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Colorado Department of Public Health and Environment

DRAFT

Colorado Greenhouse Gas Inventory – 2013 Update Including Projections to 2020 & 2030

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This is a DRAFT report that summarizes the Colorado Greenhouse Gas Inventory utilizing the most recent (February 2013)EPA version of the State Inventory Tool (SIT). For this inventory the projection model was run fully in the default mode. CDPHE is accepting comments on this inventory, and recommendations for potential modifications to the default inventory in order to more accurately reflect emissions from the State of Colorado.

Please send any comments via e-mail to
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Colorado Department of Public Health and Environment

Executive Summary

Executive Summary

This DRAFT Colorado Greenhouse Gas Inventory – 2013 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 DRAFT Inventory.

To generate this DRAFT Inventory, CDPHE used the Environmental Protection Agency's (EPA) State Inventory Tool (SIT) dated February 11, 2013 (February, 2013). This DRAFT Inventory includes a comprehensive summary of 1990-2010 outputs from the current SIT model as well as emission projections for 2020 and 2030. This Draft Inventory utilizes the Colorado default values set within the SIT model. The SIT model provides flexibility to change these default values. As part of the final inventory CDPHE will consider how to customize values to more accurately reflect Colorado GHG emissions. For example, consideration may want to be given to include Colorado's Clean Air, Clean Jobs Act in the Electrical Power sector, pursuant to which Xcel Energy is projected to reduce its greenhouse gas emissions by 28% by 2020.

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 also includes a Synthesis Tool, which summarizes emissions from each module and a Projection Tool, which utilizes the data generated in the separate modules and synthesized in the Synthesis Tool to project GHG emissions for Colorado in 2020 and 2030.

This DRAFT report includes extensive chapters which serve as a workbook to better understand the inventory. Each chapter focuses on an individual sector of the inventory

[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 DRAFT Inventory, because it is not a module in EPA's SIT 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.

(e.g. transportation, agriculture, etc.) and explains how the model was run, 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 DRAFT report track the various modules within the SIT model, data from certain modules was either consolidated or split out in order to provided a more cohesive sector based analysis of GHG emissions in Colorado.

Graphic ES-1 describes how each of the chapters incorporates outputs from the various SIT modules, including the Synthesis & Projection Tools.

[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).

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

Graphic ES-1 SIT Modules and Data Used to Generate CO2e 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 1 2012.xls State Inventory Tool (ECPSIT)** 2. **Greenhouse Gas Estimates, 1990-2030 Inventory Tool (GGEIT)**
Chapter 3. Electrical Power • **CO_2 from Fossil Fuel Combustion Module** • **N_2O and CH_4 from Stationary Combustion Module**
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 Emissions Module**
Chapter 7. Coil Mining and Oil and Gas Production • **CH_4 from Coal Mining/Oil and Gas Production Data** • **CO_2 from Oil and Gas Production Data**
Chapter 8. Agricultural Methane and Nitrous Oxide • **N_2O and CH_4 from Agricultural Module**
Chapter 9. Waste Management • **CO_2, N_2O and CH_4 from Municipal Solid Waste Module** • **N_2O and CH_4 from Wastewater Module**
Chapter 10. Land Use and Forestry • **CO_2, N_2O and CH_4 from Land Use, Land Use Change and Forestry Module Emissions and Sinks**

Table ES-1 includes a summary of the SIT model results by sector.[3] This table also includes the estimates of GHG emission reductions from sequestered carbon (based on the land use, land use change, and forestry SIT module). In addition, GHG emissions

[3] Each chapter goes into further detail about the subcategories outlined in Table 1.

based on energy consumption in Colorado are provided.[4] The DRAFT Inventory reflects that Colorado GHG emissions have increased since 1990, but that the rate of increase has slowed since 2005. For the period from 2010 through 2030 the model projects an approximately 5% increase in Colorado GHG emissions. This compares to an increase of approximately 53% during the 20 year period from 1990-2010.

Table ES-1: Summary of Colorado GHG Emissions by emission sector ($MMTCO_2e$) SIT Model Runs 1990-2030 (July 2, 2013 Analysis)

	1990	1995	2000	2005	2010	2020	2030
Electric Power	31.43	32.66	38.83	40.29	39.53	37.06	37.36
Transportation	20.11	23.73	27.02	30.88	30.47	32.95	33.71
Residential, Commercial & Industrial Fuel Use	15.01	17.87	19.96	24.50	26.81	26.77	29.10
Coal Mining & Abandoned Mines	4.81	3.73	5.32	6.61	7.54	5.96	6.60
Gas Production	1.72	2.00	5.39	5.47	6.98	7.47	7.89
Industrial Processes	0.72	1.41	2.94	3.16	3.58	4.89	6.28
Waste Management	0.81	0.80	1.29	1.97	2.62	3.73	4.20
Agriculture	8.14	8.44	9.14	8.77	9.04	9.24	8.25
Grand Total	**82.74**	**90.65**	**109.88**	**121.65**	**126.57**	**128.06**	**133.38**
Electricity Consumption	**N/A**	**N/A**	**38.75**	**43.55**	**48.32**	**62.12**	**70.04**
Land Use & Forestry	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**	**N/A**	**N/A**

This information is graphically displayed in Figure ES-1. Please note that throughout this document there may be differences in tables due to rounding.

[4] For a further discussion on energy consumption, consult Chapter 3.

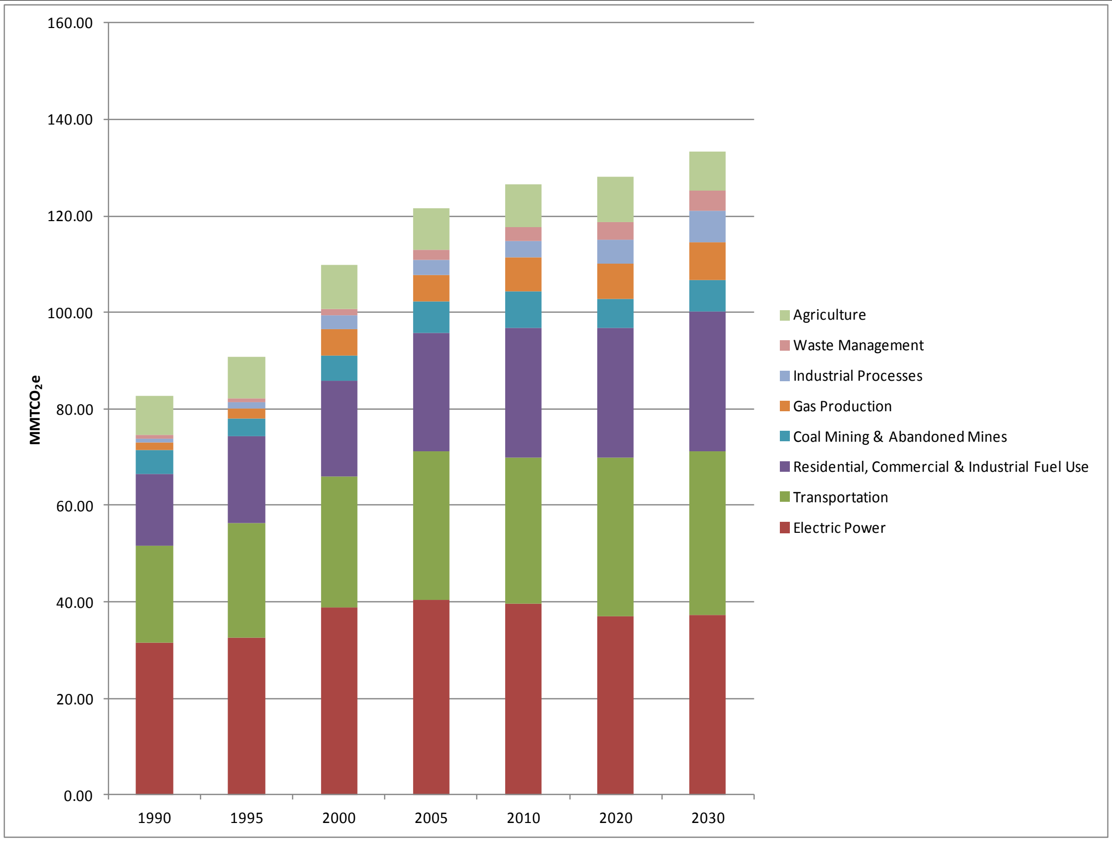

Figure ES-1: Summary of Colorado GHG Emissions by emission sector ($MMTCO_2e$) SIT Model Runs 1990-2030 (July 2, 2013 Analysis)

A detailed breakdown showing GHG emissions by SIT module is outlined in Table ES-2.

Table ES-2: Summary of Colorado GHG Emissions by Module- (MMTCO2e) SIT Model Runs 1990-2030 (2013 Analysis)

$MMTCO_2E$	1990	1995	2000	2005	2010	2020	2030
CO_2 from Fossil Fuel Combustion Module							
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	5.6	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
Total Emissions	65.33	72.68	84.17	94.38	95.99	96.44	99.78
Stationary Combustion Module N_2O & CH_4							
Residential	**0.069**	**0.069**	**0.079**	**0.072**	**0.074**	**0.019**	**0.019**
Commercial	**0.017**	**0.018**	**0.021**	**0.02**	**0.022**	**0.01**	**0.01**
Industrial	**0.01**	**0.017**	**0.017**	**0.02**	**0.021**	**0.006**	**0.006**
Electric Power	**0.157**	**0.161**	**0.187**	**0.188**	**0.184**	**0.009**	**0.009**
Total Emissions	**0.253**	**0.265**	**0.304**	**0.3**	**0.301**	**0.044**	**0.044**
Mobile Combustion Module N_2O & CH_4	0.96	1.32	1.33	0.98	0.53	0.35	0.34
Coal Mining & Abandoned Mines Module	4.81	3.73	5.32	6.61	7.54	5.96	6.6
Natural Gas and Oil Systems Module	1.72	2	5.39	5.47	6.98	7.47	7.89
Industrial Processes Module CO2e*	**0.72**	**1.41**	**2.94**	**3.16**	**3.58**	**4.89**	**6.28**
Agriculture Module	**8.14**	**8.44**	**9.14**	**8.77**	**9.04**	**9.24**	**8.25**
Waste Module CO2e							
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
Grand Total Emissions	**82.74**	**90.65**	**109.88**	**121.64**	**126.58**	**128.124**	**133.384**
Electricity Consumption Emissions (CO_2 Eq.) Module	**N/A**	**N/A**	**38.75**	**43.55**	**48.32**	**62.12**	**70.04**
LULUCF Summary of Emissions and Sequestration in Colorado Module	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**	**N/A**	**N/A**

*CO_2e=combined CO_2+CH_4+N_2O in million metric tons of CO_2 equivalent

Table ES-3 shows the breakdown of the GHG Inventory by gas in Colorado. The SIT modules generate emissions on a gas specific basis. For combustion processes, direct carbon dioxide emissions result from the oxidation of carbon based fuels. These combustion processes also generate nitrous oxide. Consumption and production of natural gas also produces methane, another powerful GHG. Finally the SIT tools inventory hydrochloroflourocarbon, perflourocarbon, and sulfur hexafluoride estimated to be emitted in Colorado.

The summary by gas table provides some insight into the relative importance of various source categories. To provide a perspective, in 2010 77% of the GHG inventory is related to carbon dioxide, 98% of which comes from fossil fuel combustion. The second largest GHG is methane representing 18% of the 2010 inventory. The majority of the CH_4 comes from agricultural sources, oil and natural gas production, and coal mining.

Table ES-3: Summary of Past and Projected GHG Emissions by Gas in Colorado ($MMTCO_2e$) SIT Model Runs 1990-2030 (2013 Analysis)

	1990	1995	2000	2005	2010	2020	2030
CO_2							
CO_2 from Fossil Fuel Combustion	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	1.72	2	5.39	5.47	6.98	7.47	7.89
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	**11.83**	**11.58**	**17.50**	**19.45**	**23.06**	**22.87**	**23.68**
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	**83.37**	**90.95**	**110.20**	**121.96**	**126.88**	**128.34**	**133.60**
Electricity Consumption Emissions (CO_2 Eq.)	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**	**62.12**	**70.04**
LULUCF	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**	**N/A**	**N/A**

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 indicated in Figure ES-2, GHG emissions per person in 2010 are approximately the same as in 1990, and are expected 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 shown in Figure ES-3.

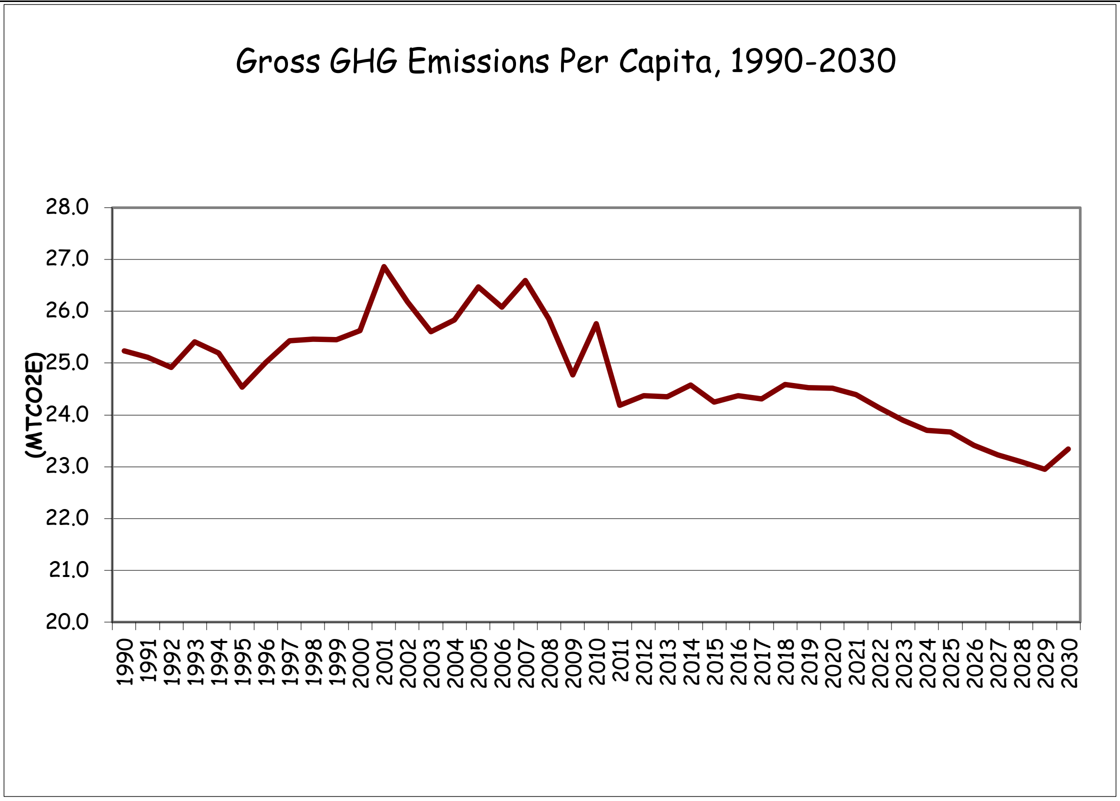

Figure ES-2: Gross GHG Emissions Per Capita, 1990-2030

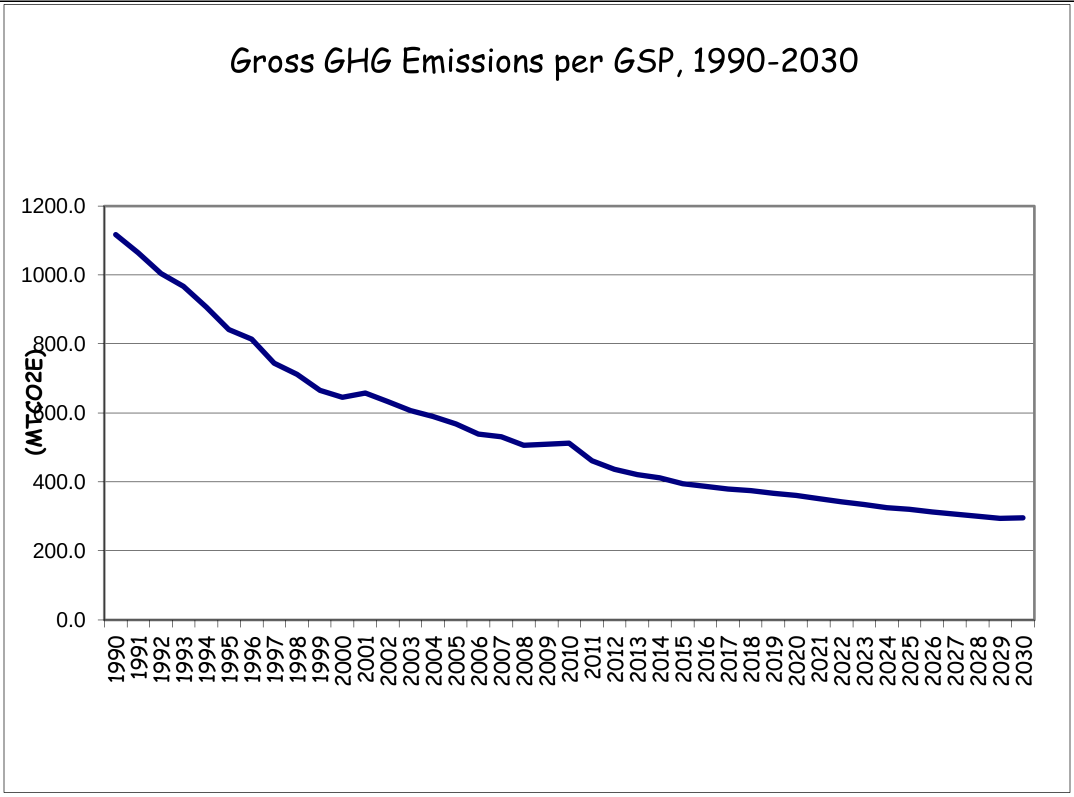

Figure ES-3: Gross Emissions Per Colorado's Gross State Product (GSP).

Although this Draft Inventory shows emissions increasing to 2020 and 2030, this is mainly due to population growth in the state. Also, because this inventory utilizes the Colorado default values set within the SIT model, a more customized approach may change the assumptions in the projections and show different emissions in the future.

CDPHE is seeking comments on this DRAFT Inventory, the methodology, assumptions, and the ways that the inventory can be tailored to Colorado emissions. Please send comments to Theresa Takushi at the following e-mail address: theresa.takushi@state.co.us by March 15, 2014. The final inventory will consider comments that have been received.

Colorado Department of Public Health and Environment

Chapter 1 – Synthesis Tool

Background

The Synthesis Tool provides a comprehensive summary of 1990-2010 outputs from the SIT model runs. While specific chapters in this inventory provide detailed tables of results, the Synthesis Tool summarizes information in a manner not available without a rigorous dissection of the SIT modules themselves, or the Export Files. This Synthesis Tool requires the user to run the eleven SIT modules using either default (as with this Colorado update) data, or state derived alternative data. After generating emission profiles for each sector, an 'Export File' must be 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. The Synthesis Tool captures the critical output from the summary of each module in tabular format. While some minor processing of the input files is accomplished in terms of summing some category data (such as the output from the municipal waste and the wastewater modules and creating more condensed data tables composited from multiple sheets, the Synthesis Tool makes no actual calculations of emissions. It should be viewed as a compendium of all module outputs designed to display summary data in a convenient and more readable format.

Once each of the SIT model modules were run for the Colorado GHG inventory update, covering 1990-2010, several steps remained to provide a summary of the emissions and projections to 2030. Following is a discussion of the tools and outputs from the Synthesis Tool. The Greenhouse Gas Estimates, 1990-2030-Projection Tool, and the Energy Consumption Projections -Projection Tool are briefly discussed here as they partially rely on results from the Synthesis Tool. For a complete discussion of the Projection Tool refer to Chapter 2.

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. This can be used to produce a summary of the data output from all the SIT modules. Following is an abbreviated description of how the Synthesis Tool works.

State Inventory Tool-Synthesis Module

A tactical decision was made in the construction of this inventory to exercise all SIT model modules in the default mode. 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. A second obvious areas needing consideration for more Colorado specific data is in the solid waste and landfill data (Table 1-14).

The tables that follow in this Chapter have been altered from the module output by eliminating most of the null data categories for brevity and appearance sake. For a complete listing of sources in a specific category, refer to the individual Chapters in this document.

After generating emission profiles for each sector, an 'Export File' must be 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). If the file is successfully linked, a date stamp is automatically placed in the file for each of the modules allowing the user, and future reviewers, to identify the vintage of the SIT model run. In each of the Chapters in this Colorado GHG Inventory, some, or all, of the information captured in this Chapter is provided. Thus, tables in this Chapter may show up in other Chapters. For the sake of capturing the relevant information in a consistent manner, the following thirteen tables and subsections document the results of the Synthesis Module. For space and appearance purposes, most tables have been edited to remove categories that had zero emissions for Colorado (e.g. bunker fuels; cable cars; trolleys, etc.) inventory.

For a comprehensive listing of source categories refer to the Synthesis Module-Projection Tool data file published with this Colorado GHG Inventory update or the EPA Synthesis Tool Users Guide.

Summary of Colorado GHG Emissions

The following tables provide the comprehensive summary of Colorado GHG emissions provided by the Synthesis Tool. They are the result of summing information from all of the modules. Table 1-1 summarizes emission by sector. Table1- 2 summarizes emissions by gas and Table 1-3 by gas intensity on a per capita and per gross state product basis.

Table 1-1: Summary of Colorado GHG Emissions by emission sector (July 2, 2013 model run)

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Energy					
CO_2 from Fossil Fuel Combustion	65.33	72.68	84.17	94.38	95.99
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	4.81	3.73	5.32	6.61	7.54
Natural Gas and Oil Systems	1.72	2	5.39	5.47	6.98
Total Emissions	**73.07**	**79.99**	**96.52**	**107.73**	**111.34**
Industrial Processes					
Total Emissions	**0.72**	**1.41**	**2.94**	**3.16**	**3.32**
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	**8.15**	**8.44**	**9.14**	**8.77**	**9.04**
LULUCF					
Total Emissions	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**
Waste					
Municipal Solid Waste	0.46	0.39	0.82	1.47	2.08
Wastewater	0.35	0.41	0.47	0.5	0.54
Total Emissions	**0.81**	**0.8**	**1.29**	**1.96**	**2.62**
Indirect CO_2 from Electricity Consumption*					
Total Emissions	27.73	31.81	38.75	43.55	48.32
Gross Emissions	**82.75**	**90.65**	**109.89**	**121.64**	**127.37**
Sinks	**-11.64**	**-10.53**	**-10.96**	**-10.97**	**-8.99**
Net Emissions	**71.11**	**80.11**	**98.93**	**110.67**	**118.38**

* Indirect emissions from Electrical Consumption are not included in the total emissions. These are reflective of end-use electrical consumption in Colorado and represent line losses and import /export of electricity in Colorado for policy information only. Refer to the discussion in Chapter 3 under Electrical Consumption. This avoids double counting of emissions from the use of electricity.

As reflected in Table 1-1, 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. This amounts to nearly 65% of the total 47 ton increase over the 20 year span of the inventory. For additional discussion of the changes and inventory, consult the Projection chapter to determine the projected increases to 2030.

Table 1-2: Summary of Colorado GHG Emissions by Gas (July 2, 2013 model run)

Emissions ($MMTCO_2e$)	1990	1995	2000	2005	2010
Gross CO_2	**65.69**	**73.32**	**85.64**	**95.71**	**98.23**
Net CO_2	**53.98**	**62.73**	**74.62**	**84.69**	**89.20**
CO_2 from Fossil Fuel Combustion	65.33	72.68	84.17	94.38	95.99
Industrial Processes	0.36	0.64	1.47	1.33	1.44
Waste	-	-	-	-	-
LULUCF	-11.71	-10.59	-11.03	-11.02	-9.03
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	4.81	3.73	5.32	6.61	7.54
Natural Gas and Oil Systems	1.72	2	5.39	5.47	6.98
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	0.009
Forest Fires	-	-	-	-	-
Waste	0.46	0.39	0.82	1.47	2.08
Wastewater	0.26	0.3	0.35	0.36	0.39
Total Emissions	**11.68**	**11.43**	**17.37**	**19.33**	**22.96**
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	<.001	<.001	<.001	<.001	<.001
Forest Fires	-	-	-	-	-
N_2O from Settlement Soils	0.07	0.06	0.06	0.06	0.04
Waste	-	-	-	-	-
Wastewater	0.09	0.11	0.13	0.14	0.15
Total Emissions	**5.08**	**5.17**	**5.47**	**4.82**	**4.08**
HFC, PFC, and SF_6					
Industrial Processes	0.36	0.78	1.47	1.83	2.14
Indirect CO_2 from Electricity Consumption*	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**
Gross Emissions	**82.81**	**90.7**	**109.96**	**121.69**	**127.41**
Sinks	**-11.71**	**-10.59**	**-11.03**	**-11.02**	**-9.03**
Net Emissions (Sources and Sinks)	**71.11**	**80.11**	**98.93**	**110.67**	**118.38**

* Indirect emissions from Electrical Consumption are not included in the total emissions. These are reflective of end-use electrical consumption in Colorado and represent line losses and import /export of electricity in Colorado for policy information only. Refer to the discussion in Chapter 3 under Electrical Consumption. This avoids double counting of emissions from the use of electricity.

In contrast to examining the summarized emissions by source sector, Table 1-2 provides a breakdown by gas. This view of the increases from 1990 to 2010 shows that of the 45.3 $MMTCO_2e$ increase in Colorado gross emissions, approximately 33 $MMTCO_2e$ is from increases in CO_2 emissions. Approximately 10$MMTCO_2e$ of the increase is attributable to methane emissions, of which approximately half is due to methane emissions from oil and gas production.

Table 1-3: Colorado GHG Emissions Summary by Intensity (July 2, 2013 model run)

Emissions Per Capita ($MTCO_2E$)	**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) ($MTCO_2E$)	**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**

Table 1-3 provides a unique view of the emissions per year expressed in on 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. That picture changes in the projection case owing to greater per person efficiency increases from 2011-2030 based on a variety of assumptions made by the EIA. 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%.

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

<u>CO_2 from Fossil Fuel Combustion</u>

CO_2 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. Table 1-4 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.

Table 1-4: Summary of CO_2 Emissions-Fossil Fuel Combustion Synthesis Tool Results

Emissions (MMTCO$_2$ Eq.)	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
Total 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
Total 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
Total 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
Total 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**

<u>Stationary Combustion</u>

Table 1-5 presents the summary methane and nitrous oxide emissions from 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 in the 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 effective as a GHG, on a per molecule basis. The results in table 1-5 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 N2O). For a more comprehensive discussion concerning stationary combustion refer to Chapter 3.

[5] EPA has recently concluded that methane is 25 times more potent as a GHG than CO_2. This new multiplier is not reflected in the SIT model version used to generate this DRAFT inventory,

Table 1-5: Summary of CH_4 and N2O Emissions from Stationary Combustion-Synthesis Tool Results

Emissions ($MMTCO_2$ Eq.)	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**
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**
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**	**0.265**	**0.304**	**0.300**	**0.302**

Mobile Combustion-Methane and Nitrous Oxide

Mobile Combustion-Methane and Nitrous Oxide sources account for 5% or 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 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 Table 1-4 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. Tables 1-6 -1-8 document the SIT model output for methane and nitrous oxide emissions from mobile source combustion. These emissions vary according to the types of control equipment and other operating parameters (temperature, oxygen levels, air fuel ratio, etc.) of 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 Tables 1-7 and 1-8 are combined on a $MTCO_2e$ basis to form the contents of Table 1-6. 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. The emissions of methane and nitrous oxide are small compared to carbon dioxide emissions and are displayed in metric tons, not millions of metric tons (e.g. 905,053 $MTCO_2e$=0.9 $MMTCO_2e$).

Table 1-6: Summary of CH_4 and N_2O Emissions from Mobile Combustion-($MTCO_2e$) Synthesis Tool Results

Fuel Type/Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	571,275	676,281	653,806	487,979	309,852
Light-Duty Trucks	314,450	548,967	575,617	371,351	108,230
Heavy-Duty Vehicles	18,514	25,857	30,272	26,090	8,977
Motorcycles	813	1,050	1,005	972	1,700
Total Emissions	**905,053**	**1,252,155**	**1,260,700**	**886,392**	**428,759**
Diesel Highway					
Passenger Cars	99	88	77	77	68
Light-Duty Trucks	159	251	319	373	247
Heavy-Duty Vehicles	4,253	6,045	7,330	8,182	9,926
Total Emissions	**4,511**	**6,384**	**7,726**	**8,632**	**10,241**
Non-Highway					
Boats	477	497	523	619	541
Locomotives	8,311	12,429	5,276	1,649	7,349
Farm Equipment	5,985	8,274	7,344	5,345	6,070
Construction Equipment	3,812	4,607	10,048	11,711	12,081
Aircraft	26,558	31,690	32,580	51,986	47,524
Other*	1,017	1,465	4,064	5,425	2,715
Total Emissions	**46,161**	**58,962**	**59,834**	**76,735**	**76,281**
Alternative Fuel Vehicles					
Light Duty Vehicles	815	976	1,879	1,487	1,967
Heavy Duty Vehicles	2,440	2,640	3,432	6,889	9,910
Buses	50	165	215	451	837
Total Emissions	**3305**	**3780**	**5525**	**8826**	**12713**
GRAND TOTAL	**959,030**	**1,321,281**	**1,333,786**	**980,586**	**527,995**

Table 1-7: Summary of CH_4 Emissions from Mobile Combustion-($MTCO_2e$) Synthesis Tool Results

Fuel Type/Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	53,384	49,600	39,681	28,199	22,533
Light-Duty Trucks	27,836	33,627	25,888	17,635	7,015
Heavy-Duty Vehicles	5,202	5,326	3,425	2,313	698
Motorcycles	334	431	407	390	681
Total	**86,755**	**88,983**	**69,400**	**48,537**	**30,925**
Diesel Highway					
Passenger Cars	3	3	2	2	2
Light-Duty Trucks	7	10	13	16	10
Heavy-Duty Vehicles	285	406	492	549	666
Total	**295**	**419**	**508**	**567**	**679**
Non-Highway					
Boats	78	81	85	101	88
Locomotives	1,452	2,171	922	288	1,284
Farm Equipment	1,651	2,283	2,026	1,475	1,675
Construction Equipment	504	609	1,329	1,549	1,598
Aircraft	2,445	2,481	2,721	3,647	3,342
Other*	135	194	538	717	359
Total	**6,265**	**7,820**	**7,621**	**7,777**	**8,346**
Alternative Fuel Vehicles					
Light Duty Vehicles	74	158	493	268	307
Heavy Duty Vehicles	85	163	450	2,224	3,653
Buses	20	66	93	195	359
Total	**179**	**386**	**1,036**	**2,687**	**4,319**
GRAND TOTAL	**93,494**	**97,608**	**78,564**	**59,568**	**44,269**

Table 1-8: Summary of N_2O Emissions from Mobile Combustion-($MTCO_2e$) Synthesis Tool Results

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	517,891	626,681	614,125	459,780	287,319
Light-Duty Trucks	286,615	515,341	549,729	353,716	101,216
Heavy-Duty Vehicles	13,312	20,531	26,847	23,778	8,279
Motorcycles	479	618	598	581.90739	1019.804
Total	**818,297**	**1,163,172**	**1,191,300**	**837,856**	**397,834**
Diesel Highway					
Passenger Cars	96	86	75	74.952245	65.837778
Light-Duty Trucks	153	240	306	357.30482	236.87197
Heavy-Duty Vehicles	3,968	5,639	6,838	7,633	9,260
Total	**4,216**	**5,965**	**7,219**	**8,065**	**9,563**
Non-Highway					
Boats	399	416	438	517.77213	452.47755
Locomotives	6,859	10,257	4,354	1,361	6,065
Farm Equipment	4,334	5,991	5,317	3,871	4,395
Construction Equipme	3,308	3,998	8,719	10,162	10,484
Aircraft	24,114	29,208	29,859	48,340	44,182
Other*	883	1,272	3,527	4,707	2,356
Total	**39,897**	**51,142**	**52,214**	**68,958**	**67,934**
Alternative Fuel Vehicles					
Light Duty Vehicles	741	818	1,386	1,219	1,660
Heavy Duty Vehicles	2,355	2,477	2,981	4,665	6,257
Buses	30	99	122	255.99139	477.69324
Total	**3,126**	**3,394**	**4,489**	**6,139**	**8,394**
GRAND TOTAL	**865,536**	**1,223,672**	**1,255,222**	**921,018**	**483,726**

* "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 the mining activities, crushing, hauling, washing, etc. and from underground mines. In Table 1-9 Abandoned Coal Mines are a category tracked separately and the 'vented', 'sealed', and 'flooded' mine emissions are totaled in the table to equal the 'Abandoned Coal Mines total. While a mine might be designated as 'sealed' they are not sealed from atmospheric leaks and this becomes the most significant source from Abandoned Mines. For a more complete discussion of Coal Mining emissions refer to Chapter 7, Fossil Fuel Industry and the SIT Coal User Guide (2013).

Table 1-9: Summary of CH_4 Emissions from Coal Mining Activities in Colorado ($MTCO_2e$)

	1990	1995	2000	2005	2010
Coal Mining	**4,162,872**	**3,056,891**	**4,357,682**	**5,486,535**	**6,634,082**
Abandoned Coal Mines	644,854	671,609	962,717	1,121,250	901,868
Vented	40,975	29,587	95,928	65,447	54,815
Sealed	598,216	639,043	855,939	1,050,363	844,145
Flooded	5,663	2,979	10,850	5,440	2,909
Total	**4,807,726**	**3,728,500**	**5,320,399**	**6,607,785**	**7,535,950**

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. Table 1-10 summarizes the output from the Natural Gas and Oil Systems module. For a complete description of this sources category refer to Chapter 8 of this Colorado update and the SIT Natural Gas and Oil system user's guide.

Table 1-10: Summary of CH_4 Emissions from Oil and Gas Activities in Colorado ($MMTCO_2$ 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**
Emissions by Gas ($MTCH_4$)-Note the following are in tons of methane, not adjusted by the factor of 21 multiplier to change this to CO_2e (See note below)					
Natural Gas					
Production	52,071	73,328	241,925	240,978	305,994
Transmission					
Distribution					
Total Emissions	**52,071**	**73,328**	**241,925**	**240,978**	**305,994**
Oil					
Total Emissions	**18,751**	**18,193**	**12,758**	**16,484**	**23,715**
Emissions by Gas ($MMTCO_2$)					
Natural Gas Flaring	0.23	0.07	0.04	0.06	0.06

Industrial Process

Industrial Processes sources accounted for less than 1% (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.). Table 1-11 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.). Most IP sources are self explanatory. The lack of emissions in some categories indicates no defined sources in the national data base for Colorado. For simplicity, these have been removed from Table 1-11. Examination of Chapter 6 results will show more source categories (see note at the bottom of Table 1-11 for a list of categories eliminated from the table). Of note, but of minor significance to the overall inventory for Colorado, is the 1990, and in some cases 1995, lack of emissions for some categories such as lime manufacturing or iron and steel production. For further details on these sources categories refer to Chapter 6 of this Colorado GHG inventory. Due to the extremely high GHG potential for SF6, PFC's, and HFCs, a small amount of emission 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. Sources in this category are expected to grow in proportion to population.

Table 1-11: Summary of GHG Emissions from Industrial Processes in Colorado ($MTCO_2$ e)

Emissions ($MTCO_2$ Eq.)	1990	1995	2000	2005	2010
Carbon Dioxide Emissions					
Cement Manufacture	317,456	475,769	553,799	622,895	559,103
Lime Manufacture		100,294	94,977	295,275	274,957
Limestone and Dolomite Use		18,838	28,451	30,305	4,989
Soda Ash	35,890	38,369	40,673	40,591	35,625
Urea Consumption	3,071	2,643	2,259	4,247	3,777
Iron & Steel Production			750,305	340,273	304,845
Total Emissions	**356,416**	**635,912**	**1,470,463**	**1,333,586**	**1,183,296**
HFC, PFC, and SF_6 Emissions					
ODS Substitutes	4,384	437,580	1,166,999	1,561,279	1,866,266
Semiconductor Manufacturing	52,518	89,243	117,120	85,198	104,082
Electric Power Transmission and Distribution Systems	302,734	251,153	189,427	184,139	166,476
Total Emissions	**359,636**	**777,976**	**1,473,547**	**1,830,615**	**2,136,824**
GRAND TOTAL	**716,052**	**1,413,887**	**2,944,010**	**3,164,202**	**3,320,120**

Note no ammonia; nitric Acid or adipic acid; magnesium; HCFC-22 or aluminum production is shown as sources for Colorado. For table simplification these sources showing zero emissions were deleted from the Synthesis Module results. Also, these emissions are in metric tons, not millions of metric tons so moving the decimal point six to the left is needed to get $MMTCO_2e$

Agriculture

Agricultural sources account for slightly less than 10% of the State inventory and are a combination of emissions from waste material decomposition, soil management, agricultural burning, enteric fermentation (flatulence), and manure management. Table 1-12 summarizes the agricultural source categories' emissions. For a complete description of these source categories refer to Chapter 9 of this inventory. Critical assumptions in this category include 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 and emission factors and calculation schema for this category.

Table 1-12: Summary of GHG Emissions from Agriculture in Colorado ($MMTCO_2e$)

	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 Wa	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 W	0.003	0.003	0.003	0.003	0.004
Agricultural Soil Managemen	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**

Land Use, Land-Use Change, and Forestry

As set forth in Table 1-13, Land use, land use change and forestry (LULUCF) acts 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, Table 1-13 overstates the emission reduction benefits from the LULUCF category. For a more complete discussion of this issue and potential impacts on the overall inventory consult Chapter 11 of this Colorado inventory. Due to this one notable exception, and to emphasize the lack of data, the null data values and categories have been left in Table 1-13.

Table 1-13: Summary of GHG Emissions from Land-Use Change and Forest Emissions and Sequestration in Colorado(MMTCO$_2$e)

	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 (see note at bottom of table)	See note	See note	See note	See note	See note
N_2O	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 the Synthesis Tool summary table for space purposes. For LULUCF this included liming of agricultural soils. Forest fires were specifically left in to point to this deficiency in the model data base. See Chapter 11 for a more in-depth discussion of this category and issue.

Municipal Solid Waste

Municipal solid waste and landfill emissions and sequestration are listed in Table 1-14 and represent about 0.5% of the overall Colorado inventory balancing sequestration of carbon in landfills against direct emissions of waste combustion and waste degradation.

Table 1-14: Total Emissions from Landfills and Waste Combustion (MMTCO$_2$e)

	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 (MTCO$_2$E)					
Potential CH_4	**703,381**	**953,466**	**1,309,577**	**2,074,403**	**2,854,739**
MSW Generation	657,366	891,090	1,223,904	1,938,694	2,667,981
Industrial Generation	46,016	62,376	85,673	135,709	186,759
CH_4 Avoided	**-193,260**	**-515,097**	**-400,559**	**-444,937**	**-547,215**
Flare	-160,919	-482,756	-356,377	-444,937	-547,215
Landfill Gas-to-Energy	-32,341	-32,341	-44,182		
Oxidation at MSW Landfills	**46,411**	**37,599**	**82,334**	**149,376**	**212,077**
Oxidation at Industrial Landfills	**4,602**	**6,238**	**8,567**	**13,571**	**18,676**
Total CH_4 Emissions	**459,109**	**394,532**	**818,116**	**1,466,519**	**2,076,772**
CO_2 and N_2O Emissions from Waste Combustion (MTCO$_2$E) (SEE NOTE BELOW re: NULL Emissions					
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 accounts for less than a half of one percent of the gross Colorado emissions. This, as with all other major categories of the inventory are required elements to be accounted for under international guidelines for creating comprehensive inventories. For a complete discussion of emissions from wastewater treatment consult the EPA Module 10 user's guide (EPA 2013). 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.

Note fruits and vegetables along with poultry and pulp and paper show no emissions for the Colorado default inventory and have been removed from the summary table. Emissions associated with poultry and fruits and vegetables are partly accounted for in the agricultural and land use modules. For further discussion about this category consult Chapter 10 of this document.

Table 1-15: 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

For a more comprehensive discussion of emissions generated during wastewater treatments consult Chapter 10, Waste Management, of this inventory.

Indirect CO_2 from Electricity Consumption

Electrical consumption based emissions are represented by inventorying electrical use in the State versus total electricity generated. Table 1-16 provides the summary from the SIT model run. For a more comprehensive discussion concerning indirect CO_2 emissions from electrical consumption refer to Chapter 3.

Table 1-16: Summary of Indirect CO_2 Emissions-Electricity Consumption-Synthesis Tool Results

Emissions (MMTCO$_2$ Eq.)	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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Colorado Department
of Public Health
and Environment

Chapter 2 – Projection Tool

Background

Projection of emissions to 2030 is a critical element of the GHG inventory. Knowing emissions from 1990-2010 establishes the baseline. Forecasting future emissions, based on Colorado's history, and national projections, provides a basis for policy makers to assess future trends and determine whether strategies should be pursued to alter these trends.. The SIT Model Projection Tool (PT) provides this forecast. This chapter describes how the PT operates and provides projections of emissions to 2030. The nature of the tool is more complex than the other modules. Prior to using the PT, one must run all the base case SIT modules and produce the summary data Export File for each. These summary files are used in various ways to construct a continuum of emissions from 1990-2030. While many elements of running the PT 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 PT utilizing growth assumptions that are embedded in the tool.

The SIT PT has four major parts:

1. 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
2. Population and Production-1990-2030 population and gross state product by year based on national trends apportioned to the state
3. 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
4. Emission projections for:
    - 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-N2O 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
- 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 N2O 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 N2O 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

The first part of the PT generates energy consumption projections for all sectors anticipated to directly use fossil fuels. If the State opts to input data different from the default assumptions, a separate energy consumption tool is available and must be run and input provided to the PT. For this default inventory, using the energy PT was not necessary as in the default mode the PT generates an energy use profile for the State. The second part generates expected population and gross annual product figures, which are used in parts of the projections. The third part projects animal populations, which drive elements of the agricultural projections. The final part of the tool utilizes the results from each of the SIT modules to create a long term picture (1990-2030) based on consistent emission assumptions noted above. As shown in the list, in some cases the 1990-2010 data is used to create trends for future emissions while in other cases the PT only uses the historical data to create a baseline of comparison. Each of the elements of the PT is described in this chapter. Summary tables, extracted from the PT, and in some cases, added to from other parts of the SIT tools are presented to form the most continuous picture of the inventory within the constraints of running the model in the default mode.

Summary of Projected Gas Emissions

Emissions by Gas

After each of the projection elements of the model are exercised, the model produces summaries of the emissions in several different ways. The model sorts out emissions by gas and by source. It also apportions emissions by population and by gross state product. The PT 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. Table 2-1 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.

Table 2-1: 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	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	1.72	2	5.39	5.47	6.98	7.47	7.89
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	**11.83**	**11.58**	**17.50**	**19.45**	**23.06**	**22.87**	**23.68**
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	**83.37**	**90.95**	**110.20**	**121.96**	**126.88**	**128.34**	**133.60**
Electricity Consumption Emissions (CO_2 Eq.)	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**	**62.12**	**70.04**

Figure 2-1 provides a graphical summary from the PT, based on the data in Table 2-1, showing the majority of Colorado's increase projected 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 $C0_2$ emissions in Colorado.

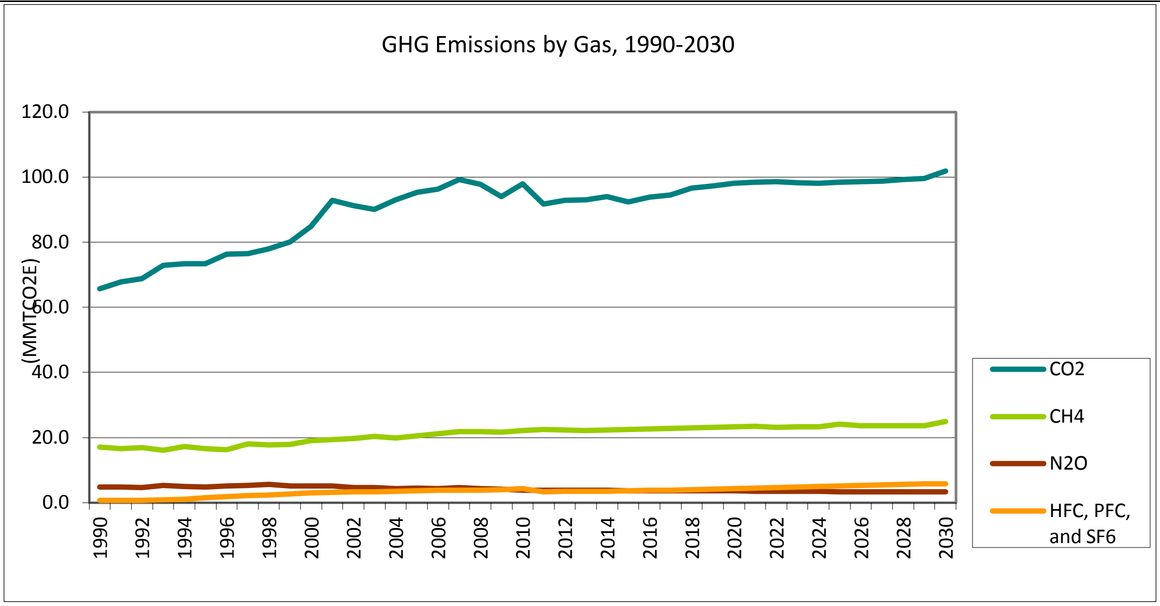

Figure 2-1: Trend in historical and projected Colorado GHG emission by gas (EPA SIT PT Summary

Methane emissions are the second largest GHG category, representing 17.7% of the 2030 projected inventory. Over half of the methane emissions come from coal mining, natural gas, and oil systems. The remaining major categories of methane emissions are enteric fermentation and waste management, accounting for less than 6% of the overall state inventory. Figure 2-2 provides a visual representation of the trend and relative contribution from major source categories.

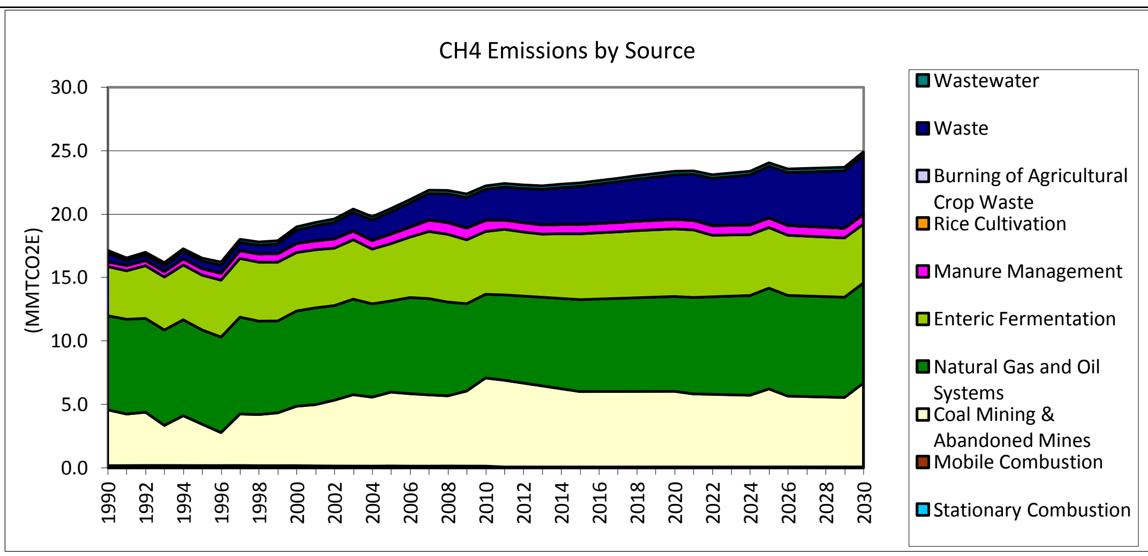

Figure 2-2: Trend in Colorado methane emissions by source category (EPA PT, September 2013)

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 or manure management. Figure 2-3 depicts the trend in Colorado projected emissions and is 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. Nitrous oxide is produced from combustion processes and agriculture practices so discussions of emissions are found in several areas of the inventory.

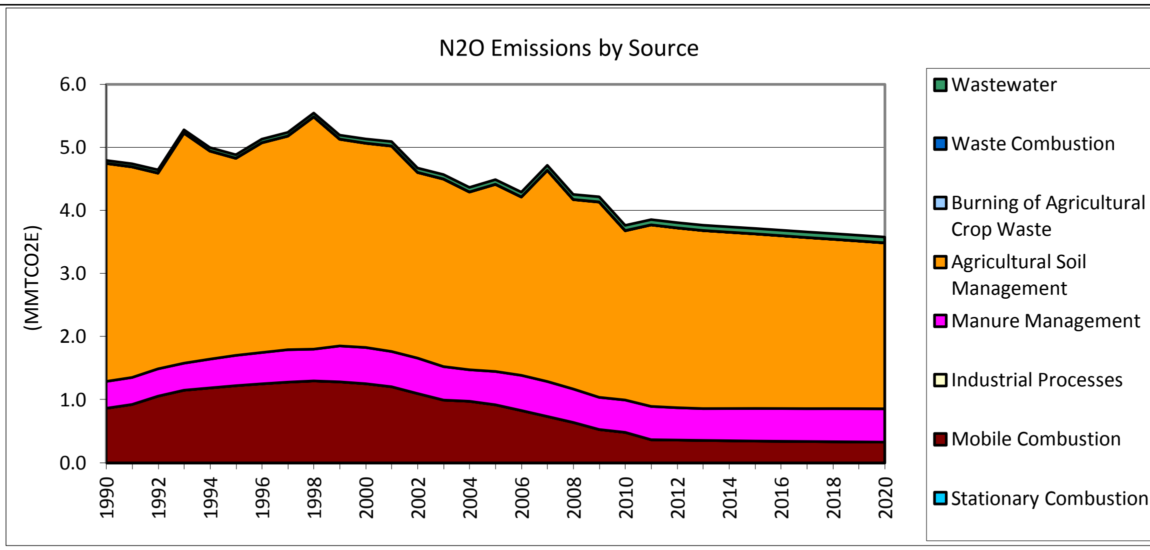

Figure 2-3: Trend in Colorado nitrous oxide GHG emissions by source category (EPA PT, September 2013)

<u>Emissions by Source Type</u>

Table 2-2 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. Energy use and production within Colorado is the single largest source category with fossil fuel combustion leading the way. This includes transportation, electrical power generation and burning natural gas and coal in commercial, industrial and residential settings.

Here we see energy production and consumption dominate the Colorado inventory with agriculture and waste representing less than 10% of the overall emissions picture and Industrial processes (cement manufacturing, limestone production, etc.) being about 6% of the 2030 emission profile for Colorado.

Table 2-2: Summary of historical and projected Colorado emissions by Source in $MMTCO_2e$

	1990	1995	2000	2005	2010	2020	2030
Energy							
CO_2 from Fossil Fuel Combustion	65.33	72.68	84.17	94.38	95.99	96.44	99.78
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	1.72	2	5.39	5.47	6.98	7.47	7.89
Total Emissions	**73.07**	**79.99**	**96.52**	**107.73**	**111.34**	**110.46**	**114.84**
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	**83.00**	**90.94**	**110.19**	**121.93**	**126.89**	**128.32**	**133.58**
Electricity Consumption Emissions (CO_2 Eq)	**27.73**	**31.81**	**38.75**	**43.55**	**48.32**	**62.12**	**70.04**

Table 2-3 provides a summary of GHG Emissions by population and gross state product in Colorado (EPA PT, September 2013).

Figure 2-4 presents the trend in GHG emissions by sector in Colorado from 1990-2030 and provides a visual representation of how much energy production and use dominates the GHG inventory. Increases in emissions are due to projected increases in energy use and production due to growth in the State. For a more comprehensive discussion of the assumptions used to make these projections, consult the sub-sections of this chapter.

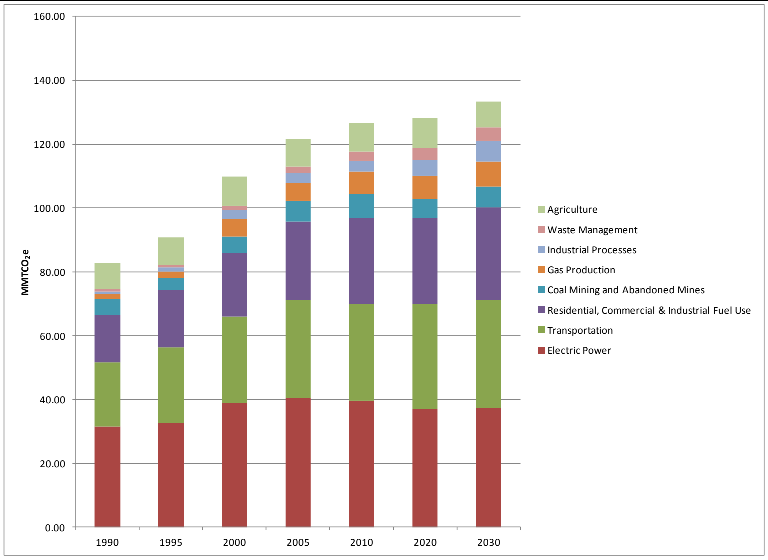

Figure 2-4: Summary of Colorado GHG Emissions by emission sector SIT Model Runs 1990-2030 (July 2, 2013 Analysis)

Emissions are expressed in the SIT PT 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. Figures 2-5 and 2-6 present the total inventory as a function of state population and gross state production. 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.

Table 2-3: Emissions Per Person $MTCO_2e$ (September 10, 2013 model run)

	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

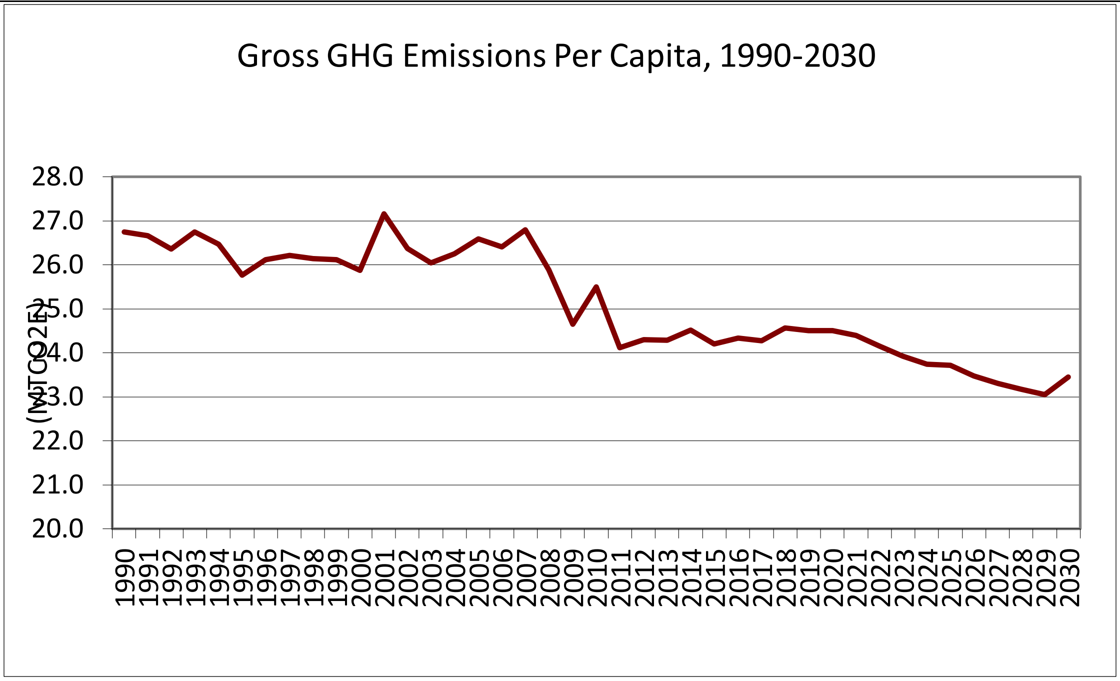

Figure 2-5: Gross GHG emissions as a function of population showing decreased emissions per person (September 9, 2013)

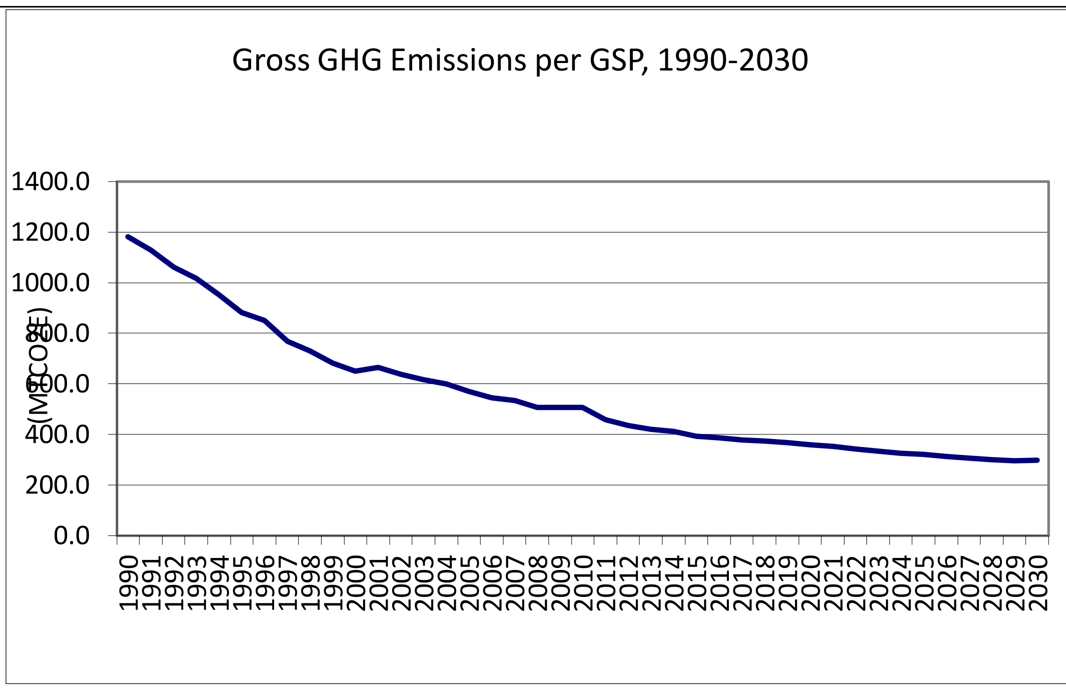

Figure 2-6: Gross GHG emissions as a function of gross state product showing decreased emissions dollar of goods produced is decreasing (September 9, 2013)

Projection Tool (PT) Details and Results

As with all the SIT modules, this element of the EPA GHG inventory toolbox is a dynamically, 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 PT uses various elements of the national and local data to produce future emissions. There is no universal statement that can be made to describe how each part of the PT works. As an example, projected Agricultural emissions, described in Chapter 9, are driven by Colorado animal populations and emission factors either provided by the user, or acquired automatically as 'default' factors. Historical agricultural data is imported from the Agricultural Summary file created by the Agricultural SIT Tool. This input data is then used by the PT, to support calculations in more specific areas. Agricultural animal populations are used to generate projected manure management methane emissions, enteric fermentation, and biomass waste sent to sewage treatment facilities. Projected activity factors must be made for each part of the agricultural activities to produce expected emissions. Other parts of the PT operate in a totally different manner. 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.

Calculations are activated each time the model is operated, connecting the spreadsheet to either imported files from the SIT tools, or from national data bases. Due to the dynamic nature of the model and data bases, a fully run version of the spreadsheet can only be saved and viewed in its entirety in a static mode. In the active version of the model all data is summarized in a tabular and graphical output. In the static version only the tabular data can be saved.

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 Web site. Example tables in this Chapter vary and attempt to capture the 1990-2030 five year intervals where available and relevant.

For this 2013 inventory update, the PT estimates emissions in the future (2011-2030) by using the June 2013 version of the State Projection Inventory Tool (SIT) module. Unlike the individual SIT modules that were updated in February 2013, the PT was not updated by the EPA until May 15, 2013. This version was released to the public in mid-June. As is the case in many of the data projections, a small to moderate discontinuity can often be seen when crossing the boundary from actual historical Colorado data to the projected 2011 and beyond data. In a few cases the discontinuity is quite evident but generally has little impact on the 2020 and 2030 projections.

For this inventory the projection model was run fully in the default mode selecting the option to 'Import Historical Data' at every opportunity provided by the model. Projections were then generated by selecting the option to 'Use Default Historic Data'.

Details for which options were available are discussed below in each of the sub-sections in this Chapter. As of the publication of this inventory update, the EPA had not published a user's guide for this element of the SIT tool. As a result more of the process for the workings of the model have been copied from the spreadsheet into this chapter since no other reference exists to describe the workings of the model. In the PT 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.

The PT, as with the Synthesis Tool, requires the user to import SIT module's 'Export Files' as key information to complete the projections. In some cases emissions for 2011–2030 are based on a trend established in the 1990-2010. Alternatively, in other cases, the model uses national trends established from a variety of data bases. These may be built into the PT.

Energy Production is handled in the PT in a slightly different approach than the other modules. For a more detailed description of the Energy Production Projections refer to that sub-section of this Chapter. In brief, a national assessment of energy production and consumption was developed by the U.S. Energy Information Administration. 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 PT 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. The decision to create the Colorado update in the default mode allows for the establishment of a baseline comparable to other state inventories, and the national inventory, if they followed a similar approach. This also allows Colorado the chance to examine a more tailor made inventory in the future to indicate what impact state decisions may have on future emissions.

For a more complete detail of the individual assumptions for each part of the PT consult the subsections in each of the following elements of this Chapter. The EPA description has been extracted and displayed in each source sector.

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

The Synthesis Tool and the PT 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 PT. While some minor processing of the input files is accomplished in the Synthesis Tool in terms of totaling some category data, no emissions are actually calculated in that module. An example of what the Synthesis Tool does is to produce a table of ‘waste emissions’. This comes from the output from the municipal waste and the wastewater modules. The Synthesis Tool creates a condensed data table composited from these two modules. As noted, no actual calculations of emissions are made in the Synthesis Tool so in this example, the end result is just the addition of sub-categories of emissions between several output files. The Synthesis Tool tables should be viewed as a compendium of all module outputs, designed to display summary data in a convenient and more readable format.

The Synthesis Tool does not link to, or influence the PT. However, the format of the condensed data tables often serves as a convenient way of displaying projected emissions. In this Colorado 2013 inventory selected data tables from the Synthesis Tool were used to construct the 1990-2030 comprehensive data summary where the PT failed to produce such a table. In other cases, discontinuity between the PT, 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 PT 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 PT are the individual module Export Files. However, as noted below, the PT has more projection elements often using the Export Files in several different tools, combining those summaries of emissions with national and regional data to create the projected emission picture.

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.

The two major tools are:

1. Energy Consumption Projection 1 2012.xls State Inventory Tool (ECPSIT). This module projects State energy consumption from 2011 through 2030. The PT 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 PT.

2. Greenhouse Gas Estimates, 1990-2030 Inventory Tool (hereafter called the Projection Tool or PT).

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

- Transportation
- Residential
- Commercial
- Industrial
- Electrical generation

The 2011-2030 GHG emission are all projected cases. When exercising the PT the user must link to the Export Files. By doing so, the user generally has the option of allowing the PT to calculate future emissions based on the 1990-2010 trends calculated from the SIT module specific to the category. In any case, all past emissions calculated by the SIT modules are graphically and numerically combined with the projected case so a comprehensive long term picture can be seen.

The Process

Step 1-

Prior to running the PT, the user must run the following SIT modules and then produce the Export File by selecting this option on the Control page of each module:

- CO_2 from Fossil Fuel Combustion
- Electricity Consumption
- Stationary Combustion
- Mobile Combustion
- Coal Mining
- Natural Gas and Oil Systems
- Industrial Processes
- Agriculture
- Municipal Solid Waste
- Wastewater

Note the *Land Use and Land Use Change and Forestry* (LULUCF) module is not used by the PT as no accounting for this segment of the inventory is made. The summary data file used by the PT is the same file used by the *Synthesis Tool*. The data creates background files used in the PT as described in this chapter.

Step 2

Run the *Energy Consumption Projection State Inventory Tool (ECPSIT)*. This will only be used if alternative State level data is used for the projection. Otherwise, the first sub-sheet of the *PT* performs the same calculations. The user can opt for running both and comparing to ensure they are the same in the default mode.

Step 3-Run the elements of the model

The *PT* has six steps to develop the comprehensive Colorado projected emissions. Within each step there are options to select default data and/or to import historical data.

Sub-step 1 is to select a State after activating the interactive 'Options' selection as is done with all the SIT model elements. Enabling the macros allow the model to access national or other data bases as directed by the user.

Sub-step 2 allows the user to capture the energy use projection and populate that element of the model with state specific or default data. As noted the 'default' data was used for all projection assumptions in this inventory update.

Sub-step 3 selects the population data base used to drive other elements of the model. Population figures are based on U.S. Census Bureau information from several past reports. See the description in Table 5 of this Chapter for further details.

Sub-step 4 selects the livestock population sheet. For a description of the basis for these projections consult Figures 7 and 8 and Table 6 of this Chapter.

Sub-step 5 allows the user to navigate to each of the fifteen calculation sub-sheets and select options within each of the sheets. Each sheet relates to one of the SIT Export files. In several cases the sub-sheet of the *PT* uses the same Export file for separate parts of the projection calculation. To create the comprehensive projection, one must populate all the sub-sheets by accessing the Export files as directed in the *PT*. Most of the sub-sheets allow the user to import historical emissions and a graphical summary will then include historical and projected emissions in one chart. This is a convenient tool since discontinuities can immediately be seen between historical data and the projected data due to the nature of how the projection and historical are, or are not, linked. In most modules, using the historical data generated in the SIT modules creates the trend line, or benchmark data point, used by the *PT*. Consult the discussions below for each of the modules to determine how the *PT* worked for each part of the inventory.

Sub-step 6-three projected data summary sheets will now be complete in the *PT*. These are: Summary by Gas, Summary by Sector, and Summary by Industry. Graphical and tabular summaries are provided and can be extracted using a cut and paste approach. The results of the summary table are provided at the beginning of this chapter.

No tool appears to be available to export the data from the *PT*. A static, non-working version of the Colorado emissions projections has been saved and is published with this inventory. This Chapter captures key data outputs for each element of the inventory on a five year basis.

Energy Consumption Projection (ECP)

A state projection of energy consumption may be developed as input to the *PT* if state specific data is to be used. In the default mode the output from the *ECPSIT* is reported by the EPA to be identical to that used in the *PT*. Table 1 provides a five year interval projection of energy use in the state based on the *PT* process. For the purposes of this default inventory the following discussion applies to the *PT* and the ECPSIT as no modifications were used to change default assumptions for Colorado.

As noted in the opening section of this chapter, there are three major elements in the Energy Consumption Projection used as a basis for projecting energy production and consumption by fuel type and use sector in this module. It is the heart of the GHG emission projection process if one considers the far reaching implications of energy use in Colorado compared to other emission sectors.

No EPA guidance document is available for using this part of the SIT. However, most pages of the projection spreadsheet based model have sufficient discussion and transparency to understand how the *PT* functions and what the State-by-State consumption rates are.

The following subsection provides more detail about the ECP sections and results from each of these.

State and Regional Energy Consumption

Table 4 summarizes state fuel consumption in Colorado using default assumptions. These figures are in billions of BTUs and are used in other parts of the *PT* 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 *PT* is at the heart of how emissions are calculated and projected to 2030 for fossil fuel related segments of the model. As noted, in the default mode, the SIT *PT* duplicates the workings of the Energy Consumption Projections module. The following description of how the *PT* models future use of energy is identical to the process used in both parts of the *PT*. The following three point description, extracted from the Energy Consumption Projections May 15, 12.xls model, explains the logic behind how state level energy consumption figures 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 made in the model.

1. Regional energy consumption projections (from 2011 through 2030) were obtained from the Energy Information Administration's (EIA) Annual Energy Outlook 2012. This report projects energy consumption by sector (e.g. residential) and fuel type (e.g., motor gasoline) for 9 regions [of the U.S.]
2. State energy consumption in 2010 from EIA's State Energy Data 2010 Consumption tables (EAI 2012) were obtained and used to downscale the regional energy consumption estimates. Regional consumption was downscaled by calculating the state's percent consumption (from the State Energy Data)

relative to the region. EIA's State Energy Data are available online at http://www.eia.doe.gov/states/_seds.html

3. Projected regional consumption was disaggregated to state-level estimates by applying the selected state's proportion of consumption in 2010 from EIA's State Energy Date 2010 Consumption tables (EIA 2012) to the regional energy consumption data (EPA 2012)

Table 2-4: Energy Consumption-PT Fossil Fuel Consumption (Billion BTU) 8/June/2013 SIT Version)

State/Sector/Fuel	2015	2020	2025	2030
Residential				
Coal	459	433	408	384
Natural Gas	134,266	135,422	138,163	141,005
Distillate Fuel	68	57	48	40
Kerosene	16	15	14	13
LPG	11,076	11,037	11,126	11,270
Total BTU	**145,884**	**146,964**	**149,758**	**152,711**
Commercial				
Coal	4,422	4,425	4,418	4,410
Natural Gas	65,735	65,942	67,101	68,916
Distillate Fuel	7,367	7,219	7,067	6,934
Kerosene	14	16	18	19
LPG	2,328	2,329	2,387	2,453
Motor Gasoline	197	209	224	233
Total BTU	**80,063**	**80,141**	**81,216**	**82,965**
Industrial				
Other Coal	3,548	3,595	3,628	3,663
Natural Gas	213,536	223,097	220,537	225,182
Distillate Fuel	19,838	19,140	18,641	18,316
LPG	6,753	7,358	7,522	7,516
Motor Gasoline	3,921	4,020	4,010	3,910
Asphalt and Road Oi	1,932	1,939	1,955	1,954
Lubricants	971	974	982	981
Petroleum Coke	4,153	4,166	4,203	4,198
Still Gas	13,456	13,499	13,617	13,604
Misc. Petro Products	2,076	2,083	2,101	2,099
Total BTU	**270,185**	**279,871**	**277,196**	**281,422**
Transportation*				
Natural Gas	15,106	15,714	16,635	20,105
Distillate Fuel	105,731	114,693	120,545	124,647
Jet Fuel, Kerosene	77,671	80,465	84,111	87,719
LPG	617	668	716	787
Motor Gasoline	242,988	242,208	235,058	231,673
Residual Fuel	-	-	-	-
Other Petroleum				
Aviation Gasoline	342	357	369	382
Lubricants	1,845	1,924	1,993	2,060
Total BTU	**444,301**	**456,029**	**459,426**	**467,371**
Electric Power				
Coal	314,947	350,557	345,714	352,763
Natural Gas	60,009	73,311	77,948	75,265
Distillate Fuel	458	509	505	505
Residual Fuel	7,399	7,400	7,400	7,400
Total BTU	**382,812**	**431,777**	**431,568**	**435,933**

Note: Projections begin at 2011 with historical data cutting off at 2010 based on SIT model runs

Regional energy consumption profiles are built into the *PT* based on the EIA Annual Energy Outlook 2011 report (2011). It has sector level, and fuel type, data for 9 regions of the country. Colorado is in the 'Mountain' region along with Arizona, Idaho, Montana, New Mexico, Nevada, Utah, and Wyoming.

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

Within each of the sectors, fuel types are apportioned by percentage. Table 2-5 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. A brief examination of the table, comparing the Colorado 2009 and Western Regional 2009, shows no consistent pattern from Colorado sources to regional ones. As an example, Colorado appears to be 87% of the EIA Mountain Regional coal consumption (653 BBTU /749 BBTU), but only 35.5% of the natural gas consumption and 27% of the LPG consumption. As such, allocation percentages for each fuel category need to be specifically developed in the *PT* model. 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. However, one can easily back-calculate growth and allocation rates from the results in each of the data tables presented in following tables.

Table 2-5: Projected Regional consumption (BBTU-EIA annual energy outlook through 2030 (Updated tool 5-15-2012) and Colorado

	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
Petroleum Coke	-	6,853	0%	7,399	7,400	7,400
Residual Fuel	-	0	0%			

Table 2-6 contains the historical Colorado fuel consumption figures in the SIT CO_2 *Emissions from Combustion of Fossil Fuel-State* module. These are derived from the national Energy Information Agency's long term use report (2012). Historical energy consumption may be used in the SIT *PT* to establish trends of energy use in the state. These trends are used by the model, at the user's option, to project the 2011-2030 emissions.

Table 2-6: Colorado Sector and Fuel use in BBtu (18 June, 2013 update)

	1990	1995	2000	2005	2010[a]
Commercial Coal	992	379	1,546	2,720	5,360
Commercial Distillate Fuel	2,576	4,093	3,524	3,641	6,046
Commercial Kerosene	55	992	43	173	26
Commercial LPG	1,164	1,501	1,935	2,519	1,897
Commercial Motor Gasoline	1,385	301	654	212	213
Commercial Natural Gas	66,489	67,585	60,753	63,809	58,630
Commercial Residual Fuel	-	-	-	-	-
Commercial Wood	800	986	1,374	1,097	1,119
Commercial Other					
Electric Power Coal	320,752	327,951	376,872	376,774	369,089
Electric Power Distillate Fuel	291	163	1,106	251	216
Electric Power Natural Gas	13,432	24,085	66,799	95,866	95,210
Electric Power Residual Fuel	0	50	46	-	-
Electric Power Wood	-	-	-	8	29
Industrial Asphalt and Road Oil	21,614	24,689	25,681	17,548	12,040
Industrial Aviation Gasoline Blending Components	1	30	20	48	-1
Industrial Coal	15,383	15,814	9,270	6,939	7,479
Industrial Distillate Fuel	15,799	16,012	19,072	21,309	21,344
Industrial Kerosene	103	27	27	31	4
Industrial LPG	3,475	4,619	11,000	5,690	7,947
Industrial Lubricants	1,481	1,413	1,509	1,273	1,188
Industrial Misc. Petro Products	-	-	64	65	99
Industrial Motor Gasoline	2,135	2,778	2,785	7,087	3,733
Industrial Motor Gasoline Blending Components	273	-	-	-	-
Industrial Natural Gas	66,493	86,622	117,445	182,765	208,904
Industrial Pentanes Plus	-	-	-	-	-
Industrial Petroleum Coke	1,792	1,986	2,423	2,550	3,007
Industrial Residual Fuel	79	2	-	-	-
Industrial Special Naphthas	398	214	641	107	-
Industrial Still Gas	7,485	8,035	7,498	8,570	8,951
Industrial Unfinished Oils	-1,875	-1,819	-2,077	16	170
Industrial Waxes	-	434	408	239	131
Industrial Wood	331	344	339	177	172
Industrial Other Coal	15,383	15,814	9,270	6,939	7,479
Residential Coal	248	57	191	237	662
Residential Distillate Fuel	160	203	361	51	63
Residential Kerosene	127	113	165	204	34
Residential LPG	6,493	8,374	10,798	12,933	12,369
Residential Natural Gas	92,191	105,766	116,133	127,677	133,463
Residential Wood	7,318	7,191	8,215	6,832	6,697
Transportation Aviation Gasoline	841	624	790	655	553
Transportation Distillate Fuel	40,100	50,497	66,606	77,044	87,533
Transportation Ethanol	803	3,149	5,067	3,797	9,990
Transportation Jet Fuel, Kerosene	33,053	40,083	42,993	69,852	63,841
Transportation Jet Fuel, Naphtha	1,498	1,919	-	-	-
Transportation LPG	286	263	216	296	267
Transportation Lubricants	2,499	2,385	2,547	2,149	2,005
Transportation Motor Gasoline	182,468	209,401	238,500	256,543	250,792
Transportation Natural Gas	9,152	11,630	9,780	13,841	14,759

Population and Gross Product History and Projections

Population and gross annual product are used in various elements of the *PT* to apportion national metrics to Colorado projections where projections for Colorado are not available. Table 2-7 provides the population and gross state product assumptions used by the *PT*. These originate from several Census Bureau reports and national economic reports.

Population projections are calculated in the *PT* using the data sources and assumptions outlined in Figure 7 which is extracted from the Data Assumptions sub-sheet of the *PT*. 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 figures 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 Table 7 is also the annual Gross State Product which is projected by using an apportionment of 1990-2010 figures applied to the national data base.

Table 2-7: State population assumptions used in the PT (updated 18/June/2013)

	State Population ('000 people)	US Population & Projections ('000 people)	% 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

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.

Figure 2-7: State population assumptions used in the PT

Projections of livestock are calculated by the SIT PT using the assumptions outlined in Figures 2-8 – 2-11 (EPA SIT PT 2013). 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 based on that data. The 2010 Colorado to national ratios are then applied to each future year to predict state head counts.

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.

Figure 2-8: Livestock population projection assumptions for cattle used by SIP PT (EPA 2012

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)

Figure 2-9: Livestock population projection assumptions for swine used by SIP PT (EPA 2012)

Poultry, goats, sheep, and horse populations for the future are calculated using a different scheme than for swine and cattle. Figures 10 and 11, from the EPA PT, provide details of the process. A multistep process is applied to USDA data from 2001 to 2010 and 1990 to 2010 NASS data. The 1990-2010 NAAS information was used to project future national head counts. The percent yearly increase was applied to the Colorado 2010 estimates.

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.

Figure 2-10: Livestock population projection assumptions for poultry used by SIP PT (EPA 2012)

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.

Figure 2-11: Livestock population projection assumptions for goats, horses, and sheep used by SIP PT (EPA 2012)

Livestock populations are presented in Table2-008 and represent historical and projected animal counts. Head counts are used to determine emissions from several of the sub-sheets in the Agricultural *PT*, 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.

Table 2-8: Livestock population in Colorado 2001-2030 projections (updated 18 June, 2013) All livestock populations are in '000 head

	2001	2005	2010	2015	2020	2025	2030
Dairy and Beef Cows							
Dairy Cows	90	101	97	97	96	99	99
Dairy Replacement He	45	50	38	37	38	34	33
Beef Cows	840	639	668	690	730	585	558
Beef Replacement Hei	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**

Note: Popululations are in '000 head

Projection of Emissions by Source Sector

The SIT *PT* 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 *PT.* Published with this GHG inventory is a copy of the complete output from the *PT* found on the State of Colorado web site. That spreadsheet contains emissions for each year from 2011-2030, along with the historical date from the Export Files. Following is a description from the *PT* for each of the model segments.

For specific data outputs beyond those contained within this Chapter, refer to the detailed *PT* spreadsheet published with this GHG Inventory:

Projected Emissions from Fossil Fuel Consumption in Colorado

While the *PT* uses the term consumption in the title of the sub-sheet, and in the calculation description in Figure 2-12, (extracted from the *PT* 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, industrial sectors of energy use. Details of how the SIT model produces emissions for future years for fossil fuel combustion are found in Figure 12. Despite the term consumption being in the discussion, this specifically addresses combustion. Lacking a guidance document for this element of the GHG inventory, this Chapter provides the process for calculating future emissions. Table2- 9 contains the five year projected emissions from fossil fuel combustion in Colorado. This fossil fuel combustion sub-element of the *PT* allows the user to import the historical emissions from the SIT *Fossil Fuel Combustion* module. Because the *PT* 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. Categories of emissions were combined from Table 9 to create emission totals in the Executive summary and are presented in the summary Table 10.

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".

Figure 2-12: Assumptions used by SIT PT for Fossil Fuel Consumption (EPA 2012)

Table 2-9: Projected CO_2 Emissions from Fossil Fuel Combustion in Colorado (From SIT Table 4 of $FFCCO_2$ sub-page) (18/June/2012 updated model) (June 25, 2013 model run)

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
Total 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
Total 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
Total 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
Total 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
Total Emissions	**33.03**	**37.05**	**36.84**	**37.35**
Grand Total	**91.00**	**96.44**	**96.54**	**99.78**

Table 2-10 provides the 1990-2030 $MMTCO_2e$ combining output from the PT and the SIT CO_2 from Fossil Fuel Combustion module.

Table 2-10: Summary of Colorado Historical and Projected CO_2 from fossil fuel combustion emissions in $MMTCO_2e$ from Table2 of EPA SIT PT (18/June/2012 updated model) (June 25, 2013 model run)

	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
Total 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
Total 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
Total 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
Total 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. Figure 2-13, extracted from the SIT *PT*, details how the calculation of future CH_4 and N_2O emissions are calculated based on historical Colorado and national data. In essence energy use projections documented in Table 2-4 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 can be reflected. For a more comprehensive discussion of this process consult the EPA Guidance document noted in Figure 2-13. Table 2-13 provides a summary of the historical and projected emissions produced by the *PT* and the Stationary Source Combustion SIT module.

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.

Figure 2-13: Assumptions used by SIT PT to Calculate Methane and Nitrous Oxide from Stationary Combustion (EPA 2012)

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 processes to emit various forms of nitrogen oxides. Nitrous oxide, a very minor player in terms of nitrogen oxide emissions, is powerful greenhouse gas. The SIT combustion module for Stationary Sources provides emissions profiles for a range of combustion sources from 1990 to 2010. The *PT* does not have an accounting for wood burning in the residential, commercial or industrial segments generating a zero emission profile from 2011-2030 but in the 1990-2010 years, wood burning estimates are provided as part of the default emissions profile. States are encouraged to provide wood burning figures. For the purposes of this default inventory no adjustments were made as it would not be a 'default' selection in the inventory process. In the 1990-2010 data base wood consumption and emissions are calculated and are a substantial component of the residential N_2O emissions accounting for 56% of the 2010 residential emissions and 68% of the 1990. However, when considering the inventory as a whole, the stationary source combustion component of nitrous oxide is less than 0.01% of the inventory and likely not worth adding to the projection case.

Table 2-11: N2O Emissions from Stationary Source Combustion, $MMTCO_2e$ (figures in white background extracted from CH_4 and N2O Emissions from Stationary Combustion Module July 2013 run using Feb. 2013 version of the SIT model. Figures in gray from SIT PT July 2013 model run)

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
Total 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
Total 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 F	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
Total 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
Total 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 *PT* calculates future methane emission based on the scheme detailed in Figure 2-13, previously discussed in the nitrous oxide from stationary source combustion section. The *PT* 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. Of note in the methane projections is the lack of estimated wood burning in the RCI categories after 2010. The SIT stationary source combustion module accounts for some woodburning in Colorado and produces both nitrous oxide and methane estimates from 1990-2010. The *PT* suggests provide state specific data for wood burning from 2011-2030. As with other parts of this inventory, the default mode was exercised and no projections beyond 2010 were substituted in this inventory. As with nitrous oxide, the overall impact of not considering wood burning for methane emissions amounts to a fraction of a percent and likely is inconsequential to the overall inventory. Table 2-14 provides five year increments for the 1990-2030 base years and projected years for methane in $MMTCO_2e$.

Table 2-12: CH_4 Emissions from Stationary Source Combustion ($MMTCO_2e$)

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
Total 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
Total 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
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
Total 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
Total 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 (presented in Tables 4 and 5), an accounting for methane and nitrous oxide is made in the *PT* for CH_4 and N_2O from mobile sources. The SIT module *Mobile Source Combustion* produces CH_4 and N_2O emissions from 1990-2010 based on a complex distribution of the total vehicle miles traveled per year for the fleet and an apportioning of those miles to vehicle classes. An age distribution and emission technology is applied to the data to calculate the N_2O and CH_4 from mobile sources for 1990-2010. 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*. Figure 2-14 provides the logic employed by the *PT* to project emissions from 2011 to 2030. Tables 2-15 and 2-16 provide 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 *PT*. 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 *PT*, the overall methane contribution in 2010 from all mobile sources, accounting for the higher potency, is three hundredths of a percent. The same drop in N_2O emissions 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.

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.

Figure 2-14: Assumptions used by SIT PT to Calculate Methane and Nitrous Oxide from Mobile Source Combustion (EPA 2012)

CH_4 from Mobile Sources

Table 2-13: CH_4 Emissions from Mobile Sources in $MTCO_2e$

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Gasoline Highway									
Passenger Cars	53,384	49,600	39,681	28,199	22,533	6,986	7,044	7,102	7,161
Light-Duty Trucks	27,836	33,627	25,888	17,635	7,015	6,685	6,494	6,307	6,126
Heavy-Duty Vehicles	5,202	5,326	3,425	2,313	698	400	400	400	400
Motorcycles	334	431	407	390	681	37	18	9	5
Total Emissions	**86,755**	**88,983**	**69,400**	**48,537**	**30,925**	**14,109**	**13,956**	**13,819**	**13,692**
Diesel Highway									
Passenger Cars	3	3	2	2	2	2	2	2	2
Light-Duty Trucks	7	10	13	16	10	17	18	20	23
Heavy-Duty Vehicles	285	406	492	549	666	429	477	530	589
Total Emissions	**295**	**419**	**508**	**567**	**679**	**447**	**497**	**552**	**614**
Alternative Fuel Vehicles									
	179	**386**	**1,036**	**2,687**	**4,319**	**1,614**	**1,736**	**1,867**	**2,008**
Non-Highway									
Boats	78	81	85	101	88	46	47	49	50
Locomotives	1,452	2,171	922	288	1,284	110	118	125	134
Farm Equipment	1,651	2,283	2,026	1,475	1,675	1,707	1,789	1,875	1,966
Construction Equipmer	504	609	1,329	1,549	1,598	3,511	3,804	4,122	4,467
Aircraft	2,445	2,481	2,721	3,647	3,342	2,164	2,384	2,627	2,895
Other*	135	194	538	717	359	1,231	1,353	1,487	1,635
Total Emissions	**6,265**	**7,820**	**7,621**	**7,777**	**8,346**	**8,768**	**9,495**	**10,286**	**11,146**
GRAND TOTAL	**93,494**	**97,608**	**78,564**	**59,568**	**44,269**	**24,938**	**25,684**	**26,524**	**27,459**

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

N_2O from Mobile Sources

Table 2-14: N2O Emissions from Mobile Sources (MTCO$_2$e)

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Gasoline Highway									
Passenger Cars	517,891	626,681	614,125	459,780	287,319	151,081	153,641	156,245	158,892
Light-Duty Trucks	286,615	515,341	549,729	353,716	101,216	130,028	106,467	87,176	71,380
Heavy-Duty Vehicles	13,312	20,531	26,847	23,778	8,279	6,746	6,746	6,746	6,746
Motorcycles	479	618	598	582	1,020	55	28	14	7
Total Emissions	**818,297**	**1,163,172**	**1,191,300**	**837,856**	**397,834**	**287,911**	**266,882**	**250,180**	**237,025**
Diesel Highway									
Passenger Cars	96	86	75	75	66	51	56	62	69
Light-Duty Trucks	153	240	306	357	237	380	422	469	521
Heavy-Duty Vehicles	3,968	5,639	6,838	7,633	9,260	5,968	6,630	7,366	8,184
Total Emissions	**4,216**	**5,965**	**7,219**	**8,065**	**9,563**	**6,398**	**7,109**	**7,898**	**8,775**
Alternative Fuel Vehicles									
	3,126	**3,394**	**4,489**	**6,139**	**8,394**	**4,801**	**5,061**	**5,335**	**5,624**
Non-Highway									
Boats	399	416	438	518	452	235	242	250	258
Locomotives	6,859	10,257	4,354	1,361	6,065	521	556	593	632
Farm Equipment	4,334	5,991	5,317	3,871	4,395	20,478	21,466	22,502	23,588
Construction Equipmer	3,308	3,998	8,719	10,162	10,484	9,213	9,983	10,818	11,722
Aircraft	24,114	29,208	29,859	48,340	44,182	8,251	9,092	10,019	11,040
Other*	883	1,272	3,527	4,707	2,356	8,078	8,878	9,758	10,724
Total Emissions	**39,897**	**51,142**	**52,214**	**68,958**	**67,934**	**46,775**	**50,217**	**53,939**	**57,964**
GRAND TOTAL	**865,536**	**1,223,672**	**1,255,222**	**921,018**	**483,726**	**345,885**	**329,269**	**317,352**	**309,388**

* "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 Table 2-15 in MTCO$_2$e. The totals for mobile source CH_4 and N_2O a represent less than a half percent of the overall 2010 and 2030 inventory. Thus, 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.

Table 2-15: Total Emissions from Mobile Sources ($MTCO_2e$)

Fuel Type/ Vehicle Type	1990	1995	2000	2005	2010	2015	2020	2025	2030
Gasoline Highway									
Passenger Cars	571,275	676,281	653,806	487,979	309,852	158,067	160,685	163,347	166,053
Light-Duty Trucks	314,450	548,967	575,617	371,351	108,230	136,713	112,961	93,483	77,506
Heavy-Duty Vehicles	18,514	25,857	30,272	26,090	8,977	7,146	7,146	7,146	7,146
Motorcycles	813	1,050	1,005	972	1,700	93	46	23	11
Total Emissions	**905,053**	**1,252,155**	**1,260,700**	**866,392**	**428,759**	**302,019**	**280,838**	**263,999**	**250,717**
Diesel Highway									
Passenger Cars	99	88	77	77	68	52	58	64	72
Light-Duty Trucks	159	251	319	373	247	397	441	489	544
Heavy-Duty Vehicles	4,253	6,045	7,330	8,182	9,926	6,397	7,107	7,896	8,773
Total Emissions	**4,511**	**6,384**	**7,726**	**8,632**	**10,241**	**6,846**	**7,606**	**8,450**	**9,388**
Alternative Fuel Vehicles									
	3,305	**3,780**	**5,526**	**8,826**	**12,713**	**6,415**	**6,797**	**7,201**	**7,632**
Non-Highway									
Boats	477	497	523	619	541	280	289	299	308
Locomotives	8,311	12,429	5,276	1,649	7,349	631	673	718	766
Farm Equipment	5,985	8,274	7,344	5,345	6,070	22,184	23,255	24,377	25,553
Construction Equipmer	3,812	4,607	10,048	11,711	12,081	12,724	13,787	14,940	16,189
Aircraft	26,558	31,690	32,580	51,986	47,524	10,415	11,476	12,646	13,935
Other*	1,017	1,465	4,064	5,425	2,715	9,310	10,232	11,245	12,359
Total Emissions	**46,161**	**58,962**	**59,834**	**76,735**	**76,281**	**55,543**	**59,712**	**64,224**	**69,110**
GRAND TOTAL	**959,030**	**1,321,281**	**1,333,786**	**980,586**	**527,995**	**370,823**	**354,953**	**343,875**	**336,847**

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

Electricity Consumption/Indirect CO_2 Emissions

Indirect emissions of CO_2 equivalents are produced in the *PT* to help in making policy decisions related to energy use in the State. In the fossil fuel combustion part of the *PT,* direct emissions from fuel combustion are calculated for the State and were presented in Tables 4-6. Thus, coal, natural gas, oil and petroleum products that are burned for energy production are characterized in that part of the *PT.* However, electricity consumption at the residential, commercial, industrial, and transportation (light rail) level must account for two factors not reflected in direct combustion figures. Loss of electricity in transmission, and imported electricity into the state, show up at the use end but not at the generation end. Regional electrical consumption are apportioned to Colorado (and other states) by using the 2010 consumption ratio and then applying that factor to future regional projections. Figure 15 provides a more complete description and the Electrical Consumption chapter in this inventory. Projected and historical emissions in $MMTCO_2e$ are presented in Table 16 which is extracted from the *PT*.

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.

Figure 2-15: Assumptions used by SIT PT to Calculate Methane and Nitrous Oxide from Mobile Source Combustion (EPA 2012)

Table 2-16: Historical and Projected Emissions from State Electricity Consumption in Colorado (EPA 2013)

	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 a requirement for safety purposes. Untreated emissions may be released directly to the atmosphere. Abandoned mines continue to emit methane and are the more significant ones are reported to a national data base. Projection of emissions to 2030 is accomplished in the *PT* by using national coal production projections through 2020 and extrapolation to 2030 based on the national trend. The 2010 Colorado emissions are compared to the national 2010 data and future years for Colorado are based on that ratio. Figure 16 provides a more comprehensive discussion concerning how the PT allocates emissions to the future. Table 17 summarizes the expected coal mining emissions in $MMTCO_2e$.

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

Figure 2-16: Assumptions used by SIT PT to Calculate Methane from Mining (EPA 2012)

Table 2-17: 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 [a]	**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	0	0	0

<u>Oil and Gas Production</u>

Projected emission from oil and gas production are based on a combination of national trend information apportioned to the state based on Colorado's 2010 ratio compared to the national 2010 production. In 2010 Colorado was 7.4% of the national natural gas production; 1.9% of the consumption; and 2.3 % of the petroleum production gas emissions. The apportionment of Colorado's 2010 emissions to national emissions allotted Colorado at 4.1% of the national production profile. This figure is arrived at by apportioning the production and consumption figures with the assumption being the gas produced in the state is not all used in the state, and what is used does not all come from where it is produced. Figure 2-17 provides the logic applied by the *PT* to oil and gas production. The *PT* allows the State to substitute other protections as far as natural gas and oil production. In this inventory we opted to run the model in the default mode, using the 'Use Default Historic Data' option. The data is presented in Table 2-18.

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.

Figure 2-17: Assumptions used by SIT PT to Calculate Methane from Natural Gas and Oil Systems (EPA 2012)

Table 2-18: Historical and Projected Methane from Oil and Gas Production ($MMTCO_2e$) (from Projection Tool September 2013 data run, sub-page Projected Emissions from Natural Gas and Petroleum Systems in Colorado)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Natural Gas	1.322	1.613	5.119	5.119	6.486	6.8	7.06	7.55	7.56
Petroleum	0.394	0.382	0.268	0.346	0.498	0.45	0.42	0.39	0.33
TOTAL	**1.715**	**1.995**	**5.387**	**5.465**	**6.984**	**7.25**	**7.47**	**7.95**	**7.89**

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) to the atmosphere. These potent GHGs are not necessarily manufactured in Colorado, nor does the state have an accounting for activities using these gases. The *PT* 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 Figure 18 for a more detailed description of the PT's handling of emission projections for this category. Table 2-19 provides detailed historical and projected emissions. Note in Table 2-19 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 large 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 PT relies on the national EPA Vintaging Model to apportion national emissions back to states. The *PT* makes no attempt to correct this data.

Figure 2-18 provides a discussion from the EPA PT module relative to how IP emissions are projected. An error in the PT 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 PT tool model errors, the output file table was manually corrected to insure a complete emissions picture from 1990-2030 is provided. Table 2-19 provides a corrected accounting for the 1990-2030 emissions for Colorado for 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.

Figure 2-18: Assumptions used by SIT PT to Calculate Industrial Processes (EPA 2012)

Table 2-19: Industrial Processes Emissions ($MTCO_2e$)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Carbon Dioxide Emissions									
Cement Manufacture	317 ,456	475,769	553,799	622,895	559,103	976,272	1,114,329	1,252,386	1,390,443
Lime Manufacture		100,294	94,977	295,275	274,957	387,634	452,875	518,117	583,358
Limestone and Dolomite Use		18,838	28,451	30,305	4 ,989	22,116	24,498	26,879	29,260
Soda Ash	35,890	38,369	40,673	40,591	35,625	40,288	40,897	41,505	42,113
Ammonia & Urea	3,071	2,643	2,259	4,247	3,777	3,994	4,295	4,597	4,898
Iron & Steel Production			750,305	340,273	304,845				
Total Emissions	**356 ,416**	**635,912**	**1,470,463**	**1,333,586**	**1,443,296**	**1,430,305**	**1,636,894**	**1,834,483**	**2,050,073**
Nitrous Oxide Emissions									
Nitric Acid Production									-
Adipic Acid Production									-
Total Emissions									**-**
HFC, PFC, and SF_6 Emissions									
ODS Substitutes	4 ,384	437,580	1,166,999	1,561,279	1,866,266	2,539,732	3,054,268	3,568,803	4,083,339
Semiconductor Manufacturing	52 ,518	89,243	117,120	85,198	104,082	116,039	124,877	133,715	142,553
Magnesium Production									
Electric Power Trans. and Distr. Systems	302 ,734	251,153	189,427	184,139	166,476	107,397	71,762	36,126	491
HCFC-22 Production									
Aluminum Production									-
Total Emissions	**359 ,636**	**777,976**	**1,473,547**	**1,830,615**	**2,136,824**	**2,763,168**	**3,250,907**	**3,738,644**	**4,226,383**
GRAND TOTAL	**716,052**	**1,413,887**	**2,944,010**	**3,164,202**	**3,580,120**	**4,193,473**	**4,887,801**	**5,582,127**	**6,276,456**

Enteric Fermentation

Enteric fermentation emissions are calculated from an animal populations inventory for the State. For a description of generation of methane from this source category refer to the Agriculture chapter of this inventory. Briefly, the PT 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 *PT.* As is the case with a number of the projections, the 2010 Colorado emissions were used to create a ratio of Colorado versus national emission for that year. This apportionment was used for all future years and a national data base was accessed by the *PT* to create projected emissions. Figure 2-19 contains a more detailed description of how the *PT* handles methane projections from enteric fermentation. Table2- 20 provides the projected emissions to 2030.

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.

Figure 2-19: Assumptions used by SIT PT to Calculate Methane from Enteric Fermentation (EPA 2012)

Table 2-20: Emissions in $MMTCO_2e$

	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				
Total 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
Total 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 are described in the Agricultural chapter. Manure from domestic animals is estimated by animal type and animal population and an annual production estimate as described in the Agriculture chapter. The projection method is outlined in Figure 2-20. Historical emissions were calculated using the animal populations for the State shown in Table 2-8 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.

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.

Figure 2-20: Assumptions used by SIT PT to Calculate Methane Emissions from Manure Management (EPA 2012)

Table 2-21: Emissions, $MMTCO_2e$

	2015	2020	2025	2030
Dairy Cattle				
Dairy Cows	0.375	0.37	0.382	0.383
Dairy Replacement Heife	0.020.	0.021	0.0.19	0.018
Total 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 Heifer	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
Total 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
Total 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
Total Emissions	**0.02**	**0.02**	**0.02**	**0.02**
GRAND TOTAL	**1.25**	**1.28**	**1.25**	**1.25**

N_2O Emissions from Manure Management

To estimate emissions of nitrous oxide (N_2O) from manure management, not including manure used as daily spread or manure that is excreted directly on pasture, range, and paddock, the following steps are performed: (1) obtain the required data on animal populations and manure management practices; (2) calculate the total Kjeldahl nitrogen[1] for manure managed in each system type; and (3) calculate nitrous oxide emissions from manure management. The data used to project emissions include:

The information needed to estimate direct N_2O emissions from manure management consists of: animal population (in number of head) for each type of animal, typical animal mass (TAM), Kjeldahl N emitted per unit of animal mass (kg per 1,000 kg animal mass per day), and the percent of manure managed in each type of manure management system (WS%).

The TAM and Kjeldahl N were derived from the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*.

The WS% for each system for dairy cattle, swine, and poultry layers were developed from the U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks*. State data for the WS%, when available, were used in place of U.S. default values. The WS% breakdown of the systems used to manage manure for the remaining animals was developed for use in the state inventory guidance.

To calculate total Kjeldahl N, population is multiplied by the TAM, Kjeldahl N per 100 kg animal mass, and 365 days per year. This is performed separately for waste managed in liquid systems (anaerobic lagoons and liquid/slurry systems) and dry systems (solid storage and drylot).

To calculate total N_2O emissions, Kjeldahl N is multiplied by the appropriate emissions factor, for either liquid or dry

Notes and assumptions about manure management:

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

Assumed that 2010 animal characteristics remain constant for future projections.

[1] Total Kjeldahl nitrogen is a measure of organically bound nitrogen and ammonia nitrogen.

Figure 2-21: Assumptions used by SIT PT to Calculate Nitrous Oxide from Manure Management (EPA 2012)

Table 2-22: N2O Emissions from Agricultural Soils (MMTCO$_2$e)

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 Soils

Agricultural soils are responsible for nitrous oxide emissions from several processes. Calculating N_2O from agricultural soils is described in the Agricultural chapter of this Colorado 2013 inventory update. Figure 2-22 describes the calculation scheme for predicting future emissions of nitrous oxide from agricultural soils. In essence the Projection Tool uses the historical date attributed to Colorado and projects future emission based on the trend.

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.

Figure 2-22: Assumptions used by SIT PT to Calculate Nitrous Oxide from Agricultural Soils (EPA 2012)

Table 2-23: Enteric Fermentation Emissions – Metric Tons of CH_4

	2015	2020	2025	2030
Dairy Cattle				
Dairy Cows	17,017	16,801	17,335	17,383
Dairy Replacement Heifers	67	68	62	60
Total Emissions	**17083**	**16869**	**17396**	**17443**
Beef Cattle				
Feedlot Heifers	664	679	616	599
Feedlot Steer	838	856	777	756
Bulls	67	68	62	60
Calves	42	43	39	38
Beef Cows	900	952	763	727
Beef Replacement Heifers	110	113	102	99
Steer Stockers	766	783	711	691
Heifer Stockers	800	817	742	721
Total Emissions	**4187**	**4310**	**3811**	**3692**
Swine				
Breeding	2,730	2,859	2,988	3,117
Market < 60 lb	1,875	1,964	2,053	2,141
Market 60-119 lb	772	809	845	882
Market 120-179 lb	1,252	1,312	1,371	1,430
Market 180+ lb	2,463	2,579	2,696	2,812
Total Emissions	**9,093**	**9,523**	**9,952**	**10,382**
Poultry				
Hens > 1 yr	2,890	2,847	2,805	2,762
Pullets	1,000	1,157	1,314	1,472
Chickens	65	73	80	88
Broilers			-	-
Turkeys	10	10	10	10
Total Emissions	**3965**	**4087**	**4209**	**4332**
Other				
Sheep on Feed			-	-
Sheep Not on Feed	13	13	13	13
Goats	5	5	5	5
Horses	797	806	814	822
Total Emissions	**815**	**823**	**832**	**840**
GRAND TOTAL	**35,143**	**35,613**	**36,201**	**36,688**

Agricultural Residue Burning

Figure 2-23 shows the assumptions used by the SIT tool to calculate methane and nitrous oxide from agriculture residue burning. Table 2-24 shows the results from the projection tool for agricultural burning in Colorado.

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

Figure 2-23: Assumptions used by SIT PT to Calculate Methane and Nitrous Oxide from Agricultural Residue Burning (EPA 2012)

Table 2-24: Projected Emissions from Agricultural Residue Burning in Colorado in MMTCO₂e

	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**

<u>Waste Combustion Emissions and Municipal Solid Waste</u>

Municipal solid waste is treated in the model by assuming waste is either landfilled, where the carbon is sequestered resulting negative carbon emissions, or 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. Table 2-25 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. For a description of the calculation scheme refer to Figure 2-19. The bottom section of Table 2-25 provides the details for the categories of sources. Due to the smaller emissions from many of these categories the SIT produces emissions for the sub-categories in metric tons in Table 2-25 and then converts them to million metric tons for the totals.

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, $(1\text{-}e\text{-}^{k})/k$

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.

Figure 2-24: Assumptions used by SIT PT to Calculate Methane and Nitrous Oxide from Waste Combustion (EPA 2012)

Table 2-25: Total Emissions from Landfills and Waste Combustion ($MMTCO_2e$)

	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 ($MTCO_2E$)-Note emissions details below produce the sum of sequestered, avoided and emitted gases from municipal waste combustion and landfills.									
	1990	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Potential CH_4									
MSW Generation	810,146	1,029,325	1,348,976	2,051,847	2,784,481	3,216,536	3,521,231	3,763,504	3,951,922
Industrial Generation	56,710	72,053	94,428	143,629	194,914	225,158	246,486	263,445	276,635
Total Potential CH_4	**866,857**	**1,101,378**	**1,443,404**	**2,195,476**	**2,979,395**	**3,441,693**	**3,767,717**	**4,026,949**	**4,228,557**
CH_4 Avoided									
Flare	-160,919	-482,756	-356,377	-444,937	-547,215	-566,851	-620,547	-663,243	-696,448
Landfill Gas-to-Energy	-32,341	-32,341	-44,182	-	-	-	-	-	-
Total CH_4 Avoided	**-193,260**	**-515,097**	**-400,559**	**-444,937**	**-547,215**	**-566,851**	**-620,547**	**-663,243**	**-696,448**
Oxidation at MSW Landfills									
	61,689	**51,423**	**94,842**	**160,691**	**223,727**	**264,969**	**290,068**	**310,026**	**325,547**
Oxidation at Industrial Landfills									
	5,671	**7,205**	**9,443**	**14,363**	**19,491**	**22,516**	**24,649**	**26,345**	**27,663**
TOTAL CH_4 EMISSIONS	**606,237**	**527,653**	**938,560**	**1,575,485**	**2,188,961**	**2,587,358**	**2,832,453**	**3,027,336**	**3,178,898**
CO_2, N_2O, and CH_4 Emissions from Waste Combustion ($MTCO_2E$)									
Gas/Waste Product	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
CO_2	105,578	160,444	170,301	196,446	196,089	226,939	244,311	262,274	281,154
N_2O	6,288	6,534	6,175	6,351	5,977	5,499	5,203	4,913	4,632
CH_4	2	2	2	2	2	1	1	1	1
TOTAL CO_2 & N_2O EMISSIONS	**111,868**	**166,980**	**176,477**	**202,799**	**202,068**	**232,439**	**249,515**	**267,189**	**285,787**

Wastewater Treatment

Figure 2-25 shows the assumptions used by the SIT tool to calculate methane and nitrous oxide from wastewater treatment. Table 2-26 shows the results from the projection tool for wastewater treatment in Colorado.

CH_4 and N_2O Emissions from Wastewater Treatment

Methane (CH_4) and nitrous oxide (N_2O) emissions from wastewater treatment were estimated based on 1990-2010 emissions estimates reported in the EPA's *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2010*

The national CH_4 and N_2O emissions 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

Note: 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 US 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

Figure 2-25: Assumptions used by SIT PT to Calculate Methane and Nitrous Oxide from Wastewater Treatment

Table 2-26: Projected Emissions of CH4 and N20 from Wastewater Treatment (MMT CO2 Eq)

	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
CH4 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)*

—— 2012*Historical natural gas annual 2011* http://wwweiagov/naturalgas/annual/pdf/nga11pdf *(accessed 30 April, 2013)*

EPA 2013 *User's guide for states using the greenhouse gas synthesis tool* State Climate and Energy Program February

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

Colorado Department
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and Environment

Chapter 3 – Electrical Power

Background

For this 2013 inventory update, the electrical power generation emissions are produced by using the February 11, 2013 version of the State Inventory Tool (SIT). For this inventory the model was run fully in the Colorado default mode. The origins of this SIT model element are rooted in the EPA Emissions Inventory Improvement Program (EIIP) for Electrical Power. The EIIP was developed to create greenhouse gas emissions "consistent with the Inventory of U.S. Greenhouse Gas Emissions and Sinks" (U.S. EPA 2012).

This chapter discusses three modules from the SIT model.

CO_2 from Fossil Fuel Combustion module (CO_2FFC)

This module calculates the energy produced in the state from the sector of Electricity

(This module also calculates energy produced from Residential, Commercial, Industrial, and Transportation sectors. For more details please refer to Chapters 4 & 5 respectively.)

Stationary Combustion

This module estimates N_2O and CH_4 from the electricity sector

(This module also calculates energy produced from Residential, Commercial, and Industrial, sectors. For more details please refer to Chapter 4 respectively.)

Electrical Consumption (Indirect CO_2 Emissions)

This module estimates direct and indirect emissions related to how the power is used in Colorado by looking at an end use analysis. It considers transmission losses and the balance of imported and exported power generate in the state and out of state. This module is used only for planning purposes and the actual emissions associated with energy consumption are provided for information related to policy decisions but are not incorporated into the Colorado inventory.

Three guidance documents are used in this chapter and describe in more depth how the emissions are calculated using the latest version of the SIT. These are:

- *User's Guide for Estimating Methane and Nitrous Oxide Emissions form Stationary Combustion Using the State Inventory Tool*
- *User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool*
- *User's Guide for Estimating Indirect Carbon Dioxide Equivalent Emissions from Electricity Consumption Using the State Inventory Tool.*

When considering total emissions, the Electrical Power sector accounted for approximately 31% of this inventory for 2010.

Inventory Update

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. Projections to 2030 were developed by using the EPA *Projection Tools* and are describe in Chapter 2-Projection Tool. Final electrical power emissions are a combination of the results from the *Fossil Fuel Combustion for* CO_2 *emissions*, 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 could be utilized to make policy decisions.

2013 SIT Inventory Methodology

Stationary Combustion Module

The following steps were used to run the *Stationary Combustion Module for* N_2O *and* CH_4 emissions after opening the *Stationary Combustion Module* excel spreadsheet. Select "Options" in the opening sheet and then select "Enable this content" when the pop-up box appears. When the second pop-up box appears, which links the sheet to the EPA State Climate and Energy Program (ICF International) data base, click on the X to close this pop-up box. This will activate the macros in Stationary Combustion Module and link the spreadsheet to the national data bases needed to support the calculations.

(1) select a state (CO)

(2) Select "Complete the Bulk Data Sheet"

(3) Select 'Check All' to populate the default emission factors for the residential sector
(4) Select 'Check All' to populate the default emission factors for the commercial sector and view estimates

(5) Select 'Check All' to populate the default emission factors for the electric power sector and view estimates

(6) Select 'Check All' to populate the default emission factors for the industrial sector and view estimates

(7) Go to the Industrial N_2O sub-sheet and select 'Check all boxes' to populate the nitrous oxide from the industrial sector data. Note the residential N_2O and CH_4, commercial N_2O and CH_4, electric power N_2O and CH_4 self populate based on default

selections in steps 1-6. When the N_2O from industrial sources sheet populates, it also causes the industrial CH_4 sheet to self populate. Without completing this step, the summary and export files, Synthesis and Projection module will not contain this element of emissions.

(8) Return to the Control sheet and select the option 'export data' to generate the summary export data sheet. This export data file is used by the *Synthesis Tool* and the *Projection Tool*.

For further detailed information on the operation and formulas for this module, consult the *Stationary Combustion User's Guide*. . The essential data inputs for this module include coal, coaking coal, natural gas, wood and 'other' as outlined in Table 3-1, extracted from the User's Guide.

Table 3-1: Fuel Types Consumed by Sector (EPA 2013a)

Residential	Commercial	Industrial	Electric Utilities
Coal	**Coal**	**Coking Coal** **Independent Power Coal** **Other Coal**	**Coal**
Natural Gas	**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 < 401°F Other oils > 401°F Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Naphthas Unfinished Oils Waxes Aviation Gasoline Blending Components Motor Gasoline Blending Components	**Petroleum:** Distillate Fuel Residual Fuel Petroleum Coke
Wood	**Wood**	**Wood**	**Wood**
Other	**Other**	**Other**	**Other**

Source: U.S. EPA 2012.

An example of a general emission equation from this module is listed below in Figures 3-1 and 3-2. For the Industrial Sector, non-energy use of fuels is considered in the emissions equation.

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

Figure 3-1: General Emission Equation for calculating N_2O or CH_4 from stationary sources

Emissions ($MMTCO_2e$)= [total Consumption (BBtu) – Non-Energy Consumption (BBtu)} x Emission Factor (MT/BBtu) x GWP ÷ 1,000,000 (to yield $MMTCO_2e$)

Figure 3-2: Emission Equation for the Industrial Sector

Table 3-2 provides a summary of the 1990-2010 CH_4 and N_2O emissions from the Stationary Sources Combustion module. These results are utilized in the *Synthesis Tool* and *Projection Tool* via the export file

Table 3-2: $MMTCO_2e$ from methane and Nitrous Oxide from Stationary Source Combustion (SIT CH_4 and N_2O from Stationary Source Combustion Module- February 11, 2013 version- Model run

Emissions ($MMTCO_2$ Eq.)	**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**
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**
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**	**0.265**	**0.304**	**0.300**	**0.302**

<u>Fossil Fuel Combustion Module</u>

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. For example, transportation related CO_2 emission are calculated from fuel use data provided to FHWA on an annual basis by states. This data is based on state tracking of fuel sales in all categories which is, in almost all cases, tied to tax revenues. Such data is likely the most accurate information in the inventory. Another example is the generation of CO_2 emissions from burning coal or natural gas in electrical generation facilities. Again, reporting of 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.

The steps to run the FFC module are similar to those described above for the SSC Module, and are not repeated here.

For further detailed information on the operation and formulas for this module, consult the CO_2 *Fossil Fuel Combustion User's Guide* 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..

Some examples of the methods and formulas from this module are listed below.

To calculate CO_2 emissions from fossil fuel combustion, the following data are required:

• 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.

Table 3-3: Fuel Types Consumed by Sector

End-Use Equipment by Sector

Residential[1]	Commercial[2]	Industrial[3]	Transportation[4]
Space Heating	Space Heating	**Indirect Uses- Boiler Fuel**	Automated Guideway
Air-conditioning	Cooling	Conventional Boiler Use	Bus (charged batteries)
Water Heating	Ventilation	CHP and/or Cogeneration Process	Cable Car
Refrigeration	Water Heating	**Direct Uses- Total Process**	Commuter Rail
Other Appliances and Lighting	Lighting	Process Heating	Heavy Rail
	Cooking	Process Cooling and Refrigeration	Inclined Plane
	Refrigeration	Machine Drive	Light Rail
	Office Equipment	Electro-Chemical Processes	Trolleybus
	Computers	Other Process Use	Other
	Other	**Direct Uses- Total Nonprocess**	
		Facility HVAC	
		Facility Lighting	
		Other Facility Support	
		Onsite Transportation	
		Other Nonprocess Use	

Equation 3-3. General Emissions Equation

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 $MMTCO_2E$)

Emissions ($MMTCO_2e$)=

Consumption (BBtu) x Emission Factor (lbs C/BBtu) x 0.0005 short ton/lbs x Combustion efficiency (% as a decimal) x 0.9072 (ration of Short Tons to Metric Tons) ÷ 1,000,000 x (44/12) (to yield $MMTCO_2e$)

Figure 3-3: General Emissions Equation (EPA 2013b)

Emissions ($MMTCO_2e$) =

(Total Consumption (BBtu) – [Non-Energy Consumption (BBtu) x Storage Factor (%)] x Emission Factor (lbs C/BBtu) x Combustion Efficiency (% as a decimal)) x 0.9072 (Ratio of Short Tons to Metric Tons) ÷ 1,000,000 x (44/12) (to yield $MMTCO_2e$)

Figure 3-4: Emission Equation for the Industrial Sector (this equation also applies to lubricants consumed in the transportation end-use sector (EPA 2013b, 1.8)

A comprehensive summary of the SIT module is published with this inventory on the Colorado GHG inventory site. Following, Table3- 4 provides a summary of the CO2 emission from fossil fuel combustion by sector for 1990-2010 in five year increments.

Table 3-4: Colorado carbon dioxide emissions from fossil fuel combustion MMTCO2e (SIT model 11, February, 2013; Model run 25 June, 2013)

Emissions (MMTCO$_2$ Eq.)	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
Total 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
Total 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
Total 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
Total 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**

2013 SIT Model Inventory -Electrical Power Consumption

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 Fossil Fuel Combustion module, N_2O, and CH_4 from Stationary Source Combustion) result from 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 industrial, commercial, transportation (light rail) and residential 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 in 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..Electricity consumption within Colorado does not necessarily correspond to electricity generated in that state,. States are encouraged to include direct emissions in their inventory estimates, and estimate and include indirect emissions as an informational line item. As a cautionary note, the EPA warns states including both direct and indirect estimates may lead to double counting. If the goal of the inventory is to encourage action and reduce emissions within the state, it would be beneficial to include emissions at the point of consumption (i.e., indirect emissions from electricity consumption).

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. Please note that even data given in Btu may be preceded by a prefix indicating order of magnitude (i.e. thousand, million, billion). For a better understanding of the quantity prefixes used with Btu, refer to Box 1.

Box 1: Energy Units

A British thermal unit (Btu) is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2° Fahrenheit.

Btu	British thermal unit	1 Btu
MBtu	Thousand Btu	1×10^3 Btu
MMBtu	Million Btu	1×10^6 Btu
BBtu	Billion Btu	1×10^9 Btu
TBtu	Trillion Btu	1×10^{12} Btu
QBtu	Quadrillion Btu	1×10^{15} Btu

The Electricity Consumption (EC) module calculates carbon dioxide equivalent (CO_2e) emissions from electricity consumption by end-use equipment types, shown in Table 3-5. The EC module calculates emissions beginning in 2000, because emission factor and activity data from 1990 through 1999 are not available.

Table 3-5: End-Use Equipment by Sector

End-Use Equipment by Sector

Residential[1]	Commercial[2]	Industrial[3]	Transportation[4]
Space Heating	Space Heating	**Indirect Uses- Boiler Fuel**	Automated Guideway
Air-conditioning	Cooling	Conventional Boiler Use	Bus (charged batteries)
Water Heating	Ventilation	CHP and/or Cogeneration Process	Cable Car
Refrigeration	Water Heating	**Direct Uses- Total Process**	Commuter Rail
Other Appliances and Lighting	Lighting	Process Heating	Heavy Rail
	Cooking	Process Cooling and Refrigeration	Inclined Plane
	Refrigeration	Machine Drive	Light Rail
	Office Equipment	Electro-Chemical Processes	Trolleybus
	Computers	Other Process Use	Other
	Other	**Direct Uses- Total Nonprocess**	
		Facility HVAC	
		Facility Lighting	
		Other Facility Support	
		Onsite Transportation	
		Other Nonprocess Use	

(EPA 2013c)

Electrical Power Generation emissions produced for this 2013 Colorado GHG Inventory Update only include consumption based emissions generated by EPA's SIT model. 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. Projections to 2030 were developed by using the EPA projection tools and are described in Chapter 2. This module estimates indirect CO_2e emissions from sectors and end-use equipment that consume electricity.

The Electricity Consumption module calculates emissions after you enter factors on the emission factor 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).

Because the objective of this report is to run the inventory in default mode, the emissions associated with electricity generation are not taken into account in this module. See data assumptions and uncertainty section below for more discussion on how this factors into the data obtained.

The following steps were used to run the Electricity Consumption Module for CO_2 Emissions:

Step 1. Open the Electricity Consumption Module excel spreadsheet. Select “Options” in the opening sheet and then select “Enable this content” when the pop-up box appears. When the second pop-up box appears, which links the sheet to the EPA State Climate and Energy Program (ICF International) data base, click on the X to close this pop-up box. This will activate the macros in Electricity Consumption Module and link the spreadsheet to the national data bases needed to support the calculations.

The general equation use to calculate indirect CO_2e emissions from electricity consumption is shown in Equation 1.

Equation 1. General Emission Equation

$$\text{Emissions } (MMTCO_2E) = \{(\text{Total State Consumption (kWh)} \times \text{End-Use Equipment Consumption (\%)}) \div (1 - \text{Transmission Loss Factor (\%)})\} \times \text{Emission Factor } (\text{lbs } CO_2E/\text{kWh}) \times 0.0005 \text{ short ton/lbs} \times 0.90718 \text{ (Ratio of Short Tons to Metric Tons)} \div 1{,}000{,}000$$

Step 2. Choose a State–Colorado

Step 3. Complete the Factors Worksheet

Click on each worksheet separately and click on “choose default mode” to run each module spreadsheet in the default mode, running through each spreadsheet until the summary sheet appears at the bottom of the screen.

(a) select complete the emission factors and transmission losses worksheet,

(b) select default emission factors,

(c) select each of the individual sector worksheets (residential, commercial, transportation, industrial) & select default emission factors for each sheet.

Default emission factors for electricity consumption (lbs CO_2e/kWh) are provided in the Factors worksheet. Values are derived from Year 2005 and 2007 Emissions & Generation Resource Integrated Database (eGRID) subregion values, weighted by the number of households based on distribution utilities 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 must be applied. The transmission loss factor takes into account electric energy lost due to the transmission and distribution of electricity. Additional information on eGRID emission factors is provided in Box 3.

Box 3: eGRID Emission Factors

The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of environmental attributes of electric power systems. The preeminent source of air emissions data for the electric power sector, eGRID is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. eGRID integrates many different federal data sources on power plants and power companies, from three different federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). eGRID also provides aggregated data by state, U.S. total, company, and by three different sets of electric grid boundaries.

Plant level emissions in eGRID are built by summing its component parts – which could simply be unit level boilers and/or turbines or a combination of boilers and prime movers representing an aggregation of like generating units. In general, eGRID plant level emissions reflect a combination of monitored and estimated data. Emissions and emission rates in eGRID represent emissions and rates at the point(s) of generation. They do account for losses within the generating plants (net generation).

Note that default emission factors are identical throughout the time series. While these emission and transmission loss factors were developed for 2005 and 2007, emission factor and household data were not available for the remaining years in the time series. To facilitate emission calculations for other years, the tool utilizes the 2005 and 2007 emission factors as proxies (2005 emission factors used from 1990 through 2006, and 2007 emission factors from 2007 through 2030). Emission factors within the module will be updated as soon as new data become available.

Step 4. Review summary information on the summary sheet.

Table 3-6 provides a summary of the emissions from electricity consumption in Colorado from 1990-2010. Consult the Projection Chapter for projected emissions through 2030 based on the consumption model. A summary of the emissions are also presented in the Synthesis Chapter.

Box 4: End-Use Equipment Data Sources

Residential

Residential end-use equipment activity is from the Residential Energy Consumption Survey (RECS) (EIA 2008a). The Residential Energy Consumption Survey (RECS) provides information on the use of energy in residential housing units in the United States. This information includes: the physical characteristics of the housing units; the appliances utilized including space heating and cooling equipment; demographic characteristics of the household; the types of fuels used; and other information that relates to energy use. The RECS also provides energy consumption and expenditures data for: natural gas, electricity, fuel oil, liquefied petroleum gas (LPG), and kerosene. The RECS is published in 4 year intervals. As a result, the Electricity Consumption Module uses 2001 and 2005 RECS data, and interpolates to estimate intervening years. Activity data beyond 2005 is proxied to the 2005 values. The Electricity Consumption Module utilizes regional-level data available from the RECS.

RECS data are available online at: http://www.eia.doe.gov/emeu/recs/.

Commercial

Commercial end-use equipment activity is from the Commercial Building Energy Consumption Survey (CBECS) (EIA 2008b). The Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures. Commercial buildings include all buildings in which at least half of the floorspace is used for a purpose that is not residential, industrial, or agricultural, so they include building types that might not traditionally be considered "commercial," such as schools, correctional institutions, and buildings used for religious worship. The CBECS is published in 4 year intervals. As a result, the Electricity Consumption Module uses 2003 data, and proxies other years in the time series to this 2003 estimate. The Electricity Consumption Module utilizes regional-level data available from the CBECS.

CBECS data are available online at: http://www.eia.doe.gov/emeu/cbecs/.

Transportation

Transportation end-use equipment activity is from the National Transit Database (NTD) (FTA 2007). The NTD was established by Congress to be the Nation's primary source for information and statistics on the transit systems of the United States. The data contained in the 2007 National Transit Database (NTD) is one of three publications comprising the National Transit Database Program's Annual Report. It provides detailed summaries of financial and operating data submitted to the Federal Transit Administration (FTA) by the nation's mass transit agencies for the report year ending on or between January 1 and December 31, 2007. The Electricity Consumption Module uses 2007 through 2010 data from the NTD, and proxies 1990 through 2006 to 2007, and 2011 through 2020 to 2010. The Electricity Consumption Module utilizes state-level data available from the NTD.

NTD data are available online at:
http://www.ntdprogram.gov/ntdprogram/pubs/dt/2007/2007_Data_Tables.htm#51

Industrial

Industrial end-use equipment activity is from the Manufacturing Energy Consumption Survey (MECS) (EIA 2009). The Manufacturing Energy Consumption Survey (MECS) is the Federal Government's comprehensive source of information on energy use by U.S. manufacturers. The survey collects data on energy consumption and expenditures, fuel-switching capability, onsite generation of electricity, byproduct energy use, and other energy related topics. The Electricity Consumption Module uses 2002 and 2006 data from the MECS, and 1990 through 2005 are proxied to 2002, while all other years are proxied to 2006. The Electricity Consumption Module utilizes regional-level data available from the MECS.

MECS data are available online at:
http://www.eia.doe.gov/emeu/mecs/mecs2006/2006tables.html.

Table 3-6: Colorado Indirect Emissions of CO_2 from Electrical Consumption $MMTCO_2e$ (EPA SIT model 11 February, 2013; Model run 25 September, 2013)

Emissions ($MMTCO_2$ Eq.)	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

Note: For space purposes zero emission fields in Transportation were eliminated from the data table.

Data Assumptions and Uncertainties

Uncertainty from Stationary Combustion Module

Uncertainty Associated With Stationary Combustion Emissions

Excerpted from EIIP Guidance, Chapter 2.

Return to the N_2O Summary Sheet

Return to the CH_4 Summary Sheet

Return to the Total Summary Sheet

The amount of methane (CH_4) and nitrous oxide (N_2O) emitted from stationary combustion depends on 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, as noted in the Revised 1996 IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997), the contribution of CH_4 and N_2O to overall emissions is small and the estimates are highly uncertain. Uncertainties exist in both the emission factors and activity data used to derive emission estimates.

As noted in Section 2.2, the combustion temperature at which the technology operates impacts the level of CH_4 and N_2O emissions. For instance, N_2O emissions 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). Because of the combined difficulty in obtaining specific combustion technology information and the relatively low contribution of this source to a state's total emissions, IPCC states that the Tier 1 approach (the methodology presented in this chapter) is sufficient. However, the emission factors used are aggregated by sector, representing only a limited subset of combustion conditions. Therefore, the results of the IPCC Tier 1 approach are far more uncertain than those estimated using the more detailed IPCC Tier 2 approach. The Tier 2 emission factors account for specific pollution control technologies used with each combustion technology, but still have uncertainty because these factors represent the average performance of technologies.

Uncertainties may also exist in the activity data used to derive emission 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 estimation of the fraction of fuels used for non-energy.

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.

Additionally, using eGRID data is useful however WECC Rockies data may not accurately reflect the powerplant mix used in Colorado. Looking at imports and exports of electricity in Colorado might also be a useful exercise.

A 2012 analysis by Dr. Anu Ramaswami, at the University of Denver, Graduate School found the following in regard to data uncertainty:

There are a number of potential political, technological, economic, and regulatory changes that may affect the validity of the original 2007 projections. For the Electricity Projection section these changes include the passage of 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), the municipalization of Boulder's power utilities, and increased black carbon emissions.

Additionally, 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.

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.

Uncertainty Associated With These Emissions Estimates

Excerpted from EIIP Guidance, Chapter 1.

Return to the $MMTCO_2E$ Summary Sheet

The amount of CO_2 emitted from fossil fuel combustion depends on 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 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.

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 on the fuel and use. This guidance and the State Inventory Tool provide default values for the amount of non-energy use and percentage of carbon stored by fuel type, based on data collected at the national level. State-specific data can reduce these uncertainties.

The accounting for emissions from international bunker fuels also introduces uncertainty. In accordance with international inventory practices (IPCC/UNEP/OECD/IEA 1997), if state-level data are available, emissions from international bunkers may be calculated and reported by the state of origin, but not included in the state's total emission figures. However, in practice, this can be difficult to do at the state level. Therefore, not subtracting out emissions from international bunker fuels overestimates emissions of these fuels.

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. EIA takes into account the variability of carbon contents of coal by state in EIA's Electric Power Annual 2006 (2007a); these coefficients are also provided in the State Inventory Tool.

Many different factors introduce uncertainties into estimating emissions from imports and exports of electricity. The precise fuel mix used to generate the power crossing state lines is very difficult to determine, due to the highly complex nature of electricity flow through the U.S. power grid. Therefore, an average fuel mix for all electricity generation within a specific region of the grid must usually be used. Moreover, these emission factors are generated by emission monitors (rather than carbon contents of fuels), which may overestimate CO_2 emissions to a small extent.

Uncertainty from Indirect CO_2 Emissions

The 2013 SIT module estimates indirect CO_2 equivalent emissions from sectors and end-use equipment that consume electricity. Because the objective of this report is to run the inventory in default mode, the emissions associated with electricity generation are not taken into account in this module.

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)

Colorado Department of Public Health and Environment

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

Background

For this 2013 Colorado Greenhouse Gas (GHG) Baseline Inventory update, Residential, Commercial and Industrial Fuel Use emissions are produced using the EPA State Inventory Tool (SIT) model fully in the Colorado default mode. The origins of the current SIT model are rooted in the EPA Emissions Inventory Improvement Program (EIIP). The EIIP was developed to create greenhouse gas emissions that are consistent with the Inventory of U.S. Greenhouse Gas Emissions and Sinks (U.S.EPA 2012, 1.4). In addition, the 2012 SIT has been replaced by a February 2013 SIT update. Data from the 2013 update is used for this 2013 Inventory.

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."

CO_2 Emissions from fossil fuel combustion RCI sectors are derived in the SIT from coal, natural gas and petroleum fuel types. N_2O and CH_4 emissions from Stationary Combustion are also derived from coal, natural gas and petroleum fuel types. More detailed information on these fuel types is listed in Table 4-1 below. Electrical energy use to produce RCI fuels, including distribution of electrical energy use to produce RCI emissions, are accounted for in the Electrical Energy Production Chapter of the 2013 Inventory and are not included in this chapter.

When considering total emissions, the RCI sector accounted for approximately 21% of this inventory for 2010.

2013 SIT Model Inventory Update

The EPA released its updated SIT Model on February 11, 2013. This release was used for this 2012 inventory update emissions and projections. The 2012 inventory combines CH_4, N_2O emissions from stationary combustion with CO_2 emissions from fossil fuel use, to generate RCI GHG emissions.

SIT Model Residential, Commercial and Industrial Sector Emissions

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

CO_2 From Fossil Fuel Combustion

The CO_2FFC module of the SIT estimates CO_2 emissions from sectors that consume fossil fuels. Within the CO_2FFC module, these sectors are residential, commercial, industrial, transportation, electric power, and bunker fuels. 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 calculated.

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 CO_2FFC module follows the general methodology outlined in the EIIP guidance, however because of the automation of the calculations within the tool, the order of steps discussed in this User's Guide do not follow the order of steps discussed within the EIIP guidance document. The User's Guide provides an overview of the estimation methodology used in the CO_2FFC module by walking through the following eleven steps: (1) select a state; (2) fill in the variables used throughout the module; (3) complete the bulk data energy consumption worksheet; (4) complete the residential sector worksheet; (5) complete the commercial sector worksheet; (6) complete the transportation sector worksheet; (7) complete the electric power sector worksheet; (8) complete the bunker fuels sector worksheet; (9) complete the industrial sector worksheet; (10) review summary information; and (11) export data.

Table 4-1: 2013 SIT Model Fuel Types Consumed by RCI Sectors

Residential	Commercial	Industrial
Coal	Coal	Coking 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 Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Naphthas Unfinished Oils Waxes Aviation Gasoline Blending Components Motor Gasoline Blending Components

Steps to Calculate CO_2 Emissions from the Fossil Fuel Combustion Module

There are ten steps involved in estimating emissions using the SIT Model Fossil Fuel Combustion module:

Step(1) select Fossil Fuel Combustion;(2) select a state; (3) select the default emission factors and other variables used throughout the module; steps (4-8) view emissions estimates for the individual RCI sector worksheets; (9) complete non-energy use activity data on the industrial sector worksheet; (10) review summary information on the summary sheet.

The general equation used to calculate CO_2 emissions from fossil fuel combustion is shown in Equation 4-1. 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 4-2.

Equation 4-1. General CO_2 Emissions Equation

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 $MMTCO_2E$)

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

$$\text{Emissions (MMTCO}_2\text{E)} = (\text{Total Consumption (BBtu)} - [\text{Non-Energy Consumption (BBtu)} \times \text{Storage Factor (\%)}] \times \text{Emission Factor (lbs C/BBtu)} \times \text{Combustion Efficiency (\% as a decimal)}) \times 0.9072 \text{ (Ratio of Short Tons to Metric Tons)} \div 1{,}000{,}000 \times (44/12) \text{ (to yield MMTCO}_2\text{E)}$$

* This equation also applies to lubricants consumed in the transportation end-use sector.

Three Types of Data Requirements for CO_2 Fossil Fuel Combustion Module

The first 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 requested in 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, 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 (Step 9).

Industrial Sector Special Conditions for CO_2 Fossil Fuel Module

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, entered in Step 2). 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. The net combustible consumption is multiplied by the carbon content and the combustion efficiency to obtain the total carbon oxidized. Then, the total tons of carbon oxidized are converted into MMTCO_2e, by multiplying by the ratio of metric tons per short ton (0.9072) to obtain metric tons and dividing by 106 and multiplying by 44/12 to express emissions in MMTCO_2e (Equation 4-2). Click on the orange "Click here for the bulk data worksheet." button to return to the energy consumption data entry worksheet.

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 Table 4-1. The module provides default data for fuel types where possible. For a more detailed discussion, see Chapter 3 – Electrical Energy Generation.

Table 4-2: Fuel Types Consumed by Sector – NO2 and CH_4 Combustion Emissions

Residential	Commercial	Industrial	Electric Utilities
Coal	**Coal**	**Coking Coal** **Independent Power Coal** **Other Coal**	**Coal**
Natural Gas	**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	**Petroleum:** Distillate Fuel Residual Fuel Petroleum Coke
Wood	**Wood**	**Wood**	**Wood**
Other	**Other**	**Other**	**Other**

Source: U.S. EPA 2012.

Steps to Calculate CH_4 and N_2O Emissions from the Stationary Combustion Module

The following is extracted and edited from the EPA 2013 SIT Module User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel and the 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 following steps are followed to generate emissions for Stationary Combustion. (1) select a state; (2) complete the bulk data energy consumption worksheet; (3) enter emission factors for the residential sector and view estimates; (4) enter emission factors for the commercial sector and view estimates; (5) enter emission factors for the electric power sector and view estimates; (6) enter emission factors for the industrial sector and view estimates; (7) review summary information; and (8) export data.

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.

Methane, carbon monoxide, 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.

The activity data used to populate the energy consumption input cells is annual state energy consumption data based on *primary fuel type* (e.g., coal, petroleum, and natural gas) and *secondary fuel type* (e.g., gasoline, residual oil, natural gas, etc.) *by sector* (e.g., residential, commercial, industrial, and electric utilities). A list of potential fuel types consumed in each sector is provided in Table 4-1.

Industrial Sector Special Case

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.

2013 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 Stationary Combustion Module. Below are Tables 4-3 and 4-4 which show the 2013 SIT Model results for each of the aforementioned modules.

Table 4-3: Colorado carbon dioxide emissions from fossil fuel combustion MMTCO2e – RCI Only (SIT model 11, February, 2013; Model run 25 June, 2013)

Emissions ($MMTCO_2$ Eq.)	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
Total 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
Total 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**
Total Emissions	**14.91**	**17.77**	**19.84**	**24.39**	**26.69**

Table 4-4: Summary of CH4 and N2O Emissions from Stationary Combustion-Synthesis Tool Results

Emissions ($MMTCO_2$ Eq.)	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**
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**
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**	**0.265**	**0.304**	**0.300**	**0.302**

Uncertainties Associated With Stationary Combustion (N_2O and CH_4) Emissions Estimates from the RCI Sectors

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.

Uncertainties Associated With Fossil Fuel Combustion (CO_2) Emissions Estimates from the RCI Sectors

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.

Projections to 2030

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

References

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Colorado Department of Public Health and Environment

Chapter 5 – Transportation

Background

For this 2013 Colorado GHG baseline inventory update, transportation emissions are produced by using the State Inventory Tool (SIT) model fully in the default mode. The origins of this SIT model element are rooted in the EPA Emissions Inventory Improvement Program (EIIP). The current process utilizes two emission modules in the SIT toolkit. The EIIP was developed to create greenhouse gas emissions consistent with the Inventory of U.S. Greenhouse Gas Emissions and Sinks' (U.S. EPA 2012, 1.4). The February 2013 update to the SIT replaces previous EPA guidance on creating greenhouse gas inventories. The current 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). The current emissions are calculated in the SIT for methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2). Carbon dioxide is derived from fuel sales of the various fossil fuels sold in the state using emission factors for each fuel type. Annual fuel sales from 1990 to 2010 are acquired from the model from national data bases. The CH_4 and N_2O are calculated based on annual vehicle miles traveled for each vehicle type and specific emission factors for the vehicle type by model year. When considering total emissions, the transportation sector accounted for approximately 24% of this inventory for 2010.

2013 Inventory Update

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. Projections to 2020 were developed by using the EPA projection tools and are describe in Chapter 2-Projection Tool. 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 from the transportation sector. The Mobile Combustion Module of the SIT includes CH_4 and N_2O emissions for highway vehicles, aviation, boats, vehicles, locomotives, other non-highway sources and alternative fuel vehicles. The Fossil Fuel Combustion SIT module was run to obtain CO_2 emissions from the transportation sectors. This includes aviation fuel, gasoline, distillate fuel, jet fuel-kerosene, jet fuel-naphtha, liquid petroleum gas (LPG), motor gasoline, residual fuel, natural gas and others.

2013 SIT Inventory Methodology-Transportation

Mobile Combustion Module

The following steps were used to run the Mobile Combustion Module for N_2O and CH_4 emissions:

Step 1: Open the Mobile Combustion Module excel spreadsheet. Select "Options" in the opening sheet and then select "Enable this content" when the pop-up box appears. When the second pop-up box appears, which links the sheet to the EPA State Climate and Energy Program (ICF International) data base, click on the X to close this pop-up box. This will activate the macros in Mobile Combustion Module and link the spreadsheet to the national data bases needed to support the calculations.

Step 2: Select Modes of Transportation – vehicle types.

Step 3: Choose a State (Colorado)

Step 4: Click on each worksheet separately and click on "choose default mode" to run each module spreadsheet in the default mode, running through each spreadsheet until the summary sheet appears at the bottom of the screen.

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. The guide will take you through all of steps used to run this module in the default mode, or when a user has entered his own data to replace the defaults.

An example of the formula from this module is listed below in Equation 1.

Equation 1. General Mobile Combustion Equation

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

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)

<u>Fossil Fuel Combustion Module</u>

The steps to run the FFC module are similar to those described above for the MSC Module, and are not repeated here.

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. The guide will take you through all of steps used to run this module in the default mode, or when a user has entered his own data to replace the defaults.

Some examples of the methods and formulas from this module are listed below.

To calculate CO_2 emissions from fossil fuel combustion, the following data are required:

- 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

Table 5-1: Fuel Types Consumed by Sector

Residential	Commercial	Industrial	Transportation	Electric Utilities	International Bunker Fuels
Coal	**Coal**	**Coking Coal** **Other Coal**	**Coal**	**Coal**	
Natural Gas	**Natural Gas**	**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 Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Naphthas Unfinished Oils Waxes Aviation Gasoline Blending Components Motor Gasoline Blending Components	**Petroleum:** Distillate Fuel LPG Motor Gasoline Residual Fuel Lubricants Aviation Gasoline Jet Fuel, Kerosene Jet Fuel, Naphtha	**Petroleum:** Distillate Fuel Residual Fuel Petroleum Coke	**Petroleum:** Jet Fuel, Kerosene Distillate Fuel Residual Fuel
Other	**Other**	**Other**	**Other**	**Other**	

Source: U.S. EPA 2012.

Equation 2-2. General Emissions Equation

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

2013 SIT Model Results

For the transportation sector the SIT Model was used in the default mode for both the *Fossil Fuel Combustion* (FFC) and the *Mobile Combustion (MC)* modules. Thus, the results of the modeling are for both direct fuel use resulting in CO_2 and combustion derived emissions based on VMT and emission factors to produce the CH_4 and N_2O

emissions from transportation sources. The final results are summarized in Table 3. The summary spreadsheets are available on the APCD climate change inventory web site. Data from the FFC sub-sheet titled Transportation is extracted to produce the emissions from transportation fuel shown in Table 2. The Total is calculated from the two sums (Total Mobile tailpipe CH_4 + N_2O $MMTCO_2e$ and Total $MMTCO_2e$ transportation Fuel use-direct CO_2).

CO_2 Fossil Fuel Combustion (FFC)

The Fossil Fuel Combustion module uses fuel consumed per year for the sectors shown in Table 2. 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 by total British Thermal Units (BTU) are broken into the categories listed in Table 2. The FFC module uses the emission factors and multiplies those times the amount of fuel used in each of the eight transportation sectors (Aviation 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 (natural gas for all years) to a high of 45.11 lb/MMBTU (used for all years). 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:

> 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 $MMTCO_2e$).

Table 2 is a profile of fuel use in Colorado, listed in BTUs.

Table 5-2: 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

Table 5-3: Summary of CO2 Emissions-Fossil Fuel Combustion Synthesis Tool Results

Emissions (MMTCO$_2$ Eq.)	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
Total 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
Total 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
Total 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
Total 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**

CH_4 and N_2O from Mobile Combustion

A second emissions profile is generated from the MSC SIT model by multiplying emissions factors for CH_4 and N_2O times the vehicle miles traveled for each vehicle class. Table 5 summarizes these emissions from the MSC SIT module. The EPA Emissions Workbook describes the calculations in more detail. As seen in Table 5-4, 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)
- Alternative Fuel Vehicles (light-duty vehicles, heavy duty vehicles, buses)

Table 5-4: Summary of CH_4 and N_2O Emissions from Mobile Combustion ($MTCO_2e$) Synthesis Tool Results

Fuel Type/Vehicle Type	1990	1995	2000	2005	2010
Gasoline Highway					
Passenger Cars	571,275	676,281	653,806	487,979	309,852
Light-Duty Trucks	314,450	548,967	575,617	371,351	108,230
Heavy-Duty Vehicles	18,514	25,857	30,272	26,090	8,977
Motorcycles	813	1,050	1,005	972	1,700
Total Emissions	**905,053**	**1,252,155**	**1,260,700**	**886,392**	**428,759**
Diesel Highway					
Passenger Cars	99	88	77	77	68
Light-Duty Trucks	159	251	319	373	247
Heavy-Duty Vehicles	4,253	6,045	7,330	8,182	9,926
Total Emissions	**4,511**	**6,384**	**7,726**	**8,632**	**10,241**
Non-Highway					
Boats	477	497	523	619	541
Locomotives	8,311	12,429	5,276	1,649	7,349
Farm Equipment	5,985	8,274	7,344	5,345	6,070
Construction Equipment	3,812	4,607	10,048	11,711	12,081
Aircraft	26,558	31,690	32,580	51,986	47,524
Other*	1,017	1,465	4,064	5,425	2,715
Total Emissions	**46,161**	**58,962**	**59,834**	**76,735**	**76,281**
Alternative Fuel Vehicles					
Light Duty Vehicles	815	976	1,879	1,487	1,967
Heavy Duty Vehicles	2,440	2,640	3,432	6,889	9,910
Buses	50	165	215	451	837
Total Emissions	**3305**	**3780**	**5525**	**8826**	**12713**
GRAND TOTAL	**959,030**	**1,321,281**	**1,333,786**	**980,586**	**527,995**

Vehicle Miles of Travel for Mobile Sources

After running the SIT CH_4 and N_2O Mobile Combustion Module, the breakdown of Vehicle Miles of Travel (VMT) by vehicle type is listed in the Highway section of the MCM module). The VMT breakdown is listed Table 5-5below.

Table 5-5: 2013 SIT Model Total VMT by Vehicle Class, in millions (March 27, 2013 Mobile Combustion Module Run)

	1990	1995	2000	2005	2010
HDDV	1664	2359	2861	3208	4388
HDGV	386	441	456	474	250
LDDT	202	326	417	485	321
LDDV	172	161	145	146	129
LDGT	7039	11056	13578	16131	9552
LDGV	17604	22572	24158	27354	32007
MC	110	142	158	164	293
Total	**27718**	**35057**	**41771**	**47962**	**46940**

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 Table 5-6. 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 process 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.

Table 5-6: Transportation Sector MMTCO$_2$ Emissions from Fossil Fuel Consumption in Colorado (in million metric tons)

	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 N	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

a 1990-2010 values are extracted from CO_2 emissions from combustion of fossil fuel sub-sheet rounded to the nearest hundredth. The SIT Projection Tool is used for 2011-2030 values.

Uncertainties in Mobile Combustion Emissions Estimates

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 is 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 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 latest version of the MOBILE6a Model, it has not been decided whether the addition of updated MOBILE Model data into the SIT modeling process for this inventory update would introduce any significant changes to mobile emissions estimates.

Non-Highway Vehicle Uncertainty

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).

Colorado Department of Public Health and Environment

Chapter 6 – Industrial Processes

Background

For this 2013 Colorado Greenhouse Gas (GHG) Inventory update, the Industrial Processes (IP) emissions are produced by using the February 2013 version of the State Inventory Tool (SIT). For this inventory the model was run fully in the default mode. The origins of this SIT model element are rooted in the EPA Emissions Inventory Improvement Program (EIIP) for Industrial Processes (as well as ten other sectors) emissions. The EIIP was developed to create greenhouse gas emissions consistent with the "Inventory of U.S. Greenhouse Gas Emissions and Sinks" (U.S. EPA 2012).

The IP module calculates carbon dioxide (CO_2), nitrous oxide (N_2O), hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6) emissions from the IP sectors.

The sectors included in the IP module are 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. Since the methodology varies by sector, they are discussed separately and specific examples for each sector are provided.

2013 SIT Model Inventory Update

Industrial processes emissions generated for this 2013 Colorado GHG inventory update only include emissions generated by EPA's SIT model. 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 and are describe later in this Chapter. 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).

Steps for SIT Model Industrial Processes Module

The following discussion is extracted and edited from the 2013 SIT Model User's Guide.

The following steps were used to run the Industrial Processes Module for CO_2 Emissions:

Step 1: Open the Industrial Processes Module Excel spreadsheet. Select "Options" in the opening sheet and then select "Enable this content" when the pop-up box appears. When the second pop-up box appears, which links the sheet to the EPA State Climate and Energy Program (ICF International) data base, click on the X to close this pop-up box. This will activate the macros in Industrial Processes Module and link the spreadsheet to the national data bases needed to support the calculations.

Step 2: Choose a State – Colorado

Steps 3 through 16: Complete the Factors Worksheets. There are separate worksheets for each sector in the IP Module. Select each worksheet separately and click on "check all boxes" to choose the default mode to run each module spreadsheet, running through each spreadsheet until the summary sheet appears at the bottom of the screen.

The sectors for the IP Module are listed below in Table 6-1.

In addition to a worksheet for each sector, the user's guide lists equations for calculating emissions from each IP sector. Several equations are shown below for explanatory purposes. Consult the user's guide for a complete listing of equations.

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)

Table 6-1: 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.

Step 17: Review summary information on the summary sheet.

Step 18: Export Data

The steps above provide estimates of total CO_2, N2O, and HFC,PFC, and SF_6 emisisons from the IP sector. Total emissions are equal to the sum of emissions from each of the fourteen IP sectors by year. The information is collected by sector on the summary worksheets. There is a summary worksheet in the IP module that displays results in

$MTCO_2e$. Additionally, the summary worksheet provides an overview of sources included from current emissions estimates.

Data Discussion and Summary

The 2013 SIT Model for IP sector GHG emissions summarizes results into three categories by pollutant:

1. carbon dioxide (CO_2),

2. nitrous oxide (N_2O),

3. hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6) combined together.

Total emissions from the IP sector increase 10 fold from 1990 (716,052 $MTCO_2$) to 2030 (7,910,004 $MTCO_2$). The majority of the increase occurs from the increasing use ODS substitutes from 1990 (4,384 $MTCO_2$) through 2030 (3,054,268 $MTC0_2$). Other significant increases occur in cement manufacturing and adipic acid, which is used to make plastics. In addition, the electric power transmission and distribution systems category greatly reduces from 1990 (302,734 $MTCO_2$) to 2030 (71,762 $MTCO_2$), as a result of removing ------- canisters from these systems.

The SIT Model does not provide Colorado-based emissions for the following sources:

- Cement Manufacture,
- Lime Manufacture,
- Limestone and Dolomite Use,
- Soda Ash, Ammonia & Urea,
- Iron & Steel,
- Nitric Acid Production,
- Magnesium Production,
- HCFC-22 Production,
- Aluminum Production.

Results from the module are displayed below in Table 6-2.

Table 6-2: SIT Projection Tool Industrial Processes $MTCO_2$ Emissions

Emissions ($MTCO_2$ Eq.)	1990	1995	2000	2005	2010
Carbon Dioxide Emissions					
Cement Manufacture	317,456	475,769	553,799	622,895	559,103
Lime Manufacture		100,294	94,977	295,275	274,957
Limestone and Dolomite Use		18,838	28,451	30,305	4,989
Soda Ash	35,890	38,369	40,673	40,591	35,625
Urea Consumption	3,071	2,643	2,259	4,247	3,777
Iron & Steel Production			750,305	340,273	304,845
Total Emissions	**356,416**	**635,912**	**1,470,463**	**1,333,586**	**1,183,296**
HFC, PFC, and SF_6 Emissions					
ODS Substitutes	4,384	437,580	1,166,999	1,561,279	1,866,266
Semiconductor Manufacturing	52,518	89,243	117,120	85,198	104,082
Electric Power Transmission and Distribution Systems	302,734	251,153	189,427	184,139	166,476
Total Emissions	**359,636**	**777,976**	**1,473,547**	**1,830,615**	**2,136,824**
GRAND TOTAL	**716,052**	**1,413,887**	**2,944,010**	**3,164,202**	**3,320,120**

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

Background

The *Coal SIT Module* produces estimates of methane emissions in Colorado related to the production of coal and 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, produce heat for homes, and power industrial sources are expressed in other parts of the Colorado inventory. Estimated emissions of methane from surface coal mining, mine vents at active and abandoned mines are about 6% of the gross Colorado inventory in 2010.

Coal Mining and Abandoned Coal Mines

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). For this 2013 GHG inventory all default assumptions 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. The user is guided to provide more specific state date if available. 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. The sum of underground, surface and post-mining activates for surface and underground mines represent total methane released to the atmosphere. Table 7-1, extracted from the user's guide, provides a listing of the specific elements used to calculate mining emissions (EPA 2013).

Table 7-1: Required Inputs for the Coal Module

Coal Module Sectors	Input Data Required
CH_4 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. To calculate the default emissions the following steps were followed:

Step 1: After downloading and opening the Methane Emissions from Coal Mining SIT from the EPA GHG inventory website, enable the macros by selecting 'Enable Macros' in the 'Options' box at the top of the sheet.

Step 2: Close the ICF pop-up box after the sheet activates

Step 3: Select the State (Colorado) from the 'Select a State' options box

Step 4: Select the default emission factors by selecting 'Check All'

Step 5: Select 'Click to continue to CH_4 from Coal Mining Worksheet' icon

Step 6: On the CH_4 from Coal Mining worksheet select 'Check all boxes'. This will link the coal production figures for Colorado to all years from 1990-2010. The Colorado specific data is contained in a data sub-sheet within the module. The calculation scheme is laid out in each of the years and can be revealed by selecting the (+) sign on the left of the sheet by the year. The amount of coal produced from underground mines and from surface mines is contained in the 'Coal Production' data box. 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 Figures 7-1 and 7-2 below.

<u>Methane from coal mining</u>

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). Table 7-2 captures the five year increments of coal produced in thousands of short tons/year. These figures are 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.

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)

Figure 7-1: Methane emissions calculation scheme for underground mining (EPA 2013; 1.9)

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)

Figure 7-2: Methane emissions calculation from surface coal production (EPA 2013; 1.10)

The measured ventilation rate for the mine and degasification emissions are added together and any allowance for degasification equipment is subtracted from this total. Table7- 2 provides the historical, five year incremental emissions for operating and abandoned coal mines.

Table 7-2: 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. Table 7-3 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.

Table 7-3: Abandoned coal mines in Colorado used as the basis for calculating methane emissions from leaks

	Mine Name	County	Basin	Year Abandoned
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

Table 7-4 summarizes methane emissions from coal mining in Colorado. Data from the Projection Tool is also combined with the 1990-2010 default inventory results.

Table 7-4: Summary of Colorado CH_4 Emissions from Coal Mining Activities ($MMTCO_2e$)

	1990	1995	2000	2005	2010	2015	2020	2025	2030
Total CH4 from Coal Mining	**4.81**	**33.73**	**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	0	0	0

Data Uncertainties-Coal use and projections

Recent modifications at one Colorado mine included the installation of a methane recovery and electrical generation system. Such modifications may significantly reduce underground coal emission in the future. The projected emissions do not take such changes into account.

The Projection Tool indicates Colorado trends are not utilized to make projections past 2010. The 2010 Colorado coal production is compared to the national coal production and a percentage is established in 2010. This percentage is applied to the national coal projection data base provided by the EIA.

Since part of the emissions are dependent on the amount of coal produced, the difference between default, and state specific, 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. The 2012 production figures indicate 29 million tons of coal were produced, ranking Colorado 9th in the U.S. as far as coal production (2013). Comparing the coal production figures in the SIT model in Table 1, with the CMA shows the 2012 figure is well within the range of past production amounts for Colorado. The CMA also reports 2/3 of Colorado's 2012 production of 29.5 million tons of coal is from long wall underground mining operations at 7 mines. The remaining 1/3 is produced at 3 surface mines (CMA 2013).

Sanderson reports the Colorado coal production in 2011 was 29 million tons. The CMA reports 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; a 43% increase. This appears to agree well with Sanderson's data. The Colorado GHG default projections show a slight decline in coal production in the State by 2030.

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.

Colorado Department of Public Health and Environment

Chapter 8 – Gas Production

Background

The *Oil and Gas Production SIT module* produce estimates of Colorado emissions related to the production of oil and gas. Emissions from this SIT tool produce estimates of CH_4 and CO_2 related to the extraction, production and transmission of natural gas. 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 CO_2, and 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 expressed in other parts of the Colorado inventory. Estimated emissions from oil and gas production are about 6% of the gross Colorado inventory in 2010.

Natural Gas and Oil Systems

Emission sources for this module cover a wide range of activities associated with the production and transmission of natural gas and petroleum. Table 8-1 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. The absence of some information is discussed in the data uncertainties section of this Chapter.

Table 8-1: 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 are

Natural gas and oil systems address the production of oil and gas in much the same was as coal production is calculated. Activity factors, and total natural gas and oil production data, are used to generate emissions of methane in metric tons. The factor of 21 is used to convert the metric tons to CO_2 equivalents. The EPA user's guide contains the details for the calculations and this chapter documents the key emissions calculation schemes. The model considers the four major gas production components of processing, transmission, storage and distribution. Natural gas and oil systems account for 2% of the gross State emissions in 1990. This increases to 5% by 2010 due to increased production of natural gas. Table 8-2 summarizes the output from the Natural Gas and Oil Systems module. For a complete description of this source category refer to the *SIT Natural Gas and Oil System User's Guide (*EPA 2013b*)*.

Methodology

Step 1: After downloading and opening the Natural Gas and Oil Systems SIT from the EPA GHG inventory website, enable the macros by selecting 'Enable Macros' in the 'Options' box at the top of the sheet.

Step 2: Close the ICF pop-up box after the sheet activates

Step 3: Select the State (Colorado) from the 'Select a State' options box

Step 4: Select the default emission factors by selecting 'Check All'

Step 5: In Section 2 of the Control sheet select 'Go to Natural Gas-Production Sheet and on that sheet select 'Check All Boxes' and then 'Return to Control Sheet'. This sheet contains the well counts for active wells in Colorado and the numbers are summarized in Table 6.

Step 6: In Section 3 of the Control sheet select 'Go to Natural Gas- Transmission Sheet and select 'Check all boxes' then select 'Return to Control Sheet'. Note this sheet is not linked to any default or state specific data. The miles of gathering pipeline, number of gas processing plants, number of LNG storage compressor stations, miles of transmission pipeline, numbers of gas transportation compressor stations, and number of gas storage compressor stations are all required inputs (See Table 8-4 & 8-5). By selecting the Check All Boxes option, the 'Check if you don't have data for gas transmission and storage compressor stations for this year' is activated for each year. This still requires manually inputting data for miles of gathering and transmission pipes and the number of gas processing and compressor stations. See the discussion under data uncertainties at the end of this chapter for more details about the lack of data in this area when running the model in the default mode.

Step 7: Under Section 4 of the Control Sheet, select 'Go to Natural Gas-Distribution Sheet. Selecting 'Check All Boxes' selects all years from 1990 to 2010 and the 'check here if you wish to use the alternative method for this year' option. The calculation of NG distribution involves knowing the miles of cast iron pipe in the distribution system; miles of unprotected steel distribution pipeline; miles of protected steel distribution pipeline and miles of plastic distribution pipeline (See Table 8-5). The 'alternative method' requires only an estimate of total miles of distribution pipeline. Since no default is provided, and to be consistent with the approach taken in all other elements of this default inventory, no data was input for these fields. Select 'Return to Control Sheet'.

Step 8: Under Section 5 of the Control Sheet go to Natural Gas Venting and Flaring sheet. Selecting Check all Boxes will select all years between 1990 and 2010 and will use the default activity data (54.71 metric tons CO_2/year/billion BTU). Return to the Control Sheet.

Step 9: Under section 6 of the control sheet select 'Go to Petroleum Systems Sheet'. Selecting 'Check All Boxes' populates the amount of oil produced in the state data field for all years from 1990 to 2010. Petroleum systems are broken into three sub-categories; Oil Production; Oil Refining; Oil Transportation. The default mode only populates the Oil Production data field.

Due to the controversial nature of the methane production and distribution losses some additional information is provided in this Chapter to describe the default emissions calculations. All calculation details can be gleaned from the SIT module spreadsheets and are further described in the User's Guide. The following discussion addresses each of the SIT sub-elements related to natural gas emissions.

NG Production-Emissions from production in Colorado use only the total number of operating wells. Well counts are based on reported data from Colorado (EIA 2013b). These don't reflect the total well count in Colorado. Refer to the data uncertainties section of this chapter for a discussion concerning discrepancies in the active well count data. An emission factor in metric tons of CH_4/year/well is multiplied times the well count to produce metric tons of CH_4. The activity factor is reflected in Table 8-4. Metric tons of CH_4 are converted to $MMTCO_2e$ by multiplying the output times 21. See Figure 3 for the calculation scheme.

NG Transmission-No default miles of pipeline, number of gas processing plants, or compressor stations, are provided in the default data base. 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. Consult the data uncertainties section of this chapter to gain a perspective on this omission of data.

NG Distribution-Consult Table 8-4 for the listing of data inputs driving this sub-section of the model. Two methods are built into the data base, one relying on total miles of pipeline in the state along with service information and the other, preferred method relies on knowledge of the miles of different types of pipes in the state. Neither of these approaches (the alternative or the preferred) have data for Colorado. Thus, in the default mode no emissions are estimated for this part O&G.

NG Venting and Flaring-Venting of natural gas Flaring of natural gas is calculated in the model by multiplying the billions of BTUs of natural gas processed in the state per year, adjusted by 80% to account for gas flared versus that which is vented. The resulting metric tons of gas in $MMTCO_2$ range from 0.06 $MMTCO_2e$ in 2010 to 0.23 $MMTCO_2e$ in 1990.

In Table 8-3, natural gas transmission is based on miles of pipeline, amount of natural gas processed and the number of compressor facilities. An activity factor is multiplied times the miles of pipelines and another activity factor is applied to the number of compressor stations. Table 8-4 contains the model assumptions for the default emission factors and activity data. See Figure 3 for the details of the calculation. There is no national or Colorado default data for this part of the SIT model and 'States are encouraged to provide local data if available'. This information is available from historical records in Colorado. A discussion in the data uncertainty section addresses this lack of default data along with the lack of distribution data for the state. As this inventory is a reflection of the model's output exercised in the default mode, no substitute information was input into this section of the inventory. Production emissions represent the bulk of the emissions related to natural gas and oil activities in Colorado in the default mode

$MMTCO_2e$ from CH_4 Production= Total well count x 10.62 $MTCH_4$/yr/activity factor x 21 (GWP)/1,000,000

Figure 8-1: Calculation scheme for natural gas production (note the 10.62 figure is used from 2005 forward and the value varies from 9.07 in 1990, 10.45 in 1995)

Venting and flaring of natural gas is a common practice resulting in methane emissions. 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.

The $MMTCO_2e$ in Table 8-2 for natural gas is derived by taking the metric tons of methane emitted from the sum of production, transmission and distribution. As noted, the SIT default does not provide transmission and distribution estimates for states and bases the production on the number of wells multiplied by the activity unit built into the model. This activity unit is provided in the table and is extracted from the SIT subsheet 'Natural Gas-Production. Figure 8-2 provides an example calculation for the natural gas emitted in 2010 based on the SIT model assumptions:

$MMTCO_2e$= {[(28,813 wells) x (10.62 $MTCH_4$/well)] x 21 $GWPCH_4$} x 10^{-6} + .06 $MMTCO_2e$ flaring= 6.486 $MMTCH_4$

Figure 8-2: Example calculation for total natural gas emissions for 2010 from Table 6 figures

Table 8-2: Summary of CH_4 Emissions from Oil and Gas Activities in Colorado ($MMTCO_2e$.)

	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**

Table 8-3: Emissions by Gas ($MTCH_4$)-Note the following are in tons of methane, not adjusted by the factor of 21 multiplier to change this to CO_2e (See note below)

Natural Gas					
Production	52,071	73,328	241,925	240,978	305,994
Transmission					
Distribution					
Total Emissions	**52,071**	**73,328**	**241,925**	**240,978**	**305,994**
Oil					
Total Emissions	**18,751**	**18,193**	**12,758**	**16,484**	**23,715**
Emissions by Gas ($MMTCO_2$)					
Natural Gas Flaring	0.23	0.07	0.04	0.06	0.06

Default emission factors and activity data for natural gas distribution providing two alternatives (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)

Table 8-4: Emission Factors from SIT Module for Natural Gas Distribution

	Default Emision Factor	Factor Used
Preferred Methodology		
Metric tons of CH_4 per mile of cast iron distribution pipeline	5.8	5.8
Metric tons of CH_4 per mile of unprotected steel distribution pipeline	2.12	2.12
Metric tons of CH_4 per mile of protected steel distribution pipeline	0.06	0.06
Metric tons of CH_4 per mile of plastic distribution pipeline	0.37	0.37
Alternate Methodology		
Metric tons of CH_4 per mile of distribution pipeline	0.54	0.54
Metric tons of CH_4 per service	0.02	0.02
Metric tons of CH_4 per unprotected steel services	0.03	0.03
Metric tons of CH_4 per protected steel services	0.003	0

Table 8-5: SIT Module Default emission factors and activity data for natural gas transmission (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)

	Default Emision Factor	Factor Used
Metric tons of CH_4 per mile of gathering pipeline	0.4	0.4
Metric tons of CH_4 per gas processing plant	1249.95	1249.95
Metric tons of CH_4 per gas transmission compressor station	983.66	983.66
Metric tons of CH_4 per gas storage compressor station	964.15	964.15
Metric tons of CH_4 per mile of transmission pipeline	0.62	0.62
Metric tons of CH_4 per LNG storage compressor station	1184.99	1184.99

Data Uncertainties-Natural Gas Production

The production of natural gas is broken into several segments in the SIT model. Transmission of natural gas involves miles of pipelines in the state, the volume of gas transmitted, and the number of compressor stations. Leaks are associated with that system. In addition, flaring, venting, and storage losses all contribute to the larger methane emission picture. A 2013 research project by CSU is attempting to better define methane losses from natural gas transmission and storage (Magill 2013). In the default mode the SIT does not provide state specific miles of pipeline and relies on well counts for estimating leakage. Howarth, Santoro, and Ingraffea estimate lifecycle loss of methane to be related to production volume of a well and indicate this varies between 3.6% and 7.9% (2011). Recent studies by NOAA indicate methane emissions from leaks to be nearly double estimates in current inventories. The Colorado Oil and Gas Conservation Commission reported over 47,000 operational wells in Colorado in 2012, a count substantially greater than reflected in the EIA data used by the SIT model. Such a difference in counts would make a significant difference in the overall estimated methane emissions.

In the transmission of natural gas, compressor stations are used to collect gas from the wells as well as to maintain constant pressure in the transmission part of the system. The number of compressor stations is also not in the SIT data base and states are encouraged to provide their own data. As with the number of miles of pipelines, historical possibly projected miles of pipeline, and the number of compressor stations, is likely available. The decision to run the SIT model totally in the default mode allowed Colorado to compare State emissions against the national picture and against other states operating the model in a similar mode. For most parts of the model the default mode relied on state specific data derived from national data sources. In the case of natural gas transmission and compressor stations this is not the case and if states enter no data this part of the O&G module produces a null result.

The EIA reports Colorado processed 1,434,000 MCF of natural gas in 2010 and extracted 57,924 thousand barrels of liquids and lost 82,637 MCF in extraction (EIA 2013d). Based on rough estimates of using 4,000 miles of gathering pipeline, 10 gas processing plants, 5 LNG storage compressor stations and 5,000 miles of transmission lines with 40 gas transmission compressor stations, the SIT would estimate 1.25 $MMTCO_2e$ of methane would have been emitted in 2010 from distribution losses. Another approximately 1 $MMTCO_2e$ would be emitted by transmission losses, increasing the natural gas emissions from 6.5 $MMTCO_2e$ to 8.75 $MMTCO_2e$. Overall this underestimate grows proportionately in 2020 and 2030 simply because the model growth in emissions are proportional to national growth figures applied to the total methane released. Thus the lack of transmission and distribution data, while troubling in the sense that it creates a smaller footprint than likely exists, is even more complex in the future as new rules and processes are expected to contain many of these losses.

The EIA reports Colorado had 9,088 miles of interstate pipelines in 2010 and 3,040 in 1994 (2013). Using the 9,088 figure in the model generates an estimated 1.51 $MMTCO_2e$ as the model populates an estimated 54 compressor stations and 14 gas storage compressor stations to produce 72,072 $MTCH_4$. Pipelines in cities establish a second level of potential leaks but the model generally considers just the total interstate and intrastate miles. The EIA also indicates Colorado had 7,803 mile of pipeline in 2008 and the national total was 305,954 miles, of which 217,306 was interstate and 88,648 was non-interstate. This number is in conflict with the other EIA data source.

The EIA reports Colorado has 42 working natural gas storage facilitie with a daily withdrawal capability of 1,088 MMcf (EIA 2007). They also show 6-7 underground storage facilities. The number of storage facilities, compressor stations, miles of pipeline, total gas produced and number of wells are all figures likely available to create a more Colorado specific data base for the SIT module. However, given the significant investment by both industry and the environmental groups to fund a ‘leak’ study based on better data, the more likely issue is the set of assumptions used to generate leakage rates. Since field studies by NOAA and others indicate fugitive methane emissions may be substantially higher than current inventories show, this is one area the default assumptions in the model may provide an imperfect, at best, picture of the real GHG emissions.

Data Uncertainty Petroleum Systems

Three data inputs are required to fully estimate methane emissions from oil systems. As noted, only the total oil production is provided in the default mode. Oil Refining, while not significant in Colorado, still takes place and should be represented in the inventory. Oil transportation is another data field left blank in the default mode and, while likely a much smaller contributor to the overall inventory, it should be also included in the calculations scheme.

Projections to 2030

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

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Colorado Department of Public Health and Environment

Chapter 9 – Agriculture

Background

For this 2013 inventory update, the agricultural emissions are produced by using the February 2013 version of the EPA State Inventory Tool (SIT). The model was run fully in the default mode for this inventory. As with the most other elements of the SIT, the model has its roots in the EPA Emissions Inventory Improvement Program (EIIP) program. The EIIP was developed to create greenhouse gas emissions consistent with the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA 2012, 1.4). Agricultural emissions are calculated in the SIT for methane (CH_4) and nitrous oxide (N_2O) considering the following:

- enteric emissions (flatulence),
- manure management, and
- agricultural soils
    - Ag Soils-Plant-Residues and Legumes,
    - Ag Soils-Plant-Fertilizers;
    - Ag Soils-Animals.

Direct carbon dioxide (CO_2) emissions from farm equipment and processes are reflected in statewide gasoline or diesel fuel use or industrial operations. These would add to the overall agricultural emissions picture had they been considered separately.

When considering direct emissions, the agricultural sector accounted for approximately 7% of the 2010 inventory.

Nitrous Oxide Emissions from Agriculture

Emission Factors and Data Requirements

All animal related emission factors in the model were expressed in kilograms per animal per year (kg/animal/yr). The EPA user's guidance document provides details concerning the model evaluation process (U.S. EPA 2012, 1.4-1.5). In addition to emission factors per animal, soil characteristics, fertilizer use, crop production, and assumptions concerning plant residue are part of the model calculation.

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.

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. The resultant model runs in default mode are available on the State GHG inventory website.

For a discussion of options, or concerns with use of default Colorado information, see the closing section of this Chapter.

Methodology

The following steps were used in running the SIT Ag module:

Step 1: Select ‘Options’ in the opening sheet and ‘Enable this content’ when the pop up box appears. When the second pop-up box appears linking the sheet to the EPA State Climate and Energy Program (ICF International-Draft 2/11/2013) data base, close this sub-window by clicking on the ‘X’, then selecting OK when the warning box appears. This will activate the macros in the Ag SIT module and link the spreadsheet to the national data bases needed to support the calculations. The national data is contained in sub-spreadsheets within the SIT tool along with a description of the sources of data.

Step 2: Select ‘Colorado’ from the dropdown box.

Step 3: Select ‘Check/Uncheck All’ (the Defaults)’ for the Enteric Fermentation Control Sheet and for all other categories appearing below this section (Section; 3. Manure Management and Animal Calculation Values; 4a. Ag Soils-Plant-Residue & Legumes; 4b. Ag Soils-Plant-Fertilizers; 4c. Ag Soils-Animal Calculations Values; 5. Rice Cultivation-Seasonal Emission Factors; 6. Agricultural Residue Burning).

Step 4: Select the ‘Click here to continue to the Enteric Fermentation Sheet’ at the opening section of this first sheet (or go the bottom of the spreadsheet and select the next ‘tabbed’ page). This takes you to the same location, that being the second sheet of the Ag Module. Select ‘Check All Boxes’ in the upper right gray box. This will populate all years from 1990-2010 with the numbers of animals, emission factors and emission calculations. It will calculate the emissions and convert them from methane in kg to Million Metric tons CO_2 ($MMtCO_2e$). By applying the multiplier of 21 for methane, and the molecular weight ratio of ‘carbon to methane’, the carbon dioxide equivalent number is produced.

Step 5: Continue working through each of the sub-sheets selecting ‘select all’ for selection of the defaults and allowing the sheet to populate the data fields. To view an actual year’s data, such as enteric fermentation for 1995, you must select the ‘+’ sign next to the year on the enteric fermentation sheet.

2013 Inventory Update for Agriculture

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). Table 9-1 shows the animal head count per year.

Table 9-1: Enteric Fermentation animal head count for Colorado using EPA SIT default model (March 18, 2013 run)

Agriculture	1990 Thousand head	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 (on and off feed	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 emissions from animals in the agricultural module is as follows:

Equation 1. Emission Equation for Enteric Fermentation

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

Manure Management CH_4 and N_2O

In accordance with the EPA workbook, data required for manure management 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. The SIT model assumes at some point manure is applied to the soil and a separate emissions sheet and calculation is used to define overall emissions from animal management. Manure breaks down to emit ammonia as nitrogen and is eventually partially converted to nitrous oxide, a greenhouse gas with a GWP 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.

Emissions from manure management are as follows:

Equation 2. Emission Equation for CH_4 Manure Management

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

(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)

Agricultural Soils-Plant Residue and Legumes

Emissions from legumes are calculated in accordance with Equation 4. This data is also used for other crop based emissions.

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)

Crop production is calculated in accordance with Equation 5. 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 is 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 table 9-2 below.

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)

Table 9-2: 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	nd	nd	nd
Millet ('000 bushels)	nd	nd	2,850	5,500	7,095
Dry Edible Beans ('000 hundredweight)	4,275	2,558	1,980	1,095	1,254

ndOncludes 'typical animal mass nd = no data in national data base. Substitute values could be used.

Not used=the projection case does not rely on filling out the crop table but on using the trend in growth or decline of a particular crop on a percentage growth per year factor. See the data discussion for further details on potential impacts or corrections to the data based on this knowledge.

Fertilizer use

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.

Table 9-3 provides a summary of fertilizer use per year from the 2013 SIT model.

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

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

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

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

Table 9-3: Colorado Fertilizer use per year[a] summary in kg of nitrogen (SIT Methane and Nitrous Oxide from Agriculture , Table 4b-March 18, 2013 run)

	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 (EPA 2013b; table.

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

Agricultural Soil from Animal Waste

Emissions due to animal production are mainly an accounting of animal waste (ammonia generation) and is a generalized approach with no state or site specific considerations. 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.

Rice Cultivation

Rice is not cultivated in Colorado. Therefore there was no data in the default SIT model.

Agricultural Residue Burning CH_4 and N_2O

Crop waste burning in Colorado is not a common practice. While ditch burning in agricultural lands is common, few other instances occur. The SIT Agricultural module uses the crop production figures from Table 2 and applies a fraction of residue burned, dry matter fraction, and burning efficiency to each total crop production figure. Total emissions estimated from burning are approximately a tenth of a percent of the total agricultural emission profile.

Data Summary from 2013 SIT Model

Table 9-4 summarizes agricultural emissions using the default version of the SIT model. For projection estimates refer to Chapter 2, Projections.

Table 9-4: GHG Agriculture CO_2e Emissions 2013 SIT Model (in million metric tons)

	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 W	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$_2$O)					
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 V	0.003	0.003	0.003	0.003	0.004
Agricultural Soil Managemer	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$_2$O)					
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 Uncertainties

The SIT model contains an uncertainty section for each module explaining general 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 in the Emissions Summary section, 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 and 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 figures.

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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Colorado Department of Public Health and Environment

Chapter 10 – Waste Management

Background

For this 2013 Colorado Greenhouse Gas (GHG) baseline inventory update, Waste Management emissions are produced using the EPA State Inventory Tool (SIT) model fully in the default mode. The origins of the current SIT model are rooted in the EPA Emissions Inventory Improvement Program (EIIP). The EIIP was developed to create greenhouse gas emissions that are consistent with the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S.EPA 2012, 1.4

For this chapter, 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*.*

Emissions from the waste management sector are calculated in the SIT as Municipal Solid Waste, which are derived from the following;

- landfills,
- waste combustion,
- plastic combustion,
- synthetic rubber combustion
- and synthetic fiber combustion.

The SIT Municipal Solid Waste module calculates methane (CH_4) emissions from landfills of solid waste and carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions from combustion of solid waste.

The Wastewater module calculates CH_4 and N_2O emissions from the treatment of municipal and industrial wastewater. Emissions from Wastewater are derived from the following sources:

municipal wastewater (CH_4, direct N_2O emissions and N_2O emissions from Biosolids),

industrial wastewater from fruits and vegetables, red meat, poultry, pulp and paper.

When considering total GHG $MMCO_2e$ (million metric tons equivalent) emissions in the state, Waste Management Emissions account for 2% of total emissions.

Waste Management

The waste management sector GHG emissions estimates are the sum of N_2O and CH_4 emissions from the SIT Model 2013 Wastewater module and CO_2, N_2O and CH_4 emissions from Municipal Solid Waste module.

Wastewater Module

There are twelve general steps involved in estimating emissions using the SIT 2013 Wastewater module:

Step 1: select industrial wastewater sources

Step 2: select a state (Colorado)

Step 3: select default emission factors and other variables used throughout the module

Step 4: complete municipal wastewater worksheet

Step 6: complete municipal wastewater N_2O emissions worksheet

Step 7: complete industrial wastewater CH_4 from fruits and vegetables worksheet

Step 8: complete industrial wastewater CH_4 from red meat worksheet

Step 9: complete industrial wastewater CH_4 from poultry worksheet

Step 10: complete industrial wastewater CH_4 from pulp and paper worksheet

Step 11: review summary information for completeness

Step 12: select export data.

Some of the significant equations to obtain GHG emissions from this module are listed below.

Equation 1. CH_4 Emissions from Municipal Wastewater Treatment

$$CH_4 \text{ Emissions } (MMTCO_2E) = \text{State Population} \times BOD_5 \text{ Production (kg/day)} \times 365 \text{ days/year} \times 0.001 \text{ (metric ton/kg)} \times \text{Fraction Treated Anaerobically} \times \text{Emission Factor } (Gg\ CH_4/Gg\ BOD_5) \times 10^{-6} \text{ (MMT/metric ton)} \times 21 \text{ (GWP)}$$

Equation 2. Direct N_2O Emissions from Municipal Wastewater Treatment

$$\text{Direct } N_2O \text{ Emissions } (MMTCO_2E) = \text{State Population} \times \text{Fraction of Population not on Septic (\%)} \times \text{Emission Factor } (g\ N_2O/\text{person/year}) \times 10^{-6} \text{ (metric ton/g)} \times 10^{-6} \text{ (MMT/metric ton)} \times 310 \text{ (GWP)}$$

Equation 3. N_2O Emissions from Biosolids Municipal Wastewater Treatment

N_2O Emissions ($MMTCO_2E$) =
[State Population × Protein Consumption (kg/person/year) ×
$FRAC_{NPR}$ (kg N/kg protein) × Fraction of Nitrogen not Consumed
0.001 (metric ton/kg) – Direct N Emissions (metric tons)] ×
[1 – Percentage of Biosolids used as Fertilizer (%)] ×
Emission Factor (kg N_2O-N/kg sewage N produced) ×
44/28 (kg N_2O /kg N) × 10^{-6} (MMT/metric ton) × 310 (GWP) +
Direct N_2O Emissions

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*.

Municipal Solid Waste Module

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.

There are sixteen steps involved in estimating the MSW from the module, to estimate GHG emissions from solid waste management. In the user's guide, the two sectors within the MSW module, landfills and combustion, are treated separately. Steps 4-8 address the estimation of landfill CH_4, while Step 9 deals with combustion. The user's guide for this module explains in detail the sixteen steps necessary to run the module. Below is a table from the user's guide that shows the required data inputs for MSW.

Table 10-1: 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

Landfills

Once you have made your selections and entered data for the previous three steps, you may view preliminary calculations of CH_4 emissions from MSW landfills in your state by clicking on the gray arrow that says "Go to the Calculations Sheet." This worksheet shows the preliminary results of the FOD model calculations for MSW. These calculations are considered preliminary because CH_4 emissions for the amount collected and burned and the amount oxidized at the surface of the landfill is taken into account in later steps. The FOD model estimates the potential CH_4 emissions that occur during the inventory year, but which are associated with the waste landfilled over the past thirty years, using Equation 1.

As the equation shows, 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 and is automatically chosen based on the selected state from Step (1). Figure 5 shows the

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 put in gas collection systems in place. At some landfills in Colorado CH_4 collected by these systems is flared and is not counted as CO_2 emissions. The following equation 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

There are separate worksheets for each of the three types of fossil-derived MSW (plastics, synthetic rubber, and synthetic fiber) and each of the worksheets is similar in layout. An example of the plastics combustion worksheet is shown in Figure 8. Emissions are calculated using the following equation:

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)

Step (13) Review Estimates on the N_2O from MSW Combustion Calculation Worksheet

This worksheet does not require any data inputs; it presents an example of how the emissions are calculated based on the following equation (the emission factor is from U.S. EPA 2012a):

Equation 4. N_2O Emissions from Combustion

N_2O Emissions ($MTCO_2E$) =
MSW Combusted (short tons) × 0.00005 (emission factor in tons N_2O/ton MSW) × 310 (N_2O GWP) × 0.9072 (short tons to metric tons conversion)

Step (14) Review Estimates on the CH_4 from MSW Combustion Calculation Worksheet

This worksheet does not require any data inputs; it presents an example of how the emissions are calculated based on the following equation (the emission factor is from U.S. EPA 2012a):

Equation 5. CH_4 Emissions from Combustion

CH_4 Emissions ($MTCO_2E$) = MSW Combusted (short tons) × 0.00002 (emission factor in tons N_2O/ton MSW) × 21 (CH_4 GWP) × 0.9072 (short tons to metric tons conversion)

Wastewater Module

The Wastewater (WW) Module uses the EPA used 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 vegetable, red meat, poultry, and pulp and paper industrial waste water. Below is Table 10-2 from the user's guide shows the required data inputs for WW.

Table 10-2: Required Data Inputs for the Waste Water 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)

SIT Model Results

Table 10-3: Total CO_2e Emissions from Landfills and Waste Combustion (in million metric tons)

	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 ($MTCO_2E$)					
Potential CH_4	**703,381**	**953,466**	**1,309,577**	**2,074,403**	**2,854,739**
MSW Generation	657,366	891,090	1,223,904	1,938,694	2,667,981
Industrial Generation	46,016	62,376	85,673	135,709	186,759
CH_4 Avoided	**-193,260**	**-515,097**	**-400,559**	**-444,937**	**-547,215**
Flare	-160,919	-482,756	-356,377	-444,937	-547,215
Landfill Gas-to-Energy	-32,341	-32,341	-44,182		
Oxidation at MSW Landfills	**46,411**	**37,599**	**82,334**	**149,376**	**212,077**
Oxidation at Industrial Landfills	**4,602**	**6,238**	**8,567**	**13,571**	**18,676**
Total CH_4 Emissions	**459,109**	**394,532**	**818,116**	**1,466,519**	**2,076,772**
CO_2 and N_2O Emissions from Waste Combustion ($MTCO_2E$) (SEE NOTE BELOW re: NULL Emissions					
CO_2					
Plastics	-	-	-	-	-
Synthetic Rubber in MSW	-	-	-	-	-
Synthetic Fibers	-	-	-	-	-
N_2O	**-**	**-**	**-**	**-**	**-**
CH_4	**-**	**-**	**-**	**-**	**-**
Total CO_2, N_2O, CH_4 Emissions	**-**	**-**	**-**	**-**	**-**

Table 10-4: Total Emissions from wastewater treatment (MMTCO2e)

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

In regard to projections made by for the 2013 GHG SIT Inventory Update, projections change based on federal and state regulations every few years. CDPHE and other agencies preparing projections of GHG are aware of the following regulations regarding waste management that affect inventory projections.

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

There are several sources of uncertainty associated with the method used for estimating CH_4 emissions from landfills. CH_4 production is impacted by temperature, rainfall and landfill design, characteristics that 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 onseptic tank usage data. The national default estimate of the fraction of wastewater stream 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.

References

Strait, Randy, Steve Roe, Alison Ballie, Holly Lindquist, Alison Manison, Ezra Hausman, Alice Napoleon. *2007 Final Colorado Greenhouse Gas Inventory and Reference Case Projections 1990-2020.* Center For Climate Strategies. October.

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.

U.S.EPA. 2013. User's *Guide For Estimating* CO_2 *Emissions From Municipal Solid Waste Using the State Inventory Tool.* ICF International. State and Energy Program.

Chapter 11 – Land Use and Forestry

Background

The origins of this SIT model element are rooted in the EPA Emissions Inventory Improvement Program (EIIP) for Land Use and Forestry (as well as ten other sectors') emissions. The EIIP was developed to create greenhouse gas emissions "consistent with the Inventory of U.S. Greenhouse Gas Emissions and Sinks" (U.S. EPA 2012, 1.4). The SIT updates previous EPA guidance for creating greenhouse gas inventories published in 2004 as *Volume VIII of the U.S. Greenhouse Gas Emissions and Sinks.*

For this 2013 inventory update, the Land Use, Land Use Change, and Forestry (LULUCF), sinks and emissions are produced by using the February 2013 version of the EPA State Inventory Tool (SIT). 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

This SIT module calculates emissions for methane (CH_4) and nitrous oxide (N_2O) released from forest fires. For this inventory the model was run fully in the default mode. For issues or uncertainties due to this approach, refer to the last section of this Chapter dealing with data uncertainties.

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, either as CH_4 and/or N_2O, and balances these against production of forest and urban trees. Table 1 is extracted from the User's Guide and provides a brief summary of the sub-elements of this module. Much of this element 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.

Table 11-1: Data Input Table 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 projection tool does not forecast LULUCF emissions for future years. Table 11-5 provides a summary of 1990-2010 LULUCF emissions.

The SIT model notes local data is not always available to populate the model and inputs should be checked carefully. One default for the model is not directly available, that of forest fires, and requires acquisition of state level data. This is further discussed below under the section titles Forest Fires.

A discussion concerning LULUCF data uncertainties, inputs, and assumptions for the Colorado inventory is found at the end of this Chapter and are also 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).

Emission Factors and Data Requirements

Forest and land use emission factors in the model were expressed in various units related directly to the type of sector. This module calculates:

- CO_2 emissions from liming (Colorado has no assumed liming)
- CO_2 from urea fertilization in tons/metric ton of urea applied
- Carbon storage in urban trees
- N_2O from settlement soils which are direct emissions for managed soils

Defaults for Colorado were used in the model and were based on Colorado and national data.

The EPA guidance addresses substituting state specific data for default information. This produces carbon tons which are converted to carbon dioxide equivalents.

Methodology

The following steps were used in running the SIT LULUCF module:

Step 1: Open the spreadsheet Land-Use, Land-Use Change, and Forestry from the EPA GHG emission inventory SIT toolbox. Beginning on the first spreadsheet (Control) Select 'Options' and 'Enable this content' when the pop up box appears. A second pop-up box appears indicating linking the sheet to the EPA State Climate and Energy Program (ICF International 2/13/2013) data base has been accomplished. Close this sub-window by clicking on the 'X'. Select 'OK' when the warning box appears. This will activate the macros in the LULUCF SIT module and link the spreadsheet to the national data bases contained in sub-spreadsheets within the model which are needed to support the calculations. Note for forest fires, no link to a national data base is established. Refer to the section in this Chapter concerning forest fire related GHG emissions.

Step 2: In the top left of the Control sheet, select 'Colorado' from the 'Choose a State' dropdown box.

Step 3: Leave the Forest Carbon Flux option to default to the USDA Forest Service default data. The EPA users' guide also notes the model allows the user to enter user specific data. In this inventory update the default mode was selected. It should be noted, due to drought conditions and pine beetle kill, some consideration was given to making such a substitution. However two problems are presented which are further discussed in the data uncertainties section of this Chapter.

Step 4: Select the 'Check/Uncheck All' block under 'Enter emission factors'. This will populate default emission factors for items 3-8 which are:

- CO_2 from Liming of Agricultural Soils
- CO_2 from Urea Fertilization
- C Storage in Urban Trees (sequestration)
- N_2O from Settlement Soils

- Non-CO_2 from forest fires
- Carbon Storage in Land-filled Yard Trimming and Food Scraps

Step 5: Continue working through each of the sub-sheets choosing 'select all' and allowing the sheet to populate the data fields. To view an actual year's data you must select the '+' sign next to the year.

2013 SIT Model Inventory Update for Forestry and Land Use

Emission factors

This emissions module covers a range of emissions and sinks related primarily to forestry in terms of tree growth, loss and use. Consideration of factors involved in soil conditions, use of fertilizers, urban tree planting, disposal of yard trimmings and food scraps in landfills are all included in this module. 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 in Colorado Worksheet

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. As reflected in Table 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.

The net sequestration (or emissions) from the above ground and below ground, dead wood, litter, and soil organic carbon is produced from data in Table 11-2.

Table 11-2: MMT 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			-2.85	-2.85	-2.29
Belowground Biomass			-0.5	-0.5	-0.42
Dead wood			-2.22	-2.22	-0.9
Litter				-2.07	-2.07
Soil Organic				-2.31	-2.31

[a] The EPA Projection Tool does not project Forestry and Land Use emissions or growth/death factors to 2030.

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 from synthetic ammonia and carbon dioxide (Wikipedia n.d.). Urea [$CO(NH_2)_2$] is mostly used as fertilizer in agricultural and urban settings. Agricultural application of fertilizer is accounted for in Chapter 9, Agriculture. Default values were used for Colorado. The amounts of applied fertilizer and resultant emissions are shown in Table 3. The calculation scheme for this is extracted from the EPA workbook and is shown in Figure 11-1. Note the only variable in the equation is the amount of applied urea.

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 $MMTCO_2E$)

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

(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. Table 11-3 presents the N_2O emissions from Settlement Soils.

The calculation scheme for N_2O emissions is shown in Figure 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).

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 ($MT/MMTCO_2E$)

Figure 11-2: Nitrous Oxide from Settlement Soils

(U.S. EPA 2013, 1.12)

Table 11-3: 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.

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 Figure 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.

$$\text{Sequestration (MMTCO}_2\text{E)} = \text{Total Urban Area (km}^2) \times \text{Urban Area with Tree Cover (\%)} \times 100\ (\text{ha/km}^2) \times \text{C Sequestration Factor (metric tons C/ha/yr)} \times 44/12\ (\text{ratio of CO}_2 \text{ to C}) \div 1{,}000{,}000\ (\text{to yield MMTCO}_2\text{E})$$

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

(U.S. EPA 2013b)

Table 11-4: Carbon Stored in Urban Trees (in million metric tons)

	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					

Burning CH_4 and N_2O

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. This year is not included in our summary Table 11-5 (U.S. EPA 2013b, Burning CH_4 & Burning N_2O).

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).

2013 Inventory Data Summary

Table 11-5 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.

Table 11-5: Summary of GHG Emissions from Land-Use Change and Forest Emissions and Sequestration in Colorado ($MMTCO_2$ Eq.)

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 (see note at bottom of table)	See note	See note	See note	See note	See note
N_2O	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 the Synthesis Tool summary table for space purposes. For LULUCF this included liming of agricultural soils. Forest fires were specifically left in to point to this deficiency in the model data base. See Chapter 11 for a more in-depth discussion of this category and issue.

Data Uncertainties

The SIT model contains an uncertainty section for each module explaining general 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. Changes in biomass in forested areas are 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 reasonable. 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 may have upset the sequestration balance sufficiently that trends in emissions over the shorter ten and 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 for this element expert judgment was used to estimate the input.

Uncertainties Related to Urban Tree

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 Table 4, 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 more Colorado tailored 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 a figure of 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, equal to the total agricultural emission category for Colorado. 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

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

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END OF DOCUMENT

CDPHE is seeking comments on this DRAFT Inventory, the methodology, assumptions, and the ways that the inventory can be tailored to Colorado emissions. Please send comments to Theresa Takushi at the following e-mail address: theresa.takushi@state.co.us by March 15, 2014. The final inventory will consider comments that have been received.