U.S. Greenhouse Gas Emissions: Recent Trends and Factors

name redacted
Specialist in Environmental Policy

November 24, 2014

Congressional Research Service
7-....
www.crs.gov
R43795

Summary

On June 25, 2013, President Obama affirmed his commitment to reduce U.S. greenhouse gas (GHG) emissions by 17% below 2005 levels by 2020 if all other major economies agreed to limit their emissions as well. In addition, during a November 2014 trip to China, President Obama announced a new policy target to reduce U.S. net GHG emissions by 26%-28% by 2025. Whether these objectives will be met is uncertain, but emission levels and recent trends remain a topic of interest among policy makers.

U.S. GHG emissions increased during most of the years between 1990 and 2007, and then decreased substantially in 2008 and 2009. Although emissions increased in 2010, levels decreased again in 2011 and 2012, eventually reaching levels comparable to those from 1995. In terms of the President's 2020 emissions target, in 2012, U.S. GHG emissions were approximately 10% below 2005 levels—more than halfway toward the 2020 target.

In the United States, GHG emissions are generated by millions of discrete sources, including smokestacks, vehicle exhaust pipes, commercial buildings, and households. However, carbon dioxide (CO_2) emissions from the combustion of fossil fuels—petroleum, coal, and natural gas—have received the most attention because they account for the vast majority of human-related GHG emissions: 78% of total U.S. GHG emissions in 2012.

In addition, (1) CO_2 emissions from large stationary sources are easy to measure and have been tracked for almost 20 years, and (2) CO_2 emissions from smaller sources can be estimated through relatively straightforward calculations. In 2012, the percentage contributions of CO_2 emissions by sector were as follows:

- 40% from electricity,
- 35% from transportation,
- 15% from industrial,
- 6% from commercial, and
- 4% from residential.

Although multiple factors have some level of influence on U.S. GHG emission levels, it may be instructive to examine several broad energy-related factors including population, income, energy intensity (energy use per economic output such as gross domestic product, or GDP) and carbon intensity (CO_2 emissions per unit of energy use). Although decreases in population and/or income would contribute to reducing U.S. GHG emissions, policies that would seek to directly limit these emissions drivers are essentially outside the bounds of U.S. public policy. Therefore, this report focuses on the impacts of energy intensity and carbon intensity on GHG emission levels.

As energy use has grown at a slower rate than the economy, U.S. energy intensity declined by about 2% each year for more than two decades. Between 1990 and 2013, U.S. GDP (in 2009$) increased at an average annual rate of approximately 2.5%. Energy use, in contrast, increased from 1990 to 2000 at an annual average rate of 1.6%, but then remained relatively constant (excepting some annual fluctuations) through 2013.

The U.S. carbon content of energy use remained relatively constant from 1990 to 2005, but by 2013, it was approximately 8% lower than in 2005. In this report, carbon intensity measures the

amount of CO_2 emissions generated per unit of energy used. Energy sources—coal, natural gas, petroleum, nuclear, renewables—vary dramatically in the amount of carbon released per unit of energy supplied. For example, coal combustion accounts for almost twice the carbon content per unit of energy than natural gas, and some energy sources, when consumed, do not directly generate any emissions.

This recent decrease in the carbon content of energy use is partially explained by changes in the energy sources used to generate electricity, because the electric power sector accounts for approximately 40% of total energy use. For example, between 2004 and 2013, the percentage of electricity from coal generation decreased from 50% to 39%, while the percentage of electricity generated using natural gas increased from 18% to 28%. In addition, renewable energy use increased by 100%, and the use of petroleum to generate electricity decreased by approximately 100%.

Contents

Figures

Tables

Contacts

Introduction

U.S. greenhouse gas (GHG) emission levels remain a topic of interest among policy makers and stakeholders. On June 25, 2013, President Obama affirmed his commitment to reduce U.S. GHG emissions[1] by 17% below 2005 levels by 2020 if all other major economies agreed to limit their emissions as well.[2] In addition, during a November 2014 trip to China, President Obama and President Xi of China made a bilateral announcement concerning GHG emissions. President Obama announced a new policy target to reduce U.S. net GHG emissions by 26%-28% by 2025. President Xi agreed to "peak" Chinese carbon dioxide (CO_2) emissions around 2030, perhaps earlier, and to increase the non-fossil share of China's energy to around 20% by 2030 compared to 2005 levels.[3]

A question for policy makers is whether U.S. GHG emissions will remain at current levels, decrease to meet the President's 2020 and 2025 goals, or increase to former (or even higher) levels. Multiple factors, including socioeconomics, technology, and climate policies, may impact GHG emission levels.

The human-related GHG emission[4] and related data in this report are from publicly available sources, particularly reports and tables produced regularly by the Environmental Protection Agency (EPA) and the Energy Information Administration (EIA).

This first section of this report provides current levels and recent trends in U.S. GHG emissions. The second section takes a closer look at some of the key factors that influence emission levels. The third section discusses the challenges in making GHG emission projections by comparing observed emissions with preobserved emission estimates.

U.S. GHG Emissions

As **Figure 1** illustrates, U.S. GHG emissions increased during most of the years between 1990 and 2007, and then decreased substantially in 2008 and 2009. Although emissions increased in 2010, levels decreased again in 2011 and 2012, eventually reaching levels comparable to those in 1995. In terms of the President's 2020 emissions target (17% below 2005 levels), U.S. GHG emissions in 2012—the most recent year with available GHG emission data—were approximately 10% below 2005 levels.

---

[1] The primary GHGs emitted by humans (and estimated by EPA in its annual inventories) include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

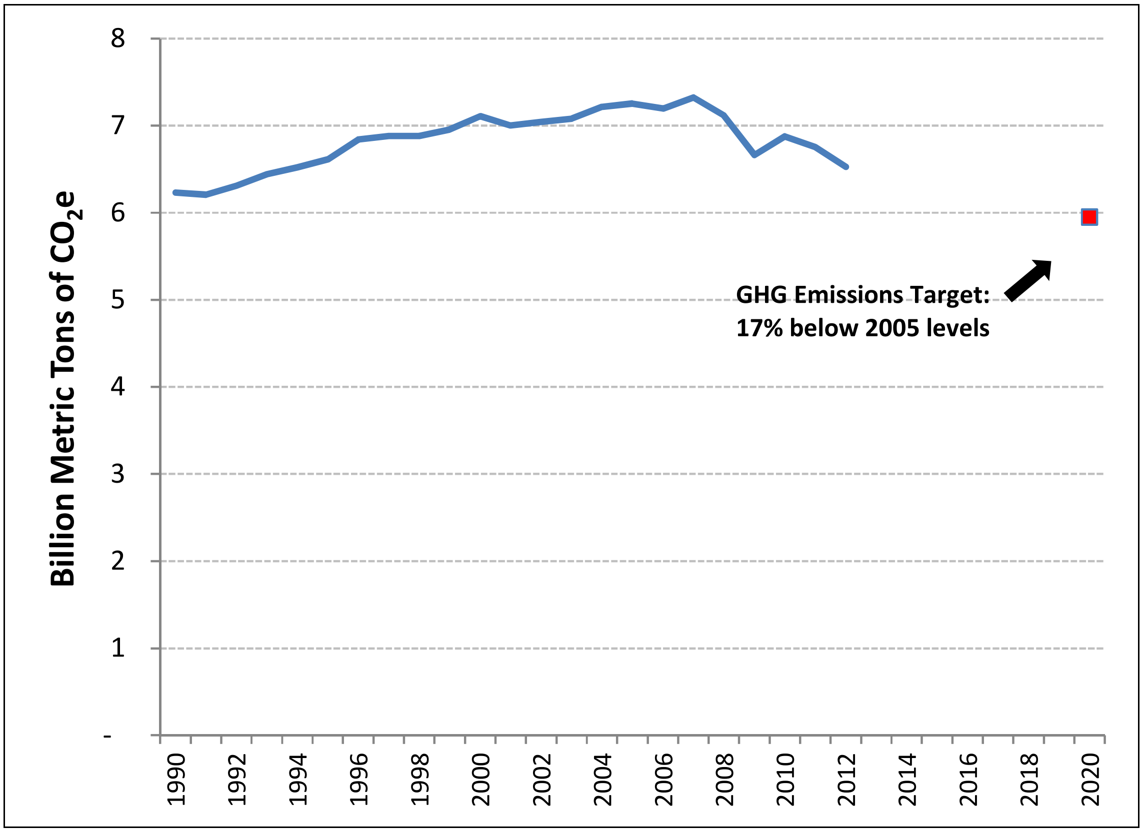
[2] Executive Office of the President (EOP), The President's Climate Action Plan, June 2013, at http://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf. For more information, see CRS Report R43120, *President Obama's Climate Action Plan*, coordinated by (name redacted).

[3] For further discussion, see CRS Report IN10181, *President Obama's November 2014 Visit to China: The Bilateral Announcements*, by (name redacted), (name redacted), and (name redacted).

[4] GHG emissions are also released through a variety of natural processes such as methane emissions from wetlands. This report focuses on human-related (anthropogenic) GHG emissions.

Figure 1. U.S. GHG Emissions (1990-2012)

Excludes Emissions from Land Use, Land-Use Change, and Forestry



Source: Prepared by CRS; emissions data from EPA April 2014 GHG Emissions Inventory (Figure 2-1), at http://epa.gov/climatechange/ghgemissions/usinventoryreport.html.

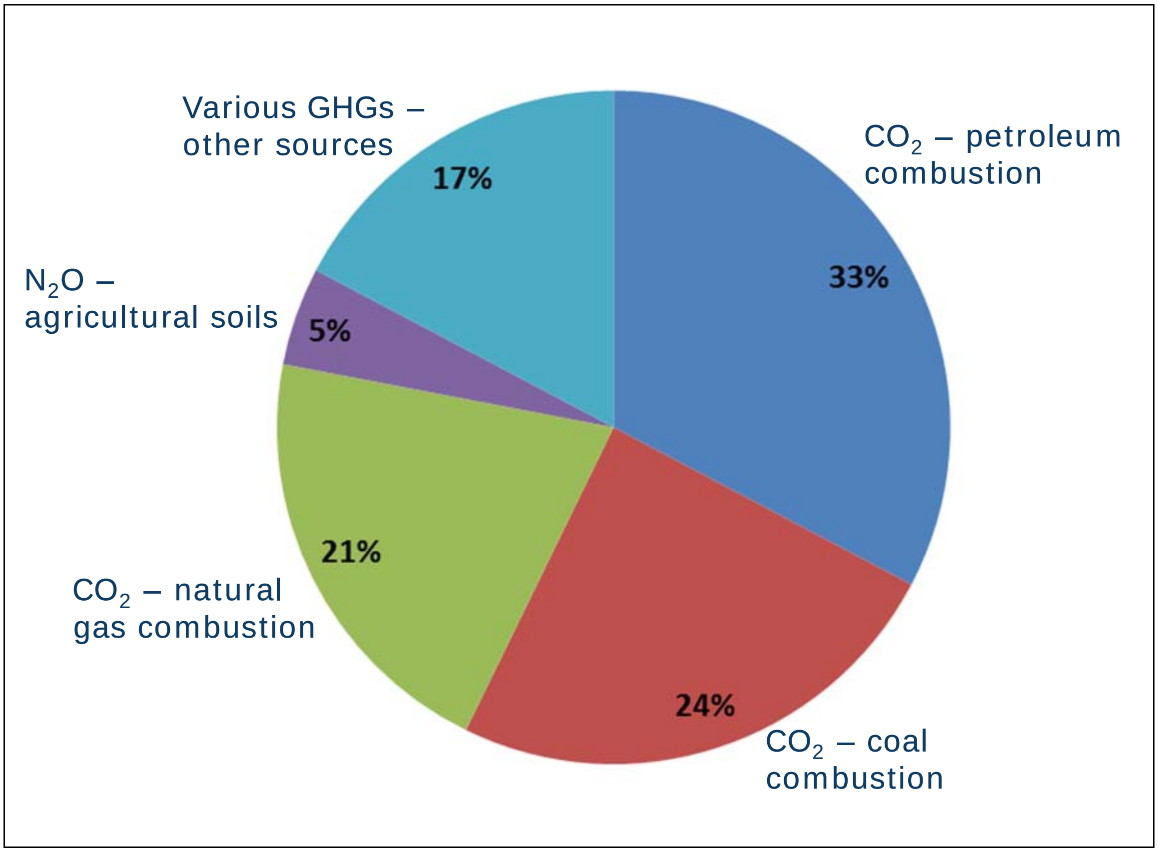
Notes: The 2020 GHG emissions target is from the Obama Administration's Climate Action Plan, at http://www.whitehouse.gov/share/climate-action-plan.

GHG emissions are typically measured in tons of CO_2-equivalent (CO_2e). This term of measure is used because GHGs vary by global warming potential (GWP). GWP is an index of how much a GHG may contribute to global warming over a period of time, typically 100 years. GWPs are used to compare gases to CO_2, which has a GWP of 1. For example, methane's GWP is 25, and thus a ton of methane is 25 times more potent a GHG than a ton of CO_2.

GHG Emissions by Source

GHG emissions are generated throughout the United States by millions of discrete sources: smokestacks, vehicle exhaust pipes, households, commercial buildings, livestock, etc. **Figure 2** illustrates the breakdown of U.S. GHG emissions by gas and type of source. The figure indicates that CO_2 from the combustion of fossil fuels—petroleum, coal, and natural gas—accounted for 78% of total U.S. GHG emissions in 2012. The next section examines CO_2 emissions from fossil fuel combustion.

Figure 2. U.S. GHG Emissions by Gas and Source (2012)



Source: Prepared by CRS; data from April 2014 GHG Emissions Inventory, at http://epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Notes: The "Various GHGs – other sources" include five sources that each account for approximately 2% of total GHG emissions: CO_2 from non-energy fuel uses; methane (CH_4) from natural gas systems; CH_4 from livestock; CH_4 from landfills; and hydrofluorocarbons (HFCs) from the substitution of ozone-depleting substances. In addition, the following "other sources" each account for approximately 1% of total GHG emissions: CO_2 from iron and steel production; CH_4 from coal mines; and CH_4 from manure management. Multiple sources account for the remaining 5%. These percentages may not add up precisely due to rounding.

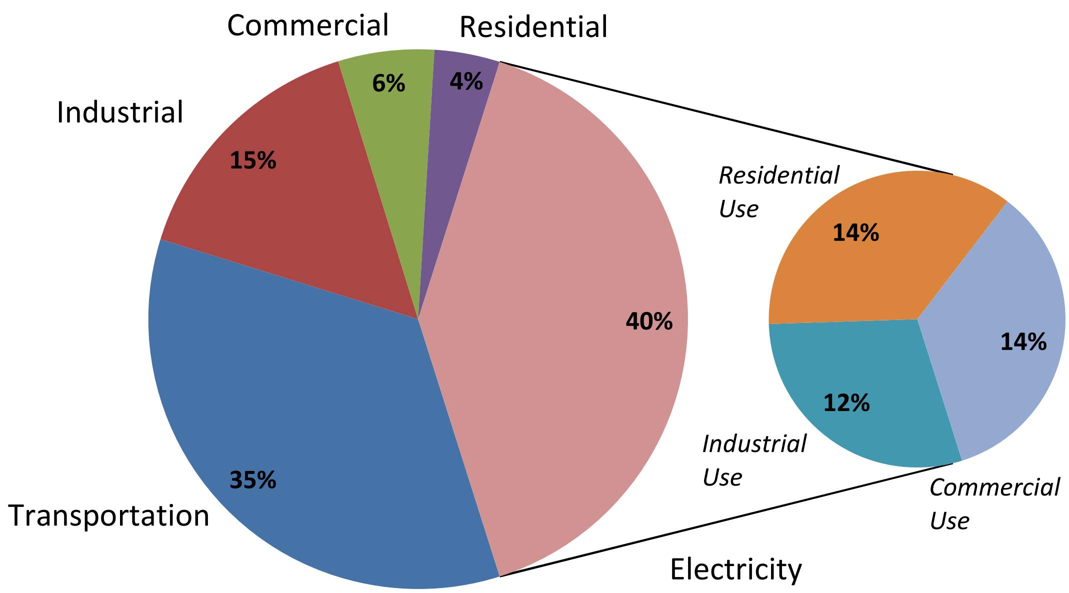
CO_2 Emissions from Fossil Fuel Combustion

In the context of GHG emission reduction programs and legislative proposals, CO_2 emissions from the combustion of fossil fuels have received the most attention. CO_2 emissions are fairly easy to verify from large stationary sources, like power plants. For almost 20 years, measurement devices have been installed in smokestacks of large facilities, reporting electronic information to EPA and the appropriate state. For smaller sources, CO_2 emissions are a relatively straightforward and accurate calculation based on the carbon content of fossil fuels consumed. In addition, according to EPA, "changes in emissions from fossil fuel combustion have been the dominant factor affecting U.S. emission trends."[5]

[5] EPA, April 2014 GHG Emissions Inventory, ES-9.

Figure 3 illustrates the CO_2 emission contributions by sector from the combustion of fossil fuels. The largest contribution (40%) is from electricity generation. The generated electricity is distributed almost equally to the residential, industrial, and commercial sectors.[6]

Figure 3. CO_2 Emissions from Fossil Fuel Combustion by Sector (2012)



Source: Prepared by CRS; data from EPA's April 2014 GHG Emissions Inventory, at http://epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Notes: CO_2 emissions related to electricity use in the transportation sector account for less than 1% of CO_2 emissions from total electricity generation. These emissions are not included in the above figure. In addition, the above chart does not include CO_2 emissions from the U.S. territories.

[6] CO_2 emissions related to electricity use in the transportation sector account for less than 1% of CO_2 emissions from total electricity generation.

U.S. GHG Emissions—a Closer Look

Multiple variables impact U.S. GHG emission levels. One approach often taken in climate change analysis is to examine several broad energy-related factors that influence GHG emission levels, including

- population,
- income—measured here as per capita gross domestic product (GDP),
- energy intensity—measured here as energy use per gross domestic product, and
- carbon intensity—measured here as CO_2 emissions per energy use.[7]

As illustrated in the equation below, GHG emission levels can be approximated by multiplying together these four factors.

GHG Emissions	=	Population	X	Income	X	Energy Intensity	X	Carbon Intensity
($MTCO_2e$)		(Persons)		(GDP/Person)		(Tons of Energy/GDP)		($MTCO_2e$/Tons of Energy)

$MTCO_2e$ stands for metric tons of carbon dioxide equivalent.

Although decreases in population and/or per capita income would contribute to lowering U.S. GHG emissions, policies that would seek to directly limit these emissions drivers are essentially outside the bounds of U.S. public policy.[8] Thus the most relevant factors in terms of climate change policy are energy intensity and carbon intensity, which are discussed below.

Energy Intensity

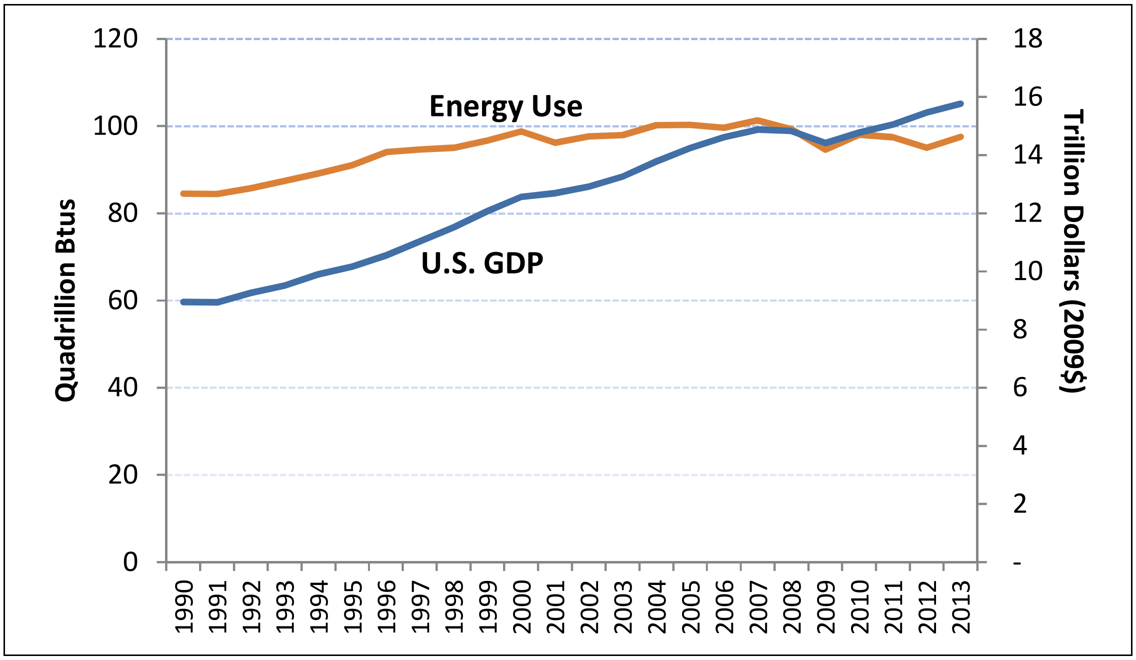
Energy intensity is the amount of energy consumed—often measured in metric tons of oil equivalent (toe) or British thermal units (Btus)—per a level of economic output such as GDP. **Figure 4** illustrates the U.S. total energy consumption and GDP between 1990 and 2013. The figure indicates that energy use increased from 1990 to 2000 at an annual average rate of 1.6%, and then remained relatively constant (excepting some annual fluctuations) through 2013. In contrast, U.S. GDP (in 2009$) has increased at an average annual rate of approximately 2.5% from 1990 through 2013. Thus, U.S. energy intensity declined between 1990 and 2013.

[7] This combination of factors is often referred to as the "Kaya Identity." See, e.g., Intergovernmental Panel on Climate Change, Contribution of Working Group III to the Fourth Assessment Report, Chapter 1, 2007.

[8] During the past two decades, U.S. GDP (in 2009$) has increased every year except 1991 and 2008. A trend in U.S. population annual growth rates is worth noting: although the annual growth rate of the U.S. population has declined in recent years (in 1991 it was 1.4%), the U.S. population increased by 0.7% in 2013. For more discussion, see CRS Report RL32701, *The Changing Demographic Profile of the United States*, by (name redacted) and (name redacted).

Figure 4. U.S. Energy Consumption and U.S. GDP (2009$)

1990-2013

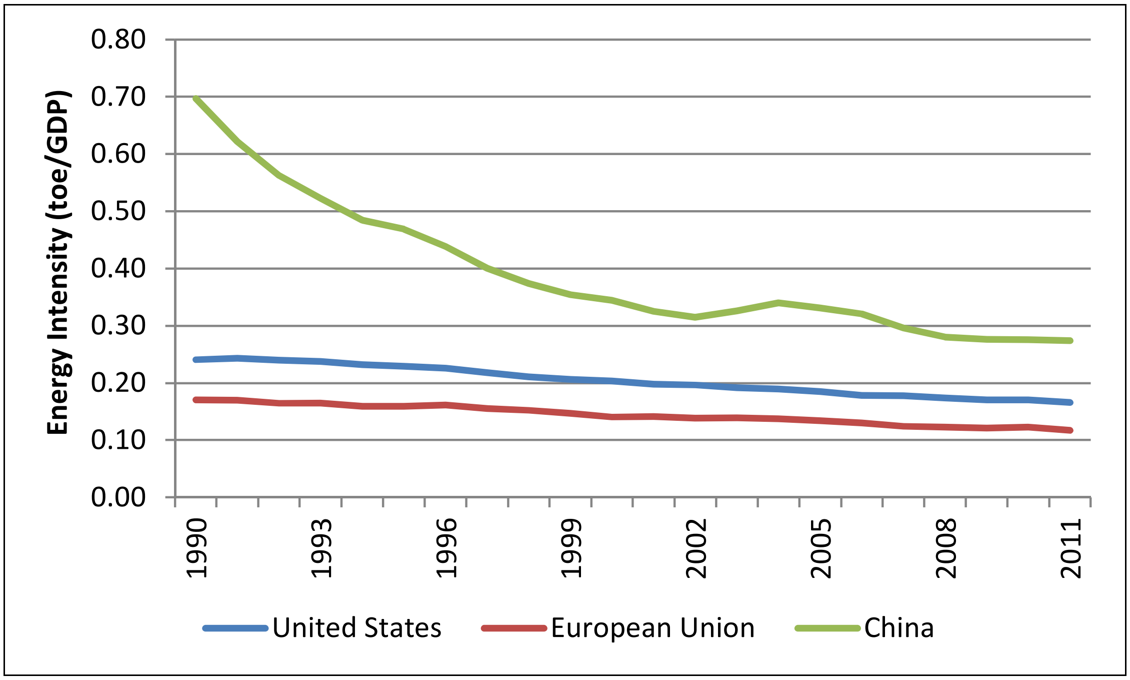


Source: Prepared by CRS; energy consumption data from EIA, April 2014 Monthly Energy Review, at http://www.eia.gov/totalenergy/data/monthly/; U.S. GDP data from Bureau of Economic Analysis, Table 1.1.6, at http://bea.gov/national/index.htm#gdp.

Figure 5 compares the energy intensities of the United States, the European Union (28 nations), and China between 1990 and 2011. As the figure illustrates, U.S. energy intensity has been declining by about 2% each year for two decades: the U.S. energy intensity in 2011 was 31% lower than it was in 1990. However, the energy intensity in the United States was 42% higher in 2011 than in the European Union.

Figure 5. Energy Intensity Comparison

Energy Use per Economic Output



Source: Prepared by CRS; data from World Resources Institute (WRI), Climate Analysis Indicators Tool.

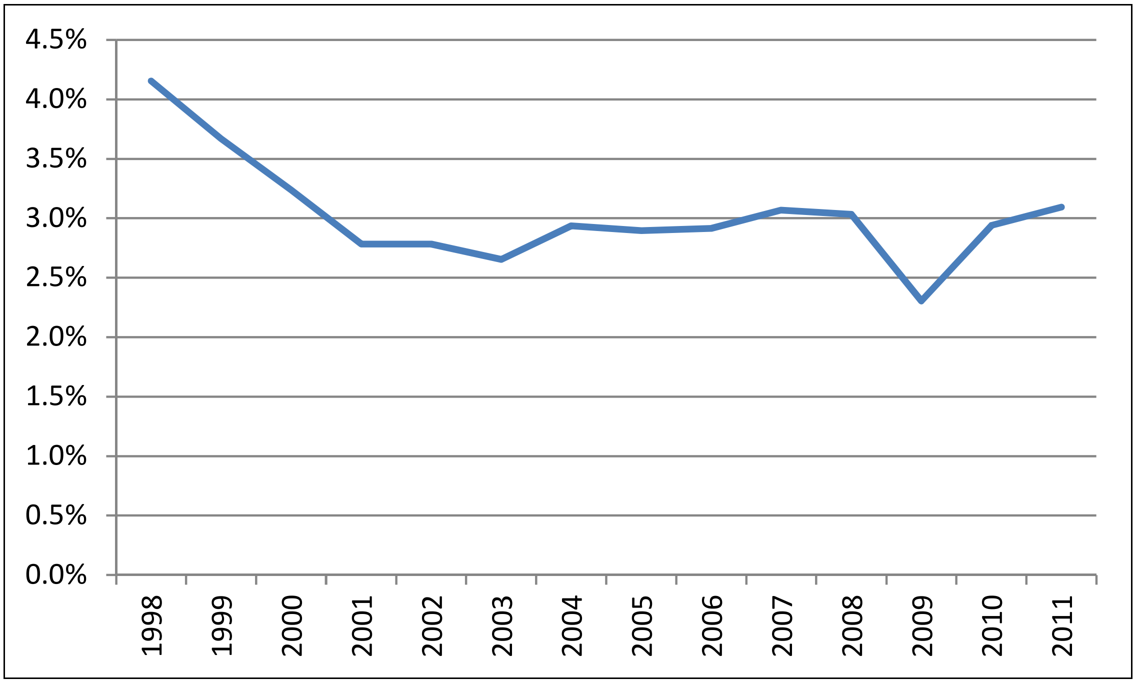
Note: The European Union includes 28 countries.

The degree to which the U.S. economy is composed of industries with relatively high energy intensities likely plays a role in determining the energy intensity of United States. **Figure 6** indicates that the percentage contribution to the U.S. GDP from selected energy-intensive industries decreased from 4.2% in 1998 to 3.2% in 2011. **Figure 6** includes 44 industries in the six-digit North American Industry Classification System (NAICS). These industries have an energy intensity of at least 5%, measured by dividing energy expenditures by the value of an industry's shipments.[9]

[9] This list of energy-intensive industries comes from a 2009 interagency report that assessed effects of H.R. 2454 ("Waxman-Markey"), the GHG emission cap-and-trade bill that passed the House during the 111th Congress. See Interagency Report, *The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries*, 2009, at http://www.epa.gov/climatechange/EPAactivities/economics/legislativeanalyses.html.

Figure 6. Contribution to U.S. GDP from Selected Energy-Intensive Industry Sectors

In 2005 Dollars



Source: Prepared by CRS; the energy intensive industries are from a 2009 interagency report: *The Effects of H.R. 2454 on International Competitiveness and Emission Leakage in Energy-Intensive Trade-Exposed Industries*; GDP data are from Bureau of Economic Analysis, Gross Output by NAICS code, at http://bea.gov/industry/gdpbyind_data.htm.

Carbon Intensity

In this report, carbon intensity measures the amount of CO_2 emissions generated during energy use, which includes fuel combustion for electricity generation and transportation purposes. Energy sources (e.g., coal, natural gas, petroleum, nuclear, and renewables) vary dramatically in the amount of carbon released per unit of energy supplied. As indicated in **Table 1**, coal generates approximately 80% more CO_2 emissions per unit of energy than natural gas, and approximately 28% more emissions per unit of energy than crude oil.[10] Moreover, other energy sources, such as nuclear or specific renewable sources, do not directly generate any CO_2 emissions.

[10] See Energy Information Administration (EIA), "Emissions Factors and Global Warming Potentials," updated January 2011, at http://www.eia.gov/oiaf/1605/emission_factors.html.

Table 1. CO_2 Emissions per Unit of Energy for Fossil Fuels

Fossil Fuel	CO_2 Emissions per Unit of Energy (million metric tons/quadrillion Btus)
Coal	96
Crude oil	75
Natural gas	53

Source: Prepared by CRS, based on Energy Information Administration (EIA), "Emissions Factors and Global Warming Potentials," updated January 2011, at http://www.eia.gov/oiaf/1605/emission_factors.html.

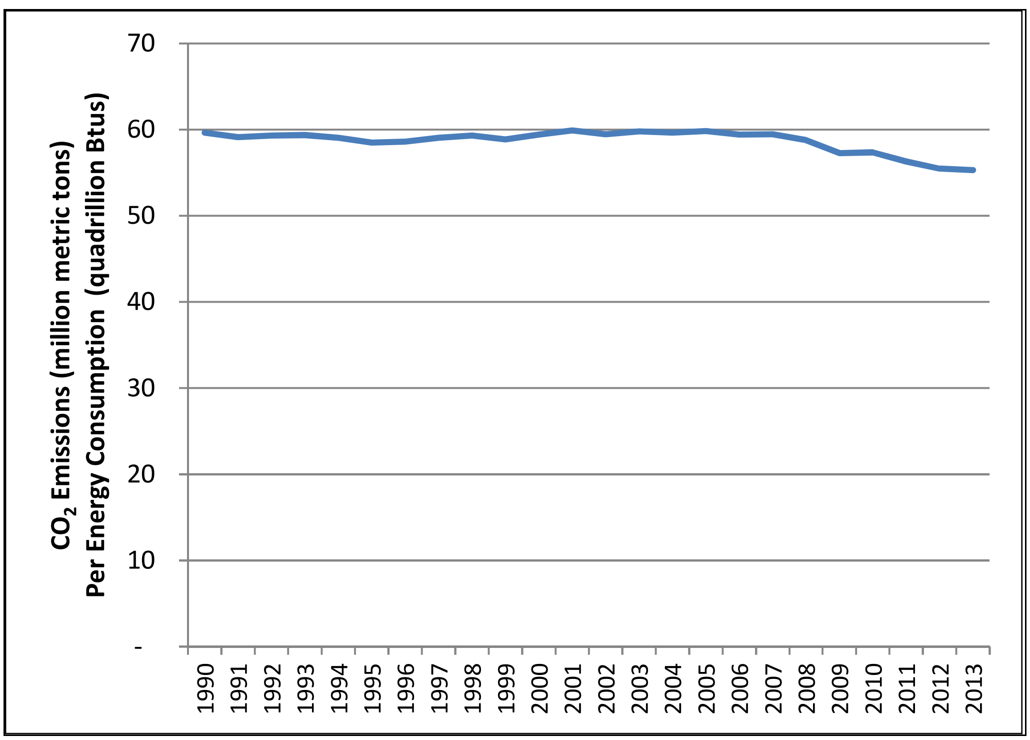
Notes: Coal emissions intensity values vary by type of coal, from 93 million to 104 million metric tons/quadrillion Btus. The value above is for coal use in the U.S. electric power sector. The natural gas value above is the weighted national average of all uses, as prepared by EIA.

Carbon Content of Energy Use

Figure 7 illustrates the U.S. carbon content of energy use—CO_2 emissions per Btu—between 1990 and 2013. This includes energy used (i.e., consumed) in the electricity, industrial, transportation, commercial, and residential sectors. The figure indicates that this measure remained relatively constant from 1990 to 2005, when it began to decline. By 2013, the carbon content of energy use was approximately 8% lower than it was in 2005. This decline is largely related to the recent change in the portfolio of fuels consumed for energy purposes.

Figure 7. Carbon Content of Energy Use

1990-2013

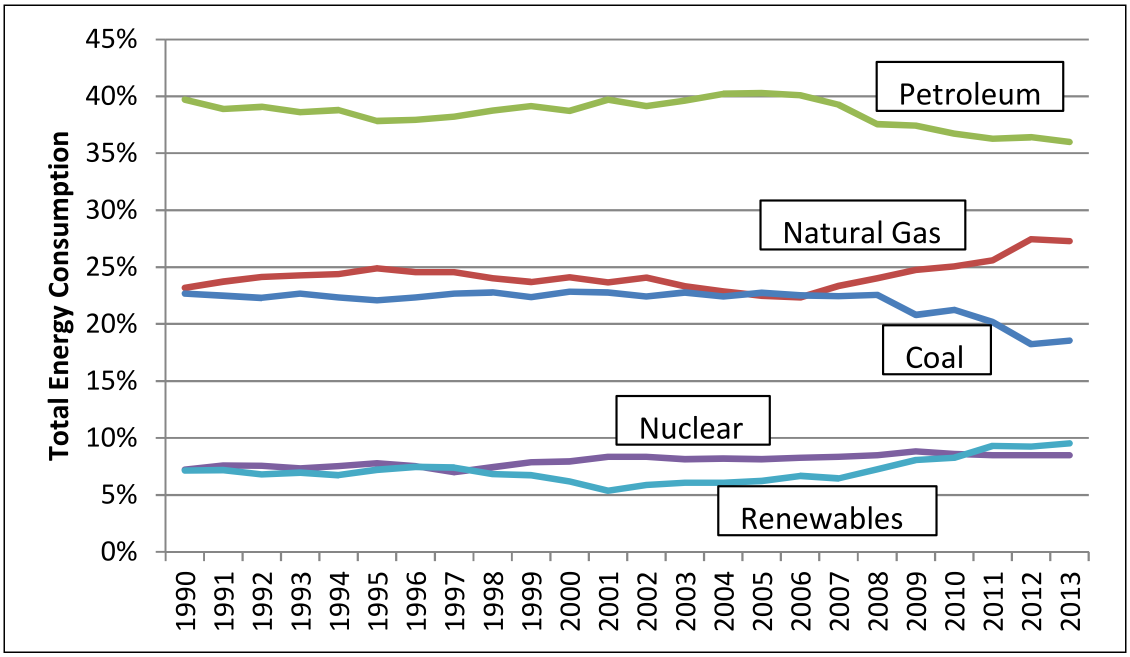


Source: Prepared by CRS; total energy consumption data and CO_2 emissions data from EIA.

Figure 8 compares the consumption percentage of different energy sources in the United States. The figure indicates that the trajectories of coal and natural gas have diverged in recent years. Since 2008, coal's percentage contribution has decreased from 23% to 19%. In contrast, natural gas's percentage contribution has increased from 24% to 27% during that time frame. In addition, renewable energy's share of total energy consumption has increased substantially over the past decade.

Figure 8. U.S. Energy Consumption by Source

1990-2013



Source: Prepared by CRS; data from EIA, April 2014 Monthly Energy Review.

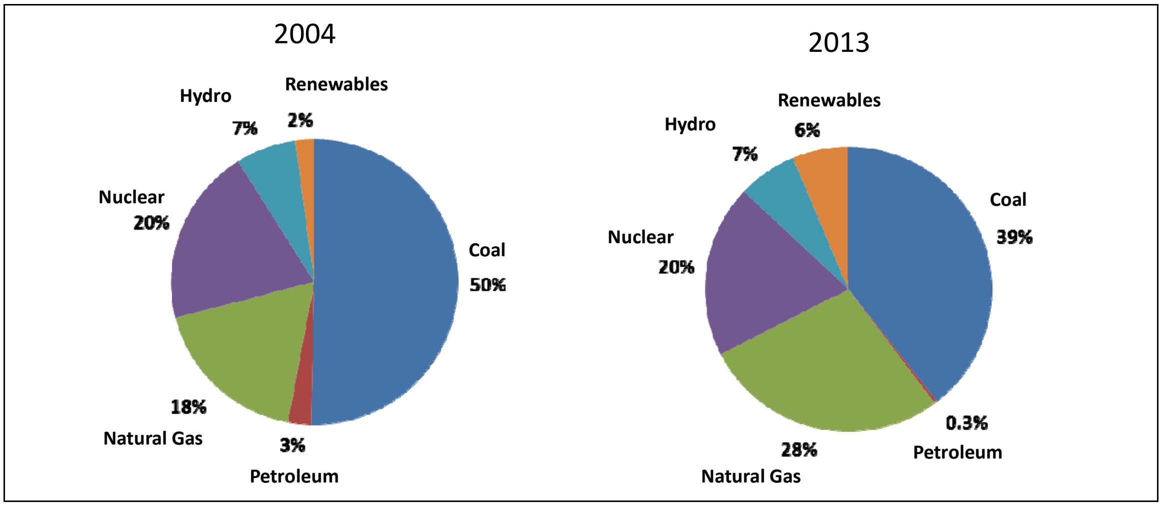
Carbon Content of Electricity Generation

The recent changes in energy consumption are partially explained by changes in the energy sources used to generate electricity, because the electric power sector accounts for approximately 40% of total energy use.[11] As an illustration of recent changes in the electricity sector, **Figure 9** compares electricity generation by energy source between 2004 and 2013. The figure indicates a substantial decrease in coal use with a simultaneous increase in natural gas. Moreover, the percentage share of renewable sources increased from 2% to 6%, and petroleum decreased from 3% to less than 1%.

[11] CRS calculation based on EIA data for 2012, *Annual Energy Review*, Table 2.1, "Energy Consumption by Sector."

Figure 9. Electricity Generation by Energy Source

2004 vs. 2013



Source: Prepared by CRS; data from EIA, *Electric Power Monthly*, Table 1.1, "Net Generation by Energy Source."

Note: According to the EIA data, total electricity generation (in megawatt-hours, or MWh) increased by 2% between 2004 and 2013.

Estimating Future Emissions

Accurately forecasting future GHG emission levels is a complex and challenging, if not impossible, endeavor. Consequently, analysts often provide a range of emissions based on different scenarios or assumptions. As discussed above, several broad energy-related factors influence emission levels. In addition, other variables have impacts in ways that cannot be accurately predicted. Such variables may include

- technological developments,
- energy price fluctuations,
- availability of less carbon-intensive energy sources (e.g., hydroelectric, other renewables, and nuclear power),
- seasonal weather and temperature patterns, and
- policy changes in the United States and abroad.

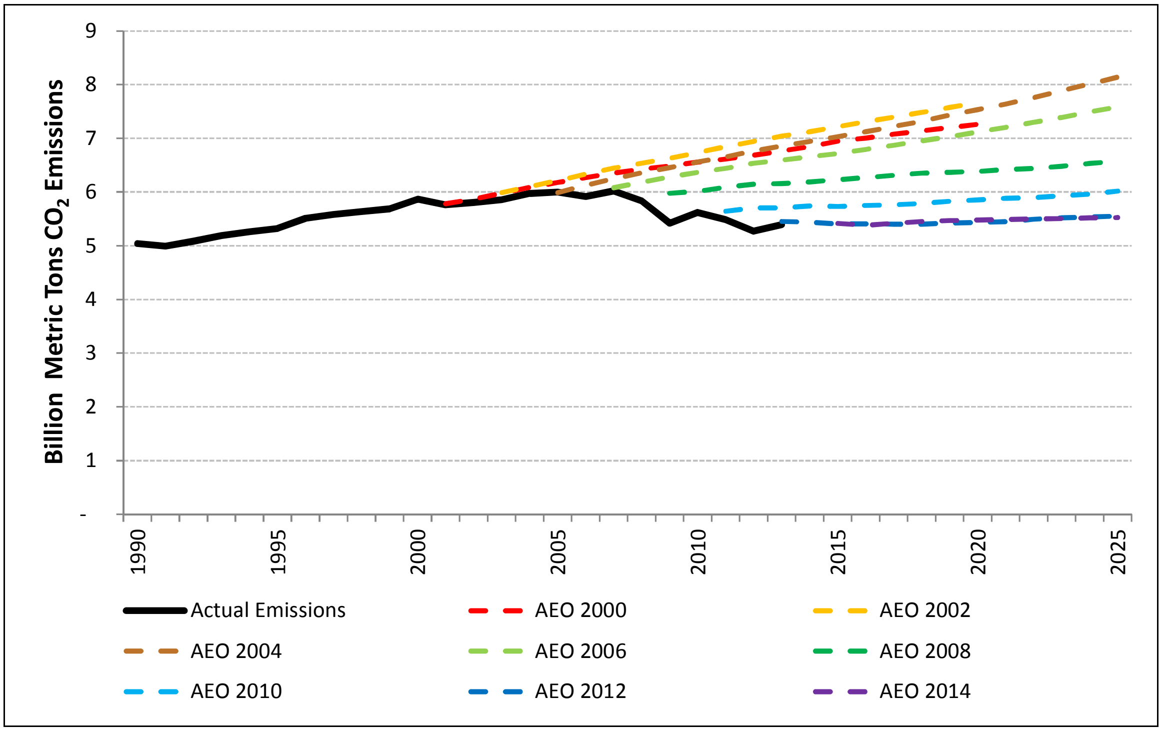
EIA provides annual forecasts of CO_2 emissions in its *Annual Energy Outlook* (AEO) publications. Regarding its various estimates, EIA states the following:

> The projections in the AEO are not statements of what will happen but of what might happen, given assumptions and methodologies. The AEO Reference case projection assumes trends that are consistent with historical and current market behavior, technological and demographic changes, and current laws and regulations. The potential impacts of pending or

proposed legislation, regulations, and standards are not reflected in the Reference case projections.[12]

Figure 10 compares actual CO_2 emissions between 1990 and 2012 with selected EIA emission projections made in past years. In general, actual emissions have remained well below projections, particularly the projections made in 2008 or earlier. For example, the AEO from 2000 projected CO_2 emissions would be almost 6.7 billion metric tons in 2012, about 20% higher than has been observed. By comparison, the more recent projections (AEO 2012 and 2014) indicate that CO_2 emissions will remain relatively flat over the next decade.

Figure 10. Actual CO_2 Emissions and Selected Past EIA CO_2 Emission Projections



Source: Prepared by CRS; data from EIA *Annual Energy Outlook* publications, at http://www.eia.gov.

Notes: EIA publishes annual projections. The above figure includes only projections from the even-numbered years.

Author Contact Information

(name redacted)
Specialist in Environmental Policy
/redacted/@crs.loc.gov, 7-....

[12] EIA, *Annual Energy Outlook Retrospective Review: Evaluation of 2013 and Prior Reference Case Projections*, April 2014.