventoryGuidance.html.
[21] http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.htm.

- **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 Kansas. 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 2002 to 2005), with projections to 2025.
- **Use of Consumption-Based Emissions Estimates:** To the extent possible, we estimated emissions that are caused by activities that occur in Kansas. For example, we reported emissions associated with the electricity consumed in Kansas. 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 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 Kansas. This entails accounting for the electricity sources used by Kansas 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 Kansas, 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.

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 Industry
- Appendix F. Agriculture
- Appendix G. Waste Management
- Appendix H. Forestry

Table 3. Key Sources for Kansas 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 for 1990-2005. US EPA SIT contains default data for each State for most of the information required for an inventory. 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 1990-2005 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) forms; State Energy Data (SED)	EIA SED provides energy use data in each State, annually to 2005 for all RCI sectors and fuels, except for commercial wood consumption for which 2003 is the latest year for which data are available from EIA, and for transportation fuels. EIA forms (759, 906) provide generation and primary energy use data at electric power generators.	EIA SED is the source for most energy use data. Emission factors from US EPA SIT are used to calculate energy-related emissions. EIA forms (906, 759) were used to develop plant-specific generation and energy use profiles.
EIA State Electricity Profiles	EIA provides information on the electric power industry generation by primary energy source for 1990 – 2005.	EIA State Electricity Profiles were used to determine the mix of in-state electricity generation by fuel. Electricity sales were projected off of 2005 sales provided in this reference.
EIA AEO2007	EIA AEO2007 projects energy supply and demand for the US from 2004 to 2030. Energy consumption is estimated on a regional basis. Also used to provide projected mix of onroad vehicles and aircraft efficiency gains for transportation sector.	EIA AEO2007 is used to project changes in fuel use by the RCI sectors.
Kansas Department of Transportation	Historical statewide vehicle miles traveled (VMT) estimates and projected VMT for 2010 and 2020.	VMT used in estimating onroad CH_4 and N_2O emissions; projected emissions of CO_2 estimated based on converting projected VMT to fuel consumption using EPA fuel economy data.
Federal Aviation Administration (FAA)	Aircraft operation projections for Kansas.	Projected aircraft operations data used to develop aviation sector growth factors, in combination with national commercial aircraft fuel efficiency gains data from *AEO2007*.

Source	Information provided	Use of Information in this Analysis
US Department of Transportation (DOT), Office of Pipeline Safety (OPS)	Natural gas transmission pipeline mileage for 2001-2005, distribution pipeline mileage for 2004-2005, and number of services for 2004–2005.	OPS transmission data backcasted to 1990 using EIA data on average of the volume of natural gas transported into and out of Kansas. OPS distribution data backcasted based on total number of natural gas consumers in Kansas, as reported by EIA. Natural gas transmission emissions projected based on application of smallest annualized decrease in state gathering transmission emissions (-0.51%), and distribution emissions projected using smallest annualized growth rate in state distribution emissions (+0.06%), from each of 3 historical periods analyzed.
EIA Natural Gas Navigator	EIA provides the number of gas and associated wells and amount of gas flared and vented in Kansas for 1990-2005.	Natural Gas Navigator data entered into SIT to calculate historical emissions. Gas well emissions projected based on application of *AEO2007* Midcontinent region natural gas production forecast growth rates; flaring emissions projected using smallest annualized decrease in state level venting/flaring of natural gas (-2.55%) from each of 3 historical periods.
EIA Petroleum Navigator	Volume of oil refined in Kansas for 1990-2005. Assumed oil transported was same as oil refined.	EIA data entered into SIT to calculate historical emissions. Oil refining emissions projected based on *AEO2007* PAD II region refinery capacity forecast growth rates.
Kansas Corporation Commission (KCC)	Miles of gathering pipeline in 2005	Backcasted to 1990 based EIA Natural Gas Navigator data on Kansas natural gas production; forecasted based on application of smallest annualized decrease in state gathering transmission emissions (-0.51%) from each of 3 historical periods analyzed.
Kansas Geological Survey (KGS)	Annual oil production data.	Oil production emissions projected based on smallest annualized decline in state oil production (-0.91%) from each of 3 periods analyzed (2000-2005).
US EPA GHG Inventory and Sinks Report	CH_4 emissions from coal mining	Projected based on application of smallest annualized decrease in state coal emissions (-2.64%) from each of 3 historical time periods analyzed (2000-2005).
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.

Appendix A. Electricity Supply and Use

Overview

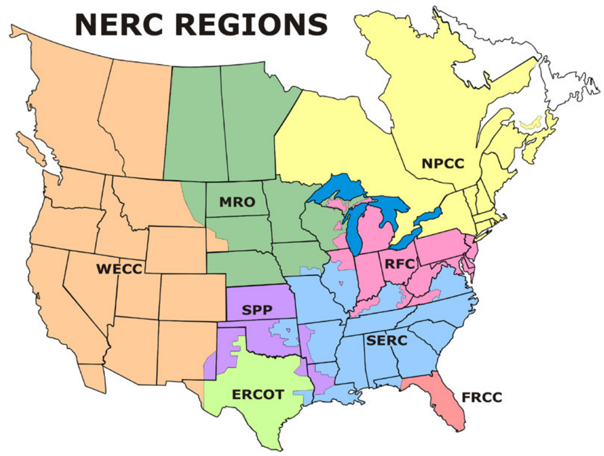
This appendix describes the data sources, key assumptions, and the methodology used to develop an inventory of greenhouse gas (GHG) emissions over the 1990-2005 period associated with the generation of electricity to meet electricity demand in Kansas. It also describes the data sources, key assumptions, and methodology used to develop a forecast of GHG emissions over the 2006-2025 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 Kansas GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Methodology – Reference Case:* This section provides an overview of methodological approach used to develop the Kansas GHG reference case projections (forecast) for the electric supply sector.
- *Greenhouse Gas Inventory Results:* This section provides an overview of key results of the Kansas GHG inventory for the electric supply sector.
- *Greenhouse Gas Forecast Results:* This section provides an overview of key results of the Kansas 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 Kansas power plants. These are briefly summarized below:

- *2005 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 2005. Data was extracted for Kansas. Data from these forms provide, among other things, fuel consumption and net generation in power stations and combined heat and power facilities (CHP) by plant type. This information can be accessed from http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html.



- *Annual Energy Outlook 2007.* 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, the analysis used regional outputs for the Southwest Power Pool (SPP) region where Kansas is located (see map). The SPP results include forecasts of gross generation, net generation, combustion efficiency, total sales, and exports/imports through the year 2025. This information is available in supplemental tables that can be accessed directly from http://www.eia.doe.gov/oiaf/aeo/supplement/index.html.
- *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, sub-bituminous, anthracite, or lignite) as well as the coal quantity consumed in Kansas power plants over the period 1990-2005. 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 Kansas power plants over the period 1990-2005. 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 2005. 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 2005 for power stations and CHP facilities. 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 2005 for power stations and CHP facilities. It can be accessed directly from http://www.eia.doe.gov/cneaf/electricity/epa/consumption_state.xls.
- *State combined heat and power 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 2005, and as a check against other sources. 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., switch grass, 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 2005. It can be accessed directly from http://www.eia.doe.gov/cneaf/solar.renewables/page/renewelec.html.
- *Energy conversion factors.* This is based on Table Y-2 of Appendix Y in the USEPA's 2005 GHG Inventory for the US. The table is entitled "Conversion Factors to Energy Units (Heat Equivalents)". This information can be accessed directly from the following website: http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/LHOD5MJTCL/$File/2005-final-inventory_annex_y.pdf.
- *Fuel combustion oxidation factors.* This is based on Appendix A of the USEPA's 2005 US GHG inventory for the US. This information can be accessed directly from: http://www.epa.gov/climatechange/emissions/downloads06/06_Annex_Chapter2.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 2005 GHG inventory for the US. This information can be accessed directly from: http://www.epa.gov/climatechange/emissions/downloads06/06_Annex_Chapter2.pdf. 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/pub/reports.htm.

Greenhouse Gas Inventory Methodology

The methodology used to develop the Kansas 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. There are four fundamental premises of the GHG inventory developed for Kansas, as briefly described below:

- The GHG inventory should be estimated based on both the production and consumption of electricity. Developing the production estimate involves tallying up the GHG emissions associated with the operation of power plants physically located in Kansas, regardless of ownership. Developing the consumption estimate involves tallying up the GHG emissions associated with consumption of electricity in Kansas, regardless of where the electricity is produced. As Kansas is a net exporter of electricity in most of the years, these estimates will be different.

- The GHG inventory should be estimated based on emissions at the point of electric generation only. That is, GHG emissions associated with 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. By convention, the emissions associated with these activities are tracked in other sectors of the GHG inventory and forecast.
- As an approximation, it was assumed that all power generated in Kansas was consumed in Kansas. This is a simplifying assumption, the purpose of which is to facilitate the calculation of imports/exports. In fact, some of the power generated in Kansas is exported. However, given the similarity in the average carbon intensity of Kansas power stations and that of power stations in the surrounding SPP region (i.e., in 2005 SPP had a carbon dioxide intensity of 0.82 tonnes/MWh; in 2005 KS had a carbon dioxide intensity of 0.78 tonnes/MWh), the potential error associated with this simplifying assumption is small, on the order of about 5%, plus or minus.
- Several key assumptions were used for making projections of CO_2, CH_4, and N_2O emissions for the electric sector out to 2025. These are summarized in Table A1.

There were several steps in the methodology for the development of the electric sector GHG inventory for the period 1990-2005. These are briefly outlined below:

- Determine the coal quality used in Kansas power stations (i.e., share of anthracite, bituminous, lignite, sub-bituminous, and coal wastes used).
- Determine the oil grades used in Kansas power stations (i.e., share of fuel oil #2, #4, #5, or #6 used).
- Determine on a fuel-specific basis the gross annual primary energy consumption by Kansas power stations and CHP facilities by plant and fuel type.
- Determine on a fuel-specific basis the gross annual generation and primary energy use at power stations and CHP facilities associated with exports/imports.
- Multiply fuel-specific gross annual primary energy consumption by Kansas power stations and CHP facilities by fuel-specific CO_2e emission factors.
- Multiply fuel-specific gross annual primary energy consumption associated with exports/imports by fuel-specific CO_2e emission factors.
- A production-based emission estimate is calculated by adding the total emissions associated with power production in KS, independent of the gross generation required to meet demand.
- A consumption-based emission estimate is calculated relative to the gross generation required to meet demand in KS, independent of the source of the generation (i.e., whether produced in-state or out-of-state).

Table A1. Key Assumptions used in the GHG Reference Case Projection

Key Assumptions	2005	2025	Average annual growth rate (%/yr)
KS electricity demand (GWh)	39,024	51,185	1.37%
KS gross generation (GWh)	49,284	61,878	1.14%
KS gross generation to meet KS demand (GWh)	45,298	58,979	1.33%
Gross generation associated with net imports from SPP Region (GWh)	-3,985	-2,900	-1.58%
Power plant heat rate (btu/kwh)			
Coal	10,069	9,854	-0.11%
Natural Gas	12,820	13,282	0.18%
Petroleum	11,773	10,778	-0.44%
Nuclear	10,582	10,582	0.00%
Hydroelectric	10,320	10,320	0.00%
Wind	10,320	10,320	0.00%
MSW Landfill gas	10,500	10,500	0.00%
Losses (%)			
From on-site usage (coal stations)	9.00%	9.00%	0.00%
From on-site usage (non-coal stations)	0.15%	0.09%	-2.60%
From Transmission and Distribution (T&D)	6.82%	6.19%	-0.48%

Note: negative values for net imports indicates exports to the SPP NERC region; heat rates for hydro and wind refer top equivalent fuel displacement

Greenhouse Gas Forecast Methodology – Reference Case

We consider that the most useful methodology for constructing a GHG forecast is one that attempts to build information from the bottom-up. The use of detailed State-specific data regarding 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 would be the preferred basis by which to construct a forecast if GHG emissions.

However, while some of this information was available in Kansas, some key data were not available at the time the forecast was prepared. The information that was available includes an estimate of parasitic load for coal power stations of about 9%, and the repowering from natural gas/oil to natural gas only for Gordon Evans Units 1 and 2, Hutchinson Unit 4, Murray Gill Unit 1, 2, 3, and 4, and Neosho Unit 7. Therefore, it was necessary to use a top-down approach using best available proxy information regarding future gross in-state generation, supply-side efficiency improvements, and changes over time regarding losses. This approach, while less satisfactory for representing state-specific conditions, nonetheless offers an acceptable starting point for exploring projections of GHG emissions from the electric sector in Kansas. The methodological steps used for forecasting CO_2e emissions are described below.

Coal quality. An overview of the methodology applied to forecast quality of coal used in Kansas power stations is briefly summarized below:

- For the Base Year of 2005, determine the coal quality used in Kansas power stations (i.e., share of anthracite, bituminous, lignite, sub-bituminous, and coal wastes used).

- For the period 2006 through and including 2025, assume that the coal quality is the same as the Base year.

Oil grade. An overview of the methodology applied to forecast oil grades used in Kansas power stations is briefly summarized below:

- For the Base Year of 2005, determine the oil grades used in Kansas power stations (i.e., share of fuel oil #2, #4, #5, or #6 used).
- For the period 2006 through and including 2025, assume that the oil grade shares are the same as the Base year, except for the Westar gas/oil units which are assumed to be natural gas-fired.

Total sales. An overview of the methodology applied to forecast annual sales of electricity to Kansas consumers is briefly summarized below:

- For the Base Year of 2005, establish actual total retail electricity sales in Kansas (i.e. 39,024 GWh) from data sources noted earlier.
- For the period 2006 through and including 2025, assume electricity demand in the state grows at the same rate as in the rest of the SPP NERC region.

Combustion efficiency. An overview of the methodology applied to forecast annual heat rates at Kansas power stations is briefly summarized below:

- For the Base Year of 2005, estimate gross heat rate of Kansas power stations by dividing actual plant type-specific 2005 gross primary energy consumption (in BTUs) by the actual plant type-specific 2005 gross generation (in kWh).
- For the period 2006 through and including 2025, assume power plant-specific heat rates change consistent with the rest of the SPP NERC region.

Gross generation at power stations. An overview of the methodology applied to forecast annual gross electricity generation by Kansas power stations is briefly summarized below:

- For the Base Year of 2005, assume losses associated with on-site usage of electricity (i.e., parasitic load) by plant type for Kansas power plants are consistent with SPP average annual values (i.e., between 0.09% and 0.15% of gross generation, depending on year) for non-coal-fired stations.
- For the Base Year of 2005, assume losses associated with on-site usage of electricity (i.e., parasitic load) for Kansas coal-fired power plants are 9% due to the installation of pollution control equipment.
- For the Base Year of 2005, combine actual net electric generation data and estimated on-site losses to estimate gross generation by plant type.
- For the period 2006 through and including 2025, assume plant-specific gross generation grows at the same rate as in the rest of the SPP NERC region, relative to plant type.

Energy use. An overview of the methodology applied to forecast annual primary energy use at Kansas power stations is briefly summarized below:

- For the Base Year of 2005, establish actual primary energy consumption for Kansas power plants from data sources noted earlier.

- For the period 2006 through and including 2025, multiply estimates of annual gross generation by annual heat rate for each plant type in Kansas.

Gross generation associated with electricity exports/imports. An overview of the methodology applied to forecast annual gross generation associated with electricity exports from, or imports to Kansas is briefly summarized below:

- For the Base Year of 2005 through and including 2025, if the total gross generation at KS power stations exceeds the total gross generation required to meet demand, it is assumed that this difference is exported to the SPP region.
- For the Base Year of 2005 through and including 2025, if the total gross generation at KS power stations is less than the total gross generation required to meet demand, it is assumed that the difference is imported from the SPP region.

Primary energy associated with electricity exports/imports. An overview of the methodology applied to forecast annual primary energy associated with electricity exports from, or imports to Kansas is briefly summarized below:

- For the Base Year of 2005 through and including 2025, if the total primary energy consumed at KS power stations exceeds the total primary energy required to meet electricity demand, it is assumed that the difference is exported to the SPP region in the form of electricity.
- For the Base Year of 2005 through and including 2025, if the total primary energy consumed at KS power stations is less than the total primary energy required to meet demand, it is assumed that the difference is imported from the SPP region in the form of electricity.

Carbon dioxide-equivalent emissions from Kansas power stations. An overview of the methodology applied to forecast annual CO_2e emissions from Kansas power stations is briefly summarized below:

- For the Base Year of 2005 through and including 2025, estimate total CO_2 emissions from Kansas power stations by multiplying total primary energy use by the CO_2 emission factor and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total CH_4 emissions from Kansas power stations by multiplying total primary energy use by the CH_4 emission factor and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total N_2O emissions from Kansas power stations by multiplying total primary energy use by the N_2O emission factor and the global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total CO_2e emissions from Kansas power stations by adding the CO_2e of CO_2, CH_4, and N_2O.

Carbon dioxide-equivalent emissions from exported/imported electricity. An overview of the methodology applied to forecast annual CO_2e emissions from electricity imports is briefly summarized below:

- For the Base Year of 2005 through and including 2025, estimate total CO_2 emissions associated with exports/imports by multiplying total primary energy use associated with exports/imports by the CO_2 emission factor and its global warming potential.

- For the Base Year of 2005 through and including 2025, estimate total CH_4 emissions associated with exports/imports by multiplying total primary energy use associated with exports/imports by the CH_4 emission factor and its global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total N_2O emissions associated with exports/imports by multiplying total primary energy use associated with exports/imports by the N_2O emission factor and its global warming potential.
- For the Base Year of 2005 through and including 2025, estimate total CO_2e emissions associated with exported/imported electricity by adding the CO_2e of CO_2, CH_4, and N_2O.

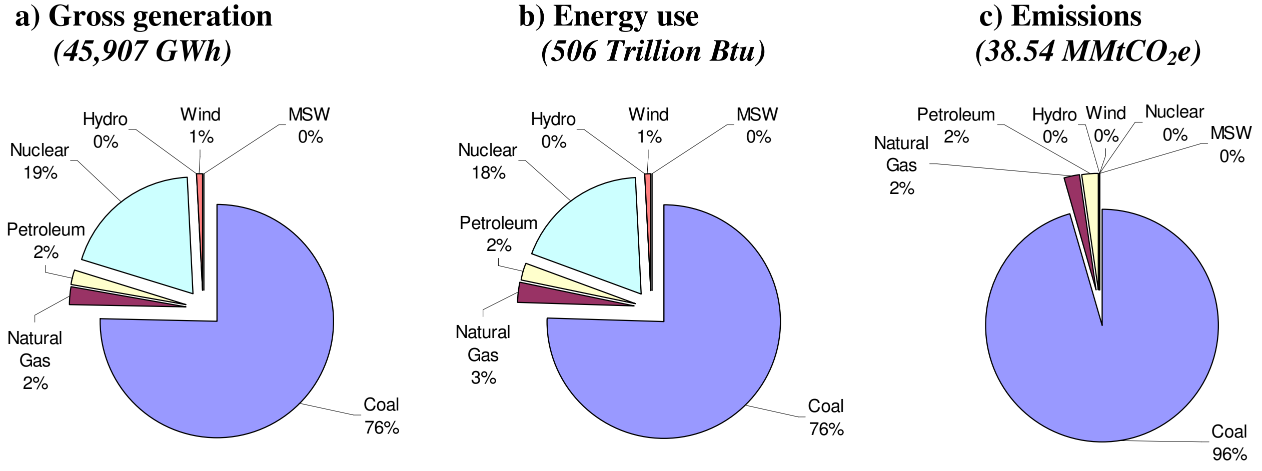
Results

Table A2 and Figure A1 summarize the characteristics of the electric generation system in Kansas, together with a breakdown in generation and emissions for Kansas power stations for 2005. The following subsections provide an overview of the results of the GHG emissions inventory and reference case projections estimated using the methodological approach described above.

Table A2. Summary of KS electric generation characteristics for the 2005 Base Year

Fuel	Gross Generation (GWh)	Fuel used or displaced (Trillion Btu)	Heat rate (Btu/KWh)	Emissions ($MMtCO_2e$)
Coal	37,891	382	10,069	36.85
Natural Gas	1,139	15	12,820	0.78
Other Gases	0	0	10,500	0.00
Petroleum	987	12	11,773	0.91
Nuclear	8,829	93	10,582	0.00
Hydroelectric	11	0	10,320	0.00
Geothermal	0	0	10,500	0.00
Solar/PV	0	0	10,320	0.00
Wind	424	4	10,320	0.00
MSW Landfill gas	2	0	10,500	0.00
Biomass	0	0	10,500	0.00
Other wastes	0	0	10,500	0.00
Pumped storage	0	0	10,500	0.00
Exports	3,985	41		3.27
Imports	0	0		0.00
Total (production-based)	49,284	506		38.54
Total (consumption-based)	45,298	464		35.27
Note: heat rates for hydro, wind and , solar refer top equivalent fuel displacement				

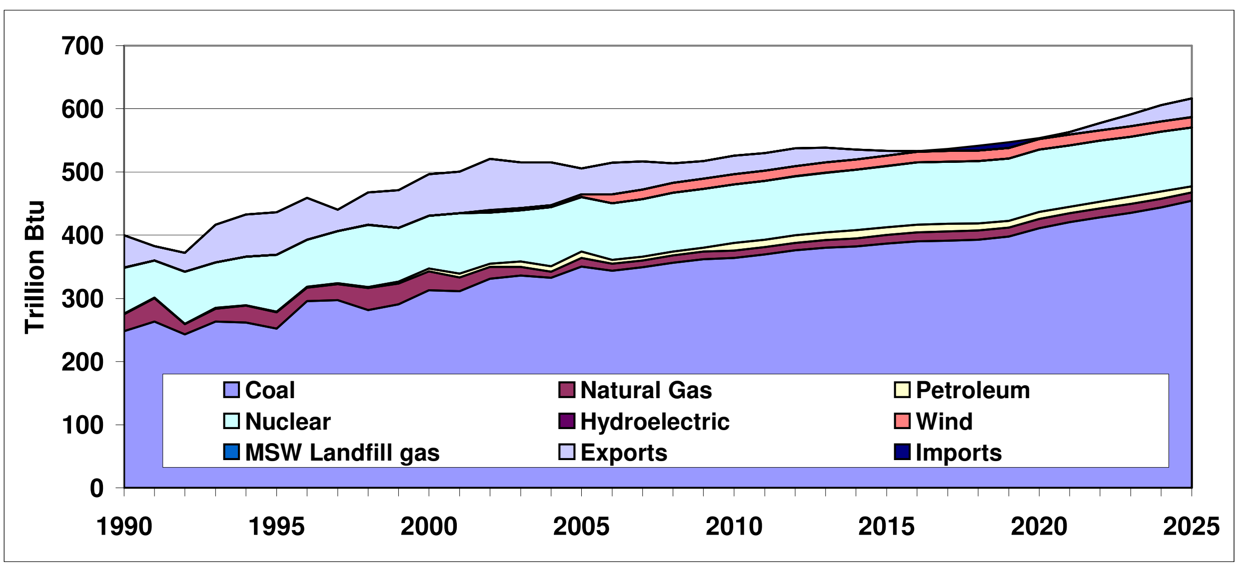
Figure A1. Breakdown of KS Generation, energy use and CO_2 Emissions – 2005 Base Year (production basis)



Primary Energy Consumption

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

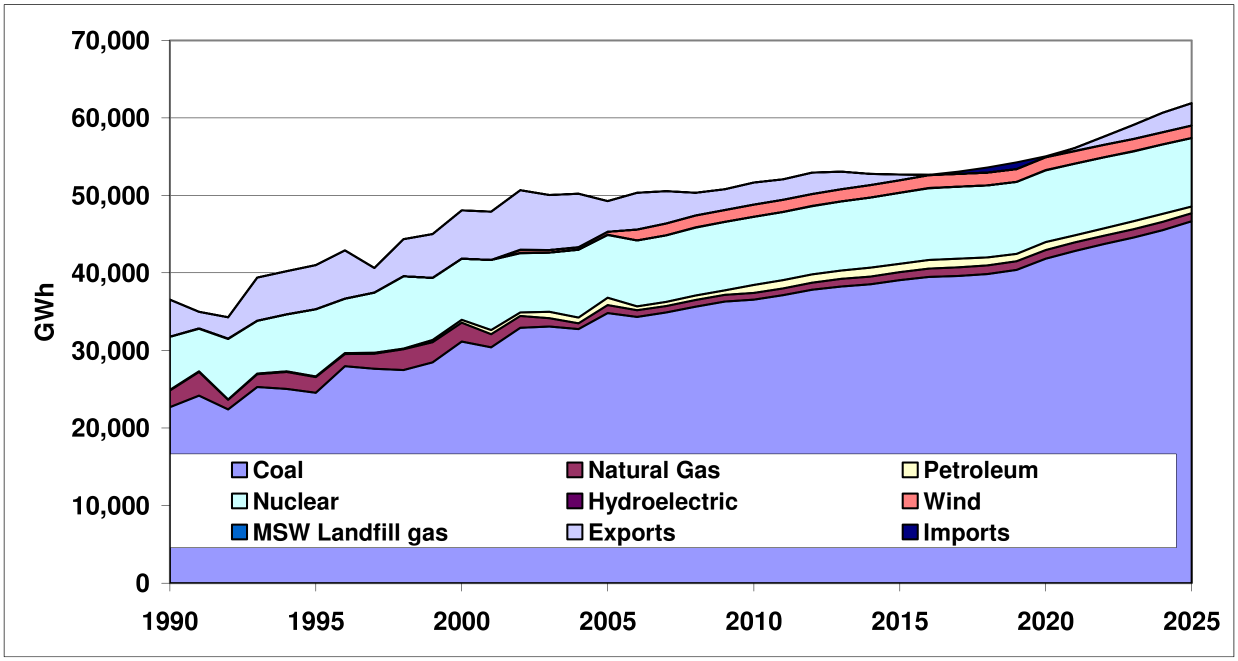
Figure A2. Gross Primary Energy Use at Kansas Power Stations



Gross Generation

Total gross generation by Kansas power plants is summarized in Figure A3. Gross generation in Kansas is dominated by steam units, which are primarily based on coal and nuclear fuel.

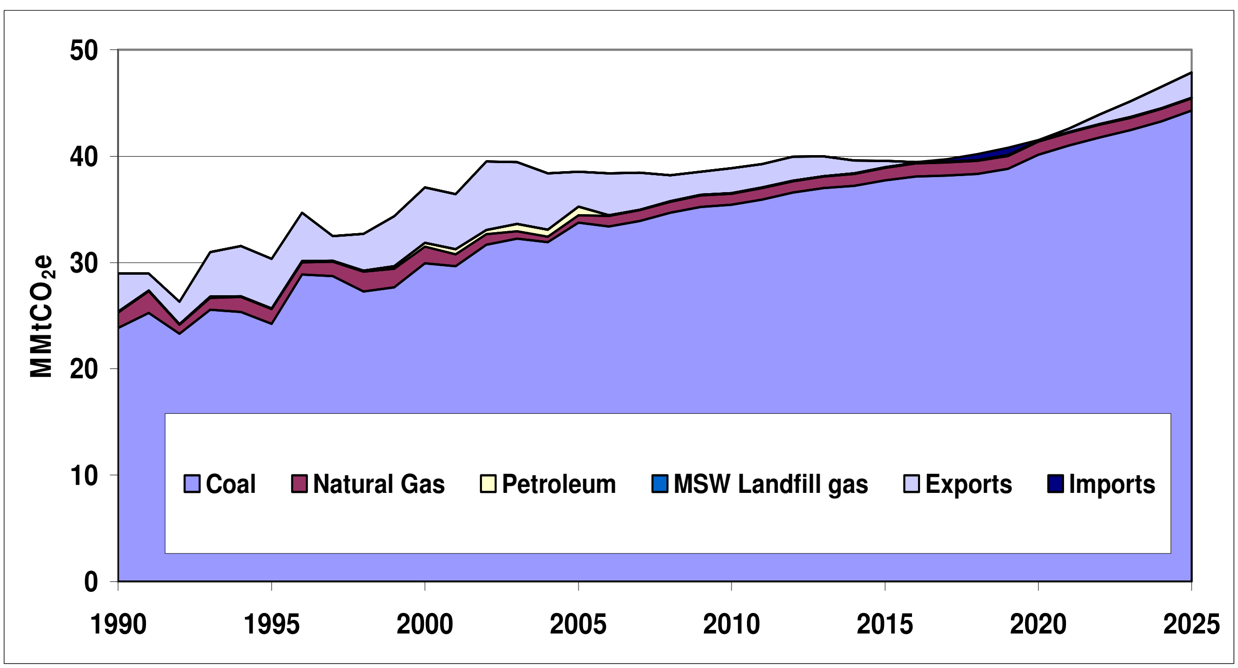
Figure A3. Gross Generation at Kansas Power Stations



GHG Emissions

Total gross GHG emissions associated with electricity generation to meet electricity demand within Kansas are summarized in Figure A4 by fuel type.

Figure A4. Total Gross GHG Emissions Associated with Kansas Electric Demand by Fuel Type



On a consumption basis, emissions were about 35.3 $MMtCO_2e$ in 2005 and are projected to increase to about 45.2 $MMtCO_2e$ in 2025, representing an overall increase of about 28% during this 20-year period. During this period, Kansas was primarily an exporter of electricity. On a production basis, emissions were about 38.5 $MMtCO_2e$ in 2005 and are projected to increase to about 47.6 $MMtCO_2e$ in 2025, representing an overall increase of about 24% during this 20-year period.

Key Uncertainties

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

- The methodologies used in this initial preliminary analysis rely on state-specific data on electricity generating units available from the EIA for computing the historical estimates of GHG emissions. The forecast relies primarily on EIA data available from the AEO2007 forecast for the SPP region. As AEO2008 will be out in the next few weeks, the forecast could be updated from the AEO2007 values.
- Electricity on-site usage and transmission and distribution loss estimates were used to estimate gross generation in the forecast from sales data. The on-site usage loss estimates are taken from the EIA AEO2007 for the SPP region for non-coal-fired stations. For KS coal-fired stations they are assumed to be 9% to account for the range of pollution control devices installed at these facilities. The transmission and distribution loss estimates are taken from the EIA AEO2007 for the SPP region. Improvements to these estimates, particularly a time series of parasitic load at KS power stations over the 1990-2005 period could help to get more accurate in-state gross generation.
- There are uncertainties associated with the future statewide fuel mix. As indicated earlier, the KS electric system is expected to evolve similarly to the SPP region. This assumption should be reviewed and revised as needed. Moreover, input assumptions such as coal emission factors, and conversion factors (to convert electricity from a heat input basis to electricity output) should be reviewed and revised with data that is specific to Kansas power generators.
- Fuel price changes influence consumption levels and, to the extent that price trends for competing fuels differ, may encourage switching among fuels, and thereby affect emissions estimates. Although the effects of fuel price changes on the supply and demand of electricity are included in the EIA regional modeling used for this initial analysis, unanticipated events that affect fuel prices could affect the electricity forecast for Kansas.
- There is at this point in time still uncertainty whether 0, 1, or 2 large coal-fired electricity generating units will be built in the state over the next two years. Should the courts overrule the Sunflower denial and the permit is issued, this development would need to be reflected in the analysis.

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

Overview

Activities in the RCI[22] 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 Kansas. 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.[23] Direct use of oil, natural gas, coal, and wood in the RCI sectors accounted for an estimated 18.3 MMtCO_2e of gross greenhouse gas (GHG) emissions in 2005.[24]

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.[25] The default data used in SIT for Kansas are from the United States Department of Energy (U.S. DOE) Energy Information Administration's (EIA) *State Energy Data* (SED). The SIT files were updated to include 2004 and 2005 SED information for Kansas.[26]

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

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22 The industrial sector includes emissions associated with agricultural energy use and natural gas consumed as lease and plant fuel. Emissions associated with pipeline fuel use are included in Appendix E.

23 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.

24 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.

25 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.

26 EIA *State Energy Data through 2005* (http://www.eia.doe.gov/emeu/states/_seds_updates.html).

document.[27] 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,[28] 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. The 1990-2005 electricity sales by RCI sector were obtained from EIA.[29] For 2005 to 2025, the annual growth rate in the electricity sales for each sector was assumed to be the same as the regional growth rate for the Southwest Power Pool reported by EIA's *Annual Energy Outlook 2007* (AEO2007).[30] The proportion of each RCI sector's sales to total sales was used to allocate emissions associated with the electricity supply sector to each of the RCI sectors.

Table B2 shows historic 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 AEO2007. For the RCI sectors, annual growth rates for natural gas, oil, wood, and coal were calculated from the AEO2007 regional forecast that EIA prepared for the West North Central modeling region. For the residential sector, the AEO2007 annual growth rate in fuel consumption from 2005 through 2025 was normalized using the AEO2007 population forecast and then weighted using Kansas' population forecast over this period. Kansas' rate of population growth is expected to average about 0.4% annually between 2005 and 2025.[31] For the commercial and industrial sectors, the AEO2007 regional fuel forecast data by sector (commercial or industrial) and fuel type were used to estimate growth. These estimates of growth 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).

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[27] EIIP, Volume VIII: Chapter 1 "Methods for Estimating Carbon Dioxide Emissions from Combustion of Fossil Fuels", August 2004.

[28] A mixture of hydrocarbons, mostly pentanes and heavier fractions, extracted from natural gas.

[29] Kansas Electricity Profile, Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/st_profiles/Kansas.html.

[30] EIA AEO2007 with Projections to 2030 (http://www.eia.doe.gov/oiaf/archive.html#aeo).

[31] Kansas Population Projections through 2027 (http://budget.ks.gov/ecodemo.htm).

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

Sector	1990-2005*	2005-2025**
Residential	2.4%	1.4%
Commercial	4.0%	1.8%
Industrial	-0.1%	0.7%
Total	**2.0%**	**1.3%**

* 1990-2005 compound annual growth rates calculated from Kansas electricity sales by year from EIA state electricity profiles (Table 8), http://www.eia.doe.gov/cneaf/electricity/st_profiles/kansas.html.
** 2005-2025 growth rates calculated from AEO2007 projections for Southwest Power Pool.

Table B2. Historical and Projected Average Annual Growth in Energy Use in Kansas, by Sector and Fuel, 1990-2025

	1990-2005[a]	2005-2010[b]	2010-2015[b]	2015-2020[b]	2020-2025[b]
Residential					
natural gas	-0.53%	0.77%	0.51%	0.26%	0.07%
petroleum	3.79%	0.46%	-0.16%	-0.31%	-0.36%
wood	-1.74%	1.26%	-0.49%	0.11%	-0.08%
coal	-100%	N/A	N/A	N/A	N/A
Commercial					
natural gas	-4.07%	1.14%	1.76%	0.98%	0.85%
petroleum	-0.87%	0.60%	1.06%	0.26%	0.38%
wood	0.92%	0.000%	0.000%	0.000%	0.000%
coal	-100%	N/A	N/A	N/A	N/A
Industrial					
natural gas	-1.84%	7.55%	0.46%	0.53%	1.12%
petroleum	-2.52%	-2.19%	-0.03%	-0.11%	-0.16%
wood	-3.36%	23.0%	1.34%	1.11%	1.37%
coal	1.87%	-0.04%	-0.38%	-0.15%	0.02%

[a] Compound annual growth rates calculated from EIA SED historical consumption by sector and fuel type for Kansas. 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 2005 are calculated from AEO2007 projections for EIA's West North Central region. Regional growth rates for the residential sector are adjusted for Kansas' projected population.
N/A—not applicable because there is no residential or commercial coal consumption by 2005.

Results

Figures B1, B2, and B3 show historical and projected emissions for the RCI sectors in Kansas from 1990 through 2025. 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. The residential sector's share of total RCI emissions from direct fuel use and electricity was 24% in 1990, increased to 29% in 2005, and is projected to remain at 29% in 2025. The commercial sector's share of total RCI emissions from direct fuel use and electricity use was 21% in 1990, increased to 27% in 2005, and is projected to increase to 30% by 2025. The industrial sector's share of total RCI emissions from direct fuel use and electricity use was 55% in 1990, decreased to 44% in 2005, and is projected to decrease to 42% in 2025. Emissions associated with the generation of electricity to meet RCI demand accounts for about 72% of the emissions for the residential sector, 83% of the emissions for the commercial sector, and 43% of the emissions for the industrial sector, on average, over the 1990 to 2025 time period. From 1990 to 2025, natural gas consumption is the next highest source of emissions for the residential and commercial sectors, accounting, on average, for about 25% and 15% of total emissions, respectively. For the industrial sector, emissions associated with the combustion of natural gas, petroleum, and coal account for about 33%, 22%, and 2% respectively, on average, from 1990 to 2025.

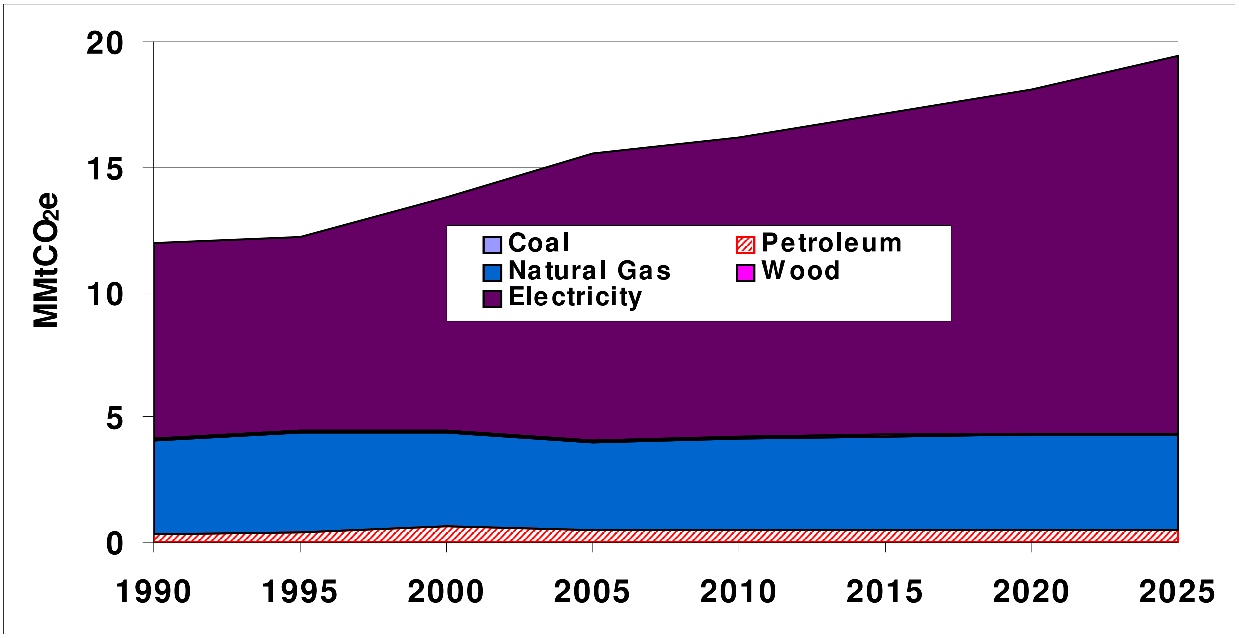
Residential Sector

Figure B1 presents the emission inventory and reference case projections for the residential sector. Figure B1 was developed from the emissions data in Table B3a. Table B3b 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 11.9 MMtCO_2e, and are estimated to increase to almost 19.5 MMtCO_2e by 2025. Emissions associated with the generation of electricity to meet residential energy consumption demand accounted for about 65% of total residential emissions in 1990, and are estimated to increase to 78% of total residential emissions by 2025. In 1990, natural gas consumption accounted for about 32% of total residential emissions, and is estimated to account for about 20% of total residential emissions by 2025. Residential-sector emissions associated with the use of coal, petroleum, and wood in 1990 were about 0.3 MMtCO_2e combined, and accounted for about 3% of total residential emissions. Emissions from these fuels increased to 0.5 MMtCO_2e in 2005. Emissions associated with the consumption of these three fuels in 2025 are estimated to remain at 0.5 MMtCO_2e, accounting for 3% of total residential sector emissions by that year.

For the 20-year period 2005-2025, residential-sector GHG emissions associated with the use of electricity are expected to increase by 1.4% per year. Emissions associated with the use of natural gas and wood are expected to increase slightly by about 0.4% and 0.2%, respectively. Emissions associated with the use of petroleum are expected to decrease slightly by about 0.1%. Total GHG emissions for this sector increase by an average of about 1.0% annually over the 20-year period.

Figure B1. Residential Sector GHG Emissions from Fuel Consumption



Source: Calculations based on approach described in text.
Note: Emissions associated with coal and wood combustion are too small to be seen on this graph.

Table B3a. Residential Sector Emissions Inventory and Reference Case Projections (MMtCO_2e)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.000	0.012	0.003	0.000	0.000	0.000	0.000	0.000
Petroleum	0.29	0.35	0.61	0.50	0.51	0.51	0.50	0.49
Natural Gas	3.79	4.04	3.78	3.50	3.64	3.73	3.78	3.79
Wood	0.05	0.04	0.03	0.03	0.04	0.04	0.04	0.04
Electricity Consumption	7.80	7.77	9.33	11.53	12.00	12.87	13.78	15.16
Total	11.92	12.21	13.76	15.56	16.19	17.15	18.10	19.48

Source: Calculations based on approach described in text.

Table B3b. Residential Sector Proportions of Total Emissions by Fuel Type (%)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.00	0.09	0.02	0.00	0.00	0.00	0.00	0.00
Petroleum	2.4	2.9	4.4	3.2	3.2	3.0	2.8	2.5
Natural Gas	31.8	33.1	27.5	22.5	22.5	21.8	20.9	19.5
Wood	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Electricity Consumption	65.4	63.6	67.8	74.1	74.1	75.1	76.1	77.8

Source: 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.

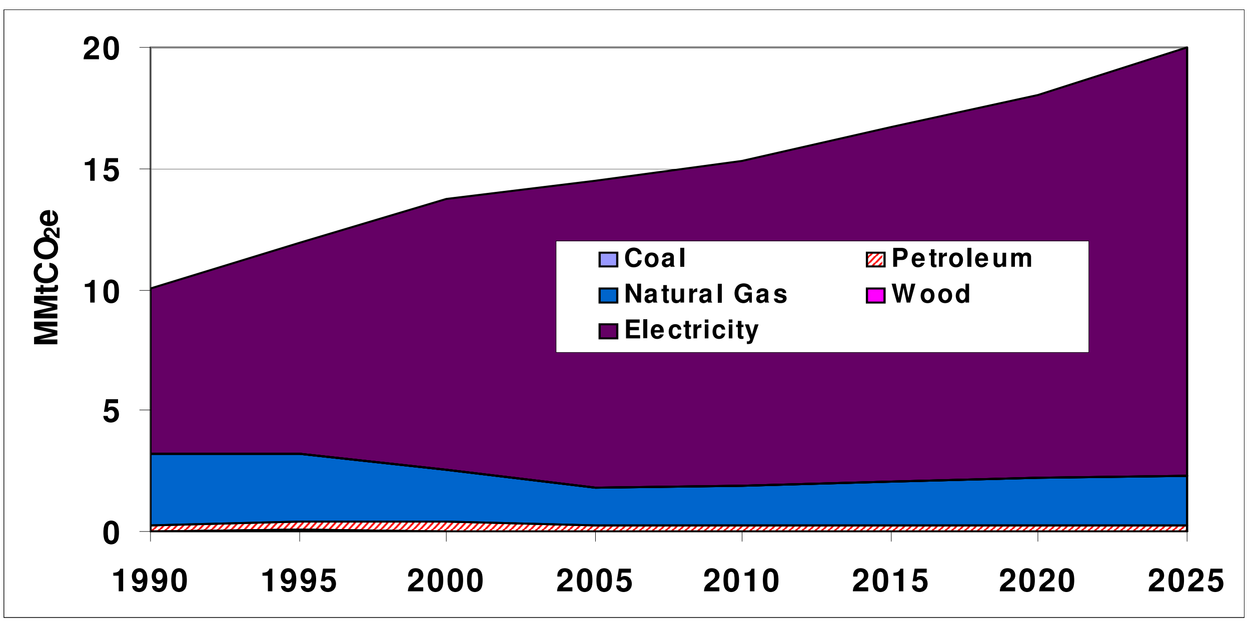
Commercial Sector

Figure B2 presents the emission inventory and reference case projections for the commercial sector. Figure B2 was developed from the emissions data in Table B4a. Table B4b show 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 10.0 $MMtCO_2e$, and are estimated to increase to about 20.0 $MMtCO_2e$ by 2025. Emissions associated with the generation of electricity to meet commercial energy consumption demand accounted for about 68% of total commercial emissions in 1990, and are estimated to increase to 89% of total commercial emissions by 2025. In 1990, natural gas consumption accounted for about 30% of total commercial emissions and is estimated to account for about 11% of total commercial emissions by 2025. Commercial-sector emissions associated with the use of coal, petroleum, and wood in 1990 were about 0.3 $MMtCO_2e$ combined, and accounted for about 3% of total commercial emissions. By 2025, emissions associated with the consumption of these three fuels are estimated to remain at about 0.3 $MMtCO_2e$, but account for slightly more than 1% of total commercial sector emissions.

For the 20-year period 2005-2025, commercial-sector GHG emissions associated with the use of electricity, natural gas, and petroleum are expected to increase at average annual rates of about 1.7%, 1.2%, and 0.6% respectively. Emissions associated with the use of coal and wood are not expected to change relative to 2005. Total GHG emissions for this sector increase by an average of about 1.6% annually over the 20-year period.

Figure B2. Commercial Sector GHG Emissions from Fuel Consumption



Source: Calculations based on approach described in text.
Note: Emissions associated with coal and wood combustion are too small to be seen on this graph.

Table B4a. Commercial Sector Emissions Inventory and Reference Case Projections (MMtCO$_2$e)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.001	0.07	0.02	0.000	0.000	0.000	0.000	0.000
Petroleum	0.27	0.34	0.38	0.23	0.23	0.24	0.25	0.25
Natural Gas	2.98	2.83	2.16	1.60	1.69	1.84	1.94	2.02
Wood	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006
Electricity Consumption	6.77	8.72	11.18	12.65	13.38	14.57	15.85	17.71
Total	10.02	11.97	13.75	14.48	15.31	16.67	18.04	19.99

Source: Calculations based on approach described in text.

Table B4b. Commercial Sector Proportions of Total Emissions by Fuel Type (%)

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.01	0.6	0.2	0.00	0.00	0.00	0.00	0.00
Petroleum	2.7	2.8	2.8	1.6	1.5	1.5	1.4	1.3
Natural Gas	29.7	23.7	15.7	11.0	11.0	11.1	10.7	10.1
Wood	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03
Electricity Consumption	67.6	72.9	81.3	87.4	87.4	87.4	87.9	88.6

Source: 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 B3 presents the emission inventory and reference case projections for the industrial sector. Figure B3 was developed from the emissions data in Table B5a. Table B5b show the relative contributions of emissions associated with each fuel type to total industrial sector emissions.[32]

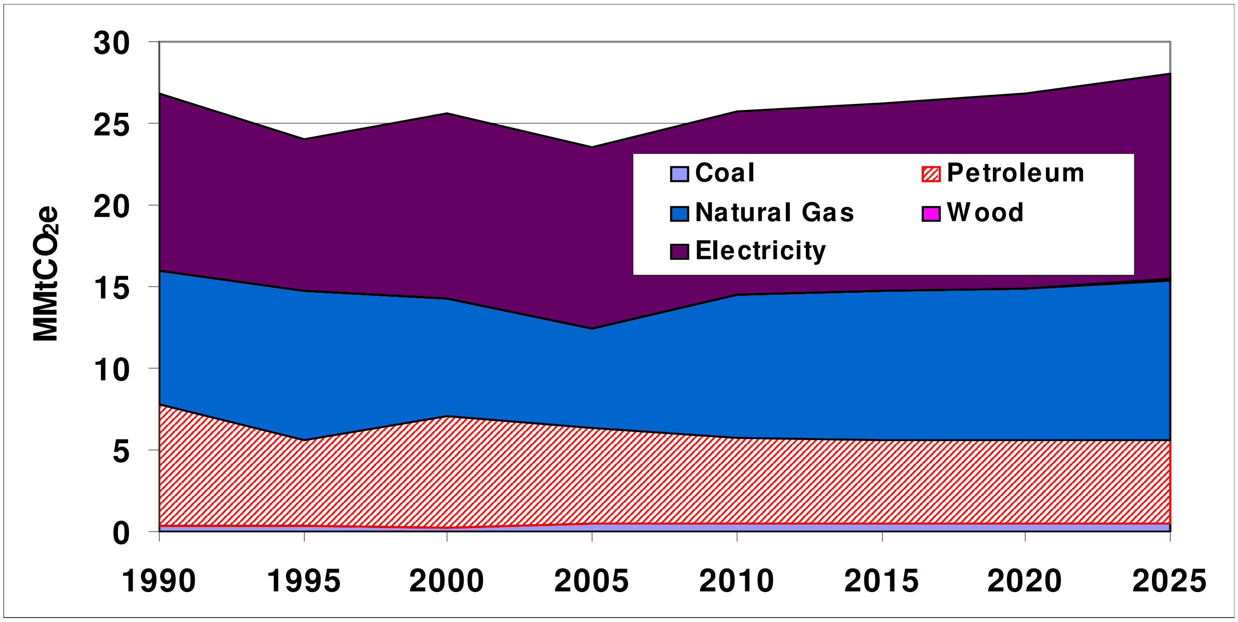
For the industrial sector, emissions from electricity and direct fuel use in 1990 were about 26.8 MMtCO$_2$e and are estimated to increase only slightly to about 28.0 MMtCO$_2$e by 2025. Emissions associated with the generation of electricity to meet industrial energy consumption demand accounted for about 40% of total industrial emissions in 1990, and are estimated increase to about 45% of total industrial emissions by 2025. In 1990, natural gas consumption accounted for about 31% of total industrial emissions, and is estimated to be about 35% of total industrial emissions in 2025. Petroleum consumption accounted for about 28% of total industrial emissions in 1990, and is estimated to decrease to about 18% of total industrial emissions by 2025. In 1990, coal consumption accounted for about 1.3% of total industrial emissions, and is estimated to be about 1.6% of total industrial emissions in 2025. Emissions associated with wood consumption by the industrial sector are less than 2% of total emissions from 1990 through 2025.

For the 20-year period 2005 to 2025, industrial-sector GHG emissions associated with the use of electricity, natural gas, and wood are expected to increase at average annual rates of about 0.6%, 2.4%, and 6.3% respectively. Emissions associated with the use of petroleum and coal are

[32] Kansas Department of Health and Environment had requested that the industrial emission data be broken down by major industrial category, such as cement, refineries, and chemical plants. However, the data that would be needed to perform such a breakdown (i.e., historical fuel consumption by sector) are not currently available.

expected to decrease annually by about 0.6% and 0.1%, respectively. Total GHG emissions for the industrial sector increase by an average of about 0.9% annually over the 20-year period.

Figure B3. Industrial Sector GHG Emissions from Fuel Consumption



Source: Calculations based on approach described in text.
Note: Emissions associated with wood combustion are too small to be seen on this graph.

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

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	0.35	0.31	0.30	0.47	0.46	0.46	0.45	0.45
Petroleum	7.41	5.30	6.76	5.82	5.21	5.20	5.17	5.13
Natural Gas	8.21	9.15	7.20	6.15	8.85	9.05	9.30	9.83
Wood	0.008	0.007	0.004	0.005	0.014	0.015	0.016	0.017
Electricity Consumption	10.80	9.20	11.32	11.10	11.14	11.52	11.88	12.60
Total	26.77	23.97	25.59	23.53	25.68	26.24	26.82	28.03

Source: Calculations based on approach described in text.

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

Fuel Type	1990	1995	2000	2005	2010	2015	2020	2025
Coal	1.3	1.3	1.2	2.0	1.8	1.7	1.7	1.6
Petroleum	27.7	22.1	26.4	24.7	20.3	19.8	19.3	18.3
Natural Gas	30.7	38.2	28.1	26.1	34.5	34.5	34.7	35.1
Wood	0.03	0.03	0.02	0.02	0.05	0.06	0.06	0.06
Electricity Consumption	40.3	38.4	44.2	47.2	43.4	43.9	44.3	45.0

Source: 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.

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 West North 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 Kansas to the extent that such data become available.
- Once data are available to break the industrial sector down by major sector, the use of growth rates specific to those sectors rather than the use of growth rates based on regional fuel consumption should improve the industrial sector projections.

Appendix C. Transportation Energy Use

Overview

The transportation sector is one the largest sources of greenhouse gas (GHG) emissions in Kansas. The transportation sector includes light- and heavy-duty on-road vehicles, aircraft, rail engines, and marine engines. Carbon dioxide (CO_2) accounts for about 97% of the transportation sector's GHG emissions in 1990 and is projected to increase to about 98% of transportation GHG emissions by 2025. Most of the remaining GHG emissions from the transportation sector are due to nitrous oxide (N_2O) emissions from gasoline engines.

Historical 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 on-road 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 (2005) from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) *State Energy Data* (SED) added.[35] The default VMT data in SIT were replaced with annual VMT provided by the Kansas Department of Transportation (KDOT).[36] Default data from the Federal Highway Administration (FHWA)[37] were used to allocate the VMT by vehicle type in the State.

On-road Vehicles

KDOT provided historical statewide VMT data for the years 1990, 1995, and 2000 through 2006.[38] These data were used to replace the default SIT VMT data for calculating CH_4 and N_2O emissions. These VMT data were distributed by vehicle type in the same proportion as the default VMT data in the SIT. The data were interpolated for years with missing data. The default EIA SED gasoline and diesel fuel consumption data were used to calculate the CO_2 emissions from on-road vehicles for the historical years through 2003. The Kansas Department of Revenue

[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] Kansas historical VMT data, "Kansas – Daily Vehicle Miles of Travel by County – Selected Years 1976 to 2006," from KDOT provided to CCS in electronic file DVMT history 1976_2006.xls, December 14, 2007.
[37] Highway Statistics, Federal Highway Administration, http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm.
[38] Kansas historical VMT data, "Kansas – Daily Vehicle Miles of Travel by County – Selected Years 1976 to 2006," from KDOT provided to CCS in electronic file DVMT history 1976_2006.xls, December 14, 2007.

Table C1. Key Assumptions and Methods for the Transportation Inventory and Projections

Vehicle Type and Pollutants	Methods
On-road gasoline, diesel, natural gas, and liquefied petroleum gas (LPG) vehicles – CO_2	**Inventory (1990-2005, Onroad 1990-1007)** US EPA SIT and fuel consumption from EIA SED. Onroad gasoline and ethanol fuel consumption for 2004-2007 from Kansas Department of Revenue. **Reference Case Projections (2006-2025, Onroad 2008-2025)** Gasoline and diesel fuel use projected using Kansas Department of Transportation (KDOT) VMT projections adjusted by fuel efficiency improvement projections from EPA. Other on-road fuels projected using West North Central Region fuel consumption projections from EIA AEO2007 adjusted using state-to-regional ratio of population growth.
On-road gasoline and diesel vehicles – CH_4 and N_2O	**Inventory (1990-2005)** US EPA SIT, on-road vehicle CH_4 and N_2O emission factors by vehicle type and technology type within SIT were updated to the latest factors used in the US EPA's *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2005.* State total VMT replaced with VMT provided by KDOT, VMT allocated by vehicle type using default data in SIT. **Reference Case Projections (2006-2025)** State total VMT projections provided by KDOT and allocated to vehicle types using vehicle specific growth rates from AEO2007.
Non-highway fuel consumption (jet aircraft, gasoline-fueled piston aircraft, boats, locomotives) – CO_2, CH_4 and N_2O	**Inventory (1990-2005)** US EPA SIT and fuel consumption from EIA SED. Commercial marine based on allocation of national fuel consumption. **Reference Case Projections (2006-2025)** Aircraft projected using aircraft operations projections from Federal Aviation Administration (FAA). No growth assumed for rail diesel. Marine gasoline projected based on historical data.

provided gasoline and gasohol consumption data that were used for the years 2004-2007.[39] The gasoline consumption estimates for 1990 through 2007 were adjusted by subtracting ethanol consumption, per the methodology used in SIT. For the 1990-2001 period, the volume of ethanol consumption, as a percentage of the total gasoline volume, ranged from about 0.63% of the gasoline consumption in 1990, down to 0.20% in 2001. Ethanol consumption began to increase starting in 2002, rising to 3.2% of gasoline consumption in 2003. Ethanol consumption dropped to 0.31% of gasoline consumption on a volume basis in 2004, but the volume share of ethanol has generally been increasing since that time, reaching 3.8% in 2007. The volume percentage of ethanol was estimated to continue increasing on a linear basis through the projection years, until a maximum of 10% volume share of ethanol would be achieved in 2013. The ethanol volume share was projected to remain at 10% for the remainder of the projection years.[40]

On-road vehicle gasoline and diesel emissions were projected based on statewide projected VMT data for 2010 and 2020 provided by KDHE.[41] CCS interpolated the VMT data for the intervening years. The annual growth rate calculated based on the 2010 and 2020 projected VMT data were used to estimate projected VMT from 2021 through 2025.

The resulting total annual VMT data were then allocated by vehicle type based on national VMT forecasts by vehicle type reported in EIA's *Annual Energy Outlook 2007* (AEO2007).[42] The AEO2007 data were incorporated because the growth rates calculated from the AEO data result in significantly different VMT growth rates for certain vehicle types (e.g., 27% growth between 2005 and 2025 in light-duty gasoline vehicle VMT versus 61% growth in heavy-duty diesel truck VMT over this period). The AEO2007 vehicle type-based national growth rates were applied to the 2005 Kansas estimates of VMT by vehicle type. These VMT data were then proportionally adjusted to total to the KDOT-based projected statewide VMT totals for each year. The resulting vehicle-type VMT estimates and compound annual average growth rates are displayed in Tables C2 and C3, respectively. These VMT growth rates were used to forecast the CH_4 and N_2O emissions from on-road gasoline and diesel vehicles. These VMT growth rates were also applied to natural gas vehicles.

For forecasting CO_2 emissions, growth in fuel consumption is needed. On-road gasoline and diesel fuel consumption were forecasted by developing a set of growth factors that adjusted the VMT projections shown in Table C2 to account for improvements in vehicle fuel efficiency. Projected vehicle fuel efficiency data were obtained from EPA, and are shown in Table C4. The resulting on-road fuel consumption growth rates are shown in Table C5. Growth rates for projecting CO_2 emissions from natural gas vehicles, lubricants, and other fuel consumption were calculated by allocating the AEO2007 consumption of these fuels in the West North Central

[39] Spreadsheet "EtOH% of gasoline Jul03-Jan08.xls" developed by Steve Neske, Kansas Department of Revenue, provided electronically to CCS.
[40] Ethanol projection assumptions provided by KDHE based on comments from the Kansas Department of Commerce.
[41] Kansas projected VMT data, "Kansas Demographics – Percentage Growth Graph Data," provided to CCS by Andy Hawkins, KDHE, in electronic file DVMT trends dec2007.xls, December 14.
[42] US Department of Energy, Energy Information Administration, *Annual Energy Outlook 2007 with Projections to 2030,* DOE/EIA-0383(2007), February 2007, available at http://www.eia.doe.gov/oiaf/archive/aeo07/index.html.

region[43] and allocating this to Kansas based on the ratio of the State's projected population to the region's projected population.

Table C2. Kansas Projected Vehicle Miles Traveled Estimates (million miles)

Vehicle Type	2005	2010	2015	2020	2025
Heavy Duty Diesel Vehicle	2,001	2,378	2,698	3,001	3,349
Heavy Duty Gasoline Vehicle	295	308	327	352	387
Light Duty Diesel Truck	303	382	487	639	892
Light Duty Diesel Vehicle	91	115	146	192	268
Light Duty Gasoline Truck	10,059	10,964	11,800	12,617	13,489
Light Duty Gasoline Vehicle	17,057	18,592	20,010	21,395	22,873
Motorcycle	102	111	120	128	137
Total	29,908	32,850	35,588	38,325	41,396

Table C3. Kansas Vehicle Miles Traveled Compound Annual Growth Rates

Vehicle Type	1990-2005	2005-2010	2010-2015	2015-2020	2020-2025
Heavy Duty Diesel Vehicle	2.22%	3.52%	2.56%	2.15%	2.21%
Heavy Duty Gasoline Vehicle	-1.11%	0.83%	1.19%	1.50%	1.94%
Light Duty Diesel Truck	3.91%	4.76%	4.97%	5.61%	6.90%
Light Duty Diesel Vehicle	-3.02%	4.76%	4.97%	5.61%	6.90%
Light Duty Gasoline Truck	3.58%	1.74%	1.48%	1.35%	1.35%
Light Duty Gasoline Vehicle	0.99%	1.74%	1.48%	1.35%	1.35%
Motorcycle	0.67%	1.74%	1.48%	1.35%	1.35%

Table C4. Fuel Economy Values by Vehicle Type (miles/gallon)

Vehicle Type	2005	2010	2015	2020	2025
Heavy Duty Diesel Vehicle	7.1	7.2	7.2	7.2	7.2
Heavy Duty Gasoline Vehicle	9.6	9.7	9.8	9.8	9.8
Light Duty Diesel Truck	22.4	21.4	20.7	20.9	21.0
Light Duty Diesel Vehicle	29.6	32.4	32.4	32.4	32.4
Light Duty Gasoline Truck	17.7	18.2	18.5	18.6	18.7
Light Duty Gasoline Vehicle	24.0	24.1	24.1	24.1	24.1
Motorcycle	50.0	50.0	50.0	50.0	50.0

Table C5. Kansas On-road Fuel Consumption Compound Annual Growth Rates

Fuel Growth Factors	1990-2005	2005-2010	2010-2015	2015-2020	2020-2025
On-road gasoline	0.07%	-0.09%	0.61%	1.27%	1.31%
On-road diesel	2.14%	3.34%	2.75%	2.40%	2.62%

[43] The AEO West North Central region includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota.

Aviation

For the aircraft sector, emission estimates for 1990 to 2005 are based on SIT methods and fuel consumption from EIA. Emissions were projected from 2006 to 2025 using general aviation and commercial aircraft operations for 2006 through 2025 from the Federal Aviation Administration's (FAA) Terminal Area Forecast System[44] and national aircraft fuel efficiency forecasts. To estimate changes in jet fuel consumption, itinerant aircraft operations from air carrier, air taxi/commuter, and military aircraft were first summed for each year of interest. The post-2005 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 AEO2007. Because AEO2007 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 Kansas, which was obtained from the FAA source noted above. The resulting compound annual average growth rates are displayed in Table C6.

Table C6. Kansas Aviation Fuels Compound Annual Growth Rates

Fuel	1990-2005	2005-2010	2010-2015	2015-2020	2020-2025
Aviation Gasoline	3.05%	1.20%	1.08%	0.71%	0.74%
Jet Fuel	-4.76%	-0.59%	0.09%	0.15%	0.33%

Rail and Marine Vehicles

For the rail and recreational marine sectors, 1990-2005 estimates are based on SIT methods and fuel consumption from EIA. Marine gasoline consumption was projected to 2025 based on a linear regression of the 1990 through 2005 historical data. The historic data for rail shows no significant positive or negative trend; therefore, no growth was assumed for this sector. It is noted that Burlington Northern Santa Fe Railway has plans for a large intermodal facility in Kansas. If this is built, it will likely increase rail traffic.

For the commercial marine sector (marine diesel and residual fuel), 1990-2005 emission estimates are based on SIT emission rates applied to estimates of Kansas 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 Kansas marine vessel fuel consumption. Kansas fuel consumption estimates were developed by allocating 1990-2005 national diesel and residual oil vessel bunkering fuel consumption estimates obtained from EIA.[45] Marine vessel fuel consumption data were allocated to Kansas using the marine vessel activity allocation methods/data compiled to support the development of EPA's National Emissions Inventory (NEI).[46] 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

[44] Terminal Area Forecast, Federal Aviation Administration, http://www.apo.data.faa.gov/main/taf.asp.
[45] 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).
[46] See methods described in ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/mobile/2002nei_mobile_nonroad_methods.pdf

underway). National port area fuel consumption was allocated to Kansas 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."[47]

Non-road Engines

It should be noted that fuel consumption data from EIA includes non-road gasoline and diesel fuel consumption in the commercial and industrial sectors. Emissions from these non-road engines are included in the inventory and forecast for the residential, commercial, and industrial (RCI) sectors. Table C7 shows how EIA divides gasoline and diesel fuel consumption between the transportation, commercial, and industrial sectors.

Table C7. 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

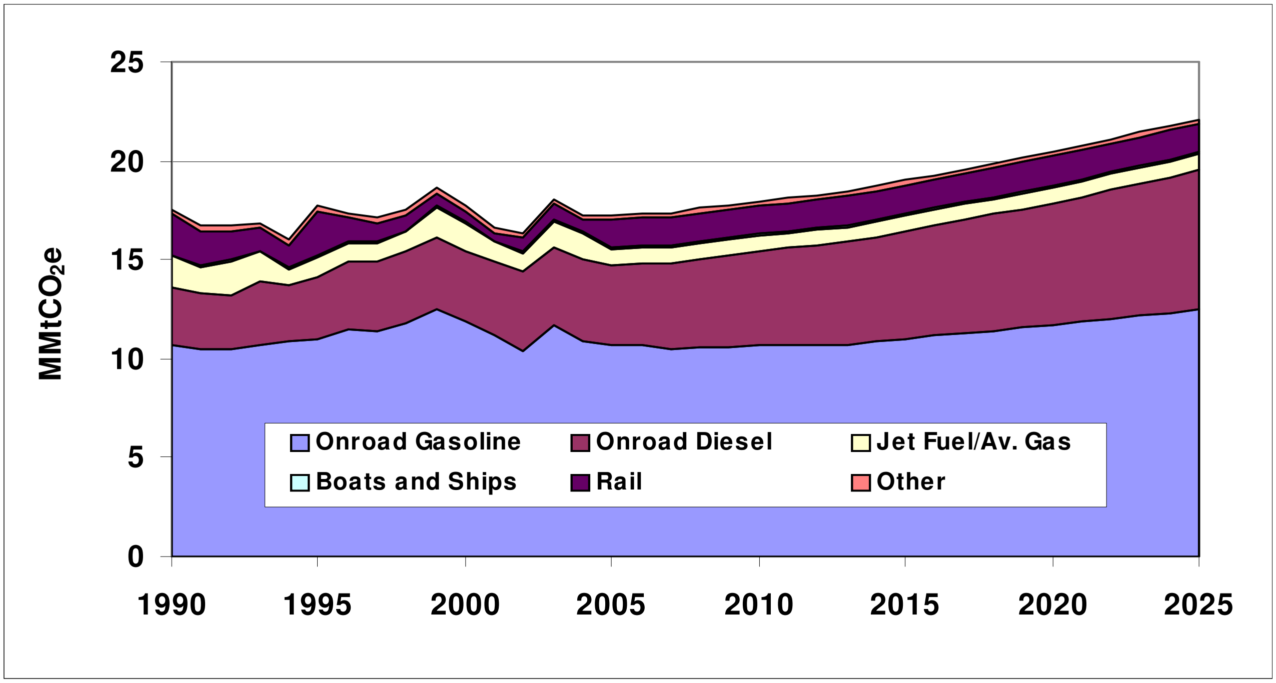
Results

As shown in Figure C1 and in Table C8, on-road gasoline consumption accounts for the largest share of transportation GHG emissions. Emissions from on-road gasoline vehicles decreased by about 0.1% from 1990 to 2005, accounting for 62% of total transportation emissions in 2005. GHG emissions from on-road diesel fuel consumption increased by 37% from 1990 to 2005, and by 2005 accounted for 23% of GHG emissions from the transportation sector. Rail emissions decreased by 30% from 1990 to 2005, accounting for 8% of 2005 transportation emissions in Kansas. Emissions from all other categories combined (aviation, boats and marine fuel, natural gas and liquefied petroleum gas (LPG), and oxidation of lubricants) contributed to over 6% of total transportation emissions in 2005.

GHG emissions from on-road gasoline consumption are projected to increase by about 17%, and emissions from on-road diesel consumption are expected to increase by 73% between 2005 and 2025. Emissions from the aviation sector decreased from 1990 to 2005, but show an increase of about 2% from 2005 to 2025. Rail emissions were projected to remain constant from 2005 to 2025, while marine emissions are projected to increase by 37% from 2005 to 2025.

[47] Note that it was necessary to estimate 1990-1996 values by applying the available 1997 KS percentage of national waterborne tonnage.

Figure C1. Transportation Gross GHG Emissions by Category, 1990-2025



Source: Calculations based on approach described in text.

Table C8. Gross GHG Emissions from Transportation (MMtCO2e)

Source	1990	1995	2000	2005	2010	2015	2020	2025
On-road Gasoline	10.69	10.94	11.91	10.68	10.66	11.00	11.72	12.51
On-road Diesel	2.95	3.15	3.52	4.05	4.77	5.47	6.16	7.00
Jet Fuel/Aviation Gas	1.54	1.03	1.39	0.79	0.78	0.78	0.79	0.81
Boats and Ships - Ports/Inshore	0.08	0.07	0.07	0.09	0.09	0.10	0.11	0.12
Rail	2.04	2.28	0.54	1.43	1.43	1.43	1.43	1.43
Other	0.29	0.26	0.27	0.24	0.24	0.24	0.23	0.23
Total	**17.59**	**17.72**	**17.70**	**17.28**	**17.97**	**19.02**	**20.45**	**22.11**

Key Uncertainties

Uncertainties in On-road Fuel Consumption

A major uncertainty in this analysis is the conversion of the projected VMT to fuel consumption. These are based on first allocating Kansas' total VMT by vehicle type using national vehicle type growth projections from AEO2007 modeling, which may not reflect Kansas conditions. The conversion of the VMT data to fuel consumption also includes national assumptions regarding fuel economy by vehicle type, as shown in Table C4. If Kansas' vehicle fleet turns over at a slower or faster rate than the rest of the nation, these fuel economy values may not reflect conditions in Kansas.

Energy Independence and Security Act of 2007
The reference case projections documented here do not include the corporate average fuel economy 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 fuel economy and biofuels provisions of this Act will be separately quantified at a later date.

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 out-of-state flights. 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 general aviation data classified by fuel type are 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; and
- The proportion of freight tonnage at ports in Kansas to the total national freight tonnage reflects the proportion of national marine fuel that is consumed in Kansas.

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 Kansas, and for which emissions are estimated in this inventory, include the following:

- Carbon dioxide (CO_2) from:
  - Production of cement, iron and steel, ammonia and urea, ceramics, glass, carbon black;
  - Consumption of limestone, dolomite, and soda ash;
- Nitrous oxide (N_2O) from:
  - Nitric acid production;
- Methane (CH_4) from:
  - Carbon black production;
- 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 from HCFC-22 production.

In addition, at Kansas Department of Health and Environment (KDHE)'s request, CCS has developed CO_2 emission estimates from fermentation of grain sugar that occurs during ethanol production. However, these emission estimates are reported separately at the end of this appendix, and are not included in the emission totals for industrial processes or the Kansas statewide emission summaries, because it is assumed that the biomass used in ethanol production absorbs CO_2 when it is grown, and adds no net CO_2 to the atmosphere.

Other industrial processes that are sources of GHG emissions but are not found in Kansas include the following:

- CO_2 from lime production
- N_2O from adipic acid production;
- PFCs from aluminum production;
- SF_6 from magnesium production and processing;
- HFCs, PFCs, and SF_6 from semiconductor manufacture.

Historical Emissions and Reference Case Projections

Greenhouse gas emissions for 1990 through 2005 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.[48] 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. To the extent possible, information provided by Kansas state and local sources was used in this analysis.

Industrial processes that were not included in SIT software were estimated based on methodologies from Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines.[49] These processes include the production of ceramics, glass, and carbon black. For each of these cases, the method of calculating the GHG emissions is outlined individually.

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: 1990-2005, 1995-2005, and 2000-2005 (or the closest available approximation of these 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.

[48] 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.

[49] *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 3 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol3.htm); Chapters 2 and 3.

Table D1. Approach to Estimating Historical Emissions

Source Category	Time Period for which Data Available	Required Data for SIT	Data Source
Cement Manufacture	1990 - 2005	Metric tons (Mt) of clinker produced and masonry cement produced each year.	Historical production for Kansas from USGS Minerals Yearbook, Cement Statistics and Information. Default clinker production for 1992 is not available in SIT, so the average of 1991 and 1993 clinker production was used as a surrogate for 1992 production. (http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb).
Limestone and Dolomite Consumption	1994 - 2004	Mt of limestone and dolomite consumed.	Historical consumption (sales) for Kansas 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 and for 2005; data for 1994 were used for 1990 – 1993 as a surrogate to fill in production data missing for these years; data for 2004 were used for 2005 production.
Soda Ash Consumption	1990 - 2005	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/). -- US (1990-2000 and 2000-2005) and state (2000-2005) population from US Census Bureau (http://www.census.gov/popest/states/). -- State (1990-2000) population from US Census Bureau (http://www.census.gov/popest/archives/2000s/vintage_2001/CO-EST2001-12/CO-EST2001-12-20.html).
Ammonia and Urea Production	1990-2005	Mt ammonia and urea produced.	Production data for ammonia and urea ammonium nitrate for 1990-2005 from Kansas Department of Health and the Environment (KDHE). Urea production estimated by assuming 30% composition of urea ammonium nitrate; assumption from European Fertilizer Manufacturers Association (EFMA), http://www.efma.org/Publications/BAT%2095/Bat05/section11.asp.
Iron and Steel Production	1990, 1995, 2000, 2005	Mt of crude steel produced by production method.	KDHE provided production data for 1990, 1995, 2000, and 2005. KDHE provided emission factor for Electric Arc Furnace (EAF) production method at 0.004 metric ton CO_2 per metric ton production; this is the EAF emission factor used in U.S. EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* (http://www.epa.gov/climatechange/emissions/usinventoryreport.html). GHG emissions for the intervening years are interpolated from 1990, 1995, 2000, and 2005 emissions.
Nitric Acid Production	1990, 1995, 2000, 2005	Mt of nitric acid produced	KDHE provided production data for 1990, 1995, 2000, and 2005. GHG emissions for the intervening years are interpolated from 1990, 1995, 2000, and 2005 emissions.
HCFC-22 Production	1990, 1995, 2000	Mt of HCFC-22 production	KDHE provided production data for 1990, 1995, and 2000. HCFC-22 production plant in Kansas closed in 2002, therefore, post-2001 year emissions were set to zero. GHG emissions for the intervening years are interpolated from 1990, 1995, and 2000 emissions. Production data for 2000 were used as a surrogate for 2001 production.
ODS Substitutes	1990 - 2005	Based on state's population and estimates of emissions per capita from the US EPA national GHG inventory.	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). References for US Census Bureau national and state population figures are cited under the data sources for soda ash above.

Source Category	Time Period for which Data Available	Required Data for SIT	Data Source
Electric Power T&D Systems	1990 - 2005	Emissions from 1990 to 2005 based on the national emissions per kilowatt-hour (kWh) and state's electricity use provided in SIT.	National emissions are apportioned to the state based on the ratio of 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 ODS substitutes above.
Glass Manufacture	1990, 1995, 2000, 2005	Mt of glass produced.	KDHE provided production data for 1990, 1995, 2000, and 2005. GHG emissions for the intervening years are interpolated from 1990, 1995, 2000, and 2005 emissions. Methodology for calculating CO_2 emissions and CO_2 emission factor from *2006 IPCC Guidelines*, Vol. 3, Ch. 2 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf).
Ceramics Production (incl. Brick mfg)	1990, 1995, 2000, 2005	Mt of brick produced	KDHE provided production data for 1990, 1995, 2000, and 2005. GHG emissions for the intervening years are interpolated from 1990, 1995, 2000, and 2005 emissions. Methodology for calculating CO_2 emissions from *2006 IPCC Guidelines*, Vol. 3, Ch. 2 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf). CO_2 emission factor provided by KDHE (Source: EC Ref. Document (2007) *Reference Document on Best Available Techniques in the Ceramic Manufacturing Industry*, European Commission, August 2007).
Carbon Black Manufacturing	1990, 1995, 2000, 2005	Mt of carbon black produced	KDHE provided production data for 1990, 1995, 2000, and 2005. GHG emissions for the intervening years are interpolated from 1990, 1995, 2000, and 2005 emissions. Methodology for calculating CO_2 and CH_4 emissions and CO_2 and CH_4 emission factors from *2006 IPCC Guidelines*, Vol. 3, Ch. 2 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf).

Table D2. Approach to Estimating Projections for 2006 through 2025

			Annual Growth Rates (%)			
Source Category	**Projection Assumptions**	**Data Source**	**2005 to 2010**	**2010 to 2015**	**2015 to 2020**	**2020 to 2025**
Cement Manufacture	National cement consumption growth rates	Annual growth rates calculated from national cement consumption forecast from the Portland Cement Association's *The Monitor Forecast Report*, "Long-Term Cement Consumption Outlook - 2008"	-0.3	2.2	1.9	1.8
Limestone and Dolomite Consumption	Smallest historical annual decline in state consumption from each of three periods analyzed (1990-2005)	Annual change in Kansas limestone and dolomite consumption: 1990-2005 = -2.3% 1995-2005 = -5.8% 2000-2005 = -4.6%	-2.3	-2.3	-2.3	-2.3
Soda Ash Consumption	Smallest historical annual decline in state consumption from each of three periods analyzed (1990-2005)	Annual change in Kansas soda ash consumption: 1990-2005 = -0.8% 1995-2005 = -1.1% 2000-2005 = -1.2%	-0.8	-0.8	-0.8	-0.8
Ammonia and Urea Production	No growth assumption due to conflicting historical trends.	Annual change in Kansas ammonia production and urea consumption: 1990-2005 = 0.5% 1995-2005 = --0.7% 2000-2005 = 1.2%	0	0	0	0

			Annual Growth Rates (%)			
Source Category	Projection Assumptions	Data Source	2005 to 2010	2010 to 2015	2015 to 2020	2020 to 2025
Iron and Steel Production	Smallest historical annual increase in state production from each of three periods analyzed (1995-2005).	Annual change in Kansas iron and steel production: 1990-2005 = +11.3% 1995-2005 = +6.3% 2000-2005 = +12.3%	6.3	6.3	6.3	6.3
Nitric Acid Production	Smallest historical annual increase in state production from each of three periods analyzed (1990-2005).	Annual change in Kansas nitric acid production: 1990-2005 = +2.1% 1995-2005 = +3.7% 2000-2005 = +10.6%	2.1	2.1	2.1	2.1
HCFC-22 Production	No growth assumption since the only HCFC-22 plant in Kansas closed in 2002.	Plant closed in 2002.	0.0	0.0	0.0	0.0
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 D1 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.	8.7	6.4	5.0	5.0
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 D8 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.	-1.6	-0.8	-0.7	-0.7
Glass Manufacture	Smallest historical annual increase in state production from each of three periods analyzed (1990-2005).	Annual change in Kansas Glass Manufacture: 1990-2005 = +2.8% 1995-2005 = +3.0% 2000-2005 = +4.7%	2.8	2.8	2.8	2.8
Ceramics Production (including Brick Manufacturing)	Smallest historical annual increase in state production from each of three periods analyzed (1990-2005).	Annual change in Kansas brick production: 1990-2005 = +3.4% 1995-2005 = +10.5% 2000-2005 = +8.2%	3.4	3.4	3.4	3.4
Carbon Black Manufacturing	Smallest historical annual increase in state production from each of three periods analyzed (2000-2005).	Annual change in Kansas carbon black production: 1990-2005 = +3.2% 1995-2005 = +6.0% 2000-2005 = +1.3%	1.3	1.3	1.3	1.3

Results

Figures D1 and D2 show historic and projected emissions for the industrial processes sector from 1990 to 2025. Table D3 shows the historic and projected emission values upon which Figures D1 and D2 are based. Total gross Kansas GHG emissions were about 2.8 million metric tons of CO_2 equivalents ($MMtCO_2e$) in 1990, 5.7 $MMtCO_2e$ in 2005, and are projected to increase to about 9.5 $MMtCO_2e$ by 2025. Emissions from the overall industrial processes category are expected to grow about 2.5% annually from 2005 through 2025, as shown in Figures D1 and D2, with emissions growth primarily associated with increasing use of HFCs and PFCs in refrigeration and air conditioning equipment.

Cement Manufacture

The cement production process is one that releases relatively high amounts of CO_2 in the industrial non-fuel combustion sector. 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 (see black line) and Table D3, emissions from this source are estimated to be about 0.79 $MMtCO_2e$ in 1990 and are projected to increase to about 1.9 $MMtCO_2e$ by 2025. Historical clinker and masonry cement production data for Kansas were obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate CO_2 emissions for 1990-2005. National cement consumption forecasts were used to project Kansas clinker/masonry cement production emissions from 2006 to 2025.

Figure D1. GHG Emissions from Industrial Processes, 1990-2025

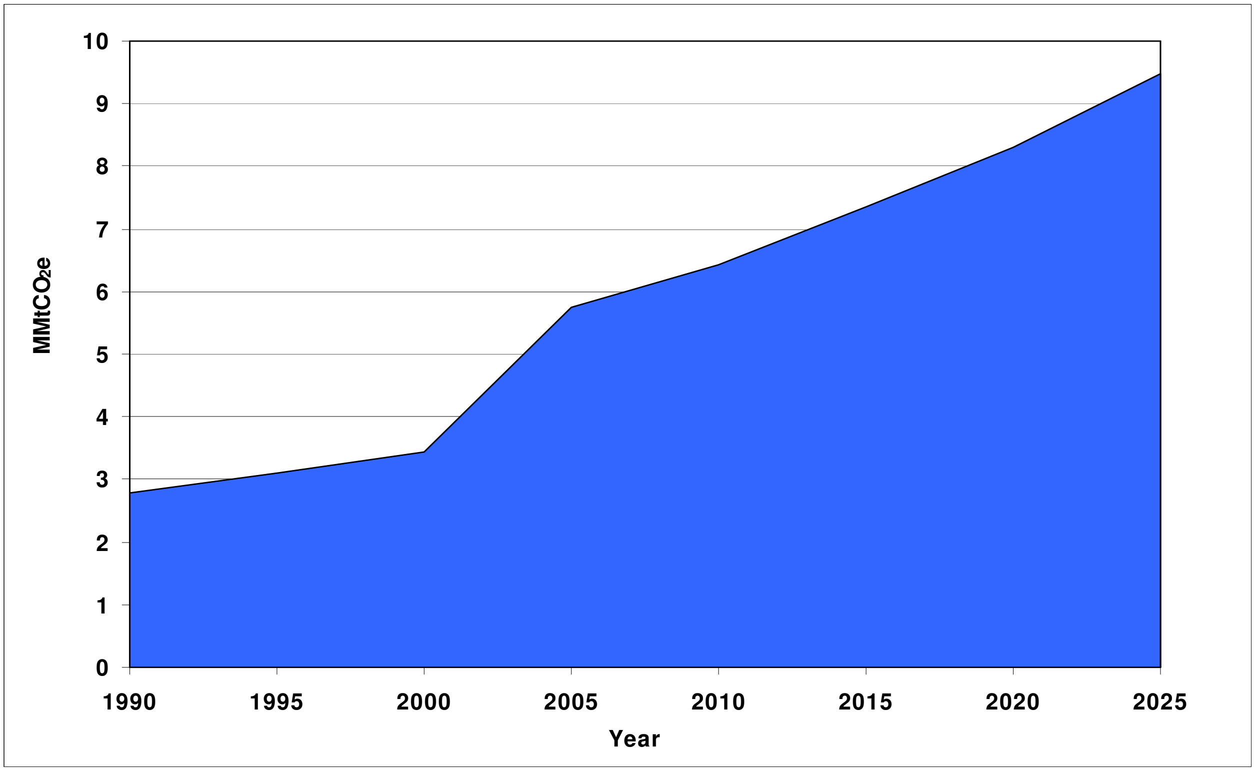


Figure D2. GHG Emissions from Industrial Processes, 1990-2025

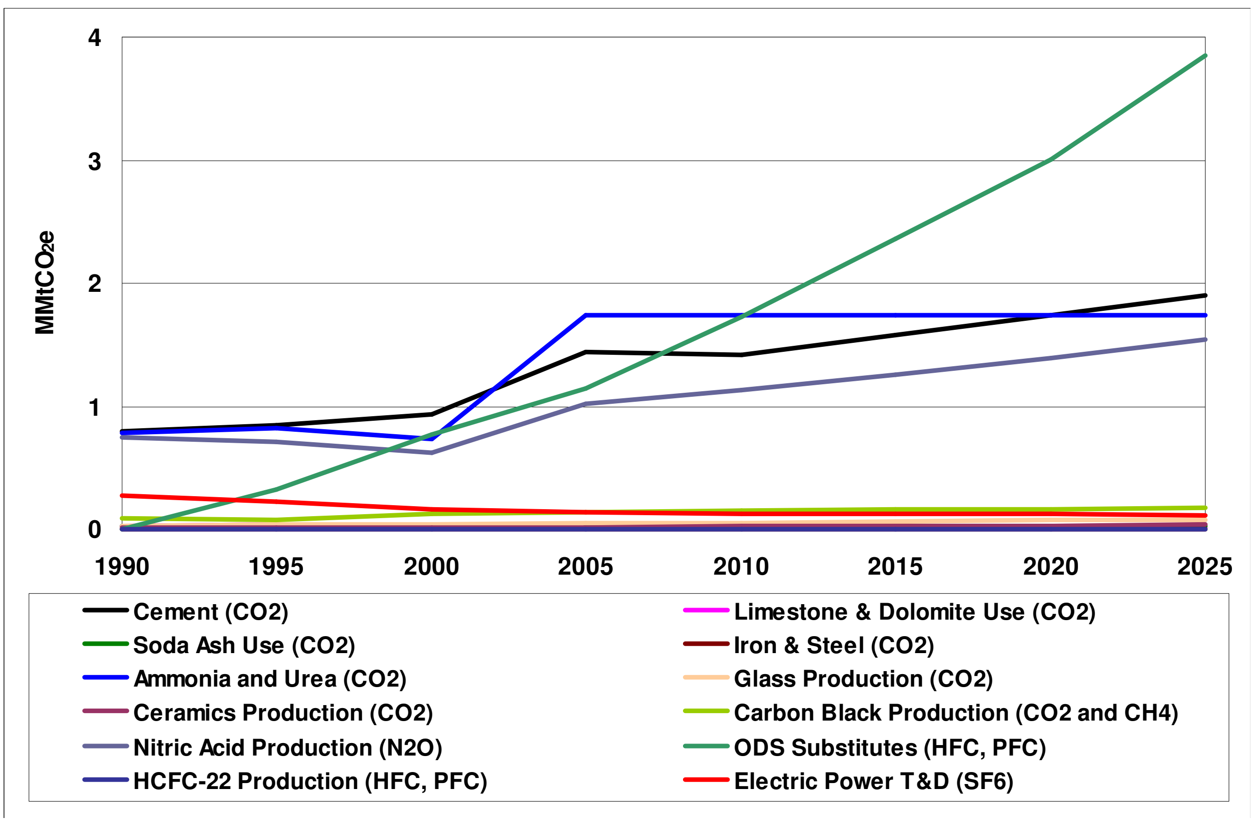


Table D3. Historic and Projected Emissions for the Industrial Processes Sector ($MMtCO_2e$)

Industry	1990	1995	2000	2005	2010	2015	2020	2025
Cement (CO_2)	0.792	0.850	0.929	1.444	1.420	1.580	1.734	1.907
Limestone & Dolomite Use (CO_2)	0.031	0.043	0.030	0.024	0.021	0.019	0.017	0.015
Soda Ash Use (CO_2)	0.027	0.027	0.025	0.024	0.023	0.022	0.021	0.020
Ammonia and Urea (CO_2)	0.782	0.819	0.734	1.742	1.742	1.742	1.742	1.742
Iron & Steel (CO_2)	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.003
Glass Production (CO_2)	0.031	0.035	0.037	0.046	0.053	0.061	0.070	0.080
Ceramics Production (CO_2)	0.011	0.007	0.012	0.018	0.021	0.025	0.029	0.035
Carbon Black Production (CO_2 and CH_4)	0.086	0.076	0.129	0.137	0.146	0.156	0.166	0.177
Nitric Acid Production (N_2O)	0.751	0.711	0.617	1.024	1.135	1.258	1.394	1.546
ODS Substitutes (HFC, PFC)	0.003	0.317	0.767	1.139	1.730	2.356	3.011	3.850
Electric Power Transmission and Distribution (SF_6)	0.272	0.220	0.159	0.141	0.130	0.125	0.120	0.116
HCFC-22 Production (HFC, PFC)	0.000	0.000	0.000	-	-	-	-	-
Total	**2.785**	**3.105**	**3.440**	**5.738**	**6.422**	**7.344**	**8.307**	**9.489**

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.[50]

Historical limestone and dolomite consumption (sales) data for Kansas obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate CO_2 emissions for 1994-2004. Data on limestone and dolomite consumption for 1990-1993 were not available for Kansas; therefore, 1994 production data was used as a surrogate to estimate emissions for 1990-1993. Limestone and dolomite consumption for 2005 is also not available, 2004 production data were used as a surrogate. Emission projections from 2005 to 2025 are assumed to decrease at a rate of -2.30% per year, reflecting the negative 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 (ranging from 0.03 $MMtCO_2e$ to 0.02 $MMtCO_2e$ between 1990 and 2005), and therefore, appear at the bottom of the graph because of scaling effects (pink line at the bottom of Figure D2).

[50] 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 under the methods for the agricultural sector), and (3) limestone used in cement production (which is counted in the methods for cement production).

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. An annual -0.81% decrease was assumed for the forecast period based on the negative consumption trends observed over the historical periods analyzed. Relative to total industrial non-combustion process emissions, CO_2 emissions from soda ash consumption are low (about 0.03 $MMtCO_2e$ to 0.02 $MMtCO_2e$ per year from 1990 through 2005). Soda ash therefore appears at the bottom of the graph because of scaling effects (green line at the bottom of Figure D2).

Ammonia and Urea Production

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 CO_2 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.

Ammonia and urea are typically produced from conventional catalytic reforming of natural gas feedstock. However, there is one plant in Kansas (Coffeyville Resources Nitrogen Fertilizer) that uses petroleum coke feedstock. The CO_2 emission factor applied for this plant is much higher than that applied to others (3.57 metric tons CO_2/metric ton NH_3 versus 1.2 metric tons CO_2/metric ton NH_3). KDHE provided CCS with ammonia and urea production for each plant for 1990-2005. Ammonia and urea production make up a significant portion of the total GHG emissions in Kansas' Industrial Processes sector. The emissions from ammonia and urea production were 0.78 $MMtCO_2e$ in 1990 and 1.74 $MMtCO_2e$ in 2005. Projections from 2006-2025 are assumed to stay constant at 2005 levels due to conflicting historical trends.

Iron and Steel Production

Kansas has two important iron and steel production facilities: Atchison Steel Casting & Machining and Griffin Wheel Company. 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 software was used to estimate Kansas' CO_2 emissions from steel production (see Table D1). The basic activity data needed were the quantities of crude steel produced (defined as first cast product suitable for sale or further processing) by production method. Plant-specific production data by the Electric Arc Furnace (EAF) method were provided by KDHE for the years 1990, 1995, 2000, and 2005. Default SIT emission factor of 0.08 metric ton CO_2 per metric ton production was replaced by 0.004 metric ton CO_2 per metric ton production at the request of KDHE, as the latter is the EAF emission factor used in U.S. EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*. Production data for intervening years were not available from KDHE and the emissions are therefore interpolated from 1990, 1995, 2000, and 2005 emissions. Kansas' iron and steel industry process emissions for 1990-2025 are very small and cannot be seen in Figure D2 (due to scaling effects) as they are less than 0.01 $MMtCO_2e$ for all years. The annual rate of iron and steel production over the 1995-2005 period (6.3% per year) was used to project emissions from 2006 to 2025.

Nitric Acid Production

The manufacture of nitric acid (HNO_3) produces N_2O as a by-product, via the oxidation of ammonia. Nitric acid is a raw material used primarily to make synthetic commercial fertilizer. It is also a major component in the production of adipic acid (a feedstock for nylon) and explosives. Relatively small quantities of nitric acid are also employed for stainless steel pickling, metal etching, rocket propellants, and nuclear fuel processing.[51] The SIT uses a default emission factor of 0.008 metric tons of N_2O emissions per metric ton of nitric acid produced based on a weighted-average calculated over the different types of emissions control technologies typically employed by nitric acid plants nationwide.[52]

Default SIT data were not used for nitric acid estimation as KDHE provided production data for nitric acid for the years 1990, 1995, 2000, and 2005. Production data for intervening years were not available from KDHE and so the emissions are interpolated from the 1990, 1995, 2000, and 2005 emissions. Emission projections from 2005 to 2025 are assumed to increase at a rate of 2.1% per year, reflecting the positive trends observed for the historical periods analyzed. As seen from Figure D2, nitric acid emissions are one of the more significant industrial process emissions in Kansas, with 0.75 $MMtCO_2e$ emitted in 1990 and 1.02 $MMtCO_2e$ emitted in 2005; Projected 2025 emissions are 1.55 $MMtCO_2e$.

HCFC-22 production

One type of HFC known to be emitted in significant quantities is HFC-23, which is emitted as a by-product of HCFC-22 production. Using national estimates, the standard procedure is to assume 0.02 metric tons of HFC-23 for every ton of HCFC-22 produced. HFC-23 has a global warming potential of 11,700, so even a small emission of this substance can be very significant. HCFC-22 was produced in Kansas at the ELF Atochem plant, which was permanently closed in 2002. KDHE provided production data for the years 1990, 1995 and 2000. EPA's SIT software was used to estimate GHG emissions. As production data for the intervening years were not

[51] EIIP, Volume VIII: Chapter. 6. "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes", August 2004.

[52] According to Chapter 6 of the EIIP guidance document, the nitric industry controls for oxides of nitrogen through two technologies: non-selective catalytic reduction (NSCR) and SCR. Only one of these technologies, NSCR, is effective at destroying N_2O emissions in the process of destroying oxides of nitrogen emissions. NSCR technology was widely installed in nitric acid plants built between 1971 and 1977. Due to high-energy costs and associated high gas temperatures, this technology has not been popular with modern plants. Only about 20% of the current plants have NSCR technology installed. All other plants have installed SCR technology. Since 80% of the current plants have SCR technology installed and 20% have NSCR technology, the weighted-average emission factor used in the SGIT is equal to (0.0095 x 0.80) x (0.002 x 0.20) = 0.008 metric tons N_2O per metric ton of nitric acid produced.

available, the emissions are therefore interpolated from 1990, 1995, and 2000. Production data for 2000 was used as a surrogate for 2001 data. Total GHG emissions from this source are very small, accounting for 0.00004 $MMTCO_2e$ from 1990-2001.

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*.[53] 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 have increased from less than 0.01 $MMtCO_2e$ in 1990 to about 1.14 $MMtCO_2e$ in 2005, and are expected to increase at an average rate of 6.3% per year from 2005 to 2025 (to 3.85 $MMtCO_2e$ by 2025) due to increased substitutions of these gases for ODS (see light orange line in Figure D2). The projected rate of increase for these emissions is 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 decreased since the mid-1990s 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.[54]

As shown in Table D3, SF_6 emissions from electric power T&D were about 0.27 $MMtCO_2e$ in 1990 and 0.14 $MMtCO_2e$ in 2005. Emissions in 2025 are projected at 0.12$MMtCO_2e$. Emissions in Kansas from 1990 to 2005 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 Kansas 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 2005-2025 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 Kansas. The decline in SF_6 emissions in the future reflects expectations of future actions by the electric power industry to reduce these emissions.

[53] 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.

[54] 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.

Glass Manufacture

Glass Manufacture involves heating soda and lime and then cooling rapidly. This can require a significant amount of energy inputs, but these are considered in the Residential, Commercial and Industrial (RCI) analysis. Glass manufacture also has chemical byproducts that can lead to global warming. Kansas has four main glass and fiberglass companies: AFG Industries, CertainTeed Corporation, Johns Manville, and Owens Corning Insulating Systems, LLC. The four plants produced over 339,000 tons of material (glass and fiberglass) in 1990 and almost 512,000 tons of material in 2005.[55]

The major glass raw materials which emit CO_2 during the melting process are limestone, dolomite, and soda ash. Glass makers also produce glass from a certain amount of recycled scrap glass (cullet). The cullet ratio (the fraction of the furnace charge represented by cullet) is typically in the range of 0.4 to 0.6. Using the IPCC Tier 1 methodology, a cullet ratio of 0.5 is applied and an emission factor of 0.2 metric tons CO_2 per metric tons of glass is used. Estimated emissions from glass production are 0.03 $MMtCO_2e$ in 1990 and 0.05 $MMtCO_2e$ in 2005. Emissions are assumed to increase at a rate of 2.8% per year over the 2005-2025 period, to 0.08 $MMtCO_2e$ in 2025, reflecting the positive trends observed for the historical periods analyzed.

Ceramic Production (incl. Brick manufacturing)

Bricks are primarily used in construction and pavement. Bricks may be made from clay, shale, soft slate, calcium silicate, concrete, or shaped from quarried stone. In manufacturing, these materials (typically clay) are heated and then cooled into the appropriate shape. Process-related emissions from brick production result from the calcinations of carbonates in the clay, as well as from additives. Kansas has two main brick factories, the Acme Brick Company and Cloud Ceramics. Between the two of them, they produced over 78,000 tons of brick in 1990 and over 130,000 tons in 2005. KDHE provided production data for 1990, 1995, 2000 and 2005 and also provided an emission factor of 0.15 metric tons CO_2 per metric ton bricks produced.[56] Emissions from brick production are estimated at 0.01 $MMtCO_2e$ in 1990, 0.02 $MMtCO_2e$ in 2005, and 0.04 $MMtCO_2e$ in 2025. The annual rate of increase of brick production over the 1990-2005 period (3.4% per year) was used to project emissions from 2006 to 2025.

Carbon Black

Carbon Black is a material produced by the incomplete combustion of petroleum products. About 90% of carbon black produced worldwide is used in the tire and rubber industry (known as 'rubber black') and the remainder is used in pigment applications and other applications.[57] The Columbian Chemicals Company produces carbon black in Kansas. This company produced 36,066 tons of carbon black in 1990 and 57,609 tons of carbon black in 2005.[58] CO_2 and CH_4 emissions for carbon black are estimated by applying the process and feedstock-specific emission factors to the carbon black production activity data. IPCC emission factors of 2.62

[55] Production data provided by KDHE.
[56] KDHE brick production CO_2 emission factor source: EC Ref. Document (2007) *Reference Document on Best Available Techniques in the Ceramic Manufacturing Industry*, European Commission, August 2007 (http://www.jrc.es/pub/english.cgi/0/733169)
[57] IPCC 2006 Guidelines, Vol. 3, Ch. 3 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf)
[58] Production data provided by KDHE; February, 2008.

metric tons CO_2 per metric tons carbon black and 0.06 kilogram CH_4 per metric tons carbon black were applied. Emissions from carbon black production are estimated at 0.09 $MMtCO_2e$ in 1990, increased to 0.14 $MMtCO_2e$ in 2005, and are projected to increase to 0.18 $MMtCO_2e$ in 2025. The annual rate of increase of carbon black production over the 2000-2005 period (1.3% per year) was used to project emissions from 2006 to 2025.

Ethanol Production

The IPCC considers the CO_2 from fermentation as a biogenic source of CO_2, so no accounting methods have been developed for fermentation (only anthropogenic GHG sources have IPCC methods). In the case of process emissions (outside of fuel combustion), neither EPA nor the IPCC has a methodology to include fermentation off-gases in any sort of accounting scheme. To account for emissions from an ethanol production plant, the only focus is on the combustion of fossil fuels at the plant. These emissions resulting from fuel combustion are accounted for under the industrial fuel use sector category.

Currently, Kansas has 12 ethanol facilities that use corn and grain sorghum as feedstock to produce ethanol. Ethanol is commercially produced in one of two ways, using either the wet mill or dry mill process. In either process, yeast converts the grain sugar into ethanol and CO_2. It is during this fermentation process that CO_2 is released as a co-product. This CO_2 is either vented into the atmosphere, or captured and sold into beverage or other industrial markets. In Kansas, CO_2 is also injected into oil-producing rocks 3,000 feet underground to recover oil from marginal oil fields (generally Enhanced Oil Recovery (EOR)). In accounting for fugitive CO_2 from oil and gas operations, the only focus is on the "anthropogenic" CO_2, like off-spec CO_2 from cleaning out natural gas that is then piped off to an EOR field.

At the request of KDHE, CCS has estimated the amount of CO_2 released and projected to be released in Kansas from ethanol fermentation based on ethanol production capacity data provided by KDHE for the years 1995 through 2015. Without knowing the details of each fermentation plant, CCS estimated CO_2 produced from ethanol fermentation based on the chemical equation for ethanol fermentation:

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

As shown in this equation, for every 2 moles of ethanol (C_2H_5OH) produced from 1 mole of glucose ($C_6H_{12}O_6$), 2 moles of CO_2 are produced. CCS assumed 100% production capacity for the ethanol facilities in KS for all years. Table D4 shows other assumptions used in the calculation of CO_2 emissions from the fermentation process and provides a sample emission calculation.

This method is a slight overestimation of the actual CO_2 produced during the fermentation process as the actual amount is determined by the pressure, temperature, the percent conversion of glucose to ethanol and CO_2, and other plant-specific factors (see Table D5 for emission estimates). However, one lab study in Kansas showed that the actual CO_2 emissions from fermentation are 96.8% of the emissions estimated here, confirming the validity of the assumptions used. The CO2 emission factor from the lab experiment was around 6.1 lb/gal of ethanol produced and was derived using actual measurements.

Table D4. CO_2 Estimation Method

Ethanol Density	0.789	g/cm^3
Molecular Weight of Ethanol	46	g/mol
Molecular Weight of CO_2	44	g/mol
Gallon to Cubic Centimeter	3785.412	cm^3/gal
Metric Ton to Gram	1,000,000	g/Mt
Example Calculation: 1995 CO_2 Emissions = 56,000,000 gal Ethanol * (0.789 g/cm^3) * (3,785.412 cm^3/gal) * ((44 g/mol CO_2l) / (46 g/mol Ethanol$_)$) * (1Mt/1,000,000 g)		

Table D5. Estimated CO_2 Emissions from Ethanol Fermentation

Year/Ethanol Production		CO_2 Emissions from Fermentation ($MMtCO_2e$)
1990	First ethanol facility in state brought on-line in1992	
1995	56 million gallons ethanol per year total capacity by 3 facilities	**0.16**
2000	440 million gallons ethanol per year total capacity by 10 facilities	**1.26**
2005	650 million gallons ethanol per year total capacity by 12 facilities	**1.86**
2010	1,755 million gallons ethanol per year total capacity by 26 facilities (includes 14 facilities currently planned but not yet constructed at potential 1,105 million gallons per year total capacity)	**5.01**
2015	2,135 million gallons ethanol per year total capacity by 33 facilities (includes 7 additional, recently announced facilities at potential 413 million gallons per year total capacity)	**6.10**

Note: CO_2 emissions estimated from ethanol fermentation process only. CCS did not have enough information to estimate the proportion of CO_2 released into the atmosphere.

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 Kansas manufacturers in these industries, and the specific nature of the production processes used in Kansas.
- One of the largest projected sources of future industrial emissions, HFCs and PFCs used in cooling applications, is subject to several uncertainties as well. Emissions through 2025 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 iron and steel production and nitric acid 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 example, for limestone and dolomite consumption, 1994 activity data were used as a surrogate to estimate emissions for 1990 through 1993.
- 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.
- Activity data provided by Kansas were in 5-year increments; historical emission estimations for the intervening years were interpolated. Having available activity data from year to year would increase the accuracy of Kansas' GHG emission inventory in the Industrial Processes sector.

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 Kansas.[59] In 2005, emissions from the subsector accounted for an estimated 7.41 million metric tons (MMt) of CO_2 equivalent (CO_2e) of total gross greenhouse gas (GHG) emissions in Kansas, and are estimated to decrease to about 7.09 $MMtCO_2e$ by 2025.

Emissions and Reference Case Projections

Oil and Gas Production
Kansas' crude oil production totals 93,000 barrels (bbls) per day and accounts for about 1.8% of US production making it one of the top ten oil-producing states in the country.[60] Proved crude oil reserves sit at 281 million bbls, which is about 1.3% of US totals. Oil production has steadily declined in Kansas for more than two decades, with peak production occurring in 1984 and 1985 (207,000 bbls per day).[61] Kansas' three operating petroleum refineries are responsible for approximately 2% of the Nation's refining capacity, with a crude oil distillation capacity of 296,200 bbls per day.[62]

The Anadarko Shelf in southwestern Kansas contains some of the most productive natural gas fields in the Nation within the Hugoton Gas Area. Kansas consumes about 70% of state natural gas production (in 2005, Kansas consumed about 255 billion cubic feet [Bcf] of natural gas while it produced about 377 billion Bcf), and exports the remaining gas to states in the east.[62]

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 (EIIP) guidance[63] 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

[59] 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.
[60] US Department of Energy (DOE), Energy Information Administration, "Crude Oil Production", accessed from http://tonto.eia.doe.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm, January 2008.
[61] US DOE, Energy Information Administration, "Crude Oil Proved Reserves, Reserves Changes, and Production," accessed from http://tonto.eia.doe.gov/dnav/pet/pet_crd_pres_dcu_SKS_a.htm, January 2008.
[62] "State Energy Profiles: Kansas", US DOE Energy Information Administration, January 2008, accessed from http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=KS.
[63] Emission Inventory Improvement Program, Volume VIII: Chapter 5. "Methods for Estimating Methane Emissions from Natural Gas and Oil Systems," August 2004.

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.

Given the large number of oil and gas sector facilities in the state (19,000 active oil and gas wells, 13 operational gas processing plants, and more than 47,000 miles of gas pipelines), there are inevitable uncertainties associated with estimating Kansas' GHG emissions from this sector. This is compounded by the fact that there are no regulatory requirements to track GHG emissions. However, the EPA's State Greenhouse Gas Inventory Tool (SIT) facilitates the development of state-level GHG emission estimates. 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),[64] the US Department of Transportation's Office of Pipeline Safety (OPS),[65] and the University of Kansas' Geological Survey.[66] Kansas Department of Health and Environment (KDHE) staff provided direction as to the preferred data source in cases where more than one set of activity estimates were available. Emissions were estimated using the SIT, with reference to methods/data sources outlined in the EIIP guidance document for natural gas and oil systems.[67] Emissions of CO_2, CH_4, and N_2O associated with pipeline natural gas combustion are estimated using SIT emission factors[68] and Kansas 1990-2005 natural gas data from EIA for the "consumed as pipeline fuel" category.[69]

Unfortunately the OPS has not collected data from pipeline operators using a consistent set of reporting requirements over the entire 1990-2005 analysis period. In particular, OPS has only required operators to report state-level data for their transmission pipelines since 2001 and state-level data for their distribution pipelines since 2004. Before these dates, a large number of Kansas pipeline records report data as multi-state totals. In addition, OPS only requires operators to report natural gas gathering pipeline information for pipelines that fall under the Department of Transportation's jurisdiction. The Kansas Corporation Commission (KCC) was able to provide an estimate of total gathering pipeline mileage in Kansas (11,200 miles)—this estimate was used to represent mileage for the final year of the analysis period (2005). To estimate a complete time-series of natural gas pipeline mileage/service counts, CCS compiled surrogate data to back-cast the 2001 transmission pipeline mileage, 2004 distribution pipeline mileage/service counts, and 2005 gathering pipeline mileage for each year back to 1990. Table E1 provides an overview of data sources and approaches used to develop historic oil and gas

[64] "Petroleum Navigator" and "Natural Gas Navigator," US DOE Energy Information Administration website, January 2008, accessed at http://www.eia.doe.gov.

[65] US Department of Transportation, Office of Pipeline Safety, "Distribution and Transmission Annuals Data: 1990 to 2005," accessed from http://ops.dot.gov/stats/DT98.htm, January 2008.

[66] University of Kansas, Kansas Geological Survey, "Oil and Gas Production in Kansas," accessed from http://www.kgs.ku.edu/PRS/petro/interactive.html, January 2008.

[67] Emission Inventory Improvement Program, Volume VIII: Chapter. 5. "Methods for Estimating Methane Emissions from Natural Gas and Oil Systems", August 2004.

[68] 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.

[69] US DOE, Energy Information Administration, *State Energy Consumption, Price, and Expenditure Estimates (SEDS)*, (http://www.eia.doe.gov/emeu/states/_seds.html).

Table E1. Approach to Estimating Historical and Projected GHG Emissions from Fossil Fuel Systems

Activity	**Approach to Estimating Historical Emissions** *Required SIT Data*	*Data Source*	**Surrogate Data Used to Backcast Activity to 1990**	**Forecasting Approach** *Projection Assumption*
Natural Gas Production	Number of gas and associated wells	EIA[70]		Application of *Annual Energy Outlook* (AEO) *2007* Midcontinent region natural gas production forecast growth rates.[71]
Natural Gas Processing	Number of gas processing plants	*Oil and Gas Journal*[72]		No change based on nearly constant number of plants for the last 6 years.
	Flaring of Entrained Gas	EIA[73]		Application of smallest annualized decrease in state level venting/flaring of natural gas (-2.55%) from each of 3 historical periods analyzed (1990-2005).
Natural Gas Transmission	Miles of gathering pipeline	KCC[74]	KS natural gas production as reported by EIA[75]	Application of smallest annualized decrease in state gathering-transmission emissions (-0.51%) from each of 3 historical periods analyzed (1990-2005).
	Miles of transmission pipeline	Office of Pipeline Safety[65]	Average of the volume of natural gas transported into KS and transported out of KS, as reported by EIA[76]	
	Number of gas transmission compressor stations	EIIP[77]		
	Number of gas storage compressor stations	EIIP[78]		

[70] US DOE, Energy Information Administration, "Kansas Natural Gas Number of Gas and Gas Condensate Wells," accessed from http://tonto.eia.doe.gov/dnav/ng/hist/na1170_sks_8a.htm, January 2008.
[71] US DOE, Energy Information Administration, "Annual Energy Outlook 2007 with Projections to 2030," accessed from http://www.eia.doe.gov/oiaf/archive/aeo07/index.html, January 2008.
[72] PennWell Corporation, "Worldwide Gas Processing," *Oil and Gas Journal* (1990-2005 June/July issues).
[73] US DOE, Energy Information Administration, "Kansas Natural Gas Vented and Flared," accessed from http://tonto.eia.doe.gov/dnav/ng/hist/n9040ks2A.htm, January 2008.
[74] Personal communication, Haynos, Leo, Kansas Corporation Commission, "RE: State GHG Inventory Tool (SIT) Data for Fossil Fuel Production," to Larry Holloway, Kansas Corporation Commission, February 26, 2008.
[75] US DOE, Energy Information Administration, "Kansas Dry Natural Gas Production," accessed from http://tonto.eia.doe.gov/dnav/ng/hist/na1160_sks_2a.htm, January 2008.
[76] US DOE, Energy Information Administration, "International and Interstate Movements of Natural Gas by State," accessed from http://tonto.eia.doe.gov/dnav/ng/ng_move_ist_a2dcu_SKS_a.htm , January 2008.
[77] Number of gas transmission compressor stations = miles of transmission pipeline x 0.006 – EIIP, Volume VIII: Chapter 5, March 2005.
[78] 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 and Projected GHG 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[65]	Total number of natural gas consumers in KS as reported by EIA[79]	Application of smallest annualized growth rate in state distribution emissions (+0.06%) from each of 3 historical periods analyzed (2000-2005).
Natural Gas Pipeline Fuel Use (CO_2, CH_4, N_2O)	Volume of natural gas consumed by pipelines	EIA[69]		Application of smallest annualized decrease in pipeline fuel consumption (-0.26%) from each of 3 periods analyzed (2000-2005).
Oil Production	Annual production	KGS[80]		Application of smallest annualized decrease in state oil production (-0.91%) from each of 3 historical periods analyzed (2000-2005).
Oil Refining	Annual amount refined	EIA[81]		Application of AEO 2007[71] PAD II region refinery capacity forecast growth rates.
Oil Transport	Annual oil transported	Unavailable (per SIT, assumed oil refined = oil transported)		(same as oil refining)
Coal Mining	Methane emissions in million cubic feet	US Environmental Protection Agency (EPA)[82]		Application of smallest annualized decrease in state coal emissions (-2.64%) from each of 3 historical periods analyzed (2000-2005).

[79] US DOE, Energy Information Administration, "Number of Natural Gas Customers," accessed from http://tonto.eia.doe.gov/dnav/ng/ng_cons_num_a_EPG0_VN7_Count_a.htm, January 2008.
[80] University of Kansas, Kansas Geological Survey, "Oil and Gas Production in Kansas," accessed from http://www.kgs.ku.edu/PRS/petro/interactive.html, January 2008.
[81] Refining is assumed to be equal to the total input of crude oil into PADD II times the ratio of Kansas' 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, Energy Information Administration, "Petroleum Navigator." PADD capacity data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/moclep22A.htm. PADD crude input data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/mgirip22A.htm. State capacity data accessed from http://tonto.eia.doe.gov/dnav/pet/hist/8_na_8do_sks_4a.htm, January 2008.
[82] US Environmental Protection Agency, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005, USEPA #430-R-07-002, April 2007.

sector emission estimates for Kansas, including a description of the surrogate data that were used to back-cast natural gas pipeline mileage and service count estimates for the analysis period.

Coal Production Emissions

Methane occurs naturally in coal seams, and is typically vented during mining operations for safety reasons. Coal mine CH_4 emissions are usually considerably higher, per unit of coal produced, from underground mining than from surface mining.

Kansas has only one active coal mine, located in the southeastern part of the state. This surface mine produced only 117 thousand short tons of coal in 2005.[83] As reported in this inventory, CH_4 emissions from coal mines are as reported by the EPA, and include emissions from mining as well as post-mining activities.[82]

Emission Forecasts

Table E1 provides an overview of data sources and approaches used to develop projected fossil fuel production sector emission estimates for Kansas.

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 2007* forecast data for each 5-year time-frame over the 2005-2025 analysis period, and the other using historical activity data for each of 3 periods (i.e., 1990 to 2005, 1995 to 2005, and 2000 to 2005). Because available AEO forecast information is for a broad region that may not reflect Kansas-specific trends (e.g., AEO forecasts of natural gas production are for the Midcontinent Region, which includes 7 states in addition to Kansas), the AEO forecast growth rates were only used when they were in-line with the Kansas historical growth rates. Therefore, the majority of fossil fuel production sector projections are based on state-level historical activity/emissions trends. In cases where each of 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.

Results

Table E2 displays the estimated emissions from the fossil fuel industry in Kansas for select years over the period 1990 to 2025. Emissions from this sector decreased by 12% from 1990 to 2005 and are projected to decrease by a further 4% between 2005 and 2025. The natural gas industry is the major contributor to both historic emissions and projected emission declines.

[83] US DOE Energy Information Administration, "Coal Production and Number of Mines by State and Mine Type," accessed from http://www.eia.doe.gov/cneaf/coal/page/acr/table1.html, January 2008.

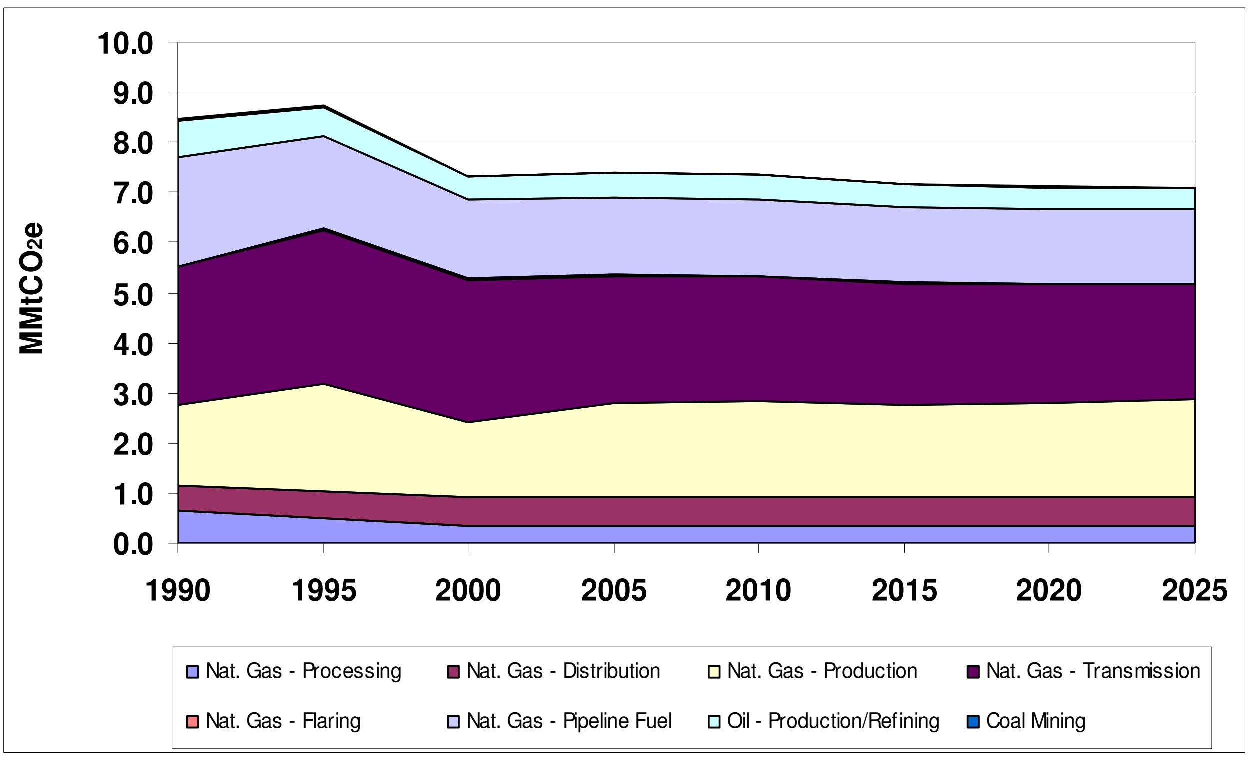
Table E2. Historical and Projected Emissions for the Fossil Fuel Industry

(Million Metric Tons CO2e)	1990	1995	2000	2005	2010	2015	2020	2025
Fossil Fuel Industry	8.45	8.72	7.33	7.41	7.36	7.18	7.11	7.09
Natural Gas Industry	7.69	8.12	6.86	6.90	6.87	6.71	6.66	6.66
Production	1.59	2.15	1.50	1.87	1.93	1.86	1.89	1.97
Processing	0.66	0.50	0.34	0.34	0.34	0.34	0.34	0.34
Transmission	2.75	3.04	2.85	2.54	2.48	2.42	2.35	2.29
Distribution	0.51	0.55	0.57	0.57	0.57	0.57	0.57	0.58
Flaring	0.03	0.04	0.03	0.02	0.02	0.01	0.01	0.01
Pipeline Fuel	2.16	1.85	1.57	1.55	1.53	1.51	1.49	1.47
Oil Industry	0.74	0.59	0.46	0.51	0.48	0.46	0.44	0.42
Production	0.72	0.58	0.45	0.49	0.47	0.45	0.43	0.41
Refining	0.016	0.013	0.013	0.012	0.012	0.012	0.012	0.012
Coal Mining	0.023	0.009	0.006	0.006	0.005	0.004	0.004	0.003

Source: Calculations based on approach described in text.

Figure E1 displays process-level emission trends from fossil fuel systems, on an $MMtCO_2e$ basis.

Figure E1. Fossil Fuel Industry Emission Trends ($MMtCO_2e$)



Source: 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 are based on industry-wide averages, and until estimates are available for local facilities, some level of uncertainty will remain.
- Due to data limitations associated with OPS reporting, natural gas gathering, transmission, and distribution 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.[84] Because distribution 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 are inherently uncertain.
- The assumptions used for the projections do not reflect unknown 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.

[84] For example, transmission pipeline emissions were back-cast to pre-2001 years by applying the ratio of Kansas natural gas production in each pre-2001 year to Kansas 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 enteric fermentation, manure management, and agricultural soils. Emissions and sinks of carbon in agricultural soils are also covered. Energy emissions (combustion of fossil fuels in agricultural equipment) are included in the residential, commercial, and industrial (RCI) sector estimates (see Appendix B).

There are two livestock sources of greenhouse gas (GHG) emissions: enteric fermentation and manure management. Methane emissions from enteric fermentation are the result of normal digestive processes in ruminant and some 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. 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 conditions. Under aerobic conditions, N_2O emissions are dominant. Emissions estimates from manure management are based on manure that is stored and treated on 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.

The management of agricultural soils can result in N_2O emissions and net fluxes of carbon dioxide (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 de-nitrification cycles, which produce 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, 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 runoff and is transported off-site before entering the nitrification/denitrification cycle. Methane and N_2O emissions also result when crop residues are burned.

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. Finally, the practice of adding limestone and dolomite to agricultural soils (for neutralizing acidic soil conditions) results in CO_2 emissions.

Emissions and Reference Case Projections

Methane and Nitrous Oxide

GHG emissions for 1990 through 2005 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.[85] 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, crop production 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.[86]

Data on crop production in Kansas from 1990 to 2005 and the number of animals in the state from 1990 to 2005 were obtained from the United States Department of Agriculture (USDA) National Agriculture Statistical Service (NASS) and incorporated as defaults in SIT.[87] 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 the Fertilizer Institute. Activity data for fertilizer includes all potential uses in addition to agriculture, such as residential and commercial (e.g., golf courses). The estimates are reported in the agriculture sector but they represent emissions occurring on other land uses.

Crop production data from USDA NASS were available for the SIT historical years of 1990 through 2005. These data were used to calculate N_2O emissions from crop residues and crops that use nitrogen (i.e., nitrogen fixation) and N_2O and CH_4 emissions from agricultural residue burning. Emissions for the other agricultural crop production categories (i.e., synthetic and organic fertilizers) were also calculated through 2005. No rice cultivation occurs in Kansas, so no emissions were estimated. Also, cultivation of histosols (high organic soils) does not occur in Kansas, so emissions from that practice are also not applicable.

There is some agricultural residue burning conducted in Kansas. Emissions are estimated to be relatively small, approximately 0.07 $MMtCO_2e$ in 2005. For agricultural burning, emissions of CH_4 and N_2O are included, but not CO_2. This is because the CO_2 is considered to be of biogenic origin and part of a short term carbon cycle. The default SIT method was used to calculate emissions. 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 and burned, the resultant dry matter, and the carbon/nitrogen content of the dry matter.

[85] GHG emissions were calculated using SIT, with reference to EIIP, 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.
[86] Revised 1996 Intergovernmental 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/).
[87] USDA, NASS (http://www.nass.usda.gov/Statistics_by_State/Kansas/index.asp).

For Kansas, SIT assumes that 3% of the residue from barley, corn, soybeans, and wheat are burned. Because no reliable growth factor could be found, 2005 emissions levels were used to estimate emissions between 2006 and 2025.

Emissions from enteric fermentation and manure management were projected based on forecasted animal populations. Dairy cattle forecasts were based on state-level projections of dairy cows from the Food and Agricultural Policy Research Institute (FAPRI).[88] Projections for all other livestock categories were estimated based on linear forecasts of the historical 1990-2005 populations. Livestock population growth rates are shown in Table F1. The historical (1990-2005) growth rate was used to forecast sheep and layer populations to avoid cases of negative livestock figures. SIT default had a 23% spike in beef cattle populations in 2004 – NASS data did not show the same spike so the 2004 population was replaced with the average of 2003 and 2005.

Table F1. Growth Rates Applied for the Enteric Fermentation And Manure Management Categories

Livestock Category	2006-2025 Annual Growth
Dairy Cattle	0.37%
Beef Cattle	0.72%
Swine	0.83%
Sheep	-6.42%
Goats	1.22%
Horses	-0.01%
Turkeys	2.92%
Layers	-5.33%

Projections for agricultural soils were based on linear extrapolation of the 1990-2005 historical data. Table F2 shows the 2006-2025 annual growth rates estimated for each category.

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 US Inventory of Greenhouse Gas Emissions and Sinks[89] and the US 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 US Agriculture and Forestry Greenhouse Gas Inventory. The inventory also reports national estimates of CO_2 emissions from agricultural limestone and dolomite applications from

[88] FAPRI Agricultural Outlook 2006, Food and Agricultural Policy Research Institute, http://www.fapri.iastate.edu/outlook2006.
[89] US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005 (and earlier editions), US Environmental Protection Agency, Report # 430-R-07-002**,** April 2007. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

the United States Geological Survey (USGS).[90] Currently, these are the best available data at the state-level for this category. In the case of liming of agricultural soils, 2005 emissions were projected to hold constant through 2025 to avoid forecasting negative emissions in this category.

Table F2. Growth Rates Applied for Agricultural Soils and Burning

Agricultural Category	2005-2025 Growth Rate
Agricultural Burning	0.00%
Liming of Agricultural Soils	0.00%
Agricultural Soils – Direct Emissions	
Fertilizers	0.07%
Crop Residues	-0.08%
Nitrogen-Fixing Crops	0.04%
Histosols	0.00%
Livestock	-0.94%
Agricultural Soils – Indirect Emissions	
Fertilizers	0.22%
Livestock	-1.36%
Leaching/Runoff	-0.19%

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 Kansas, Table F3 shows a summary of the latest estimates available from the USDA, which are for 1997.[91]

[90] 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/.
[91] US 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 F3. The sum of the first nine columns is equivalent to the mineral soils category.

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
2.05	(0.99)	0.00	(1.32)	0.00	(0.70)	0.00	(1.54)	(0.88)	0.00	(3.37)

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.

The data shows that changes in agricultural practices are estimated to result in a net reduction of 3.4 million metric tons $MMtCO_2e$ per year in Kansas; these reductions come from manure applications, participation in the CRP, cropland conversions to hayland or grazing land, and cropland management. Since data are not yet available from USDA to make a determination of whether the emissions are increasing or decreasing in the subsequent years, emissions of -3.4 $MMtCO_2e$ per year are 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 the 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.

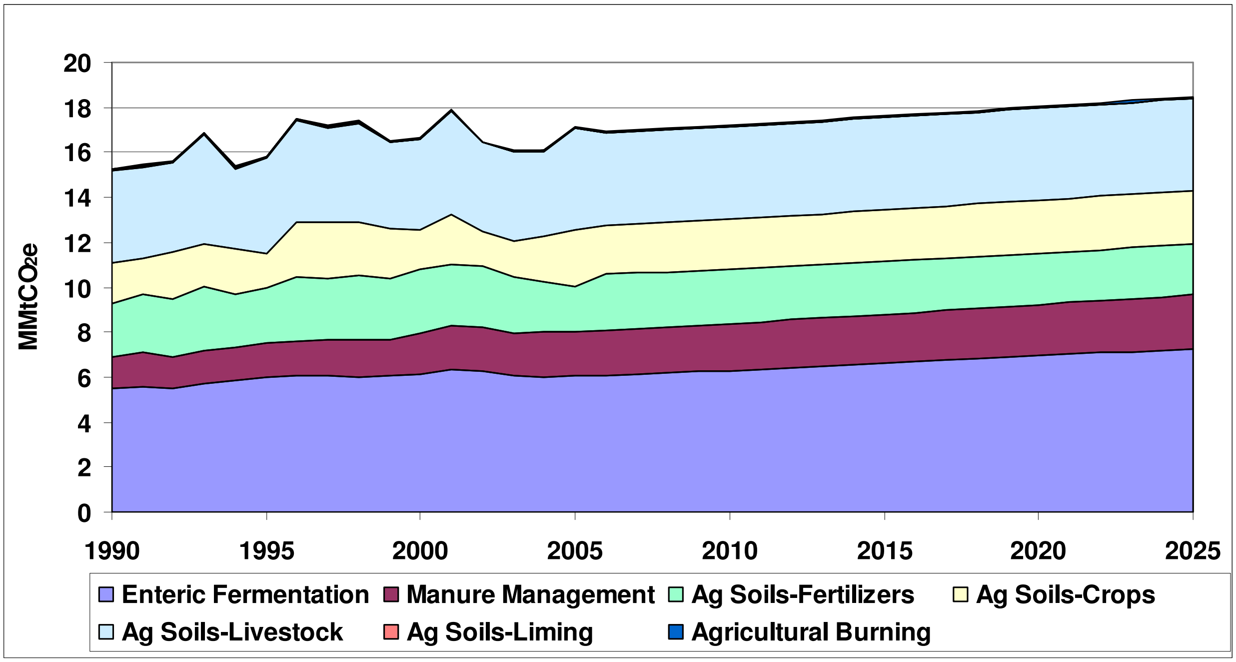
Results

Figure F1 and Table F4 show gross GHG emissions associated with the agricultural sector from 1990 through 2025.

In 1990, enteric fermentation accounted for about 36% (5.52 $MMtCO_2e$) of gross agricultural emissions in Kansas. Enteric fermentation emissions increased slightly to 6.03 $MMtCO_2e$ between 1990 and 2005. The beef cattle population, dairy and swine populations are all projected to increase slightly, and therefore emissions from enteric fermentation are estimated to increase to 6.87 $MMtCO_2e$ in 2025, or 38%, of gross agricultural emissions.

The manure management category accounted for 9% (1.36 $MMtCO_2e$) of gross agricultural emissions in 1990 and increased by 2005, accounting for 12% (2.00 $MMtCO_2e$) of the gross emissions from the agriculture sector. Manure management emissions are projected to increase modestly through 2025, and will likely account for 13% (2.29 $MMtCO_2e$) of gross agricultural emissions at that time. This is mostly due to the projected increase in cattle populations in the state.

Figure F1. Gross GHG Emissions from Agriculture, 1990-2025



Source: 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); emissions for agricultural residue burning and agricultural soils-liming are too small to be seen in this chart. Emissions from soil carbon due to cultivation practices are a net carbon sink and are not reflected on this chart – hence, the 2025 total on this chart and the 2025 total in Table F4 are not the same.

Table F4. Gross and Net GHG Emissions from Agriculture in Kansas

Source	1990	1995	2000	2005	2010	2015	2020	2025
Enteric Fermentation	5.52	6.02	6.14	6.03	6.21	6.43	6.65	6.87
Manure Management	1.36	1.51	1.78	2.00	2.06	2.14	2.22	2.29
Ag Soils-Fertilizers	2.42	2.44	2.86	1.98	2.43	2.36	2.30	2.24
Ag Soils-Crops	1.77	1.56	1.75	2.50	2.20	2.28	2.35	2.42
Ag Soils-Livestock	4.13	4.22	4.03	4.56	4.12	4.10	4.09	4.07
Ag Soils-Liming	0.04	0.05	0.03	0.00	0.00	0.00	0.00	0.00
Agricultural Burning	0.05	0.04	0.05	0.07	0.07	0.07	0.07	0.07
Total Gross Emissions	**15.3**	**15.8**	**16.7**	**17.1**	**17.1**	**17.4**	**17.7**	**18.0**
Soil Carbon (Cultivation Practices)	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37	-3.37
Total Net Emissions	**11.92**	**12.48**	**13.28**	**13.77**	**13.72**	**14.01**	**14.30**	**14.60**

The largest source of emissions in the agricultural sector is the agricultural soils category, which includes crops (legumes and crop residues), fertilizer, manure application, application of limestone and dolomite, and indirect sources (leaching, runoff, and atmospheric deposition). Agricultural soils is projected to increase from 1990 to 2025, with 1990 emissions accounting for 55% (8.36 $MMtCO_2e$) of gross agricultural emissions and 2025 emissions estimated to be about 49% (8.74 $MMtCO_2e$) of gross agricultural emissions.

As noted previously, cultivation of soils is a GHG sink and is estimated to reduce GHG emissions in Kansas by 3.37 $MMtCO_2e$ throughout the analysis period. Emission sinks due to the cultivation of soils are assumed to remain constant throughout the inventory and forecast period since data are not yet available from USDA to determine if this emission reduction is increasing or decreasing. The emissions from this category are estimated to reduce gross agricultural emissions by 22% in 1990 and by about 19% in 2025.

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 which are derived from several variables including manure production levels, volatile solids content, 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. The largest contributors to uncertainty in emissions from manure management are the emission factors, which are derived from limited data sets.

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 CRP acreage to retire and possibly return to active cultivation prior to 2025, the emissions could be appreciably affected.

Uncertainties in the estimates of emissions from liming result from both the emission factors and the activity data. It is uncertain what fraction of agricultural lime is dissolved by nitric acid – a process that releases CO_2 – and what portion reacts with carbonic acid (H_2CO_3), resulting in the uptake of CO_2. Also, there is uncertainty in the limestone and dolomite data (reported to USGS) as some producers do not distinguish between them, and report them both as limestone.

Emissions associated with the burning of grasslands in Kansas have not been captured in this inventory. As data on acres burned and fuel loadings are identified, emission estimates will be incorporated.

Uncertainty in agricultural soils is introduced by the national emissions factor, which reconciles differences between methodologies used in the 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.

Another contributor to the uncertainty in the emission estimates is the forecast assumptions. The growth rates for most categories are assumed to continue growing at historical 1990-2005 growth rates. These historic trends may not reflect future projections.

Appendix G. Waste Management

Overview

Greenhouse gas (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)[92];
- 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

Solid Waste Management

For solid waste management, landfill emplacement data for medium and large landfills were obtained from the Kansas Department of Health and Environment (KDHE).[93] The United States Environmental Protection Agency's (US EPA) State Inventory Tool (SIT) software was then used to estimate emissions based on the waste emplaced levels indicated by KDHE. CCS applied the SIT assumption that 10% of landfill CH_4 is oxidized as it travels through the surface layers of the landfill.

KDHE indicated that industrial landfills are primarily monofills (flyash, cement kiln dust, foundry sand, waste tires, etc.) that do not emit methane so emissions for industrial solid waste landfills were estimated to be zero.[94] There are construction and demolition landfills in Kansas with degradable wood waste that likely emit small amounts of methane. However, there are currently no methods to estimate emission from construction and demolition sites.

The amount of CH_4 captured for flaring and use in landfill gas-to-energy (LFGTE) plants was calculated based on waste emplacement data for controlled landfills and date of emission capture equipment installation. Information on controlled landfills was obtained from KDHE and a database of landfill gas-to-energy (LFGTE) projects compiled by the EPA[95] The amount of landfill gas captured in Kansas may be underestimated if KS flaring and LFGTE controls have been underreported to KDHE and EPA. MSW landfill growth rates were estimated by using the historic (2002-2005) growth rates of total net emissions from landfills, which was 0.84%. The years 2002 through 2005 were used to calculate these growth rates since, previous to that, most

[92] CCS acknowledges that N_2O and CH_4 emissions are also produced from the combustion of landfill gas; however, these emissions tend to be negligible for the purposes of developing a state-level inventory for policy analysis.
[93] Andy Hawkins, Kansas Department of Health and Environment, Bureau of Waste Management database; communicated via email to Maureen Mullen, CCS, December 31, 2007.
[94] Andy Hawkins, Kansas Department of Health and Environment, communicated via email to Maureen Mullen, CCS, May 1, 2008.
[95] EPA Landfill Methane Outreach Program, http://www.epa.gov/lmop/proj/index.htm, accessed February, 2008.

flaring and LFGTE controls were not in place. The annual growth rate for industrial landfills is 3.5%, based on the historic (2000-2005) growth rate.

Solid Waste Combustion

Sources of solid waste combustion in Kansas include medical waste and hazardous waste incineration. There is no municipal waste combustion in Kansas. KDHE provided quantities of waste incinerated for the Stericycle medical waste facility. Quantities of hazardous waste incinerated from the Army Ammunition Plant were not available, and the significance of the potential for GHG emissions is unknown. The SIT defaults for emission factors and waste characteristics were used in the estimation of emissions for the Stericycle facility. The historic (1990-2005) growth rate of 5.1% for incineration emissions was used to estimate future growth rates.

Open burning of MSW at residential sites (e.g. backyard burn barrels) also contributes to GHG emissions. US EPA's 2002 National Emissions Inventory provides estimates of the quantity of waste burned per person at rural residential sites in Kansas.[96] Emissions from open burning were calculated using rural county population data from 1990 through 2025 provided by KDHE[97] using SIT emission factors and waste characteristics. Estimates from 2006 onward were calculated using the SIT waste characteristics for 2005.

Wastewater 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. The key SIT default values are shown in Table G1 below.

Table G1. SIT Key Default Values for Municipal Wastewater Treatment

Variable	Default Value
BOD	0.09 kilogram (kg) /day-person
CH_4 emission factor	0.6 kg/kg BOD
Water treatment N_2O emission factor	4.0 g N_2O/person-yr
Biosolids emission factor	0.01 kg N_2O-N/kg sewage-N

Source: US EPA SIT – Wastewater Module.

The percentage of KS residents not on septic is 82%.[98] For the State of Kansas, the amount of BOD anaerobically treated by mechanical water treatment plants is approximately 25%, and the methane produced by the process is captured and reused for heat in the treatment process or is burned in a flare.[99] Another 5% of mechanically treated water is assumed to decompose under

[96] EPA, ftp://ftp.epa.gov/EmisInventory/2002finalnei/documentation/nonpoint/2002nei_final_nonpoint_documentation0206version.pdf.
[97] Andy Hawkins, Kansas Department of Health and Environment, Bureau of Waste Management database; communicated via email to Rachel Anderson, CCS, March, 2008, (source: http://budget.ks.gov/ecodemo.htm).
[98] Rod Geisler, Bureau of Water, communicated via email to Rachel Anderson, February, 2008.
[99] Rod Geisler, Bureau of Water, communicated via email to Rachel Anderson, April 2008.

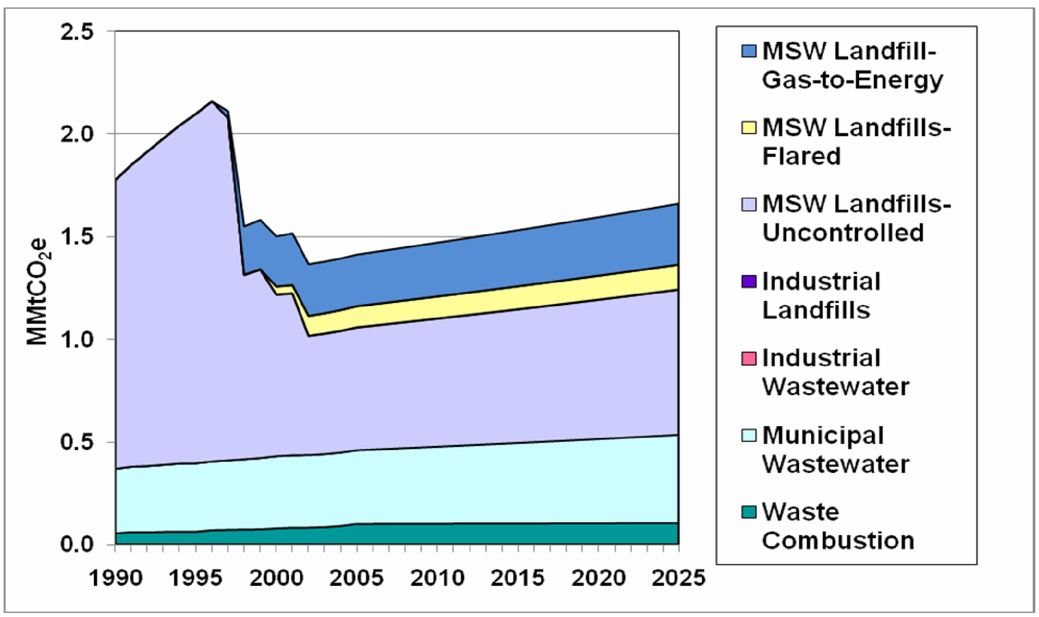
anaerobic conditions during other parts of the treatment process.[100] Thirty-three percent of municipal wastewater is treated in facultative lagoons where approximately 20% of BOD decomposes under anaerobic conditions.[101] Of the 18% not on municipal treatment systems[102] approximately 50% of BOD decomposes under anaerobic conditions.[103] Municipal wastewater emissions were projected based on the historic growth rate for 1990-2005 for a growth rate of 0.89% per year.

For industrial wastewater emissions, SIT provides default assumptions and emission factors for three industrial sectors: Fruits & Vegetables, Red Meat & Poultry, and Pulp & Paper. KDHE provided industrial wastewater flow data. The only KS industry with wastewater flow not connected to city sewer systems is red meat processing. Current industrial wastewater flow data for red meat were used to estimate all historic years from 1990-2005. The SIT emission factors were used to estimate emissions for red meat production. Emissions were projected to 2025 based on the 1990-2005 annual growth rate of 0.0%.

Results

Figure G1 and Table G2 show the emission estimates for the waste management sector. Overall, the sector accounts for 1.68 $MMtCO_2e$ in 2005, and emissions are estimated to be 1.66 $MMtCO_2e$/yr in 2025.

Figure G1. Kansas GHG Emissions from Waste Management, 1990-2025



Source: Based on approach described in text.
* Industrial Wastewater emissions are greater than zero but are too small to be seen at this scale

[100] US EPA, "Improvements to the U.S. Wastewater Methane and Nitrous Oxide Emissions Estimates," Elizabeth Scheele and Michiel Doorn, http://www.epa.gov/ttn/chief/conference/ei12/green/scheehle.pdf.
[101] KDHE, communicated to Rachel Anderson, CCS from Rod Geisler, Bureau of Water via email, April 2008.
[102] Septic and lagoons.
[103] US EPA, "Improvements to the U.S. Wastewater Methane and Nitrous Oxide Emissions Estimates," Elizabeth Scheele and Michiel Doorn, http://www.epa.gov/ttn/chief/conference/ei12/green/scheehle.pdf.

Table G2. Kansas GHG Emissions from Waste Management ($MMtCO_2e$)

Source	1990	1995	2000	2005	2010	2015	2020	2025
MSW Landfill-Gas-to-Energy	0.00	0.00	0.24	0.25	0.26	0.27	0.29	0.30
MSW Landfills - Flared	0.00	0.00	0.04	0.10	0.11	0.11	0.12	0.12
MSW Landfills - Uncontrolled	1.41	1.70	0.79	0.60	0.62	0.65	0.68	0.71
Waste Combustion	0.06	0.06	0.08	0.10	0.10	0.10	0.10	0.11
Municipal Wastewater	0.32	0.33	0.35	0.36	0.38	0.39	0.41	0.43
Industrial Wastewater	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**1.78**	**2.10**	**1.50**	**1.41**	**1.47**	**1.53**	**1.59**	**1.66**

The largest contributor to waste management emissions is the solid waste sector, particularly municipal landfills. Emissions from MSW landfills dropped steeply after 1995 due to application of landfill controls. In 2005, municipal landfills accounted for 67% of total waste management emissions, the bulk of which is from uncontrolled landfills. By 2025, the contribution from these sites is expected to be about 68%.

Figure G2 shows the distribution of potential 2005 MSW emissions in Kansas by landfill control type. Potential emissions are the emissions that would occur were there no landfill controls in place. In 2005, 50% of potential methane emissions from MSW are in landfills with LFGTE controls while 20% of potential emissions are from landfills with flares. The remaining 30% of potential emissions are from sites with no emissions controls. Figure G3 shows actual estimated landfill emissions by landfill control type. Actual emissions from LFGTE landfills account for only 26% because a significant portion of their methane emissions are thermally destroyed. The same holds true for flared landfills, which account for about 11% of actual emissions. Landfills without controls account for about 63% of actual MSW landfill emissions.

In 2005, about 26% of the waste management sector emissions were contributed by municipal wastewater treatment systems and negligible emissions (just 0.15 metric tons CO_2e) were contributed by industrial wastewater. By 2025, municipal wastewater treatment sectors are expected to contribute about 26% and industrial wastewater is expected to contribute negligible emissions (0.15 metric tons CO_2e) to the waste management sector.

Emissions from waste combustion contributed 7% of waste sector emissions in 2005 and are expected to decrease to 6% by 2025.

Key Uncertainties

For municipal waste landfills, the modeling of landfill emissions does not account for uncontrolled landfills that will need to apply controls during the period of analysis due to triggering requirements of the federal New Source Performance Standards/Emission Guidelines. According to KDHE, landfill waste emplacement rates were unavailable for small landfills, so the total emissions for this sector are expected to be a slight underestimate.

Figure G2. Kansas Potential MSW Emissions by Landfill Control Type, 2005

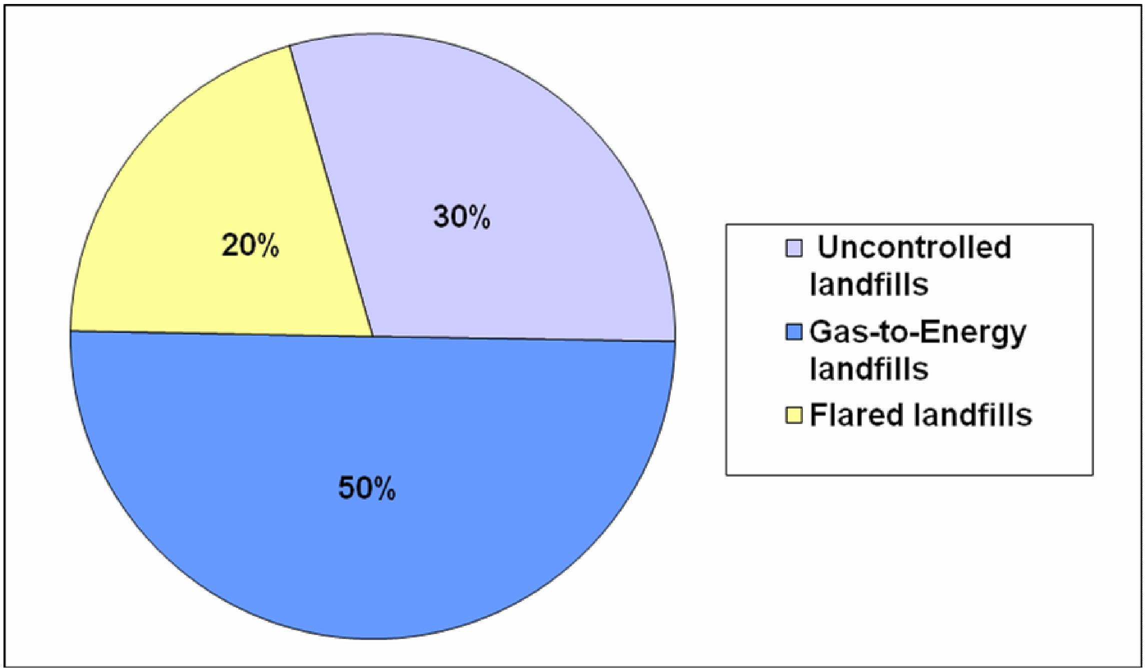
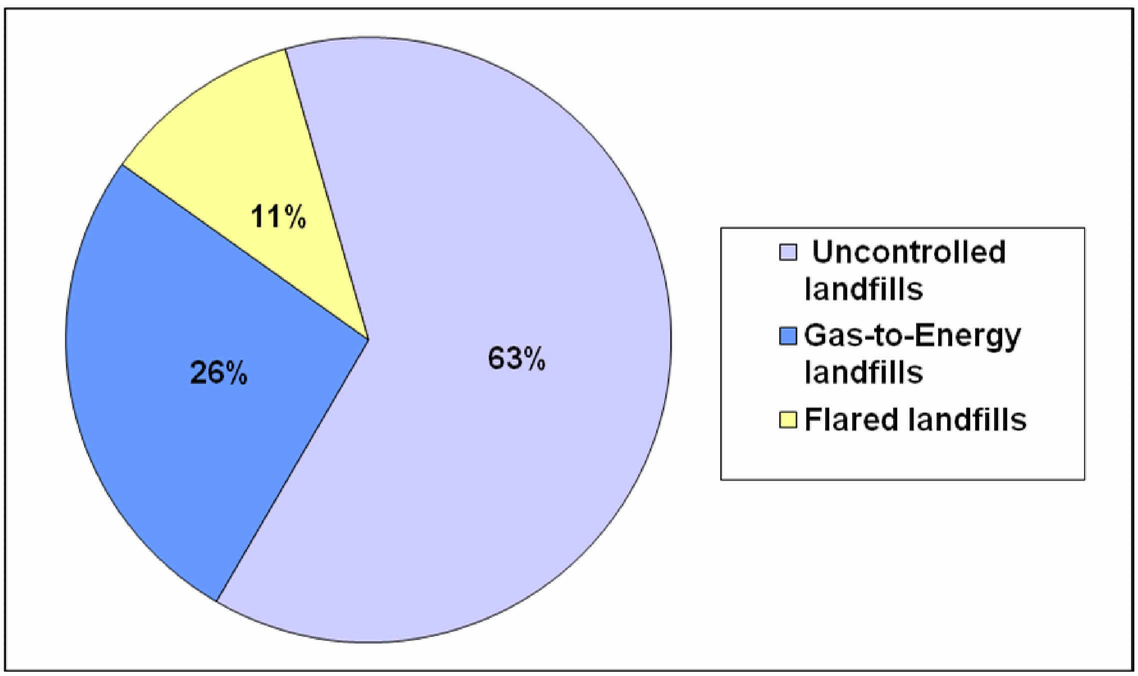


Figure G3. Kansas Actual MSW Emissions by Landfill Control Type, 2005



Although waste emplacement data do capture waste imports from other states, additional details will be incorporated as data are available to characterize the emissions from imported waste separately from that generated in-state. To the extent that any waste is exported out of state for management, the inventory and forecast should attempt to capture these emissions as well. This additional detail on waste import and export will be incorporated based on available data from KDHE.

There is limited scientific backing for the SIT assumption that 10% of landfill CH_4 is oxidized as it travels through the surface layers of the landfill so MSW landfill emissions may be underestimated.

For industrial landfills, emissions were estimated to be zero. The presence of wood waste in construction and demolition landfills makes this an underestimate.

SIT default assumptions for waste composition that are optimized for municipal waste were used to estimate medical waste combustion emissions. To the extent that medical waste composition is significantly different than municipal waste, the resulting emissions may be a slight under- or overestimate. The quantity of hazardous waste incinerated was not available and the significance of the potential for GHG emissions is unknown. Facilities that burn refuse as an energy source, such as cement kilns or boilers, are not included in the waste sector inventory but are addressed in the commercial fuel source inventory. Open burning of waste at residential sites was estimated using EPA's National Emission Inventory (NEI) methodology and SIT emissions factors and waste composition defaults based on rural county population data provided by KDHE. Depending on actual burn rates and waste composition, this could be an over- or underestimate. Emissions from open burning of yard waste were not estimated but are expected to be small (for yard waste, only CH_4 and N_2O emissions would be of interest, since the CO_2 would be of biogenic origin).

For the wastewater sector, the key uncertainties are associated with the application of SIT default values for the parameters listed in Table G1 above. The SIT defaults were derived from national data. Methane emissions from facultative lagoons are complex. The percent of organic material that breaks down under anaerobic conditions is dependent on many factors including depth of lagoon, temperature of inflow water, season, and ambient temperature. Because it is such a complex system, it is difficult to define the percent of anaerobic digestion occurring at each lagoon. Since a significant fraction of KS wastewater is treated in facultative lagoons, the total emissions for this sector may represent an under- or overestimate depending on actual lagoon emissions. KS mechanical wastewater treatment plants flare all methane generated from anaerobic digestion of biosolids. To the extent that additional methane is being generated outside of the anaerobic digestion process, these emissions will be underestimated. Also, potential emissions from treatment plant sludge that is applied to the surface of landfills were not quantified in this inventory.

For industrial wastewater, emissions were only estimated for the red meat industry using state data. KDHE noted that there are 133 small meat locker facilities and 13 dairy facilities connected to city sewage. Flow data for these facilities were not available. Therefore, emissions from industrial wastewater are likely to be slightly underestimated. There are no fruit and vegetable processing nor poultry processing facilities nor pulp and paper manufacturing facilities.

Appendix H. Forestry & Land Use

Overview

Forestry sector emissions refer primarily to the net carbon dioxide (CO_2) flux[104] from forested lands in Kansas, which account for about 4% of the state's land area.[105] The dominant forest type in Kansas is Oak/hickory which makes up about 53% of forested lands. Another common forest type is Elm/ash/cottonwood at 30% of forested land. All other forest types make up less than 6% each of the State's forests.[106]

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 CO_2 flux is 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 (C) 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 Kansas 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.[107] Additional forest carbon information is in the form of specific carbon conversion factors.[108]

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[104] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.
[105] Total forested acreage is 2.1 million acres in 2006. Acreage data for Kansas is available from the USFS Northern Research Station at: http://nrs.fs.fed.us/pubs/2598. The total land area in Kansas is 52.4 million acres (http://www.50states.com/kansas.htm).
[106] Forest type data from USFS Northern Research Station, Kansas' Forestry Resources, 2005 (http://nrs.fs.fed.us/pubs/9479).
[107] 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: 1990-2005 (and earlier editions), US Environmental Protection Agency, Report # USEPA #430-R-07-002, April

The forest CO_2 flux methodology relies on input data in the form of plot-level forest volume statistics from the Forest Inventory and Analysis (FIA) Program. 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 (see Table H1 for Kansas C pools). Additional background on the FORCARB system is provided in a number of publications.[109]

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 different carbon pools. The different forests also include differences in ownership class: 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.[110]

Carbon pool data for three FIA cycles to estimate flux for two different periods were available for Kansas. The carbon pool data for three points in time are shown in Table H1 below. Note that prior to 1994, the Northern FIA Program took periodic forest inventory surveys of Kansas (approximately on a 13-year schedule). Beginning in 2001, Kansas transitioned from periodic to

2007, available at: http://epa.gov/climatechange/emissions/usinventoryreport.html. Both Annex 3.12 and Chapter 7 LULUCF are useful 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.

[108] 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.

[109] 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.

[110] 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.

annual inventories as modifications to the FIA program were applied. The annual inventories are on a 5-year cycle and sample 20% of the state forests each year. The 2005 carbon pool data in Table H1 include 100% of the 2001-2005 5-year inventory cycle.

These underlying FIA data, shown in Table H1, display a net increase in forested area for all inventory years: 187,000 acres between 1981 and 1994, and 552,000 acres between 1994 and 2005. This results in a net increase in forested area of 739,000 acres in the 1981-2005 period. Most of the forested lands in Kansas are considered timberland, meaning that they are unreserved productive forest land producing, or capable of producing, crops of industrial wood. The timberland area is shown to have increased by 283,000 acres between 1981 and 1994 while it increased 529,000 acres between 1994 and 2005. This increase in timberland area appears to be the driving variable in the large increase in carbon (54 million metric tons) from forested areas between 1981 and 2005.

Table H1. USFS Forest Carbon Pool Data for Kansas

Forest Pool	1981 (MMtC)	1994 (MMtC)	2005 (MMtC)
Live Tree – Above Ground	24.2	34.1	45.4
Live Tree – Below Ground	4.6	6.5	8.7
Understory	1.1	1.0	1.6
Standing Dead	2.0	2.3	2.8
Down Dead	2.0	2.6	3.7
Forest Floor	9.5	11.2	10.7
Soil Carbon	44.9	55.5	69.4
Totals	**88**	**113**	**142**
Forest Area	**1981 (10^3 acres)**	**1994 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	1,358	1,545	2,097
Timberland	1,208	1,491	2,020

MMtC = million metric tons of carbon. Positive numbers indicate net emission. Multiply MMtC by 3.667 (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), December 2007.

Table H2 shows the annualized carbon stocks interpolated from Kansas FIA data using the Carbon Calculation Tool (CCT).[111] These annualized carbon stocks differ from the carbon stocks in Table H1 in that they are interpolated values (between forest inventory years) to January 1st of each year. The difference in carbon between each consecutive year is the carbon flux for that year. The carbon fluxes for each period shown in Table H3 are based on these annualized carbon stock estimates.

[111] 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.

Table H2: Annualized Forest Carbon Pool from USFS Carbon Calculation Tool

Forest Pool	1990 (MMtC)	1994 (MMtC)	2005 (MMtC)
Live Tree – Above Ground	30.9	33.9	47.4
Live Tree – Below Ground	5.9	6.5	9.0
Understory	1.1	1.0	1.7
Standing Dead	2.2	2.3	2.9
Down Dead	2.4	2.6	3.9
Forest Floor	10.6	11.1	10.7
Soil Carbon	52.0	55.3	71.9
Totals	**105**	**113**	**147**
Forest Area	**1981 (10^3 acres)**	**1994 (10^3 acres)**	**2005 (10^3 acres)**
All Forests	1,485	1,542	2,195
Timberland	1,399	1,486	2,113

In addition to the forest carbon pools, additional carbon is stored in biomass removed from the forest for the production of harvested wood products (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 WOODCARB II for the purposes of modeling national HWP carbon storage.[112] State-level information for Kansas was provided to CCS by USFS.[113]

As shown in Table H3, about 0.02 million metric tons (MMt) of CO_2 per year (yr) is estimated by the USFS to be sequestered annually (1981-2005) in wood products. Also, as shown in this table, the total flux estimate including all forest pools is -11.7 $MMtCO_2e$/yr between 1994 and 2005.[114] This total includes a large sink estimate for soil carbon (-5.6 $MMtCO_2$/yr). Given the changes noted above in timberland, it appears that much of the negative trend in carbon flux (sequestration) is from the increase in timberland between 1994 and 2005.

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.[115] The forest carbon flux estimates provided in the summary tables at the front of this report are those without the soil carbon pool.

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[112] 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.
[113] Obtained from the Harvested Wood Product model developed by Ken Skog, USFS
[114] 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), December 2007.
[115] For further information regarding the nature of uncertainties associated with estimating soil carbon stocks, see pg. 7-11 of *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* (http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf).

Table H3. USFS Annual Forest Carbon Fluxes for Kansas

Forest Pool	1981-1994 Flux (MMtCO2)	1994-2005 Flux (MMtCO2)
Forest Carbon Pools (non-soil)	-4.08	-6.05
Soil Organic Carbon	-3.00	-5.59
Harvested Wood Products	-0.02	-0.02
Totals	**-7.09**	**-11.7**
Totals (excluding soil carbon)	**-4.10**	**-6.07**

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, December 2007.

For historic emission estimates, CCS used the 1981-1994 carbon flux to represent yearly forest carbon flux prior to 1994. Current flux estimates (1994-2005) are from 1994 periodic inventory and 2005 annual inventory stocks. For the reference case projections (2005-2025), 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/gains in forested area.

Biomass burned in forest fires emits CO_2, methane (CH_4), and N_2O, in addition to many other gases and pollutants. The CO_2 emissions are captured under total carbon flux calculations (as the biomass loss during a fire would be captured during the subsequent forest inventory). Activity data from Kansas were not available to estimate CH_4 and N_2O emissions from forest fires. Since forestlands consist only 3% of Kansas land area, CCS does not deem the emissions significant.

Urban Forestry & Land Use

GHG emissions for 1990 through 2005 were estimated using the EPA SIT software and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for the sector.[116] 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.). Table H4 displays the emissions and reference case projections for Kansas.

Table H4. Urban Forestry Emissions and Reference Case Projections ($MMtCO_2e$)

Urban Forestry & Land Use Subsector	1990	2000	2005	2010	2020	2025
Urban Trees	-0.3	-0.36	-0.38	-0.38	-0.38	-0.38
Landfilled Yard Trimmings and Food Scraps	-2.27	-0.49	-0.5	-0.5	-0.5	-0.5
N_2O from Settlement Soils	0.24	0.32	0.32	0.32	0.32	0.32
Total	**-2.33**	**-0.53**	**-0.56**	**-0.56**	**-0.56**	**-0.56**

*Data for settlement soils was obtained from AAPFCO (2006) Commercial Fertilizers 2005. Association of American Plant Food Control Officials and The Fertilizer Institute. University of Kentucky, Lexington, KY.

[116] GHG emissions were calculated using SIT, with reference to EIIP, Volume VIII: Chapter 8.

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 varied from 1876 square kilometers [km^2] to 2425 km^2 between 1990 and 2005) was multiplied by the state estimate of the percentage of urban area with tree cover (21% for Kansas) 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.[117] Estimates of urban area in the intervening years (1990-1999) and subsequent years (2001-2005) are interpolated and extrapolated, respectively.

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. This trend is consistent with changes in the waste management industry during this period.

Settlement soils include all developed land, transportation infrastructure and human settlements of any size. Projections for urban trees, landfilled yard trimmings and food scraps, and settlement soils were kept constant at 2005 levels. Table H5 provides a summary of the estimated flux for the entire forestry and land use sector.

Rangeland Burning
Kansas Department of Health and Environment (KDHE) did provide CCS with activity data for rangeland burning. Biomass burned in rangeland fires also emits CO_2, CH_4, N_2O, and other pollutants. CCS used an Intergovernmental Panel for Climate Change (IPCC) methodology for grassland biomass burning to estimate Kansas' rangeland burning emissions.[118] The CO_2 emissions were not estimated because they are largely balanced by the CO_2 that gets reincorporated back into the grasslands through photosynthetic activity (see footnote below). CH_4 and N_2O emissions were estimated from KDHE's year 2002 acres of rangeland burned data. As these were the only data available, 1990-2005 emissions were assumed to be the same as 2002. Projected emissions for 2005-2025 were assumed to be held constant at 2005 emissions. The emission estimates are presented in Table H-5.

Table H5. Forestry and Land Use Flux and Reference Case Projections ($MMtCO_2e$)

Subsector	1990	2000	2005	2010	2020	2025
Forested Landscape (excluding soil carbon)	-4.1	-6.07	-6.07	-6.07	-6.07	-6.07
Urban Forestry and Land Use	-2.33	-0.53	-0.56	-0.56	-0.56	-0.56
Rangeland Burning	0.68	0.68	0.68	0.68	0.68	0.68
Total	**-5.75**	**-5.92**	**-5.95**	**-5.95**	**-5.95**	**-5.95**

[117] 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.
[118] *2006 IPCC Guidelines for National Greenhouse Gas Inventory*, Volume 4, Chapter 2 (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf), Chapter 6 (Tier 1 Methodology) (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_06_Ch6_Grassland.pdf) .

Key Uncertainties

It is important to note that there were methodological differences in the three FIA cycles (used to calculate carbon pools and flux) that can produce different 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 cycles 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 Kansas 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. The effect of these changes in survey methods has not been estimated by the USFS.

Emissions from rangeland burning in Kansas were estimated based on State acres burned data from 2002. 1990-2001 and 2003-2005 rangeland acres burned data were not available, so the emissions were assumed to be the same as 2002 emission levels. Since fire activity typically varies largely from year to year, future forecasts are hard to estimate. However, emissions from rangeland burning in Kansas are relatively small, and they do not impact the estimated flux significantly.

Much of the urban forestry & land use emission estimates rely on national default data and could be improved with state-specific information.