5

Projected Greenhouse Gas Emissions

This chapter is concerned mostly with business-as-usual greenhouse gas (GHG) emission projections, but it begins with a description of the Obama administration's goals to reduce GHGs from that trajectory.

ADMINISTRATION POLICY AND GOALS

The Obama administration supports the implementation of a market-based cap-and-trade program to spur growth in the low-carbon economy and reduce GHG emissions to 83 percent below 2005 levels by 2050 (Figure 5-1). Since taking office in January 2009, the Obama administration has made investments in low-carbon and renewable technologies a priority, including through the American Recovery and Reinvestment Act of 2009 (ARRA).[1] The administration has also worked to reduce GHGs through robust actions by the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and other executive agencies. While ARRA and the actions of these agencies will result in significant emission reductions, the projections in this chapter show that GHG emissions will gradually increase in the long term without additional measures, such as a cap-and-trade program.

In June 2009, the U.S. House of Representatives passed the American Clean Energy and Security Act, which includes economy-wide GHG reduction goals of 3 percent below 2005 levels in 2012, 17 percent below 2005 levels in 2020, and 83 percent below 2005 levels in 2050. Through a cap-and-trade program and other complementary measures, the bill would promote the development and deployment of new clean

[1]For the complete bill text, see http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=111_cong_bills&docid=f:h1enr.pdf.

energy technologies that would fundamentally change the way we produce, deliver, and use energy.

The bill would: (1) advance energy efficiency and reduce reliance on oil; (2) stimulate innovation in clean coal technology to sequester GHG emissions before they enter the atmosphere; (3) accelerate the use of renewable sources of energy, including biomass, wind, solar, and geothermal; (4) create strong market demand in the long run for these next-generation technologies, which will result in increased domestic manufacturing and enable American workers to play a central role in U.S. clean energy transformation; and (5) play a critical role in the American economic recovery and job growth—from retooling shuttered manufacturing plants to make wind turbines, to using equipment and expertise in drilling for oil to develop clean energy from underground geothermal sources, to tapping into American ingenuity to engineer coal-fired power plants that do not contribute to climate change.

In early 2010, the Senate was considering its own legislation, with similarly bold targets, to promote clean energy and reduce GHG emissions. If the Senate and House pass bills, a conference committee will be convened to resolve disagreements and negotiate a compromise bill for consideration in both legislative bodies.

In December 2009, at the Fifteenth Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC), as part of a Copenhagen Accord involving GHG mitigation contributions by developed and key developing countries, the Obama administration proposed a U.S. GHG emissions reduction target in the range of 17 percent below 2005 levels by 2020 and approximately 83 percent below 2005 levels by 2050, ultimately aligned with final U.S. legislation.

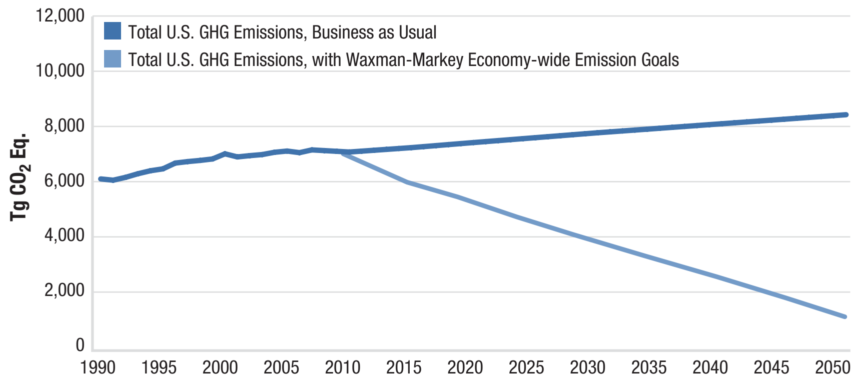
CHAPTER OVERVIEW

This chapter provides business-as-usual projections of U.S. GHG emissions through 2020 and beyond. These projections reflect national estimates considering population growth, long-term economic growth potential, and historical rates of technology improvement, and the projections are consistent with historic average weather. The projections are based on anticipated trends in technology deployment and adoption, demand-side efficiency gains, fuel switching, and many of the implemented policies and measures discussed in Chapter 4.[2]

Despite the recent global economic turmoil, the U.S. economy is expected to recover and emissions are expected to grow in the long term in a business-as-usual case. Even with projected growth in absolute emissions, emissions per unit of gross domestic product are expected to decline.

Figure 5-1 Projected U.S. GHG Emissions Meeting Recently Proposed Goals Versus Business as Usual

By 2050, the Obama administration's goal is to reduce U.S. greenhouse gas emissions approximately by 83 percent from 2005 levels, in the same range as legislation passed by the U.S. Congress.



Source: U.S. EPA 2009. The historical data are derived from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007*; the baseline scenario is from EPA's ADAGE (Applied Dynamic Analysis of the Global Economy) model; and the decreasing emissions line includes the Waxman-Markey goals for 2012, 2020, 2030, and 2050, with intervening years interpolated.

Projections are provided by gas and by sector. In keeping with the reporting guidelines of the UNFCCC, gases included in this report are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). CO_2 emissions are reported for the following sectors: electric power generation and residential, commercial, industrial, and transportation end use.

Proposed or planned policies that had not been implemented as of March 31, 2009, as well as sections of existing legislation that require implementing regulations or funds that have not been appropriated, are not included in the projections. The projections include provisions from ARRA, but do not include, for example, the vehicle fuel economy and emission standards announced by the President in May 2009 and finalized in 2010.[3]

U.S. GREENHOUSE GAS EMISSIONS: 2000–2020

Trends in Total Greenhouse Gases

DOE's Energy Information Administration (EIA) April 2009 update of the *Annual Energy Outlook 2009* (AEO 2009) provides a baseline projection of energy-related CO_2 emissions out to 2030, and reflects the provisions of ARRA, enacted in mid-February 2009 (U.S. DOE/EIA 2009h). Projected CO_2 emissions in the AEO 2009 are adjusted to match the international inventory convention.[4] EPA prepared the projections of non-energy-related CO_2 emissions and non-CO_2 emissions. Non-CO_2 emission projections are based on the report *Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990–2020* (U.S. EPA/OAP 2006b). The U.S. Department of Agriculture prepared the estimates of carbon sequestration. Historical

[2] Because Chapter 5 projections and Chapter 4 mitigation effects of policies and measures are calculated using different methodologies, estimates of the total effect of policies and measures derived from each chapter are not directly comparable.

[3] For the full text of the announcement, see http://www.whitehouse.gov/the_press_office/Remarks-by-the-President-on-national-fuel-efficiency-standards/.

[4] The AEO 2009 estimate for bunker fuels was subtracted and replaced with an EPA estimate that reflects a broader definition of bunker fuels consistent with the international inventory convention. The AEO 2009 estimate of non-energy CO_2 emissions was replaced by an EPA estimate of non-energy CO_2 emissions from fuel use and all other non-energy CO_2 emissions (e.g., industrial processes). This is consistent with previous *U.S. Climate Action Reports*. An estimate of CO_2 emissions in the U.S. territories was added to the AEO 2009 number, since these emissions are not included in the AEO.

emissions data are drawn from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2007* (U.S. EPA/OAP 2009). In general, the projections reflect long-run trends and do not attempt to consider short-run departures from those trends, with the exception that EIA explicitly models the current recession in its 2010 CO_2 emissions projection.

All GHGs in this chapter are reported in teragrams of CO_2 equivalents (Tg CO_2 Eq.), in keeping with the reporting guidelines of the UNFCCC. The conversions of non-CO_2 gases to CO_2 equivalents are based on the 100-year global warming potentials listed in the Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 1996).

Inventory totals of GHG emissions for 2000, 2005, and 2007 and projections for 2010, 2015, and 2020 are shown in Table 5-1. From 2005 to 2020, total GHG emissions in the baseline are projected to increase by 4 percent, from 7,109 Tg CO_2 Eq. to 7,416 Tg CO_2 Eq., while the U.S. gross domestic product is projected to grow by 40 percent (US DOE/EIA 2009a).

Given the implementation of programs and measures in place as of spring 2009 and current economic projections, total gross U.S. GHG emissions are expected to drop slightly below 2005 emissions in the short term, but will rise steadily in the long term as population and total economic activity grow. Increased demand for energy services will be offset in part by shifts toward less energy-intensive industries, efficiency improvements, and increased use of renewable energy technologies and other less carbon-intensive energy fuels. More rapid improvements in technologies that emit fewer GHGs, new GHG mitigation requirements, or more rapid adoption of voluntary GHG emission reduction programs could result in lower GHG emission levels than in the baseline projection (U.S. DOE/EIA 2009a, 2009b).

Between 2005 and 2020, CO_2 emissions in the baseline projection are estimated to increase by 1.5 percent. Over the same period, CH_4, N_2O, and PFC emissions are expected to grow by 8 percent, 5 percent, and 4 percent, respectively. A large portion of emissions growth is driven by HFCs, which are projected to more than double between 2005 and 2020, as they are more extensively used as a substitute for ozone-depleting substances. Slow growth in CO_2 emissions is driven by a combination of policies implemented to increase efficiency and the use of renewable energy, as well as increasing energy prices and economic projections that are lower than those estimated in the 2006 *U.S. Climate Action Report* (2006 CAR). Some non-CO_2 emission sources are less affected by short-term economic disruptions than CO_2 emission sources. For example, CH_4 emissions from landfills are a result of waste deposited over a long period of time, as opposed to sources based only on current economic activity.

Carbon Dioxide Emissions

Energy-related CO_2 emission estimates are taken from EIA's AEO 2009, but are adjusted to match interna-

Table 5-1 **Historical and Projected U.S. Greenhouse Gas Emissions from All Sources: 2000–2020** (Tg CO_2 Eq.)

Between 2005 and 2020, total gross U.S. greenhouse gas emissions are expected to grow by 4 percent, while U.S. gross domestic product is expected to increase by 40 percent. Energy-related CO_2 emissions are expected to grow by 1.5 percent, reflecting the development and deployment of clean energy technologies, while non-CO_2 emissions growth will be driven by the shift from gases regulated under the *Montreal Protocol* to hydrofluorocarbons.

Greenhouse Gases	Historical GHG Emissions			Projected GHG Emissions		
	2000[1]	2005[1]	2007[1]	2010	2015	2020
Energy-Related Carbon Dioxide[2]	5,562	5,724	5,736	5,633	5,721	5,813
Non-energy Carbon Dioxide[3]	394	368	368	368	368	368
Methane[4]	591	562	585	590	593	605
Nitrous Oxide[4]	329	316	312	314	322	332
Hydrofluorocarbons[4]	100	116	126	147	209	279
Perfluorocarbons[4]	14	6	8	7	7	6
Sulfur Hexafluoride[4]	19	18	17	15	13	13
International Bunker Fuels (not included in totals)	100	113	110	109	108	107
U.S. Territories	36	53	51	63	74	86
Total Gross Emissions	**7,008**	**7,109**	**7,150**	**7,074**	**7,233**	**7,416**
Net Sequestration Removals[5]	–718	–1,123	–1,063	–1,238	–1,218	–1,210
Total Net Emissions	**6,291**	**5,986**	**6,088**	**5,836**	**6,014**	**6,206**

[1] Historical emissions and sinks data are from U.S. EPA/OAP 2009. Bunker fuels and biomass combustion are not included in inventory calculations.

[2] Energy-related CO_2 projections are calculated from U.S. DOE/EIA 2009h, with adjustments made to remove any non-energy CO_2.

[3] Non-energy CO_2 includes emissions from non-energy fuel use and industrial processes.

[4] Non-CO_2 emission projections are based on US EPA/OAP 2006b, adjusted to 2007 inventory emissions.

[5] Details on disaggregated historical and projected sequestration data can be found in Table 5-3.

Note: Totals may not sum due to independent rounding.

tional inventory convention, as described later in this chapter. AEO 2009 presents projections and analysis of U.S. energy supply, demand, and prices through 2030, based on results from EIA's National Energy Modeling System. The projections in AEO 2009 look beyond current economic and financial turmoil and focus on factors that drive U.S. energy markets in the longer term. Key issues highlighted in AEO 2009 include higher but uncertain world oil prices, growing concern about GHG emissions and their impacts on energy investment decisions, the increasing use of renewable fuels, the expanding production of unconventional natural gas, the shift in the transportation fleet to more efficient vehicles, and improved efficiency in end-use appliances (U.S. DOE/EIA 2009a, 2009b).

Energy-related CO_2 emissions are projected to grow by 0.1 percent per year from 2005 to 2020, as compared with 1.3 percent per year from 1990 to 2005. The growth rate between 2005 and 2020 is moderated by the impact of the current recession in the United States. In 2020, energy-related CO_2 emissions are projected to total 5,813 Tg CO_2, about 1.5 percent higher than in 2005 (U.S. DOE/EIA 2009h).

Non-energy sources of CO_2 emissions include feedstock use of energy fuels in manufacturing, natural gas production and processing, the cement industry, and waste handling and combustion. As U.S. firms voluntarily adopt recapture technologies and other mitigation practices, these emissions will slow in growth and even decline in some sectors. Because the underlying sources are so varied, no single driver of projections is available. Therefore, the estimates presented here are historical extrapolations from the U.S. GHG inventory trends (U.S. EPA/OAP 2009). Emissions from these sources are expected to remain approximately constant, as some sources have historically increased and others have decreased, at 368 Tg CO_2 Eq. in 2005 and 2020.

Non-Carbon Dioxide Emissions

Emissions other than CO_2 currently represent about 15 percent of U.S. GHG emissions. Non-CO_2 GHG emissions include CH_4 emissions from natural gas production and transmission, coal mine operations, landfills, and livestock operations; N_2O emissions from agriculture and, to a lesser degree, transportation; and HFCs, PFCs, and SF_6 gases from industrial activities including, in some cases, the life cycles of the resulting products (Table 5-2).

Non-CO_2 emission projections are based on EPA's *Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990–2020* (U.S. EPA/OAP 2006b). Projections in this report are based on a combination of trends in historical emissions and source-specific modeling. These projections have been adjusted to align with the most recent U.S. GHG emissions inventory (U.S. EPA/OAP 2009). EPA is currently updating its non-CO_2 emission projections, but the results were not available in time for this report. In some cases, non-CO_2 emissions can be less sensitive to short-term economic disruptions than energy-related CO_2 emissions. For example, CH_4 emissions from landfills result from waste deposited over a long period of time.

Methane Emissions

Between 2005 and 2020, total CH_4 emissions are estimated to increase by about 8 percent as underlying economic activity increases over the projection period, with fugitive emissions from increased natural gas production the largest influence. However, these increases are expected to be mitigated by greater control of CH_4 emissions from landfills, coal mines, and manure through increased flaring, recovery, and use. CH_4 capture-and-use projects are driven in part by the prices of electricity and natural gas, which increase over the projection period.

Nitrous Oxide Emissions

N_2O emissions are estimated to rise from 316 Tg CO_2 Eq. in 2005 to 332 Tg CO_2 Eq. in 2020—an increase of 5 percent. Emissions from agriculture, the largest

Table 5-2 **U.S. Non-CO_2 Emissions by Source and Gas** (Tg CO_2 Eq.)

Emissions other than CO_2 include methane from agriculture, landfills, and natural gas production; nitrous oxide from agriculture; and HFCs, PFCs, and SF_6 from industrial production. Of these, HFCs are expected to grow the fastest due to the ongoing CFC and HCFC phaseout and replacement with HFCs.

Gases and Sources	2005	2010	2015	2020
Methane (CH_4)	**562**	**590**	**593**	**605**
Agriculture CH_4	186	192	189	189
Landfills	128	130	128	128
Natural Gas	106	113	125	138
Coal Mines	63	61	56	56
Other	79	95	94	95
Nitrous Oxide (N_2O)	**316**	**314**	**322**	**332**
Agriculture N_2O	225	227	232	237
Mobile Combustion	37	26	26	28
Nitric and Adipic Acid Production	25	29	30	32
Other	29	32	33	34
Hydrofluorocarbons (HFCs)	**116**	**147**	**209**	**279**
ODS Substitutes (HFCs)	100	135	198	268
HCFC-22 (HFC-23)	16	12	11	11
Semiconductors	0.2	0.3	0.2	0.2
Perfluorocarbons (PFCs)	**6**	**7**	**7**	**6**
Aluminum	3	4	4	4
Semiconductors	3	4	3	3
Sulfur Hexafluoride (SF_6)	**18**	**15**	**13**	**13**
Electrical Transmission and Distribution	14	12	12	11
Magnesium	3	2	1	1
Semiconductors	1	1	1	1

CFCs = chlorofluorocarbons; ODS = ozone-depleting substance; HCFCs = hydrochlorofluorocarbons.

Note: Totals may not sum due to independent rounding.

source of N_2O emissions, are estimated to increase from 225 Tg CO_2 Eq. in 2005 to 237 Tg CO_2 Eq. in 2020. In contrast, N_2O emissions from transportation are estimated to decrease over the same time period due to improvements in vehicle emission control technologies.

HFCs, PFCs, and SF_6 Emissions

HFC emissions are estimated to increase by more than 140 percent between 2005 and 2020, from 116 Tg CO_2 Eq. to 279 Tg CO_2 Eq. Over the same period, PFC emissions are estimated to remain flat, and SF_6 emissions are estimated to decline somewhat through increased voluntary control.

HFC emissions are increasing because demand for refrigeration and air conditioning is increasing and because HFCs are predominantly used as alternatives for ozone-depleting substances, such as the hydrochlorofluorocarbons (HCFCs) that are being phased out under the *Montreal Protocol on Substances That Deplete the Ozone Layer*. Both HFCs and HCFCs are GHGs, but HCFCs are not included here consistent with UNFCCC guidelines. Growth of HFCs is anticipated to continue well beyond 2020 if left unconstrained. Other sources of HFCs, PFCs, and SF_6 in industrial production include aluminum, magnesium, and semiconductor manufacturing and, in the case of SF_6, electricity transmission and distribution. These projections assume that voluntary emission reduction goals set by these industries will be met by implementing process improvements and emission control technologies.

Bunker Fuels

Bunker fuels consist of jet fuel, residual fuel oil, and distillate fuel oil used for international aviation and marine transport. Between 1990 and 2007, CO_2 emissions from bunker fuels declined by 5 percent from 114 million metric tons of carbon dioxide ($MMTCO_2$) to 109 $MMTCO_2$. Although emissions from international flights departing the United States have increased by 14 percent, emissions from international shipping voyages have decreased by 18 percent. The projection in Table 5-1 extends the annual rate of decline (from 1990 to 2007) through 2020 (U.S. EPA/OAP 2006b).

Sequestration

Forests and agricultural soils sequester a large amount of CO_2 from the atmosphere. In 2007, American forests and soils sequestered approximately 1,063 Tg CO_2 Eq., or 15 percent of total gross U.S. GHG emissions (U.S. EPA/OAP 2009). This net removal of atmospheric CO_2 is largely the result of careful land-use decisions in the forestry and agriculture sectors, including afforestation, reforestation, forest management techniques, and increased adoption of reduced-tillage practices in agriculture. The continuation and increased adoption of such practices are expected to increase net carbon sequestration within the next decade.

Net sequestration estimated in this report is –1,210 Tg CO_2 Eq. in 2020 (specific data on sequestration for each significant sink can be found in Table 5-3). Net forest land area in the United States is expected to decline by 2 percent from 2002 to 2030 (Haynes et al. 2007), largely due to conversion to urban forest and developed areas.[5] Given this low rate of projected change in U.S. forest land area, the projected increase in net forest carbon uptake is largely due to expected changes in management practices (including intensification), afforestation/reforestation, and increased adoption of sustainable forestry practices.

Intensified management of forests can lead to an increased rate of growth, which will increase the uptake of carbon. Though harvesting on forest land removes much of the above-ground carbon, there is a positive growth-to-harvest ratio in U.S. forests, meaning that more carbon is accruing than is being harvested. Because most of the timber harvested from U.S. forests is stored in wood products or disposed of in solid waste disposal facilities, significant quantities of carbon in harvested wood are stored rather than released. The reversion of cropland to forest land also increases carbon in biomass.

In the agricultural sector, changes in agricultural soil management can lead to increases in carbon sequestration. Much of the carbon accumulation that has occurred in cropped soils in the United States over the last 20 years is attributable to the Conservation Reserve Program (see Chapter 4) and land-use conversions from annual crops to perennial hay and grazing land (USDA 2008). Changes in other soil management practices have also contributed to the higher carbon stock in U.S. agricultural soils and are projected to continue through 2020 (Table 5-3). These practices include increased use of conservation tillage (particularly no-till), reduced frequency of summer fallow, and increased application of manure to cropland and pasture.

Adjustments

Adjustments, primarily to the energy-related CO_2 emissions reported in this chapter, were made to more closely adhere to UNFCCC guidelines. Emissions in U.S. territories, predominantly fuel-related, were added, and the military and civilian international use of bunker fuels was subtracted from the totals and is reported separately. Emissions from fuel use in U.S. territories are projected to increase from 53 Tg CO_2 Eq. to 86 Tg CO_2 Eq. in 2020, based on extrapolation of historical trends. Emissions from international bunker fuels will decrease from 113 Tg CO_2 Eq. in 2005 to 107 Tg CO_2 Eq. in 2020 based on extrapolation of historical trends.

[5] Updated projections for urban forest land are expected in the upcoming U.S. Forest Service 2010 Resources Planning Act (RPA) Assessment. See http://www.fs.fed.us/research/rpa/.

Sectoral Carbon Dioxide Emissions

Electric Power CO_2 Emissions

The largest share of U.S. energy-related CO_2 emissions comes from electricity generation, currently about one-third of U.S. GHG emissions. CO_2 emissions are projected to increase by approximately 4 percent from 2005 to 2020, or from 2,381 Tg CO_2 to 2,466 Tg CO_2 (Table 5-4). Of the CO_2 emissions attributable to the electricity consumed in each economic sector, most of the increase can be attributed to the residential and commercial sectors; emissions attributable to the industrial sector are expected to decrease during that time (Table 5-5).

The combination of recently enacted energy policies, such as energy efficiency measures and renewable energy incentives, and rising energy prices slows the growth in U.S. consumption of primary energy relative to historical trends. Further, when slower demand growth is combined with increased use of renewable energy technologies and fewer additions of new coal-fired conventional power plants, growth in CO_2 emissions due to electricity generation also is slowed relative to historical experience. The share of electricity generation that comes from fossil fuels—primarily, coal and natural gas—is expected to decline, and the share from renewables is expected to increase from 8 percent in 2005 to 15 percent in 2020.

Although a comprehensive federal policy has yet to be enacted to address climate change, growing concerns about GHG emissions appear to be affecting investment decisions in the electricity sector. In the United States, potential regulatory policies to address climate change are in various stages of development at the state, regional, and federal levels. In addition to ongoing uncertainty with respect to future demand growth

Table 5-3 **Projections of Net Carbon Sequestration Uptake** (Tg CO_2 Eq.)

Increases in carbon sequestration from forests will lead to an overall increase in sequestration from today's levels by 2020.

Sources of Sequestration	2000[1]	2005[1]	2007[1]	2010	2015	2020
Forests[2]	400	872	810	976	947	928
Wood Products[3]	113	104	100	104	105	109
Urban Forests[4]	82	93	98	104	115	126
Agricultural Soils[4]	111	44	45	44	42	39
Other[4,5]	11	10	10	10	9	8
Total Sequestration	**718**	**1,123**	**1,063**	**1,238**	**1,218**	**1,210**

[1] Historical values are from U.S. EPA/OAP 2009.

[2] Estimates include carbon in above-ground and below-ground biomass, dead wood, litter, and forest soils. Projections reflect adjustments to the historical value for 2005. Forest carbon stocks are calculated by the FORCARB2 model (Smith and Heath 2004), based on forest areas and volumes from the base case U.S. Forest Service 2005 *RPA Timber Assessment Update* (Haynes et al. 2007). Emissions from forest fires are implicitly included in these estimates. Historical climate is assumed in the base projection.

[3] Estimates are composed of changes in carbon held in wood products in use and in landfills, including carbon from domestically harvested wood and exported wood products (Production Accounting Approach). Projections are made using the Woodcarb II model (Skog 2008), based on base case projections of forest products production and trade from Haynes et al. 2007.

[4] Projections are estimated from historical trends.

[5] "Other" category includes landfilled yard trimmings and food scraps.

Note: Projections reflect average annual values over each period ending with the labeled year. Totals may not sum due to independent rounding.

Table 5-4 **Electricity Generation and Greenhouse Gas Emissions**

The electricity sector will experience an accelerating shift toward renewable generation through 2020.

Sources of Electricity	2005		2010		2015		2020[5]	
	Emissions (Tg CO_2 Eq.)	Generation (billion kWh)	Emissions (Tg CO_2 Eq.)	Generation (billion kWh)	Emissions (Tg CO_2 Eq.)	Generation (billion kWh)	Emissions (Tg CO_2 Eq.)	Generation (billion kWh)
Fossil Fuels[1,2]	**2,381**	**2,793**	**2,342**	**2,756**	**2,382**	**2,717**	**2,466**	**2,832**
Petroleum	102	116	47	52	38	43	40	45
Natural Gas	320	684	322	700	261	561	285	620
Coal	1,958	1,992	1,962	2,003	2,071	2,113	2,129	2,166
Other[3,4]	0.4	1	12	1	12	1	12	1
Non-Fossil Fuels	**0**	**1,102**	**0**	**1,240**	**0**	**1,423**	**0**	**1,512**
Nuclear	0	782	0	809	0	831	0	876
Renewable	0	320	0	431	0	592	0	636
Non-Fossil % Share Generation	**28%**		**31%**		**34%**		**35%**	
Total Fossil and Non-Fossil Fuel Generation	**3,896**		**3,996**		**4,141**		**4,344**	

[1] Historical emissions are from U.S. EPA/OAP 2009, and historical generation data are from U.S. DOE/EIA 2009b, Table 8.2.

[2] Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

[3] Other fossil fuel emissions include emissions from geothermal power and nonbiogenic emissions from municipal waste.

[4] Due to slight differences in categories between the EPA inventory and EIA projections, the "other" category in the historical inventory is not directly comparable to the "other" category in the projections.

[5] 2020 projections are from U.S. DOE/EIA 2009h.

kWh = kilowatt-hour; Tg CO_2 Eq. = teragrams of carbon dioxide equivalents.

Note: Totals may not sum due to independent rounding.

Table 5-5 **U.S. Energy-Related CO_2 Emissions by Sector and Source[1]** (Tg CO_2 Eq.)

Electricity generation accounts for the largest share—about one-third—of U.S. energy-related CO_2 emissions. In 2020, energy-related CO_2 emissions are projected to total 5,813 Tg CO_2, about 2 percent higher than in 2005.

Sectors and Sources	2005[2]	2010	2015	2020
Electric Power	**2,381**	**2,342**	**2,382**	**2,466**
Petroleum	102	47	38	40
Natural Gas	320	322	261	285
Coal	1,958	1,962	2,071	2,129
Other	0.4	12	12	12
Transportation[3]	**1,882**	**1,835**	**1,858**	**1,853**
Petroleum	1,848	1,800	1,823	1,817
Natural Gas	33	35	35	36
Electricity	5	4	5	6
Industrial[3]	**828**	**805**	**839**	**840**
Petroleum	330	336	326	321
Natural Gas	382	370	389	387
Coal	116	99	124	132
Electricity	731	580	607	610
Residential[3]	**358**	**363**	**346**	**344**
Petroleum	95	93	83	78
Natural Gas	262	268	262	265
Coal	1	1	1	1
Electricity	849	879	855	882
Commercial[3]	**222**	**225**	**223**	**224**
Petroleum	50	45	42	41
Natural Gas	163	173	174	176
Coal	9	6	6	6
Electricity	797	879	916	968
U.S. Territories	**53**	**63**	**74**	**86**

[1] U.S. DOE/EIA 2009h, with adjustments for bunker fuels, non-energy CO_2 emissions, and U.S. territories.

[2] Historical emissions data are from U.S. EPA/OAP 2009.

[3] Sector total emissions do not include indirect emissions from electricity usage.

Note: Totals may not sum due to independent rounding.

and the costs of fuel, labor, and new plant construction, it appears that capacity planning decisions for new generating plants are already being affected by the potential impacts of policy changes that could limit or reduce GHG emissions.

This concern is recognized in the electric sector projections by adding a 3 percent premium on investment in carbon-intensive electric generation sources, leading to limited additions of new coal-fired capacity. Much less new coal capacity is projected in this report than in recent years (U.S. DOE/EIA 2009). Renewable generation is expected to be about half of cumulative new capacity additions through 2020, and is the largest source of new capacity additions. Key federal tax credits and a new loan guarantee program in ARRA are expected to lead to a significant expansion of renewable energy generation compared with a case without ARRA.

As a result of these factors, while electricity generation is projected to increase by 0.7 percent per year from 2005 to 2020, CO_2 emissions from electricity generation will increase by only 0.2 percent per year.

Residential CO_2 Emissions

Energy-related CO_2 emissions from the residential sector are estimated to increase by about 1.5 percent between 2005 and 2020, including indirect emissions from electricity. U.S. energy use will grow more slowly than the U.S. population because of investments in energy efficiency, including those spurred by ARRA. Emissions from electricity should increase over the projection period, while emissions from combustion of natural gas should decrease. Since population is expanding faster in the warmer climates of the West and South, less natural gas will be used for heating and more electricity will be necessary for cooling.

Commercial CO_2 Emissions

Commercial floorspace is expected to continue to expand, following trends in economic and population growth. Improvements in efficiency can only partly offset increases in emissions from the commercial sector. Increased disposable income will continue to lead to growth in commercial floorspace in hotels, restaurants, stores, and theaters. Growth in natural gas use, predominantly for heating, will be slower than growth in electricity use because of the more rapid growth in the South and West, where heating represents a smaller share of energy use.

Industrial CO_2 Emissions

Energy-related CO_2 emissions from the industrial sector are expected to grow slowly, from 828 Tg CO_2 in 2005 to 840 Tg CO_2 in 2020. Production from energy-intensive manufacturing industries will grow more slowly than the sector average, partly accounting for the slow growth in overall emissions. Including indirect emissions from electricity, industrial emissions are expected to decline by approximately 7 percent by 2020.

Transportation CO_2 Emissions

Transportation-related CO_2 emissions are the second-largest source of U.S. emissions. As with other energy-related sources of CO_2 emissions, transportation CO_2 emission projections for this report are based on EIA's April 2009 update of AEO 2009, and adjusted to match international inventory convention (U.S. DOE/EIA 2009a). Future emissions in the transportation sector will be impacted by a number of factors.

As shown in Table 5-6, AEO 2009 projects that slower growth in income per capita and higher fuel costs will reduce the growth of personal travel, slowing the growth in demand for both highway and aviation fuels. AEO 2009 also projects that emissions from heavy-duty vehicles will grow more rapidly than light-duty vehicles as a result of increases in commercial activity (U.S. DOE/EIA 2009h). While not included in AEO 2009, future regulatory efforts, including the

[6] See http://www.epa.gov/otaq/climate/regulations.htm.

Table 5-6 **Comparison of the 2002, 2006, and 2010 CAR Assumptions and Model Results for 2020**

The 2010 *U.S. Climate Action Report* reflects assumptions of lower GDP growth and higher energy prices.

Factors	Assumptions for 2020		
	2002 CAR	2006 CAR	2010 CAR
Real GDP (billion chain-weighted 2000 dollars)[1]			
Reported	18,136	17,541	15,398
Corrected	17,688	17,541	15,398
Population (millions)	325	337	343
Energy Intensity (Btu per 2000 chain-weighted dollar of GDP)[2]			
Reported	8,712	6,877	6,798
Corrected	7,398	6,877	6,798
Light-Duty Vehicle Miles Traveled (billion miles)	3,631	3,474	3,137
Refiners' Acquisition Cost of Imported Crude Oil (2000 dollars/barrel)	24.68	41.24	95.56
Wellhead Natural Gas Price (2000 dollars/thousand cubic feet)	3.26	4.49	5.67
Minemouth Coal Price (2000 dollars/short ton)	12.79	18.52	22.85
Average Electricity Price (2000 cents/kWh)	6.5	6.6	7.7
All Sector Motor Gasoline Price (2000 dollars/gallon)	1.40	1.90	3.02
Energy Consumption (quadrillion Btus)	131	121	105

[1] A table in the 2006 CAR reported that the real GDP, as reported in the 2002 CAR, was $18,136 billion in 2000 dollars (while not reported as chain-weighted these are chain-weighted dollars). This appears to be an incorrect conversion from $15,525 billion chain-weighted 1996 dollars as originally reported in the 2002 CAR. Using the deflator from the *2002 Annual Energy Outlook* (U.S. DOE/EIA 2002) for consistency, it should have been only $17,688 billion chain-weighted 2000 dollars.

[2] Energy intensity, which is total energy consumption divided by real GDP, was reported as 7,920 Btu per 1996 dollar of GDP in the original 2002 CAR. In the 2006 CAR, energy intensity for the 2002 CAR was reported as 8,712 Btu per 2000 dollar of GDP. Using a corrected real GDP, energy intensity in the 2002 CAR should be 7,398 Btu per chain-weighted 2000 dollar of GDP.

Btus = British thermal units; CAR = U.S. Climate Action Report; GDP = gross domestic product; kWh = kilowatt-hour.

Sources: U.S. DOE/EIA 2002, 2009h.

GHG tailpipe standards proposed on September 28, 2009,[6] will bring about additional reductions in future GHG emissions.

ASSUMPTIONS USED TO ESTIMATE FUTURE GHG EMISSIONS

Changes Between the 2006 CAR and the 2010 CAR, Including the Effects of New Policies and Measures

GHG emissions under the "with measures" case presented in this report are significantly lower than emission estimates in the 2006 CAR. These differences can be traced to a combination of changes in policies, energy prices, and economic growth. In the 2006 CAR, emissions increased by 19 percent from the reported 2000 levels, versus a 5.6 percent increase from 2000 levels by 2020 (4 percent from 2005 to 2020) in this 2010 CAR.

Current estimates of energy-related CO_2 emissions include the effects of a number of policies that have been implemented since the analysis was completed for the 2006 CAR. These policies include ARRA and the Energy Independence and Security Act of 2007. They also include various state vehicle technology programs and renewable portfolio standards that have been implemented since 2006 and the Regional Greenhouse Gas Initiative in the northeastern and Mid-Atlantic United States. In addition, anticipation of future limits on GHG emissions has already shifted business practices. Analysis of the changes in energy-related CO_2 emission projections between the 2006 CAR and the 2010 CAR shows that about half of them are due to the influence of newly implemented or anticipated public policies, equivalent to about 500 Tg CO_2 in 2020.

Changes in long-term economic growth estimates and energy prices account for the remaining changes in projected emissions between the 2006 CAR and the 2010 CAR. The macroeconomic projection used for this report estimates that the U.S. economy will grow by an average of 2.3 percent per year through 2020. This is a significant departure from the 3.0 percent projection in the 2006 CAR. The anticipated price of oil in 2020 has doubled along with significant increases in the anticipated prices of natural gas, coal, and electricity (U.S. DOE/EIA 2009).

Description of NEMS and Methodology

EIA's Office of Integrated Analysis and Forecasting developed and maintains the National Energy Modeling System (NEMS). The projections in NEMS are developed using a market-based approach to energy analysis. For each fuel and consuming sector, NEMS balances energy supply and demand, accounting for economic competition among the various energy fuels and sources. The time horizon of NEMS is 2005 through 2030, approximately 25 years into the future.

NEMS is organized and implemented as a modular system. The modules represent each of the fuel supply markets, conversion sectors, and end-use consumption sectors of the energy system. NEMS also includes macroeconomic and international modules. The primary flows of information among the modules are the delivered prices of energy to end users and the quantities consumed by product, region, and sector. The delivered fuel prices encompass all the activities necessary to produce, import, and transport fuels to end users. The information flows also include other data on such areas as economic activity, domestic production, and international petroleum supply.

Each NEMS component represents the impacts and costs of existing legislation and environmental regulations that affect that sector. NEMS accounts for all combustion-related CO_2 emissions, as well as emissions of sulfur dioxide, nitrogen oxides, and mercury from the electricity generation sector. The potential impacts of pending or proposed federal and state legislation, regulations, or standards—or of sections of legislation that have been enacted but that require funds or implementing regulations that have not been provided or specified—are not reflected in NEMS.

Table 5-6 shows the underlying assumptions and results in NEMS for the year 2020 and how they have changed from the 2002 and 2006 CARs.

Key Uncertainties Affecting Projected GHG Emissions

Any projection of future emissions is subject to considerable uncertainty. In the short term (less than five years), the key factors that can increase or decrease estimated net emissions include unexpected changes in retail energy prices, shifts in the competitive relationship between natural gas and coal in electricity generation markets, changes in economic growth, abnormal winter or summer temperatures, and imperfect projection methods. Additional factors may influence emission rates over the longer term, notably technology developments, shifts in the composition of economic activity, and changes in government policies. Finally, the indirect effects and interactions among some emission sources are not fully considered in the projections. For example, the indirect effects of increased biofuel production are not considered.

Technology Development

The projections of U.S. GHG emissions take into consideration likely improvements in technology over time. For example, technology-based energy efficiency gains, which have contributed to reductions in U.S. energy intensity for more than 30 years, are expected to continue. However, while long-term trends in technology are often predictable, the specific areas in which significant technology improvements will occur and the specific new technologies that will become dominant in commercial markets are highly uncertain, especially over the long term.

Unexpected scientific and technical breakthroughs can cause changes in economic activities with dramatic effects on patterns of energy production and use. Such breakthroughs could enable the United States to considerably reduce future GHG emissions. While U.S. government and private support of research and development efforts can accelerate the rate of technology change, the effect of such support on specific technology developments remains to be seen.

Regulatory or Statutory Changes

The current projections of U.S. GHG emissions do not include the effects of any legislative or regulatory action that was not finalized before March 31, 2009. Consequently, the projections do not include any increase in the stringency of equipment efficiency standards, even though existing law requires DOE to periodically strengthen its existing standards and issue new standards for other products. Similarly, the projections do not include the Obama administration's proposed goals of reducing U.S. GHG emissions by 17 percent below 2005 levels in 2020 and 83 percent in 2050. However, the GHG projections do reflect some of the uncertainty surrounding the adoption of national climate policy and, in particular, the decreased investment in new coal power capacity that results from this uncertainty.

Energy Prices

The relationship between energy prices and emissions is complex. Lower energy prices generally reduce the incentive for energy conservation and tend to encourage increased energy use and related emissions. However, a reduction in the price of natural gas relative to other fuels could encourage fuel switching that, in turn, could reduce carbon emissions. Alternatively, coal could become more competitive vis-à-vis natural gas, which could increase emissions from the power sector.

The energy-related CO_2 projections reflect a shift in oil market assumptions, with projected oil prices substantially higher than in previous analyses (U.S. DOE/EIA 2006, 2009a, 2009b). However, energy and oil price projections are subject to significant uncertainty. Decreases in delivered energy prices could result from increased competition in the electric utility sector or improved technology. On the other hand, energy price increases could result from the faster-than-expected depletion of oil and gas resources, from political or other disruptions in oil-producing countries, or from increases in oil demand abroad.

Economic Growth

Economic growth increases the future demand for energy services, such as vehicle miles traveled, amount of lighted and ventilated space, and process heat used in industrial production. However, growth also stimulates capital investment and reduces the average age of the capital stock, increasing its average energy efficiency. The energy-service demand and energy-efficiency effects of economic growth work in opposing directions. However, the effect on service demand is the stronger of the two, so that levels of primary energy use are positively correlated with the size of the economy. The economic growth data used for this report suggest that growth will be slower (2.3 percent per year) through 2020 than projected in the 2006 CAR (3.0 percent per year), which is expected to slow emissions growth.

Weather and Natural Occurrences

Energy use for heating and cooling is directly responsive to weather variation. In the EIA projection of CO_2 emissions, normal weather is defined by the average population-weighted number of heating and cooling degree-days for the most recent 10 years of historical data. Unlike other sources of uncertainty, for which deviations between assumed and actual trends may follow a persistent course over time, the effect of weather on energy use and emissions in any particular year is largely independent from year to year. For sequestration projections, historical climate and natural disturbances are assumed. For example, emissions from forest fires are implicitly included in the estimates for forest sequestration in Table 5-3. However, the extent to which climate change could exacerbate impacts on agriculture and forestry sinks—e.g., via increased pests, different degrees of dieback, and forest fire incidence—is not included in these estimates.

LONG-TERM GREENHOUSE GAS EMISSION PROJECTIONS TO 2050

The GHG emission projections in this chapter generally extend to 2020. EPA has also developed a number of modeling tools to evaluate long-term GHG mitigation policies, often extending to 2050. One of these models is the Applied Dynamic Analysis of the Global Economy (ADAGE) model. The focus of this model is policy analysis, but it includes long-term reference scenarios that are used as a basis to evaluate proposed policies.

Reference scenarios for long-term projections are based on the same data sources used for this report to the extent data are available. Energy-related CO_2 emission projections are based on EIA's AEO 2009 (U.S. DOE/EIA 2009h), and non-CO_2 emission projections are based on *Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions: 1990–2020* (U.S. EPA/OAP 2006b). Currently, the EPA models use the projections from the main release of AEO 2009 published in March 2009, which used slightly different economic projections and did not include ARRA. Sector definitions in ADAGE differ from those used for national inventory reporting. For these reasons, ADAGE long-term projections will not match those presented in other parts of this chapter. In addition, the sources for baseline projections used in this chapter do not extend to 2050, which required taking long-term projections from other sources. AEO 2009 extends to 2030, while the *Global Anthropogenic Non-CO_2 Greenhouse Gas Emissions* report extends to 2020. Longer-term projections are drawn from emission scenarios prepared by the U.S Climate Change Science Program (U.S. CCSP 2007).

Table 5-7 presents long-term U.S. GHG emission projections used in ADAGE to evaluate policy.

Table 5-7 **Long-Term U.S. GHG Emission Projections in ADAGE** (Tg CO_2 Eq.)

EPA's ADAGE model projects total U.S. greenhouse gas emissions will increase gradually, by about 18 percent between 2010 and 2050.

2010	2020	2030	2040	2050
7,118	7,390	7,765	8,101	8,379

ADAGE = Applied Dynamic Analysis of the Global Economy; EIA = Energy Information Administration; EPA = Environmental Protection Agency.

Note: At the time of this report, ADAGE was calibrated to EIA's March 2009 release of its *Annual Energy Outlook* (AEO 2009) (U.S. DIE/EIA 2009h). The ADAGE projections may be different from other projections in this chapter due to differences in modeling and lag time in calibrating model baselines to new versions of AEO 2009.