Chapter 2
Inventory and Projections of GHG Emissions

Introduction

This chapter presents a summary of the full study, *Montana Greenhouse Gas Inventory and Reference Case Projections 1990-2020*, (hereafter, the *Inventory and Projections,* Appendix D to this report) and includes the emission estimates (historical and projected) along with key methodological issues and uncertainties. These estimates are intended to assist the state and stakeholders understand past, current, and possible future greenhouse gas (GHG) emissions in Montana, and thereby inform the policymaking process.

Historical GHG emissions estimates (1990 through 2005)[1] were developed using a set of generally accepted principles and guidelines for state GHG emissions inventories, relying to the extent possible on Montana-specific data and inputs. The reference case projections (2006-2020) are based on a compilation of various existing Montana and regional projections of electricity generation, fuel use, and other GHG-emitting activities, along with a set of simple, transparent assumptions described later in this chapter. Developing a "reference case" projection for the most likely development of Montana's electricity and fossil fuel production sectors is particularly challenging, given the many factors impacting energy production-related emissions. The principal uncertainty of interest is on the high side, given the many plans and initiatives to increase coal utilization locally and nationally. As a result, an alternative scenario of future energy supply development – the high fossil fuel production scenario – is also included.

Inventory and Projections covers the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these greenhouse gases are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a Global Warming Potential (GWP) weighted basis.

It is important to note that the preliminary emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Montana's demands,* corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the GHG emissions produced by electricity generation facilities in the state. For many years, Montana power plants have tended to produce considerably more electricity than is consumed in the state – emissions associated with exported electricity are excluded from the consumption-based emissions. This report covers both methods of accounting for emissions, but for consistency, all total results are reported as *consumption-based.*

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

Montana Greenhouse Gas Emissions: Sources and Trends

Table 2-1 provides a summary of GHG emissions estimated for Montana by sector for the years 1990, 2000, 2005, 2010, and 2020. As shown in this table, Montana 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 estimating forest carbon sink estimates. 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.

This next section of the report provides a summary of the historical emissions (1990 through 2005) followed by a summary of the forecasted reference case projection year emissions (2006 through 2020), key uncertainties and next steps. We also provide an overview of the general methodology, principles, and guidelines followed for preparing the inventory.

Table 2-1
Montana historical and reference case GHG emissions, consumption-based by sector[a]

(Million Metric Tons CO_2e)	1990	2000	2005	2010	2020
Energy	**22.9**	**25.3**	**27.7**	**29.2**	**32.0**
Electricity Use	8.9	9.5	10.0	10.0	11.0
Transportation Fuel Use	5.9	7.3	8.0	8.8	10.4
Fossil Fuel Industry	3.5	4.1	5.0	5.2	5.3
Res/Comm/Other Ind. Fuel Use	4.5	4.5	4.8	5.2	5.3
Other	**9.3**	**10.9**	**9.1**	**9.3**	**9.8**
Industrial Processes	1.2	1.0	0.9	1.1	1.5
Agriculture	7.9	9.5	7.9	7.9	7.9
Waste Management	0.2	0.2	0.3	0.3	0.4
Gross Emissions	**32.2**	**36.1**	**36.8**	**38.5**	**41.7**
change relative to 1990		*12%*	*14%*	*19%*	*30%*
change relative to 2000			*2%*	*6%*	*15%*
Forestry	**-23.1**	**-23.1**	**-23.1**	**-23.1**	**-23.1**
Agricultural Soils Sink	**-2.3**	**-2.3**	**-2.3**	**-2.3**	**-2.3**
Net Emissions (incl. sinks)	**6.8**	**10.7**	**11.4**	**13.1**	**16.3**
change relative to 1990		*57%*	*67%*	*92%*	*139%*
change relative to 2000			*7%*	*22%*	*52%*
Per Capita Gross Emissions	**40.3**	**40.1**	**39.4**	**39.7**	**40.8**
Per Capita Net Emissions	**8.5**	**11.9**	**12.2**	**13.5**	**15.9**

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

Historical Emissions

Overview

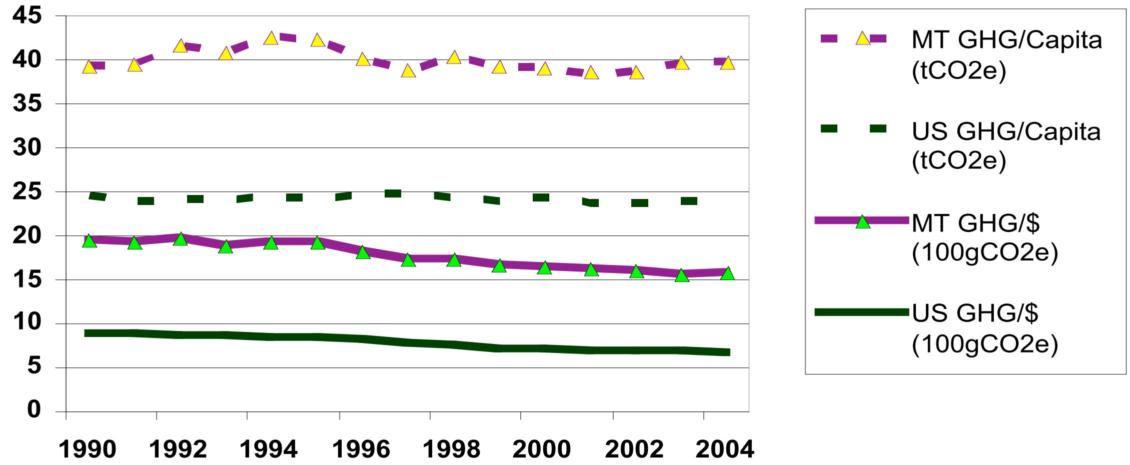
Preliminary analyses suggest that in 2005, activities in Montana accounted for approximately 37 million metric tons (MMt) of CO_2e gross emissions, an amount equal to 0.6% of total U.S. GHG emissions.[2] Montana's *gross* GHG emissions are rising at about the same rate as the nation as a whole. [3] Montana's gross GHG emissions were up 11 % from 1990 to 2004, while national emissions rose by 15 % during this period.

Although Montana's GHG emissions are low on an absolute scale compared to the total national output, on a per capita basis, during the period from 1990 to 2004, Montanans emit about 40 metric tons (Mt) of CO_2e, much higher than the national average of 25 $MtCO_2e$ over this same time period. The reasons for the higher per capita intensity in Montana are varied, but include the state's strong fossil fuel production industry, large agricultural industry, large distances for transportation, and low population base. Figure 2-1 illustrates the state's emissions per capita and per unit of economic output. It also shows that like the nation as a whole, per capita emissions have remained fairly flat, while economic growth exceeded emissions growth throughout the 1990-2004 period. From 1990 to 2004, emissions per unit of gross product dropped by 25% nationally, and by 18% in Montana.

[2] United States emissions estimates are drawn from US EPA 2006. *Inventory of US Greenhouse gas Emissions and Sinks:1990-2004*.

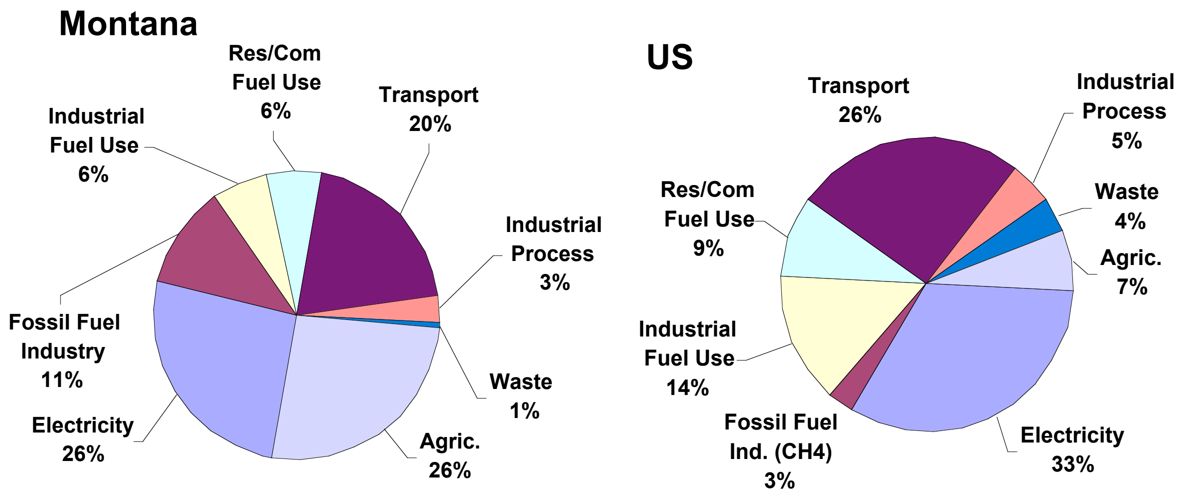
[3] *Gross* emissions estimates only include those sources with positive emissions. Carbon sequestration in soils and vegetation is included in *net* emissions estimates. All emissions reported in this section for Montana reflect consumption-based accounting (excluding emissions from electricity exports). 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.

Figure 2-1
Montana and U.S. gross GHG emissions, per capita and per unit gross product



Electricity use, agriculture, and transportation are the state's principal GHG emissions sources. Together, the combustion of fossil fuels for electricity generation used in-state and in the transportation sector account for about 46% of Montana's *gross* GHG emissions, as shown in Figure 2-2. The relative contribution of agricultural emissions (methane and N_2O emissions from manure management, fertilizer use, and livestock) is much higher in Montana (26%) than in the nation as a whole (7%). This is a result of more agricultural activity per capita in Montana compared to the U.S. The state also has higher levels of emissions (methane) from the fossil fuels industry – natural gas, oil products, and coal - than the national average (11% of the state's emissions). The remaining use of fossil fuels in the residential, commercial, industrial and institutional (RCII) sectors constitutes another 12% of state emissions.

Figure 2-2
Gross GHG emissions by sector, 2000, Montana and US



Industrial process emissions comprise only about 3% of state GHG emissions in 2000, but these emissions are expected to rise in the future due to the increasing use of HFC as substitutes for ozone-depleting chlorofluorocarbons.[4] Other industrial process emissions result from CO_2 released during aluminum and cement production, soda ash, limestone, and dolomite use. Landfills and wastewater management facilities produce CH_4 and N_2O emissions accounting for the remaining 1% of the state's emissions in 2000.

[4] 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 final Appendix (Appendix J).

Based on data from 1989 to 2004, Montana's forests are estimated to be net sinks, accounting for -23.1 $MMtCO_2$ of GHG emissions (the negative value indicates a net sequestration of carbon dioxide from the atmosphere). Also, agricultural soils are estimated to sequester an additional 2.3 $MMtCO_2$. With these GHG sinks, Montana's net emissions were 6.8 $MMtCO_2$ 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 Montana are estimated to increase to about 16.3 $MMtCO_2e$/yr.
CCS also prepared emission estimates for black carbon (BC), which is an aerosol species (component of particulate matter) that has positive climate forcing potential. The 2002 estimates for BC were 2.6 $MMtCO_2e$ across all source sectors. This is about 7% of the total emissions for the six GHGs shown in Table 2-1 during this period. Important sources of BC are diesel combustion: nonroad engines (31%), rail (29%), and onroad vehicles (24%). An assessment of these sources using available data for a 2018 projection from the Western Regional Air Partnership showed a decrease in the onroad and nonroad diesel sectors due to new Federal engine and fuel standards for particulate matter. Rail emissions rose only slightly. Overall, future BC emissions are expected to drop as a result of the new federal standards.

A Closer Look at the Three Major Sources: Electricity, Agriculture and Transportation

As shown in Figure 2-2, the electric, agriculture and transportation sectors are the largest contributors to Montana's gross consumption-based emissions. These sectors accounted for 26%, 26% and 20%, respectively, of total GHG emissions in 2000.

It is important to note that the electricity emissions estimates reflect the *GHG emissions associated with the electricity sources used to meet Montana demands,* corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the GHG emissions produced by electricity generation facilities in the state. For many years, Montana power plants have produced almost twice the electricity that is consumed in the state – in the year 2000, for example, Montana exported 41% of the electricity produced in the state. As a result, in 2000, emissions associated with electricity consumption (9.5 $MMtCO_2e$) were much lower than those associated with electricity production (17.1 $MMtCO_2e$).[5]

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 exported to other states would need to be covered

[5] 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 described in Appendix A of *Inventory and Projections*.

in those states' accounts in order to avoid double counting or exclusions. (Indeed, Arizona, California, Oregon, New Mexico, and Washington are currently considering such an approach.)

Emissions from agricultural sources, CH_4 and N_2O emissions from enteric fermentation, manure management, agricultural soils and crop residue burning, ranged from about 8 to 10 $MMtCO_2e$ during the period 1990 to 2005. Total GHG emissions increased from 8 $MMTCO_2e$ in 1990 to a high of 10 $MMTCO_2e$ in 1996 before dropping back to 8 $MMTCO_2e$ in 2002 and remaining at this level. Except for emissions from agricultural soils, emissions in each subsector were fairly static. For agricultural soils, emissions grew through the mid-1990's, but then have begun to fall since the late 1990s. Emissions from agricultural soils are N_2O emissions from the use of synthetic fertilizers, crop residue, nitrogen fixing crops, and manure application. Manure application is the largest contributor to the emissions from agricultural soils.

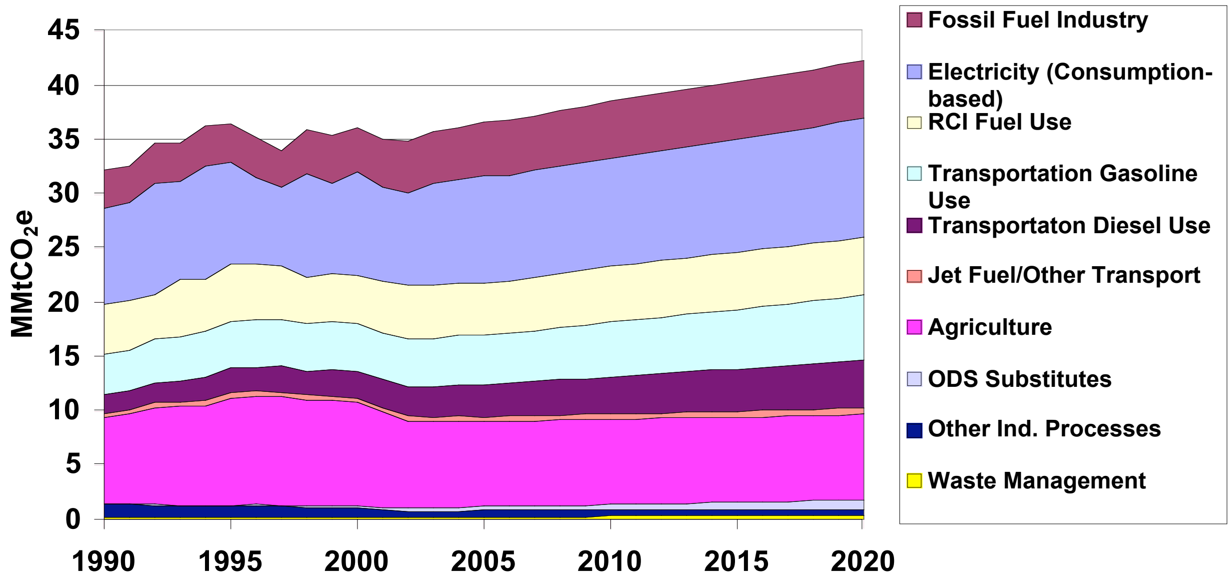
Like electricity emissions, GHG emissions from transportation fuel use have risen steadily since 1990 at an average rate of slightly over 2% annually. Gasoline-powered vehicles account for about 54% of transportation GHG emissions in 2005. Diesel consumption accounts for another 39%; air travel for roughly 6%, and the remainder of transportation emissions come from natural gas and liquefied petroleum gas (LPG) vehicles and lubricants. As the result of Montana's population and economic expansion and an increase in miles traveled during the 1990s, gasoline use has grown at rate of 0.9% annually from 1990 to 2005. Meanwhile, over the same period, onroad diesel fuel use has risen 4% annually, suggesting an even more rapid growth in freight movement within the State.

Reference Case Projections

Relying on a variety of sources for projections of electricity and fuel use, as noted below and in *Inventory and Projections*, we developed a simple reference case projection of GHG emissions through 2020. As illustrated in Figure 2-3 and shown numerically in Table 2-1, under the reference case projections, Montana gross GHG emissions continue to grow steadily, climbing to 42 $MMtCO_2e$ by 2020, 30% above 1990 levels. Transportation is projected to be the largest contributor to future emission growth, followed by the electric sector, as shown in Figure 2-4. Other major sources of emissions growth include the fossil fuel industry, and RCII fuel use. The decrease in GHG emissions from *All Other Sources* in Figure 2-4 is driven by the drop in aluminum production from 1990 to 2005.

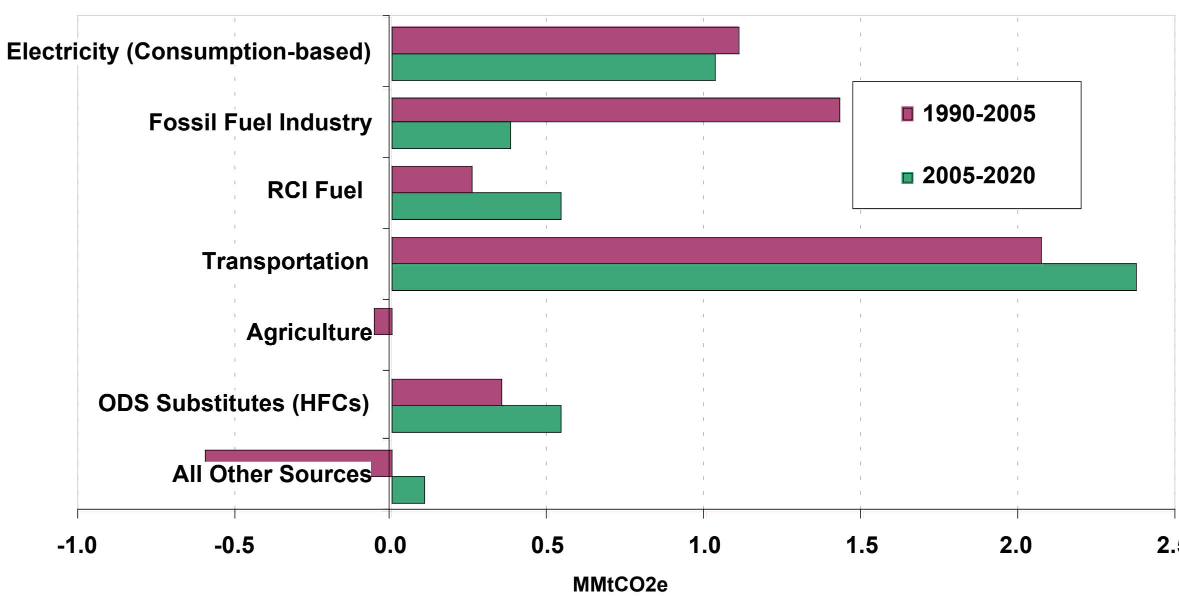
Figure 2-3

Montana gross GHG emissions by sector, 1990-2020: historical and projected under reference case assumptions



*RCI – direct fuel use in residential, commercial, and industrial sectors (excluding the fossil fuel production industry) ODS Substitutes – Ozone Depleting Substances Substitutes. Other Ind. Processes includes process-related GHG emissions from aluminum production; cement production; and soda ash, limestone, and dolomite use.

Figure 2-4
Sector contributions to emissions growth in Montana, 1990-2020: historic and reference case projections



*RCI – direct fuel use in residential, commercial and industrial sectors (excluding the fossil fuel production industry) ODS Substitutes – Ozone Depleting Substances Substitutes, HFC - Hydrofluorocarbons.

High Fossil Fuel Production Scenario

Given the many factors impacting energy production-related emissions and a diversity of assumptions by stakeholders within the energy sector, developing a "reference case" projection for the most likely development of Montana's electricity and fossil fuel production sectors is particularly challenging. The principal uncertainty of interest is on the high side, given the many plans and initiatives to increase coal utilization locally and nationally. As a result, we explore an alternative scenario of future energy supply development – the high fossil fuel production scenario. The high fossil fuel scenario assumes

- Additional new transmission lines will be built to export power from Montana. The total additional transmission lines in this case would have a capacity of 2,500 additional MW over the reference case addition of 500 MW, or 3,000 total additional MW capacity, relative to current levels. The new power plants built in Montana to use the capacity of the additional transmission lines are assumed to be a mix of 67% fluidized bed coal and 33% wind.
- Total natural gas production triples between 2005 and 2010, and increases an additional 74% above 2010 levels by 2020. Much of this increase is driven by increased coal bed methane development. To support this production, the scenario assumes two new natural gas transmission lines cross the state.
- Montana refining capacity increases, both through expansion of existing refineries and the addition of a new refinery, for refining of Athabasca crude from Alberta's oil sands.
- Two commercial coal-to-liquids plants are assumed to begin operation in Montana and coal mining increases modestly to support these plants.

The above assumptions reflect the high end of estimates for future fossil fuel development, under favorable conditions.

Table 2-2 presents a summary of GHG emissions from the electric sector in Montana on a production basis for both the reference case and the high fossil fuel scenario and on a consumption basis, which has the same estimated emissions for each case. Though the GHG emissions are significantly different from each other, each set of estimates is valid depending on circumstances. The difference between the emissions in the reference case and the high fossil fuel scenario estimates reflect the uncertainty in future energy development in Montana. The consumption-based emissions represent a focus on the emissions associated with electricity consumption in Montana – this focus is important when evaluating the effects of actions directed at in-state electricity conservation.

Table 2-2
Summary GHG emissions for Montana electric sector

(Million Metric Tons CO_2e)	1990	2000	2005	2010	2020
Production-based					
Reference case	**15.8**	**17.1**	**19.3**	**21.5**	**23.8**
High Fossil Fuel Scenario	**15.8**	**17.1**	**19.3**	**21.5**	**34.2**
Consumption-based	**8.9**	**9.5**	**10.0**	**10.0**	**11.0**

Note: Consumption-based emissions are the same for both the reference case and the high fossil fuel scenario because electricity consumption in Montana is the same for both cases.

Table 2-3 presents a summary of GHG emissions from the Montana fossil fuel sector for both the reference case and the high fossil fuel scenario. The projected growth between 2005 and 2020 is only 7% in the reference case and 216% in the high fossil fuel case, in which a number of unconventional technologies are assumed to reach commercial scale production. Under the high fossil fuel scenario, GHG emissions in 2020 are 10 MMtCO_2e higher than in the reference case, adding approximately 19% the state's production-based emissions in that year.

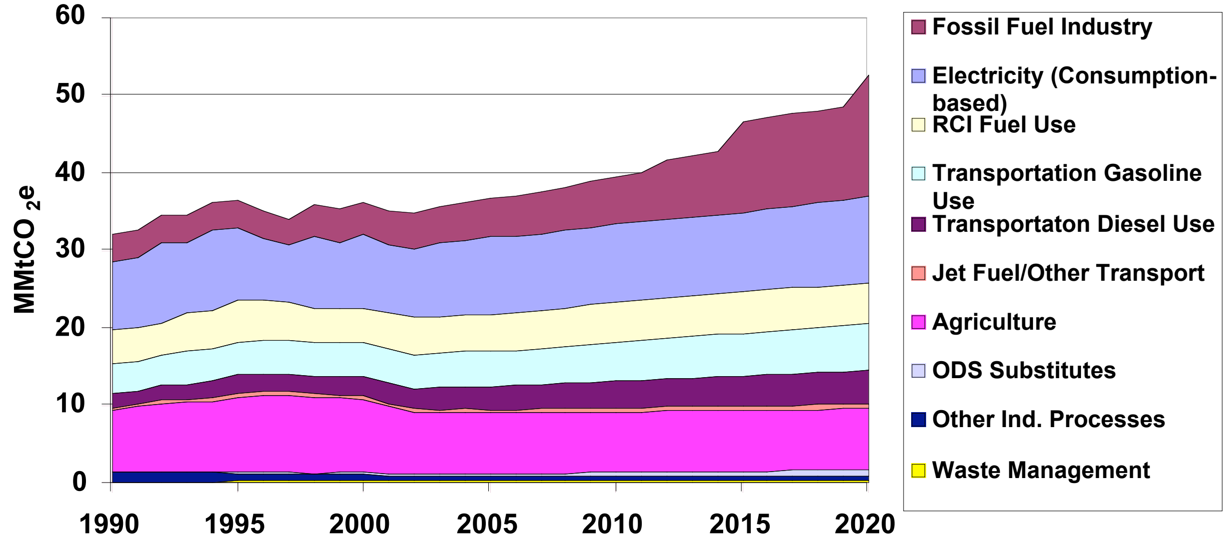
Table 2-3
Comparison of total fossil fuel industry GHG emissions for reference and high fossil fuel scenario

(Million Metric Tons CO_2e)	1990	2000	2005	2010	2015	2020
Fossil Fuel Industry						
Reference Case	**3.5**	**4.1**	**5.0**	**5.2**	**5.3**	**5.3**
Natural Gas Industry	1.4	1.7	2.0	2.3	2.3	2.4
Oil Industry	2.0	2.2	2.7	2.8	2.8	2.8
Coal Mining	0.2	0.2	0.2	0.2	0.2	0.2
Coal-to-Liquids	0.0	0.0	0.0	0.0	0.0	0.0
High Fossil Fuel Scenario	**3.5**	**4.1**	**5.0**	**6.2**	**11.7**	**15.7**
Natural Gas Industry	1.4	1.7	2.1	2.9	3.4	3.6
Oil Industry	2.0	2.2	2.7	3.1	4.4	4.4
Coal Mining	0.2	0.2	0.2	0.2	0.2	0.3
Coal-to-Liquids	0.0	0.0	0.0	0.0	3.7	7.3

Figure 2-5 illustrates the Montana gross GHG emissions under the high fossil fuel scenario assumptions. In this case, gross GHG emissions are projected to grow to 52 MMtCO_2e by 2020, 61% above 1990 levels.

Figure 2-5

Montana gross GHG emissions by sector, 1990-2020: historical and projected under high fossil fuel scenario assumptions



Key Uncertainties

Some data uncertainties exist in this inventory, and particularly in the reference case projections. Potential improvements to this work include developing a better understanding of the electricity generation sources currently used to meet Montana loads (in collaboration with state utilities), and review and revision of key drivers such as the electricity and transportation fuel use growth rates that will be major determinants of Montana's future GHG emissions (See Table 2-4). These growth rates are driven by uncertain economic, demographic, and land use trends (including growth patterns and transportation system impacts), all of which could be refined further.

Perhaps the variable with the most important implications for GHG emissions is the type and number of power plants built in Montana between now and 2020. The assumptions related to vehicle miles traveled (VMT) and air travel growth also have large impacts on the GHG emission growth in the state. Finally, uncertainty remains on estimates for historic GHG sinks from forestry and agriculture, and projections for these emissions will greatly impact the net GHG emissions attributed to Montana.

Table 2-4
Key annual growth rates for Montana, historical and projected

	1990-2005	2005-2020	Sources
Population	1.0%	0.6%	U.S. Bureau of Census
Employment			Montana Department of Labor website, based on analysis by the US Bureau of labor and Statistics
Goods	2.5%	0.9%	
Services	2.3%	1.7%	
Electricity Sales	0.0%	1.6%	EIA data for 1990-2004 (0% growth is mix of increased residential and commercial electricity sales countered by large decrease in industrial sales), projections based on plans from Montana utilities (all sectors projected to have increased sales)
Vehicle Miles Traveled	1.7%	1.9%	Federal Highway Administration, Highway Statistic; projections from Montana Department of Transportation

* Population and employment projections for Montana were used together with US DOE's Annual Energy Outlook 2006 projections of changes in fuel use on a per capita and per employee, as relevant for each sector. For instance, growth in Montana's residential natural gas use is calculated as the Montana population growth times the change in per capita natural gas use for the Mountain region. Montana population growth is also used as the driver of growth in cement production, soda ash consumption, dolomite and limestone use.