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U.S. Carbon Dioxide Emission Trends and the Role of the Clean Power Plan

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Summary

Recent international negotiations and domestic policy developments have generated interest in current and projected U.S. greenhouse gas (GHG) emission levels. GHG emissions are generated throughout the United States from millions of discrete sources. Of the GHG source categories, carbon dioxide (CO_2) emissions from fossil fuel combustion account for the largest percentage (76%) of total U.S. GHG emissions. The electric power sector contributes the largest percentage (36%) of CO_2 emissions from fossil fuel combustion.

In the context of international climate change negotiations, President Obama announced, on separate occasions, U.S. GHG emission reduction goals for both 2020 and 2025: 17% below 2005 levels by 2020 and 26% to 28% below 2005 levels by 2025. In 2014, U.S. GHG levels were 7.5% below 2005 levels. Whether the United States achieves its goals would likely depend, to some degree, on CO_2 emissions from power plants.

The Environmental Protection Agency (EPA) promulgated standards for CO_2 emissions from existing electric power plants on August 3, 2015. The rule, known as the Clean Power Plan (CPP), is the subject of ongoing litigation involving a number of entities. On February 9, 2016, the Supreme Court stayed the rule for the duration of the litigation.

Multiple factors generally impact CO_2 emission levels from the electric power sector. Some factors are listed below in no particular order:

- Economic growth/recession,
- Relative prices of energy sources for electricity—particularly natural gas—and renewable energy sources,
- Electricity generation portfolio (i.e., the ratio of electricity generation from coal, natural gas, and renewable energy sources),
- National and/or state policy developments (e.g., CPP implementation), and
- Demand-side efficiency improvements (e.g., commercial and residential electricity use).

Recent changes in the electric power sector may be informative. Between 1975 and 2010, electricity generation and CO_2 emissions from the electric power sector generally increased. While electricity generation remained relatively flat after 2010, CO_2 emissions from the electric power sector decreased. Electricity generation in 2015 was essentially equivalent to generation in 2005, whereas the CO_2 emissions in 2015 were 19% below 2005 levels.

Recent changes in the U.S. electricity generation portfolio played a key role in the CO_2 emission decrease. The electricity portfolio affects CO_2 emission levels because different sources of electricity generation produce different rates of CO_2 emissions per unit of electricity (zero in the case of some renewables). For example, between 2005 and 2015:

- coal's contribution to total electricity generation decreased from 50% to 33%,
- natural gas's contribution to total electricity generation increased from 19% to 33%, and
- renewable energy's contribution to total electricity generation increased from 2% to 7%.

If implemented, the CPP would likely play a role in shaping the electricity generation portfolio. Modeling results indicate that the CPP would have a significant impact on future CO_2 emission levels from electricity generation. Under the models' baseline scenarios, power sector CO_2

emissions in 2030 would decrease by 10% to 17% compared to 2005 levels. Under the models' CPP implementation scenarios, power sector CO_2 emissions in 2030 would decrease by 26% to 40% compared to 2005 levels.

If the CPP is not implemented, questions remain as to whether existing policies and trends in electricity generation would continue to lower CO_2 emissions. In December 2015, Congress extended and modified the production tax credit and the investment tax credit for specific renewable energy technologies (e.g., wind and solar). This development will likely impact the electricity generation portfolio (compared to baseline), but at least one analysis suggests that the extensions would not be a substitute for CPP implementation.

Accurately forecasting future CO_2 emission levels is a complex and challenging endeavor. A comparison of actual CO_2 emissions (from energy use) between 1990 and 2014 with selected emission projections illustrates this difficulty. In general, actual emissions have remained well below projections. The more recent projections, which do not include CPP implementation, indicate that CO_2 emissions will remain relatively flat over the next decade.

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Introduction

U.S. greenhouse gas (GHG) emission levels, particularly from carbon dioxide (CO_2), remain a topic of interest among policymakers and stakeholders.[1] Recent international negotiations and domestic policy developments have generated increased attention to current and projected U.S. GHG emission levels. An understanding of GHG emission source data and the underlying factors that affect emission levels might help inform the discussion among policymakers regarding GHG emission mitigation.

In June 2013, President Obama stated his commitment to reduce U.S. GHG emissions by 17% below 2005 levels by 2020 if all other major economies agreed to limit their emissions as well.[2] In November 2014, President Obama announced an additional interim goal to reduce U.S. GHG emissions by 26% to 28% below 2005 levels by 2025 in the context of negotiations toward an agreement applying to all countries to address climate change beyond 2020.[3] In December 2015, delegations from 195 nations, including the United States, adopted an agreement in Paris that creates an international structure for nations to pledge to abate their GHG emissions, adapt to climate change, and cooperate to achieve these ends, including financial and other support.[4]

Whether the United States ultimately achieves the 2020 and 2025 targets will likely depend, to some degree, on GHG emission levels from electric power plants—one of the largest sources of U.S. emissions.

The Environmental Protection Agency (EPA) promulgated standards for CO_2 emissions from existing fossil-fuel-fired electric power plants on August 3, 2015.[5] EPA cites Section 111(d) of the Clean Air Act (CAA) as the authority to issue its final rule.[6] The rule, known as the Clean Power Plan (CPP), appeared in the *Federal Register* on October 23, 2015.[7]

The CPP is the subject of ongoing litigation. A number of states and other entities have challenged the rule, while other states and entities have intervened in support of the rule. On February 9, 2016, the Supreme Court stayed the rule for the duration of the litigation. The rule therefore currently lacks enforceability or legal effect, and if the rule is ultimately upheld, at least some of the deadlines would likely be delayed.[8]

A question for policymakers is whether U.S. GHG emissions will remain at current levels, decrease to meet the President's 2020 and 2025 goals, or increase toward former (or even higher)

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[1] The primary GHGs associated with human activity (and estimated by EPA in its annual inventories) include carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, chlorofluorocarbons, hydrofluorocarbons, and perfluorocarbons.

[2] Executive Office of the President, "The President's Climate Action Plan," June 2013, 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] White House, "Fact Sheet: U.S.-China Joint Announcement on Climate Change and Clean Energy Cooperation," press release, November 11, 2014, https://www.whitehouse.gov/the-press-office/2014/11/11/fact-sheet-us-china-joint-announcement-climate-change-and-clean-energy-c.

[4] See CRS Insight IN10413, *Climate Change Paris Agreement Opens for Signature*, by (name redacted).

[5] See CRS Report R44341, *EPA's Clean Power Plan for Existing Power Plants: Frequently Asked Questions*, by (name redacted) et al.

[6] 42 U.S.C. §7411(d).

[7] EPA, "Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units," Final Rule, 80 *Federal Register* 64661, October 23, 2015.

[8] See CRS Report R44341, *EPA's Clean Power Plan for Existing Power Plants: Frequently Asked Questions*, by (name redacted) et al.

levels. Multiple factors—including economics, technology, and climate policies—may impact GHG emission levels.

This report examines recent trends in U.S. GHG emissions, particularly CO_2 emissions from electricity generation, and the factors that impact emission levels in that sector. In addition, this report examines the degree to which CPP implementation (or lack thereof) may impact CO_2 emission levels from electric power plants.

The first section provides an overview of various sources of GHG emissions in the United States. This includes an overview of CO_2 emissions from fossil fuel combustion and a closer look at CO_2 emissions from electricity generation, which account for the largest percentage of CO_2 emission from fossil fuel combustion. The second section examines projections of CO_2 emissions in the electric power sector, with a particular focus on the role of the CPP and other factors. The final section highlights the challenges in making CO_2 emission projections with a comparison of actual CO_2 emissions with prior emission forecasts.

Emissions Data in This Report

This report uses GHG emissions data from two different sources: EPA and the Energy Information Administration (EIA). Estimates of total GHG emissions ("economy-wide") come from EPA's annual GHG emissions inventory. These estimates provide a big-picture view of U.S. GHG emission levels and GHG emission sources, particularly in the context of recent GHG emission reduction goals. EPA released a draft of the most recent version of its inventory in February 2016. This version includes GHG emissions data through 2014.

The CO_2 emissions data in this report come from EIA. This report uses EIA data for CO_2 emissions, because the data go through 2015. However, the CO_2 data in EPA's CPP modeling results come from EPA.

U.S. GHG Emissions

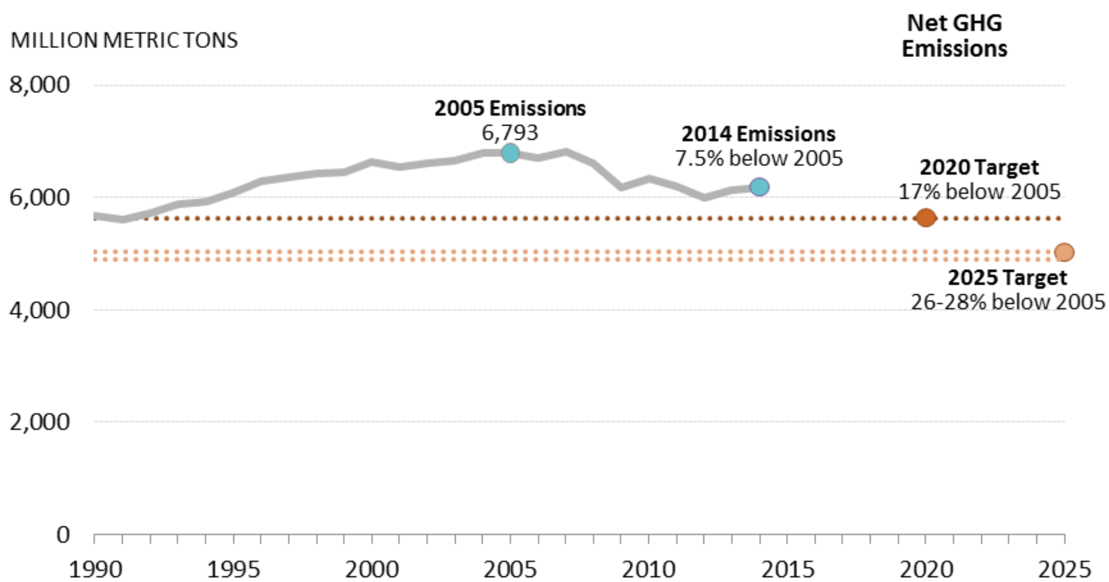
Figure 1 illustrates U.S. GHG between 1990 and 2014. As the figure indicates, U.S. GHG emissions increased during most of the years between 1990 and 2007. GHG emissions decreased substantially in 2008 and 2009 as a result of a variety of factors—some economic, some the effect of government policies at all levels. Over the last four years, emissions have fluctuated but have not surpassed 2009 levels. Emissions in 2014 were roughly equivalent to 1995 emission levels.

Figure 1 compares recent U.S. GHG emission levels to the 2020 and 2025 emission goals. Based on 2014 GHG emission levels, the United States is almost halfway to reaching the Administration's 2020 goal (17% below 2005 levels). U.S. GHG levels in 2014 were 7.5% below 2005 levels.[9]

[9] U.S. GHG emissions in 2012 were 10% below 2005 levels. See EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014*, draft, February 2016, http://epa.gov/climatechange/ghgemissions/.usinventoryreport.html.https://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html#fullreport.

Figure 1. U.S. GHG Emissions (Net)

Compared to 2020 and 2025 Emission Targets



Source: Prepared by CRS; data from EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014*, draft, February 2016, at http://epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Notes: Net GHG emissions includes net carbon sequestration from Land Use, Land Use Change, and Forestry. This involves carbon removals from the atmosphere by photosynthesis and storage in vegetation.

Accurately forecasting future emission levels is a complex and challenging endeavor. Consequently, analysts often provide a range of emissions based on different scenarios or assumptions. The Energy Information Administration (EIA) provides annual forecasts of CO_2 emissions in its *Annual Energy Outlook* (AEO) publications. Regarding its various estimates, EIA states the following:

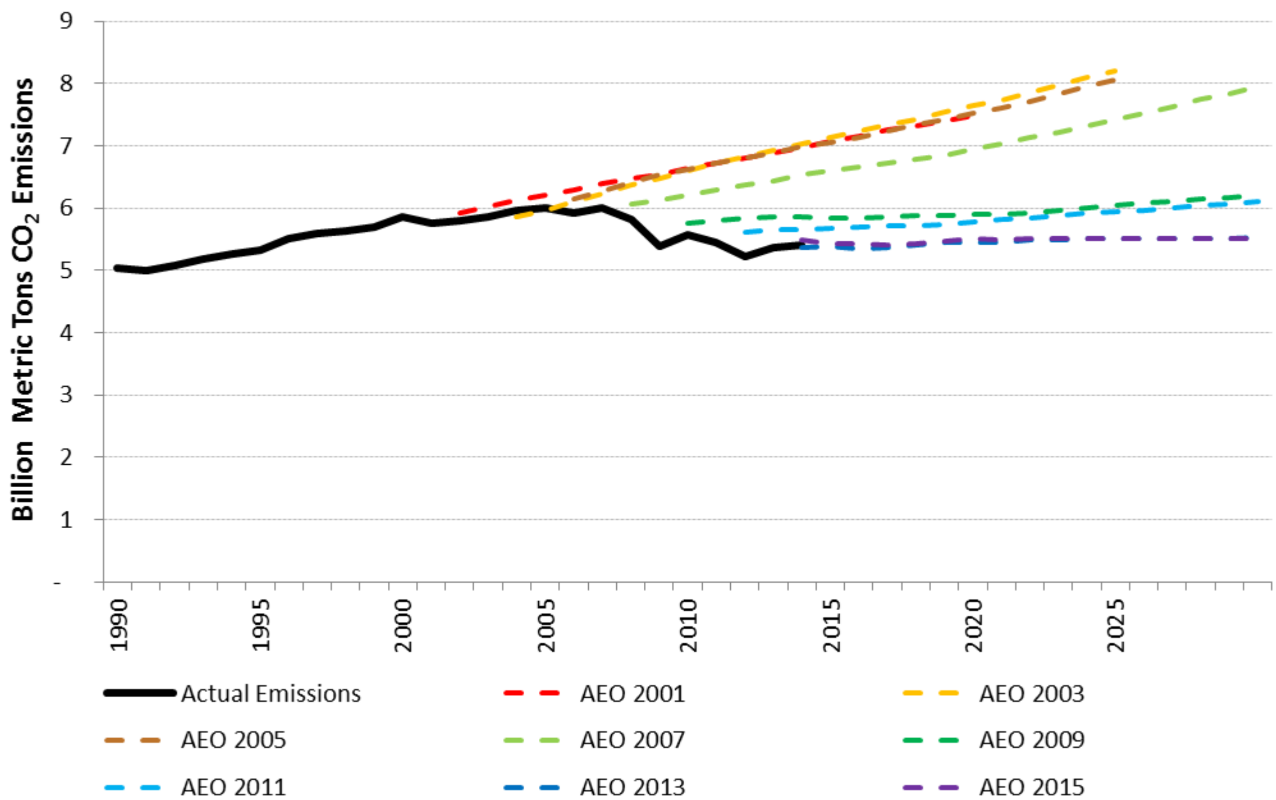
> Projections by EIA are not statements of what will happen but of what might happen, given the assumptions and methodologies used for any particular case. The AEO2015 Reference case projection is a business-as-usual trend estimate, given known technology and technological and demographic trends.... The main cases in AEO2015 generally assume that current laws and regulations are maintained throughout the projections. Thus, the projections provide policy-neutral baselines that can be used to analyze policy initiatives.[10]

Figure 2 compares actual CO_2 emissions between 1990 and 2014 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 1999 projected that CO_2 emissions would be almost 6.9 billion metric tons in 2014, about 23% higher than has been observed. By comparison, the more recent projections (AEO 2013 and AEO 2015) indicate that CO_2 emissions will remain relatively flat over the next decade.

[10] EIA, *Annual Energy Outlook 2015*, April 2015, p. iii.

Figure 2. Actual CO_2 Emissions and Selected Past EIA CO_2 Emission Projections

CO_2 Emissions from Energy Use



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

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

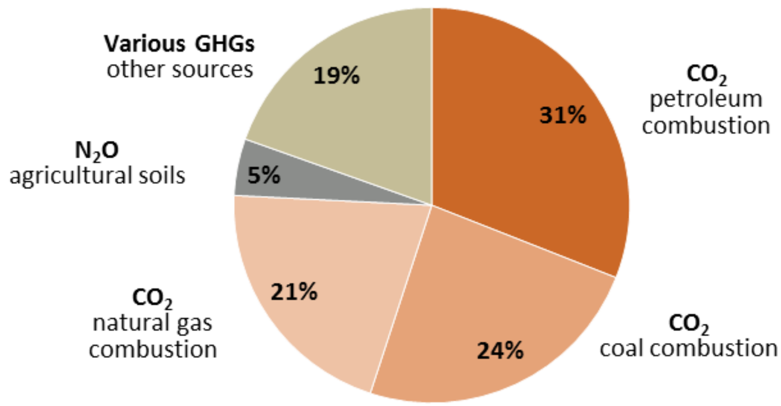
GHG Emission Sources

GHG emissions are generated throughout the United States from millions of discrete sources: power plants, vehicles, households, commercial buildings, agricultural activities (e.g., soils and livestock), and industrial facilities.[11] **Figure 3** 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 76% of total U.S. GHG emissions in 2014. Recent legislative proposals that would address climate change have generally focused on GHG emissions from fossil fuel combustion.

[11] 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 3. U.S GHG Emissions by Source

2014 Data Measured in Metric Tons of CO_2-equivalent



Source: Prepared by CRS; data from EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014*, draft, February 2016, http://epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Notes: N_2O is nitrous oxide. The "Various GHGs – other sources" include methane (CH_4) from landfills, accounting for 3% of total GHG emissions, and four sources that each account for approximately 2% of total GHG emissions: CO_2 from non-energy fuel uses, CH_4 from natural gas systems, CH_4 from livestock, and hydrofluorocarbons from the substitution of ozone-depleting substances. In addition, the following 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.

GHG emissions are typically measured in tons of CO_2-equivalent. 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.

CO_2 Emissions from Fossil Fuel Combustion

Figure 4 illustrates the U.S. CO_2 emission contributions by sector from the combustion of fossil fuels. The largest share of CO_2 emissions in 2015 was from electricity generation (36%). Within the electricity sector, the residential and commercial sectors account for 14% and 13%, respectively, of fossil fuel combustion CO_2 emissions and the industrial sector accounts for 9% of fossil fuel combustion CO_2 emissions (**Figure 4**).[12]

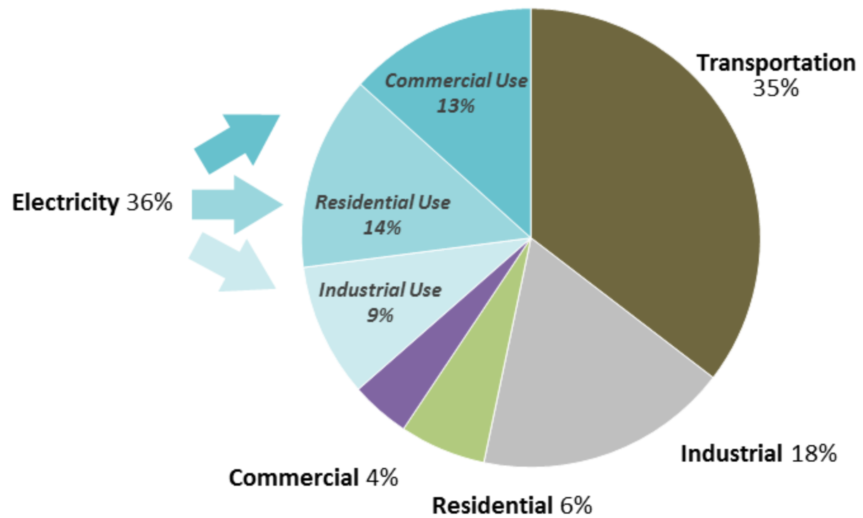
Many GHG emission reduction programs (e.g., the Regional Greenhouse Gas Initiative)[13] and legislative proposals have often focused on CO_2 emissions from the electricity generation sector, due to the sector's GHG emission contribution and the relatively limited number of emission sources. In addition, electric power plants have been measuring and reporting CO_2 emissions to the EPA for multiple decades.

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

[13] See CRS Report R41836, *The Regional Greenhouse Gas Initiative: Lessons Learned and Issues for Congress*, by (name redacted) .

Figure 4. U.S. CO_2 Emissions from Fossil Fuel Consumption by Sector

2015 Data



Source: Prepared by CRS; data from EIA, "U.S. Carbon Dioxide Emissions from Energy Consumption," http://www.eia.gov/environment/data.cfm#summary.

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, which account for less than 1% of CO_2 emissions from fossil fuel combustion.

The data in this figure do not include emissions associated with various processes that may be generated prior to combustion (e.g., fugitive CH_4 emissions from natural gas production). For more details on this issue, see CRS Report R44090, *Life-Cycle Greenhouse Gas Assessment of Coal and Natural Gas in the Power Sector*, by (name redac ted) .

Regulations of GHG Emissions from Vehicles

Light-duty vehicles (cars, SUVs, vans, and pickup trucks) and medium- and heavy-duty vehicles (including buses, heavy trucks of all kinds, and on-road work vehicles) are collectively the largest emitters of GHGs other than power plants. Together, on-road motor vehicles accounted for about 22% of U.S. GHG emissions in 2012. Reducing GHG emissions from this source category is a key component of President Obama's Climate Action Plan.[14]

EPA began to promulgate GHG emission standards for specific vehicles in 2010, using its authority under Section 202 of the Clean Air Act. GHG standards for light-duty vehicles first took effect for Model Year (MY) 2012. Allowable GHG emissions will be gradually reduced each year from MY2012 through MY2025. In MY2025, emissions from new vehicles must average about 50% less per mile than in MY2010. The standards for heavier-duty vehicles began to take effect in MY2014. They will require emission reductions of 6% to 23%, depending on the type of engine and vehicle, when fully implemented in MY2018. A second round of standards, to address MY2021 and later medium- and heavy-duty vehicles, was proposed on June 19, 2015.

For more information, see CRS Report R40506, *Cars, Trucks, and Climate: EPA Regulation of Greenhouse Gases from Mobile Sources*, by -name redacted- and -name redacted- .

[14] See Executive Office of the President, *The President's Climate Action Plan*, 2013, https://www.whitehouse.gov/sites/default/files/image/president27sclimateactionplan.pdf; and CRS Report R43120, *President Obama's Climate Action Plan*, coordinated by (name redacted).

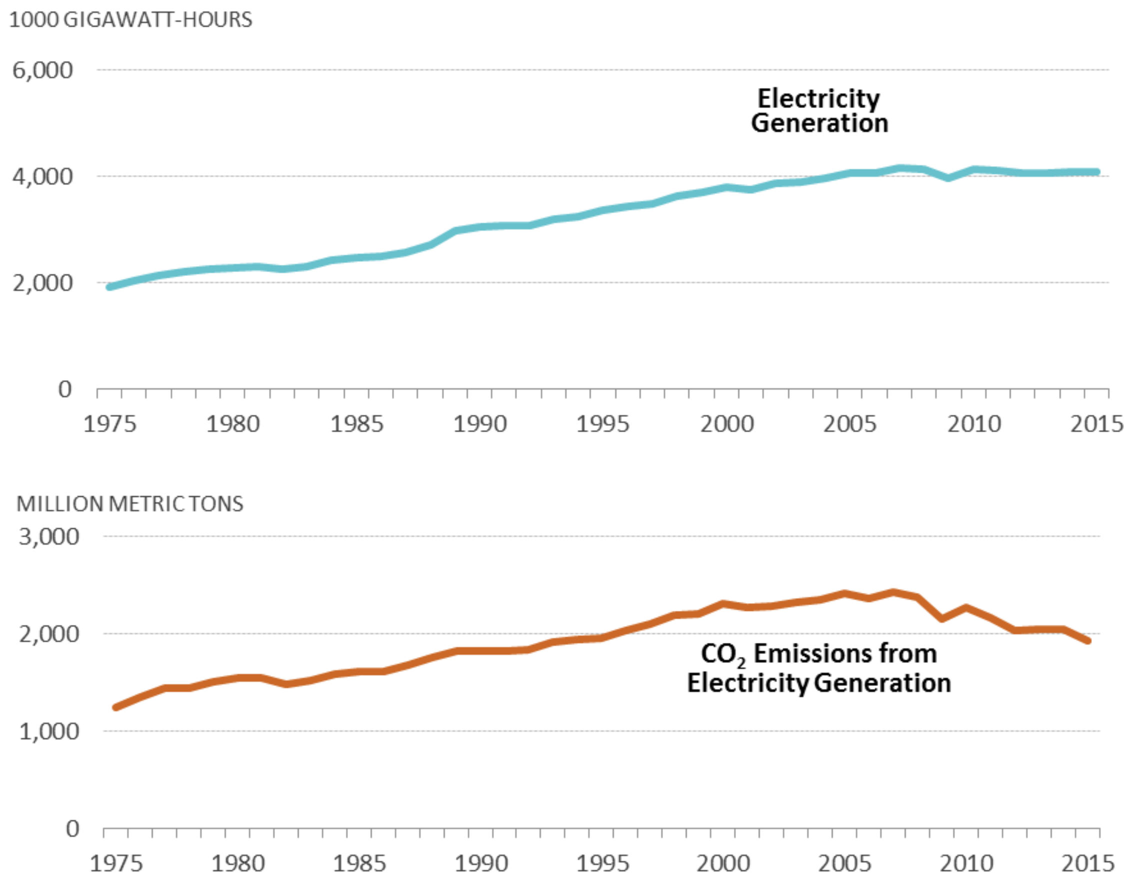
CO_2 Emissions from Electricity Generation

Figure 5 compares U.S. electricity generation with CO_2 emissions from the electricity sector between 1975 and 2015. As the figure illustrates, U.S. electricity generation generally increased between 1975 and 2007 and then decreased in 2008 and 2009. Historically, CO_2 emissions from electricity generation followed a similar course. However, in 2010, these trends decoupled. While electricity generation remained flat after 2010, CO_2 emissions continued a trend of reduction. Thus in 2015, electricity generation was essentially equivalent to generation in 2005, while CO_2 emissions were 19% below 2005 levels.

The decrease in CO_2 emissions in the electricity sector in recent years was likely a result of several factors. The economic downturn in 2008 and 2009 likely played a substantial role in both generation and emission levels. The U.S. gross domestic product (GDP) decreased in both of those years. Historically, annual GDP decreases are a relatively uncommon occurrence: The United States has seen an annual decrease in GDP seven times over the last 50 years. The 2.9% GDP decrease in 2009 was the largest GDP decrease during that timeframe.[15]

[15] Bureau of Economic Analysis, gross domestic product data, http://www.bea.gov/national/index.htm.

Figure 5. Electricity Generation and CO_2 Emissions from U.S. Electricity Sector
1975-2015



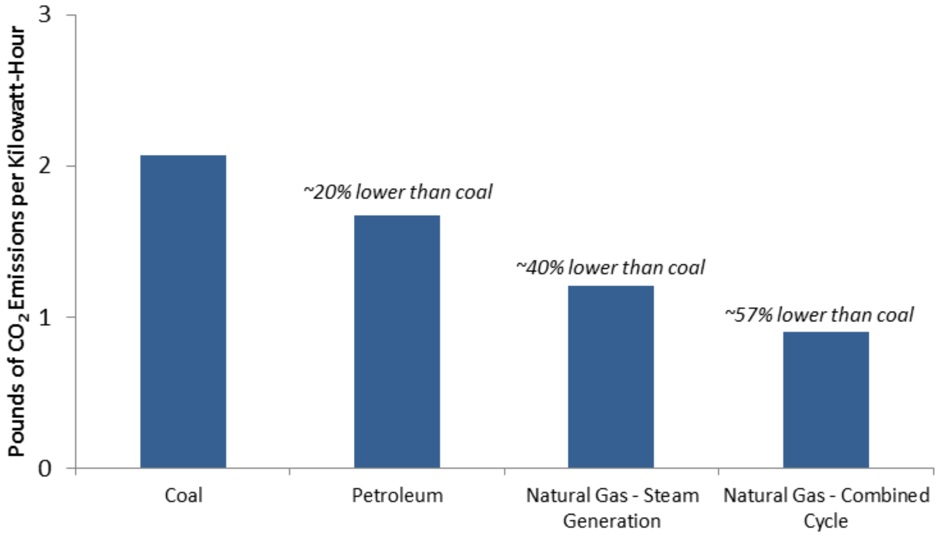
Source: Prepared by CRS; data from EIA, *Monthly Energy Review*, net electricity generation from Table 7.2 and emissions from Table 12.6, http://www.eia.gov/totalenergy/data/monthly/.

Another factor contributing to the recent decrease in CO_2 emissions from electricity generation was the change in the electricity generation portfolio. Electricity is generated from a variety of sources in the United States. Some sources—nuclear, hydropower, and some renewables—directly produce no CO_2 emissions with their electricity generation. Fossil fuels generate different amounts of CO_2 emissions per unit of electricity generated. **Figure 6** illustrates the relative comparison of CO_2 emissions between electricity produced from coal, petroleum, and natural gas. As the figure indicates, petroleum-fired electricity yields approximately 80% of the CO_2 emission of coal-fired electricity per kilowatt-hour of electricity. Natural-gas-fired electricity from a steam generation unit yields approximately 60% of the CO_2 emissions of coal-fired electricity per kilowatt-hour of electricity. Natural-gas-fired electricity from a combined cycle unit yields approximately 43% of the CO_2 emissions of coal-fired electricity per kilowatt-hour of electricity.[16]

[16] For further discussion, see CRS Report R44090, *Life-Cycle Greenhouse Gas Assessment of Coal and Natural Gas in the Power Sector*, by (name redacted) .

Therefore, altering the U.S. electricity generation portfolio would likely have (all else being equal) a considerable impact on emissions from the electricity sector, which in turn, would have a meaningful impact on total U.S. GHG emissions.

Figure 6. Comparison of Fossil Fuels' Carbon Content in Electricity Generation



Source: Prepared by CRS; data from EIA, "How Much Carbon Dioxide Is Produced per Kilowatthour When Generating Electricity with Fossil Fuels?," https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11.

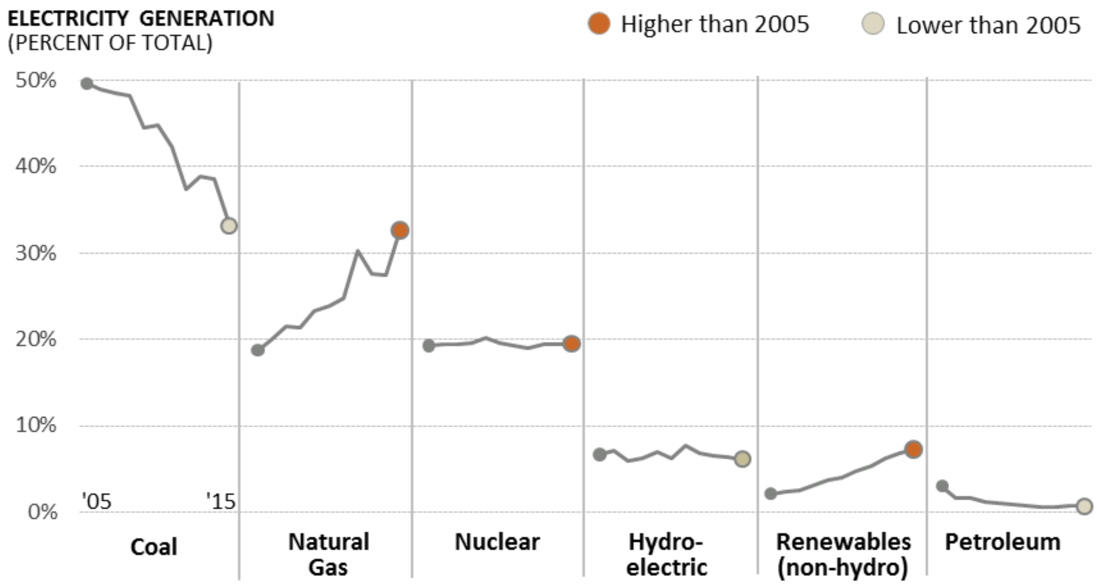
Notes: Carbon content values are derived by multiplying the fuel's CO_2 emission factor by the heat rate of a particular electric generating unit. In this figure, CRS used the coal emission factor for bituminous coal and the petroleum emission factor measure for distillate oil (number 2). Natural gas has only one factor. The heat rates of different electricity unit types can vary substantially. CRS used EIA's average steam generation value for coal, petroleum, and natural gas, as well as the average combined cycle value for natural gas. The above comparison does not account for the so-called life-cycle emissions associated with the energy supply chain. For more information, see CRS Report R44090, *Life-Cycle Greenhouse Gas Assessment of Coal and Natural Gas in the Power Sector*, by (name redacted) .

Figure 7 illustrates the percentage of electricity generated by source between 2005 and 2015. As the figure indicates, the U.S. electricity generation portfolio has changed considerably in recent years. Highlights include:

- Coal: Between 2005 and 2015, coal-fired generation decreased by 33%. Its contribution to total electricity generation decreased from 50% to 33%.
- Natural gas: Between 2005 and 2015, natural-gas-fired generation increased by 75%. Its contribution to total electricity generation increased from 19% to 33%.
- Renewable energy: Between 2005 and 2015, non-hydro renewable energy generation increased by 213%. Its contribution to total electricity generation increased from 2% to 7%.
- Petroleum: Between 2005 and 2015, petroleum-fired generation decreased by 83%. Its contribution to total electricity generation increased from 3% to less than 1%.

Figure 7. Percentage of Total Electricity Generation by Energy Source

2005-2015



Source: Prepared by CRS; data from EIA, *Electric Power Monthly*, Table 1.1, http://www.eia.gov/beta/epm/.

Notes: Renewable sources include wind, utility scale solar, wood fuels, landfill gas, biogenic municipal solid waste, other biomass, and geothermal. Petroleum includes petroleum liquids and petroleum coke.

Several factors likely played a role in these recent changes. Due in large part to technological advances—particularly directional drilling and hydraulic fracturing[17]—U.S. natural gas production increased dramatically (by 33%) between 2005 and 2015.[18] Natural gas production levels reached record levels in 2011 and have increased further each year since. Relatedly, the average annual price of natural gas dropped by almost 50% between 2008 and 2009 and has remained at relatively low levels since that decline.[19] By comparison, coal prices increased by about 11% between 2008 and 2014.[20] This change in relative fuel prices has played a role in altering the economics of power generation (i.e., order of dispatch), leading to some natural gas displacement of coal in particular regions of the country.[21]

Figure 8 provides a more detailed breakdown of the changes in generation from non-hydro renewable energy sources. The vast majority of the increased generation from renewable energy over the past 10 years is due to wind power, which increased 11-fold between 2005 and 2015. Although solar increased 48-fold over that timeframe, the magnitude of wind generation dwarfs solar generation (190 Terawatt-hours of wind in 2015 versus 26 Terawatt-hours of solar). The

[17] Hydraulic fracturing is an industry technique that uses water, sand, and chemicals under pressure to enhance the recovering of natural gas and oil. It has taken on new prominence as it has been applied to tight oil and shale gas formation as an essential method for producing resources from those types of formations. See CRS Report R43148, *An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions*, by (name redacted) and (name redacted)

[18] EIA, "U.S. Dry Natural Gas Production, 1930-2015," http://www.eia.gov/dnav/ng/hist/n9070us2a.htm.

[19] EIA, "U.S. Natural Gas Electric Power Price," http://www.eia.gov/dnav/ng/hist/n3045us3a.htm.

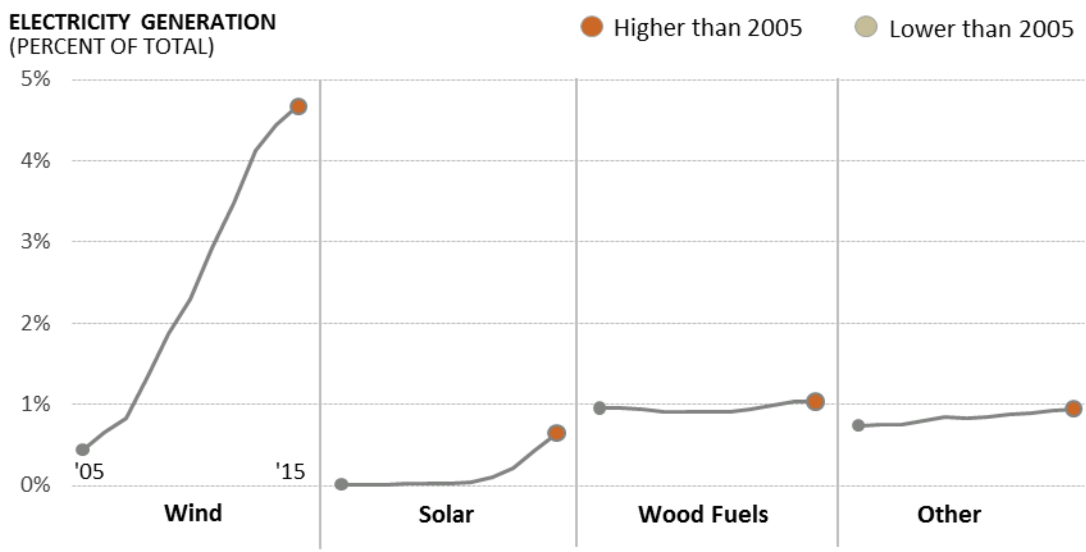
[20] EIA, "Price of Coal Shipments to the Electric Power Sector," http://www.eia.gov/coal/data.cfm#prices.

[21] See for example, EIA, *Fuel Competition in Power Generation and Elasticities of Substitution*, 2012, http://www.eia.gov/analysis/studies/fuelelasticities/.

other sources of renewable energy (e.g., wood fuels and other sources) have remained relatively constant during this timeframe.

Figure 8. Percentage of Total Electricity Generation from Non-Hydro Renewable Energy Sources

2005-2015



Source: Prepared by CRS; data from EIA, *Electric Power Monthly*, Table 1.1A, http://www.eia.gov/beta/epm/.

Notes: Solar generation includes utility-scale solar but not estimates of distributed solar generation. EIA has estimates of distributed solar but only for 2014-2015. Including these estimates would increase the percentage of solar generation in 2014 from 0.4% to 0.7% and in 2015 from 0.6% to 0.9%. The "other" category includes landfill gas, biogenic municipal solid waste, other biomass, and geothermal sources.

Electricity CO_2 Emission Projections and the CPP

As previously discussed, CO_2 emissions from fossil fuel combustion account for the vast majority (76%) of total U.S. GHG emissions, and the electric power sector contributes the largest percentage (36%) of CO_2 emissions from fossil fuel combustion. Therefore, policymakers and stakeholders are paying attention to both recent trends and future projections of CO_2 emissions in the electricity generation sector.

Multiple factors will likely impact CO_2 emission levels from the electricity sector. Some of these factors, identified below in no particular order, are interrelated:

- Economic impacts (e.g., level of GDP growth);
- Prices of fossil fuels—particularly natural gas—and renewable energy sources;
- Electricity generation portfolio (e.g., whether recent trends in coal, natural gas, and renewable energy use continue);
- Federal and/or state policy developments (e.g., CPP implementation, state renewable energy requirements); and
- Improvements in demand-side energy efficiency (e.g., commercial and residential electricity use).

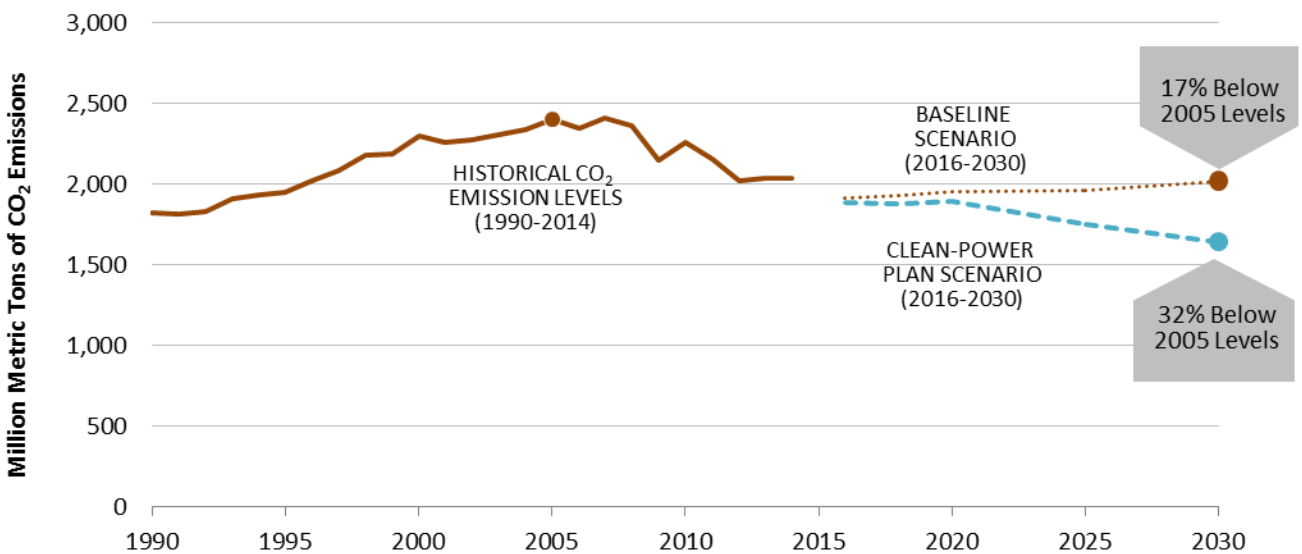
Most, if not all, of these factors are difficult to forecast with precision. In particular, the fate of the CPP is unknown, which raises a question: What impact would the CPP have on CO_2 emissions in the electricity sector?

Although it has been widely reported that the rule would require a 32% reduction in CO_2 emissions from the electricity sector by 2030 compared to 2005 levels, this percentage reduction comes from EPA's modeling of the effects of the rule in conjunction with other factors. The rule establishes uniform national CO_2 emission performance rates—measured in pounds of CO_2 per megawatt-hour of electricity generation—and state-specific CO_2 emission rate and emission targets. Each state determines which measure to use to be in compliance.

Figure 9 compares EPA's projections of CO_2 emissions in the electricity sector resulting from the final rule with historical CO_2 emissions (1990-2014) from the electricity sector and projected emissions under EPA's baseline scenario. This scenario does not include the 2015 renewable energy tax extensions, discussed below. The figure indicates that the final rule would reduce CO_2 emissions in the electricity sector by 32% in 2030 compared to 2005 levels. Under the baseline scenario (i.e., without the CPP), EPA projects a 17% reduction by 2030 compared to 2005 levels. In terms of metric tons, EPA's CPP scenario would reduce an additional 377 million metric tons (or 15 percentage points) of CO_2, compared to EPA's baseline scenario.

Figure 9. CO_2 Emissions from U.S. Electricity Generation

Historical Emissions, EPA Baseline Projection, and EPA Clean Power Plan Projection



Source: Prepared by CRS; historical emissions from EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014*, draft, February 2016; baseline and CPP projections from EPA, Power Sector Modeling, http://www.epa.gov/airmarkets/programs/ipm/cleanpowerplan.html.

Notes: CRS converted EPA's projected emissions from short tons to metric tons. The historical emission levels are included for illustrative purposes only. In its analysis, EPA compared its CO_2 emission projections to a 2005 emission level (2,433 million metric tons) produced from the Emissions & Generation Resource Integrated Database. This 2005 value includes emissions only from the contiguous United States; the historical levels in the figure include all 50 states. However, the CO_2 emissions from Alaska's and Hawaii's electricity sectors generally account for less than 1% of total CO_2 emissions from that sector.

Based on EPA's *Regulatory Impact Analysis*, several factors may explain the emission results in 2030 between the baseline and CPP scenarios:

- Demand-side energy efficiency (DSEE) improvements: States may employ DSEE improvement activities as part of their plans to meet their targets. In its analysis, EPA assumed that DSEE efforts would decrease total electricity generation by 8% in 2030 compared to its baseline projection.[22]
- Coal generation decreases: Compared to EPA's 2030 baseline projection, coal generation is expected to decrease by 22%-23% in 2030.[23]
- Natural gas generation increases: Compared to EPA's 2030 baseline projection, natural gas generation is expected to increase by 5%-18% in 2030.[24]
- Renewable energy generation increases: Compared to EPA's 2030 baseline projection, non-hydro renewable energy generation is expected to increase by 8%-9% in 2030.[25]

Other organizations used models to compare baseline scenarios with various CPP scenarios. **Table 1** lists the CO_2 emission projections from these groups and EPA. Some of these groups produced multiple projections, employing different assumptions of future activities: CPP implementation options (e.g., whether states engaged in emissions trading) and levels of energy efficiency improvements, among others. Only one of the models (National Renewable Energy Laboratory) included the 2015 renewable energy tax extensions, discussed below. The modeling results in **Table 1** indicate that the CPP would have a substantial impact on future CO_2 emission levels from electricity generation.

Table 1. Comparison of Selected Clean Power Plan and 2030 Baseline Projections

Million Metric Tons of CO_2 Emissions

Modeling Group	Baseline: 2030 CO_2 Emissions	% Below 2005 Levels	CPP Scenario(s): 2030 CO_2 Emissions	% Below 2005 Levels
EPA	2,021	16%	1,644	32%
M.J. Bradley & Associates	1,997	17%	1,783-1,902	26%-34%
Center for Strategic and International Studies/Rhodium Group	2,174	10%	1,570–1,595	34%-35%
National Economic Research Associates	2,063	14%	1,449–1,580	34%-40%
National Renewable Energy Laboratory	Not included	Not included	1,448–1,556	32%-36%

Source: EPA data from the agency's Power Sector Modeling, http://www.epa.gov/airmarkets/programs/ipm/cleanpowerplan.html; M.J. Bradley & Associates data from "EPA's Clean Power Plan: Summary of IPM Modeling

[22] EPA, *Regulatory Impact Analysis for the Clean Power Plan Final Rule*, August 2015 (hereinafter RIA), http://www2.epa.gov/cleanpowerplan/clean-power-plan-final-rule-regulatory-impact-analysis.

[23] EPA, RIA, Table 3-11. The range reflects the different compliance options in EPA's model: rate-based and mass-based approaches.

[24] Ibid.

[25] Ibid.

Results," January 2016, http://www.mjbradley.com/reports/modeling-analysis-epas-clean-power-plan; Center for Strategic and International Studies/Rhodium Group data from "Assessing the Final Clean Power Plan: Emissions Outcomes," January 2016, http://rhg.com/wp-content/uploads/2016/01/RHG_ENR_AssessingCleanPowerPlan_Emissions_Jan5_2016.pdf; National Economic Research Associates data from "Energy and Consumer Impacts of EPA's Clean Power Plan," November 2015, http://www.nera.com/publications/archive/2015/energy-and-consumer-impacts-of-epas-clean-power-plan.html (and personal correspondence with authors for additional data); National Renewable Energy Laboratory data from *Impacts of Federal Tax Credit Extensions on Renewable Deployment and Power Sector Emissions*, February 2016, http://www.nrel.gov/docs/fy16osti/65571.pdf (and personal correspondence with report authors).

Notes: The groups in the table used different values for 2005 emission levels, but the differences were minimal. The percentage reductions in the table are based on the specific group's emission level in 2005.

If the CPP is not implemented, will existing policies and trends in electricity generation continue to reduce CO_2 emissions? A recent development in renewable energy policy would likely have some impact on CO_2 emission levels, regardless of CPP implementation. On December 18, 2015, the President signed into law the Consolidated Appropriations Act, 2016 (P.L. 114-113). The act, among other provisions, extended and modified the production tax credit (PTC) and the investment tax credit (ITC) for specific renewable energy technologies.[26] Prior to the December 2015 development, the PTC had expired and the ITC was scheduled to expire at the end of 2016.

The National Renewable Energy Laboratory (NREL) study, listed in **Table 1**, was the only model to include both CPP implementation and the PTC/ITC renewable energy tax extensions in its CO_2 emissions projections. The NREL results, which are illustrated in **Figure 10**, may be informative to policymakers.

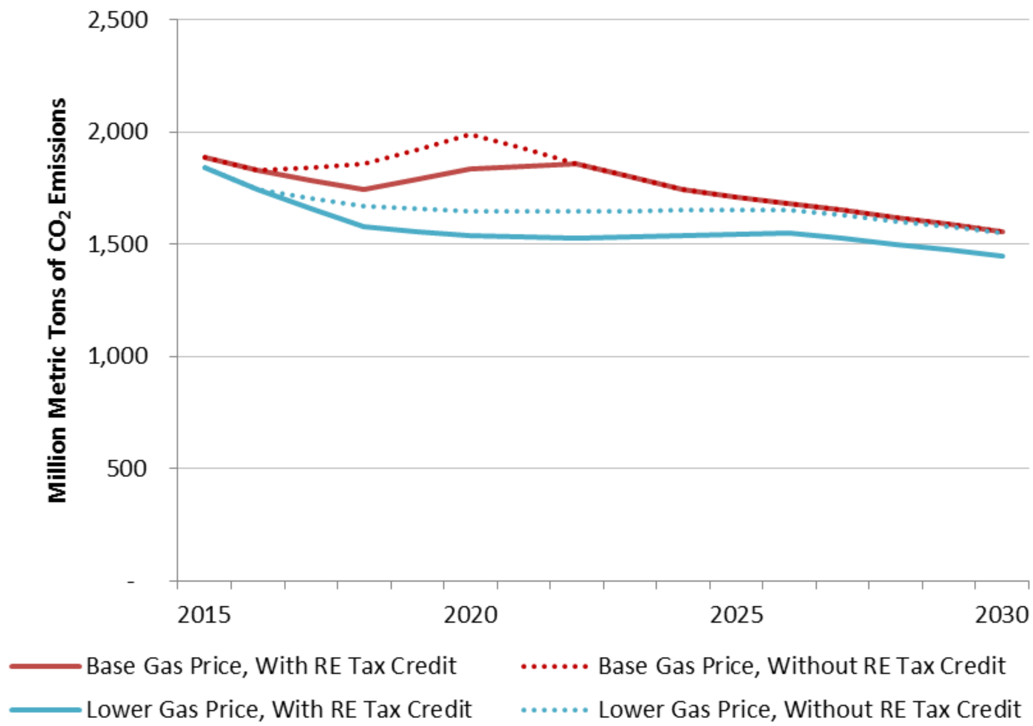
As the figure indicates, the long-term (i.e., 2030) annual CO_2 emissions appear to be influenced by both the price of natural gas and renewable energy tax credit extensions. The renewable energy tax extension scenario produces lower CO_2 emissions in 2030, but only for the lower natural gas price case (solid blue line). Under the baseline gas price scenarios (solid and dotted red lines), the renewable energy tax credit extensions yield lower annual CO_2 emissions in the early years (i.e., 2016-2021) but nearly identical CO_2 emissions between 2022 and 2030. The report stated that the lower natural gas price scenario would lead to further displacement of coal by natural gas.

Each of the NREL report scenarios included CPP implementation. Because the NREL analysis included both the CPP implementation and tax extensions in its modeled scenarios, it is uncertain which policy driver is having the greater impact on CO_2 emissions in the electric power sector.

[26] See National Renewable Energy Laboratory, *Impacts of Federal Tax Credit Extensions on Renewable Deployment and Power Sector Emissions*, February 2016, http://www.nrel.gov/docs/fy16osti/65571.pdf.

Figure 10. NREL CO_2 Emission Projections for Electric Power Sector

Comparison of Four Scenarios



Source: Reproduced by CRS with data from the National Renewable Energy Laboratory, *Impacts of Federal Tax Credit Extensions on Renewable Deployment and Power Sector Emissions*, February 2016, http://www.nrel.gov/docs/fy16osti/65571.pdf (and personal correspondence with report authors).

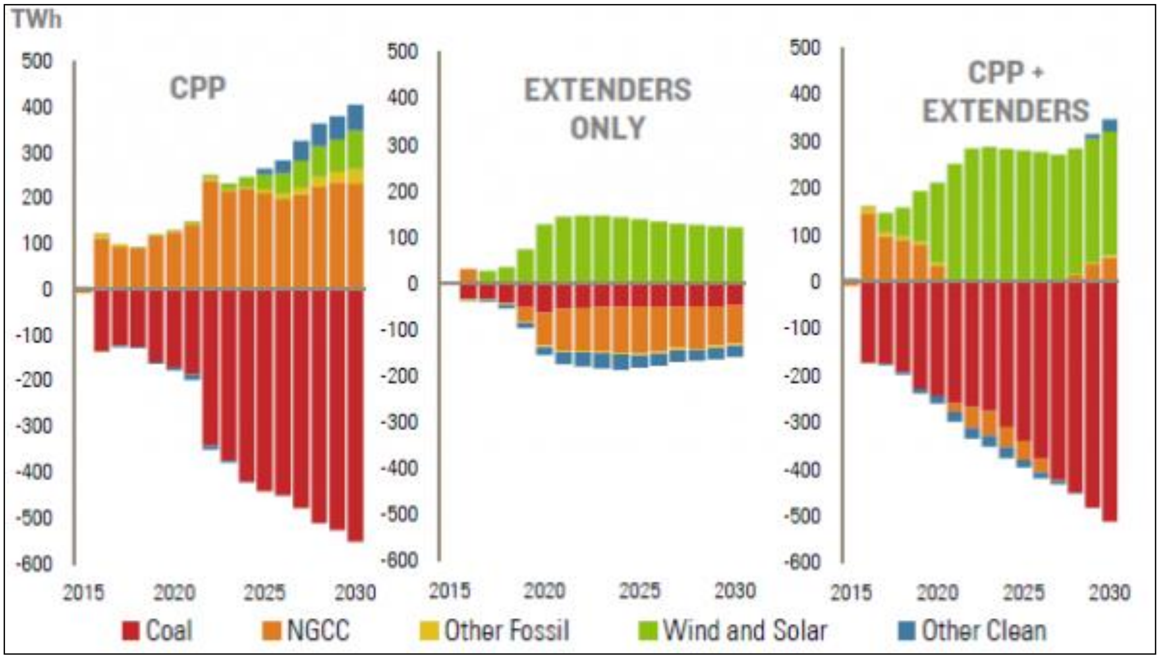
Notes: Each of the four scenarios assumes implementation of the CPP. For more details on the four scenarios and associated assumptions, see the source document.

CRS is not aware of a study that has projected CO_2 emissions in the electric power sector using the renewable energy tax credits but not the CPP. The Rhodium Group prepared a separate analysis from the one in **Table 1** that compares the changes in electricity generation by fuel source between three scenarios: CPP only, renewable energy tax extensions only, and CPP and renewable energy tax extensions.[27] Although this analysis does not address changes in CO_2 emissions, the results of the comparison may be informative and are depicted in **Figure 11**.

[27] John Larsen et al., Rhodium Group, "What Happens to Renewable Energy without the Clean Power Plan," February 2016, http://rhg.com/notes/renewable-energy-without-the-clean-power-plan.

Figure 11. Comparison of Electricity Generation Changes by Source

Rhodium Group Analysis



Source: Reproduced from John Larsen et al., Rhodium Group, "What Happens to Renewable Energy Without the Clean Power Plan," February 2016, http://rhg.com/notes/renewable-energy-without-the-clean-power-plan.

Notes: The above scenarios involve (1) the Clean Power Plan (CPP) only; (2) the renewable energy tax credit extensions (PTC and ITC) only; and (3) the CPP and the renewable energy tax credit extensions combined.

The study found varied results in electricity generation depending on the scenario:

- CPP only: This scenario includes CPP implementation but not the enacted renewable energy tax extensions. The study projected that increased natural gas generation would displace coal and that renewable energy generation increases would be relatively modest.
- Extenders only: This scenario assumes that the CPP would not be implemented and the enacted renewable energy tax extension would remain in place. The study projected that renewable energy would displace natural gas, and coal generation would decrease at a relatively smaller scale than the "CPP only" scenario.
- CPP + extenders: This scenario assumes that both the tax credits and the CPP are included. The study projected that comparatively larger increases in renewable energy generation would displace coal, with less change in natural gas generation.

The authors point out that changes in their model assumptions substantially alter the model results. In particular, the study found that assumptions of natural gas prices and renewable energy costs can have considerable impacts on the generation changes in renewable energy, natural gas, and coal.[28]

[28] See Figure 3 in John Larsen et al., Rhodium Group, "What Happens to Renewable Energy Without the Clean Power Plan," February 2016, http://rhg.com/notes/renewable-energy-without-the-clean-power-plan.

Concluding Observations

Recent international negotiations and domestic policy developments have increased interest in current and projected U.S. GHG emission levels. In the context of international climate change negotiations, President Obama has announced, on separate occasions, U.S. GHG emission reduction goals for both 2020 and 2025. Whether the United States ultimately achieves its goals would likely depend, to some degree, on CO_2 emissions from power plants.

Historically, CO_2 emissions from electricity generation have followed an upward course similar to electricity generation levels. However, in 2010, their courses diverged. While electricity generation remained flat after 2010, CO_2 emissions continued a trend of reduction. Thus in 2015, electricity generation was essentially equivalent to generation in 2005, while CO_2 emissions were 19% below 2005 levels.

Multiple factors generally impact CO_2 emission levels from the electric power sector. Recent changes in the U.S. electricity generation portfolio between 2005 and 2015 played a key role:

- Coal's contribution to total electricity generation decreased from 50% to 33%;
- Natural gas's contribution to total electricity generation increased from 19% to 33%; and
- Renewable energy's contribution to total electricity generation increased from 2% to 7%.

If these recent trends in the electric power sector continue, CO_2 emissions in that sector may continue to decrease. Assuming this were to occur, some might question the importance of the CPP in terms of meeting U.S. GHG emission goals (e.g., 26%-28% below 2005 levels by 2025).

Each of the CO_2 emission models cited in this report indicates that the CPP would have a substantial impact on future CO_2 emission levels from the electric power sector. Under the models' baseline scenarios, power sector CO_2 emissions in 2030 would decrease by 10% to 17% compared to 2005 levels. Under the models' CPP implementation scenarios, power sector CO_2 emissions in 2030 would decrease by 26% to 40% compared to 2005 levels.

However, this comparison is problematic, because none of the models' baseline scenarios included the December 2015 renewable energy tax extensions. This development adds further uncertainty to the analysis. The renewable energy tax extensions will likely impact the electricity generation portfolio (compared to baseline), but at least one analysis suggests that the extensions would not be a substitute for CPP implementation in terms of CO_2 emission reductions.

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