

# Chapter 2

## Inventory and Projections of GHG Emissions

### Introduction

This chapter presents a summary of Colorado’s anthropogenic greenhouse gas (GHG) emissions and sinks (carbon storage) from 1990 to 2020. The Center for Climate Strategies (CCS) prepared a preliminary draft GHG emissions inventory and reference case projection for the Colorado Department of Public Health and Environment (CDPHE) through an effort of the Western Regional Air Partnership.<sup>1</sup> The preliminary draft report was provided to the Climate Action Panel (CAP) (and its Policy Work Groups [PWGs]) of the Colorado Climate Project to assist the CAP in understanding past, current, and possible future GHG emissions in Colorado, and thereby inform the policy option development process. The CAP and the PWGs provided comments for improving the reference case projections. Subsequently, the inventory and reference case projection estimates were revised to incorporate revisions approved by the CAP. The information presented in this chapter reflects the information presented in the final inventory and reference case projections report (hereafter referred to as the *Inventory and Projections*).<sup>2</sup>

Historical GHG emissions estimates (1990 through 2005)<sup>3</sup> were developed using a set of generally accepted principles and guidelines for state GHG emissions inventories, relying to the extent possible on Colorado-specific data and inputs. The reference case projections (2006–2020) are based on a compilation of various existing Colorado and regional projections of electricity generation, fuel use, and other GHG-emitting activities, along with a set of simple, transparent assumptions described in the appendixes of the *Inventory and Projections* report.

The *Inventory and Projections* report covers the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF<sub>6</sub>). Emissions of these GHGs are presented using a common metric, CO<sub>2</sub> equivalence (CO<sub>2</sub>e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential- (GWP-) weighted basis.

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

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<sup>1</sup> *Draft Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020*, prepared by the Center for Climate Strategies for the Colorado Department of Public Health and Environment (CDPHE) through an effort of the Western Regional Air Partnership, January 2007.

<sup>2</sup> *Final Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020*, prepared by the Center for Climate Strategies for the Climate Action Panel of the Colorado Climate Project, October 2007.

<sup>3</sup> The last year of available historical data varies by sector; ranging from 2000 to 2005.

## Colorado GHG Emissions: Sources and Trends

Table 2-1 provides a summary of GHG emissions estimated for Colorado by sector for the years 1990, 2000, 2005, 2010, and 2020. As shown in this table, Colorado is estimated to be a net source of GHG emissions, but with significant sinks of GHG emissions due to the forestry sector and agricultural soils. We note that there are significant uncertainties associated with forest carbon sink estimates.<sup>4</sup> In the sections below, we discuss GHG emission sources (positive, or *gross*, emissions) and sinks (negative emissions) separately in order to identify trends, projections, and uncertainties clearly.

**Table 2-1. Colorado historical and reference case GHG emissions, consumption-based by sector**

<b>(Million Metric Tons CO<sub>2</sub>e)</b>	<b>1990</b>	<b>2000</b>	<b>2005</b>	<b>2010</b>	<b>2020</b>
<b>Energy</b>	<b>75.4</b>	<b>96.0</b>	<b>102.2</b>	<b>114.1</b>	<b>129.1</b>
Electricity use (consumption)	32.7	40.9	42.9	48.2	52.6
Transportation fuel use	19.0	25.5	28.0	30.6	36.2
Fossil fuel industry	7.5	9.3	10.1	11.8	12.3
RCI fuel use <sup>†</sup>	16.3	20.2	21.2	23.6	27.9
<b>Other</b>	<b>10.7</b>	<b>13.6</b>	<b>13.9</b>	<b>15.2</b>	<b>18.4</b>
Industrial processes	0.8	2.1	2.9	3.8	5.9
Agriculture	8.7	9.6	8.9	8.9	9.1
Waste management	1.2	1.9	2.1	2.5	3.5
<b>Gross emissions</b>	<b>86.1</b>	<b>109.6</b>	<b>116.1</b>	<b>129.3</b>	<b>147.5</b>
<i>change relative to 1990</i>		27%	35%	50%	71%
<i>change relative to 2000</i>			6%	18%	35%
<b>Forestry</b>	<b>-24.7</b>	<b>-24.7</b>	<b>-24.7</b>	<b>-24.7</b>	<b>-24.7</b>
<b>Agricultural soils</b>	<b>-2.0</b>	<b>-2.0</b>	<b>-2.0</b>	<b>-2.0</b>	<b>-2.0</b>
<b>Net emissions (incl. sinks)</b>	<b>59.4</b>	<b>82.9</b>	<b>89.4</b>	<b>102.6</b>	<b>120.8</b>
<i>change relative to 1990</i>		39%	50%	73%	103%
<i>change relative to 2000</i>			8%	24%	46%
<b>Per capita gross emissions</b>	<b>26.1</b>	<b>25.3</b>	<b>24.6</b>	<b>24.8</b>	<b>21.7</b>
<b>Per capita net emissions</b>	<b>18.0</b>	<b>19.1</b>	<b>18.9</b>	<b>19.7</b>	<b>17.8</b>

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

† RCI = residential, commercial, and industrial fuel use. Totals reflect emissions associated with the direct use of natural gas, oil, coal, and wood for all years and avoided emissions associated with recent demand-side management initiatives from 2007 through 2020.

The next section of this chapter provides a summary of the historical emissions (1990 through 2005) followed by a summary of the reference case projection year emissions (2006 through

<sup>4</sup> The standing forest carbon sink estimates in states like CO with a large amount of unproductive forest area (e.g. Pinyon-Juniper forests) are highly uncertain (with potential for over-estimation of the sink). This is because these types of forest were not well represented in earlier US Forest Service surveys. Since they are now being inventoried, it is anticipated that future inventories will reduce the amount of uncertainty. See Appendix H of the report Final Colorado Greenhouse Gas Inventory and Reference Case Projections, 1990–2020, for a discussion of uncertainties associated with the estimates for this sector.

2020), and key uncertainties and next steps. We also provide an overview of the general methodology, principles, and guidelines followed for preparing the inventories.

## Historical Emissions

### Overview

In 2005, on a gross emissions consumption basis (i.e., excluding carbon sinks), Colorado accounted for approximately 116 million metric tons (MMt) of CO<sub>2</sub>e emissions, an amount equal to 1.6% of total United States (US) gross GHG emissions. On a net emissions basis (i.e., including carbon sinks), Colorado accounted for approximately 89 MMtCO<sub>2</sub>e of emissions in 2005, an amount equal to 1.4% of total US net GHG emissions.<sup>5</sup> Colorado's GHG emissions are rising more quickly than those of the nation as a whole.<sup>6</sup> From 1990 to 2005, Colorado's gross GHG emissions were up 35% while national gross emissions rose by 16% during this period. Much of Colorado's emissions growth can be attributed to its population growth. From 1990 to 2005, Colorado's population grew by 43% as compared with a national population growth of 19%.

Figure 2-1 illustrates the state's emissions per capita and per unit of economic output. Colorado's per capita emission rate is slightly more than the national average of 25 MtCO<sub>2</sub>e/year. Between 1990 and 2005, per capita emissions in Colorado and national per capita emissions have changed relatively little. Economic growth exceeded emissions growth in Colorado throughout the 1990–2005 period. From 1990 to 2005, emissions per unit of gross product dropped by 40% nationally, and by 54% in Colorado.

Electricity use and transportation are the state's principle GHG emissions sources. Together, the combustion of fossil fuels for electricity generation and in the transportation sector accounted for 60% of Colorado's *gross* GHG emissions in 2000, as shown in Figure 2-2. The remaining use of fossil fuels—natural gas, oil products, and coal—in the residential, commercial, and industrial (RCI) sectors, plus the emissions from fossil fuel production, constituted another 28% of total state emissions.

Agricultural activities such as manure management, fertilizer use, and livestock (enteric fermentation) result in CH<sub>4</sub> and N<sub>2</sub>O emissions that account for another 9% of state GHG emissions. Industrial process emissions comprise about 2% of state GHG emissions in 2000, and these emissions are rising rapidly due to the increasing use of HFCs and PFCs as substitutes for ozone-depleting chlorofluorocarbons.<sup>7</sup> Other industrial processes emissions result from cement

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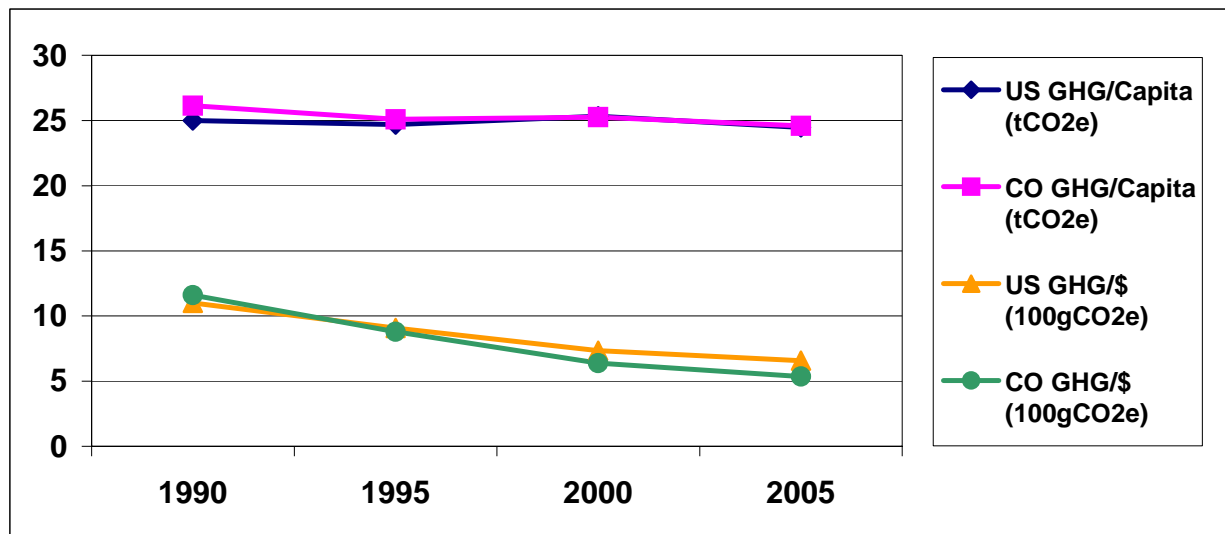
<sup>5</sup> National emissions from *Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2005*, April 2007, US EPA #430-R-07-002, (<http://www.epa.gov/climatechange/emissions/usinventoryreport.html>).

<sup>6</sup> *Gross* emissions estimates only include those sources with positive emissions. Carbon sequestration in soils and vegetation is included in *net* emissions estimates. All emissions reported in this section for Colorado reflect consumption-based accounting (including emissions from electricity imports). On a national basis, little difference exists between *production-based* and *consumption-based* accounting for GHG emissions because net electricity imports are less than 1% of national electricity generation.

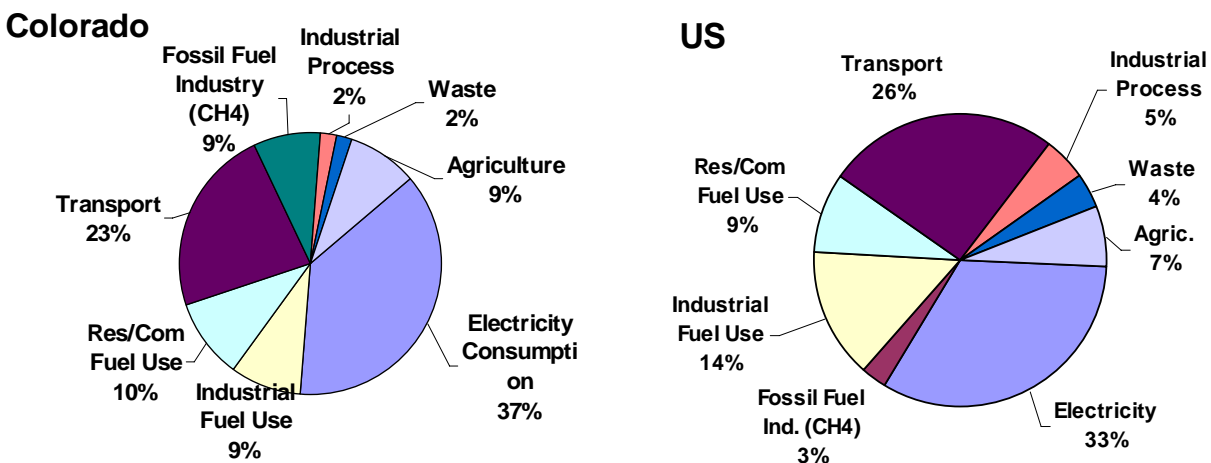
<sup>7</sup> Chlorofluorocarbons (CFCs) are also potent GHGs; however they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol. See Appendix J in the *Inventory and Projections* report for Colorado.

and lime manufacturing; PFC use in semiconductor manufacture; CO<sub>2</sub> released during soda ash, limestone, and dolomite use; and SF<sub>6</sub> released from transformers used in electricity transmission and distribution systems. Landfills and wastewater management facilities produce CH<sub>4</sub> and N<sub>2</sub>O emissions accounting for the remaining 2% of the state's gross GHG emissions in 2000.

**Figure 2-1. Colorado and US gross GHG emissions, per capita and per unit gross product**



**Figure 2-2. Gross GHG emissions by sector, 2000, Colorado and United States**



Based on data from the early 1980s through 2004, Colorado's forests are estimated to be net sinks, accounting for -24.7 MMtCO<sub>2</sub> of GHG emissions (the negative value indicates a net sequestration of CO<sub>2</sub> from the atmosphere). Also, agricultural soils are estimated to sequester an additional -2.0 MMtCO<sub>2</sub>. With these GHG sinks, Colorado's net emissions were 59.4 MMtCO<sub>2</sub> in 1990. Due to a lack of information to estimate future trends, these sinks were estimated to remain constant throughout the forecast period from 2005 through 2020. Thus, with the increase

in GHG emission sources, by 2020, the net emissions in Colorado are estimated to increase to about 121 MMtCO<sub>2</sub>e.

Emissions of aerosols, particularly “black carbon” (BC) from fossil fuel combustion, could have significant climate impacts through their effects on radiative forcing.<sup>8</sup> Estimates of these aerosol emissions on a CO<sub>2</sub>e basis were developed for Colorado based on 2002 and 2018 data from the Western Regional Air Partnership. The results were a total of 6.75 MMtCO<sub>2</sub>e, which is the midpoint of a range of estimated emissions (4.3–9.2 MMtCO<sub>2</sub>e) in 2002. Based on an assessment of the primary contributors, it is estimated that BC emissions will decrease substantially by 2018 after new engine and fuel standards take effect in the onroad and nonroad diesel engine sectors (decrease of about 4.0 MMtCO<sub>2</sub>e). These estimates are not incorporated into the totals shown in Table 2-1 because a global warming potential for BC has not yet been assigned by the Intergovernmental Panel on Climate Change (IPCC). By including BC emission estimates in the inventory, however, additional opportunities for reducing climate impacts can be identified as the scientific knowledge related to BC emissions improves.

### **A Closer Look at the Two Major Sources: Electricity and Transportation**

As shown in Figure 2-2, electricity consumption accounted for about 37% of Colorado’s gross GHG emissions in 2000 (about 40.9 MMtCO<sub>2</sub>e), which was higher than the national average share of emissions from electricity consumption (33%).<sup>9</sup> The GHG emissions associated with Colorado’s electricity sector increased by 8.2 MMtCO<sub>2</sub>e between 1990 and 2000, accounting for about 35% of the state’s net growth in gross GHG emissions in this time period. In 2000, emissions associated with Colorado’s electricity consumption were slightly higher than those associated with electricity production (38.7 MMtCO<sub>2</sub>e). The higher level for consumption-based emissions reflects GHG emissions associated with net imports of electricity to meet the state’s electricity demand.<sup>10</sup> See Chapter 4 for additional information.

While we estimate both the emissions from electricity production and consumption, unless otherwise indicated, tables, figures, and totals in this report reflect electricity consumption emissions. The consumption-based approach can better reflect the emissions (and emissions reductions) associated with activities occurring in the state, particularly with respect to electricity use (and efficiency improvements) and is particularly useful for policy making. Under this approach, emissions associated with electricity imported from other states would need to be covered in those states’ accounts in order to avoid double counting or exclusions. (Indeed,

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<sup>8</sup> Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 1996). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth), <http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm>.

<sup>9</sup> For the US as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the US imports only about 1% of its electricity, and exports far less. Colorado’s situation is different, since it is a net electricity importer.

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

Arizona, California, Oregon, New Mexico, and Washington are currently considering such an approach.)

Like electricity emissions, GHG emissions from transportation fuel use have risen steadily from 1990 through 2000 at an average rate of slightly under 3% annually. In 2002, onroad gasoline vehicles accounted for about 66% of transportation GHG emissions. Onroad diesel vehicles accounted for another 20% of emissions, and air travel for roughly 11%. Rail, marine gasoline, and other sources (natural gas- and liquefied petroleum gas- (LPG-) fueled-vehicles and used in transport applications) accounted for the remaining 2% of transportation emissions. As the result of Colorado’s population and economic growth and an increase in total vehicle miles traveled (VMT) during the 1990s, onroad gasoline use grew 32% between 1990 and 2002. Meanwhile, onroad diesel use rose 151% during that period, suggesting an even more rapid growth in freight movement within or across the state. Aviation fuel use grew by 16% from 1990 to 2002.

## Reference Case Projections

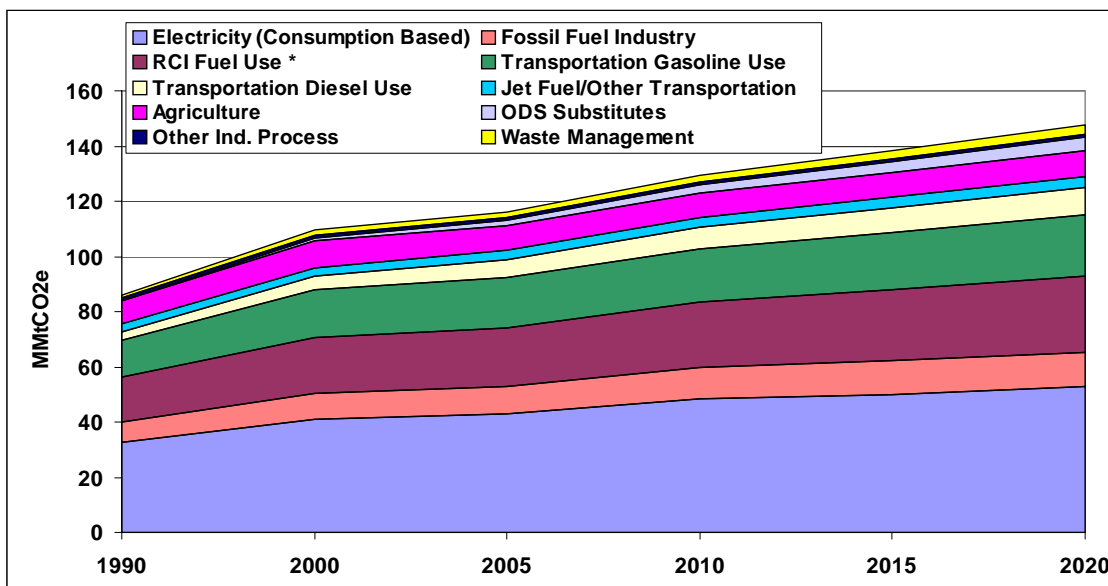
Relying on a variety of sources for projections of electricity and fuel use, as noted below and in the *Inventory and Projections* report, a simple reference case projection of GHG emissions through 2020 was developed. Table 2-2 shows key annual growth rates used to project emissions for Colorado and provides historical growth rates for comparison. As illustrated in Figure 2-3 and shown numerically in Table 2-1, under the reference case projections, Colorado gross GHG emissions continue to grow steadily, climbing to approximately 148 MMtCO<sub>2e</sub> by 2020, 71% above 1990 levels. Overall, the average annual projected rate of emissions growth in Colorado is 1.6% per year from 2005 to 2020. Demand for electricity is projected to be the largest contributor to future emissions growth accounting for about 36% of total gross GHG emissions in 2020, followed by emissions associated with transportation (25%), RCI fossil fuel use (19%), and fossil fuel production (8%) (see Figure 2-4).

**Table 2-2. Key annual growth rates for Colorado, historical and projected**

	1990–2005	2005–2020	Sources
Population*	2.4%	1.8%	Colorado State Demography Office
Employment*			Colorado Department of Labor and Employment website, based on analysis by the US Bureau of Labor Statistics.
Goods	1.0%	2.7%	
Services	2.8%	2.8%	
Electricity sales	3.0%	2.1%	US DOE Energy Information Administration (EIA) data for 1990-2004 (3.0% growth is mix of increased residential and commercial electricity sales countered by a decrease in industrial sales). The growth rate for 2005-2020 is based on electricity sales forecasts developed for the energy supply sector, and includes state legislation passed in 2007 establishing new requirements for Colorado’s renewable portfolio standard and for demand-side management programs.
Vehicle miles traveled	3.1%	2.1%	Federal Highway Administration, Highway Statistic; Metropolitan Planning Organizations and CDPHE

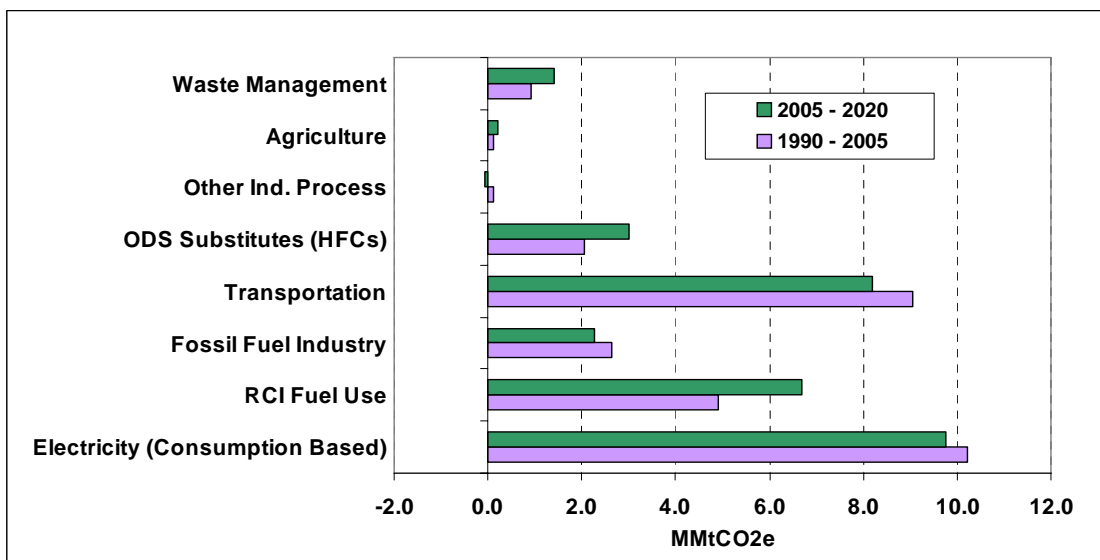
\* For the RCI fuel consumption sectors, population and employment projections for Colorado were used together with US DOE EIA’s Annual Energy Outlook 2006 (AEO2006) projections of changes in fuel use for the EIA’s Mountain region on a per capita basis for the residential sector and on a per employee basis for the commercial and industrial sectors. For instance, growth in Colorado’s residential natural gas use is calculated as the Colorado population growth times the change in per capita natural gas use for the Mountain region.

**Figure 2-3. Colorado gross GHG emissions by sector, 1990–2020: historical and projected under reference case assumptions**



\* RCI = direct fuel use in residential, commercial, and industrial sectors; ODS Substitutes = ozone depleting substances substitutes. Other Industrial Processes include process-related GHG emissions from cement and lime manufacturing; semiconductor manufacture; soda ash, limestone, and dolomite use; and electricity transmission and distribution systems.

**Figure 2-4. Sector contributions to emissions growth in Colorado, 1990–2020: historic and reference case projections**



\* RCI = direct fuel use in residential, commercial, and industrial sectors; ODS Substitutes = ozone depleting substances substitutes; HFC = hydrofluorocarbons.

## CAP Revisions

The following identifies the revisions that the CAP made to the inventory and reference case projections thus explaining the differences between this report and the initial assessment completed during January 2007:

- Energy Supply: Lowered emissions to account for changes in reference case assumptions associated with Colorado's renewable portfolio standard (RPS), which was amended upward in 2007 by the state legislature's passage of House Bill (HB) 07-1281 (Renewable Energy Standards):
  - Investor-Owned Utilities (IOUs) to provide 20% renewable energy by 2020
  - Non-IOUs (e.g., municipal utilities and rural electric cooperatives) to provide 10% renewable energy by 2020
  - Incentives for in-state generation, community-based projects, and solar energy
- RCI: Reduced energy consumption in the reference case projections associated with the passage of HB 07-1146 (Energy Conservation Building Codes) in 2007. This bill requires local governments who have building codes to adopt energy efficiency codes for certain buildings.<sup>11</sup> Reduction in emissions is accounted for under the RPS adjustment to avoid double counting of emission reductions.
- RCI: Reduced energy consumption in the reference case projections associated with the passage of HB 07-1037 (legislation recently passed requiring that public electric and gas utilities implement demand-side management programs)<sup>12</sup> and Xcel's demand side management commitments under a recent legal settlement, both of which have the effect of limiting demand growth relative to what it would have been in the absence of these factors.<sup>13</sup>
- Waste Management: Revisions to municipal solid waste (MSW) to reflect revisions the US Environmental Protection Agency made to the methods for calculating emissions in US EPA's State Greenhouse Gas Inventory Tool (SGIT; i.e., change was from use of regression equations to LANDGEM model equation):
  - 1990 emissions decrease from 1.6 to 0.8 MMtCO<sub>2</sub>e
  - 2020 emissions decrease from 5.7 to 2.7 MMtCO<sub>2</sub>e
- Forestry: Removed forest soil organic carbon emissions sink as recommended by the United States Forest Service (USFS). Relative to the January 2007 report, this change removed 7.1 MMtCO<sub>2</sub>e of emissions from the forest sink pool for 1990 through 2020.

## Key Uncertainties

Some data uncertainties exist in this inventory, and particularly in the reference case projections. Key tasks for future refinement of this inventory and projection include review and revision of key drivers, such as the electricity and transportation fuel use growth rates that will be major determinants of Colorado's future GHG emissions (see Table 2-2). These growth rates are driven

<sup>11</sup> <http://www.statebillinfo.com/sbi/index.cfm?fuseaction=Bills.View&billnum=HB07-1146>.

<sup>12</sup> <http://www.statebillinfo.com/sbi/index.cfm?fuseaction=Bills.View&billnum=HB07-1037>.

<sup>13</sup> Comprehensive Settlement Agreement, docket 04A-214E, 04A-215E, and 04A-216E, issued December 3, 2004, available at <http://www.xcelenergy.com/docs/corpcomm/SettlementAgreementFinalDraftclean20041203.pdf>.

by uncertain economic, demographic, and land use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion.

Perhaps the variable with the most important implications for GHG emissions is the type and number of power plants that will be built in Colorado between now and 2020. The assumptions on VMT and air travel growth also have large impacts on projected GHG emissions growth in the state. Finally, uncertainty remains on estimates for historic and projected GHG sinks from forestry, which can greatly affect the net GHG emissions attributed to Colorado.