Colorado Greenhouse Gas Inventory—2014 Update
Including Projections to 2020 & 2030

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With Assistance from Blue Parish
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Executive Summary

This Colorado Greenhouse Gas Inventory – 2014 Update (Including Projections to 2020 & 2030) is a summary of Colorado's greenhouse gas (GHG) emissions and sinks from 1990 to 2030.

This inventory fulfills the requirement of Executive Order (EO) #D 004 08 issued on April 22, 2008 under then Governor Bill Ritter, Jr. The EO directed the Colorado Department of Public Health and Environment (CDPHE) to perform updates to the state's greenhouse gas emissions inventory every five years.

This inventory is the latest in a series of inventories of Colorado GHG emissions and sinks, the last of which was completed in late 2007. While there are some similarities among these inventories, this inventory is organized somewhat differently and utilizes updated methodologies and data developed over the past 5 years.[1] Accordingly, it is not possible to draw accurate conclusions regarding GHG emission trends in Colorado by comparing this inventory with past inventories. Rather, emission trends for Colorado should be assessed using the historical and projected emissions included in this inventory.

To generate this inventory, CDPHE used the Environmental Protection Agency's (EPA) State Inventory Tool (SIT) dated February 2013. This inventory includes a comprehensive summary of 1990-2010 outputs from the current SIT model as well as emission projections for 2020 and 2030. As a general matter, this inventory utilizes the Colorado default values set within the SIT model. The SIT model provides flexibility to change these default values. Based on comments received during the three month comment period, CDPHE has considered various ways to customize values to more accurately reflect Colorado GHG emissions. Based on these considerations, CDPHE has made targeted changes to the SIT model default values. For the most part, however, this final inventory retains the default values either because there is insufficient data to create customized values, or potential changes to the default values would not materially change the calculated emissions.

The Projection Tool utilizes the data generated in the separate modules to project GHG emissions for Colorado in 2020 and 2030. The Projection Tool uses a different methodology for projecting emissions; therefore it is included in a separate section of the inventory. While these projections are useful for looking at trends over the long term, there are some significant uncertainties and limitations. Specifically, while Colorado data could be included in calculating emissions for 1990-2010, this option was not available for the 2020 and 2030 projections. Accordingly, the projections may not include significant policy changes and emissions reductions that are scheduled to take effect after 2010. For example, for both the electricity and oil and gas production sectors, Colorado has adopted emission control strategies that go beyond what is considered in the model. Moreover EPA has proposed a Clean Power

[1] One notable area of difference between the current draft inventory and the 2007 inventory regards black carbon. The 2007 Inventory included an assessment of black carbon that is not included in this Inventory, because it is not a module in EPA's State Inventory Tool model. The EPA provides a discussion of black carbon and its impacts on climate at the following link: http://www.epa.gov/blackcarbon/basic.html.

Plan rule that is designed to reduce greenhouse gas emissions from the power sector. This is discussed in more depth in the Projection Chapter.

This report includes extensive chapters which serve as a workbook to better understand the inventory. Each chapter focuses on an individual sector of the inventory (e.g. transportation, agriculture, etc.), explains model runs, data assumptions, and uncertainties. Additionally, each chapter offers suggestions for how to tailor the inventory to make it more reflective of actual Colorado specific emissions.[2] While for the most part the chapters in this report track the various modules within the SIT model, data from certain modules were either consolidated or split out in order to provide a more cohesive sector based analysis of GHG emissions in Colorado. This is described more fully in the Synthesis Chapter.

Exhibit ES-1 includes a summary of the SIT model results by sector.[3] The inventory reflects that Colorado GHG emissions have increased since 1990, but that the rate of increase has slowed since 2005. Additionally, the data shows that most GHG emissions in Colorado come from the electric power, transportation and residential/commercial/industrial fuel use sectors.

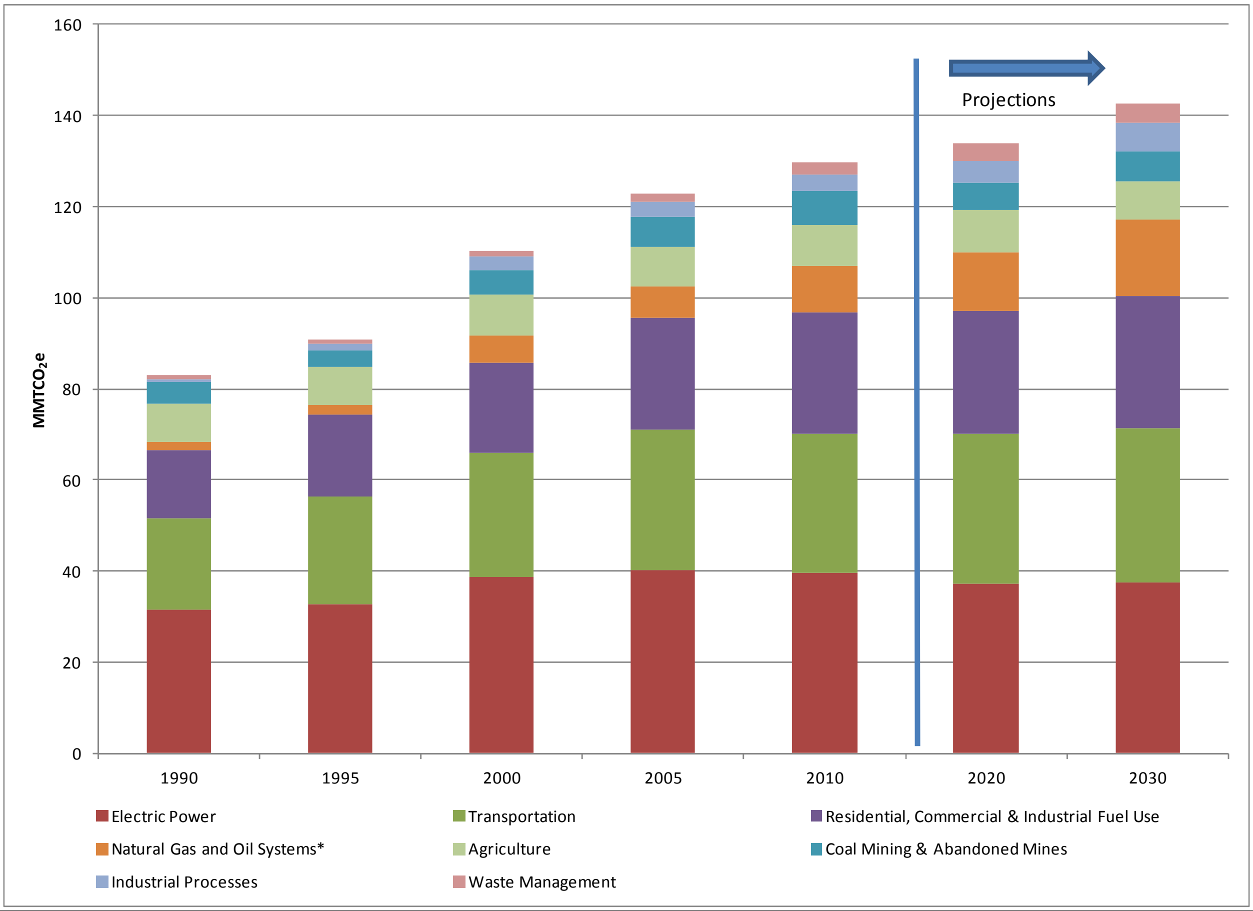
Exhibit ES-1 Summary of Colorado GHG Emissions by Emission Sector ($MMTCO_2e$) SIT Model Runs 1990-2010

	1990	1995	2000	2005	2010
Electric Power	31	33	39	40	40
Transportation	20	24	27	31	30
Residential, Commercial & Industrial Fuel Use	15	18	20	25	27
Natural Gas and Oil Systems*	2	2	6	7	10
Agriculture	8	8	9	9	9
Coal Mining & Abandoned Mines	5	4	5	7	8
Industrial Processes	1	1	3	3	4
Waste Management	1	1	1	2	3
Grand Total	83	91	110	123	130

Exhibit ES-2 shows a summary of estimated and projected Colorado GHG Emissions by Emission Sector ($MMTCO_2e$) in graphical form. This Exhibit also shows predicted GHG emissions by sector for the years 2020 and 2030. For the period from 2010 through 2030 the model projects an approximately 10% increase in Colorado GHG emissions. This compares to an increase of approximately 56% during the 20 year period from 1990-2010.

[2] The University of Colorado, Denver, under the leadership of Dr. Anu Ramaswami, provided insight into how to improve the inventory which is captured in these recommendations (2012).
[3] Each chapter goes into further detail about the subcategories outlined in Exhibit ES-1.

Exhibit ES-2 Summary of Colorado GHG Emissions by Emission Sector (MMTCO2e) SIT Model Runs 1990-2030



As an alternative to looking at GHG emissions by sector, Exhibit ES-3 shows the breakdown of the estimated and projected GHG Inventory by gas in Colorado. As with the data presented throughout this inventory, emissions of each of the greenhouse gases are reflected in terms of carbon dioxide equivalent (CO_2e) to reflect the different global warming potentials of the various gases. This Exhibit provides some insight into the relative importance of the various greenhouse gases. For example, in 2010 carbon dioxide accounted for 75% and methane accounted for 20% of the inventory. The remainder of the gases accounted for approximately 5% of the CO_2e emissions in 2010. Exhibit ES-3 reflects similar trends for the other modeled years.

Exhibit ES-3 Summary of Past and Projected GHG Emissions by Gas in Colorado ($MMTCO_2e$) SIT Model Runs 1990-2030

	1990	1995	2000	2005	2010	2020	2030
CO_2							
CO_2 from Fossil Fuel Combustion							
Residential	5.33	6.15	6.88	7.61	7.91	7.86	8.22
Commercial	3.98	4.04	3.79	4.09	4.19	4.6	4.75
Industrial	5.60	7.58	9.17	12.69	14.59	14.27	16.09
Transportation	19.15	22.41	25.69	29.9	29.94	32.6	33.37
ElectricPower	31.27	32.5	38.64	40.1	39.35	37.05	37.35
Sub Total Emissions	**65.33**	**72.68**	**84.17**	**94.38**	**95.99**	**96.44**	**99.78**
Industrial Processes	0.36	0.64	1.47	1.33	1.44	1.64	2.05
Waste Combustion and Landfills	0.11	0.16	0.17	0.20	0.20	0.26	0.30
Total Emissions	**66**	**73**	**86**	**96**	**98**	**98**	**102**
CH_4							
Stationary Combustion	0.08	0.08	0.09	0.09	0.09	0.04	0.04
Mobile Combustion	0.09	0.1	0.08	0.06	0.04	0.03	0.03
Coal Mining & Abandoned Mines	4.81	3.73	5.32	6.61	7.54	5.96	6.6
Natural Gas and Oil Systems*	1.91	2.07	5.82	6.74	10.05	13.01	16.90
Enteric Fermentation	3.87	4.32	4.61	4.52	4.95	5.33	4.64
Manure Management	0.38	0.51	0.71	0.75	0.87	0.75	0.77
Rice Cultivation	-	-	-	-	-	-	-
Burning of Agricultural Crop Waste	0.009	0.009	0.009	0.009	0.012	0.004	0.004
Waste Combustion and Landfilles	0.61	0.53	0.94	1.58	2.19	2.83	3.18
Wastewater	0.26	0.3	0.35	0.36	0.39	0.46	0.53
Total Emissions	**12**	**12**	**18**	**21**	**26**	**28**	**33**
N_2O							
Stationary Combustion	0.17	0.18	0.21	0.21	0.21	0.19	0.19
Mobile Combustion	0.87	1.22	1.26	0.92	0.48	0.33	0.31
Industrial Processes	-	-	-	-	-	-	-
Manure Management	0.43	0.48	0.57	0.53	0.51	0.53	0.48
Agricultural Soil Management	3.45	3.12	3.24	2.96	2.68	2.63	2.35
Burning of Agricultural Crop Waste	0.003	0.003	0.003	0.003	0.004	0.002	0.002
Waste Combustion and Landfills	0.01	0.01	0.01	0.01	0.01	0.01	0
Wastewater	0.09	0.11	0.13	0.14	0.15	0.18	0.22
Total Emissions	**5**	**5**	**5**	**5**	**4**	**4**	**4**
HFC, PFC, and SF_6							
Industrial Processes	0.72	0.77	1.47	1.83	2.14	3.25	4.23
GRAND TOTAL	**84**	**91**	**111**	**123**	**130**	**134**	**143**

*** Modified to account for COGCC well counts**

The SIT projection tool also provides data on GHG emissions on both a per capita and per gross state product basis, from 1990 projected through 2030, as discussed in the Projection Chapter. GHG emissions per person in 2010 are approximately the same as in 1990, and are projected to decline slightly through 2030. Emissions per gross state product, however, have declined dramatically since 1990, and are expected to continue to decline gradually through 2030.

As reflected in the above data, GHG emissions in Colorado increased during the period from 1990-2010, though the growth has slowed considerably since 2000. The increase in GHG emissions since 1990 appears to be the result of population growth, since per capita emissions have actually decreased slightly since 1990, and emissions per gross state product have declined considerably.

The SIT predicts a modest increase in GHG emissions during the period from 2010-2030. However, due to limitations with the Projection tool and the failure to account for recently enacted and proposed GHG reduction strategies, definitive conclusions about the trend in GHG emissions in Colorado during the next 20 years are not warranted at this time.

Chapter 1 – Synthesis Tool

Background

The Synthesis Tool provides a comprehensive summary of 1990-2010 outputs from the SIT model runs. This Synthesis Tool requires the user to run the eleven SIT modules using either default data, or state derived alternative data. The Synthesis Tool makes no actual calculations of emissions. It should be viewed as a compilation of all module outputs designed to display summary data in a convenient and more readable format.

The EPA Synthesis Tool User's Guide-February 2013 provides a comprehensive discussion addressing how 1990-2010 emissions are imported into a master summary file.

State Inventory Tool-Synthesis Module

All SIT model modules were run in the default mode, with the exception of the Oil and Gas Module[4]. In a few cases the SIT does not have default data for a Colorado source and thus a zero emission profile is generated. For example, this is most notable in the lack of actual forest fire data for Colorado reflecting a shortage in methane and nitrous oxide emissions by about a ton of CO_2e.

After generating emission profiles for each sector, an Export File is generated. Each control sheet in the SIT module has an option to export the summary data file which may then be linked to the Synthesis Tool. When opening the Synthesis Tool the user must link each of the eleven module Export Files to the Control Sheet (the first page of the spreadsheet based Synthesis Tool). In each of the chapters in this Colorado inventory, some or all of the information from the Synthesis Tool is included. Thus, exhibits in this Synthesis Tool Chapter may be repeated in each chapter.

Exhibits and subsections document the results of the Synthesis Module. For space and appearance purposes, most exhibits have been edited to remove categories that had zero emissions in Colorado (e.g. bunker fuels; cable cars; trolleys, etc.).

For a complete listing of sources in a specific category, and reasoning for any changes, refer to the individual Chapters in this document.

The SIT model is organized as a series of separate modules. These modules are each run independently to calculate historical GHG emissions produced from Colorado sources by category, as well as carbon sequestration in Colorado's trees and other plants, for 5 year intervals from 1990 through 2010. The SIT model includes a Synthesis Tool, which summarizes emissions from each module from 1990 through 2010. See Exhibit 1-1 for a listing of modules in each sector.

[4] Potential modifications to the default data in the other modules were considered, but were not pursued either because reliable and complete data was not available or because modifications to the default data would not materially change the calculated emissions.

Exhibit 1-1 SIT Modules and Data Used to Generate CO_2e Emissions for the Colorado 2013 GHG Inventory

Chapter 1. Synthesis Tool • **Combines results of all SIT Modules for total CO_2e Emissions 1990-2010**
Chapter 2. Projection Tool • **Projections of CO_2, N_2O and CH_4 for all sectors from 2011-2030 using** 1. **Energy Consumption Projection** 2. **Greenhouse Gas Estimates, 1990-2030 Inventory Tool**
Chapter 3. Electrical Power • **CO_2 from Fossil Fuel Combustion Module** • **N_2O and CH_4 from Stationary Combustion Module** • **Indirect CO_2 Emissions**
Chapter 4.Residential, Commercial, Industrial (RCI) Fuel Use • **CO_2 from Fossil Fuel Combustion Module** • **N_2O and CH_4 from Stationary Combustion Module**
Chapter 5. Transportation • **CO_2 from Fossil Fuel Combustion Module** • **N_2O and CH_4 from Mobile Combustion Module**
Chapter 6. Industrial Processes • **CO_2, N_2O, HFC, PFC, and SF_6 Industrial Processes Module**
Chapter 7. Coal Mining • **CH_4 from Coal Mining & Abandoned Mines Module**
Chapter 8. Gas Production • **CH4 from Natural Gas and Oil Systems Module**
Chapter 9. Agricultural Methane and Nitrous Oxide • **N_2O and CH_4 from Agricultural Module**
Chapter 10. Waste Management • **CO_2, N_2O and CH_4 from Municipal Solid Waste Module** • **N_2O and CH_4 from Wastewater Module**
Chapter 11. Land Use and Forestry • **CO2, N2O and CH4 from Land Use, Land Use Change and Forestry Module Emissions and Sinks**

Summary of Colorado GHG Emissions

The following Exhibits provide a comprehensive summary of Colorado GHG emissions provided by the Synthesis Tool. They are the result of summing information from all of the modules. Exhibit 1-2 summarizes emission by sector. Exhibit 1-3 summarizes emissions by gas and Exhibit 1-4 by gas intensity on a per capita and per gross state product basis.

As reflected in Exhibit 1-2, from 1990 to 2010 both gross and net GHG emissions in Colorado increased. CO_2 from fossil fuel combustion is responsible for most of the increases going from 65.33 $MMTCO_2e$ in 1990 to 95.99 $MMTCO_2e$ in 2010.

Exhibit 1-2 Summary of Colorado GHG Emissions by Emission Sector

	1990	1995	2000	2005	2010
Energy					
CO_2 from Fossil Fuel Combustion Subtotal	65.33	72.68	84.17	94.38	95.99
Residential	5.33	6.15	6.88	7.61	7.91
Commercial	3.98	4.04	3.79	4.09	4.19
Industrial	5.60	7.58	9.17	12.69	14.59
Transportation	19.15	22.41	25.69	29.9	29.94
ElectricPower	31.27	32.5	38.64	40.1	39.35
Stationary Combustion	0.25	0.26	0.3	0.3	0.3
Mobile Combustion	0.96	1.32	1.33	0.98	0.53
Coal Mining & Abandoned Mines	4.81	3.73	5.32	6.61	7.54
Natural Gas and Oil Systems*	1.91	2.07	5.82	6.74	10.05
Total Emissions	**73.26**	**80.06**	**96.94**	**109.01**	**114.41**
Industrial Processes					
Total Emissions	**0.72**	**1.41**	**2.94**	**3.16**	**3.58**
Agriculture					
Enteric Fermentation	3.87	4.32	4.61	4.52	4.95
Manure Management	0.81	0.99	1.28	1.28	1.38
Rice Cultivation	-	-	-	-	-
Agricultural Soil Management	3.45	3.12	3.24	2.96	2.68
Burning of Agricultural Crop Waste	0.01	0.01	0.01	0.01	0.02
Total Emissions	**8.14**	**8.44**	**9.14**	**8.77**	**9.04**
Waste					
Municipal Solid Waste	0.46	0.39	0.82	1.47	2.08
Wastewater	0.35	0.41	0.47	0.50	0.54
Total Emissions	**1.07**	**1.1**	**1.59**	**2.27**	**2.93**
GRAND TOTAL	**83.19**	**91.01**	**110.61**	**123.21**	**129.96**
Electricity Consumption Emissions**	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**
Land Use & Forestry - LULUCF**	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**

*** Modified to account for COGCC well counts**

**** Indirect emissions from Electrical Consumption & LULUCF are not included in the total emissions.**

Exhibit 1-3 Summary of Colorado GHG Emissions by Gas in $MMTCO_2e$

	1990	1995	2000	2005	2010
CO_2					
CO_2 from Fossil Fuel Combustion					
Residential	5.33	6.15	6.88	7.61	7.91
Commercial	3.98	4.04	3.79	4.09	4.19
Industrial	5.60	7.58	9.17	12.69	14.59
Transportation	19.15	22.41	25.69	29.9	29.94
ElectricPower	31.27	32.5	38.64	40.1	39.35
Sub Total Emissions	**65.33**	**72.68**	**84.17**	**94.38**	**95.99**
Industrial Processes	0.36	0.64	1.47	1.33	1.44
Waste Combustion and Landfills	0.11	0.16	0.17	0.20	0.20
Total Emissions	**65.8**	**73.48**	**85.81**	**95.91**	**97.63**
CH_4					
Stationary Combustion	0.08	0.08	0.09	0.09	0.09
Mobile Combustion	0.09	0.1	0.08	0.06	0.04
Coal Mining & Abandoned Mines	4.81	3.73	5.32	6.61	7.54
Natural Gas and Oil Systems*	1.91	2.07	5.82	6.74	10.05
Enteric Fermentation	3.87	4.32	4.61	4.52	4.95
Manure Management	0.38	0.51	0.71	0.75	0.87
Rice Cultivation	-	-	-	-	-
Burning of Agricultural Crop Waste	0.009	0.009	0.009	0.009	0.012
Waste Combustion and Landfills	0.61	0.53	0.94	1.58	2.19
Wastewater	0.26	0.3	0.35	0.36	0.39
Total Emissions	**12.02**	**11.65**	**17.93**	**20.72**	**26.13**
N_2O					
Stationary Combustion	0.17	0.18	0.21	0.21	0.21
Mobile Combustion	0.87	1.22	1.26	0.92	0.48
Industrial Processes	-	-	-	-	-
Manure Management	0.43	0.48	0.57	0.53	0.51
Agricultural Soil Management	3.45	3.12	3.24	2.96	2.68
Burning of Agricultural Crop Waste	0.003	0.003	0.003	0.003	0.004
Waste Combustion and Landfills	0.01	0.01	0.01	0.01	0.01
Wastewater	0.09	0.11	0.13	0.14	0.15
Total Emissions	**5.02**	**5.12**	**5.42**	**4.77**	**4.04**
HFC, PFC, and SF_6					
Industrial Processes	0.72	0.77	1.47	1.83	2.14
GRAND TOTAL	**83.56**	**91.02**	**110.63**	**123.23**	**129.95**
Electricity Consumption Emissions**	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**
Land Use & Forestry - LULUCF**	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**

*** Modified to account for COGCC well counts**

**** Indirect emissions from Electrical Consumption & LULUCF are not included in the total emissions.**

Exhibit 1-4 provides a unique view of the emissions per year expressed in a Gross State Product (GSP) basis and a per capita basis. On a per capita basis the gross intensity per person remains basically unchanged over the twenty year history of the inventory. The gross state product increased by a factor of 3.4, but emissions dropped on a per dollar generated basis over the same time frame by approximately one half. Specifically, the Gross State Product went from $75 billion dollars in 1990 to $253 billion in 2010, but GHG emissions only increased by 54%.

Exhibit 1-4 Colorado GHG Emissions Summary by Intensity

Emissions Per Capita (MTCO$_2$E)	**1990**	**1995**	**2000**	**2005**	**2010**
Gross Emissions Intensity	25.14	24.26	24.80	26.11	25.33
Net Emissions Intensity (Sources and Sinks)	21.58	21.43	22.32	23.74	23.54
Emissions Per GSP (Gross State Product) (MTCO$_2$E)	**1990**	**1995**	**2000**	**2005**	**2010**
Gross Emissions Intensity	**1,108.59**	**831.98**	**639.14**	**559.94**	**503.4**
Net Emissions Intensity (Sources and Sinks)	**951.88**	**734.86**	**575.04**	**509.22**	**467.73**

Gross emissions includes sources of CO_2e that contribute to Colorado's total positive impact. Net emissions include sources that are positive and negative sources of carbon including carbon sinks – which absorb carbon rather than emitting it.

The following sections explain the individual sources of data from each module run.

CO_2 from Fossil Fuel Combustion

Carbon dioxide from fossil fuel combustion accounts for approximately 75-80% of the State inventory and is a combination of emissions from electrical power production, use of fossil fuels in residential, commercial and industrial applications and transportation related fuel use. Carbon dioxide is directly emitted from the combustion of all forms of fossil fuels. This ancient stored carbon is released into the atmosphere causing fresh emissions of carbon dioxide to be created as opposed to the combustion of contemporary carbon sources such as trees or refuse.

Exhibit 1-5 shows CO_2 emissions from fossil fuel combustion by sector and fuel type. This data indicates that the use of coal to generate electricity is the largest source of CO_2 emissions in Colorado, followed by the use of petroleum products for transportation, and natural gas used in residential commercial and industrial applications. For a more comprehensive discussion refer to Chapters 3-5.

Exhibit 1-5 Summary of CO_2e Emissions-Fossil Fuel Combustion Synthesis Tool Results

Emisions (MMTCO$_2$e)	1990	1995	2000	2005	2010
Residential					
Coal	0.02	0.01	0.02	0.02	0.06
Petroleum	0.42	0.54	0.71	0.82	0.77
Natural Gas	4.89	5.61	6.16	6.77	7.07
Subtotal Emissions	**5.33**	**6.15**	**6.88**	**7.61**	**7.91**
Commercial					
Coal	0.1	0.04	0.14	0.25	0.5
Petroleum	0.36	0.42	0.43	0.45	0.58
Natural Gas	3.52	3.58	3.22	3.38	3.11
Subtotal Emissions	**3.98**	**4.04**	**3.79**	**4.09**	**4.19**
Industrial					
Coal		0.82	0.42	0.14	0.7
Petroleum	2.14	2.26	2.71	3.16	3.02
Natural Gas	3.46	4.5	6.05	9.38	10.87
Total Emissions	**5.6**	**7.58**	**9.17**	**12.69**	**14.59**
Transportation					
Coal					
Petroleum	18.66	21.8	25.17	29.16	29.16
Natural Gas	0.49	0.62	0.52	0.73	0.78
Subtotal Emissions	**19.15**	**22.41**	**25.69**	**29.9**	**29.94**
Electric Utilities					
Coal	30.54	31.21	35.01	35.00	34.29
Petroleum	0.02	0.02	0.09	0.02	0.02
Natural Gas	0.71	1.28	3.54	5.08	5.05
Subtotal Emissions	**31.27**	**32.5**	**38.64**	**40.1**	**39.35**
Coal Total	30.66	32.07	35.59	35.42	35.55
Petroleum Total	21.61	25.03	29.1	33.61	33.55
Natural Gas Total	13.06	15.58	19.48	25.35	26.88
GRAND TOTAL	**65.33**	**72.68**	**84.17**	**94.38**	**95.99**

Stationary Combustion

Exhibit 1-6 presents the summary methane and nitrous oxide emissions from the stationary source combustion processes. Nitrous oxide is generated any time a combustion process takes place in the presence of oxygen and nitrogen from the atmosphere. Methane is lost to the atmosphere as a result of incomplete combustion of natural gas. Methane is considered to be 21[5] times more potent as a GHG than carbon dioxide and nitrous oxide 310 times more potent as a GHG. The results in Exhibit 1-6 consider the total tons of emissions from major stationary sources, residential, and commercial facilities and adjusts the emission rate using the standard multipliers (x21 for CH_4 and x310 for N_2O). For a more comprehensive discussion concerning stationary combustion refer to Chapter 3.

Exhibit 1-6 Summary of CH_4 and N_2O Emissions from Stationary Combustion

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Residential					
N_2O	0.013	0.013	0.015	0.014	0.014
CH_4	0.056	0.056	0.064	0.058	0.06
Subtotal Emissions	**0.069**	**0.069**	**0.079**	**0.072**	**0.074**
Commercial					
N_2O	0.004	0.004	0.005	0.006	0.007
CH_4	0.013	0.014	0.016	0.015	0.015
Subtotal Emissions	**0.017**	**0.018**	**0.021**	**0.02**	**0.022**
Industrial					
N_2O	0.007	0.012	0.011	0.013	0.014
CH_4	0.003	0.005	0.005	0.006	0.007
Subtotal Emissions	**0.01**	**0.017**	**0.017**	**0.02**	**0.021**
Electric Utilities					
N_2O	0.150	0.153	0.177	0.178	0.174
CH_4	0.007	0.007	0.009	0.010	0.010
Subtotal Emissions	**0.157**	**0.161**	**0.187**	**0.188**	**0.184**
Total By Gas					
N_2O	0.173	0.182	0.209	0.211	0.209
CH_4	0.079	0.083	0.095	0.089	0.092
GRAND TOTAL	**0.252**	**0.27**	**0.3**	**0.300**	**0.3**

Mobile Combustion-Methane and Nitrous Oxide

Mobile Combustion-Methane and Nitrous Oxide sources accounted for 5% of the 1990 transportation portion of the inventory (about 1% of the total net inventory). By 2010 this declines to about 1% of the transportation sector and a

[5] Recent analyses suggest that methane may be an even more potent GHG. The SIT uses 21 times potency factor, so this factor is reflected in the calculated inventory.

few tenths of a percent for the state total. Emissions in this category are a combination of emissions from automobiles, aircraft, diesel on and off-road mobile sources, including farm equipment, trains and boats. Mobile sources contribute to the GHG inventory by direct emissions of carbon dioxide, methane and nitrous oxide from the combustion of carbon based fossil fuels. Emissions of carbon dioxide are directly related to fuel consumption and are captured in Exhibit 1-7 and are discussed in detail in Chapter 5. A second part of the mobile source combustion to be considered is direct tailpipe emissions of methane and nitrous oxide. Exhibits 1-8 and 1-9 document the SIT model output for methane and nitrous oxide emissions from mobile source combustion. These emissions vary according to the types of emission control equipment and other operating parameters (temperature, oxygen levels, air fuel ratio, etc.) of a mobile source.

This element of the SIT model calculates methane and nitrous oxide emissions for mobile sources and, as with stationary source combustion, the GHG intensity factors are applied to the total tons of emissions to calculate the CO_2e burden. Totals from Exhibits 1-8 and 1-9 are combined to form the $MMTCO_2e$ contents of Exhibit 1-7. In the overall inventory these emissions are added to the CO_2 direct mobile source emissions to provide the overall mobile source GHG emissions impacts in $MMTCO_2e$. The emissions of methane and nitrous oxide are small compared to carbon dioxide emissions.

Exhibit 1-7 Summary of CH_4 and N_2O Emissions from Mobile Combustion- ($MMTCO_2e$)

Fuel Type/Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	0.571	0.676	0.654	0.488	0.310
Light-Duty Trucks	0.314	0.549	0.576	0.371	0.108
Heavy-Duty Vehicles	0.019	0.026	0.030	0.026	0.009
Motorcycles	0.001	0.001	0.001	0.001	0.002
Subtotal Emissions	0.905	1.252	1.261	0.886	0.429
Diesel Highway					
Passenger Cars	0.000	0.000	0.000	0.000	0.000
Light-Duty Trucks	0.000	0.000	0.000	0.000	0.000
Heavy-Duty Vehicles	0.004	0.006	0.007	0.008	0.010
Subtotal Emissions	0.005	0.006	0.008	0.009	0.010
Non-Highway					
Boats	0.000	0.000	0.001	0.001	0.001
Locomotives	0.008	0.012	0.005	0.002	0.007
Farm Equipment	0.006	0.008	0.007	0.005	0.006
Construction Equipment	0.004	0.005	0.010	0.012	0.012
Aircraft	0.027	0.032	0.033	0.052	0.048
Other*	0.001	0.001	0.004	0.005	0.003
Subtotal Emissions	0.046	0.059	0.060	0.077	0.076
Alternative Fuel Vehicles					
Light Duty Vehicles	0.001	0.001	0.002	0.001	0.002
Heavy Duty Vehicles	0.002	0.003	0.003	0.007	0.010
Buses	0.000	0.000	0.000	0.000	0.001
Subtotal Emissions	0.003	0.004	0.006	0.009	0.013
GRAND TOTAL	0.959	1.321	1.334	0.981	0.528

*Other includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel equipment.

Exhibit 1-8 Summary of CH_4 Emissions from Mobile Combustion ($MMTCO_2e$) Synthesis Tool Results

Fuel Type/Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	0.053	0.050	0.040	0.028	0.023
Light-Duty Trucks	0.028	0.034	0.026	0.018	0.007
Heavy-Duty Vehicles	0.005	0.005	0.003	0.002	0.001
Motorcycles	0.000	0.000	0.000	0.000	0.001
Subtotal	0.087	0.089	0.069	0.049	0.031
Diesel Highway					
Passenger Cars	0.003	0.003	0.002	0.002	0.002
Light-Duty Trucks	0.007	0.010	0.013	0.016	0.010
Heavy-Duty Vehicles	0.285	0.406	0.492	0.549	0.666
Subtotal	0.295	0.419	0.508	0.567	0.679
Non-Highway					
Boats	0.000	0.000	0.000	0.000	0.000
Locomotives	0.001	0.002	0.001	0.000	0.001
Farm Equipment	0.002	0.002	0.002	0.001	0.002
Construction Equipment	0.001	0.001	0.001	0.002	0.002
Aircraft	0.002	0.002	0.003	0.004	0.003
Other*	0.000	0.000	0.001	0.001	0.000
Subtotal	0.006	0.008	0.008	0.008	0.008
Alternative Fuel Vehicles					
Light Duty Vehicles	0.000	0.000	0.000	0.000	0.000
Heavy Duty Vehicles	0.000	0.000	0.000	0.002	0.004
Buses	0.000	0.000	0.000	0.000	0.000
Subtotal	0.000	0.000	0.001	0.003	0.004
GRAND TOTAL	0.093	0.098	0.079	0.060	0.044

*Other includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered equipment, and heavy-duty diesel powered utility equipment.

Exhibit 1-9 Summary of N_2O Emissions from Mobile Combustion ($MMTCO_2e$) Synthesis Tool Results

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	0.518	0.627	0.614	0.460	0.287
Light-Duty Trucks	0.287	0.515	0.550	0.354	0.101
Heavy-Duty Vehicles	0.013	0.021	0.027	0.024	0.008
Motorcycles	0.000	0.001	0.001	0.001	0.001
Subtotal	0.818	1.163	1.191	0.838	0.398
Diesel Highway					
Passenger Cars	0.000	0.000	0.000	0.000	0.000
Light-Duty Trucks	0.000	0.000	0.000	0.000	0.000
Heavy-Duty Vehicles	0.004	0.006	0.007	0.008	0.009
Subtotal	0.004	0.006	0.007	0.008	0.010
Non-Highway					
Boats	0.000	0.000	0.000	0.001	0.000
Locomotives	0.007	0.010	0.004	0.001	0.006
Farm Equipment	0.004	0.006	0.005	0.004	0.004
Construction Equipment	0.003	0.004	0.009	0.010	0.010
Aircraft	0.024	0.029	0.030	0.048	0.044
Other*	0.001	0.001	0.004	0.005	0.002
Subtotal	0.040	0.051	0.052	0.069	0.068
Alternative Fuel Vehicles					
Light Duty Vehicles	0.001	0.001	0.001	0.001	0.002
Heavy Duty Vehicles	0.002	0.002	0.003	0.005	0.006
Buses	0.000	0.000	0.000	0.000	0.000
Subtotal	0.003	0.003	0.004	0.006	0.008
GRAND TOTAL	0.866	1.224	1.255	0.921	0.484

* Other includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Coal Mining

Coal mining emissions are primarily from methane released in the process of exposing coal to the atmosphere. These emissions are direct emissions related to mining activities - crushing, hauling, washing, etc. - and from underground mines. In Exhibit 1-10 Abandoned Coal Mines are a category tracked separately and the vented, sealed, and flooded mine emissions are totaled in the Exhibit to equal the Abandoned Coal Mines total. While a mine might be designated as sealed they are not sealed from atmospheric leaks. This becomes the most significant CH_4 source from Abandoned Mines. For a more complete discussion of Coal Mining emissions refer to Chapter 7.

Exhibit 1-10 Summary of CH_4 Emissions from Coal Mining Activities in Colorado ($MMTCO_2e$)

	1990	1995	2000	2005	2010
Coal Mining	**4.16**	**3.06**	**4.36**	**5.49**	**6.63**
Abandoned Coal Mines	**0.64**	**0.67**	**0.96**	**1.12**	**0.90**
Vented	**0.04**	**0.03**	**0.10**	**0.07**	**0.05**
Sealed	**0.60**	**0.64**	**0.86**	**1.05**	**0.84**
Flooded	**0.01**	**0.00**	**0.01**	**0.01**	**0.00**
Total	**4.81**	**3.73**	**5.32**	**6.61**	**7.54**

Natural Gas and Oil Systems

Methane leaks can occur throughout the natural gas and oil production process. In 1990, methane leaks from natural gas and oil production accounted for 2% of the gross state GHG. This increased to 5% by 2010 due to increased production of oil and natural gas. Exhibit 1-11 summarizes the output from the Natural Gas and Oil Systems module. For a complete description of this sources category refer to Chapter 8, Gas Production.

Exhibit 1-11 Summary of CH_4 Emissions from Oil and Gas Activities in Colorado ($MMTCO_2e$)

	1990	1995	2000	2005	2010
Natural Gas	1.31	1.61	5.5	6.34	9.49
Oil	0.39	0.39	0.28	0.35	0.5
Total*	**1.7**	**2**	**5.78**	**6.69**	**9.99**
*** Modified to account for COGCC well counts**					

As noted above, CDPHE utilized Colorado specific data in calculating CH_4 emissions from the natural gas and oil sector. Specifically, CDPHE used actual well counts from the Colorado Oil and Gas Conservation Commission in running the Natural Gas and Oil Systems Module. This resulted in an approximately 43% increase in emissions from this sector relative to default values in 2010.

Industrial Process

Industrial Process sources accounted for 0.8% of the gross Colorado inventory in 1990. By 2010 the GHG contribution from this sector increases to 3.4% of the Colorado gross inventory, due mainly to growth in cement manufacturing and leakage from Ozone Depleting Substance (ODS) substitute sources. This category is a combination of emissions from cement, lime and soda ash production along with leaking chlorinated hydrofluorocarbons used in a variety of settings as substitute chemicals for hydrocholorofluorocarbons (Freon, etc.). Exhibit 1-12 summarizes the Industrial Processes (IP) emissions associated with a range of GHG sources. These range from the direct carbon dioxide emissions from manufacturing or processing of materials to production and use/release of chlorinated and fluorinated compounds (sulfur hexafluoride, hydrocholoro-fluorocarbons, etc.). The lack of emissions in some categories indicates no defined source values in the national data base for Colorado. For simplicity, these have been removed from Exhibit 1-12. Examination of Chapter 6 results will show more source categories (see note at the bottom of Exhibit 1-12 for a list of categories eliminated from the Exhibit). Due to the extremely high GHG potential for SF6, PFC's, and HFCs, a small amount of emissions has a much greater overall $MTCO_2e$ value than does the actual tonnage of emissions. Cement manufacturing and ozone depleting substances (ODS) account for over 80% of this source category.

Exhibit 1-12 Summary of GHG Emissions from Industrial Processes in Colorado

($MMTCO_2$ e)

Emissions	1990	1995	2000	2005	2010
Carbon Dioxide Emissions					
Cement Manufacture	0.32	0.48	0.55	0.62	0.56
Lime Manufacture	0.00	0.10	0.09	0.30	0.27
Limestone and Dolomite Use	0.00	0.02	0.03	0.03	0.00
Soda Ash	0.04	0.04	0.04	0.04	0.04
Urea Consumption	0.00	0.00	0.00	0.00	0.00
Iron & Steel Production	0.00	0.00	0.75	0.34	0.30
Total Emissions	0.36	0.64	1.47	1.33	1.18
HFC, PFC, and SF_6 Emissions					
ODS Substitutes	0.00	0.44	1.17	1.56	1.87
Semiconductor Manufacturing	0.05	0.09	0.12	0.09	0.10
Electric Power Transmission and Distribution Systems	0.30	0.25	0.19	0.18	0.17
Total Emissions	0.36	0.78	1.47	1.83	2.14
GRAND TOTAL	0.72	1.41	2.94	3.16	3.32

Note: no ammonia , nitric acid, adiptic acid, magnesium, HCFC-22, and aluminum production are shown as sources in Colorado.

Agriculture

Agricultural sources account for approximately 7% of the State inventory and are a combination of emissions from waste material decomposition, soil management, agricultural burning, enteric fermentation (flatulence), and manure management. Exhibit 1-13 summarizes the agricultural source emissions. For a complete description of these source categories refer to Chapter 9. A critical assumption for this category is an inventory of the livestock in the state, so manure production can be estimated and enteric fermentation can be calculated on an animal type basis. See Chapter 9 for a listing of animal populations, emission factors, and calculations for this category.

Exhibit 1-13 Summary of GHG Emissions from Agriculture in Colorado ($MMTCO_2e$ unless otherwise noted)

	1990	1995	2000	2005	2010
Emissions By Category					
Enteric Fermentation	3.873	4.319	4.61	4.522	4.952
Manure Management	0.809	0.986	1.28	1.277	1.385
Agricultural Soil Management	3.454	3.122	3.236	2.965	2.682
Burning of Agricultural Crop Waste	0.012	0.012	0.012	0.011	0.016
Subtotal Emissions	**8.148**	**8.439**	**9.138**	**8.775**	**9.035**
Emissions by Gas ($MMTCH_4$ or $MMTN_2O$)					
Methane					
Enteric Fermentation	0.184	0.206	0.22	0.215	0.236
Manure Management	0.018	0.024	0.034	0.036	0.042
Burning of Agricultural Crop Waste	<0.001	<0.001	<0.001	<0.001	0.001
Total Emissions	**0.203**	**0.23**	**0.254**	**0.251**	**0.278**
Nitrous Oxide					
Manure Management	0.001	0.002	0.002	0.002	0.002
Burning of Agricultural Crop Waste	0.003	0.003	0.003	0.003	0.004
Agricultural Soil Management	3.45	3.12	3.24	2.96	2.68
Subtotal Emissions	**0.013**	**0.012**	**0.012**	**0.011**	**0.01**
Nitrous Oxide Emissions from Agricultural Soil Management (Metric Tons N_2O)					
Direct emissions					
Fertilizers	2,481	2,067	2,240	1,699	1,285
Crop Residues	832	705	683	550	867
N-Fixing Crops	1,361	1,436	1,518	1,211	1,232
Livestock	4,422	4,309	4,442	4,633	3,866
Subtotal Emissions	**9,096**	**8,517**	**8,882**	**8,093**	**7,250**
Indirect emissions					
Fertilizers	348	202	244	180	222
Livestock	468	445	386	437	344
Leaching/Runoff	1,231	909	928	855	837
Fertilizer Runoff/Leached	704	409	493	364	450
Manure Runoff/Leached	526	500	435	491	387
Subtotal Emissions	**2,047**	**1,555**	**1,558**	**1,471**	**1,404**
GRAND TOTAL	**11,143**	**10,072**	**10,440**	**9,564**	**8,653**

Land Use, Land-Use Change, and Forestry

As set forth in Exhibit 1-14, Land use, Land Use Change and Forestry (LULUCF) act as a net sink for carbon in Colorado. According to the SIT model default values, LULUCF is a sink for 7%-13% of the gross emissions for the state between 1990 and 2010. However, because the default values do not include data on emissions from forest fires, Exhibit 1-14 overstates the emission reduction benefits from the LULUCF category. Due to this one notable exception, and to emphasize the lack of data, the null data values and categories have been left in Exhibit 1-14. For a more complete discussion of this issue and potential impacts on the overall inventory consult Chapter 11.

Exhibit 1-14 Summary of GHG Emissions from Land Use, Land Use Change and Forest Emissions and Sequestration in Colorado ($MMTCO_2e$)

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Forest Carbon Flux					
Aboveground Biomass	-2.56	-2.56	-2.85	-2.85	-2.19
Belowground Biomass	-0.47	-0.47	-0.5	-0.5	-0.42
Dead Wood	-2.12	-2.12	-2.22	-2.22	-0.90
Litter	-2.07	-2.07	-2.07	-2.07	-2.07
Soil Organic Carbon	-2.31	-2.31	-2.31	-2.31	-2.31
Total Wood products and landf	-1.61	-0.56	-0.56	-0.56	-0.56
Total Emissions	**-11.13**	**-10.08**	**-10.5**	**-10.5**	**-8.45**
Urea Fertilization					
Total Emissions	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**
Urban Trees					
Total Emissions	**-0.28**	**-0.32**	**-0.35**	**-0.39**	**-0.42**
Landfilled Yard Trimmings					
Grass	-0.03	-0.01	-0.01	-0.01	-0.01
Leaves	-0.13	-0.09	-0.07	-0.05	-0.07
Branches	-0.13	-0.08	-0.06	-0.05	-0.06
Landfilled Food Scraps	-0.03	-0.03	-0.06	-0.06	-0.05
Total Emissions	**-0.32**	**-0.21**	**-0.20**	**-0.17**	**-0.19**
Forest Fires					
CH_4 (see note at bottom)	See note	See note	See note	See note	See note
N_2O (see note at bottom)	See note	See note	See note	See note	See note
N_2O from Settlement Soils					
Total Emissions	**0.07**	**0.06**	**0.06**	**0.06**	**0.04**
GRAND TOTAL	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**

Note: Categories with zero emissions, other than forest fires, were eliminated from this Synthesis Tool Summary Exhibit for space purposes.

Municipal Solid Waste

Municipal solid waste and landfill emissions and sequestration are listed in Exhibit 1-15 and represent about 0.5% of the overall Colorado inventory, which balances sequestration of carbon in landfills against direct emissions of waste combustion and waste degradation.

Exhibit 1-15 Total Emissions from Landfills and Waste Combustion ($MMTCO_2e$)

	1990	1995	2000	2005	2010
CH_4	0.459	0.395	0.818	1.467	2.077
CO_2					
N_2O					
Total	**0.459**	**0.395**	**0.818**	**1.467**	**2.077**
CH_4 Emissions from Landfills ($MMTCO_2E$)					
Potential CH_4	**0.70**	**0.95**	**1.31**	**2.07**	**2.85**
MSW Generation	**0.66**	**0.89**	**1.22**	**1.94**	**2.67**
Industrial Generation	**0.05**	**0.06**	**0.09**	**0.14**	**0.19**
CH_4 Avoided	**-0.19**	**-0.52**	**-0.40**	**-0.44**	**-0.55**
Flare	**-0.16**	**-0.48**	**-0.36**	**-0.44**	**-0.55**
Landfill Gas-to-Energy	**-0.03**	**-0.03**	**-0.04**	**0.00**	**0.00**
Oxidation at MSW Landfills	**0.05**	**0.04**	**0.08**	**0.15**	**0.21**
Oxidation at Industrial Landfills	**0.00**	**0.01**	**0.01**	**0.01**	**0.02**
Total CH_4 Emissions	**0.46**	**0.39**	**0.82**	**1.47**	**2.08**
CO_2 and N_2O Emissions from Waste Combustion ($MMTCO_2e$)					
CO_2					
Plastics	-	-	-	-	-
Synthetic Rubber in MSW	-	-	-	-	-
Synthetic Fibers	-	-	-	-	-
N_2O	**-**	**-**	**-**	**-**	**-**
CH_4	**-**	**-**	**-**	**-**	**-**
Total CO_2, N_2O, CH_4 Emissions	**-**	**-**	**-**	**-**	**-**

Wastewater

Methane and nitrous oxide emissions from wastewater treatment account for less than a half of one percent of the gross Colorado emissions. For a complete discussion of emissions from wastewater treatment consult Chapter 10. The disposal and treatment of municipal and industrial wastewater results in methane emissions from digesters either using aerobic or anaerobic methods. Nitrogen rich organic matter produces nitrous oxide from natural degradation of the materials via several processes. See Exhibit 1-16 below.

Exhibit 1-16 Total Emissions from Wastewater Treatment ($MMTCO_2e$)

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Municipal CH_4	0.22	0.25	0.29	0.31	0.34
Municipal N_2O	0.09	0.11	0.13	0.14	0.15
Industrial CH_4	0.04	0.05	0.05	0.04	0.05
Red Meat	0.04	0.05	0.05	0.04	0.05
Total Emissions	0.35	0.41	0.47	0.5	0.54

Indirect CO_2 from Electricity Consumption

Electrical consumption-based emissions are represented by inventorying electrical use in the State versus total electricity generated. This is distinct from emissions calculated based on electrical production in Colorado. While the consumption based figures may be useful in identifying strategies to reduce CO_2 emissions through reduced energy usage, the total Colorado emissions reflected in the inventory rely solely on emissions from electrical production. Exhibit 1-17 provides the summary from the SIT model. For a more comprehensive discussion concerning indirect CO_2 emissions from electrical consumption refer to Chapter 3.

Exhibit 1-17 Summary of Indirect CO_2 Emissions-Electricity Consumption

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Residential					
Space Heating	1.14	1.31	1.63	0.99	1.11
Air-conditioning	0.68	0.79	0.98	1.92	2.14
Water Heating	0.82	0.94	1.17	1.26	1.4
Refrigeration	1.27	1.47	1.82	1.98	2.21
Other Appliances and Lighting	4.91	5.67	7.03	8.66	9.67
Total	**8.81**	**10.18**	**12.64**	**14.8**	**16.53**
Commercial					
Space Heating	0.63	0.62	0.83	0.86	0.87
Cooling	1.68	1.66	2.21	2.31	2.31
Ventilation	1.47	1.45	1.93	2.02	2.02
Water Heating	0.28	0.28	0.37	0.38	0.38
Lighting	5.03	4.99	6.63	6.92	6.93
Cooking	0.07	0.07	0.09	0.1	0.1
Refrigeration	1.19	1.18	1.57	1.63	1.64
Office Equipment	0.42	0.42	0.55	0.58	0.58
Computers	0.63	0.62	0.83	0.86	0.87
Other	1.61	1.59	2.12	2.21	2.21
Total	**12.99**	**12.88**	**17.14**	**17.87**	**17.89**
Industrial					
Indirect Uses-Boiler Fuel	0.01	0.01	0.01	0.01	0.17
Conventional Boiler Use	0.01	0.01	0.01	0.01	0.17
Direct Uses-Total Process	4.48	6.59	6.76	8.19	10.98
Process Heating	0.53	0.79	0.81	0.98	1.32
Process Cooling and Refrigeration	0.39	0.58	0.59	0.72	0.98
Machine Drive	2.98	4.39	4.51	5.46	7.39
Electro-Chemical Processes	0.53	0.79	0.81	0.98	0.97
Other Process Use	0.03	0.05	0.05	0.06	0.33
Direct Uses-Total Non-process	1.16	1.71	1.76	2.13	2.55
Facility HVAC	0.6	0.88	0.91	1.1	1.27
Facility Lighting	0.41	0.61	0.63	0.76	0.89
Other Facility Support	0.14	0.2	0.21	0.25	0.31
Onsite Transportation	0	0.01	0.01	0.01	0.02
Other Nonprocess Use	0.01	0.01	0.01	0.01	0.06
Other	0.29	0.42	0.44	0.53	0.15
Total	**5.93**	**8.74**	**8.97**	**10.85**	**13.85**
Transportation					
Light Rail		0	0.01	0.02	0.04
Total		**0**	**0.01**	**0.02**	**0.04**
TOTAL	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**
Residential	8.81	10.18	12.64	14.8	16.53
Commercial	12.99	12.88	17.14	17.87	17.89
Industrial	5.93	8.74	8.97	10.85	13.85
Transportation		0	0.01	0.02	0.04

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Chapter 2 – Projection Tool

Background

Projection of emissions to 2030 is an important element of this GHG inventory. Emissions from 1990-2010 establish the baseline for forecasting future emissions, which are based on Colorado's historical emissions and national projections. These projections help provide a basis for policy makers to assess future trends. They also help to determine whether strategies should be pursued for further assessment to potentially alter these trends. The SIT Model Projection Tool provides the projections and forecasts. While these projections are useful for looking at trends over the long term, there are some significant uncertainties and limitations. Specifically, the model does not allow modifications beyond the default in order to alter projections to 2020 and 2030 based on state specific data. Accordingly, the projections may not include significant policy changes that are scheduled to take effect after 2010. For example, for both the electricity and oil and gas production sectors, Colorado has adopted emission control strategies that go beyond what is considered in the model.

Due to the limitations with the Projection tool, and the failure to account for recently enacted GHG reduction strategies, definitive conclusions about the trend in GHG emissions in Colorado during the next 20 years are not warranted at this time. Instead, in order to build confidence in the overall inventory, it is recommended that a working group composed of stakeholders examine the opportunities for improving our understanding of emissions from specific sectors of the inventory including: electrical power, oil and gas & electricity consumption. This will ensure that the next update to this inventory is as accurate as possible.

State Inventory Tool-Projection Tool

This chapter describes how the projection tool operates. The nature of the tool is more complex than the other modules. Prior to using the projection tool, one must run all the base case SIT modules and produce a summary data Export File for each module. These summary files are used in various ways to construct a continuum of emissions from 1990-2030. While many elements of running the projection tool are similar to the Synthesis Tool, they provide uniquely different outputs. Unlike the Synthesis Tool, where emissions are merely summarized from the Export Files for the individual modules, emissions are actually calculated in the projection tool utilizing growth assumptions that are embedded in the tool.

The first part of the projection tool generates energy consumption projections for all sectors anticipated to directly use fossil fuels. For this inventory, in the default mode, the projection tool generates an energy use profile for the State. The second part generates expected population and gross annual product data, which are used in parts of the projections. The third part projects animal populations, which drive elements of the agricultural projections. The fourth part of the tool utilizes the results from each of the SIT modules to create a long term picture (1990-2030). In some cases the 1990-2010 data is used to create trends for future emissions while in other cases the projection tool only uses 2010historical data to create a baseline for comparison. Each of the elements of the projection tool is described in this chapter.

Projection Tool (projection tool) Details and Results

As with all the SIT modules, this element of the EPA GHG inventory toolbox is a dynamic, macro driven, Excel spreadsheet. There are forty eight sub-sheets, many internally linked to common data bases imported by the user, or preloaded lookup tables, based on national information. The projection tool uses various elements of national and local data to produce future emissions. There is no universal statement that can be made to describe how each part of the projection tool works. Each part of the projection process is described in this Chapter, broken out in the same structure and organization as found in the Synthesis Chapter.

The extent of the information generated is considerable and this Chapter captures only the critical examples and summary information for representative outputs. A complete capture of the data is available with this document on the State GHG Inventory site. Example tables in this Chapter attempt to capture the 1990-2030 five year intervals where available and relevant.

Unlike the individual SIT modules that were updated in February 2013, the projection tool was not updated by the EPA until May 15, 2013. As of the publication of this inventory, the EPA had not published a user's guide for this element of the SIT tool. As a result, more of the process of the workings of the model have been copied from the spreadsheet into this chapter. In the projection tool the EPA provided a description of the assumptions used under each of the sub-sections of the model and these are outlined in this Chapter.

Energy Production is handled in the projection tool in a different approach than the other modules, because it uses a national assessment of energy production and consumption developed by the U.S. Energy Information Administration (EIA). This was based on historical use of energy by region of the country, population, and industry projections. Other assumptions concerning energy efficiency standards adopted at the national level are also considered in the EIA assessment. The projection tool uses the national and regional growth assumptions to apportion energy use and production on a state-by-state basis. This state apportionment is partially accomplished by comparing actual state use up to 2010, compared to regional and national use, and then apportioning future national and regional projections back to the state. At the national level this assumption will be of no consequence since the total national projection will be the sum of the parts. However, at the state level, such things as renewable energy portfolios, trends in energy production at the state level, and state rules to meet clean air or other demands are not taken into account. Doing so would allow Colorado the chance to examine a more tailor made inventory in the future to indicate what impact state decisions may have on future emissions.

State Inventory Tool-Synthesis Module and its Relationship to the 2030 Projected GHG Emissions

The Synthesis Tool and the projection tool utilize the same export files from the SIT modules. In some cases the summary of emissions are presented in exactly the same manner in both tools and a continuum can be displayed from 1990-2030. In other cases the Synthesis Tool provides a comprehensive summary of 1990-2010 outputs from the SIT model runs in a different structure, or detail, than does the projection tool.

The Synthesis Tool does not link to, or influence the projection tool. However, the format of the condensed data tables often serves as a convenient way of displaying projected emissions. In this inventory selected data tables from the Synthesis Tool were used to construct the 1990-2030 comprehensive data summary where the projection tool failed to produce such a table. In other cases, discontinuity between the projection tool, Synthesis Tool, and SIT module formats of outputs were sufficiently different, requiring a data table structure to be developed combining outputs from various parts of the modules. From a quality assurance perspective, an attempt has been made to ensure all data tables in this projection tool are consistent with information provided in the individual module chapters and the Synthesis Tool. In most cases this is easily done since the bases for both the Synthesis Tool and projection tool are the individual module Export Files.

Tools to Create Projections to 2030

There are two SIT tools used for developing the GHG inventory projections to 2030. These tools provide yearly estimates of energy use and GHG emissions by major source sector from 2010 through 2030. We ran the model using the projection tool, as outlined in number 1 below.

The two major tools are:

1. Greenhouse Gas Estimates, 1990-2030 Inventory Tool (hereafter called the Projection Tool or projection tool).
2. Energy Consumption Projection 1 2012.xls State Inventory Tool (ECPSIT). This module projects State energy consumption from 2011 through 2030. The projection tool notes if one is using all default information the second tool generates identical data and it is unnecessary to run the Energy Consumption Projections tool. However, if one opts to substitute

State specific data it must be done in this module first before running the second element of the projection tool.

The ECPSIT includes projected use of fossil fuel in the following categories:

- Transportation
- Residential
- Commercial
- Industrial
- Electrical generation

Exhibit 2-1 Projection Tool Master Data Tables

Sector	Description
Energy consumption-2011-2030	Residential, Commercial, Industrial, Transportation, and Electric Power fossil fuel consumption projections based on State 2010 data with national trend predictions allocated to State The *EIA Annual Energy Outlook 2012* report apportions National fossil fuel use to Residential, Commercial, Industrial, Transportation and Electrical Generation (RCITEG) categories. Over 60 subcategories show how fossil fuel is used (e.g. within transportation diesel fuel, aircraft fuel, motor gasoline, etc. are all defined with some amount of fuel use). National fuel uses are apportioned to nine sub-regions of the U.S. The Rocky Mountain Regional Projections for all fossil fuel use covers Colorado. State 2010 'actual' data compared to Rocky Mt. Regional establishes ratios of 2010 Colorado to Regional energy use. This allocation table is applied to 2011-2030 National projected figures to produce state specific energy use by fuel type and source.
Population and Production-1990-2030	Population and gross state product by year based on national trends apportioned to the state State population from U.S. Census data for 1990-2010 is combined with U.S. Census Bureau *Current Population Reports 1995-2030.* Interpolation between five year segments fills in gaps. Used linear projection of 1990-2010 to project GSP. Population drives waste and wastewater projections.
Animal population-2001-2030	Animal populations for cattle, swine, poultry, and other (sheep, goats, horses) based on State 2010 data and national trend projections allocated on a percentage basis. USDA 2001-2010 NASS data base and USDA national cow projection 2010-2014 data is extrapolated to 2030. Colorado 2010 cattle population ratio to national data is applied and that ratio is used for all future years. Most other animal populations use similar national data bases, applying a ratio of 2010 Colorado data to national data. Re-allocating national projections back to Colorado is based on those ratios.

*RCITEG-Fossil fuel use for Residential, Commercial, Industrial, Transportation, Electrical generation by fuel type in BBtu.

Summary of Projected Gas Emissions

Emissions by Gas

After the projection tool is run, the model produces summaries of the emissions in several different ways. The model allows you to look at emissions by gas and by source. It also apportions emissions by population and by gross state product. The projection tool summarizes past and projected emissions. This allows for a quick review of the grand picture, leaving the details to be gleaned from the individual modules. Exhibit 2-2 provides a breakdown by gas for Colorado showing 1990 through 2030 emissions in five year increments from 1990 to 2010 and ten year increments to 2030. For more details on interim years consult the sub-sections of this chapter or the summary SIT module data file posted on the State GHG Emission Inventory web site.

Exhibit 2-2 Summary of Historical and Projected Colorado Emissions by Gas

(in $MMTCO_2e$)

	1990	1995	2000	2005	2010	2020	2030
CO_2							
CO_2 from Fossil Fuel Combustion							
Residential	5.33	6.15	6.88	7.61	7.91	7.86	8.22
Commercial	3.98	4.04	3.79	4.09	4.19	4.6	4.75
Industrial	5.60	7.58	9.17	12.69	14.59	14.27	16.09
Transportation	19.15	22.41	25.69	29.9	29.94	32.6	33.37
ElectricPower	31.27	32.5	38.64	40.1	39.35	37.05	37.35
Sub Total Emissions	**65.33**	**72.68**	**84.17**	**94.38**	**95.99**	**96.44**	**99.78**
Industrial Processes	0.36	0.64	1.47	1.33	1.44	1.64	2.05
Waste Combustion and Landfills	0.11	0.16	0.17	0.20	0.20	0.26	0.30
Total Emissions	**65.8**	**73.48**	**85.81**	**95.91**	**97.63**	**98.34**	**102.13**
CH_4							
Stationary Combustion	0.08	0.08	0.09	0.09	0.09	0.04	0.04
Mobile Combustion	0.09	0.1	0.08	0.06	0.04	0.03	0.03
Coal Mining & Abandoned Mines	4.81	3.73	5.32	6.61	7.54	5.96	6.6
Natural Gas and Oil Systems*	1.91	2.07	5.82	6.74	10.05	13.01	16.90
Enteric Fermentation	3.87	4.32	4.61	4.52	4.95	5.33	4.64
Manure Management	0.38	0.51	0.71	0.75	0.87	0.75	0.77
Rice Cultivation	-	-	-	-	-	-	-
Burning of Agricultural Crop Waste	0.009	0.009	0.009	0.009	0.012	0.004	0.004
Waste Combustion and Landfills	0.61	0.53	0.94	1.58	2.19	2.83	3.18
Wastewater	0.26	0.3	0.35	0.36	0.39	0.46	0.53
Total Emissions	**12.02**	**11.65**	**17.93**	**20.72**	**26.13**	**28.41**	**32.69**
N_2O							
Stationary Combustion	0.17	0.18	0.21	0.21	0.21	0.19	0.19
Mobile Combustion	0.87	1.22	1.26	0.92	0.48	0.33	0.31
Industrial Processes	-	-	-	-	-	-	-
Manure Management	0.43	0.48	0.57	0.53	0.51	0.53	0.48
Agricultural Soil Management	3.45	3.12	3.24	2.96	2.68	2.63	2.35
Burning of Agricultural Crop Waste	0.003	0.003	0.003	0.003	0.004	0.002	0.002
Waste Combustion and Landfills	0.01	0.01	0.01	0.01	0.01	0.01	0
Wastewater	0.09	0.11	0.13	0.14	0.15	0.18	0.22
Total Emissions	**5.02**	**5.12**	**5.42**	**4.77**	**4.04**	**3.87**	**3.55**
HFC, PFC, and SF_6							
Industrial Processes	0.72	0.77	1.47	1.83	2.14	3.25	4.23
GRAND TOTAL	**83.56**	**91.02**	**110.63**	**123.23**	**129.95**	**133.88**	**142.61**
Electricity Consumption Emissions (CO_2e)	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**	**62.12**	**70.04**
*** Modified to account for COGCC well counts**							

Exhibit 2-3 provides a graphic summary from the projection tool, based on the data in Exhibit 2-2, showing the majority of Colorado's increase in projected GHG emissions for 2030 is due to changes in *carbon dioxide.* Carbon dioxide from fossil fuel combustion represents over 70% of the 2030 gross inventory and it represents the largest amount of growth in the inventory. For all years, fossil fuel combustion is the *dominant source* of CO_2 emissions in Colorado.

Exhibit 2-3 Trend in Historical and Projected Colorado GHG Emission by Gas

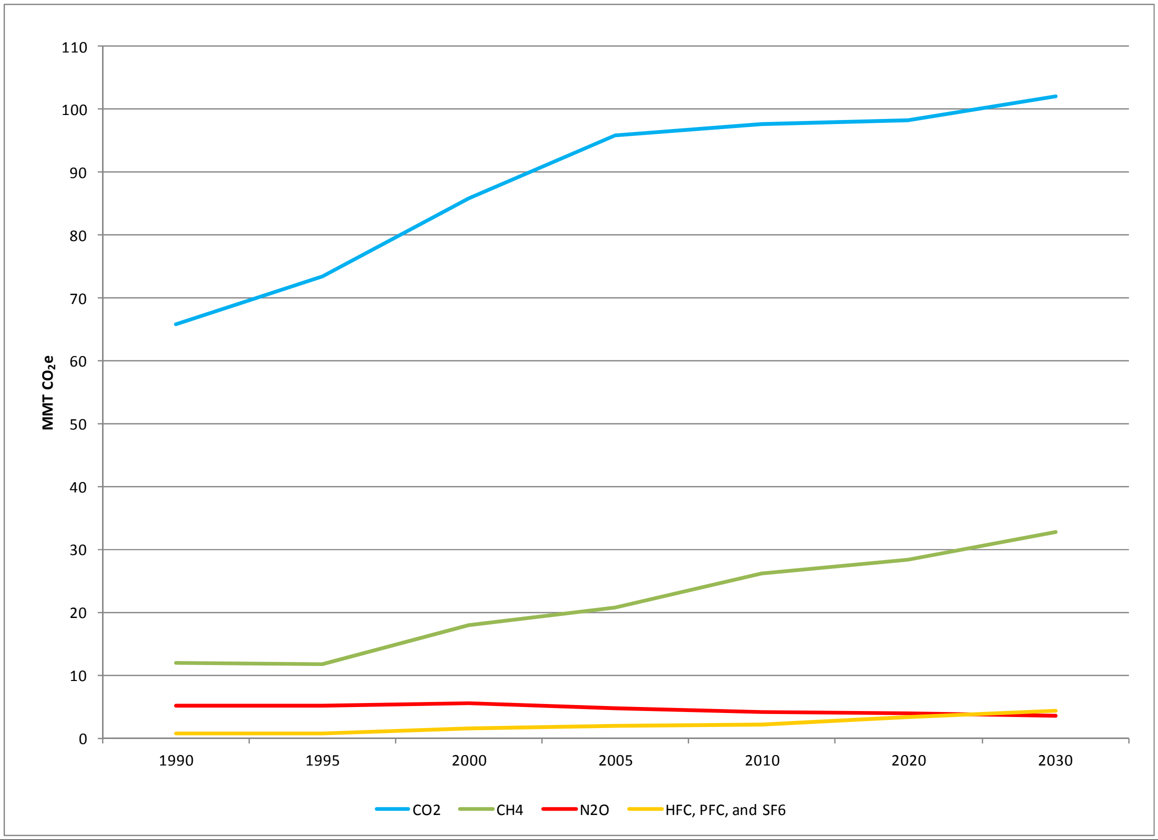
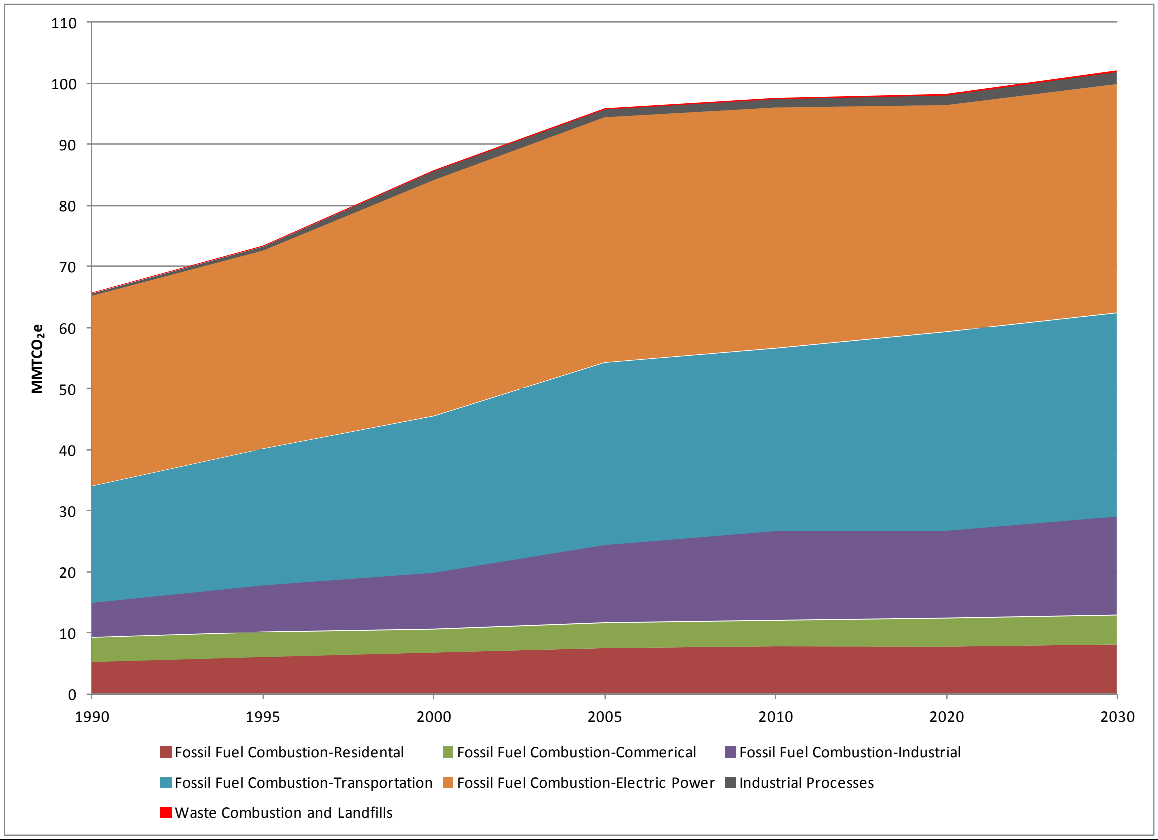


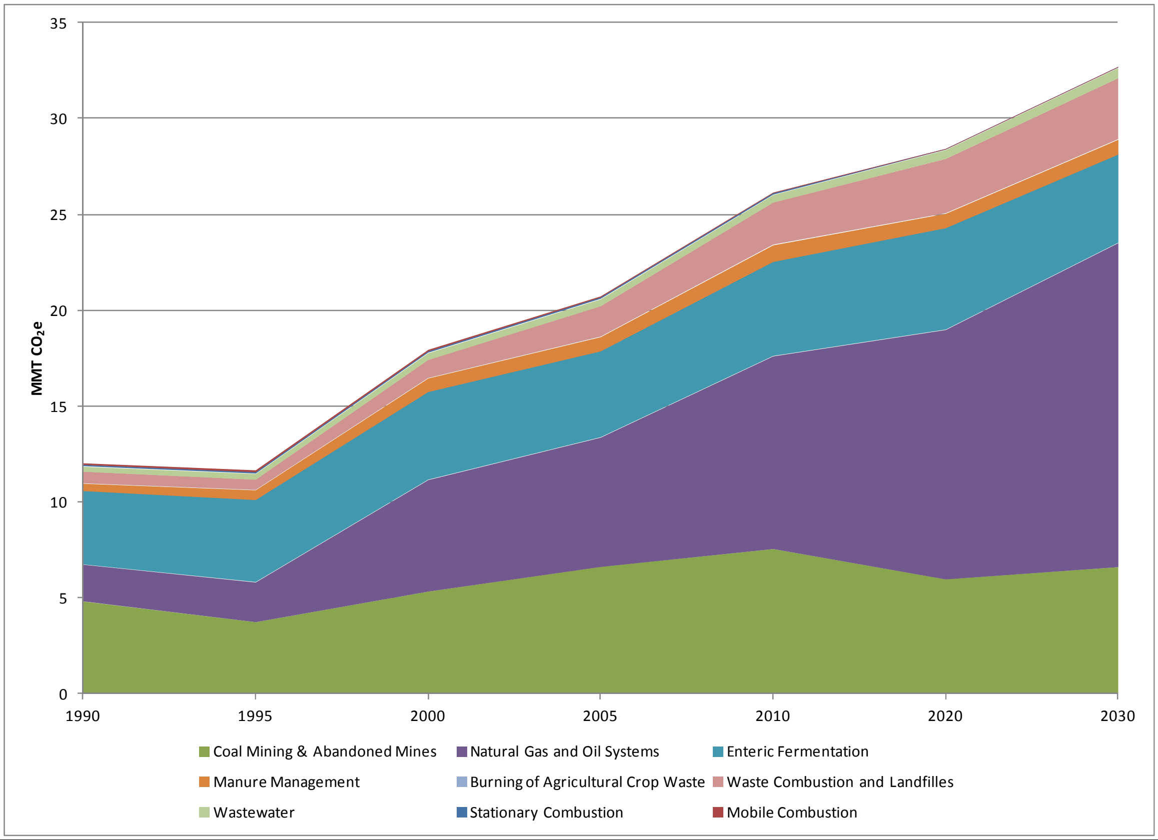
Exhibit 2-4 provides a visual representation of the trend and relative contribution from major CO_2 source categories.

Exhibit 2-4 Trend in Colorado Emissions Carbon Dioxide by Source Category



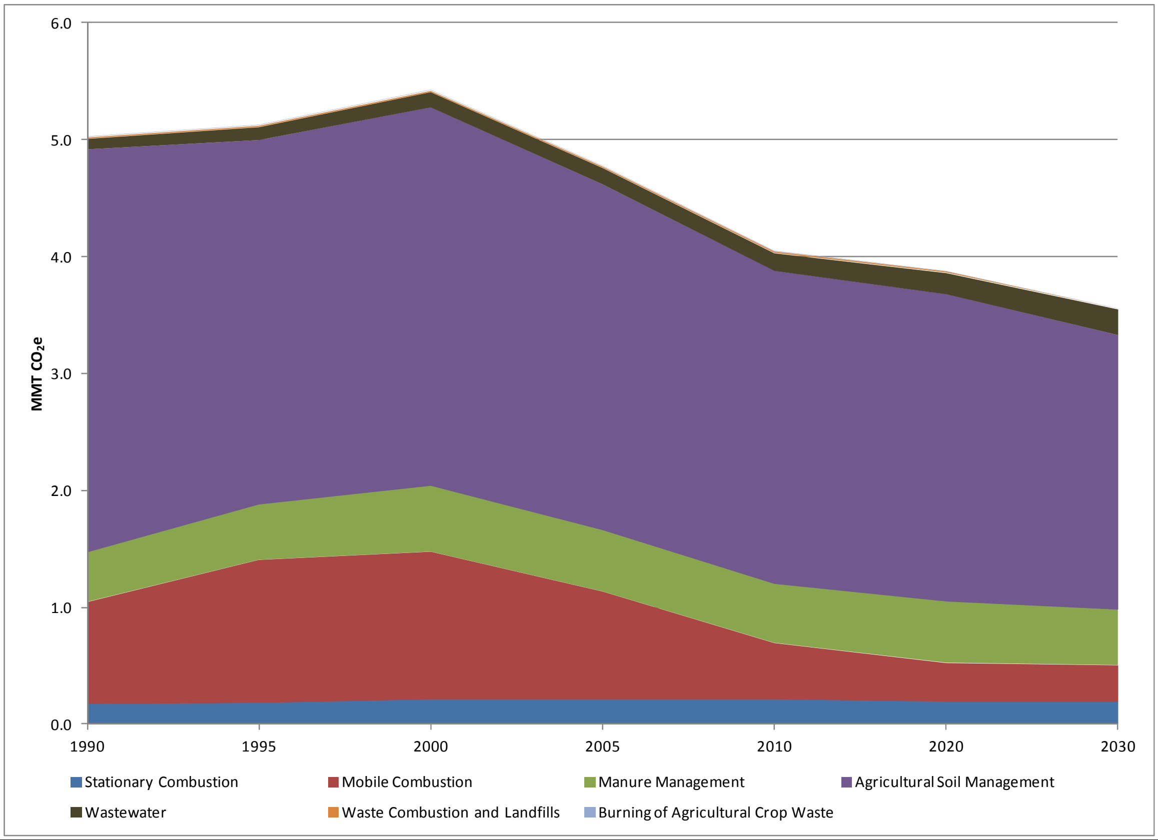
Methane emissions are the second largest GHG category, representing 23% of the 2030 projected inventory. Over half of the methane emissions come from coal mining, natural gas, and oil systems. The remaining categories of methane emissions are enteric fermentation and waste management. Exhibit 2-5 provides a visual representation of the trend and relative contribution from major methane source categories.

Exhibit 2-5 Trend in Colorado Methane Emissions by Source Category



The third largest GHG gas in Colorado is nitrous oxide, most of which comes from agricultural soil management related to fertilizer use, whether from artificial fertilizer or manure management. Exhibit 2-6 depicts the trend in Colorado projected N_2O emissions, which are the only major gaseous source to show a decline in expected emissions from 1990 to 2030. For further details on predicted nitrous oxide emissions refer to the discussions in the sub-sections of this chapter. Since N_2O is produced from both combustion processes and agriculture practices, discussions of N_2O emissions are found in several areas of the inventory.

Exhibit 2-6 Trend in Colorado Nitrous Oxide GHG Emissions by Source Category



Emissions by Source Type

Exhibit 2-7 presents a summary of past and projected emissions by source sector providing some breakdown within each sector. More detailed information is available in the individual sections of this chapter, and the complete data can be found in the data files posted with this inventory.

Exhibit 2-7 Summary of Historical and Projected Colorado Emissions by Source in MMTCO$_2$e

	1990	1995	2000	2005	2010	2020	2030
Energy							
CO_2 from Fossil Fuel Combustion Subtotal	65.33	72.68	84.17	94.38	95.99	96.44	99.78
Residential	5.33	6.15	6.88	7.61	7.91	7.86	8.22
Commercial	3.98	4.04	3.79	4.09	4.19	4.6	4.75
Industrial	5.60	7.58	9.17	12.69	14.59	14.27	16.09
Transportation	19.15	22.41	25.69	29.9	29.94	32.6	33.37
ElectricPower	31.27	32.5	38.64	40.1	39.35	37.05	37.35
Stationary Combustion	0.25	0.26	0.3	0.3	0.3	0.23	0.23
Mobile Combustion	0.96	1.32	1.33	0.98	0.53	0.35	0.34
Coal Mining & Abandoned Mines	4.81	3.73	5.32	6.61	7.54	5.96	6.6
Natural Gas and Oil Systems*	1.91	2.07	5.82	6.74	10.05	13.01	16.90
Total Emissions	**73.26**	**80.06**	**96.94**	**109.01**	**114.41**	115.99	123.85
Industrial Processes							
Total Emissions	**0.72**	**1.41**	**2.94**	**3.16**	**3.58**	**4.89**	**6.28**
Agriculture							
Enteric Fermentation	3.87	4.32	4.61	4.52	4.95	5.33	4.64
Manure Management	0.81	0.99	1.28	1.28	1.38	1.28	1.25
Rice Cultivation	-	-	-	-	-	-	-
Agricultural Soil Management	3.45	3.12	3.24	2.96	2.68	2.63	2.35
Burning of Agricultural Crop Waste	0.01	0.01	0.01	0.01	0.02	0.01	0.01
Total Emissions	**8.14**	**8.44**	**9.14**	**8.77**	**9.04**	**9.24**	**8.25**
Waste							
Municipal Solid Waste	0.46	0.39	0.82	1.47	2.08	3.08	3.46
Wastewater	0.35	0.41	0.47	0.50	0.54	0.65	0.74
Total Emissions	**1.07**	**1.1**	**1.59**	**2.27**	**2.93**	**3.73**	**4.21**
GRAND TOTAL	**83.19**	**91.01**	**110.61**	**123.21**	**129.96**	**133.85**	**142.59**
Electricity Consumption Emissions	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**	**62.12**	**70.04**

*** Modified to account for COGCC well counts**

Exhibit 2-8 presents the trend in GHG emissions by sector in Colorado from 1990-2030. It also provides a visual representation of how much three sectors electric power, transportation, and residential, commercial and industrial fuel use, dominates the GHG inventory. For a more comprehensive discussion of the assumptions used to make these projections, consult the sub-sections of this chapter.

Exhibit 2-8 Summary of Colorado GHG Emissions By Emission Sector SIT Model Runs 1990-2030

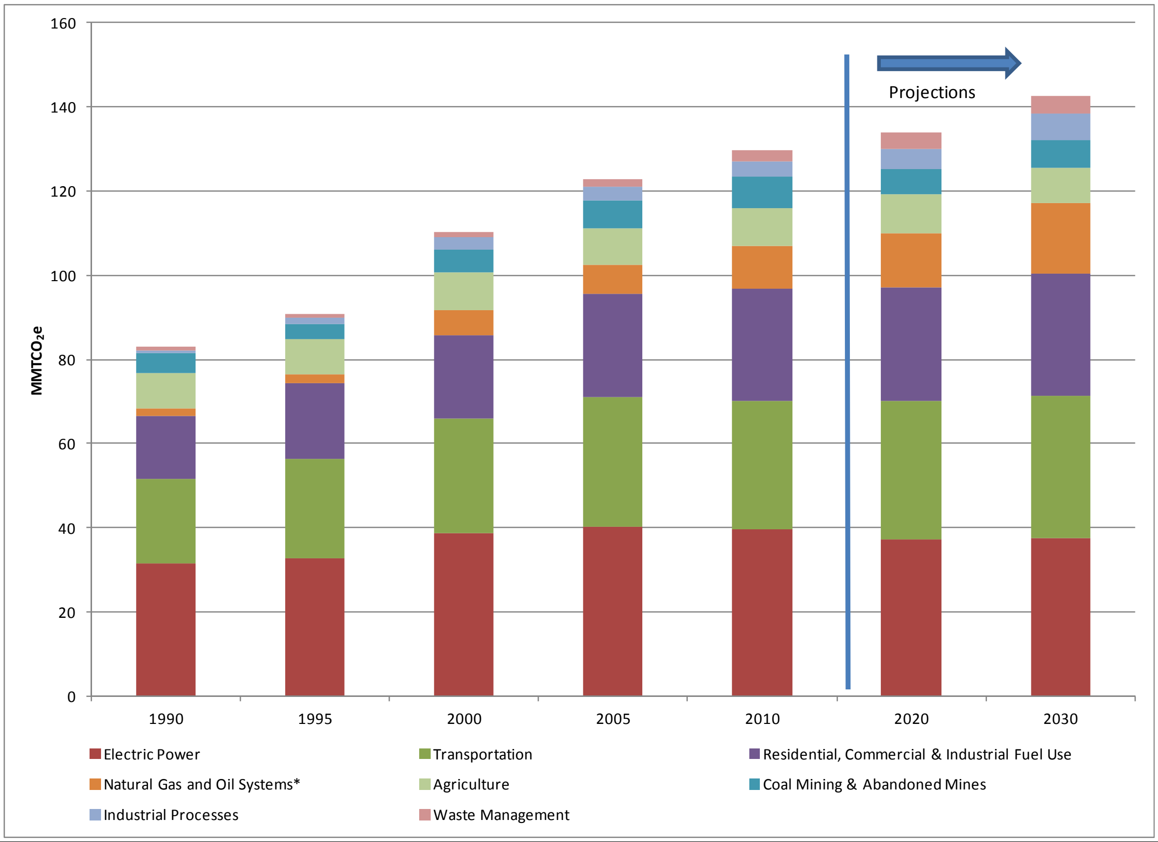


Exhibit 2-9 shows the breakdown of the graphic in Exhibit 29 above.

Exhibit 2-9 Summary Table of Colorado GHG Emissions By Emission Sector SIT Model Runs 1990-2030

	1990	1995	2000	2005	2010	2020	2030
Electric Power	31	33	39	40	40	37	38
Transportation	20	24	27	31	30	33	34
Residential, Commercial & Industrial Fuel Use	15	18	20	25	27	27	29
Natural Gas and Oil Systems*	2	2	6	7	10	13	17
Agriculture	8	8	9	9	9	9	8
Coal Mining & Abandoned Mines	5	4	5	7	8	6	7
Industrial Processes	1	1	3	3	4	5	6
Waste Management	1	1	1	2	3	4	4
Grand Total	83	91	110	123	130	134	143
* Modified to account for COGCC well counts							

Emissions are expressed in the SIT projection tool as a function of intensity related to population and gross state product. Such a view helps put growth and the general direction the state is headed into a different perspective.

Exhibit 2-10 provides a summary of GHG Emissions by population and gross state product in Colorado. Due to constraints with the model, this exhibit was not able to be updated with the new Oil and Gas emissions, based on updated well counts.

Exhibit 2-10 Emissions Per Person (in $MTCO_2e$)

	1990	1995	2000	2005	2010	2020	2030
Gross Emissions Intensity	26.74	25.76	25.87	26.59	25.5	24.51	23.45
Emissions Per GSP (Gross State Product) $MTCO_2e$/Million $	1,182.69	883.2	650.86	570.44	506.66	359.8	297.2

Exhibits 2-11 and 2-12 present the total inventory as a function of state population and gross state production. Due to constraints with the model, these exhibits were not able to be updated with the new Oil and Gas emissions, based on updated well counts. On a per capita basis improvements are expected as individuals will produce fewer emissions per person. Partly this is attributed to increased efficiency of automobiles, lighting and appliances as well as decreasing emissions from major sources as coal gives way to natural gas and renewable energy.

Exhibit 2-11 Gross GHG Emissions as a Function of Population (in Million Metric Tons CO_2e)

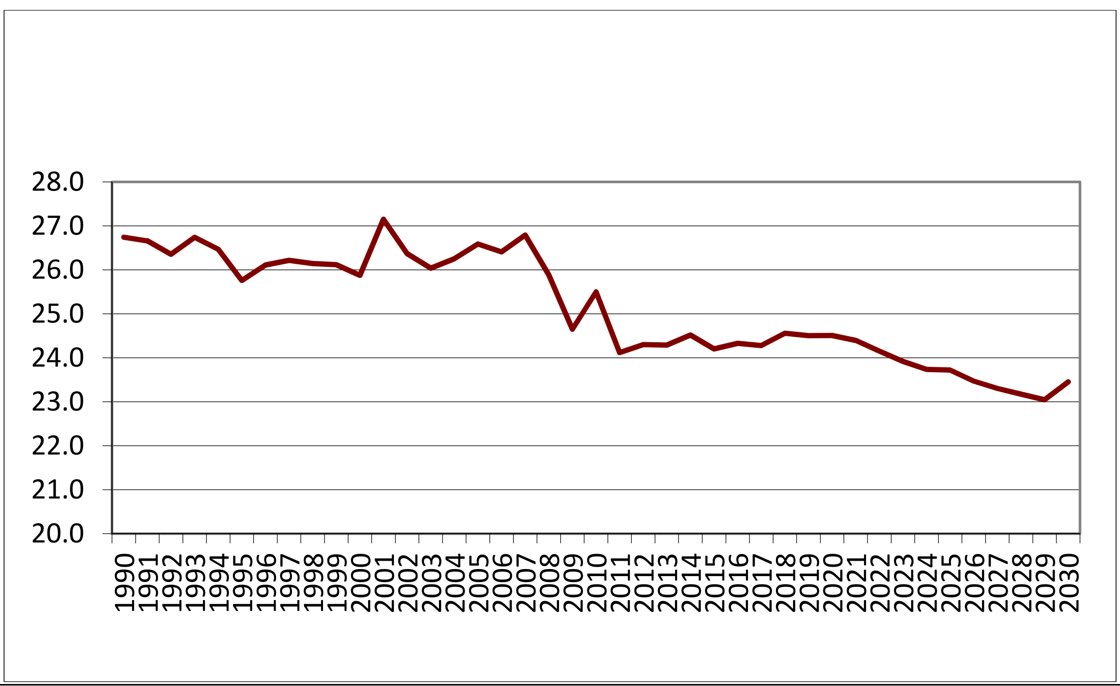
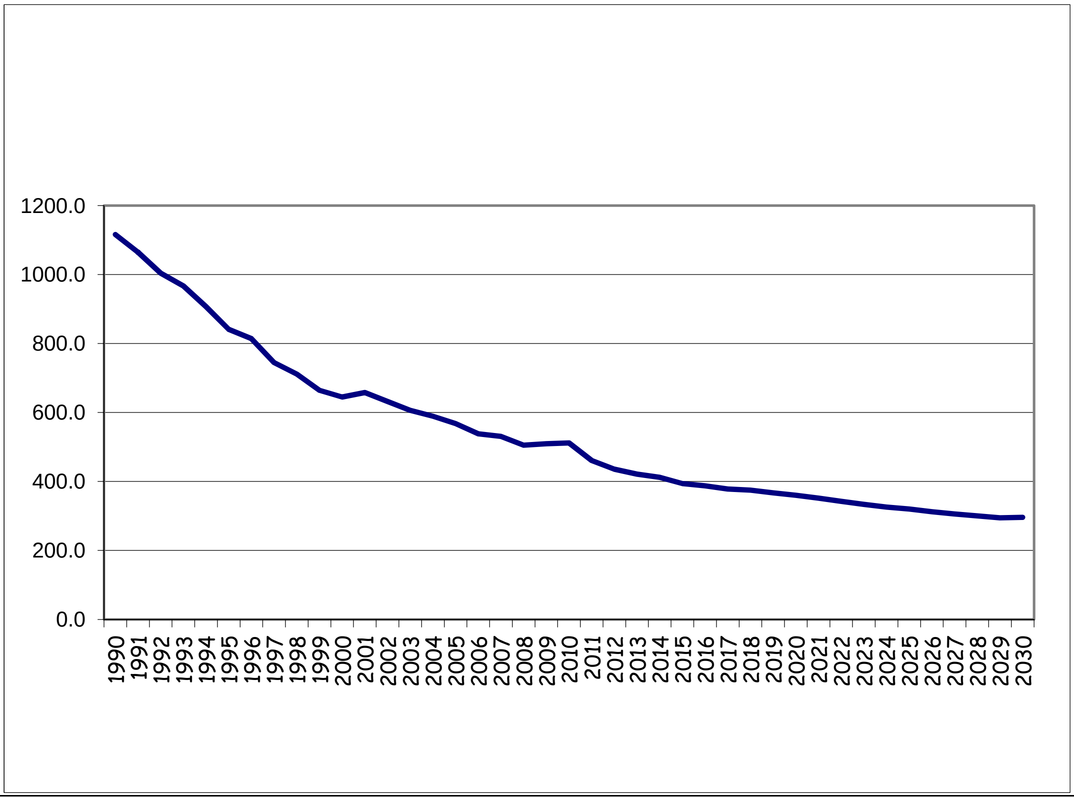


Exhibit 2-12 Gross GHG Emissions as a Function of Gross State Product

(in Million Metric Tons CO_2e)



State and Regional Energy Consumption

Exhibit 2-13 summarizes state fuel consumption in Colorado using default assumptions. These Exhibits are in billions of BTUs and are used in other parts of the projection tool to calculate emissions. Of particular note is the consumption of 'motor gasoline' in the transportation part of the sheet. This, along with other forms of transportation fuel (aviation gasoline, jet fuel, etc.) is combined in the final summary as energy consumption from fossil fuels.

The Energy Consumption projection tool is at the heart of how emissions are calculated and projected to 2030 for fossil fuel related segments of the model. The following three point description explains the logic behind how state level energy consumption tables are generated. As no guidance document exists for the tool at this point, capturing the process is critical to understanding how energy projections, and thus GHG emissions, are calculated in the model.

1. Rocky Mountain Regional energy consumption projections were obtained from the EIA Annual Energy Outlook 2011 Report (AZ, ID, MT, NM, UT, WY, CO)

2. Colorado 2010 use for each energy sector was compared to regional use

3. Projected regional consumption was apportioned to Colorado by using the 2010 Colorado/Regional data applied to 2011-2030.

Exhibit 2-13 provides the five year energy consumption by sector and fuel type.

Exhibit 2-13 Projected Regional Consumption

(BBTU-EIA annual energy outlook through 2030)

	EIA 2010 – Colorado Energy Cons. Estimates BBTU (a)	EIA Mountain Regional Energy Cons. BBTU	Percent Colorado is of EIA Mountain Region	Mountain Regional EIA Annual Energy Outlook BBTU		
	2010	2010	%	2011	2020	2030
Residential						
Coal	662	760	87%	542	497	440
Natural Gas	133,463	376,863	35%	371,190	381,579	397,309
Distillate Fuel	63	2,533	2%	3,061	2,318	1,643
Kerosene	34	170	20%	90	74	63
LPG	12,369	42,127	29%	41,692	41,394	42,268
Electricity	61,765	318,538	19%			
Commercial						
Coal	5,360	6,149	87%	5,038	5,075	5,057
Natural Gas	58,630	235,205	25%	234,190	251,156	262,481
Distillate Fuel	6,046	23,910	25%	20,478	19,678	18,901
Kerosene	26	100	26%	60	77	88
LPG	1,897	10,104	19%	11,177	12,430	13,096
Motor Gasoline	213	2,990	7%	2,723	2,712	3,025
Residual Fuel		160	0%	215	147	134
Electricity	66,866	313,443	21%			
Industrial						
Coking Coal	-	0	0%	-	-	-
Other Coal	7,479	80,563	9%	78,348	81,120	82,669
Natural Gas	208,904	551,895	38%	522,860	598,782	604,376
Distillate Fuel	21,344	149,547	14%	149,959	150,621	144,137
Petrochemical Feed stocks		0	0%	-	-	-
Feed stocks, Naphtha less than 401 F	-	0	0%	-	-	-
Feed stocks, Other Oils greater than 401 F	-	0	0%	-	-	-
LPG	7,947	29,060	27%	23,528	28,072	28,673
Motor Gasoline	3,733	25,765	15%	23,251	25,990	25,280
Residual Fuel	-	6,966	0%	4,167	4,509	4,401
Other Petroleum		0	0%	176,514	163,217	164,476
Asphalt and Road Oil	12,040	76,336	16%	13,292	12,291	12,386
Lubricants	1,188	4,506	26%	3,995	3,694	3,722
Petroleum Coke	3,007	23,845	13%	39,381	36,414	36,695
Still Gas	8,951	65,035	14%	105,536	97,586	98,339
Misc. Petro Products	99	629	16%	14,310	13,232	13,334
Transportation						
Natural Gas	14,759	92,252	16%	95,771	104,117	133,206
Distillate Fuel	87,533	516,076	17%	509,722	685,645	745,148
Jet Fuel, Kerosene	63,841	162,739	39%	215,018	224,955	245,234
LPG	267	1,856	14%	4,177	4,629	5,456
Motor Gasoline	260,782	1,136,858	23%	1,101,345	1,078,932	1,032,002
Residual Fuel	-	0	0%	-	-	-
Other Petroleum		0	0%	11,532	12,253	13,118
Aviation Gasoline	553	4,177	13%	3,772	4,008	4,291
Lubricants	2,005	8,591	23%	7,760	8,245	8,827
Electric Generators						
Coal	369,089	2,152,976	17%	2,036,475	2,155,577	2,169,146
Natural Gas	95,210	640,800	15%	425,270	444,971	456,833
Distillate Fuel	216	2,759	8%	8,184	8,661	8,584

Fuel type is broken into the same five sectors used in the fossil fuel combustion and the electrical generation SIT modules. These are:

- Residential
- Commercial
- Industrial
- Transportation
- Electrical Power

Exhibit 2-13 provides the Colorado and Regional consumption of fuel by sector and fuel type for the Mountain West Region for 2009 (actual data) and the projected Mountain Regional use for each of these sectors and fuel types. An examination of the background content of the model reveals the allocation percentages, and growth rates assumed for Colorado, the Mountain Region, and national expectations all are part of the projection process. It is beyond the scope of this Chapter to capture all the assumptions for growth and allocations for each fuel type and source category.

Renewable Portfolio Standards (RPS) from Investor-owned utilities (30% by 2020) are incorporated into the EIA, and are therefore reflected in the projections. However, the following additional RPS are not incorporated into the EIA, and are not included in the projections:

1. 10% RPS by 2020 from electric cooperatives serving fewer than 100,000 meters;
2. 20% RPS by 2020 from electric cooperatives serving 100,000 or more meters;
3. 10% RPS by 2020 from municipal utilities serving more than 40,000 customers:.

Also, the Clean Air Clean Jobs Act will result in decreases in electric power coal consumption after 2018 due to the retirement and conversion of various coal plants throughout the state. These specific reductions are not captured in this inventory due to the nature of the projections as described above. It is likely that emissions from the Electrical Power sector will be lower in the future as a result of this effort. How these reductions can best be reflected into a future inventory should be further explored.

The recent regulatory proposal of 111(d) may also impact the type of fuel consumed in the state, and this should be considered in future inventories.

Recommendation: To build confidence in the overall inventory, and this sector, it is recommended that a working group composed of stakeholders examine the opportunities for improving our understanding of emissions from the Electricity Sector for the next update to this inventory.

Population and Gross Product History and Projections

Population and gross annual product are used in various elements of the projection tool to apportion national metrics to Colorado. Exhibit 2-14 provides the population and gross state product assumptions used by the projection tool. These originate from several Census Bureau reports and national economic reports.

Population projections are calculated in the projection tool using the data sources and assumptions outlined in Exhibit 2-15 which is extracted from the Data Assumptions sub-sheet of the projection tool. Population in the future is used to drive a number of the projected activity factors or emission calculations. In essence, Colorado's 2010 portion of the national population is used to calculate future Colorado numbers. Future national tables are produced in the Census report and the percent allocation scheme does not account for anticipated regional shifts in migration or gross state product. Included in Exhibit 2-15 is also the annual Gross State Product which is projected by using an apportionment of 1990-2010 tables applied to the national data base.

As part of the stakeholder process, concern was raised about whether the projections from the state demographers office should be used as opposed to the census report. For more information, please refer to the response to comments.

Exhibit 2-14 State Population Assumptions Used in the Projection Tool

	Population (in thousands)	US Population (in thousands)	% of US	State GSP	US Gross State Product and Projections	% of US
1990	3,304	249,464	1.32	$74,701	$5,706,658	1.31
1995	3,738	262,803	1.42	$109,021	$7,309,516	1.49
2000	4,328	282,172	1.53	$172,037	$9,749,103	1.76
2005	4,663	295,561	1.58	$217,329	$12,339,002	1.76
2010	5,029	308,746	1.63	$253,101	$14,644,202	1.73
2015	5,049	322,366	1.57	$310,852	$17,032,495	1.83
2020	5,279	335,805	1.57	$359,590	$19,420,789	1.85
2025	5,523	349,439	1.58	$408,327	$21,809,082	1.87
2030	5,792	363,584	1.59	$457,065	$24,197,375	1.89

Exhibit 2-15 State Population Assumptions Used in the Projection Tool

State Population

State population for 1990-1999 from U.S. Census Bureau, "State Population Estimates: Annual Time Series, July 1, 1990 to July 1, 1999." Available online at: http://eire.census.gov/popest/archives/state/st-99-3.txt
State population for 2000-2010 from U.S. Census Bureau, "Population, Population change and estimated components of population change: April 1 2000 to July 1, 2010." Available online at: http://www.census.gov/popest/data/index.html
State population projections for the years 2005, 2010, 2015, and 2020 were obtained from the U.S. Census Bureau,"Current Population Reports, 1995-2030." Available online at: 2010, 15, 20,25,30 from http://www.census.gov/population/projections/.
The data points for the intervening years were calculated using a linear interpolation.

Livestock Projections

Projections of livestock are calculated by the SIT projection tool using the assumptions outlined in Exhibits 2-16 through 2-19. Livestock projections are based on determining the ratio of Colorado 2010 animal populations to national populations. National projections of cattle and swine populations are based on USDA predictions from 2010 to 2014 and a linear extrapolation is made to 2030. The 2010 Colorado to national ratios are then applied to each future year to predict state head counts.

Poultry, goats, sheep, and horse populations for the future are calculated using a different scheme than for swine and cattle. A multistep process is applied to USDA data from 2001 to 2010 and 1990 to 2010 NASS data. The 1990-2010 NASS information was used to project future national head counts. The percent yearly increase was applied to the Colorado 2010 estimates.

Livestock populations are presented in Exhibit 2-20 and represent historical and projected animal counts. Head counts are used to determine emissions from several of the sub-sheets in the Agricultural projection tool, such as enteric fermentation and manure management. The animal population is used directly for calculating methane and ammonia from waste and animal processing. Five year increments of the emissions are covered in this chapter under the agricultural emissions discussion. For further information about calculating agricultural emissions, consult the discussion in the Agricultural Chapter of this inventory.

Exhibit 2-16 Livestock Population Projection Assumptions For Cattle Used by SIP Projection Tool

Livestock Populations

Cattle:

Dairy Cows and Beef Cows:

Obtained 2001-2010 population values from USDA, NASS, Published Estimates Data Base (http://www.nass.usda.gov/QuickStats/).

Obtained projected national dairy cow and beef cow population data from USDA for 2010-2014. Projected 2015-2030 national estimates using a linear trend based on the 2010-2021 data. Data available online at: USDA (http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192)

Estimated state projections for 2011-2030 by multiplying a year's forecasted national projection by the ratio of a state's 2010 population to the national 2010 population.

Other Cattle:

Obtained 2001-2010 population values from USDA, NASS, Published Estimates Data Base (http://www.nass.usda.gov/QuickStats/).

Obtained national population projections, by other cattle type, from USDA for 2010-2014. Linearly projected data for national 2015-2030 estimates based on the 2010-2014 national data. Data available online at: USDA (http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192)

Estimated state projections for 2011-2014 by multiplying the ratio of 2010 state- and type-specific cattle population to the 2010 national other cattle population times the estimate of total cattle minus dairy cows minus beef cows for the desired year.

Exhibit 2-17 Livestock Population Projection Assumptions For Swine Used by SIP Projection Tool

Swine:

Obtained 2001-2010 population values from USDA, NASS, Published Estimates Data Base (http://www.nass.usda.gov/QuickStats/).

Projected 2011-2030 population estimates based on the following formula:

The ratio of 2010 state and type specific population estimate to the 2010 national, all pigs estimate, times the national projection of all pigs for that year

The national projections for total pigs for 2011-2014 are from USDA; the 2015-2030 projections are forecast from the 2011-2014 estimates, where the 2001-2010 values are from the published NASS estimates (summed by state and type) and the 2011-2014 are the USDA projections. Data available online at: USDA (http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1192)

Exhibit 2-18 Livestock Population Projection Assumptions For Poultry Used by SIP Projection Tool

Poultry (all types):

Obtained 2001-2010 population values from USDA, NASS, Published Estimates Data Base (http://www.nass.usda.gov/QuickStats/).

Projected 2011-2030 population estimates based on the 1990-2010 NASS estimates.

Multiplied the annual rate of change between 1990 and 2010 times the number of years since 2010, and added the product to the 2010 state population.

If this calculation resulted in a projection less than the threshold (10% of the 2010 state value), then the estimate was set equal to the threshold for that year.

Exhibit 2-19 Livestock Population Projection Assumptions For Goats, Horses, and Sheep Used by SIP Projection Tool

Other:

Goats and Horses:

Obtained state population values for goats and horses in 2001-2010 from USDA, NASS, Published Estimates Data Base (http://www.nass.usda.gov/QuickStats/).

Projected 2011-2030 population estimates based on the 1990-2010 NASS estimates.

Multiplied the annual rate of change between 1990 and 2010 times the number of years since 2010, and added the product to the 2010 state population.

If this calculation resulted in a projection less than the threshold (10% of the 2010 state value), then the estimate was set equal to the threshold for that year.

Sheep:

Obtained state population values by state for 2001-2010 from USDA, NASS, Published Estimates Data Base (http://www.nass.usda.gov/QuickStats/).

Projected 2011-2030 population estimates linearly based on the 1990-2010 total sheep published estimates from NASS. Adjusted these projections by multiplying by the percentage of sheep on feed or not on feed (as compared to total sheep) in the year 2010.

Note: projected values were not allowed to dip below a threshold value of 10% of the year 2010 value. If the projection as calculated above resulted in a value below this threshold, the estimate was set equal to the threshold.

Exhibit 2-20 Livestock Population in Colorado 2001-2030 Projections

(All Livestock Populations in Thousands)

	2001	2005	2010	2015	2020	2025	2030
Dairy and Beef Cows							
Dairy Cows	90	101	97	97	96	99	99
Dairy Replacement Heifers	45	50	38	37	38	34	33
Beef Cows	840	639	668	690	730	585	558
Beef Replacement Heifers	140	130	101	99	101	92	90
Heifer Stockers	163	570	643	633	646	587	571
Steer Stockers	1,000	840	861	847	865	786	764
Bulls	50	40	40	39	40	36	35
Calves	255	130	148	146	149	135	132
Feedlot Heifers	486	401	406	400	408	371	360
Feedlot Steer	694	629	568	559	571	518	504
Total Dairy and Beef Cows	**3763**	**3530**	**3570**	**3547**	**3644**	**3243**	**3146**
Swine							
Breeding	175	143	141	149	156	163	170
Market <60lb	334	378	351	371	389	406	424
Market 60-119lb	78	108	92	97	102	107	111
Market 120-179lb	78	79	89	95	99	103	108
Market 180+lb	111	119	131	139	146	152	159
Total Swine	**775**	**825**	**804**	**851**	**891**	**931**	**972**
Poultry							
Hens>1yr	3,557	3,932	3,892	3,836	3,779	3,723	3,666
Pullets	598	656	1,246	1,478	1,710	1,943	2,175
Chickens	55	66	76	86	96	107	117
Broilers	-	-	-	-	-	-	-
Turkeys	1,150	1,186	271	115	115	115	115
Total Poultry	**5360**	**5840**	**5485**	**5515**	**5700**	**5888**	**6073**
Other							
Sheep on Feed	-	-	-	-	-	-	-
Sheep Not on Feed	420	365	165	42	42	42	42
Goats	18	19	19	20	20	21	21
Horses	162	270	238	241	243	246	248
Total Other	**438**	**384**	**184**	**62**	**62**	**63**	**63**

Projection of Emissions by Source Sector

The SIT projection tool utilizes each of the Export Files from the 1990-2010 SIT model analysis to coordinate with, and in selected cases, form the basis for future projections of GHG emissions. The only exception to this is for *Land Use, Land Use Change and Forestry* which is not addressed by the projection tool. Published with this GHG inventory is a copy of the complete output from the projection tool found on the State of Colorado web site. That spreadsheet lists emissions for each year from 2011-2030, along with the historical date from the Export Files. Following is a description from the projection tool for each of the model segments. For specific data outputs beyond those contained within this Chapter, refer to the detailed *projection tool* spreadsheet published with this GHG Inventory. A brief summary description of the emission projections for each sector is found in Exhibit 2-21 below.

Exhibit 2-21 Description of Emission Projections for Each Sector

• Electrical Power: CO_2 fossil fuel combustion-2011-2030: carbon dioxide for RCI, Transportation and Electrical Production based on energy consumption projections and 2010 Colorado data, with adjustments in some categories for carbon storage
• N2O from stationary combustion: N_2O from 2011-2030 based on 2010 Colorado data apportionment with national and regional trends
• CH_4 from stationary combustion: CH_4 from 2011-2030 based on 2010 Colorado data apportionment with national and regional trends
• Mobile combustion: CH_4 and CO_2 from mobile source fuel use based on state 2010 to national data on a VMT and model year basis
• Electricity consumption: indirect emissions of CO_2 not used in overall totals
• Coal mining-2011-2030: CH_4 from coal mining and abandoned mines based on national coal trend data and Colorado 2010 data for mining and assumption that abandoned mines remain constant
• Natural gas and petroleum systems-2011-2030: CH_4 from natural gas and petroleum mining based on national trends applied to state 2010 apportionment
• Industrial processes (IP): CO_2, CH_4, N_2O, HFC, PFC, and SF6 from industrial process sources based on national trends applied to state population projections
• Agriculture: -Enteric fermentation-2011-2030: CH_4 from enteric fermentation using 2010 state to national apportionment, national trends and regional emission factors from the Cattle Enteric Fermentation Model -Manure management-2011-2030: CH_4 and N_2O from manure management based on 2010 animal characteristics in Colorado and state animal population predictions from the animal population projections portion of the model -Rice cultivation (none in Colorado) -Agricultural soils-2011-2030: N_2O from agricultural soils based on 1990-2010 State trend -Agricultural residue burning based on national trends and state 2010 to national ratio
• Solid waste based on state population trends and historical Colorado data and national assumptions concerning landfill emissions
• Wastewater based on national trends apportioned to the state and state population projections.

Projected Emissions from Fossil Fuel Consumption in Colorado

Lacking a guidance document for this element of the GHG inventory, this Chapter provides the process for calculating future emissions. While the projection tool uses the term consumption in the title of the sub-sheet, and in the calculation description in Exhibit 2-22, (extracted from the projection tool documentation), it is clear the base case emissions are from the *Fossil Fuel Combustion* module. This may appear to be a minor detail but when evaluating fossil fuel emissions in the state, the inventory process utilized the fossil fuel combustion module to generate the Colorado profile. Two separate SIT modules address state energy use, one from the generation side of the equation and the other from the consumption side. The consumption view accounts for imported electricity and transmission line losses. The *Fossil Fuel Combustion* module just looks at electricity generated in the state based on coal, oil and gas used in transportation, residential, commercial, and industrial sectors of energy use. Details of how the SIT model produces emissions for future years for fossil fuel combustion are found in Exhibit 2-22. Despite the term **consumption** being used in the discussion, this discussion actually addresses **combustion**.

Exhibit 2-22 Assumptions used by SIT Projection Tool for Fossil Fuel Consumption (EPA 2012)

Fossil Fuel Consumption

Obtained regional energy consumption projections from the Energy Information Administration's (EIA) Annual Energy Outlook 2012. This report is accessible online at: http://www.eia.doe.gov/oiaf/aeo/. Energy consumption by sector (e.g. residential) and source (e.g., motor gasoline) for 9 regions was projected.

Projected regional consumption was disaggregated to state-level estimates by applying the proportion of consumption in 2010 from EIA's State Energy Data 2011 Consumption tables (EIA 2012). This data is available online at http://www.eia.doe.gov/states/_seds.html.

Notes and assumptions about certain fuels:

Transportation motor gasoline does include some ethanol.

Regional consumption estimates of certain fuels in the AEO were disaggregated to their components using the relative consumption of each component in each region in 2010, obtained from the EIA 2012.

- Industrial petrochemical feedstocks were disaggregated to its components 1) feedstocks, naphtha less than 401 F, and 2) feedstocks, other oils greater than 401 F.
- Industrial other petroleum was disaggregated to its components 1) asphalt and road oil, 2) lubricants, 3) petroleum coke, 4) still gas, and 5) misc. petroleum products.
- Transportation other petroleum was disaggregated to its components 1) aviation gasoline, and 2) lubricants.

The AEO did not develop consumption projections for a number of fuels in the following sectors:

- Industrial: crude oil, aviation gasoline blending components, motor gasoline blending components, unfinished oils, kerosene, special naphthas, pentanes plus, waxes.
- Transportation: naphtha-based jet fuel.
- Electric Power: petroleum coke.
- However, consumption (in Btu) of these fuels in 2010 comprises less than 1% of total U.S. consumption.

The EIA has redefined their sectoral definitions, and has included nonutility generators with utility generators in the sector labeled "electric power".

Exhibit 2-23 contains the five year projected emissions from fossil fuel combustion in Colorado. This fossil fuel combustion sub-element of the projection tool allows the user to import the historical emissions from the SIT *Fossil Fuel Combustion* module. Because the projection tool tracks and calculates future emissions summarized in a slightly different set of categories than does the *Fossil Fuel Combustion,* historical SIT tool, it is difficult to make a direct comparison to the Synthesis Tool.

Exhibit 2-23 Projected CO_2 Emissions from Fossil Fuel Combustion in Colorado in $MMTCO_2e$

Sector/Fuel	2015	2020	2025	2030
Residential				
Coal	0.04	0.04	0.04	0.04
Natural Gas	7.12	7.18	7.32	7.47
Distillate Fuel	0.01	0	0	0
Kerosene	0	0	0	0
LPG	0.69	0.69	0.69	0.7
Subtotal Emissions	**7.86**	**7.91**	**8.06**	**8.22**
Commercial				
Coal	0.41	0.41	0.41	0.41
Natural Gas	3.48	3.5	3.56	3.65
Distillate Fuel	0.54	0.53	0.52	0.51
Kerosene	0	0	0	0
LPG	0.15	0.15	0.15	0.15
Motor Gasoline	0.01	0.01	0.02	0.02
Subtotal Emissions	**4.6**	**4.6**	**4.66**	**4.75**
Industrial				
Other Coal	0.33	0.33	0.34	0.34
Natural Gas	11.24	11.74	11.61	11.94
Distillate Fuel	0.76	0.73	0.71	1.35
LPG	0.16	0.17	0.18	0.47
Motor Gasoline	0.28	0.29	0.29	0.28
Asphalt and Road Oi	0.14	0.14	0.14	0.15
Lubricants	0.07	0.07	0.07	0.07
Petroleum Coke	0.42	0.42	0.42	0.43
Still Gas	0.23	0.23	0.24	0.91
Misc. Petro Products	0.15	0.16	0.16	0.16
Subtotal Emissions	**13.76**	**14.27**	**14.14**	**16.09**
Transportation				
Natural Gas	0.8	0.83	0.88	1.07
Distillate Fuel	7.81	8.48	8.91	9.21
Jet Fuel, Kerosene	5.61	5.81	6.08	6.34
LPG	0.04	0.04	0.04	0.05
Motor Gasoline	17.34	17.28	16.77	16.53
Aviation Gasoline	0.02	0.02	0.03	0.03
Lubricants	0.13	0.13	0.14	0.15
Subtotal Emissions	**31.75**	**32.6**	**32.84**	**33.37**
Electric Power				
Coal	29.26	32.57	32.12	32.77
Natural Gas	3.18	3.89	4.13	3.99
Distillate Fuel	0.03	0.04	0.04	0.04
Residual Fuel	0.56	0.56	0.56	0.56
Subtotal Emissions	**33.03**	**37.05**	**36.84**	**37.35**
Grand Total	**91.00**	**96.44**	**96.54**	**99.78**

Exhibit 2-24 provides the 1990-2030 MMTCO_2e combining output from the projection tool and the SIT CO_2 from Fossil Fuel Combustion module.

Exhibit 2-24 Summary of Colorado Historical and Projected CO_2 from Fossil Fuel Combustion Emissions (in MMTCO_2e)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Residential									
Coal	0.02	0.01	0.02	0.02	0.06	0.04	0.04	0.04	0.04
Petroleum	0.42	0.54	0.71	0.82	0.77	0.7	0.69	0.7	0.71
Natural Gas	4.89	5.61	6.16	6.77	7.07	7.12	7.18	7.32	7.47
Subtotal Emissions	**5.33**	**6.15**	**6.88**	**7.61**	**7.91**	**7.86**	**7.91**	**8.06**	**8.22**
Commercial									
Coal	0.1	0.04	0.14	0.25	0.5	0.41	0.41	0.41	0.41
Petroleum	0.36	0.42	0.43	0.45	0.58	0.7	0.69	0.69	0.68
Natural Gas	3.52	3.58	3.22	3.38	3.11	3.48	3.5	3.56	3.65
Subtotal Emissions	**3.98**	**4.04**	**3.79**	**4.09**	**4.19**	**4.6**	**4.6**	**4.66**	**4.75**
Industrial									
Coal	-	0.82	0.42	0.14	0.7	0.33	0.33	0.34	0.34
Petroleum	2.14	2.26	2.71	3.16	3.02	2.2	2.2	2.2	3.81
Natural Gas	3.46	4.5	6.05	9.38	10.87	11.24	11.74	11.61	11.94
Total Emissions	**5.6**	**7.58**	**9.17**	**12.69**	**14.59**	**13.76**	**14.27**	**14.14**	**16.09**
Transportation									
Petroleum	18.66	21.8	25.17	29.16	29.16	30.95	31.77	31.96	32.3
Natural Gas	0.49	0.62	0.52	0.73	0.78	0.8	0.83	0.88	1.07
Subtotal Emissions	**19.15**	**22.41**	**25.69**	**29.9**	**29.94**	**31.75**	**32.6**	**32.84**	**33.37**
Electric Power									
Coal	30.54	31.21	35.01	35	34.29	29.26	32.57	32.12	32.77
Petroleum	0.02	0.02	0.09	0.02	0.02	0.59	0.59	0.59	0.59
Natural Gas	0.71	1.28	3.54	5.08	5.05	3.18	3.89	4.13	3.99
Subtotal Emissions	**31.27**	**32.5**	**38.64**	**40.1**	**39.35**	**33.03**	**37.05**	**36.84**	**37.35**
Coal total	30.66	32.07	35.59	35.42	35.55	30.04	33.35	32.9	33.56
Petroleum total	21.61	25.03	29.1	33.61	33.55	35.14	35.95	36.14	38.1
Natural Gas total	13.06	15.58	19.48	25.35	26.88	25.82	27.13	27.5	28.12
GRAND TOTAL	**65.33**	**72.68**	**84.17**	**94.38**	**95.99**	**91.00**	**96.44**	**96.54**	**99.78**

CH_4 and N_2O from Fossil Fuel Combustion

Fossil fuel combustion produces direct emissions of carbon dioxide from the conversion of the carbon to CO_2. It also produces nitrous oxide, a powerful GHG, from the nitrogen and oxygen in the atmosphere and methane as part of the incomplete combustion of hydrocarbons. Exhibit 2-25, extracted from the SIT projection tool, details how calculation of future CH_4 and N_2O emissions are based on historical Colorado and national data. In essence, energy use projections are multiplied by appropriate emission factors for each energy source. An adjustment is made for non-energy use of each fuel so direct energy related emissions are reflected.

Exhibit 2-25 Assumptions Used by SIT Projection Tool to Calculate Methane and Nitrous Oxide from Stationary Combustion

CH_4 and N_2O Emissions from Stationary Combustion

To calculate CH_4 and N_2O emissions from stationary combustion, energy consumption was multiplied by a fuel-specific emission factor. Emissions factors were provided by IPCC's *2006 Guidelines for National Greenhouse Gas Inventories.* CH_4 and N_2O emissions from stationary consumption in the industrial sector are calculated by first subtracting non-energy consumption multiplied by carbon storage factors from the energy consumption for each fuel type. For industrial fuels, fuel consumption is adjusted to account for non-energy use. Total consumption is multiplied by the national percentage of fuel consumed for non-energy use and the average fuel-specific carbon storage factor, as found in the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2010.*
The proportion of fuels consumed for non-energy purposes in 2010 was applied to projected consumption estimates.

N_2O from Stationary Combustion

Nitrous oxide is emitted from the combustion of any fuel in the presence of air. The oxygen and nitrogen in the air combine under high temperature combustion to emit various forms of nitrogen oxides. Nitrous oxide, a very minor player in terms of nitrogen oxide emissions, is a powerful greenhouse gas. The SIT combustion module for stationary sources provides emissions profiles for a range of combustion sources from 1990 to 2010. The projection tool does not have an accounting for wood burning in the residential, commercial, or industrial segments generating a zero emission profile from 2011-2030. In the 1990-2010 years, wood burning estimates are provided as part of the default emissions profile. In the 1990-2010 data base, wood consumption and emissions are calculated and are a substantial component of the residential N_2O emissions.

Exhibit 2-26 provides five year increments for the 1990-2030 base years and projected years for N_2O from Stationary Combustion in $MMTCO_2e$.

Exhibit 2-26 N_2O Emissions from Stationary Source Combustion ($MMTCO_2e$

Sector/Fuel	1990	1995	2000	2005	2010	2015	2020	2025	2030
Residential									
Coal	0.0001	0.0000	0.0001	0.0001	0.0003	0.000	0.000	0.000	0.000
Natural Gas	0.0026	0.003	0.0032	0.0036	0.0037	0.004	0.004	0.004	0.004
Distillate Fuel	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Kerosene	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG	0.0012	0.0016	0.002	0.0024	0.0023	0.002	0.002	0.002	0.002
Wood	0.0086	0.0085	0.0097	0.008	0.0079	0.000	0.000	0.000	0.000
Subtotal Emissions	**0.0125**	**0.0131**	**0.016**	**0.0141**	**0.0142**	**0.006**	**0.006**	**0.006**	**0.006**
Commercial									
Coal	0.0005	0.0002	0.0007	0.0013	0.0025	0.002	0.002	0.002	0.002
Natural Gas	0.0019	0.0019	0.0017	0.0018	0.0016	0.002	0.002	0.002	0.002
Distillate Fuel	0.0005	0.0008	0.0007	0.0007	0.0011	0.001	0.001	0.001	0.001
Kerosene	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000
LPG	0.0002	0.0003	0.0004	0.0005	0.0004	0.000	0.000	0.000	0.000
Motor Gasoline	0.0003	0.0001	0.0001	0.0000	0.0000	0.000	0.000	0.000	0.000
Residual Fuel	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000
Wood	0	0.0012	0.0016	0.0013	0.0013	0.000	0.000	0.000	0.000
Subtotal Emissions	**0.0034**	**0.0045**	**0.0052**	**0.0056**	**0.0069**	**0.005**	**0.005**	**0.005**	**0.005**
Industrial									
Coking Coal	0	0-000	0-000	0-000	0-000	0-000	0-000	0-000	0-000
Other Coal	0	0.004	0.002	0.001	0.001	0.002	0.002	0.002	0.002
Natural Gas	0.002	0.002	0.003	0.005	0.006	0.006	0.006	0.006	0.007
Distillate Fuel	0.003	0.003	0.004	0.004	0.004	0.000	0.000	0.000	0.000
Petrochemical Feedstocks	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Naphtha less than 401 F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Oils greater than 401	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Motor Gasoline	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Residual Fuel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Petroleum	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Asphalt and Road Oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lubricants	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Petroleum Coke	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
Still Gas	0.001	0.001	0.001	0.002	0.001	0.000	0.000	0.000	0.000
Misc. Petro Products	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Subtotal Emissions	**0.006**	**0.011**	**0.011**	**0.013**	**0.014**	**0.010**	**0.010**	**0.010**	**0.011**
Electric Generators									
Coal	0.149	0.152	0.175	0.175	0.172	0.147	0.163	0.161	0.164
Natural Gas	0.000	0.001	0.002	0.003	0.003	0.002	0.002	0.002	0.002
Distillate Fuel	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Residual Fuel	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Wood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Subtotal Emissions	**0.149**	**0.153**	**0.177**	**0.178**	**0.175**	**0.150**	**0.166**	**0.164**	**0.167**
GRAND TOTAL	**0.1709**	**0.1816**	**0.2092**	**0.2107**	**0.2101**	**0.171**	**0.187**	**0.185**	**0.189**

CH_4 from Stationary Combustion

Combustion of fossil fuels produces trace amounts of the powerful GHG methane (CH_4). While direct CO_2 emissions are calculated in the *Fossil Fuel Combustion* element of the SIT, a separate module is used to generate nitrous oxide and methane emissions from stationary sources of combustion. The projection tool calculates future methane emission based on the scheme previously discussed in the nitrous oxide from stationary source combustion section. The projection tool allows for importing 1990-2010 emissions from the *Stationary Source Combustion module* but it does not import the raw data for a number of the sub-categories, creating issues similar to those outlined in the N_2O discussion. To extract the sub-category $MMTCO_2e$ from distillate fuels, kerosene and LPG, one must go back to the *Stationary Source Combustion module* and extract the data from the sub-sheets. Exhibit 2-27 provides five year increments for the 1990-2030 base years and projected years for methane in $MMTCO_2e$.

Exhibit 2-27 CH_4 Emissions from Stationary Source Combustion (in $MMTCO_2e$)

Sector/Fuel	1990	1995	2000	2005	2010	2015	2020	2025	2030
Residential									
Coal	0.0016	0.0004	0.0012	0.0015	0.0042	0.003	0.003	0.003	0.002
Natural Gas	0.0092	0.0106	0.0116	0.0127	0.0133	0.013	0.014	0.014	0.014
Distillate Fuel	0	0	0.0001	0	0	0	0	0	0
Kerosene	0	0	0	0	0	0	0	0	0
LPG	0.0014	0.0018	0.0023	0.0027	0.0026	0.002	0.002	0.002	0.002
Wood	0.0438	0.043	0.0491	0.0409	0.0401	0	0	0	0
Subtotal Emissions	**0.056**	**0.0558**	**0.0643**	**0.0579**	**0.0602**	**0.019**	**0.019**	**0.019**	**0.019**
Commercial									
Coal	0.0002	0.0001	0.0003	0.0006	0.0011	0.001	0.001	0.001	0.001
Natural Gas	0.0066	0.0067	0.0061	0.0064	0.0058	0.007	0.007	0.007	0.007
Distillate Fuel	0.0005	0.0009	0.0007	0.0008	0.0013	0.002	0.002	0.001	0.001
Kerosene	0	0	0	0	0	0	0	0	0
LPG	0.0002	0.0003	0.0004	0.0005	0.0004	0	0	0.001	0.001
Motor Gasoline	0.0003	0.0001	0.0001	0	0	0	0	0	0
Residual Fuel	0	0	0	0	0	0	0	0	0
Wood	0.0048	0.0059	0.0082	0.0066	0.0067	0	0	0	0
Subtotal Emissions	**0.0127**	**0.014**	**0.0159**	**0.0149**	**0.0154**	**0.01**	**0.01**	**0.01**	**0.01**
Industrial									
Coking Coal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Other Coal	0.000	0.002	0.001	0.000	0.000	0.001	0.001	0.001	0.001
Natural Gas	0.001	0.002	0.002	0.003	0.004	0.004	0.004	0.004	0.004
Distillate Fuel	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Petrochemical Feedstocks	0	0	0	0	0	0	0	0	0
Naphtha less than 401 F	0	0	0	0	0	0	0	0	0
Other Oils greater than 401 F	0	0	0	0	0	0	0	0	0
LPG	0	0	0	0	0	0	0	0	0
Motor Gasoline	0	0	0	0	0	0	0	0	0
Residual Fuel	0	0	0	0	0	0	0	0	0
Other Petroleum	0	0	0	0	0	0	0	0	0
Asphalt and Road Oil	0	0	0	0	0	0	0	0	0
Lubricants	0	0	0	0	0	0	0	0	0
Petroleum Coke	0	0	0	0	0	0	0	0	0
Still Gas	0	0	0	0.001	0.001	0	0	0	0
Misc. Petro Products	0	0	0	0	0	0	0	0	0
Wood	0	0	0	0	0	0	0	0	0
Subtotal Emissions	**0.003**	**0.005**	**0.005**	**0.006**	**0.007**	**0.006**	**0.006**	**0.006**	**0.006**
Electric Generators									
Coal	0.007	0.007	0.008	0.008	0.008	0.007	0.007	0.007	0.007
Natural Gas	0	0	0.001	0.002	0.002	0.001	0.001	0.002	0.002
Distillate Fuel	0	0	0	0	0	0	0	0	0
Residual Fuel	0	0	0	0	0	0	0	0	0
Wood	0	0	0	0	0	0	0	0	0
Subtotal Emissions	**0.007**	**0.007**	**0.009**	**0.01**	**0.01**	**0.008**	**0.009**	**0.009**	**0.009**
GRAND TOTAL	**0.079**	**0.083**	**0.095**	**0.089**	**0.092**	**0.042**	**0.043**	**0.044**	**0.044**

CH_4 and N_2O from Mobile Fossil Fuel Consumption

While the CO_2 direct emissions from mobile sources are calculated based on fuel consumption, an accounting for methane and nitrous oxide is made in the projection tool for CH_4 and N_2O from mobile sources. For a more complete description of this process consult the *Mobile Source Combustion* chapter of this inventory or the *EPA Guidance for Mobile Source Methane and Nitrous Oxide Emissions*. Exhibit 2-28 provides the logic employed to project emissions from 2011 to 2030. Exhibit 2-29 provides the methane 1990-2010 data and projected emissions to 2030 for mobile sources. An obvious drop in methane emissions from 2010 to 2030 shows most prominently in the break from the historical data to the projected case. This is mostly attributed to on-road gasoline vehicles. The decline is attributed to a change in how vehicle fleet mix and age distributions are generated for the projection tool. The reality is, bringing more highly emission controlled vehicles to the road as the aging, older vehicles are phased out, will substantially drop emissions even if more cars are on the road. While the drop in emissions may be partly due to a combination of assumptions in the projection tool, the overall methane contribution in 2010 from all mobile sources, accounting for the higher potency, is inconsequential. The same drop in N_2O emissions, as seen in Exhibit 2-30, is not as evident when looking at the differences between the 1990-2010 data and the breakpoint in 2010 to the projected values. This is partly attributed to the fact that nitrogen oxide controls on automobiles and light duty trucks were already on a sharp decline due to new control technologies on later model vehicles.

Exhibit 2-28 Assumptions Used by SIT Projection Tool to Calculate Methane and Nitrous Oxide from Mobile Source Combustion

CH_4 and N_2O Emissions from Mobile Combustion

National emissions of CH_4 and N_2O from mobile combustion were using the methodology discussed below. The State Inventory Tool was used to determine default emissions by state for 2010. Projections were then apportioned to states based the ratio of state emissions to national emissions in 2010.

Highway

Obtained estimates of vehicles miles traveled (VMT) for the different vehicle categories. These estimates were obtained from:

1990-2010: FHWA's *Highway Statistic,* table VM-1. Available at http://www.fhwa.dot.gov/policyinformation/statistics/2010/.

2011-2030: EIA's *Annual Energy Outlook: With Projections to 2035.* EIA provides projections of energy use by fuel and sector for every five years (used reference case). Extrapolated intermediate years. Used fuel consumption estimates to forecast VMT based on MPG estimates.

Weighted VMT by the representation of vehicle model year in the fleet.

The vehicle age make-up of the national fleet (for each vehicle type) was estimated by ICF from data received from Office of Transportation and Air Quality Data. The proportions of vehicle age do not change from year to year.

The annual VMT by each model year of each vehicle was estimated by ICF from data received from Office of Transportation and Air Quality data.

For each model year for each vehicle type, the percentage that the model year represents of the total fleet was multiplied by the VMT accumulated by that model year and vehicle type divided by the VMT accumulated by that vehicle type by all model years.

These weighted averages are used to calculate the percent of each vehicle type's VMT represented by each model year.

Obtained estimates of control technology representation for each year, by vehicle type. These estimates were obtained from:

1966-1995: Harvey Michaels (EPA OTAQ) in a 1998 memo

1996-2002: Lou Browning (ICF)

2003-2030: Increased percentage represented by more advanced technology by 5 percent each year. If highest technology reached 100 percent, held constant for subsequent years.

Based on representation of control technology in each model year, VMT was distributed among each control technology.

Emission factors obtained from:

IPCC's Revised Guidelines

EPA et al.

LEVs. Tests performed at NVFEL (EPA 1998) - Memo by Harvey Michaels

Tier 0. Smith and Carey (1982), Barton and Simpson (1994), and one car tested at NVFEL (EPA 1998)

Oxidation Catalyst. Smith and Carey (1982), Urban and Garbe (1980)

Non-Catalyst. Prigent and de Soete (1989), Dasch (1992), and Urban and Garbe (1979)

ICF

For each vehicle type, VMT by control technology was multiplied by the appropriate emission factor to obtain emissions of CH_4 and N_2O.

Non-Highway

Fuel consumption on non-highway sources obtained from:

1990-2010 Residual and Distillate Fuel: EIA's *Fuel Oil and Kerosene Sales 2010,* Tables 13, 14, 22, and 24.

1990-2010 Gasoline: FHWA's *Highway Statistics 2010,* table MF-24

1990-2010 Locomotives: *Railroad Facts.*

2010-2030: EIA's *Annual Energy Outlook: With Projections to 2035.* EIA provides projections of energy use by fuel and sector for every five years (used reference case). Extrapolated intermediate years.

For each mode, fuel consumption (in gallons) is multiplied by the mode-specific fuel density to obtain kg of fuel, and then by the mode-specific emission factors for N_2O and CH_4 to obtain emission estimates.

Density estimates obtained from EIA's *Emissions of Greenhouse Gases* (October 1998) and *Annual Energy Review 1996.*

Emission factors from 1996 IPCC Revised Guidelines.

CH_4 from Mobile Sources

Exhibit 2-29 CH_4 Emissions from Mobile Sources in $MMTCO_2e$

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Gasoline Highway									
Passenger Cars	0.053	0.050	0.040	0.028	0.023	0.007	0.007	0.007	0.007
Light-Duty Trucks	0.028	0.034	0.026	0.018	0.007	0.007	0.006	0.006	0.006
Heavy-Duty Vehicles	0.005	0.005	0.003	0.002	0.001	0.000	0.000	0.000	0.000
Motorcycles	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Subtotal Emissions	0.087	0.089	0.069	0.049	0.031	0.014	0.014	0.014	0.014
Diesel Highway									
Passenger Cars	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light-Duty Trucks	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Heavy-Duty Vehicles	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.001	0.001
Subtotal Emissions	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.001	0.001
Alternative Fuel Vehicles									
	0.000	**0.000**	**0.001**	**0.003**	**0.004**	**0.002**	**0.002**	**0.002**	**0.002**
Non-Highway									
Boats	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Locomotives	0.001	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000
Farm Equipment	0.002	0.002	0.002	0.001	0.002	0.002	0.002	0.002	0.002
Construction Equipment	0.001	0.001	0.001	0.002	0.002	0.004	0.004	0.004	0.004
Aircraft	0.002	0.002	0.003	0.004	0.003	0.002	0.002	0.003	0.003
Other*	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.001	0.002
Subtotal Emissions	0.006	0.008	0.008	0.008	0.008	0.009	0.009	0.010	0.011
GRAND TOTAL	0.093	0.098	0.079	0.060	0.044	0.025	0.026	0.027	0.027

* Other includes snowmobiles, four wheelers, jet skis, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

N_2O from Mobile Sources

Exhibit 2-30 N_2O Emissions from Mobile Sources (in $MTCO_2e$)

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Gasoline Highway									
Passenger Cars	0.518	0.627	0.614	0.460	0.287	0.151	0.154	0.156	0.159
Light-Duty Trucks	0.287	0.515	0.550	0.354	0.101	0.130	0.106	0.087	0.071
Heavy-Duty Vehicles	0.013	0.021	0.027	0.024	0.008	0.007	0.007	0.007	0.007
Motorcycles	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Subtotal Emissions	0.818	1.163	1.191	0.838	0.398	0.288	0.267	0.250	0.237
Diesel Highway									
Passenger Cars	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light-Duty Trucks	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Heavy-Duty Vehicles	0.004	0.006	0.007	0.008	0.009	0.006	0.007	0.007	0.008
Subtotal Emissions	0.004	0.006	0.007	0.008	0.010	0.006	0.007	0.008	0.009
Alternative Fuel Vehicles									
	0.003	**0.003**	**0.004**	**0.006**	**0.008**	**0.005**	**0.005**	**0.005**	**0.006**
Non-Highway									
Boats	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Locomotives	0.007	0.010	0.004	0.001	0.006	0.001	0.001	0.001	0.001
Farm Equipment	0.004	0.006	0.005	0.004	0.004	0.020	0.021	0.023	0.024
Construction Equipme	0.003	0.004	0.009	0.010	0.010	0.009	0.010	0.011	0.012
Aircraft	0.024	0.029	0.030	0.048	0.044	0.008	0.009	0.010	0.011
Other*	0.001	0.001	0.004	0.005	0.002	0.008	0.009	0.010	0.011
Subtotal Emissions	0.040	0.051	0.052	0.069	0.068	0.047	0.050	0.054	0.058
GRAND TOTAL	0.866	1.224	1.255	0.921	0.484	0.346	0.329	0.317	0.309

* Other includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Mobile Sources CH_4 and N_2O are combined and presented in Exhibit 2-31 in $MMTCO_2e$. While considerable effort went into attempting to define fleet mix, fuel use, and emissions from a range of vehicles, the overall result does little to help define a major source of emission reductions in the future. Overall this is a good outcome since it puts methane and nitrous oxide emissions from automobiles in a proper perspective.

Exhibit 2-31 Total Emissions from Mobile Sources (in $MTCO_2e$)

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Gasoline Highway									
Passenger Cars	0.571	0.676	0.654	0.488	0.310	0.158	0.161	0.163	0.166
Light-Duty Trucks	0.314	0.549	0.576	0.371	0.108	0.137	0.113	0.093	0.078
Heavy-Duty Vehicles	0.019	0.026	0.030	0.026	0.009	0.007	0.007	0.007	0.007
Motorcycles	0.001	0.001	0.001	0.001	0.002	0.000	0.000	0.000	0.000
Subtotal Emissions	0.905	1.252	1.261	0.866	0.429	0.302	0.281	0.264	0.251
Diesel Highway									
Passenger Cars	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Light-Duty Trucks	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Heavy-Duty Vehicles	0.004	0.006	0.007	0.008	0.010	0.006	0.007	0.008	0.009
Subtotal Emissions	0.005	0.006	0.008	0.009	0.010	0.007	0.008	0.008	0.009
Alternative Fuel Vehicles									
	0.003	**0.004**	**0.006**	**0.009**	**0.013**	**0.006**	**0.007**	**0.007**	**0.008**
Non-Highway									
Boats	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Locomotives	0.008	0.012	0.005	0.002	0.007	0.001	0.001	0.001	0.001
Farm Equipment	0.006	0.008	0.007	0.005	0.006	0.022	0.023	0.024	0.026
Construction Equipme	0.004	0.005	0.010	0.012	0.012	0.013	0.014	0.015	0.016
Aircraft	0.027	0.032	0.033	0.052	0.048	0.010	0.011	0.013	0.014
Other*	0.001	0.001	0.004	0.005	0.003	0.009	0.010	0.011	0.012
Subtotal Emissions	0.046	0.059	0.060	0.077	0.076	0.056	0.060	0.064	0.069
GRAND TOTAL	0.959	1.321	1.334	0.981	0.528	0.371	0.355	0.344	0.337

* Other includes snowmobiles, small gasoline powered utility equipment, heavy-duty gasoline powered utility equipment, and heavy-duty diesel powered utility equipment.

Electricity Consumption/Indirect CO2 Emissions

Indirect emissions of CO2 equivalents are produced in the projection tool related to energy use in the State. In the fossil fuel combustion part of the projection tool, direct emissions from fuel combustion are calculated for the State and were presented earlier. Coal, natural gas, oil and petroleum products that are burned for energy production are characterized in that part of the projection tool. Electricity consumption at the residential, commercial, industrial, and transportation (light rail) level must account for two factors not reflected in direct combustion tables: 1. loss of electricity in transmission and 2.imported electricity into the state show up at the use end but not at the generation end. Regional electrical consumption is apportioned to Colorado (and other states) by using the 2010 consumption ratio and then applying that factor to future regional projections. Exhibit 2-32 provides a more complete description. Projected and historical emissions in MMTCO2e are presented in Exhibit 2-33 which is extracted from the projection tool.

Exhibit 2-32 CO_2e Emissions From Electricity Consumption

CO_2 Eq. Emissions from Electricity Consumption

To calculate CO_2 Eq. emissions from electricity consumption combustion, electricity consumption was multiplied by a state-specific emission factor and transmission loss factor. Emissions factors and transmission factors were derived from eGRID 2012 v1.0 estimates.

Projected regional estimates of electricity consumption through 2030 are from EIA's Annual Energy Outlook. Projected regional consumption was disaggregated to state-level estimates by applying the proportion of electricity consumption in 2010 from EIA's State Energy Data 2010 Consumption tables (EIA 2012). This data is available online at http://www.eia.doe.gov/states/_seds.html.

Several stakeholders noted the disparity in emissions from the Electricity Consumption Sector with the Electricity Consumption Sector. Based on the model, it appears that Colorado will need to import electricity in the future in order to meet its electricity demands. However, this does not appear to be the current understanding of Colorado's energy needs. The Division has reached out to EPA for further explanation, but at this time this issue is still unresolved.

Recommendation: To build confidence in the overall inventory, and this sector, it is recommended that a working group composed of stakeholders & EPA examine the opportunities for improving our understanding of emissions from the Electricity Consumption Sector for the next update to this inventory.

Exhibit 2-33 Historical and Projected Emissions from State Electricity Consumption in Colorado

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Residential	8.81	10.18	12.64	14.8	16.53	19.42	21.22	23.31	25.65
Commercial	12.99	12.88	17.14	17.87	17.89	21.73	23.45	25.09	26.51
Industrial	5.93	8.74	8.97	10.85	13.85	15.98	17.32	17.71	17.56
Transportation	-	0	0.01	0.02	0.04	0.07	0.13	0.22	0.32
TOTAL	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**	**57.2**	**62.12**	**66.34**	**70.04**

Coal Mining

Emissions from coal mining result from exposing buried coal to the atmosphere, whether it is underground or open pit. In underground mines methane emissions are toxic from a chemical perspective and hazardous from an explosion perspective. Venting of methane in active mines is regulated by Occupational Safety & Health Administration (OSHA). Untreated emissions may be released directly to the atmosphere. Abandoned mines continue to emit methane and the more significant ones are reported to a national data base.

Projection of emissions to 2030 is accomplished by using national coal production estimates through 2020 and extrapolation to 2030 is based on the national trend. The 2010 Colorado emissions are compared to the national 2010 data and future years are based on that ratio. Exhibit 2-34 provides a more comprehensive discussion concerning how the projection tool allocates emissions to the future. Exhibit 2-35 summarizes the expected coal mining emissions in $MMTCO_2e$.

Exhibit 2-34 Assumptions Used by SIT Projection Tool to Calculate Methane from Mining

CH_4 Emissions from Coal Mining

Coal Mining

Obtained national coal mining emission projections for 2005, 2010, 2015, and 2020 from Table 1 in the *2003 Draft Addendum to the U.S. Methane Emissions 1990-2020: 2001 Update for Inventories, Projections, and Opportunities for Reductions*.

National coal mining CH_4 emission values for the remaining years between 2011 and 2020 were interpolated; emissions to 2030 were extrapolated based on historical estimates.

Each state's annual share of the national emissions was calculated based on default outputs from the State Inventory Tool. The proportion of national coal mining CH_4 emissions attributed to a state in 2010 was applied to projected national emission estimates to calculate the state's projected emissions.

Abandoned Coal Mines

Future (2011-2020) abandoned coal mining emissions are based on the calculated default emissions by state which assumes that the number of abandoned mines remains constant

Exhibit 2-35 Summary of Colorado CH_4 Emissions from Coal Mining Activities ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Total CH_4 from Coal Mining	**4.81**	**3.73**	**5.32**	**6.61**	**7.54**	**5.94**	**5.96**	**6.15**	**6.61**
Coal Mining	**4.16**	**3.06**	**4.36**	**5.49**	**6.63**	**5.72**	**5.76**	**5.94**	**6.4**
Abandoned Coal Mines	0.64	0.67	0.96	0,12	0.9	0.23	0.21	0.21	0.21
Vented	0.04	0.03	0.1	0.07	0.05	0.05	0.04	0.04	0.04
Sealed	0.6	0.64	0.86	1.05	0.84	0.17	0.16	0.16	0.16
Flooded	0.01	0	0.01	0.01	0	0			

Oil and Gas Production

Default projected emissions from oil and gas production are based on national trend information apportioned to the state based on Colorado's 2010 ratio compared to the national 2010 production. This ratio is used to apportion national emissions estimates from the *Annual Energy Outlook 2012* report. Using the default values in 2010, Colorado was 4.1% of the national production profile. This percentage is arrived at by apportioning the production and consumption data with the assumption being the gas produced in the state is not all used in the state. Exhibit 2-36 provides the logic applied by the projection tool to oil and gas production. The data, with the model run fully in default mode, is presented in Exhibit 2-37.

Exhibit 2-36 Assumptions used by SIT Projection Tool to Calculate Methane from Natural Gas and Oil Systems

CH_4 Emissions from Natural Gas and Oil Systems

Natural Gas Systems

Obtained historical (1990-2010) national emission estimates of CH_4 emissions from natural gas systems from the 1990-2010 U.S. Inventory.

Obtained national projections of CH_4 emissions from natural gas systems for 2005, 2010, 2015, and 2020 from the "*Addendum to the U.S. Methane Emissions 1990-2020: 2001 Update for Inventories, Projections, and Opportunities for Reductions*" Dec. 2001 draft. Interpolated national projections for the non-reported years from 2011-2020; emissions to 2030 were extrapolated based on historical estimates. These emissions were disaggregated by production (40%) and consumption (60%).

Calculated an implied emission factor for each state based on the projected natural gas consumption from 2010-2030 from the Annual Energy Outlook. This implied state emission factor was applied to the consumption emissions, and the remaining production emissions were applied to each state by the state's portion of production in 2010.

Petroleum Systems

Obtained historical (1990-2010) national emission estimates of CH_4 emissions from petroleum systems from the 1990-2010 U.S. Inventory.

Obtained national projections of CH_4 emissions from petroleum systems for 2005, 2010, 2015, and 2020 from the "*Addendum to the U.S. Methane Emissions 1990-2020: 2001 Update for Inventories, Projections, and Opportunities for Reductions*" Dec. 2001 draft. Interpolated national projections for the non-reported years from 2011-2020; emissions to 2030 were extrapolated based on historical estimates.

Calculated state's 2010 percentages of national petroleum production based on data from EIA's Petroleum Supply Annual 2011, Volume 1, Table 14.

Applied this state petroleum percentage to the national estimates and projections of CH_4 from petroleum systems to estimate state-level emissions from 1990-2030.

Exhibit 2-37 Historical and Projected Methane from Oil and Gas Production ($MMTCO_2e$)

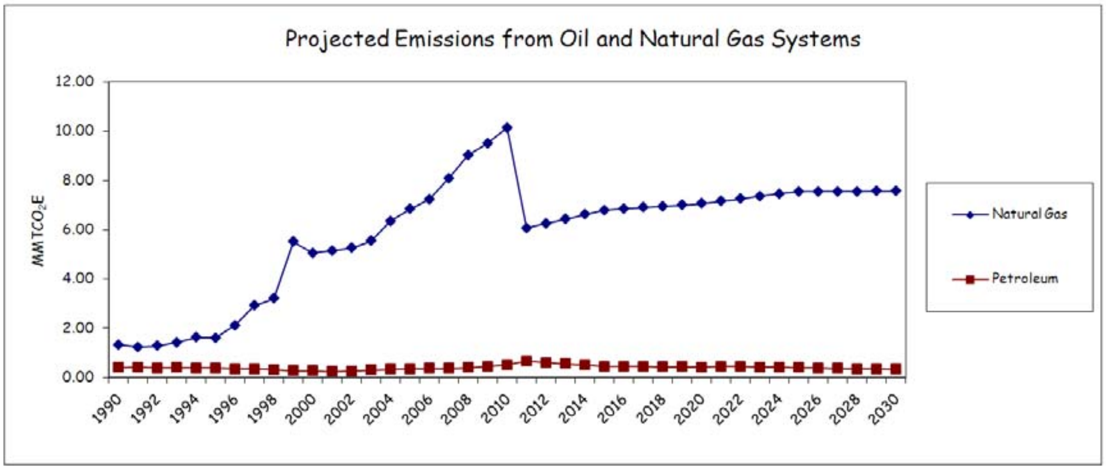
	1990	1995	2000	2005	2010	2020	2030
Natural Gas	1.31	1.61	5.5	6.34	9.49		
Oil	0.39	0.39	0.28	0.35	0.5		
Total	**1.7**	**2**	**5.78**	**6.69**	**9.99**	**13.01***	**16.9***

*Extrapolated from new COGCC well counts

Modifications to the Default Inventory

As Exhibit 2-38 shows, simply changing the well count data in the 1990-2010 base case leaves the projected emissions from 2011-2030 unchanged. See the Oil and Gas Chapter for more description about this issue of updated well counts for the 2010 baseline. Graph does not include Transmission and Distribution Emissions from 1990-2010

Exhibit 2-38 Historical O&G Colorado Emissions Based on New Well Counts and Projection Tool 2011-2030 Emissions.



This ratio of the Colorado 2010 emissions to national emissions is not produced in the model but is a fixed factor locked in the Projection Tool from the Annual Energy Outlook 2012 report. This is applied to all future national emissions to apportion back to Colorado. We are currently unable to run the model with new numbers to obtain an updated projection.

The recently published Projection Tool (projection tool) User's Guide (Guide) addresses non-CO2 and Non-Energy CO2 sources and how the Projection Tool calculates these emissions at the national level (EPA 2013, 16-28). The look-up table, upon which the projection is based, appears to be primarily driven by national natural gas production and storage. Voluntary reductions and projected regulatory controls are considered in the projection but are loosely described. Voluntary reductions built into the Projection Tool lookup table are those reported by industry to the Natural Gas STAR program (EPA 2013, 19). Regulatory controls are those expected from the existing NESHAP requirements. According to the Guide, Colorado and Wyoming Renewable Energy Credits "were built into the base year inventory"(EPA 2013, 20). The projection tool considers the NSPS for VOCs adopted in 2012 which are expected to garner significant reductions in the future. The number of well completions is an influential factor in the projections. Because the active well counts are so divergent in 2010 between the Colorado COGCC data and the default data table in the SIT tool, one might assume this is part of the reason for the significant discontinuity in the data as the projection year 2011 takes over. Exhibit 2-38 uses the modified well count information, lacking the distribution and transmission emissions.

The obvious discontinuity between the 1990-2010 base case and the projected emissions (2011-2030) can be partially rectified both from inside and outside the SIT tools and a better projection can be constructed based on:

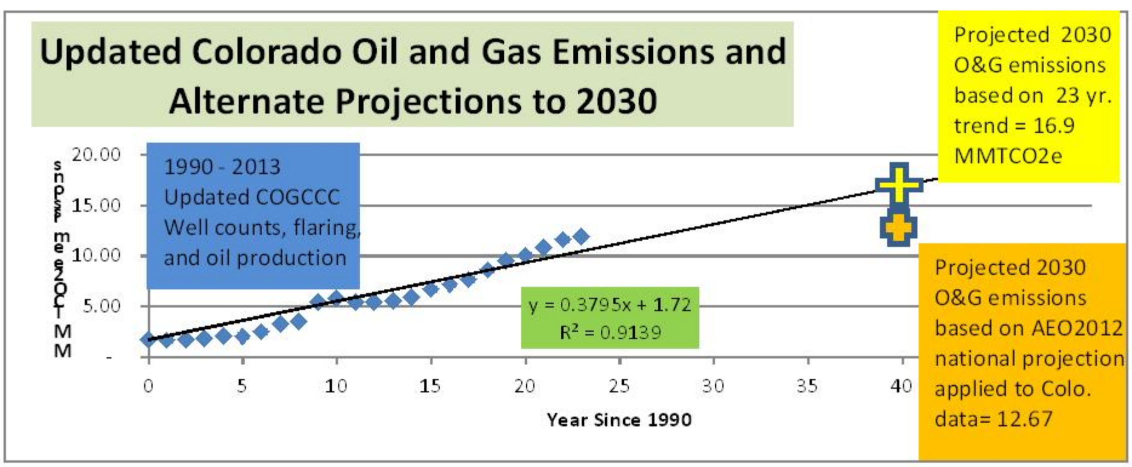
Addition of 2011-2013 updated Colorado data as outline in Exhibit 2-39 to the SIT base case extending the base case to represent 1990-2013

Use of a linear trend projection based on actual Colorado 1990-2013 data to create an 'upper bound' estimate

Use of the national AEO2012 trend projection applied to the updated Colorado data to create a 'lower bound' estimate

Exhibit 2-39 provides two estimates for 2030 based on using new active well count, oil production, and flaring data from the COGCC. There are two trends, one based on extending existing Colorado growth and the other using the national growth applied to the 2010 data. As the EPA projection tool user's guide points out, future emissions are expected to be reduced from current rates due to the combination of voluntary and regulatory controls. It is likely emissions in 2030 will increase if well counts and miles of pipe are added. The rate of increase should be less than that seen between 1990 and 2010 and more likely taking on the slope of increase used in the AEO2012 report. Neither of these are intended to address all the concerns about projections of Colorado oil and gas data to 2030 but each provides a sense of growth in emissions from this industry with a reasonable expectation for curtailed emissions from sources while accounting for increased production.

Exhibit 2-39 Alternate view of the data presented, applying a linear regression to the 1990-2013 data.



Recommendation

Clearly a more descriptive base case and projection to 2030 could be constructed using improved details about the overall nature of the Oil and Gas development and distribution network. Whether that projection would produce a picture different than what is in the current inventory, or the improved picture based on updated well counts and other factors, remains to be seen. Based on estimates of increased well count, increased emissions would result if the SIT emission factors are reasonably accurate.

To build confidence in the overall inventory, and this sector, it is recommended that a working group composed of stakeholders examine the opportunities for improving our understanding of emissions from Oil and Gas sources for the next update to this inventory.

Industrial Processes

Industrial processes include a wide range of sources releasing CO_2, N_2O, and a range of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). These potent GHGs are not necessarily manufactured in Colorado, nor does the state have an accounting for activities using these gases. The projection tool apportions emissions to states based on the model's workings. For a discussion about these gases and how emissions are calculated consult the Industrial Sources Chapter of this inventory. Projections past 2010 are done by producing a linear trend from historical data with the exception of ODS substitutes which relies on the EPA Vintaging Model with a population weighted apportioning to the state. See Exhibit 2-40 for a more detailed description of emissions projections for this category. Exhibit 2-41 provides detailed historical and projected emissions. Note that in Exhibit 2-41 there are some obvious inconsistencies in the default projected emissions between the 2010 inventory value and the 2015 and later projected values.

Cement manufacturing, one of the largest of the industrial process sources, is one category where emissions appear to drop after 2010 but then steadily increase. The increase is tied to a linear trend based on Colorado's data from 1990-2010. The difference between the historical and projected emissions is due to applying the trend to the data which removes the apparent spike in emissions from 2009 to 2010. A similar discontinuity occurs after the 2010 data for ODS substitutes. However, here the projection tool relies on the national EPA Vintaging Model to apportion national emissions back to states. The projection tool makes no attempt to correct this data.

An error in the projection tool was discovered during development of this GHG inventory update. The SIT module, and export files, published with this report, appear to provide a reasonable apportioning and accounting for Colorado IP emissions. Refer to the Industrial Processes chapter for a more comprehensive description concerning calculations of the 1990-2010 emissions. To address the projection tool model errors, the output file was manually corrected to insure a complete emissions picture from 1990-2030 is provided. Exhibit 2-41 provides a corrected accounting for the 1990-2030 emissions for Colorado for industrial processes.

Exhibit 2-40 Assumptions Used by SIT Projection Tool to Calculate Industrial Processes

Industrial Processes

Emissions from Ozone-Depleting Substance Substitutes were projected for the US through 2020 using the U.S. EPA Vintaging Model. The results were then apportioned to states based on the ratio of state population to national population. National projected emissions from Electric Power Transmission and Distribution Systems were provided by U.S. EPA and are apportioned to states by electricity consumption (Electric Power Annual, EIA, Volumes 1994-2010).
For all other states, projected emissions represent a linear trend of historic emissions, as entered by the user or imported from the State Inventory Tool. For states experiencing a significant decline in emissions from a given source during the historic data period, emissions will bottom out at zero in the projections.

Exhibit 2-41 Industrial Processes Emissions (in $MMTCO_2e$)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Carbon Dioxide Emissions									
Cement Manufacture	0.317	0.476	0.554	0.623	0.559	0.976	1114	1252	1390
Lime Manufacture	0.000	0.100	0.095	0.295	0.275	0.388	0.453	0.518	0.583
Limestone and Dolomite Use	0.000	0.019	0.028	0.030	#VALUE!	0.022	0.024	0.027	0.029
Soda Ash	0.036	0.038	0.041	0.041	0.036	0.040	0.041	0.042	0.042
Ammonia & Urea	0.003	0.003	0.002	0.004	0.004	0.004	0.004	0.005	0.005
Iron & Steel Production			0.750	0.340	0.305				
Subtotal Emissions	0.356	0.636	1470	1334	1443	1430	1637	1834	2.050
Nitrous Oxide Emissions									
Nitric Acid Production									
Adipic Acid Production									
Subtotal Emissions									
HFC, PFC, and SF_6 Emissions									
ODS Substitutes	0.004	0.438	1.167	1561	1866	2.540	3.054	3.569	4.083
Semiconductor Manufacturing	0.053	0.089	0.117	0.085	0.104	0.116	0.125	0.134	0.143
Magnesium Production	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Electric Power Trans. and Distr. Systems	0.303	0.251	0.189	0.184	0.166	0.107	0.072	0.036	0.000
HCFC-22 Production									
Aluminum Production									
Subtotal Emissions	0.360	0.778	1474	1831	2.137	2.763	3.251	3.739	4.226
GRAND TOTAL	0.716	1414	2.944	3.164	3.580	4.193	4.888	5.582	6.276

Enteric Fermentation

Enteric fermentation emissions are calculated from an animal population inventory for the State. For a description of generation of methane from this source category refer to the Agriculture chapter of this inventory. The projection tool utilizes the 2010 emission profile from the historical emissions shown in the Agricultural chapter of this inventory. The 1990-2010 summary data files were imported into the projection tool. As is the case with a number of the projections, the 2010 Colorado emissions were used to create a ratio of Colorado versus national emissions. This apportionment was used for all future years applied to a national data base. Exhibit 2-42 contains a more detailed description of how the projection tool handles methane from enteric fermentation. Exhibit 2-43 provides the projected emissions to 2030.

Exhibit 2-42 Assumptions used by SIT Projection Tool to Calculate Methane from Enteric Fermentation

CH_4 Emissions from Enteric Fermentation

Obtained regional emissions factors in kg CH_4 per head for cattle from the emissions factors developed in the Cattle Enteric Fermentation Model (CEFM). The CEFM incorporates energy utilization equations from IPCC's *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. Additional data on sub-populations such as weight gain, birth rates, feedlot placement statistics and slaughter rates from U.S. Department of Agriculture Natural Agricultural Statistics Service (USDA NASS) publications; and cattle diet characterizations and digestion from regional dairy experts to calculate emissions factors. Because of the volatility of these emissions factors from year to year, factors for the year 2010 were used for all future years. A more detailed description of the methods used to calculate the emission factors for cattle is available in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010*. National emissions factors from the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* were used for non-cattle projections.
Total emissions of CH_4 were projected by multiplying projected average annual livestock populations (see the Projected Livestock Population Sheet) by projected future trends in regional emissions factors for various cattle types and non-cattle livestock.

Exhibit 2-43 Emissions (in $MMTCO_2e$) for Enteric Fermentation

	2015	2020	2025	2030
Dairy and Beef Cows				
Dairy Cows	0.2638	0.2605	0.2687	0.2695
Dairy Replacement Heifers	0.0336	0.0343	0.0311	0.0303
Beef Cows	0.9455	1.0008	0.8014	0.7644
Beef Replacement Heifers	0.1225	0.1251	0.1136	0.1105
Steer Stockers	1.6159	1.6507	1.4986	1.4573
Heifer Stockers	0.7633	0.7797	0.7078	0.6883
Feedlot Steer	0.7821	0.799	0.7254	0.7054
Feedlot Heifers	0.5368	0.5483	0.4978	0.4841
Bulls				
Subtotal Emisions	**5.0635**	**5.1984**	**4.6444**	**4.5098**
Other Livestock				
Sheep	0.0071	0.0071	0.0071	0.0071
Goats	0.0021	0.0021	0..0022	0.0022
Swine	0.0268	0.0281	0.0293	0.0306
Horses	0.091	0.0919	0.0929	0.0938
Subtotal Emisions	**0.1269**	**0.1292**	**0.1314**	**0.1337**
GRAND TOTAL	**5.1904**	**5.3276**	**4.7758**	**4.6435**

Manure Management

Calculating methane and nitrous oxide emissions from manure management is described in the Agriculture chapter. Manure from domestic animals is estimated by animal type, animal population, and an annual production estimate as described in the Agriculture chapter. The projection method is outlined in Exhibit 2-44. Projections were calculated using the animal populations for the State shown in Exhibit 2-45 of this chapter. The projection is based on a ratio of the 2010 Colorado emissions to national emissions. A constant growth rate was applied to the 2010 data to predict future animal populations in Colorado.

Exhibit 2-44 Assumptions Used by SIT Projection Tool to Calculate Methane Emissions from Manure Management

CH_4 and N_2O Emissions from Manure Management

CH_4 Emissions from Manure Management

Manure CH_4 emission estimates are developed using the following steps: (1) obtain the required data on animal populations and manure management practices; (2) calculate the amount of volatile solids (VS) produced by each animal type; (3) estimate CH_4 emissions from each animal type, using animal specific maximum potential emissions (B_o) values and weighted methane conversion factors (MCFs); (4) convert emissions to metric tons of CH_4; and (5) sum across animal types to estimate total annual CH_4 emissions. The data used to project methane emissions include:

Animal characteristics data from 2010 were used and these characteristics were held constant for projection of future emissions. Characteristics included typical animal mass (TAM) and average volatile solids (VS) rates per 1,000 kilograms of animal mass, which were used to calculate total VS excreted by each animal. The TAM and VS rates for all animal types were obtained from the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*, though some state specific data was collected during the compilation of the state inventory guidance.

Emissions of CH_4 from each type of animal manure were projected by multiplying total VS excretion for the livestock by the maximum potential emissions factor and the methane conversion factor for the livestock manure.

direct laboratory analysis. However, because type of manure management system, climate and other regional conditions cause variation in the CH_4 emitted per quantity of volatile solids, this emissions factor was multiplied by a methane conversion factor (MCF) that accounted for such regional conditions. The B_o for all animal types except sheep, goats, and horses were obtained from the U.S. EPA's *U.S. Inventory of Greenhouse Gases and Sinks*; B_o values for sheep, goats, and horses were obtained from ASAE's *Manure Production and Characteristics.*

MCFs are determined by temperature, moisture, nutrient availability, pH, water content, and contact with oxygen in the manure management system. MCFs range from 0 to 1: an MCF of 0 represents a manure management system with climate conditions that produce no methane (thus indicating that the Bo is non-existent), while an MCF of 1 indicates that the Bo as measured in the laboratory is correct – all potential CH_4 is released from volatile solids in the manure. Weighted MCFs for dairy and feedlot cattle, swine, and poultry layers were developed from the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. MCFs for other animal types were calculated based on MCFs for each management system and the percent of waste manage by each system. This information was derived from both the state inventory guidance document, and the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sink*.

Total CH_4 emissions from manure were projected by using future livestock population trends (see Projected Livestock Population Sheet) by 2010 animal characteristics described above, and summing across livestock populations.

Notes and assumptions about manure management:

Assumed that the proportion of manure in manure management systems remains constant through 2030.

Assumed that 2008 animal characteristics remain constant for future projections.

Exhibit 2-45 Methane Emissions (in $MMTCO_2e$) for Manure Management

	2015	2020	2025	2030
Dairy Cattle				
Dairy Cows	0.375	0.37	0.382	0.383
Dairy Replacement Heifers	0.020.	0.021	0.0.19	0.018
Subtotal Emissions	**0.4**	**0.39**	**0.4**	**0.4**
Beef Cattle				
Feedlot Heifers	0.193	0.197	0.179	0.174
Feedlot Steer	0.268	0.274	0.249	0.242
Bulls	0.001	0.001	0.0.0.1	0.001
Calves	0.001	0.001	0.001	0.001
Beef Cows	0.019	0.02	0.016	0.015
Beef Replacement Heifers	0.002	0.002	0.002	0.002
Steer Stockers	0.016	0.016	0.015	0.015
Heifer Stockers	0.017	0.017	0.016	0.015
Total Emissions	**0.52**	**0.53**	**0.48**	**0.46**
Swine				
Breeding	0.071	0.075	0.078	0.0.82
Market < 60 lb	0.047	0.049	0.051	0.0.53
Market 60-119 lb	0.020.	0.021	0.021	0.0.22
Market 120-179 lb	0.032	0.033	0.035	0.0.36
Market 180+ lb	0.062	0.065	0.068	0.0.71
Subtotal Emissions	**0.23**	**0.24**	**0.25**	**0.26**
Poultry				
Hens > 1 yr	0.063	0.062	0.061	0.061
Pullets	0.022	0.025	0.029	0.032
Chickens	0.001	0.002	0.002	0.002
Broilers	-	-	-	-
Turkeys	0.002	0.002	0.0.02	0.002
Subtotal Emissions	**0.09**	**0.09**	**0.09**	**0.1**
Other				
Sheep on Feed	-	-	-	-
Sheep Not on Feed	0.005	0.005	0.005	0.005
Goats	0.000.	0.000.	0.0.00.	0.000.
Horses	0.017	0.017	0.017	0.017
Subtotal Emissions	**0.02**	**0.02**	**0.02**	**0.02**
GRAND TOTAL	**1.25**	**1.28**	**1.25**	**1.25**

Agricultural Soils

Agricultural soils are responsible for nitrous oxide emissions from several processes. Calculating N_2O from agricultural soils is described in the Agriculture chapter of this Colorado 2013 inventory update. Exhibit 2-46 describes the calculation scheme for predicting future emissions of nitrous oxide from agricultural soils. In essence the Projection Tool uses the historical data attributed to Colorado and projects future emission based on the trend. Exhibit 2-47 shows the results from the projection tool.

Exhibit 2-46 Assumptions Used by SIT Projection Tool to Calculate Nitrous Oxide from Agricultural Soils

N_2O Emissions from Agricultural Soils

Forecasted 2011-2030 agricultural soils N_2O emissions based on the observed 1990-2010 emissions trend (either from State Inventory Tool default numbers or state-reported data).

1990-2010 national estimates of N_2O from agricultural soils were obtained from the agricultural soils spreadsheet for the 1990-2010 U.S. Inventory.

Exhibit 2-47 N2O Emissions from Agricultural Soils (in MMTCO2e)

1990	1995	2000	2005	2010	2015	2020	2025	2030
3.45	3.12	3.24	2.97	2.68	2.77	2.63	2.49	2.35

Agricultural Residue Burning

Exhibit 2-48 shows the assumptions used by the SIT tool to calculate methane and nitrous oxide from agriculture residue burning. Exhibit 2-49 shows the results from the projection tool for agricultural burning in Colorado.

Exhibit 2-48 Assumptions Used by SIT Projection Tool to Calculate Methane and Nitrous Oxide from Agricultural Residue Burning

CH_4 and N_2O Emissions from Agricultural Residue Burning

Forecasted (2011-2030) national agricultural residue burning emissions of CH_4 and N_2O emissions based on national 1990-2010 estimates of CH_4 and N_2O emissions from agricultural residue burning from the 1990-2010 U.S. Inventory.
Calculated state's proportion of national residue burning emissions in 2010 based on default state data from the State Inventory Tool.

Estimated state emissions of CH_4 and N_2O by applying the year 2010 state-to-national ratio to national emission estimates for 1990-2010. Projected state emissions of each gas for 2011-2030 by applying the ratio to the forecast national emissions.
Note: State percentages of national emissions were used in place of default state estimates generated by the State Inventory Tool because the SIT does not include default data for all crops that contribute to emissions from agricultural

Exhibit 2-49 Projected Emissions from Agricultural Residue Burning in Colorado

	1990	1995	2000	2005	2010	2015	2020	2025	2030
CH_4 ($MMTCO_2e$)	0.009	0.009	0.009	0.008	0.012	0.003	0.004	0.004	0.004
N_2O ($MMTCO_2e$)	0.003	0.003	0.003	0.003	0.004	0.002	0.002	0.002	0.002
TOTAL	0.012	0.012	0.012	0.011	0.016	0.005	0.006	0.006	0.006

Waste Combustion Emissions and Municipal Solid Waste

Municipal solid waste is treated in the model by assuming waste is either in a landfill, where the carbon is sequestered resulting in negative carbon emissions, it is burned as a fuel for electricity generation, or just flared to reduce methane emissions. For a description of municipal solid waste emissions refer to Chapter 10. For a description of the calculation scheme refer to Exhibit 2-50. The bottom section of the Exhibit provides the details for the categories of sources. Exhibit 2-51 provides a summary of the total emissions for waste combustion and landfills considering the historical 1990-2010 Colorado emissions and the projections to 2030. Projections past 2010 use population and other national indicators of waste as the basis for future emissions. Trends from 1990-2010 based on Colorado data are partially considered as well as national trend data.

Exhibit 2-50 Assumptions Used by SIT Projection Tool to Calculate Methane and Nitrous Oxide from Waste Combustion

CH_4 and N_2O Emissions from Solid Waste Management

Landfills

The State Inventory Tool was modified to include state population forecasts and projected per capita waste generation estimates, then calculate future emissions using the first-order decay model (FOD), the same methodology as historical emissions are currently calculated in the state inventory tool for waste.

The FOD model estimates the potential CH_4 emissions that occur during the inventory year, but are associated with the waste landfilled over the past thirty years. These emissions vary not only by the amount of waste present in the landfill, but also by the CH_4 generation rate (k). The CH_4 generation rate varies according to several factors pertaining to the climate in which the landfill is located. In the CLIP tool, these factors are simplified into two values, one for arid and one for non-arid states. For arid states (i.e., those states for which the average annual rainfall is less than 25 inches), a "k" value of 0.02 is used, for non-arid states, a "k" value of 0.04 is used. The methane generation potential (L_o) is equal to 100 m^3/metric ton (EPA 1995). The first order decay model is based on the following equation:

$$Q_{tx} = A * k * R_x * L_o * e^{-k(T-x)}$$

Where, $Q_{T,x}$ = Amount of CH_4 generated in year T by the waste R_x,

T = Current year

x = Year of waste input,

A = Normalization factor, $(1-e^{-k})/k$

k = CH_4 generation rate (yr^{-1})

R_x = Amount of waste landfilled in year x

L_o = CH_4 generation potential

Projected reductions in per capita landfilling rate were held constant at the national 1990-2000 level of 0.02 percent per year for each state (STAPPA/ALAPCO/EPA. 2003. Emissions Inventory Improvement Project, Chapter 13 Methods for Estimating Greenhouse Gas Emissions From Municipal Solid Waste 2005).

Projected estimates for flaring and LFGTE rates through 2030 are based on the reported/default 2010 value.

This approach allows for state specific activity data to be utilized for estimating GHG emissions, which is the most accurate methodology possible. Limitations can be found in the per capita landfilling rate and landfill gas collection projection factors. There is the potential for significant variability at the state level for both of these factors. Nonetheless, this projection approach is the most accurate method available based on current landfill characteristic projections.

Waste Combustion

Obtained national estimates of CO_2, N_2O, and CH_4 emissions from MSW combustion for 1990-2010. These estimates were obtained from EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010.

Converted and summed emissions to obtain total GHG emissions from MSW combustion in MMTCE.

Used a linear trend to predict national emissions for 2011-2030. This function predicts values based on known values (i.e., emission totals for 1990-2010).

Apportioned GHG emissions to states based on population. For each year and state, divided state population by national population to determine the fraction of national population that each state represented. Multiplied these values by the respective year's national GHG emissions estimates to determine state contributions to MSW combustion emissions.

Note: This methodology assumes that in all states, equal amounts of waste are combusted per capita. In reality, some states may combust a higher proportion of their waste than others. Also, individuals in some states may produce more waste per capita than others.

Exhibit 2-51 Total Emissions from Landfills and Waste Combustion (in $MMTCO_2e$)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
CH_4	0.606	0.528	0.939	1.575	2.189	2.587	2.832	0.3027	3.179
CO_2	0.106	0.16	0.17	0.196	0.196	0.227	0.244	0.262	0.281
N_2O	0.006	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.005
TOTAL	**0.718**	**0.695**	**1.115**	**1.778**	**2.391**	**2.82**	**3.082**	**3.295**	**3.465**

CH_4 Emissions from Landfills ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Potential CH_4									
MSW Generation	0.81	1.03	1.35	2.05	2.78	3.22	3.52	3.76	3.95
Industrial Generation	0.06	0.07	0.09	0.14	0.19	0.23	0.25	0.26	0.28
Total Potential CH_4	0.87	1.10	1.44	2.20	2.98	3.44	3.77	4.03	4.23
CH_4 Avoided									
Flare	-0.16	-0.48	-0.36	-0.44	-0.55	-0.57	-0.62	-0.66	-0.70
Landfill Gas-to-Energy	-0.03	-0.03	-0.04	-	-	-	-	-	-
Total CH_4 Avoided	-0.19	-0.52	-0.40	-0.44	-0.55	-0.57	-0.62	-0.66	-0.70
Oxidation at MSW Landfills									
	0.06	**0.05**	**0.09**	**0.16**	**0.22**	**0.26**	**0.29**	**0.31**	**0.33**
Oxidation at Industrial Landfills									
	0.01	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**
TOTAL CH_4 Emissions	**0.61**	**0.53**	**0.94**	**1.58**	**2.19**	**2.59**	**2.83**	**3.03**	**3.18**

CO_2, N_2O, and CH_4 Emissions from Waste Combustion ($MMTCO_2E$)

Gas/Waste Product	1990	1995	2000	2005	2010	2015	2020	2025	2030
CO_2	0.11	0.16	0.17	0.20	0.20	0.23	0.24	0.26	0.28
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
CH_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL CO_2 & N_2O Emissions	0.11	0.17	0.18	0.20	0.20	0.23	0.25	0.27	0.29

Wastewater Treatment

CH_4 and N_2O Emissions from Wastewater Treatment

Exhibit 2-52 shows the assumptions used by the SIT tool to calculate methane and nitrous oxide from wastewater treatment. Exhibit 2-53 shows the results from the projection tool for wastewater treatment in Colorado.

Exhibit 2-52 Assumptions Used in the SIT Model to Calculate Methane and Nitrous Oxide Emissions from Wastewater

CH_4 and N_20 emissions from wastewater treatment were estimated based on 1990-2010 emissions estimates reported in EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks.* The national CH_4 and N_20 emission estimates for 1990-2010 were projected to 2030 using a statistical forecasting algorithm. For each state, the projected emissions values were factored by the respective state's projected percentage of the national population. This produces a projected wastewater emissions estimate for that state.

The emissions projection methodology used for wastewater is a very top-level approximation. It is based on a simple forecasting (or trend projection) of national wastewater emissions estimates, which is then apportioned by state population projected by the U.S. Census Bureau. It is not driven by any analysis of projected national activity data, or state specific activity data, which would potentially increase its accuracy.

Exhibit 2-53 Projected Emissions of CH_4 and N_20 from Wastewater Treatment (in $MMTCO_2e$)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
CH_4									
Municipal	0.22	0.25	0.29	0.31	0.34	0.38	0.41	0.44	0.47
Industrial	0.04	0.05	0.05	0.04	0.05	0.05	0.06	0.06	0.06
CH_4 Total	0.26	0.3	0.64	0.35	0.74	0.43	0.9	0.5	1.03
N_2O									
Municipal	0.09	0.11	0.13	0.14	0.15	0.17	0.18	0.20	0.22
GRAND TOTAL	**0.35**	**0.41**	**0.47**	**0.5**	**0.54**	**0.6**	**0.65**	**0.69**	**0.74**

References

EIA 2013Annualenergyoutlook2011

—— 2012 *State energy consumption, price, and expenditure estimates (SEDS) 2010:Consumption estimates* http://wwweiagov/state/seds/seds-data-fuel-prevcfm (accessed 30 April, 2013)

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EPA 2012 Energy consumption projections 5 15 12xls State and Local Climate and Energy Program http://wwwepagov/statelocalclimate/resources/toolhtml (accessed 25 June 2013)

EPA. 2013. *Methodologies for U.S. Greenhouse Gas Emissions Projections: Non-CO2 and Non-Energy CO2 Sources.* Climate Change Division. Office of Atmospheric Programs. December. Washington, DC.

Chapter 3 – Electrical Power

Overview

The Electrical Power Sector consists of CO_2, CH_4, and N_2O emissions resulting from the combustion of fuels used to generate electricity in Colorado.

Emission estimates for this sector were generated using the February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode. For this chapter, two emissions modules from the SIT are combined – *Estimating Carbon Dioxide (CO_2) Emissions from Combustion of Fossil Fuel* and *Estimating Methane (CH_4)* and *Nitrous Oxide (N_2O) Emissions from Stationary Combustion.* These modules also calculate CO_2, CH_4 and NO_2 emissions from the combustion of fuel for residential, commercial and industrial uses, and CO_2 generated from the combustion of fuel for transportation, but these emissions are discussed separately in Chapters 4 and 5 respectively. Current guidance on generating greenhouse gas CO_2 emissions from the combustion of fuels to generate electricity is found in the *User's Guide For Estimating Direct Carbon Dioxide Emissions From Fossil Fuel Combustion.* Guidance on generating CH_4 and N_2O greenhouse gas emissions for this sector is found in the *User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Sources.*

As shown in the Executive Summary, emissions from the Electrical Power sector accounted for approximately 30% of Colorado's GHG inventory in 2010.

In addition to calculating GHG emissions resulting from the production of electricity in Colorado, the SIT Model includes a separate module that calculates CO_2e emissions associated with Colorado's electrical consumption. This module estimates indirect emissions related to how power is used in Colorado by looking at an end use analysis. It considers transmission losses and the balance of imported and exported power generated in the state and out of state. Information from this module may be useful for planning and policy purposes but the emissions associated with Colorado electricity consumption are *not* incorporated into the totals for this Colorado inventory to avoid double counting of emissions associated with the production of electricity in Colorado. Current guidance on calculating CO_2e emissions associated with electrical consumption is found in the latest version of the SIT under the *User's Guide for Estimating Indirect Carbon Dioxide Equivalent Emissions from Electricity Consumption Using the State Inventory Tool.*

SIT Model Results

The Electrical Power GHG emissions estimates are the sum of CO_2 emissions from the 2013 SIT Model Fossil Fuel Combustion Module and the CH_4 and N_20 emissions from the Stationary Combustion Module. Exhibits 3-1 and 3-2 show the 2013 SIT Model results for the Electrical Power Sector from each of these modules.

Exhibit 3-1: Colorado CO_2Emissions from Electrical Power Generation Fossil Fuel Combustion

Emissions (MMTCO2e)	1990	1995	2000	2005	2010
Electric Utilities					
Coal	30.54	31.21	35.01	35.00	34.29
Petroleum	0.02	0.02	0.09	0.02	0.02
Natural Gas	0.71	1.28	3.54	5.08	5.05
Total Emissions	**31.27**	**32.5**	**38.64**	**40.1**	**39.35**

Exhibit 3-2 Colorado N_2O and CH_4 Emissions from Electrical Power Generation Stationary Combustion

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Electric Utilities					
N_2O	0.150	0.153	0.177	0.178	0.174
CH_4	0.007	0.007	0.009	0.010	0.010
Total Emissions	**0.157**	**0.161**	**0.187**	**0.188**	**0.184**

Data and Methodology

The EPA released its updated SIT model on February 11, 2013. This 2013 release was used for the final state inventory update and provides modeled data through 2010. Final electrical power emissions are a combination of the results from the *Fossil Fuel Combustion for* CO_2 *Emissions Module* and the *Stationary Combustion Module* (N_2O and CH_4). These results are combined to produce total $MMTC0_2e$ emissions from the electrical power sector.

For informational purposes, the SIT Model for *Electrical Consumption* was run and is discussed in this Chapter. This module estimates how the power generated in the state of Colorado is used by looking at an end use analysis. This information is *not* incorporated into the totals for this Colorado inventory to avoid double counting, but could be utilized to make policy decisions.

Fossil Fuel Combustion Module

As with the other modules in the EPA SIT tool array, the concepts for calculating direct carbon dioxide emissions from the combustion of fossil fuels has its roots in the *State Workbook for Estimating Greenhouse Gas Emissions.* This process was modified and updated after 1998 to comport with the EPA's Emissions Inventory Improvement Process (EIIP) for criteria pollutants (EPA

2013b). The SIT was developed to assist states in producing their own GHG inventories with some standardized processes to agree with international approaches, yet allow states to tailor emission factors and source data as deemed necessary. As with the other SIT modules, this one provides a range of defaults, most linked to national data bases created from various sources. Most of these data sources have their origins in state/federal reporting requirements. With respect to CO_2 emissions from electrical generation facilities the SIT model uses coal, natural gas, or other fuel burned in such facilities to calculate emissions. Fuel used, and energy produced, is tracked closely by states and such information is submitted to national data bases as part of environmental reporting procedures. Emission factors to convert fuel consumed, by source type, are provided in the default options for the module.

Specifically, to calculate CO_2 emissions from fossil fuel combustion, the following data are utilized:

- Fossil fuel energy and non-energy consumption by fuel type and sector (non-energy consumption applies only to the industrial sector);
- Carbon content coefficients;
- Carbon stored in products; and
- Percentage of carbon oxidized during combustion.

Equation 3-1 shows the general equation used to generate CO2 emissions from fuel combustion.

Equation 3-1: General Emission Equation for CO2 from Fossil Fuel Combustion

Emissions ($MMTCO_2e$) = Consumption (BBtu) x emission factor (lbs C/BBtu) x 0.0005 short tons/lbs x Combustion efficiency (% as a decimal) x 0.9072 (ratio of short tons to metric tons) divided by 1,000,000 x (44/12 to yield $MMTCO_2e$).

For further detailed information on the operation and formulas for this module, consult the *CO_2 Fossil Fuel Combustion User's Guide,* which is used to run the Fossil Fuel Combustion Module to obtain CO_2 emissions. The guide will take you through all of steps used to run this module.

Stationary Combustion Module

As described, the GHG emissions related to electrical generation are made up from carbon dioxide released when carbon based fuels are burned. Nitrogen dioxide and methane are also generated in the combustion process. Equation 3-2 shows the general calculation scheme used by the stationary source combustion module to generate nitrous oxide and methane emissions.

Equation 3-2 General Emission Equation for calculating N_2O or CH_4 from Stationary Sources

Emissions ($MMTCO_2e$)= Consumption (BBtu) x Emission Factor (MT/BBtu) x GWP ÷ 1,000,000 (to yield $MMTCO_2e$)

The following language is extracted and edited from the *EPA 2013 SIT Module User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel* and *User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion.*

> This section provides instructions for using the Stationary Combustion module of the SIT to estimate CH_4 and N_2O emissions from sectors that consume fossil fuels and wood. Within the Stationary Combustion module, these sectors are residential, commercial, industrial, and electric power. Since the methodology is similar in all sectors, a general methodology is discussed and specific examples for each sector are provided.
>
> The Stationary Combustion module automatically calculates emissions after you enter energy consumption data (and the factors on the control worksheet). The tool provides default energy consumption data, which comes from the EIA's State Energy Consumption, Price, and Expenditure Estimates (SEDS) EIA (2012). However, other more state-specific data may be used if available.
>
> Default emission factors are provided in the Stationary Combustion module for all fuel types and sectors and are available from IPCC (2006). In general, emissions of CH_4 and N_2O will vary with the type of fuel burned, the size and vintage of the combustion technology, the maintenance and operation of the combustion equipment, and the type of pollution control technology used. Nitrous Oxide is produced from the combustion of fuels, with the level of N_2O emissions dependant on the combustion temperature. Methane and non-CH_4 volatile organic compounds are unburned gaseous combustibles that are emitted in small quantities due to incomplete combustion; more of these gases are released when combustion temperatures are relatively low. Emissions of these gases are also influenced by technology type, size, vintage, and maintenance, operation, and emission controls. Larger, higher efficiency combustion facilities tend to reach higher combustion temperatures and thus emit less of these gases. Emissions may range several orders of magnitude above the average for facilities that are improperly maintained or poorly operated, which is often the case for older units. Similarly, during start-up periods, default emission factors are provided in the Stationary Combustion module for all fuel types and sectors and are available from IPCC (2006). However, users may choose to specify their own.

Electricity Consumption Module

The Electricity Consumption Module is the eleventh, and newest, module developed as part of the SIT suite of modules. EPA recognized a need for a module and guidance to estimate indirect greenhouse gas emissions from electricity consumption at the state level. In using this module, an important distinction between direct and indirect emissions must be made. **Direct emissions**, estimated in CO_2 from the Fossil Fuel Combustion module and N_2O, and CH_4 from Stationary Source Combustion, are a result of the combustion of fossil fuels at the electricity generating station. **Indirect emissions** occur at the point of use (e.g., residential space heating electricity consumption) and consider transmission lines losses and imported/exported electricity balance in the State. Simply viewed, the light bulb at a home consumes a set amount of electricity independent of how much was generated at a power plant in the state, or by imported power from out of state, and independent of the amount of electricity lost in the transmission process. If one were to sum the Residential, Commercial, and Industrial (RCI) and transportation (light rail) power consumption in the state, independent of how much power is produced, an estimate of the indirect emissions could be made.

The sum of indirect emission may be more than the amount of emissions from direct electrical production, or less, depending on the amount of power imported or exported into a state. State inventories are generally based on direct emissions associated with electricity generation occurring in the state. Indirect emissions associated with electricity consumed within the boundaries of the state can be used to evaluate potential benefits of emission reducing strategies.

EPA encourages states to include direct emissions in their inventory estimates and include indirect emissions as an informational-only line item.

Electricity consumption statistics should be collected on a kilowatt-hour (kWh) basis. Statistics providing energy consumption data in other units, British Thermal Units (Btu), may be used, but require conversion to kWh. One kWh is equivalent to 3,412 Btu.

The Electricity Consumption (EC) module calculates carbon dioxide equivalent (CO_2e) emissions from electricity consumption by end-use equipment types, shown in Exhibit 3-3.

Exhibit 3-3 End-Use Equipment by Sector

Residential	Commercial	Industrial	Transportation
space heating air conditioning water heating refrigeration other – appliances and lighting	space heating cooling ventilation water heating lighting cooking refrigeration office equipment computers others	**Indirect Uses – Boiler Fuel:** conventional boiler use CHP and/or Cogeneration **Direct uses:** process heating process cooling and refrigeration machine drive electro-chemical other **Direct Uses-Total Nonprocess:** facility HVAC facility lighting other facility support on-site transportation other	automated guideway bus (charged batteries) cable car commuter rail heavy rail inclined plane light rail trolleybus

The EC module calculates emissions after you enter the emission factors on the opening worksheet, electricity consumption data, and the percent consumption by end-use sector equipment. The tool provides default electricity consumption data, which comes from the EIA's State Energy Consumption, Price, and Expenditure Estimates (SEDS) EIA (2011). Default emission factors for electricity consumption (lbs CO_2e/kWh) are provided in the opening worksheet. Values are derived from Year 2005 and 2007 Emissions & Generation Resource Integrated Database (eGRID) subregion values, weighted by the number of households within in each eGRID subregion in each state (U.S.EPA 2008, U.S. EPA 2011). This weighted emission factor is intended to better reflect emissions related to electricity consumption within a state, and take into account the flow of electricity across state boundaries. Since these emission factors do not account for any transmission and distribution losses between the points of generation and the points of consumption, a transmission loss factor of 5.33%must be applied. The transmission loss factor takes into account electric energy lost due to the transmission and distribution of electricity.

The general equation use to calculate indirect CO_2e emissions from electricity consumption is shown in Equation 3-3.

Equation 3-3 General Emissions Equation for Electricity Consumption Emissions

(Total State Consumption (kWh) x End-use equipment consumption (%) divided by (1-transmission loss factor (%)) x Emission factor (lbs CO2e/kWh) x 0.0005 short ton/lbs x 0.90718 (Ratio of short tons to metric tons) divided by 1,000,000).

Based on these various model defaults, GHG emissions associated with Colorado electrical consumption by sector are set forth in Exhibit 3-4.

Exhibit 3-4 Colorado Indirect Emissions of CO_2 from Electrical Consumption

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Residential					
Space Heating	1.14	1.31	1.63	0.99	1.11
Air-conditioning	0.68	0.79	0.98	1.92	2.14
Water Heating	0.82	0.94	1.17	1.26	1.4
Refrigeration	1.27	1.47	1.82	1.98	2.21
Other Appliances and Lighting	4.91	5.67	7.03	8.66	9.67
Total	**8.81**	**10.18**	**12.64**	**14.8**	**16.53**
Commercial					
Space Heating	0.63	0.62	0.83	0.86	0.87
Cooling	1.68	1.66	2.21	2.31	2.31
Ventilation	1.47	1.45	1.93	2.02	2.02
Water Heating	0.28	0.28	0.37	0.38	0.38
Lighting	5.03	4.99	6.63	6.92	6.93
Cooking	0.07	0.07	0.09	0.1	0.1
Refrigeration	1.19	1.18	1.57	1.63	1.64
Office Equipment	0.42	0.42	0.55	0.58	0.58
Computers	0.63	0.62	0.83	0.86	0.87
Other	1.61	1.59	2.12	2.21	2.21
Total	**12.99**	**12.88**	**17.14**	**17.87**	**17.89**
Industrial					
Indirect Uses-Boiler Fuel	0.01	0.01	0.01	0.01	0.17
Conventional Boiler Use	0.01	0.01	0.01	0.01	0.17
Direct Uses-Total Process	4.48	6.59	6.76	8.19	10.98
Process Heating	0.53	0.79	0.81	0.98	1.32
Process Cooling and Refrigeration	0.39	0.58	0.59	0.72	0.98
Machine Drive	2.98	4.39	4.51	5.46	7.39
Electro-Chemical Processes	0.53	0.79	0.81	0.98	0.97
Other Process Use	0.03	0.05	0.05	0.06	0.33
Direct Uses-Total Non-process	1.16	1.71	1.76	2.13	2.55
Facility HVAC	0.6	0.88	0.91	1.1	1.27
Facility Lighting	0.41	0.61	0.63	0.76	0.89
Other Facility Support	0.14	0.2	0.21	0.25	0.31
Onsite Transportation	0	0.01	0.01	0.01	0.02
Other Nonprocess Use	0.01	0.01	0.01	0.01	0.06
Other	0.29	0.42	0.44	0.53	0.15
Total	**5.93**	**8.74**	**8.97**	**10.85**	**13.85**
Transportation					
Light Rail		0	0.01	0.02	0.04
Total		**0**	**0.01**	**0.02**	**0.04**
TOTAL	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**
Residential	8.81	10.18	12.64	14.8	16.53
Commercial	12.99	12.88	17.14	17.87	17.89
Industrial	5.93	8.74	8.97	10.85	13.85
Transportation		0	0.01	0.02	0.04

Uncertainties Associated With Emission Estimates for the Electric Power Sector

As with all of the SIT modules used to generate this inventory, there are uncertainties associated with each of the three modules for assessing GHG emissions from the Electric Power Sector. Some of the uncertainties associated with these modules are discussed below.

Uncertainty from CO_2FFC Module for Energy Consumption

The amount of CO_2 emitted from fossil fuel combustion depends upon the type of fuel consumed, the carbon content of the fuel and the amount of CO_2 produced per unit of fuel that is oxidized. Consequently, the more accurately these parameters are characterized, the more accurate the estimate of direct CO_2 emissions. There are uncertainties associated with each of these parameters.

In order to more accurately portray the Colorado GHG emissions from the electrical power generation sector, an analysis of the emissions from specific Colorado power plants should be considered. This information may include Continuous Emission Monitoring (CEMs) Data, rulemaking/legislation that has occurred to require control devices to be installed or alternative sources of energy to be utilized. Careful attention to detail must be used in order to avoid double counting this direct and indirect emissions data.

A 2012 analysis by Dr. Anu Ramaswami, at the University of Colorado, Graduate School found the following in regard to data uncertainty. Clean Air Clean Jobs Legislation, the adoption of the State Regional Haze Plan, the Colorado Carbon Fund, addition of legislation requiring a 30% renewable portfolio in Colorado by 2030, changes in fuel mix use at Colorado power plants, better emission factors based on evolving science, the Mercury and Air Toxics Standards (MATS), and increased black carbon emissions, all have an influence on Colorado's electricity related emissions.

Several commenters asked if historical SIT emission factor based GHG emissions could be reconciled against measured CO_2 emissions reported per CAMD (40CFR, Part 75) and GHG emission reported per the GHG Reporting Rule (40 CFR, Part 98 e-GGRT requirements).

The basis for the energy use data in the 1990-2010 base case has its origin in the EIA SEDS data which is based on industry reported information. However, for comparative purposes, the following Exhibit 3-5 reflects a comparison of CAMD and the GHG Reporting Rule data for 2012. For comparison purposes the 2012 CAMD data is less than 1% higher than the SIT Model 2010 output of 39.35, and the GHG Reporting Rule Data is less than 1% higher than of the SIT Model Output.

Exhibit 3-5 2012 GHG Reporting and CAMD Data

Facility Name	2012 Reporting Rule	2012 CAMD*
	(metric tons CO2e)	(converted to metric tons CO2e)
CRAIG	9,038,891	8,970,226
COMANCHE (470)	8,859,819	8,811,988
PAWNEE	3,394,721	3,374,582
CHEROKEE	3,062,597	3,045,857
HAYDEN	2,642,886	2,628,270
RAWHIDE ENERGY STATION	2,069,282	2,053,452
MARTIN DRAKE	1,619,283	1,607,339
RAY D NIXON	1,536,800	1,524,884
FORT ST. VRAIN	1,420,793	1,409,972
VALMONT	1,094,731	1,086,600
ARAPAHOE	1,032,702	1,027,377
ROCKY MOUNTAIN ENERGY CENTER	1,016,496	1,015,505
NUCLA	673,661	667,975
FRONT RANGE POWER PLANT	559,624	559,078
J.M. SHAFER GENERATING STATION	404,838	404,105
PUEBLO AIRPORT GENERATING STATION	317,683	317,373
SPINDLE HILL ENERGY CENTER	169,070	167,881
FOUNTAIN VALLEY POWER PLANT	145,515	144,744
MANCHIEF GENERATING STATION	103,575	103,239
BLUE SPRUCE ENERGY CENTER	100,452	100,304
LIMON GENERATING STATION	95,555	94,983
ARAPAHOE COMBUSTION TURBINE FACILITY	43,791	43,715
ZUNI	28,338	28,310
BRUSH POWER PROJECTS	42,290	19,909
FRANK KNUTSON STATION	6,662	6,603
VALMONT COMBUSTION TURBINE FACILITY	910	909
Subtotal of CAMD Units	**39,480,965**	**39,215,180**
AQUILA, INC. - AIRPORT INDUSTRIAL SITE	60	-
AQUILA, INC. - PUEBLO POWER PLANT	39	-
BLACK HILLS ELECTRIC- W.N. CLARK STATION	255,426	-
COLORADO ENERGY NATIONS COMPANY LLLP (GOLDEN FACILITY)	559,977	-
LAMAR	48	-
PLAINS END GENERATING STATION	47,909	-
PUBLIC SERVICE CO DENVER STEAM PLT	59,601	-
THERMO POWER & ELECTRIC LLC	68,637	-
UNIVERSITY OF COLORADO BOULDER - UTILITY SERVICES	38,945	-
Subtotal of Smaller Units	1,030,642	-
Total Emissions CO_2e	**40,511,607**	**39,215,180**
Total Emissions - excuding Smaller Units MMTCO_2e	**39.5**	**39.2**
* Only facilities of 25 MW report to CAMD		

Uncertainty from Stationary Combustion Module

The amount of methane and nitrous oxide emitted from stationary combustion depends upon the amount and type of fuel (coal, petroleum, natural gas, or wood) used and the type of technology in which the fuel is combusted (boilers, water heaters, or furnaces) and the type of emissions control on the technology. In general, the more detailed information available on the combustion activity, the lower the uncertainty. However, as noted in the Revised 1996 IPCC Guidelines, the contribution of CH_4 and N_2O to overall emissions is small and the estimates are highly uncertain.

The combustion temperature at which the technology operates impacts the level of CH_4 and N_2O emissions.

Uncertainties may also exist in the activity data used to derive emissions estimates. For example, in the EIA SEDR Data Sets, wood used in fireplaces, wood stoves, and campfires is not fully captured. Uncertainties are also associated with the allocation of fuel consumption data to individual end-use sectors and estimates of the fraction of fuels used for non-energy.

Uncertainty from the Electricity Consumption Module

As described in the EPA SIT module "although statistics of electricity consumption are relatively accurate at the national level, there is more uncertainty associated with the state-level data." In addition, the allocation of this consumption to individual end-use sectors (i.e., residential, commercial, industrial, and transportation) at the state level is more uncertain than at the national level.

Additionally, using eGRID data may be useful. However, WECC Rockies data may not accurately reflect the power plant mix used in Colorado. Specifically looking at imports and exports of electricity in Colorado might also be a useful exercise to assess whether differences in the calculation of emissions from electricity production and consumption can be reconciled.

More state specific data for the allocation of consumption to end-use sectors would be more reflective of actual GHG emissions from the electrical power generation sector. This should be explored in more depth in order to modify the SIT module to be more accurate for Colorado.

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

References

U.S. EPA, 2013a. User's Guide for Estimating Methane and Nitrous Oxide Emissions form Stationary Combustion Using the State Inventory Tool(February 2013)

.2013b. User's Guide for Estimating Indirect Carbon Dioxide Equivalent Emissions from Electricity Consumption using the State Inventory Tool (February 2013)

.2013c. User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool (February 2013)

Chapter 4 – Residential, Commercial, Industrial (RCI) Fuel Use

Overview

The Residential, Commercial, Industrial (RCI) Fuel Use Sector consists of CO_2, CH_4, and N_2O emissions from the combustion of fuels for various heating and commercial process purposes. The sector does not include emissions associated with the generation of electricity, which are addressed in Chapter 3, transportation related emissions addressed in Chapter 5, or non-combustion emissions from industrial facilities discussed in Chapter 6 (Industrial Processes).

Emission estimates for this sector were generated using the February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode. For this chapter, two emissions modules from the SIT are combined – *Estimating Carbon Dioxide (CO_2) Emissions from Combustion of Fossil Fuel and Estimating Methane (CH_4)* and *Nitrous Oxide (N_2O) Emissions from Stationary Combustion.* Current guidance on generating Greenhouse Gas CO_2 emissions from residential, commercial and industrial sector fuel use is found in the latest version of the SIT under the *User's Guide For Estimating Direct Carbon Dioxide Emissions From Fossil Fuel Combustion.* Guidance on generating CH_4 and N_2O Greenhouse Gas emissions from these three sectors is found in the *User's Guide for Estimating Methane and Nitrous Oxide Emissions From Stationary Sources.*

As shown in the Executive Summary, emissions from the RCI sector accounted for approximately 21% of Colorado's GHG inventory for 2010.

SIT Model Results

The RCI Sector GHG emissions estimates are the sum of emissions from the 2013 SIT Model CO_2 from the Fossil Fuel Combustion Module and the Methane and Nitrous Oxide Emissions from the Stationary Combustion Module. Below are Exhibits 4-1 and 4-2 which show the 2013 SIT Model results for each of the aforementioned modules.

Exhibit 4-1. Colorado Carbon Dioxide Emissions from Residential, Commercial and Industrial Fossil Fuel Combustion

Emissions	1990	1995	2000	2005	2010
Residential					
Coal	0.02	0.01	0.02	0.02	0.06
Petroleum	0.42	0.54	0.71	0.82	0.77
Natural Gas	4.89	5.61	6.16	6.77	7.07
Subotal Emissions	**5.33**	**6.15**	**6.88**	**7.61**	**7.91**
Commercial					
Coal	0.1	0.04	0.14	0.25	0.5
Petroleum	0.36	0.42	0.43	0.45	0.58
Natural Gas	3.52	3.58	3.22	3.38	3.11
Subotal Emissions	**3.98**	**4.04**	**3.79**	**4.09**	**4.19**
Industrial					
Coal		0.82	0.42	0.14	0.7
Petroleum	2.14	2.26	2.71	3.16	3.02
Natural Gas	3.46	4.5	6.05	9.38	10.87
Subotal Emissions	**5.6**	**7.58**	**9.17**	**12.69**	**14.59**
Total Emissions	**14.91**	**17.77**	**19.84**	**24.39**	**26.69**

Exhibit 4-2. Colorado N_2O and CH_4 Emissions from Residential, Commercial and Industrial Stationary Combustion

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Residential					
N_2O	0.013	0.013	0.015	0.014	0.014
CH_4	0.056	0.056	0.064	0.058	0.06
Total Emissions	**0.069**	**0.069**	**0.079**	**0.072**	**0.074**
Commercial					
N_2O	0.004	0.004	0.005	0.006	0.007
CH_4	0.013	0.014	0.016	0.015	0.015
Total Emissions	**0.017**	**0.018**	**0.021**	**0.02**	**0.022**
Industrial					
N_2O	0.007	0.012	0.011	0.013	0.014
CH_4	0.003	0.005	0.005	0.006	0.007
Total Emissions	**0.01**	**0.017**	**0.017**	**0.02**	**0.021**
Total By Gas					
N_2O	0.024	0.029	0.031	0.033	0.035
CH_4	0.072	0.075	0.085	0.079	0.082
GRAND TOTAL	**0.096**	**0.104**	**0.116**	**0.112**	**0.117**

Data and Methodologies

The RCI Sector GHG emissions estimates are the sum of CH_4, N_2O and CO_2 emissions from the 2013 SIT Model. These emissions are extracted from the CO_2 Fossil Fuel Module and the N_2O and CH_4 Stationary Combustion Module.

CO_2 from Fossil Fuel Combustion

The CO_2FFC module of the SIT estimates CO_2 emissions from various sectors that consume fossil fuels. Specifically, the CO_2FFC module, breaks out combustion related CO_2 emissions for the following sectors: residential; commercial; industrial; transportation; and electric power. Since the methodology is similar in all sectors, a general methodology is discussed and specific examples for each sector are provided. However, for this Chapter, only the CO_2 emissions for the RCI sectors are presented

The CO_2FFC module automatically calculates emissions after you enter energy consumption data (and the factors on the control worksheet). The tool provides default energy consumption data, which comes from the EIA's State Energy Consumption, Price, and Expenditure Estimates (SEDS) EIA (2012). However, other more state-specific data may be used if available.

The SIT model calculates CO_2 emissions from fossil fuel combustion for the RCI sectors based on usage of coal, natural gas and petroleum fuel types. The N_2O and CH_4 emissions from Stationary Combustion are also derived from the same coal, natural gas and petroleum fuel use data. More detailed information on these fuel types is listed in Exhibit 4-3 below.

Exhibit 4-3. RCI Sector Fuel Consumption Types

Residential	Commercial	Industrial	
Coal	Coal	Coking Coal Other Coal	
Natural Gas	Natural Gas	Natural Gas	
Petroleum: Distillate Fuel (Diesel) Kerosene LPG	Petroleum: Distillate Fuel Kerosene LPG Motor Gasoline Residue Fuel	Petroleum: Distillate Fuel Kerosene Lubricants Asphalt/Road Oil Crude Oil Feedstocks Unfinished Oils Waxes Aviation Gasoline Blending	LPG Motor Gasoline Residual Fuel Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Napthas Components Motor Gasoline Blending Components

Emissions from the combustion of each of these fuels are based on the following formulas:

Equation 4-1. General CO_2 Emissions Equation

Emissions ($MMTCO_2e$) = Emission factor (lbsC/BBtu) x 0.0005 short tons/lbs x combustion effeciency (% as a decimal) x 0.0972 (ratio of short tons to metric tons) divided by 1,000,000 x 44/12 to yield $MMTCO_2e$.

Equation 4-2. CO_2 Emissions Equation for the Industrial Sector

(Total consumption (BBtu) – [non-energy consumption (BBtu) x storage factor (%)] x emission factor (lbsC/BBtu) x combustion efficiency (as a decimal)) x 0.9072 (ratio of short ribs to metric tons) divided by 1,000,000 x 44/12 to yield $MMTCO_2e$.

In addition to total consumption data for the various fuel types, the RCI CO_2 emission calculations rely on three types of data. The first type of data is combustion efficiency (percent carbon oxidized). This percent is applied if the carbon is not completely oxidized during the combustion of fossil fuels. The fraction oxidized was assumed to be 100 percent for petroleum, coal, natural gas, and LPG based on guidance from IPCC (2006). If values other than module defaults are available for state-level combustion, they should be used and documented. Combustion efficiencies are used throughout the module and are pulled into each sector's worksheet.

The second type of data required for the control worksheet is the carbon content data, which is also pulled into the individual sector worksheets (depending on whether the fuel type is represented in the sector). The carbon content coefficients used in the CO_2FFC module are from the *EPA's Inventory of GHG Emissions* (EPA 2012). States are encouraged to use more detailed data if it is available and well documented. Carbon content represents the maximum amount of carbon emitted per unit of energy released, assuming 100 percent combustion efficiency. Coal has the highest carbon content of the major fuel types, petroleum has roughly 75 percent of carbon per energy as compared to coal, and natural gas has about 55 percent. However, carbon contents also vary within the major fuel types, as noted below.

The third and final type of data required for the control worksheet is the percent of carbon in each fuel that is stored from non-energy uses. Many fossil fuels have potential non-energy uses. For example, liquid petroleum gas (LPG) is used for production of solvents and synthetic rubber; oil is used to produce asphalt, naphthas, and lubricants; and coal is used to produce coke, yielding crude light oil and crude tar as by-products that are used in the chemical industry.

The carbon from natural gas used in ammonia production is oxidized quickly; many products from the chemical and refining industries are burned or decompose within a few years; and the carbon in coke is oxidized when the coke is used. The CO_2FFC module provides national default values for storage factors, but state-level fractions may differ depending on the type of non-energy uses. Where state-specific estimates are available, their use is preferred, if adequate supporting documentation is available. Data on the non-energy use storage factor is used in the industrial sector worksheet.

The industrial worksheet is unique because both total energy consumption and total non-energy consumption are required as inputs in order to calculate CO_2 emissions. Including activity data on non-energy use allows calculation of the amount of carbon from these fuels that is stored in non-energy products for a significant period of time (i.e., more than 20 years). The CO_2FFC module estimates carbon stored in non-energy uses for each state by multiplying the total number of Btu consumed by the default percent of that fuel type that is used for non-energy purposes, and then by a storage factor (i.e., the amount of carbon in non-energy uses that typically remains stored for longer than 20 years). This non-energy consumption is then subtracted from the total consumption to yield the net combustible consumption. From this point forward, the industrial worksheet functions in the same manner as the other sector worksheets. Consult equation 4-2 for a complete description of the calculation of emissions from the industrial sector.

Methane and Nitrous Oxide Emissions from the Stationary Combustion Module

The Stationary Combustion module calculates Methane (CH_4) and Nitrous Oxide (N_2O) emissions for the fuel types and end-use sectors indicated in Exhibit 4-3. The module provides default data for fuel types where possible.

Exhibit 4-3 Fuel Types Consumed by Sector - N_20 and CH_4 Combustion Emissions

Residential	Commercial	Industrial
Coal	**Coal**	**Coking Coal** **Independent Power Coal** **Other Coal**
Natural Gas	**Natural Gas**	**Natural Gas**
Petroleum: Distillate Fuel Kerosene LPG	**Petroleum:** Distillate Fuel Kerosene LPG Motor Gasoline Residual Fuel	**Petroleum:** Distillate Fuel Kerosene LPG Motor Gasoline Residual Fuel Lubricants Asphalt & Road Oil Crude Oil Feedstocks Napthas < 401ºF Other oils > 401ºF Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Naphthas Unfinished Oils Waxes Aviation Gasoline Blending Components Motor Gasoline Blending Components
Wood	**Wood**	**Wood**
Other	**Other**	**Other**

Source: U.S. EPA 2012.

The following language is extracted and edited from the *EPA 2013 SIT Module User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel* and *User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion.*

> This section provides instructions for using the Stationary Combustion module of the SIT to estimate CH_4 and N_2O emissions from sectors that consume fossil fuels and wood. Within the Stationary Combustion module, these sectors are residential, commercial, industrial, and electric power. Since the methodology is similar in all sectors, a general

methodology is discussed and specific examples for each sector are provided.

The Stationary Combustion module automatically calculates emissions after you enter energy consumption data (and the factors on the control worksheet). The tool provides default energy consumption data, which comes from the EIA's State Energy Consumption, Price, and Expenditure Estimates (SEDS) EIA (2012). However, other more state-specific data may be used if available.

The general equation used to calculate CH_4 and N_2O emissions from fuel combustion in the residential, commercial, and electric power sectors is shown in Equation 4-3. The equation used for fuels in the industrial end-use sector is similar, but includes the non-energy use of fuels, as shown in Equation 4-4.

Equation 4-3. General N_2O and CH_4 Emissions Calculation

$$\text{Emissions (MMTCO}_2\text{E)} = \text{Consumption (BBtu)} \times \text{Emission Factor (MT/BBtu)} \times \text{GWP} \div 1{,}000{,}000 \text{ (to yield MMTCO}_2\text{E)}$$

Equation 4-4. N_2O and CH_4 Emissions Calculation for the Industrial Sector

$$\text{Emissions (MMTCO}_2\text{E)} = [\text{Total Consumption (BBtu)} - \text{Non-Energy Consumption (BBtu)}] \times \text{Emission Factor (MT/BBtu)} \times \text{GWP} \div 1{,}000{,}000 \text{ (to yield MMTCO}_2\text{E)}$$

Default emission factors are provided in the Stationary Combustion module for all fuel types and sectors and are available from IPCC (2006). In general, emissions of CH_4 and N_2O will vary with the type of fuel burned, the size and vintage of the combustion technology, the maintenance and operation of the combustion equipment, and the type of pollution control technology used. Nitrous Oxide is produced from the combustion of fuels, with the level of N_2O emissions dependant on the combustion temperature. Methane and non-CH_4 volatile organic compounds are unburned gaseous combustibles that are emitted in small quantities due to incomplete combustion; more of these gases are released when combustion temperatures are relatively low. Emissions of these gases are also influenced by technology type, size, vintage, and maintenance, operation, and emission controls. Larger, higher efficiency combustion facilities tend to reach higher combustion temperatures and thus emit less of these gases. Emissions may range several orders of magnitude above the average for facilities that are improperly

> maintained or poorly operated, which is often the case for older units. Similarly, during start-up periods, default emission factors are provided in the Stationary Combustion module for all fuel types and sectors and are available from IPCC (2006). However, users may choose to specify their own.

The industrial worksheets are unique because both total energy consumption and total non-energy consumption are required as inputs in order to calculate CH_4 and N_2O emissions. This is necessary because most fossil fuels have at least some non-energy uses. For example, LPG is used for production of solvents and synthetic rubber; oil is used to produce asphalt, naphthas, and lubricants; and coal is used to produce coke, yielding crude light oil and crude tar as byproducts that are used in the chemical industry. Since these fuels are not combusted when used for purposes such as these, their consumption should be subtracted from statistics that include total fuel use.

Uncertainties Associated With Emission Estimates for the RCI Sector

As explained in the *User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion*:

> The amount of CO_2 emitted from fossil fuel combustion depends upon the type and amount of fuel consumed, the carbon content of the fuel, and the fraction of the fuel that is oxidized. Consequently, the more accurately these parameters are characterized, the more accurate the estimate of direct CO_2 emissions. Nevertheless, there are uncertainties associated with each of these parameters.
>
> Although statistics of total fossil fuel and other energy consumption are relatively accurate at a national level, there is more uncertainty associated with state-level data. In addition, the allocation of this consumption to individual end-use sectors (i.e. residential, commercial, industrial and transportation) at the state level is more uncertain than at the national level.
>
> Uses of fuels for non-energy purposes introduce additional uncertainty to estimating emissions, as the amount or rate at which carbon is emitted to the atmosphere can vary greatly depending upon the fuel and use.
>
> In comparison with fuel consumption data, the uncertainties associated with carbon contents and oxidation efficiencies are relatively low. Carbon contents of each fuel type are determined by the EIA by sampling and the assessment of market requirements and with the exception of coal, do not vary significantly from state to state.

As explained in the *User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion*:

The amount of CH_4 and N_2O emitted from stationary combustion depends upon the amount and type of fuel (coal, petroleum, natural gas, and wood) used, the type of technology in which it is combusted (e.g. boilers, water heaters, furnaces), and the type of emission control. In general, the more detailed information available on the combustion activity, the lower the uncertainty. However, the contribution of CH_4 and N_2O to overall emissions is small and the estimates are highly uncertain.

The combustion temperature at which the technology operates impacts the level of CH_4 and N_2O emissions. For instance, N_2O are negligible when temperatures reach below 800 or above 1200 degrees Kelvin; while CH_4 emissions are highest when combustion temperatures are low, usually in smaller combustion sources (IPCC/UNEP/OECD/IEA 1997). IPCC states that the Tier 1 approach is sufficient, and so is used for this module.

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

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Chapter 5 - Transportation

Overview

The Transportation Sector consists of CO_2, CH_4, and N_2O emissions from the combustion of fuels used for transportation. This consists primarily of on-highway vehicles, but also includes emissions from non-highway vehicles such as boats, locomotives, construction equipment and aircraft.

Emission estimates for this sector were generated using the February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode. Final transportation emissions are a combination of the EPA SIT Model *Mobile Combustion Emissions for* CH_4 *and* N_2O and the SIT *Model Fossil Fuel Combustion* for CO_2 emissions. These results are combined to produce total $MMTC0_2e$ emissions for the transportation sector. The two guidance documents describing how transportation emissions are calculated using the latest version of the SIT are found in *User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool (February 2013)* and *User's Guide for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion Using the State Inventory Tool* (February 2013).

As shown in the Executive Summary, emissions from the RCI sector accounted for approximately 24% of Colorado's GHG inventory for 2010.

SIT Model Results

The Transportation Sector GHG emissions estimates are the sum of transportation related CO2 emissions generated from the fossil fuel combustion module and CH_4 and N_2O emissions generated from the mobile combustion module. Exhibits 5-1 and 5-2 show the 2013 SIT Model results for each of these modules.

Exhibit 5-1: Colorado Carbon Dioxide Emissions from Transportation Related Fossil Fuel Combustion

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Transportation					
Coal					
Petroleum	18.66	21.8	25.17	29.16	29.16
Natural Gas	0.49	0.62	0.52	0.73	0.78
Total Emissions	**19.15**	**22.41**	**25.69**	**29.9**	**29.94**

Exhibit 5-2: Colorado Carbon CH_4 and N_2O Emissions from Mobile Combustion ($MMTCO_2e$)

Fuel Type/Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	0.571	0.676	0.654	0.488	0.310
Light-Duty Trucks	0.314	0.549	0.576	0.371	0.108
Heavy-Duty Vehicles	0.019	0.026	0.030	0.026	0.009
Motorcycles	0.001	0.001	0.001	0.001	0.002
Subtotal Emissions	0.905	1.252	1.261	0.886	0.429
Diesel Highway					
Passenger Cars	0.000	0.000	0.000	0.000	0.000
Light-Duty Trucks	0.000	0.000	0.000	0.000	0.000
Heavy-Duty Vehicles	0.004	0.006	0.007	0.008	0.010
Subtotal Emissions	0.005	0.006	0.008	0.009	0.010
Non-Highway					
Boats	0.000	0.000	0.001	0.001	0.001
Locomotives	0.008	0.012	0.005	0.002	0.007
Farm Equipment	0.006	0.008	0.007	0.005	0.006
Construction Equipment	0.004	0.005	0.010	0.012	0.012
Aircraft	0.027	0.032	0.033	0.052	0.048
Other	0.001	0.001	0.004	0.005	0.003
Subtotal Emissions	0.046	0.059	0.060	0.077	0.076
Alternative Fuel Vehicles					
Light Duty Vehicles	0.001	0.001	0.002	0.001	0.002
Heavy Duty Vehicles	0.002	0.003	0.003	0.007	0.010
Buses	0.000	0.000	0.000	0.000	0.001
Subtotal Emissions	0.003	0.004	0.006	0.009	0.013
GRAND TOTAL	0.959	1.321	1.334	0.981	0.528

Data and Methodologies

The Transportation Sector GHG emissions estimates are the sum of CH_4, N_2O and CO_2 emissions from the 2013 SIT Model run in default mode. These emissions are extracted from the CO_2 Fossil Fuel Module and the N_2O and CH_4 Mobile Combustion Module.

CO_2 from Fossil Fuel Combustion

The CO_2FFC module of the SIT estimates CO_2 emissions from various sectors that consume fossil fuels. Specifically, the CO_2FFC module, breaks out combustion related CO_2 emissions for the following sectors: residential; commercial; industrial; transportation; and electric power. As a general matter, to calculate these emissions for the various sectors, the module employs the following general equation:

Equation 5-1. General Emissions Equation from CO_2FFC Module

Emissions ($MMTCO_2E$) =
Consumption (BBtu) × Emission Factor (lbs C/BBtu) × 0.0005 short ton/lbs × Combustion Efficiency (% as a decimal) × 0.9072 (Ratio of Short Tons to Metric Tons) ÷ 1,000,000 × (44/12) (to yield $MMTCO_2E$)

Information utilized in running this equation includes:

- Fossil fuel energy and non-energy consumption by fuel type and sector (non-energy consumption applies only to the industrial sector);
- Carbon content coefficients;
- Carbon stored in products; and
- Percentage of carbon oxidized during combustion

For the Transportation Sector, the Fossil Fuel Combustion module uses fuel consumed per year for the transportation sector in Colorado as detailed in Exhibit 5-3, shown in British Thermal Units (BTUs).

Exhibit 5-3: Colorado Fuel Use for Transportation Sector

(in Billion British Thermal Units (BTU)

Fuel Type	1990	1995	2000	2005	2010	2020	2030
Aviation Gasoline	841	624	790	655	553	357	382
Distillate Fuel	40100	50497	66606	77044	87533	114693	124647
Jet Fuel-Kerosene	33053	40083	42993	69852	63841	80465	87719
Jet Fuel-Naptha	1498	1919	-	-	-	-	-
LPG	286	263	216	296	267	668	787
Motor Gasoline	182468	209401	238500	256543	250792	242208	231673
Residual Fuel	-	-	-	-	-	-	-
Natural Gas	9152	11630	9760	13841	14759	15714	20105
Other	-	-	-	-	-	-	-
Lubricants	2499	2385	2547	2149	2005	1924	2060

State fuel sales are tracked by the Colorado Department of Revenue for each of the fuel types due to the taxation requirements. The Colorado Department of Transportation submits these and other transportation information to a Federal Highway Administrations (FHWA) transportation data system. The SIT module links the emission factors (for each fuel), and the fuel consumed from the national data base, to generate emissions of CO_2 on a statewide basis. Gallons of fuel, represented in BTU are broken into the categories listed in Exhibit 5-3.

The FFC module uses the emission factors and multiplies those times the amount of fuel used in each of the eight transportation sectors (gasoline, distillate fuel, etc.). For each amount of fuel consumed, an emission factor is applied which varies from a low of 31.87 pounds of carbon per million BTU to a high of 45.11 lb. Within three categories (motor gasoline, LPG, and jet fuel-kerosene) slight adjustments to emission factors occur by year. No adjustment to the emission factors is made to compensate for altitude changes in the default mode. One is allowed to make such adjustments if data is available. Multiplying fuel use, times the emission factor, produces an annual emission rate which is the converted to $MMTCO_2e$ as described both in the spreadsheet and the EPA Fossil Fuel Combustion Workbook. An example calculation follows for motor gasoline for 1990 is shown in equation 5-2.

Equation 5-2 Motor Gasoline 1990
182,468 BBTU x 42.83 lbs C/MBTU x 100% combustion efficiency x 1,000 million/billion x 1 ton/2,000 lbs per short ton x .9072 Metric Tons/short ton x 1/1,000,000 x 44/12 CO_2/C ratio = 12.998 $MMTCO_2e$

For further detailed information on the operation and formulas for this module, click on the SIT Model CO_2 *Fossil Fuel Combustion User's Guide* used to run the Fossil Fuel Combustion Module to obtain CO_2 emissions.

CH_4 and N_2O from Mobile Combustion

A second emissions profile is generated from the Mobile Combustion (MC) SIT model by multiplying emissions factors for CH_4 and N_2O times the vehicle miles traveled for each vehicle class. Exhibit 5 summarizes these emissions from the MC SIT module. The EPA Emissions Workbook describes the calculations in more detail. As seen in Exhibit 5-2, emissions of CH_4 and N_2O from Mobile Sources are derived for:

- Gasoline Highway (passenger cars, light-duty trucks, heavy trucks, motorcycles)

- Diesel Highway (passenger cars, light-duty trucks, heavy-duty vehicles)
- Non-Highway (boats, locomotives, farm equipment, construction equipment, aircraft, other- including as recreational vehicles
- Alternative Fuel Vehicles (light-duty vehicles, heavy duty vehicles, buses)

The Mobile Combustion Module of the SIT includes CH_4 and N_2O emissions for highway vehicles, aviation, boats, off-road vehicles, locomotives, other non-highway sources and alternative fuel vehicles. While CO_2 emissions from the Transportation Sector are calculated using annual fuel sales, the CH_4 and N_2O are calculated based on annual vehicle miles traveled (VMT) for each vehicle type and specific emission factors for the vehicle type by model year using the following general equation on mobile combustion:

$$\text{Emissions} = \Sigma(EF_{abc} \times \text{Activity}_{abc})$$

Where,

EF = emissions factor (e.g., grams/kilometer traveled);
Activity = activity level measured in the units appropriate to the emission factor (e.g., miles);
a = fuel type (e.g., diesel or gasoline);
b = vehicle type (e.g., passenger car, light duty truck, etc.); and
c = emission control type (if any)

The VMT breakdown for highway vehicles used in this inventory is listed in Exhibit 5-4 below:

Exhibit 5-4 2013 SIT Model Total Annual VMT In Millions by Vehicle Class

	1990	1995	2000	2005	2010
HDDV	1,664	2,359	2,861	3,208	4,388
HDGV	386	441	456	474	250
LDDT	202	326	417	485	321
LDDV	172	161	145	146	129
LDGT	7,039	11,056	13,578	16,131	9,552
LDGV	17,604	22,572	24,158	27,354	32,007
MC	110	142	158	164	293
Total	**27,718**	**35,057**	**41,771**	**47,962**	**46,940**

Note: Colorado VMT data is provided annually to the Federal VMT data base by the Colorado Department of Transportation, and is used by EPA in the SIT Model.

For further detailed information on the operation and formulas for this module, click on the SIT Model *Mobile Combustion User's Guide* used to run the Mobile Combustion N_2O and CH_4 Emissions.

Transportation Sector Metric Changes

As a result of new CAFÉ standards, there will be a reduction of greenhouse gas emissions by lowering gasoline use. Diesel use will also increase, as shown in Exhibit 5-5. An examination of the SIT Model assumptions for vehicle fuel standards indicate that the new CAFÉ Standards have been incorporated in the model assumptions.

There have been changes in fossil fuel use in regard to natural gas production and activity related to oil and gas production in Colorado. In addition, the recession of 2008-2009 decreased driving for certain purposes – recreational and commute – for a period of time, as well as a spike in gasoline prices in the summer of 2010. It is assumed for purposes of this update, that these changes in fossil fuel consumption for transportation were temporary and have been accounted for in the 2013 version of the SIT, within the Fossil Fuel Use Module.

Exhibit 5-5: Transportation Sector Emissions in Colorado by Fuel Type in $MMTCO_2$

	1990	1995	2000	2005	2010	2011	2015	2020	2030
Fuel Type	19.15	22.41	25.69	29.9	29.94	30.45	31.75	32.6	33.37
Natural Gas	0.48	0.62	0.52	0.73	0.78	0.77	0.8	0.83	1.07
Distillate Fuel	2.96	3.71	4.92	5.69	6.47	6.3	7.81	8.48	9.21
Jet Fuel, Kerosene and Naptha	2.46	2.98	3.11	5.05	4.61	5.56	5.61	5.81	6.34
LPG	0.02	0.02	0.01	0.02	0.16	0.04	0.04	0.04	0.05
Motor Gasoline	13	14.86	16.91	18.22	17.89	17.64	17.34	17.28	16.53
Aviation Gasoline	0.06	0.04	0.06	0.04	0.04	0.02	0.02	0.02	0.03
Lubricants	0.17	0.16	0.17	0.14	0.13	0.12	0.13	0.13	0.15

Note: 1990-2010 values are extracted from CO_2 emissions from combustion of fossil fuel sub-sheet. The SIT Projection Tool is used for 2011-2030 values.

Uncertainties Associated With Emission Estimates for the Transportation Sector

The following discussion on Transportation Sector uncertainties is extracted and edited from the EPA 2013 SIT Model *User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion and the User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion.*

Highway Vehicle Uncertainties

Methane and nitrous oxide emissions estimates are based on activity data – vehicle miles of travel, and emission factors. Information on VMT for each state is gathered annually by the Federal Highway Administration. These estimates are based on information reported by each state. The methods states use to gather VMT data vary, and may include the use of data sources such as tax records for fuel sales. Uncertainty increases are due to state-specific differences in consumer preferences for vehicles types, due to a variety of social, legal, and economic reasons. Data from Colorado air quality programs suggest that Colorado consumers have a higher than average preference for SUVs and trucks, over the national average.

Uncertainties surrounding emission factors are relatively high, since emissions vary depending on a number of factors. Most CH_4 and N_2O emission factors were taken from IPCC/UNEP/OECD/IEA (1997) and were developed using EPA's MOBILE5a Model. While the Air Pollution Control Division has the capability of running the MOVES Model, it has not been determined whether the addition of MOVES Model data into the SIT process for this inventory update would introduce any significant changes to mobile emissions estimates. It is worth noting that although EPA requires the MOVES Model emissions calculations for conformity, NEPA, and MSAT reporting, EPA defers to the IPCC/UNEP/OECD/IEA 1997 protocols for SIT GHG estimates.

The Federal Highway Administration is updating its Greenhouse Gas (GHG) Inventory Model for Mobile Source GHG emissions inventory planning. The model is called the Energy and Emissions Reduction Policy Analysis Tool (EERPAT). It will be used by CDOT and assist with the agencies' MOVES emissions modeling for highway projects. The EERPAT Model may produce better VMT and vehicle compositions than modeling used for this inventory, and should be considered in future updates.

Non-Highway Vehicle Uncertainties

Emission estimates for non-highway sources are also driven by activity data, such as fuel consumption and emission factors. Fuel consumption data is generally gathered at the national level, and then apportioned to states. This apportionment introduces some uncertainty. Some states, including Colorado, have fuel sales data, which would likely reduce uncertainty from less quantitative methods.

Uncertainties in Fossil Fuel Combustion for Transportation Sector

The amount of CO_2 emitted from fossil fuel combustion depends upon the type of fuel consumed, the carbon content of the fuel and the amount of CO_2 produced per unit of fuel that is oxidized. Consequently, the more accurately these parameters are characterized, the more accurate the estimate of direct CO_2 emissions. There are uncertainties associated with each of these parameters.

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

References

U.S. EPA. 2013. User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool (February 2013)

______. 2013. User's Guide for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion Using the State Inventory Tool (February 2013).

Chapter 6 – Industrial Processes

Background

The Industrial Processes Sector consists of CO_2, N_2O, hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6) emissions from various industrial processes. For Colorado these processes consist of the following: cement production, lime manufacture; limestone and dolomite use; soda ash manufacture and consumption; iron and steel production; ammonia manufacture; nitric and adipic acid production; aluminum production; HCFC-22 production; consumption of substitutes for ozone depleting substances; semiconductor manufacture; electric power transmission and distribution; and magnesium production and processing.

Emission estimates for this sector were generated using the Industrial Processes Module for February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode. This 2013 release was used for the final state inventory update and provides modeled data through 2010. Projections to 2030 were developed by using the EPA projection tool as described in Chapter 2. For more specific information consult the *User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF6 Emissions From Industrial Processes Using the State Inventory Tool* (2013).

As shown in the Executive Summary, estimated emissions from industrial processes are about 3% of the gross Colorado inventory in 2010.

SIT Model Results

Emission results from the Industrial Processes Module are shown below in Exhibit 6-1:

Exhibit 6-1: Colorado Industrial Processes Emissions

($MMTCO_2e$)	1990	1995	2000	2005	2010
Carbon Dioxide Emissions					
Cement Manufacture	0.317	0.448	0.554	0.623	0.559
Lime Manufacture		0.100	0.095	0.295	0.275
Limestone and Dolomite Use		0.019	0.028	0.030	0.005
Soda Ash	0.036	0.038	0.041	0.041	0.036
Urea Consumption	0.003	0.003	0.002	0.004	0.004
Iron & Steel Production			0.750	0.340	0.305
Subtotal Emissions	**0.356**	**0.636**	**1.470**	**1.334**	**1.183**
HFC, PFC, and SF_6 Emissions					
ODS Substitutes	0.004	0.438	1.167	1.561	1.866
Semiconductor Manufacturing	0.053	0.089	0.117	0.085	0.104
Electric Power Transmission and Distribution Systems	0.303	0.251	0.189	0.184	0.166
Subtotal Emissions	**0.360**	**0.778**	**1.474**	**1.831**	**2.137**
GRAND TOTAL	**0.716**	**1.414**	**2.944**	**3.164**	**3.320**

Data and Methodologies

The Industrial Processes Module has separate worksheets for the various processes that are assessed. Exhibit 6-2 summarizes data used in calculating emissions for these various processes:

Exhibit 6-2: Industrial Processes Module: Sectors, Data Requirements and Gases Emitted

Module Worksheet	Data Required	Gas(es)
Cement Production	Emission factors and production data for clinker and cement kiln dust (CKD)	CO_2
Lime Manufacture	Emission factors and production data for high-calcium lime, and dolomitic lime	
Limestone and Dolomite Use	Emission factors and consumption data for limestone, dolomite, and magnesium produced from dolomite	
Soda Ash Manufacture and Consumption	Emission factors and consumption data for manufacture and consumption of soda ash	
Iron and Steel Production	Emission factors and production data for Basic Oxygen Furnace (BOF) at Integrated Mill with Coke Ovens, Basic Oxygen Furnace (BOF) at Integrated Mill without Coke Ovens, Electric Arc Furnace (EAF), and Open Hearth Furnace (OHF)	
Ammonia Manufacture	Emission factors and production and consumption data for ammonia production, and urea consumption	
Nitric Acid Production	Emission factor, production data, and Percent N_2O Released after Pollution Control for nitric acid production	N_2O
Adipic Acid Production	Emission factor, production data, and Percent N_2O Released after Pollution Control for adipic acid production	
Aluminum Production	Emission factor and production data for aluminum production	HFC, PFC and SF_6
HCFC-22 Production	Emission factor and production data for HCFC-22 production	
Consumption of Substitutes for Ozone-Depleting Substances (ODS)	No input data required*	
Semiconductor Manufacture	No input data required*	
Electric Power Transmission and Distribution	Emission factor and SF_6 consumption data for electric power transmission and distribution	
Magnesium Production and Processing	Emission factor and consumption data for primary production, secondary production, and casting	

*According to the most recent inventory guidance, emissions of HFCs, PFCs, and SF_6 from ODS substitutes and semiconductor production can be estimated by apportioning national emissions to each state based on population. Because this tool apportions national emissions based on state population, the emission factors and activity data for these sources are not required.

Selected equations for these processes include the following:

Equation 1. Emission Equation for Cement Production

Emissions ($MTCO_2E$) =
Production (metric tons) × Emission Factor (t CO_2/t production) + Emissions from Cement Kiln Dust (Metric tons CO_2)

Equation 2. Example Calculation for Hydrated Lime Correction

Corrected Lime Content of High-Calcium Hydrated Lime (metric tons) =
High-Calcium Hydrated Lime Production (metric tons) x (1 − 0.24 metric tons water/metric ton high-calcium hydrated lime)

Equation 3. Emission Equation for Lime Manufacture

Emissions ($MTCO_2E$) = [Production (metric tons) - Sugar Refining and Precipitated Calcium Carbonate Production (metric tons) × CO_2 Reabsorbtion Factor (80%)] × Emission Factor (MT CO_2/MT production)

Equation 4. Emission Equation for Limestone and Dolomite Use

Emissions ($MTCO_2E$) =
Consumption (metric tons) × Emission Factor (MT CO_2/MT production)

Equation 5. Emission Equation for Soda Ash Manufacture and Consumption

Emissions ($MTCO_2E$) =
Manufacture/Consumption (metric tons) × Emission Factor (MT CO_2/MT production)

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

References

US EPA. 2013. “User’s guide for estimating carbon dioxide, nitrous oxide, HFC, PFC, and SF6 emissions from industrial processes.”

Chapter 7 – Coal Mining and Abandoned Mines

Overview

The Coal Mining Sector consists of methane emissions in Colorado related to the **production** of coal at active mines and ongoing methane leakage from abandoned coal mines. The origin of the emissions are distinctly different from those calculated in the fossil fuel combustion module; stationary combustion module; and residential, industrial and commercial combustion module. All these later three estimate emissions of CH_4, from the **combustion** of coal. The combustion of coal to generate electricity and power industrial sources are expressed in other parts of the Colorado inventory.

Emission estimates for this sector were generated using the Coal Mining and Abandoned Coal Mines Module for the February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode. The February 2013 *User's Guide for Estimating Methane Emissions from Coal Mining and Abandoned Coal Mines Using the State Inventory Tool* describes in more detail the methods and process for calculating methane emissions from this source category (EPA 2013).

As shown in the Executive Summary, emissions from the Coal Mine Sector accounted for approximately 6% of Colorado's gross GHG inventory for 2010.

SIT Model Results

Exhibit 7-1 summarizes methane emissions from coal mining in Colorado.

Exhibit 7-1: Summary of Colorado CH_4 Emissions From Coal Mining Activities ($MMTCO_2e$)

	1990	1995	2000	2005	2010
Total CH4 from Coal Mining	**4.81**	**3.73**	**5.32**	**6.61**	**7.54**
Coal Mining	**4.16**	**3.06**	**4.36**	**5.49**	**6.63**
Abandoned Coal Mines	0.64	0.67	0.96	1.12	0.90
Vented	0.04	0.03	0.10	0.07	0.05
Sealed	0.60	0.64	0.86	1.05	0.84
Flooded	0.00	0.00	0.00	0.01	0.00

Data and Methodologies

For this 2013 GHG inventory all default assumptions from the Coal Mining and Abandoned Coal Mine module were used to calculate emissions. As with the other SIT modules, the EPA updated emission factors as well as the source(s) of Colorado data. Specifics of the sources of data are discussed below in each of the sub-sections. The default data for mining relies on Colorado coal production data for both surface and underground mines. A listing of abandoned coal mines in the state is also part of the national data base. Thus, Colorado specific information serves as a backbone of those calculations.

For **coal mining**, total CH_4 emissions are the sum of gasses from underground, surface coal mines, and post mining activities. For **underground mining**, CH_4 from ventilation, degasification, and energy related use of methane for equipment operations are accounted for. The **surface mining** CH_4 emission rate is based on basin specific emission factors**. Post mining activities** include coal handling and transportation and are the product of the amount of coal produced multiplied by basin specific, and/or mine specific, emission factors. Exhibit 7-2, extracted from the user's guide, provides a listing of the specific elements used to calculate mining emissions (EPA 2013).

Exhibit 7-2: Required Inputs for the Coal Module

Coal Module Sectors	Input Data Required
CH4 from Coal Mining	
Surface Mining Activities	Basin-specific emission factors (ft^3 CH_4/short ton coal)
	Surface coal production, by year and basin ('000 short tons)
Underground Mining Activities	Measured ventilation emission, by year (million ft^3)
	Degasification system emissions, by year (million ft^3)
	CH_4 recovered from degasification systems and used for energy, by year (million ft^3)
Surface Post-Mining Activities	Basin-specific emission factors (ft^3 CH_4/short ton coal)
	Underground coal production, by year and basin ('000 short tons)
Underground Post-Mining Activities	Basin-specific emission factors (ft^3 CH_4/short ton coal)
	Underground coal production, by year and basin ('000 short tons)
CH_4 from abandoned Coal Mines	A list of abandoned coal mines with the following information for each:
	Mine name or number
	County of location
	Coal rank (bituminous, sub-bituminous, or anthracite or basin
	Year abandoned
	CH_4 emissions at time of abandonment (MCF/day)
	Current status of mine(venting, sealed, or flooded)
	Percent sealed (choose among 50%, 80%, and 95% sealed
	CH_4 recovered (cubic meters per year)

Methodology

Two emission sources are considered in this module; emissions from abandoned coal mines and emissions from mining activities. The calculation logic is described fully in the information box in the top of the sub-sheet. The essence of the calculation is described in Equations 7-1 and 7-2 below.

Equation 7-1. Methane Emissions Calculation Scheme For Underground Mining

Emissions ($MTCO_2e$= {Measured Ventilation Emissions (millions ft^3) + [Degasification Systems Emissions (millions ft^3) - CH_4 Recovered from Degasification Systems and Used for Energy (millions ft^3)}} * 19.2 g/ft^3 CH_4 * $10^6 ft^3$/million Ft^3 * 10^{-6} MT/g * 21 (GWP of CH_4)
(EPA 2013; 1.9)

Equation 7-2. Methane emissions calculation from surface coal production

Emissions ($MTCO_2e$) = Surface Coal Production ('000 short tons) * Basin Specific Emission Factor (ft^3/short ton) * 19.2 g/$ft^3 CH_4$ * $10^3 ft^3$/'000 ft^3 * 10^{-4} MT/g * 21 (GWP of CH_4)
(EPA 2013; 1.9)

The SIT tool has an internal data base of annual tons of coal produced in both underground and above ground coal mining in Colorado from 1990-2010 (EIA 2013). Exhibit 7-3 captures the five year increments of coal produced in thousands of short tons/year. This data is used to calculate the vented and above ground emissions. Surface coal mining emissions are calculated by using an emission factor of 66.2 cubic feet of methane emitted per short ton produced. This is a basin specific emission factor provided by the model. Tons of emissions are calculated directly by multiplying the surface tons of coal produced times this emission rate and then the factor of 21 multiplier is applied to convert methane to carbon dioxide equivalents. Underground mining emission calculations rely on the measured ventilation emissions in millions of cubic feet which is added to the degasification emissions to produce the millions of cubic feet of methane produced each year. The measured ventilation rate for the mine and degasification emissions are added and any allowance for degasification equipment is subtracted from this total.

Exhibit 7-3 Summary of Colorado coal production in short tons/year

	1990	1995	2000	2005	2010
Coal Mining Underground	10,621	17,187	18,882	28,439	20,085
Coal Mining Above ground	8,281	8,523	9,156	10,071	5,078
Total Coal production	18,902	25,710	28,038	38,510	25,163

Methane from abandoned coal mines involves a more complicated calculation scheme and is explained in detail in the Coal SIT module on the sub-sheet CH_4 from Abandoned Coal Mines. The data used for the calculation is Colorado specific from a national listing of abandoned coal mines. This also contains information on leakage rates. Exhibit 7-4 provides a list of the Colorado abandoned coal mines and the year they were abandoned. Further details about these mines are captured in the SIT module. Abandoned coal mines are tracked on a statewide basis and the default inventory relies on the data catalog for Colorado to produce emissions estimates.

Exhibit 7-4 Closed Coal Mines in Colorado Used As the Basis for Calculating Methane Emissions from Leaks

	Mine Name	County	Basin	Year Closed
1	Sanborn Creek	Delta	Piceance	2003
2	Dutch Creek No 1	Pitkin	Piceance	1992
3	Dutch Creek No. 2	Pitkin	Piceance	1988
4	L.S. Wood	Pitkin	Piceance	1985
5	Coal Basin	Pitkin	Piceance	1981
6	Bowie No 1	Delta	Piceance	1998
7	Hawks Nest East	Delta	Piceance	1986
8	Bear Mine	Gunnison	Piceance	1982
9	Bear Creek Mine	Gunnison	Piceance	1979
10	Somerset Mine	Delta	Piceance	1989
11	Roadside North Portal	Mesa	Piceance	2000
12	Roadside South Portal	Mesa	Piceance	2000
13	Bowie #3	Delta	Piceance	2005
14	Thompson Creek No. 1	Pitkin	Piceance	1986
15	Eagle No 5	Moffat	Piceance	1996
16	Bear No 3	Gunnison	Piceance	1997
17	Hawks Nest West	Delta	Piceance	1981
18	Rienau No 2	Rio Blanco	Piceance	1986
19	Golden Eagle	Las Animas	Raton	1996
20	Allen East & West	Las Animas	Raton	1982
21	Southfield Mine	Fremont	Raton	2001

Uncertainties Associated With Emission Estimates for the Coal Mining Sector

Since coal mine emissions are largely dependent on the amount of coal produced, differences between default and state specific production data may be an important overall consideration in the coal methane estimates. The Colorado Mining Association (CMA) reports on annual coal production in the state. CMA's report on 2012 indicates that 29 million tons of coal was produced in Colorado, ranking Colorado 9th in the U.S. as far as coal production (2013). This is within the range of historical production values as reported in the SIT model as shown in Exhibit 7-3. The CMA report also indicates that overall coal production increased 48% from 2000-2010. The Colorado inventory shows methane emissions increasing from coal mining from 4.36 $MMTCO_2e$ in 2000 to 6.63 $MMTCO_2e$in 2010; a 43% increase. This appears to agree well with the CMA data.

Recent modifications at one Colorado mine included the installation of a methane recovery and electrical generation system. Such modifications may significantly reduce underground coal emissions in the future.

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

References

Colorado Mining Association. Mining facts and resources: Facts about Colorado mining. http://www.coloradomining.org/mc_miningfacts.php (accessed 3/Aug/2013).

EIA. Annual energy outlook 2013. http://www.eia.gov/forecasts/aeo/source_coal.cfm (accessed 3 August, 2013).

EPA. 2013. *User's guide for estimating methane emissions from coal mining and abandoned coal mines using the State Inventory Tool.* ICF International. February. 2013.

Chapter 8 – Gas Production

Overview

The Oil and Gas Production Sector consists of CH_4 and CO_2 emissions associated with the extraction, production and transmission of natural gas. The origin of these emissions are distinctly different from those calculated in the fossil fuel combustion module and stationary combustion module, both of which estimate of CO_2, CH_4, and N_2O from the **combustion** of oil related products, and natural gas. The combustion of fossil fuels to generate electricity, produce heat for homes, and power industrial and mobile sources are reflected in other parts of the Colorado inventory.

Emission estimates for this sector were generated using the Natural Gas and Oil Systems Module for the February 11, 2013 version of the EPA State Inventory Tool (SIT) model. As discussed in greater depth below, certain adjustments were made to the default values for this module to account for better Colorado specific data. For a complete description of this source category refer to the *SIT Natural Gas and Oil System User's Guide (*EPA 2013b*)*.

As shown in the Executive Summary, estimated emissions from oil and gas production are about 8% of the gross Colorado inventory in 2010.

SIT Model Results

Exhibit 8-1 summarizes GHG emissions from oil and gas production in Colorado with the model run in default.

Exhibit 8-1: Colorado Emissions from Oil and Gas Production in the Default Mode (MMTCO$_2$e)

	1990	1995	2000	2005	2010
Natural Gas	1.322	1.613	5.119	5.119	6.486
Oil	0.394	0.382	0.268	0.346	0.498
Total	**1.715**	**1.995**	**5.387**	**5.465**	**6.984**

Data and Methodologies

Emission estimates for this sector were generated using the Natural Gas and Oil Systems Module for the February 11, 2013 version of the EPA State Inventory Tool (SIT) model with certain adjustments to the Colorado default data in the module.

Emission sources for this module cover a wide range of activities associated with the production and transmission of natural gas and petroleum. Exhibit 8-2 is extracted from the User's Guide and lists all the input requirements, many of which are provided by the model from national data tables.

Exhibit 8-2 Data Requirements for the Natural Gas and Oil Systems Module

Module Worksheet	Activity Data and Emission Factors Required
Natural Gas-Production	Number of wells
	Emission factor MT CH_4/well
Natural Gas-Transmission	Miles of gathering pipeline
	Number of gas processing plants
	Number of gas transmission compressor stations[1]
	Number of gas storage compressor stations[1]
	Miles of transmission pipeline
	Number of LNG storage compressor stations
	Emission factors for all the above (MT CH_4 unit)
Natural Gas-Distribution	Miles of cast iron distribution pipeline[2]
	Miles of unprotected steel distribution pipeline[2]
	Miles of protected steel distribution pipeline[2]
	Miles of plastic distribution pipeline[2]
	Number of services
	Number of unprotected steel services
	Number of protected steel services
	Emissions factors for all the above (MT CH_4/unit)
	Emission factor for alternate method* (MT CH_4/mile of distribution
Natural Gas–Venting and Flaring	Billion BTUs of natural gas vented and flared
	Emission factor (MT CO2/Billion Btu natural gas vented and flared)
Petroleum Systems	Barrels of oil produced
	Barrels of oil refined
	Barrels of oil transported
	Emission factor (kg CH_4/1000 barrels)

[1] An alternate method is available in which only total transmission pipeline miles a

[2] An alternate method is available in which only total distribution pipeline miles ar

As reflected in Exhibit 8-2, there are five categories of emission sources that are combined to calculate the overall GHG emissions from the natural gas and oil production sector: 1) natural gas production; 2) natural gas transmission; 3) natural gas distribution; 4) natural gas venting and flaring; and 5) petroleum systems (oil production). The data and methodologies used to calculate emissions from each of these subsectors are discussed separately below.

Natural Gas Production

As calculated by the SIT model, the majority of GHG emissions related to natural gas and oil activities in Colorado come from the natural gas production subsector. To calculate these emissions, the model utilizes an emission factor expressed in metric tons of CH_4 per year multiplied by the total number of wells.[6] Metric tons of CH_4 are converted to CO_2e by multiplying the output times the global warming potential factor of 21. See the equation below.

Equation 8-1: Calculation scheme for natural gas production 2010

$MMTCO_2e$ from Natural Gas Production= Total well count x 10.62 $MTCH_4$/yr/activity factor x 21 (GWP)/1,000,000

As a result of this methodology, calculated GHG Emissions from the oil and gas production sector in Colorado are heavily dependent on the total number of wells in Colorado. Run in default mode, the model uses well count numbers for Colorado from the Energy Information Administration (EIA). (EIA 2013b). A comparison of these default well counts with well count data from the Colorado Oil and Gas Conservation Commission shows a growing disparity in the EIA and COGCC data starting in 2003. The disparities between these two data sources, and the impact on calculated emissions is reflected in Exhibit 8-3.

Exhibit 8-3: Well count data-SIT Default versus COGCC

Year	SIT Module Well count	Default SIT Emissions $MMTCO_2e$	COGCC Well Counts	SIT Emissions Using COGCC Well Counts	% difference (Alter - default/ default)
1990	5,741	1.09	Not avail.	1.32	21%
1991	5,562	1.09	Not avail.	1.23	12.80%
1992	5,912	1.19	Not avail.	1.28	7.60%
1993	6,372	1.32	Not avail	1.42	7.50%
1994	7,056	1.51	Not avail	1.63	7.90%
1995	7,017	1.54	Not avail	1.61	4.50%
1996	8,251	2.06	Not avail	2.12	2.60%
1997	12,433	2.82	Not avail	2.93	3.50%
1998	13,838	3.14	Not avail	3.2	1.90%
1999[a]	13,838[a]	3.14	Not avail	5.13	63.0%[a]
2000	22,442	5.08	24,126	5.5	1.20%
2001	22,117	4.97	22,190	5.15	2.80%
2002	23,554	5.27	22,742	5.14	0.90%
2003	18,774	4.19	23,300	5.26	31.00%
2004	16,718	3.73	24,589	5.54	68.60%
2005	22,691	5.06	28,164	6.34	34.00%
2006	20,568	4.59	30,135	6.78	56.20%
2007	22,949	5.12	32,135	7.23	56.60%
2008	25,716	5.74	35,978	8.1	56.10%
2009	27,021	6.03	40,184	9.03	56.60%
2010	28,813	6.43	42,324	9.49	56.60%

[1] The emission factor utilized varies slightly from year to year ranging from 9.07 in 1990 to 11.88 in 1996 to 10.62 for the years 2005-2010.

For the purposes of this inventory, well counts from the COGCC were substituted for the default well counts resulting in higher overall GHG emissions for this sector relative to the default emission values originally calculated in the draft inventory.

Exhibit 8-4 summarizes GHG emissions from oil and gas production in Colorado with the modifications to well counts shown above.

Exhibit 8-4: Colorado Emissions from Oil and Gas Production with New Well Counts ($MMTCO_2e$)

	1990	1995	2000	2005	2010
Natural Gas	1.31	1.61	5.5	6.34	9.49
Oil	0.39	0.39	0.28	0.35	0.5
Total	1.7	2	5.78	6.69	9.99

Natural Gas Transmission

The model calculates GHG emission from natural gas transmission based on the miles of pipeline, number of compressor stations and number of gas processing plants. Exhibit 8-5 shows the emission factors used in the model to calculate transmission emissions.

Exhibit 8-5: SIT Module Default Emission Natural Gas Transmission

	Default Emision Factor
Metric tons of CH_4 per mile of gathering pipeline	0.4
Metric tons of CH_4 per gas processing plant	1249.95
Metric tons of CH_4 per gas transmission compressor station	983.66
Metric tons of CH_4 per gas storage compressor station	964.15
Metric tons of CH_4 per mile of transmission pipeline	0.62
Metric tons of CH_4 per LNG storage compressor station	1184.99
Note: the default model does not contain miles of pipeline or facility numbers so these factors are provided for future consideration if such figures are added to the model	

While the model provides default emission factors, no default miles of pipeline, number of gas processing plants, or compressor stations are provided in the default data base. Accordingly, when the model was run in default mode, emissions from the transmission subsector were calculated as zero. Several sources of data are indicated as being available to populate the miles of gathering and transmission pipelines in the State. Sources of data for compressor stations, processing plants and storage facilities are also listed but no default data is provided for this part of the calculation.

In connection with this final inventory various sources of data on pipeline miles, gas processing plants, and compressor stations were looked at to determine if they should be used to generate non-default values for this subsector. Because no complete data set exists, and because of the inconsistencies and uncertainties associated with the data sets examined, this final inventory does not include emissions for the transmission subsector. Based on an analysis of the available 2010 data, the SIT model shows transmission emissions would be between 0.75-1.0 MMTCO_2e. This would be an increase of 10% in the natural gas estimates for this category. This should be considered in a future inventory update.

Natural Gas Distribution

The model calculates GHG emission from natural gas distribution based on the miles of pipeline, broken out by pipeline material type, in the distribution system. The model provides an alternate method using total miles of pipeline, with no differentiation between material type, and the number of “services” (gas meters). Exhibit 8-6 shows the emission factors used for these alternative methods.

Exhibit 8-6: Emission Factors from SIT Module for Natural Gas Distribution

	Default Emision Factor
Preferred Methodology	
Metric tons of CH_4 per mile of cast iron distribution pipeline	5.8
Metric tons of CH_4 per mile of unprotected steel distribution pipeline	2.12
Metric tons of CH_4 per mile of protected steel distribution pipeline	0.06
Metric tons of CH_4 per mile of plastic distribution pipeline	0.37
Alternate Methodology	
Metric tons of CH_4 per mile of distribution pipeline	0.54
Metric tons of CH_4 per service	0.02
Metric tons of CH_4 per unprotected steel services	0.03
Metric tons of CH_4 per protected steel services	0.003

As with the transmission subsector, while the model provides default emission factors it does not include default data to calculate distribution emissions. Accordingly, when run in default mode, the model calculates zero emissions from this subsector. Similar to what was done with respect to the transmission subsector, different sources of information regarding distribution pipeline miles and gas services were considered, but ultimately it was determined that there was not a sufficient factual basis to include emissions from the distribution subsector in this final inventory. Based on an analysis of the 2010 data, it appears emissions from this subsector in Colorado in 2010 would likely be in the range of 0.5-1.4 $MMTCO_2e$. This should be considered in a future inventory update.

Natural Gas Venting and Flaring

Venting and flaring of natural gas is a fairly common safety practice that results in GHG emissions to the atmosphere. This element of the SIT model calculates venting and flared methane based on the billions of BTUs of gas produced in the state. The model assumes 20% of the natural gas production facilities vent excess emissions and 80% use flares to control waste gas. While not part of 'leakage' related to production, venting and flaring emissions are estimated based on the BBTU produced from the EIA Natural Gas Navigator. Based on the SIT model default values, in 2010 Colorado is estimated at 1,273 BBtu, about a fourth the 1990 value of 4,837 BBtu. The resulting metric tons of gas in $MMTCO_2$ range from 0.23 $MMTCO_2e$ in 1990 to 0.06 $MMTCO_2e$ in 2010. In connection with this final inventory, updated venting and flaring emissions were looked at based on the 2014 EIA Natural Gas Navigator, but the differences with the SIT Model default values were negligible.

Petroleum Systems

The model calculates GHG emissions from the petroleum systems subsector by multiplying barrels of oil produced, refined and transported, by default emission. While the model provides default values for barrels of oil produced, it does not include Colorado data for barrels refined or transported. Based on an assessment of the model, it was determined that inclusion of Colorado specific data for oil refined and transported would have a minimal effect on emissions from this subsector. Additionally, the model default values for oil produced were compared with the reported production from the COGCC. This comparison showed insignificant differences in the two data sets. Accordingly, because it does not appear that additional Colorado specific data would have a material effect on calculated emissions for the Gas Production Sector, emissions in this final inventory for the Petroleum Systems Subsector are based on the emissions calculated in the default mode.

Uncertainties Associated With Emission Estimates for the Gas Production Sector

Many of the uncertainties associated with missing or incomplete data have been addressed in the Methodologies and Data section above. In addition to these data uncertainties, questions remain regarding the accuracy of default emission factors, especially in light of Colorado's extensive efforts over the past decade to reduce leaking and venting from the natural gas and oil production industry in Colorado. Additional analysis is warranted to examine the effects of Colorado regulatory requirements on leaking and venting in order to determine whether adjustments to the emission factors should be made. In particular, the benefits from extensive new regulatory requirements aimed at oil and gas hydrocarbon emissions adopted in February 2014 should be assessed in the next inventory update.

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

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Chapter 9 - Agriculture

Overview

The Agriculture Sector consists of CH_4 and N_2O, emissions resulting from various agricultural activities. There are three broad categories of emission sources within the Agricultural Sector: livestock enteric emissions (flatulence); manure emissions; and emissions from agricultural soils. Direct carbon dioxide (CO_2) emissions from farm equipment and processes are reflected in statewide gasoline or diesel fuel use or industrial operations.

Emission estimates for this sector were generated using the Agriculture Module for February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode.

As shown in the Executive Summary, emissions from the Agriculture Sector accounted for approximately 7% of the 2010 inventory.

SIT Model Results

Emission results from the Agriculture Module are shown below in Exhibit 9-1:

Exhibit 9-1: Colorado Agriculture Emissions

$MMTCO_2e$	1990	1995	2000	2005	2010
Emissions By Category					
Enteric Fermentation	3.873	4.319	4.61	4.522	4.952
Manure Management	0.809	0.986	1.28	1.277	1.385
Agricultural Soil Management	3.454	3.122	3.236	2.965	2.682
Burning of Agricultural Crop Waste	0.012	0.012	0.012	0.011	0.016
Total Emissions	**8.148**	**8.439**	**9.138**	**8.775**	**9.035**
Emissions by Gas ($MMTCH_4$ or $MMTN_2O$)					
Methane					
Enteric Fermentation	0.184	0.206	0.22	0.215	0.236
Manure Management	0.018	0.024	0.034	0.036	0.042
Burning of Agricultural Crop Waste	<0.001	<0.001	<0.001	<0.001	0.001
Total Emissions	**0.203**	**0.23**	**0.254**	**0.251**	**0.278**
Nitrous Oxide					
Manure Management	0.001	0.002	0.002	0.002	0.002
Burning of Agricultural Crop Waste	0.003	0.003	0.003	0.003	0.004
Agricultural Soil Management	3.45	3.12	3.24	2.96	2.68
Total Emissions	**0.013**	**0.012**	**0.012**	**0.011**	**0.01**
Nitrous Oxide Emissions from Agricultural Soil Management (Metric Tons N_2O)					
Direct emissions					
Fertilizers	2,481	2,067	2,240	1,699	1,285
Crop Residues	832	705	683	550	867
N-Fixing Crops	1,361	1,436	1,518	1,211	1,232
Livestock	4,422	4,309	4,442	4,633	3,866
Total Emissions	**9096**	**8517**	**8882**	**8093**	**7250**
Indirect emissions					
Fertilizers	348	202	244	180	222
Livestock	468	445	386	437	344
Leaching/Runoff	1,231	909	928	855	837
Fertilizer Runoff/Leached	704	409	493	364	450
Manure Runoff/Leached	526	500	435	491	387
Total Emissions	**2047**	**1555**	**1558**	**1471**	**1404**
GRAND TOTAL	**11,143**	**10,072**	**10,440**	**9,564**	**8,653**

Data and Methodologies

Emission estimates for this sector were generated using the Agriculture Module for February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode.

All animal related emission factors in the model were expressed in kilograms per animal per year (kg/animal/yr). Animal specific emissions are calculated by multiplying the number of animals in a sector by an emission factor (e.g. Beef Cows x EF= Beef cow emissions in kg). Non-animal emissions are based on a set of factors, or agricultural production numbers, including grain yields and acres of land. The EPA user's guidance document provides details concerning the model evaluation process (U.S. EPA 2012, 1.4-1.5).

Colorado specific factors for the animal population, fertilizer use, crop production, and land use are areas where specific data substitutions may be made in the future.

Enteric Fermentation

Emission factors

A default emission factor is provided for a range of livestock ages and replacements rates (death/birth) depending on the category. Beef and dairy cattle have the most extensive breakdown while 'other' just provides one emission factor (EF) for each of the animal classifications. The emission factor for cattle varies by year while 'other' is constant over the population total. Cattle are split between dairy and beef populations. Since dairy cows tend to be on a much slower replacement cycle, the population is only broken into two young ages (0-12 mos. and 12-24 mos.) and plus the total herd population. Beef cattle on the other hand are broken into nine sub-classifications with EFs for each. For a detailed description of how the SIT model uses the livestock count; age distribution and animal type to calculate total enteric fermentation, consult the EPA user's guide. The range of emission factors within this category show swine at 1.5 kg of methane per head per year up to dairy cows at 125.6 kg of methane/head.

Head count

The two elements for calculating emissions from animal related agricultural sources are the animal count and the emission factor per animal. The head count varies by year based on the SIT model data base. In this case livestock population data are derived from the National Agriculture Statistics Service of the U.S. Department of Agriculture (USDA). Exhibit 9-2 shows the animal head count per year.

Exhibit 9-2: SIT Model Default Animal Head Counts in Colorado (in thousands)

	1990	1995	2000	2005	2010
Dairy Cattle					
Dairy Cows	76	83	85	101	116
Dairy Replacement Heifers	30	45	45	50	70
Beef Cattle					
Beef Cows	764	817	835	639	714
--Beef Replacement Heifers	130	155	150	130	120
Heifer Stockers	199.2	224.7	181	570	500
Steer Stockers	865	940	990	840	770
Feedlot Heifers	247.1	305.3	400.9	358	332
Feedlot Steers	492.1	576.6	708.1	641	622
Bulls	45	50	50	40	45
Poultry total	6,622	5,698	5,366	5,840	5,373
Sheep	840	545	440	365	410
Goats	11.7	13.2	16.8	36.8	49
Swine	300	580	867.5	825	730
Horses	171.6	172.6	154	270.4	280.8

Emissions Calculation

The basic equation for calculating enteric emissions from animals in the agricultural module is shown in Equation 1 below.

Equation 1. Emission Equation for Enteric Fermentation

$$\text{Emissions } (MMTCO_2E) = \text{Animal Population ('000 head)} \times \text{Emission Factor } (kg\ CH_4/head) \times 21\ (GWP) \div 1{,}000{,}000{,}000\ (kg/MMTCO_2E)$$

(U.S. EPA 2013)

Manure Management CH_4 and N_2O

In accordance with the EPA workbook, data required for manure management emission calculations includes:

- typical animal mass (TAM)
- volatile solids production
- maximum potential methane emissions, and
- animal populations

This part of the model only deals with **stored** manure from confined animal feeding operations. However, the SIT model assumes that at some point when manure is **applied** to the soil, a separate emissions calculation is created to define overall emissions from animal management. Manure breaks down to emit ammonia as nitrogen which is eventually partially converted to nitrous oxide, which has a global warming potential of 310 times that of carbon dioxide. Direct emissions of methane are also attributed to manure management. Approximately 10% of the agricultural emissions profile is attributed to manure management.

CH_4 and N_20 Emissions calculations for manure management are shown in Equations 2 and 3:

Equation 2. Emission Equation for CH_4 Manure Management

$$\text{Emissions } (MMTCO_2E) = \text{Animal Population ('000 head)} \times \text{TAM (kg)} \times \text{VS (kg/1,000 kg animal mass/day)} \times 365 \text{ (days/yr)} \times B_o \text{ (m}^3\ CH_4\text{/kg VS)} \times MCF \times 0.678 \text{ kg/m}^3 \times 21 \text{ (GWP)} \div 1{,}000{,}000{,}000\ (MMTCO_2E)$$

(U.S. EPA 2013)

Equation 3. Emission Equation for N_2O Manure Management

$$\text{Emissions } (MMTCO_2E) = \text{Animal Population ('000 head)} \times TAM \times \text{K-Nitrogen (kg/day)} \times 365 \text{ (days/yr)} \times \text{Emission Factor (liquid or dry)} \times 310 \text{ (GWP)} \div 1{,}000{,}000{,}000 \text{ (kg/}MMTCO_2E)$$

(U.S. EPA 2013)

<u>Agricultural Soils</u>

The Agricultural Soils emissions category includes three subcategories: plant residue emissions; fertilizer emissions; and animal waste emissions (ammonia).

Plant residue is the amount of material left in field and results in nitrogen emissions as part of the decomposition process. Nitrogen content of the plant material and the fraction of dry matter per harvested crop are contained in the calculation scheme. The results are expressed in metric tons of nitrogen not fixed in the soil. These are converted to N_2O equivalent and multiplied by the factor of 310 to produce $MMTCO_2e$. See Equations 4 and 5 below.

Equation 4. Emission Equation for N-fixing Crops

$$\text{Emissions }(MMTCO_2E) = \text{Crop Production (MT)} \times \text{Mass ratio (residue/crop)} \times \text{Dry Matter Fraction} \times \text{N content} \times \text{Emission Factor } (1.0\%) \times 44/28 \text{ (Ratio of } N_2O \text{ to } N_2O\text{-N)} \times 310 \text{ (GWP)} \div 1{,}000{,}000 \text{ } (MT/MMTCO_2E)$$

(U.S. EPA 2013)

Equation 5. Emission Equation for Residues

$$\text{Emissions }(MMTCO_2E) = \text{Crop Production (MT)} \times \text{Mass ratio (residue/crop)} \times \text{Dry Matter Fraction} \times \text{Fraction Residue Applied} \times \text{N content} \times \text{Emission Factor } (1.0\%) \times 44/28 \text{ (Ratio of } N_2O \text{ to } N_2O\text{-N)} \times 310 \text{ (GWP)} \div 1{,}000{,}000{,}000 \text{ } (kg/MMTCO_2E)$$

(U.S. EPA 2013)

A key component of these calculations is crop production. Crop production numbers used in the model are set forth in Exhibit 9-3.

Exhibit 9-3: 2013 SIT Model Agricultural Crop Summary

	1990	1995	2000	2005	2010
Alfalfa ('000 tons)	2,590	3,060	3,515	2,960	2,870
Corn for Grain ('000 bushels)	128,650	92,130	144,900	140,600	182,710
All Wheat ('000 bushels)	86,950	105,260	71,370	54,035	108,234
Barley ('000 bushels)	12,000	10,000	12,075	7,670	8,379
Sorghum for Grain ('000 bushels)	10,340	4,620	6,720	3,410	7,520
Oats ('000 bushels)	2,250	2,046	2,205	1,125	585
Rye ('000 bushels)	84	60			
Millet ('000 bushels)			2,850	5,500	7,095
Dry Edible Beans ('000 hundredweight)	4,275	2,558	1,980	1,095	1,254

Fertilizer

Both synthetic and organic fertilizer use is considered in the calculation of N_2O emissions resulting from nitrogen based fertilizer application to the soil. Total kilograms of nitrogen populate the data base for these two categories.

Manure use is subtracted from the total of organic fertilizer in accordance with the EPA and IPCC guidance. Equations 7 and 8 provide the calculation details. For additional information consult the EPA User's Guide.

Equation 7. Emission Equation for Direct N_2O Emissions from Agricultural Soils

$$\text{Emissions } (MMTCO_2E) = \text{Total N} \times \text{fraction unvolatilized (0.9 synthetic or 0.8 organic)} \times 0.01 \text{ (kg } N_2O\text{-N/kg N)} \times 44/28 \text{ (Ratio of } N_2O \text{ to } N_2O\text{-N)} \times 310 \text{ (GWP)} \div 1{,}000{,}000{,}000 \text{ (kg/}MMTCO_2E)$$

(U.S.EPA 2013)

Equation 8. Emission Equation for Indirect N_2O Emissions from Agricultural Soils

$$\text{Emissions } (MMTCO_2E) = \text{Total N} \times \text{fraction volatilized (0.1 synthetic or 0.2 organic)} \times 0.001 \text{ (kg } N_2O\text{-N/kg N)} \times 44/28 \text{ (Ratio of } N_2O \text{ to } N_2O\text{-N)} \times 310 \text{ (GWP)} \div 1{,}000{,}000{,}000 \text{ (kg/}MMTCO_2E)$$

(U.S.EPA 2013)

Exhibit 9-4 provides a summary of fertilizer use per year from the 2013 SIT model.

Exhibit 9-4: Colorado Fertilizer Use Per Year[a]

	1990	1995	2000	2005	2010
Synthetic	153,167,398	128,239,960	145,240,924	112,994,969	82,311,051
Organic total	141,600	191,120	257,309	169,681	133,289
Dried manure	9,877	7,488	9,573	7,149	5,928
Activated Sewage Sludge	51,191	58,864	134,098	55,524	34,428
Other	80,533	124,768	113,638	107,008	92,933
Non-manure organics	131,724	183,632	247,736	162,532	127,361
Manure organics [b]	9,877	7,488	9,573	7,149	5,928

a:-An adjustment is made to the initial seasonal fertilizer use to apportion it to an annual basis. This is a national adjustment based on data showing 65% of the annual consumption is from January to June and 35% from July-December. Sale and distribution data from the previous July-December is applied to the following year's data

b:-According to the IPCC Good Practices Guidance, the manure portion of organics is subtracted from the total of organic fertilizers

Emissions from soils due to animal waste are mainly an accounting of animal waste (ammonia generation). Calculation of these emissions is based on a generalized approach, with no state or site specific data. The default model does not take into account differences between open range production, confined operations, or feedlots. It relies on the animal head count data to produce an amount of waste per animal on an annual basis. The same animal population used in the manure management worksheet is used for the agricultural soil nitrous oxide emissions related to animal population.

A volatilization factor is applied to the amount of manure created to produce volatilized and non-volatilized nitrogen emissions. Poultry manure production is adjusted due to an estimated 4.2% of the waste being used as animal feed and not applied to soils (EPA 2013, 1.18). The EPA Guidance describes more fully other adjustment factors taken into account including runoff and leaching.

Direct and indirect emissions of N_2O are converted to CO_2 equivalents using the multiplier of 310 for each molecule of N_2O produced.

Data Uncertainties

The SIT model contains an uncertainty section for each module explaining possible sources of error in the base data and calculations. For a complete discussion of these uncertainties for agricultural emissions consult the User's Guide.

Uncertainties Related to Animal Populations

As noted above, methane emissions from animals are generated by multiplying a pre-determined emissions factor for a type of animal by the number of those animals in the State. One uncertainty lies in the variability of the population of animals within any given year. Animal death, birth, and harvesting all impact the actual population at any given time.

Uncertainties Related to Livestock Manure

Manure production is also directly tied to the animal population. Uncertainties in the numbers of animals in a year, as noted above, can be difficult to estimate. Variability of emissions within a given type of animal can be significant. For cattle, different emission factors are used for beef cattle and dairy cattle, and these are further broken into age groups. This provides some granularity to the data which is one of the larger agricultural emission sources. However, swine, horses, and sheep have no such breakdown and one emission factor is applied to the population.

The lack of specificity of manure management systems in the state is lacking. Colorado has confined animal feeding operations for swine and poultry as well as open range animal production. Manure emissions vary considerably by animal type, size and types of feed.

Controlling factors of diet and waste storage are potentially some of the largest sources of error or uncertainty in the manure management. Colorado regulates effluent from the largest swine confined animal feeding operations which may lower emissions considerably while bovine operations have no such regulation. Thus, national assumptions for emissions from production, storage, and use of manure may not be reflective of Colorado.

Uncertainty Related to Agricultural Soil Management

The key emission associated with soil management is N_2O release. Factors of nitrogen input from fertilizers, soil moisture, pH, and other variables dictate how much N_2O is produced. The SIT discussion notes, 'combined interaction of these variables on N_2O flux is complex and highly uncertain' (U.S. EPA 2012; Uncertainty page). Midpoint emission factors for all relevant sources were selected by the EPA for this calculation. Fertilizer use estimates only include commercial use and crop residue left on soils. Expert judgment was used to estimate this input.' Finally, state-by-state factors for how much land application of urban treated sewage sludge and animal waste is only estimated from national tables.

Uncertainties Related to Fertilizer Use

The model has an option for developing calendar year emissions which attempts to apportion seasonal applications of fertilizer to releases of nitrogen during the year. Use of the calendar year calculation option causes a problem in the data representation for 2010 because part of the fall emissions (35%) are apportioned to the 2011 season. Thus, this makes 2010 appear to taper off in the 2010 data. This problem cannot be overcome as the model is fixed on this apportionment.

Uncertainties Related to Agricultural Crop Wastes

The default SIT agricultural module assumes a small (3% in Colorado) portion of wheat and corn residue is burned. The resultant, non-carbon dioxide emissions for CH_4 and N_2O oxides are based on the amount of material burned each year. This does not take into account Colorado's actual practices. The resultant emissions are small when considering overall emissions estimates. Leaving agricultural burning in the default mode likely will not present a significant error in the overall inventory.

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

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Chapter 10 – Waste Management

Overview

The Waste Management Sector consists of direct CH_4 emissions from solid waste landfills, CO_2 and N_2O emissions from the combustion of solid waste, and CH_4 and N_2O emissions from the treatment of municipal and industrial wastewater.

Waste Management emissions are produced using the EPA State Inventory Tool (SIT) model fully in the default mode. For this chapter, outputs from two emissions modules from the SIT are combined – the Wastewater module and the Municipal Solid Waste module. Current guidance on creating Waste Management GHG estimates are found in the latest version of the SIT under *User's Guide for Estimating Methane and Nitrous Oxide Emissions from Waste Water* and *User's Guide for Estimating Emissions from Municipal Solid Waste* 2013.

As shown in the Executive Summary, emissions from the Waste Management Sector accounted for approximately 2% of Colorado GHG emissions in 2010.

SIT Model Results

Calculated emissions for the Waste Management Sector are set forth below in Exhibits 10-1 and 10-2.

Exhibit 10-1: Colorado Solid Waste Landfill Emissions

	1990	1995	2000	2005	2010
CH_4	0.459	0.395	0.818	1.467	2.077
CO_2					
N_2O					
Total	**0.459**	**0.395**	**0.818**	**1.467**	**2.077**
CH_4 Emissions from Landfills ($MMTCO_2E$)					
Potential CH_4	**0.703**	**0.953**	**1.310**	**2.074**	**2.855**
MSW Generation	0.657	0.891	1.224	1.939	2.668
Industrial Generation	0.046	0.062	0.086	0.136	0.187
CH_4 Avoided	**-0.193**	**-0.515**	**-0.401**	**-0.445**	**-0.547**
Flare	-0.161	-0.483	-0.356	-0.445	-0.547
Landfill Gas-to-Energy	-0.032	-0.032	-0.044	nd	nd
Oxidation at MSW Landfills	**0.046**	**0.038**	**0.082**	**0.149**	**0.212**
Oxidation at Industrial Landfills	**0.005**	**0.006**	**0.009**	**0.014**	**0.019**
Total CH_4 Emissions	**0.459**	**0.395**	**0.818**	**1.467**	**2.077**
CO_2 and N_2O Emissions from Waste Combustion ($MMTCO_2E$)					
CO_2					
Plastics	-	-	-	-	-
Synthetic Rubber in MSW	-	-	-	-	-
Synthetic Fibers	-	-	-	-	-
N_2O	-	-	-	-	-
CH_4	-	-	-	-	-
Total CO_2, N_2O, CH_4 Emissions	-	-	-	-	-

Exhibit 10-2: Colorado Wastewater Treatment Emissions

Emissions ($MMTCO_2E$)	**1990**	**1995**	**2000**	**2005**	**2010**
Municipal CH_4	0.22	0.26	0.29	0.31	0.34
Municipal N_2O	0.09	0.11	0.13	0.14	0.15
Industrial CH_4	0.04	0.05	0.05	0.04	0.05
Red Meat	0.04	0.05	0.05	0.04	0.05
Total Emissions	0.35	0.41	0.47	0.50	0.54

Data and Methodologies

The Waste Management Sector GHG emissions estimates are the sum of CH_4, N_2O and CO_2 emissions from the 2013 SIT Model run in default mode. These emissions are extracted from the Municipal Solid Waste Module and the Wastewater Treatment Module.

Municipal Solid Waste

The Municipal Solid Waste (MSW) module combines the results of CH_4 emissions from landfills of MSW, CO_2 and N_2O emissions from the combustion of MSW. Below is a chart from the SIT module, showing the required input data used to calculate emissions. The *User's Guide for Estimating Emissions From Municipal Solid Waste* explains the methods used to obtain:

- population data,
- CH_4 emissions from landfills,
- first order decay model worksheet,
- CH_4 emissions adjustment for flaring,
- CH_4 oxidation factor,
- and variables used for combustion of MSW CO_2 emission estimates.

In the user's guide, the two sectors within the MSW module, landfills and combustion, are treated separately. The user's guide for this module explains in detail the steps necessary to run the module. Exhibit 10-3 below from the user's guide shows the required data inputs for MSW.

Exhibit 10-3: Required Data for Inputs for the Municipal Solid Waste Module

Table 1. Required Data Inputs for the Municipal Solid Waste Module

Solid Waste Sectors	Input Data
Landfills	Amount of **MSW landfilled** in state from 1960 through the present OR from 1990 through the present (short tons)
	State population data, 1960 through the present
	Amount of CH_4 flared/recovered at landfills (short tons)
	Industrial landfill CH_4 emissions, as a percent of MSW landfill emissions
	Percent of landfill CH_4 oxidized at the landfill surface (oxidation factor)
Waste Combustion	Fraction of plastics, synthetic rubber, and synthetic fiber that is oxidized in a combustion facility
	Amount of MSW combusted for 1990 through the present (short tons)
Plastic Combustion	Polyethylene terephthalate (PET) as a proportion of all MSW discards
	High-density polyethylene (HDPE) as a proportion of all MSW discards
	Polyvinyl chloride (PVC) as a proportion of all MSW discards
	Low-density/linear low-density polyethylene (LDPE/LLDPE) as a proportion of all MSW discards
	Polypropylene (PP) as a proportion of all MSW discards
	Polystyrene (PS) as a proportion of all MSW discards
	Other plastic as a proportion of all MSW discards
Synthetic Rubber Combustion	Synthetic rubber durables as a proportion of all MSW discards
	Synthetic rubber clothing and footwear as a proportion of all MSW discards
	Other synthetic rubber non-durables as a proportion of all MSW discards
	Synthetic rubber containers and packaging as a proportion of all MSW discards
Synthetic Fiber Combustion	Synthetic fiber as a proportion of all MSW discards

For landfills, an important step is to review preliminary calculations for CH_4 emissions. These calculations are considered preliminary because CH_4 emissions for the amount of waste collected and burned, and the amount of methane oxidized at the surface of a landfill is taken into account in later steps. The model estimates the potential CH_4 emissions occurring during the inventory year, but is associated with the waste landfilled over the past thirty years, using equation 1 below.

As this equation shows, emissions vary by the amount of waste present in a landfill and the CH_4 generation rate (k). The CH_4 generation rate varies according to several factors pertaining to the climate where the landfill is located and is automatically chosen based on the selected state (Colorado).

Equation 1. First Order Decay Model Equation

$$Q_{Tx} = A \times k \times R_x \times L_o \times e^{-k(T-x)}$$

Where, Q_{Tx} = Amount of CH_4 generated in year T by the waste R_x,
T = Current year
x = Year of waste input
A = Normalization factor (1-e-k)/k
k = CH_4 generation rate (yr^{-1})
R_x = Amount of waste landfilled in year x
L_o = CH_4 generation potential

Many landfills have gas collection systems. At some landfills in Colorado CH_4 collected by these systems is flared and is not counted as CO_2e emissions. Equation 2 shows this subtraction equation.

Equation 2. Net CH_4 Emissions from Landfills

Preliminary Net CH_4 Emissions =

Total CH_4 Generated – CH_4 Flared or Recovered for Energy – CH_4 Oxidized in Landfill

(U.S.EPA 2013)

There are separate worksheets for each of the three types of fossil fuel-derived MSW, which are plastics, synthetic rubber, and synthetic fiber, and each of the worksheets is similar in layout.

In the default mode, tons of municipal solid waste combusted are only populated in the years 1992-1994 and 1998-1999. Calculating emissions from these two periods indicates emissions would be .012-.018 $MMTCO_2$e for the sum of burning plastics, synthetic rubber, and synthetic fibers. Lacking sufficient data to populate the default table, and based on the small overall contribution, these categories were left as null data but expressed in the table to indicate a full evaluation could be made in the future with complete municipal waste combustion information. CO_2 Emissions from combustion are calculated using equation 3.

Equation 3. CO_2 Emissions from Combustion

CO_2 Emissions ($MTCO_2E$) =
Material as Proportion of all Discards (%) × Total MSW Combusted (short tons) × Carbon Content (%) × Fraction Oxidized (%) × 44/12 (CO_2 to C ratio) × 0.9072 (short tons to metric tons conversion)

(U.S.EPA 2013)

Wastewater

The Wastewater (WW) Module uses the EPA 1998 States Workbook revisions to format the EIIP. The WW Module calculates CH_4 and N_2O emissions from treated municipal and industrial wastewater. Disposal and treatment of industrial and municipal waste water results in CH_4 emissions. Nitrous oxide is emitted from both domestic and industrial water containing nitrogen-rich organic matter. The WW User's Guide explains in detail how the SIT derives CH_4 and direct N_2O emissions from derived municipal wastewater, N_2O from biosolids, and emissions from fruit and vegetables, red meat, poultry, and pulp and paper industrial waste water. Exhibit 10-4, from the user's guide, shows the required data inputs to WW Module.

Exhibit 10-4: Required Data Inputs for the Wastewater SIT Module N_2O and CH_4 Emissions Calculations

Wastewater Sectors	Input Data
Municipal Wastewater: CH_4 Emissions	Per capita 5-day biochemical oxygen demand (BOD_5) (kg/day) Fraction of wastewater BOD_5 anaerobically digested Emission factor (Gg CH_4/Gg BOD_5) State population
Municipal Wastewater: Direct N_2O Emissions	Factor for non-consumption nitrogen Fraction of population not on septic Direct wastewater treatment plant emissions (g N_2O/person/year)
Municipal Wastewater: N_2O Emissions from Biosolids	Emission factor (kg N_2O-N/kg sewage N produced) Fraction of nitrogen in protein ($Frac_{NPR}$) Protein content (kg/person/year) Biosolids used as fertilizer (percentage)
Industrial Wastewater: Fruits and Vegetables Industrial Wastewater: Red Meat Industrial Wastewater: Poultry	Wastewater Outflow (m^3/metric ton) WW organic content - chemical oxygen demand (COD) (g/L) Fraction of COD anaerobically degraded Emission factor (g CH_4/g COD) Production processed (metric tons)
Industrial Wastewater: Pulp and Paper	Wastewater Outflow (m^3/metric ton) WW organic content - chemical oxygen demand (COD) (g/L) Fraction of COD anaerobically degraded Emission factor (g CH_4/g COD) Production processed of woodpulp and paper & paperboard (metric tons)

Some of the significant equations to obtain GHG emissions from the Wastewater Module are listed below.

Equation 1. CH_4 Emissions from Municipal Wastewater Treatment

$$CH_4 \text{ Emissions (MMTCO}_2\text{E)} = \text{State Population} \times BOD_5 \text{ Production (kg/day)} \times 365 \text{ days/year} \times 0.001 \text{ (metric ton/kg)} \times \text{Fraction Treated Anaerobically} \times \text{Emission Factor (Gg } CH_4\text{/Gg } BOD_5) \times 10^{-6} \text{ (MMT/metric ton)} \times 21 \text{ (GWP)}$$

(U.S.EPA 2013)

Equation 2. Direct N_2O Emissions from Municipal Wastewater Treatment

$$\text{Direct } N_2O \text{ Emissions (MMTCO}_2\text{E)} = \text{State Population} \times \text{Fraction of Population not on Septic (\%)} \times \text{Emission Factor (g } N_2O\text{/person/year)} \times 10^{-6} \text{ (metric ton/g)} \times 10^{-6} \text{ (MMT/metric ton)} \times 310 \text{ (GWP)}$$

(U.S.EPA 2013)

Equation 3. N_2O Emissions from Biosolids Municipal Wastewater Treatment

$$N_2O \text{ Emissions (MMTCO}_2\text{E)} = [\text{State Population} \times \text{Protein Consumption (kg/person/year)} \times FRAC_{NPR} \text{ (kg N/kg protein)} \times \text{Fraction of Nitrogen not Consumed } 0.001 \text{ (metric ton/kg)} - \text{Direct N Emissions (metric tons)}] \times [1 - \text{Percentage of Biosolids used as Fertilizer (\%)}] \times \text{Emission Factor (kg } N_2O\text{-N/kg sewage N produced)} \times 44/28 \text{ (kg } N_2O \text{ /kg N)} \times 10^{-6} \text{ (MMT/metric ton)} \times 310 \text{ (GWP)} + \text{Direct } N_2O \text{ Emissions}$$

(U.S.EPA 2013)

For further detailed information on the operation and formulas for this module, refer to the SIT Model *User's Guide For Estimating* CH_4 *and* N_2O *Emissions From Wastewater*.

Uncertainties Associated With Estimating CH_4, N_2O and CO_2 Emissions from the Waste Management Sector

There are several sources of uncertainty associated with estimating CH_4 emissions from landfills. CH_4 production is impacted by temperature, rainfall and landfill design. These characteristics vary for each landfill. The time period over which landfill waste produces CH_4 is also not certain. Little information is available on the amount of CH_4 oxidized during diffusion through the soil cover over landfills. The assumed percent is based upon limited measurements. The presence of landfill gas recovery systems may affect activity in the anaerobic zones of landfills, since active pumping may draw more air into the fill.

There are several sources of uncertainty surrounding the estimates of CO_2 and N_2O from waste combustion, including combustion and oxidation rates, average carbon contents, and biogenic content. Due to variation in the quantity and composition of waste, the combustion rate is not exact. Similarly, the oxidation rate is uncertain because the efficiency of individual combustors varies depending upon type of waste combusted, moisture content, and other factors.

Non-biogenic CO_2 emissions from waste combustion depend upon the amount of non-biogenic carbon in the waste and the percentage of non-biogenic carbon that is oxidized.

Uncertainty surrounds estimates of CH_4 and N_2O emissions from industrial wastewater treatment. The quantity of CH_4 emissions from wastewater treatment is based upon several factors with varying degrees of uncertainty. For domestic wastewater, the uncertainty is associated with the factor to estimate the occurrence of anaerobic conditions in the treatment systems, based on septic tank usage data. The national default estimate of the fraction of wastewater not on septic is 75 percent, but that varies from state to state. There can be variation in per-capita BOD production associated with food consumption, food waste, and disposal characteristics for organic matter.

N_2O emissions are dependent upon nitrogen (N) inputs into the wastewater and the characteristics of wastewater treatment methods. There are large uncertainties associated with the industrial wastewater emission estimates. Wastewater outflows, and organics loadings, vary considerably for different plants and different sub-sectors (e.g. office paper versus newsprint, or beef versus fish). There can also be variation in the per-capita BOD production associated with industrial processes and disposal characteristics for organic matter. Further, there is variation in these factors that can be attributed to characteristics of industrial pretreatment systems, as well as eventual treatment at municipal facilities.

Projections to 2030

For a discussion of the projections, refer to Chapter 2.

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U.S. EPA. 2013. *User's Guide For Estimating* CH_4 *and N2O Emissions From Wastewater Using the State Inventory Tool.* ICF International. State Climate and Energy Program.

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Chapter 11 – Land Use and Forestry

Overview

Unlike the other sectors discussed in this inventory, which are net GHG emitters, the Land Use, Land Use Change, and Forestry (LULUCF) Sector, consists primarily of the sequestration of carbon in forests and other forms of biomass, which serves to reduce Colorado's net CO_2e emissions.

Emission estimates for this sector were generated using the LULUCF Module for February 11, 2013 version of the EPA State Inventory Tool (SIT) model run fully in the Colorado default mode.

As shown in the Executive Summary, carbon sequestration from the LULCUF Sector reduced Colorado's GHG emissions by approximately 7% in 2010.

SIT Model Results

Exhibit 11-1 provides a summary of the emissions by subcategory for all elements of the Land Use, Land Use Change and Forestry model output using default values.

Exhibit 11-1: Colorado GHG Emissions from Land-Use, Land-Use Change and Forestry

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Forest Carbon Flux					
Aboveground Biomass	-2.56	-2.56	-2.85	-2.85	-2.19
Belowground Biomass	-0.47	-0.47	-0.5	-0.5	-0.42
Dead Wood	-2.12	-2.12	-2.22	-2.22	-0.90
Litter	-2.07	-2.07	-2.07	-2.07	-2.07
Soil Organic Carbon	-2.31	-2.31	-2.31	-2.31	-2.31
Total Wood products and landfills	-1.61	-0.56	-0.56	-0.56	-0.56
Total Emissions	**-11.13**	**-10.08**	**-10.5**	**-10.5**	**-8.45**
Urea Fertilization					
Total Emissions	**0.02**	**0.02**	**0.02**	**0.03**	**0.03**
Urban Trees					
Total Emissions	**-0.28**	**-0.32**	**-0.35**	**-0.39**	**-0.42**
Landfilled Yard Trimmings and Food Scraps					
Grass	-0.03	-0.01	-0.01	-0.01	-0.01
Leaves	-0.13	-0.09	-0.07	-0.05	-0.07
Branches	-0.13	-0.08	-0.06	-0.05	-0.06
Landfilled Food Scraps	-0.03	-0.03	-0.06	-0.06	-0.05
Total Emissions	**-0.32**	**-0.21**	**-0.20**	**-0.17**	**-0.19**
Forest Fires					
CH_4	*	*	*	*	*
N_2O	*	*	*	*	*
N_2O from Settlement Soils					
Total Emissions	**0.07**	**0.06**	**0.06**	**0.06**	**0.04**
GRAND TOTAL	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**

*Categories with zero emissions, other than forest fires, were eliminated from the Synthesis Tool summary table for space purposes. Forest fires were specifically left in to point to this deficiency in the model data base.

Data and Methodologies

The latest EPA user's guide outlines the workings of this element of the model and was released in February 2013. It contains details about how this part of the emissions model works. The *User's Guide for Estimating Emissions and Sinks from Land Use, Land-Use Change, and Forestry Using the State Inventory Tool* provides emission calculations and step-by-step instructions on operating the model (U.S. EPA 2013). This Chapter contains summary results from the default model runs. This module is unique as it considers emissions produced from sources such as forest fires and urea fertilization (adding emissions into atmosphere), either as CH_4 and/or N_2O, and balances these against production of forest and urban trees (reducing emissions in the atmosphere).

Specifically, this module of the SIT calculates carbon stored in, or released to, the environment from:

- forest carbon
- agricultural liming (of which there is none in Colorado)
- urea based fertilization in urban environments
- urban tree planting
- release of N_2O from settlement soils (urban land)
- land-filled yard waste, and
- food scraps
- CH_4 or N_2O released from forest fires

Exhibit 11-2 is extracted from the User's Guide and provides a brief summary of the sub-elements of this module. Much of this portion of the inventory focuses on the sinks. These are negative fluxes of carbon, as carbon dioxide is removed from the atmosphere from forest growth, urban trees, land-filled urban waste, and wood products. For a complete listing of sources and sinks related to this model element refer to the EPA workbook.

Exhibit 11-2: Data Input Exhibit Extracted from EPA User's Guide for the LULUCF Module

Forestry Worksheets	Input Data Required
Forest Carbon Flux	Carbon emitted from or sequestered in aboveground biomass, belowground biomass, dead wood, litter, soil organic carbon, wood products and landfills (million metric tons)
Liming of Agricultural Soils	Emission factors for CO_2 emitted from use of crushed limestone and dolomite (ton C/ton limestone) Total limestone and dolomite applied to soils (metric tons)
Urea Fertilization	Emission factors for CO_2 emitted from the use of urea as a fertilizer (tons C/ ton urea) Total urea applied to soils (metric tons)
Urban Trees	Carbon sequestration factor for urban trees (metric ton C/hectare/year) Total urban area (square kilometers) Urban area tree cover (percent)
N_2O from Settlement Soils	Direct N_2O emission factor for managed soils (percent) Total synthetic fertilizer applied to settlements (metric tons nitrogen)
Non-CO_2 Emissions from Forest Fires	Emission factors for CH_4 and N_2O emitted from burning forest and savanna (grams of gas/kilogram of dry matter combusted) Combustion efficiency of different vegetation types (percent) Average biomass density (kilograms dry matter per hectare) Area burned (hectares)
Landfilled Yard Trimmings and Food Scraps	Grass, leaves, and branches constituting yard trimmings (percent) Yard trimmings and foods scraps landfilled, 1960-present (tons) Initial carbon content of yard trimmings and food scraps (percent) Dry weight/wet weight ratio of yard trimmings and foods scraps (percent) Proportion of carbon stored permanently for yard trimmings and foods scraps (percent) Half-life of degradable carbon for yard trimmings and foods scraps (years)

The SIT model notes local data is not always available to populate the model and inputs should be checked carefully. There is no default in the model for forest fires. This data must be acquired at the state level. This is further discussed below under the section Forest Fires.

A discussion concerning LULUCF data uncertainties, inputs, and assumptions for the Colorado inventory is found at the end of this Chapter and detailed in the EPA document *User's Guide for Estimating Emissions and Sinks from Land Use, Land-Use Change, and Forestry Using the State Inventory Tool* (2013).

Due to the diverse nature of sources and sinks, emission factors and calculations for each of the considered elements of Land Use, Land Use Change and Forestry are discussed separately in the individual sections as little sense would be made of showing the range of values.

Forest Carbon Flux

One of the primary building blocks of the Forest-related emissions model is the Forest Carbon Flux Worksheet. The model populates all years between 1990 and 2010 using two methods. In the first method, seen in Exhibit 11-2, the five sub-categories are estimated for the amount of carbon stored in million metric tons of carbon (MMTC). The USDA Forest Service provides yearly estimates for these sub-categories. These estimates come from the Carbon Calculation Tool (CCT). Two sub-tables are developed by this segment of the model; the first from total carbon storage and the second for changes in carbon storage.

Net sequestration of carbon from the above ground and below ground (dead wood, litter, and soil organic carbon) is produced from data in Exhibit 11-3.

Exhibit 11-3: MMMT of Carbon Stored in Forest and Land Use categories

	1990	1995	2000	2005	2010
Total Carbon Storage	**-9.53**	**-9.53**	**-9.94**	**-9.94**	**-7.89**
Aboveground Biomass	-2.56	-2.56	-2.85	-2.85	-2.19
Belowground Biomass	-0.47	-0.47	-0.50	-0.50	-0.42
Dead Wood	-2.12	-2.12	-2.22	-2.22	-0.90
Litter	-2.07	-2.07	-2.07	-2.07	-2.07
Soil Organic	-2.31	-2.31	-2.31	-2.31	-2.31

In the second element of the calculation scheme, wood products and landfills are also components for the forest carbon flux. In the default mode, assumptions are considered for estimates of harvested wood products from USDA Forest Service estimates in 1987-1992, and 1992-1997. The rate of change is calculated for the two, five year intervals to develop an annual average change (U.S. EPA 2013b; Forest Carbon Flux in Colorado sub-sheet 2; U.S. EPA 2013).

Liming

Liming, the practice of applying limestone and dolomite to agricultural soils, is a common practice in certain areas of the U.S. (North Carolina Cooperative Extension Service 2003). Due to the alkaline nature of most Colorado soils, the SIT model does not assume any liming in Colorado. The *Yearbook of Agricultural Series* reports soil in Colorado, and surrounding states, rarely show acid conditions needing liming so the SIT model assumptions for this elements appear to be reasonable (U.S. Department of Agriculture 1957).

Urea Fertilization

Fertilizer use in this area of the inventory accounts for commercial applications and where urea is created commercially. [$CO(NH_2)_2$] is mostly used as fertilizer in agricultural and urban settings. Agricultural application of fertilizer is accounted for in Chapter 9. Default values were used for Colorado. The calculation scheme for this is extracted from the EPA workbook and is shown in Equation 11-1. Note the only variable in the equation is the amount of applied urea.

Equation 11-1: Conversion Equation from Tons of Urea to $MMTCO_2e$

Emissions ($MMTCO_2E$) =
Total Urea Applied to Soil (metric tons) × Emission Factor (tons C/ton urea) × 44/12 (ratio of CO_2 to C) ÷ 1,000,000 (to yield $MMTCO_2E$)

(U.S. EPA 2013, 1.12)

N_2O from Settlement Soils

The EPA workbook defines settlement soils as "developed land, including transportation infrastructure and human settlements of any size, unless already included under other categories" (EPA 2013). The calculation addresses N_2O emissions considering synthetic fertilizer and a conversion factor estimating the amount of nitrogen converted from ammonium nitrate or urea fertilizers.

The calculation scheme for N_2O emissions is shown in Equation 11-2 and the only variable is the amount of fertilizer used on an annual basis. The emission factor is 1% of the total mass of fertilizer applied and is held constant for all years. Urea fertilization use is based on the *AAPFCO 2011 Commercial Fertilizer 2010* report and is populated into the SIT module automatically in the default mode (U.S. EPA 2013b, Urea Fertilization).

Equation 11-2: Nitrous Oxide from Settlement Soils

Emissions ($MMTCO_2E$) =
Total Synthetic Fertilizer Applied to Settlement Soils (metric ton N) × Emission Factor (percent) × 0.01 (metric tons N_2O-N/metric ton N) × 44/28 (Ratio of N_2O to N_2O-N) × 310 (GWP) ÷ 1,000,000 ($MT/MMTCO_2E$)

(U.S. EPA 2013, 1.12)

Exhibit 11-4 presents the N_2O emissions from Settlement Soils.

Exhibit 11-4 Colorado N_2O from Settlement Soils

	1990	1995	2000	2005	2010
Total synthetic fertilizer applied to settlements (metric tons)	13,845	11,561	13,187	11,316	8,243
Emissions ($MMTCO_2e$)	0.0609	0.0563	0.0642	0.0551	0.0402
Carbon balance considers fixed carbon in the production of Urea and released carbon during use.					

(U.S.EPA 2013, 1.12)

Urban Trees

The urban tree calculation considers carbon capture (sequestration) to be based on average urban land mass in the state and average percent tree cover per unit of area. The SIT module provides a default urban area based on Nowak et al. (2005), and a percent of the urban area covered by trees from the work of Dwyer et al. (2000).

The SIT uses state-by-state estimates of urban tree cover to calculate CO_2 sequestration by balancing tree planting and growth against estimated loss from pruning and mortality. The calculation scheme for urban tree sequestration is shown in Equation 11-3. The carbon sequestration factor used for the default mode is 2.23 metric tons C/hectare/year. The percent of Urban Areas Tree Cover is also a constant set at 13% for Colorado. Thus, the only variable in the calculation is the total urban area.

Equation 11-3: CO_2 Sequestration Rate from Urban Tree Planting

$$\text{Sequestration } (MMTCO_2E) = \text{Total Urban Area } (km^2) \times \text{Urban Area with Tree Cover } (\%) \times 100\ (ha/km^2) \times \text{C Sequestration Factor (metric tons C/ha/yr)} \times 44/12 \text{ (ratio of } CO_2 \text{ to C)} \div 1{,}000{,}000 \text{ (to yield } MMTCO_2E)$$

(U.S. EPA 2013b)

Exhibit 11-5: Carbon Stored in Urban Trees

	1990	1995	2000	2005	2010
Total Urban area km^2	2,630	2,964	3,298	3,632	3,966
Emissions	-0.28	-0.32	-0.35	-0.39	-0.42
Sequestered ($MMCO_2e$)					

Forest Fires

One key element for calculating the forestry emissions or sequestered carbon involves estimating how much forest mass is lost each year to fire. Methane and nitrous oxide emissions from forest fires are calculated separately from carbon captured or released from forest biomass. This is one area where the default model makes a major assumption concerning the carbon capture and release. The model assumes in the long term carbon is absorbed from the atmosphere in the growth of a tree and eventually is released during a fire or decomposition. However, the model considers the potential impacts from CH_4 and N_2O from forest fires separately. In the default mode Colorado data is provided only in 2002.

Yard Trimmings and Food Scraps

Yard trimmings mulched on site are generally considered to be carbon neutral. Collected trimmings, and food scraps, sent to landfills have a slow decomposition rate and tend to represent storage of carbon, only eventually partially released. The SIT estimates carbon flux between years, based on methodologies presented in IPCC (2003) and IPCC (2006) (U.S. EPA 2013, 1.17-1.21).

Data Uncertainties

The SIT model contains an uncertainty section for each module explaining possible sources of error in the base data and calculations. For a complete discussion of these uncertainties for Land Use and Forestry emissions and sinks consult the 'uncertainty' sub-sheet in the LULUCF SIT module and the LULUCF Module User's Guide. A brief overview of the uncertainty section follows with additional observations and concerns based on our own evaluation of the model.

Uncertainties Related to Forest Carbon Flux

Forest carbon flux is a representation of the total non-urban biomass in forested lands. Biomass in forested areas is generally considered to change slowly and the amount of carbon captured generally outweighs the carbon released from forest fires or tree death. Note the total carbon captured in the biomass is nearly four times the total emission inventory of the State. Carbon stored in trees, and other biomass, is significant and fragile in terms of instant loss of the carbon to the atmosphere due to forest fire. In the very long term, stasis in the forest mass and sequestration may be a reasonable assumption. However, Colorado has been going through a long term drought with associated forest fires releasing stored carbon and also impacting nitrous oxide and methane emissions. Additional pressure from significant pine beetle damage in Colorado forests and ash borers may have upset the sequestration balance sufficiently that trends in emissions over the shorter ten to twenty year spans of this inventory will be significant. Data on Colorado fires is currently much more closely tracked and emissions estimates are more realistic in the *National Interagency Coordination Center from their Situations and Incident Status Summary Reports* (FIA n.d.).

In the long term, forest growth and loss may be in equilibrium and the net carbon flux is zero, if we are just considering CO_2 uptake or emissions. The National Interagency Fire Center maintains a state-by-state inventory of acres of woodlands burned due to wild-land fires, prescribed fires and wild-land fire use. Data from that source shows Colorado averages 58,000 acres of forest area burned each year but the range from 1994 to 2003 had a high in 2002 at 244,253 acres (the year of the Hayman Fire) to a low of 8,826 in 1998.

Uncertainties Related to Agricultural Soil Management

The key emission associated with soil management is N_2O release. Factors of nitrogen input via fertilization, soil moisture, pH, and other variables dictate how much N_2O is produced. As the SIT uncertainty discussion notes "combined interaction of these variables on N_2O flux is complex and highly uncertain" (U.S. EPA 2012; Uncertainty page). Midpoint emission factors for all relevant sources were selected by the EPA for this calculation.

Non-agricultural fertilizer use estimates only include commercial use and crop residue left on soils and has no data source. EPA explains that for this element expert judgment was used to estimate the input.

Uncertainties Related to Urban Trees

The urban tree calculation provides default data from two sources but encourages States to utilize state specific data. As noted in the Urban Tree discussion in this Chapter, and shown in Equation 11-3, only one variable is presented; the amount of urbanized areas in Colorado. Due to the highly variable landscaping requirements from development to development, constant tree cover is likely an inaccurate reflection of the state's urban tree density. Some development leads to more trees and the direction of sequestration should be for increasing captured carbon dioxide in future years. Others may remove trees. Since tree planting is often a strategy used to offset carbon emissions, gaining a more accurate assessment of current conditions and the potential for a changed future may be important in a future inventory.

Uncertainties Related to Forest Burning CH_4 and N_2O

In the default mode, no data populates the spreadsheet for methane and nitrous oxide from forest fires in Colorado. However, for 2002, the spreadsheet has an exhibit showing 960,453 acres burned resulting in a total of 9.921 $MMTCO_2e$ (8.264 tons for methane and 1.657 tons of nitrous oxide) emissions. This is a significant amount of emissions. The Forest Service has a fire emissions tracking system and data for Colorado indicates 244,252 acres burned in Colorado in 2002. This was the year of the Hayman Fire that burned 138,000 acres so likely this is not an unreasonable number (Makings 2012). Thus, the emissions would likely be about a quarter of the calculated value. The Forest Service data for 2002 is about five to ten times higher than information reported for 1994 to 2003. Clearly this can be a significant source of GHG emissions but it raises a question about inclusion or exclusions of other highly variable natural sources of emissions in the State.

Projections to 2030

The projection tool does not forecast LULUCF emissions for future years, thus none are provided in this inventory.

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