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U.S. Energy-Related Carbon Dioxide Emissions, 2015

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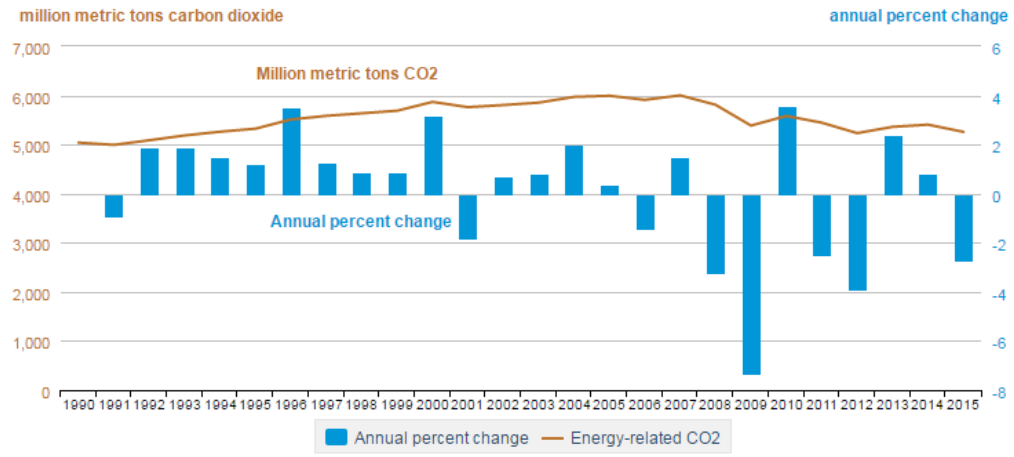
U.S. Energy-Related Carbon Dioxide Emissions Decreased 2.7% in 2015

- Energy-related carbon dioxide (CO2) emissions decreased by 146 million metric tons (MMmt), from 5,405 MMmt in 2014 to 5,259 MMmt in 2015.
- This decline occurred despite growth in real gross domestic product (GDP) of 2.6% as other factors more than offset the growth in GDP. These factors included:
    - A decline in the carbon intensity of the energy supply (CO2/British thermal units [Btu]) of 1.8%; and
    - A 3.4% decline in energy intensity (Btu/GDP).
- With GDP growth of 2.6% and the overall carbon intensity of the economy (CO2/GDP) declining by about 5.2%, energy-related CO2 declined by 2.7%.
- Energy-related CO2 emissions in 2015 were about 12% below 2005 levels.
- Emissions have declined in 6 out of the past 10 years.

Figure 1. Energy-related carbon dioxide emissions, 1990-2015



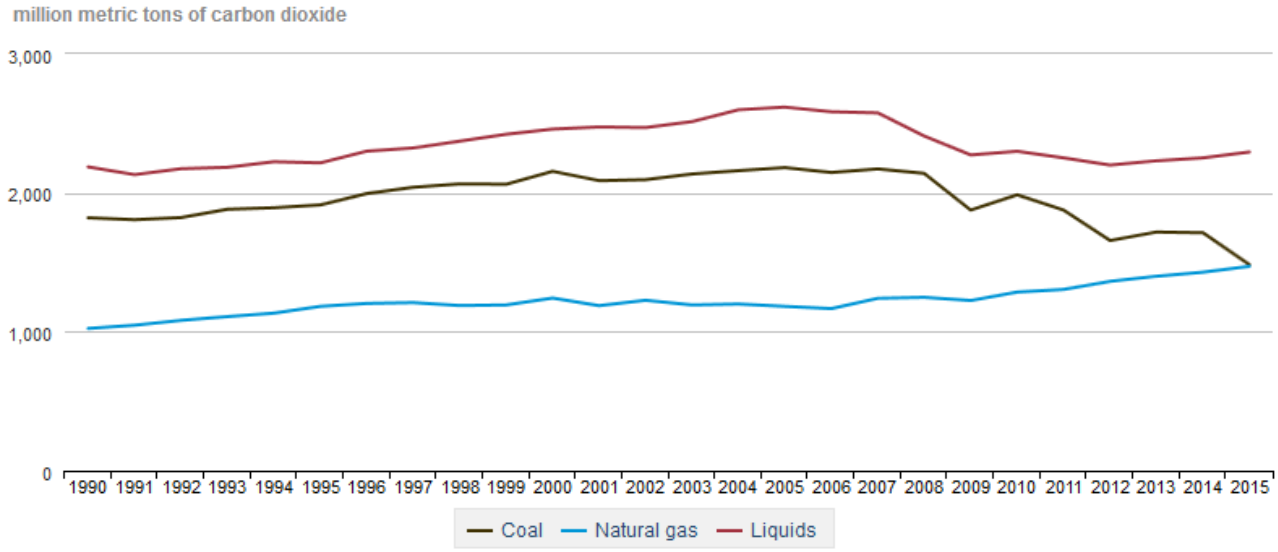
Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.1 Carbon dioxide emissions from energy consumption by source.

Note: Unless otherwise indicated, all data in this analysis refer to the U.S. Energy Information Administration's (EIA) October 2016 *Monthly Energy Review*. Because of differing coverage and data vintage, percent changes may differ slightly with other EIA publications.

Natural gas carbon dioxide emissions almost matched those from coal in 2015

- CO2 emissions from petroleum and other liquids, which have been the largest source of energy-related CO2 in recent decades, plateaued from 2004 to 2007, generally decreased through 2012, and increased slightly thereafter.
- Since the 2007–09 recession, coal CO2 emissions have also generally declined. Although total coal CO2 emissions are below those from petroleum and other liquids, more CO2 is being released per Btu of energy. The decline in coal CO2 emissions has contributed to a lower carbon intensity of U.S. energy consumption and kept emissions below pre-recession levels.
- Natural gas CO2 emissions have increased since 2009, as the natural gas share of electricity generation has grown at the expense of coal, partially offsetting the decline in energy-related CO2 emissions from petroleum and other liquids and coal. Natural gas CO2 emissions were still slightly lower than those from coal in 2015. However, natural gas produces more energy for the same amount of emissions as coal—contributing to the 2015 decline in total emissions.

Figure 2. Energy-related carbon dioxide emissions by fuel, 1990-2015

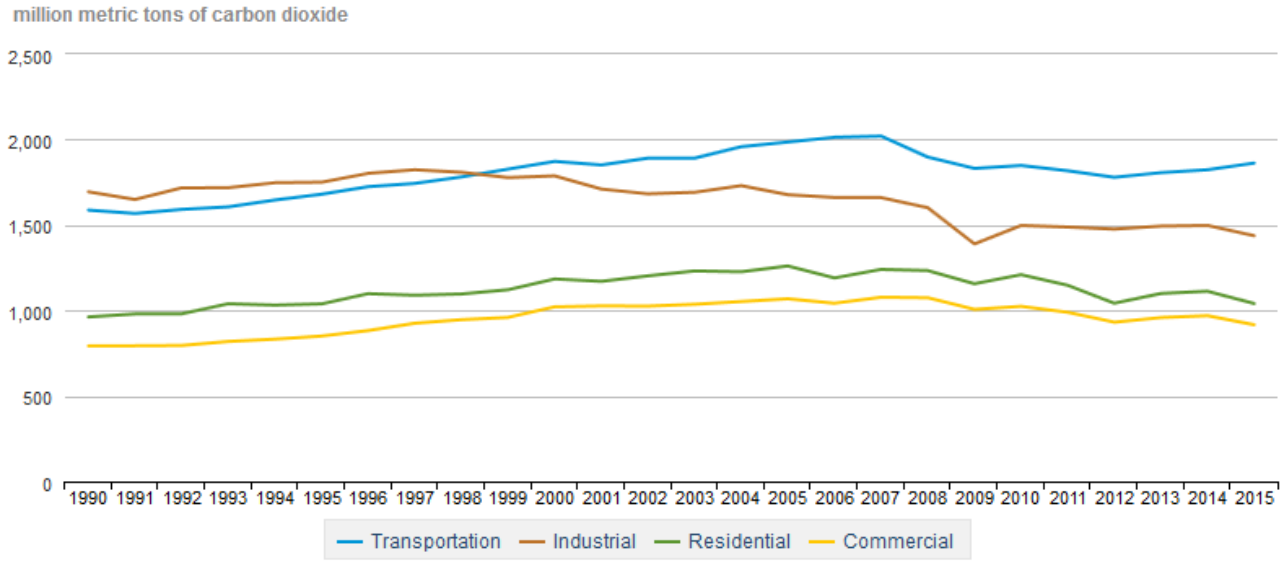


Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.1 Carbon dioxide emissions from energy consumption by source.

Of the four end-use sectors, only transportation emissions increased in 2015

- Since the late 1990s, the transportation sector has produced the most CO2 emissions. These emissions were highest in 2007, prior to the recession, and have not returned to those levels, although they have increased since 2012.
- The industrial sector, which was the largest source of CO2 emissions throughout most of the 1990s, has experienced declining emissions, with further declines occurring in 2015.
- In 2015, the difference in emissions between the transportation and industrial sectors widened as transportation sector CO2 emissions increased while industrial sector CO2 emissions declined.
- Emissions from the residential and commercial sectors, known collectively as the *building sector*, are dominated by indirect emissions from electricity use. These emissions declined about 5.4% in 2015.
- Direct building sector CO2 emissions—primarily from heating—decreased 7.4% in 2015.

Figure 3. Energy-related carbon dioxide by end-use sectors, 1990-2015



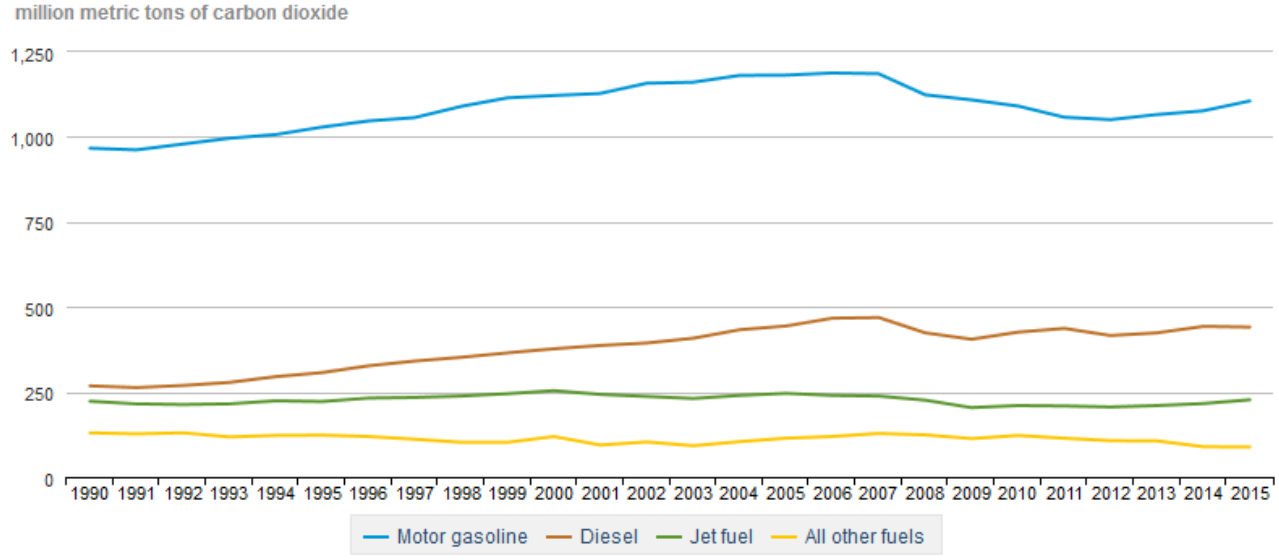
Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.2 Carbon dioxide emissions from energy consumption: residential sector. Table 12.3 Carbon dioxide emissions from energy consumption: commercial sector. Table 12.4 Carbon dioxide emissions from energy consumption: industrial sector. Table 12.5 Carbon dioxide emissions from energy consumption: transportation sector.

The 2015 increase in energy-related carbon dioxide emissions from the transportation sector was led by motor gasoline

The 28% decrease in gasoline prices (in nominal dollars) from 2014 to 2015, along with the continued economic recovery, led to higher fuel consumption. Transportation-related CO2 emissions increased by 38 million metric tons (MMmt) (2.1%) in 2015.

- Motor gasoline accounted for 77% of the 38 MMmt increase in the transportation sector—30 MMmt, an increase of 2.8% from 2014 levels.
- Emissions from jet fuel, increased by about 5% (11 MMmt).
- Diesel fuel emissions, on the other hand, declined by 0.4% between 2014 and 2015

Figure 4. Transportation-related carbon dioxide emissions by fuel, 1990-2015



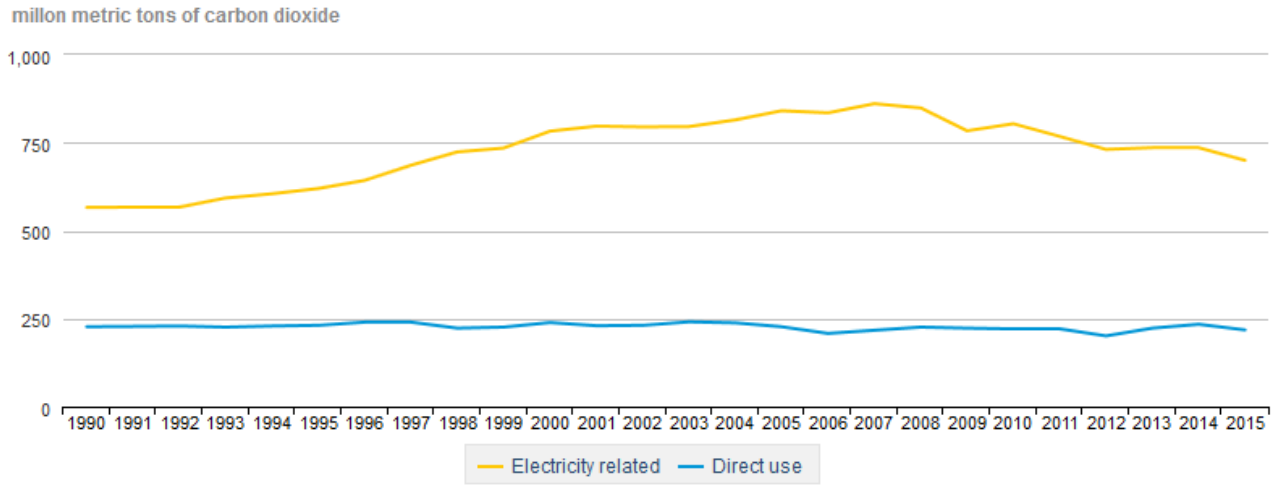
Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.5 Carbon dioxide emissions from energy consumption: transportation sector.

Commercial sector energy-related carbon dioxide emissions declined in 2015

Commercial sector CO2 emissions declined by 53 MMmt (5.4%) in 2015, accounting for 36% of the total decrease in CO2 emissions.

- Indirect CO2 emissions from the use of electricity in the commercial sector decreased by 5.0% (37 MMmt) in 2015, which was 69% of the sector's total decrease.
- Direct CO2 emissions decreased 7% (16 MMmt) in 2015, accounting for the remaining 31% of the total commercial sector decrease.

Figure 5. Commercial sector energy-related carbon dioxide emissions, 1990-2015



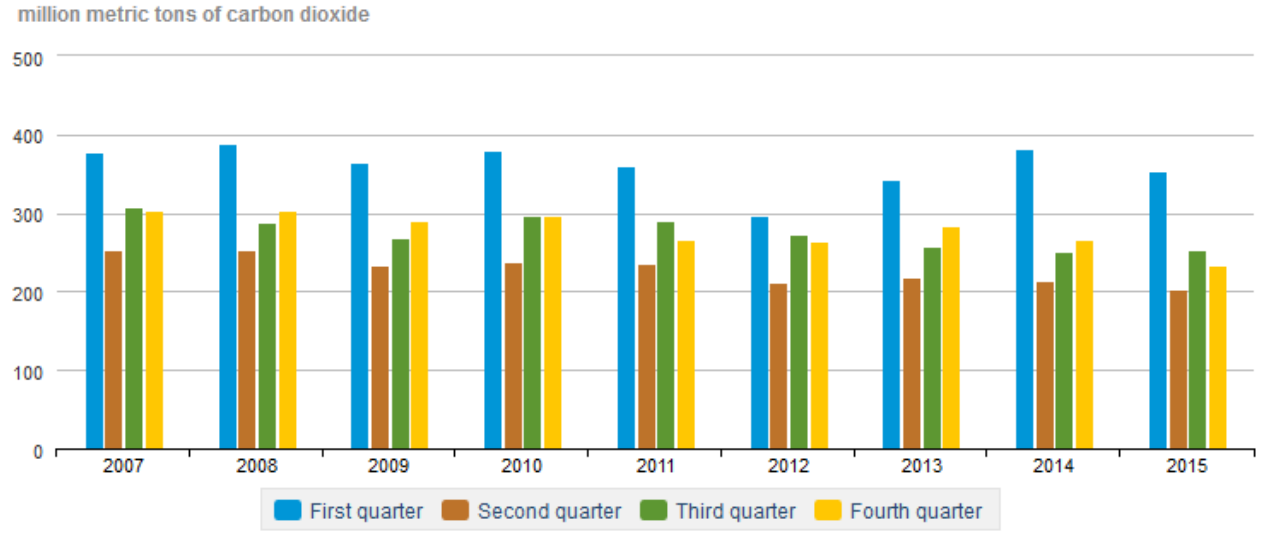
Sources: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.3 Carbon dioxide emissions from energy consumption: commercial sector.

Residential energy-related carbon dioxide emissions were lower in the last quarter of 2015 compared with recent years

Both 2012 and 2015 were warm years; however 2012 was very warm in the first quarter, 20% above normal as measured in heating degree days (HDD). While warmer than the first quarter of 2014, the first quarter of 2015 was close to normal. The last quarter of 2015 was particularly warm (also 20% warmer), and CO2 emissions reflected the lower use of fuel for heating.

- Residential CO2 emissions in the second quarter of 2015 were lower than in recent years. The second quarter tends to be less influenced by weather than the first quarter and would likely reflect the decline in the carbon intensity of electricity generation.
- The third quarter is the warmest time of year. Third-quarter CO2 emissions have generally been declining since 2010—helped by the decline in the carbon intensity of electricity generation.
- Residential sector CO2 emissions declined by 72 MMmt in 2015.

Figure 6. Residential energy-related carbon dioxide emissions by quarter, 2007-15



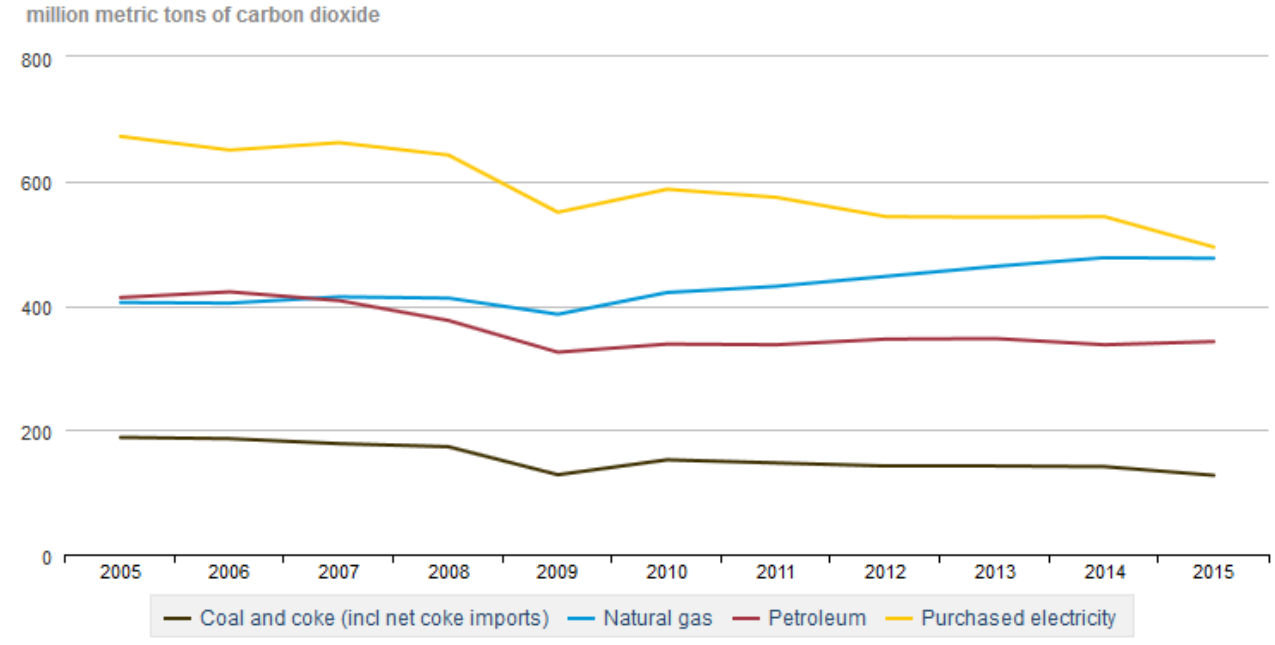
Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.2 Carbon dioxide emissions from energy consumption: residential sector

Industrial sector energy-related carbon dioxide emissions declined from 2014 to 2015

The industrial sector's CO2 emissions, which fell by 4% (60 MMmt) in 2015, have remained essentially flat in recent years despite increasing output. Continuing growth in less energy-intensive output helped to stabilize emissions.

- In 2010, CO2 emissions from all industrial fuel sources increased as the economy recovered from the recession.
- Industrial CO2 emissions from electricity and coal declined most years from 2011 to 2015.
- Petroleum CO2 emissions were relatively flat in recent years.
- Natural gas CO2 emissions rose every year since 2009, except 2015 when emissions declined slightly (0.3%). Because it is the least carbon-intensive fossil fuel, natural gas use has mitigated overall CO2 emissions growth.

Figure 7. Carbon dioxide emissions from industrial fuels, 2005-15



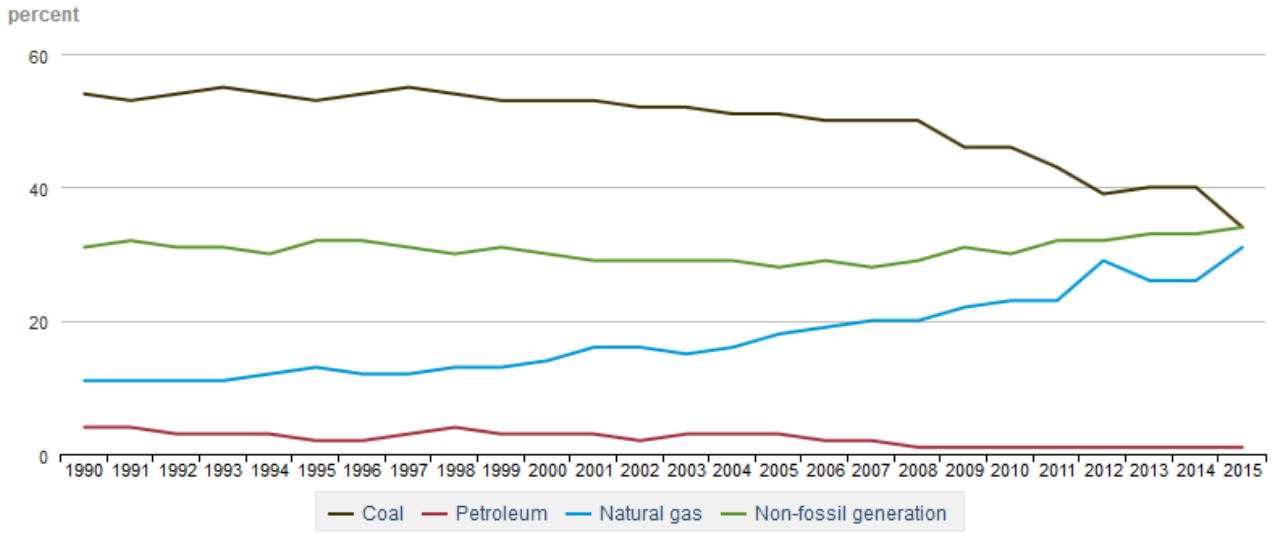
Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.4 Carbon dioxide emissions from energy consumption: industrial sector

The increasing share of non-fossil fuel electricity generation has helped lower the carbon intensity of electricity supply

The trend of declining coal-fired electricity generation in the power sector and increasing non-fossil and natural gas-fired generation continued in 2015.

- Coal's share of total electricity generation in the power sector fell from 54% in 1990 to 34% in 2015.
- The non-fossil electricity generation share, including both nuclear and renewables, in 2015 equaled that of coal at 34% in 2015.
- The natural gas share of electricity generation grew from approximately 11% in 1990 to 29% in 2012, and to 31% in 2015.

Figure 8. Share of three fossil fuels and of non-fossil fuel generation, 1990-2015



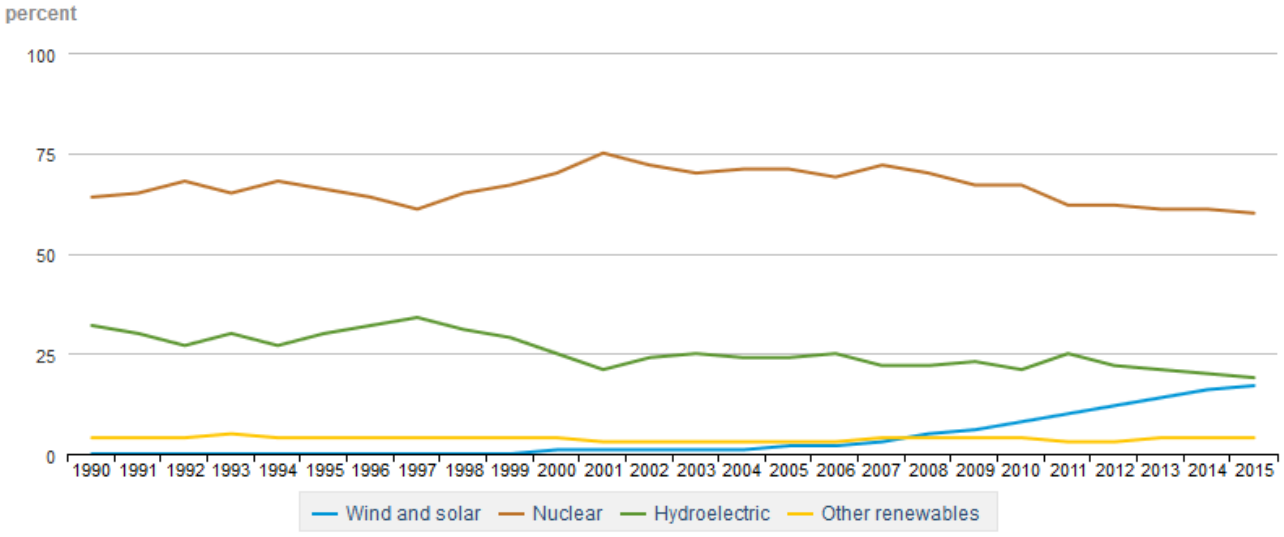
Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review* , Table 7.2b Electricity net generation: electric power sector. From 2004 to 2015, includes an estimate of distributed solar generation from the National Energy Modeling System, Table 16. Renewable Energy Generating Capacity and Generation.

Growth in wind and solar electricity generation has supported the decreasing carbon intensity of the electricity supply

Although nuclear power remains the dominant source of non-fossil electricity generation, growth in wind and solar generation since 2008 has also contributed to a decline in the carbon intensity of electricity generation.

- The nuclear share of non-fossil electricity generation has generally declined since reaching 75% in 2001.
- Hydropower, which historically has been the largest source of renewable electricity generation, has also lost share, falling from 34% of non-fossil fuel generation in 1997 to 19% in 2015.
- Wind and solar (combined) accounted for about 17% of non-fossil electricity generation in 2015 after rising from less than 1% in 2000 to 2% in 2005.
- Other renewables such as biomass have remained at about a 4% share.
- In 2015, non-hydro renewable generation exceeded hydropower generation.

Figure 9. Share of non-carbon generation by source, 1990-2015



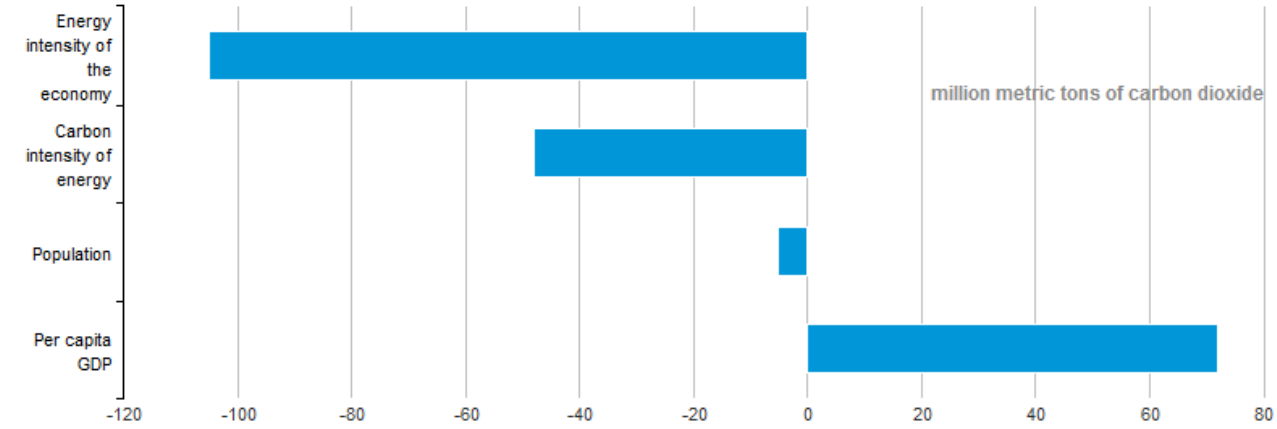
Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 7.2b Electricity net generation: electric power sector. From 2004 to 2015, includes an estimate of distributed solar generation from the National Energy Modeling System, Table 16. Renewable Energy Generating Capacity and Generation.

The decrease in energy-related carbon dioxide emissions in 2015 mainly reflected a decline in energy intensity

In 2015, the energy intensity of the U.S. economy declined by 3.4%. Over the previous decade, the average annual decline was 1.5%. Structural changes in the economy and weather fluctuations that affect energy use for heating and air conditioning can affect annual changes in energy intensity. CO2 emissions were 105 MMmt lower in 2015 than they would have been if energy intensity had declined by only 1.5% in 2015.

- A faster decline in carbon intensity—which fell by 1.8% in 2015 versus an average decline over 2005–14 of 0.9%–subtracted about 48 MMmt of CO2.
- Population growth of 0.7% —slightly below the 0.8% average over the previous decade–put downward pressure on CO2 emissions–growth resulting in a 5 MMmt decline in CO2 emissions compared with the 2015–14 trend.
- Growth in GDP per capita put upward pressure on CO2 emissions, adding about 72 MMmt as compared to the trend.
- The net effect for 2015 was CO2 emissions that were about 86 MMmt lower than had components of the Kaya energy/carbon decomposition (shown in Figure 10) matched their trend rates of change over 2005–14.

Figure 10. Changes in emissions attributed to key drivers from 2014 to 2015 as compared to the trend from the prior decade



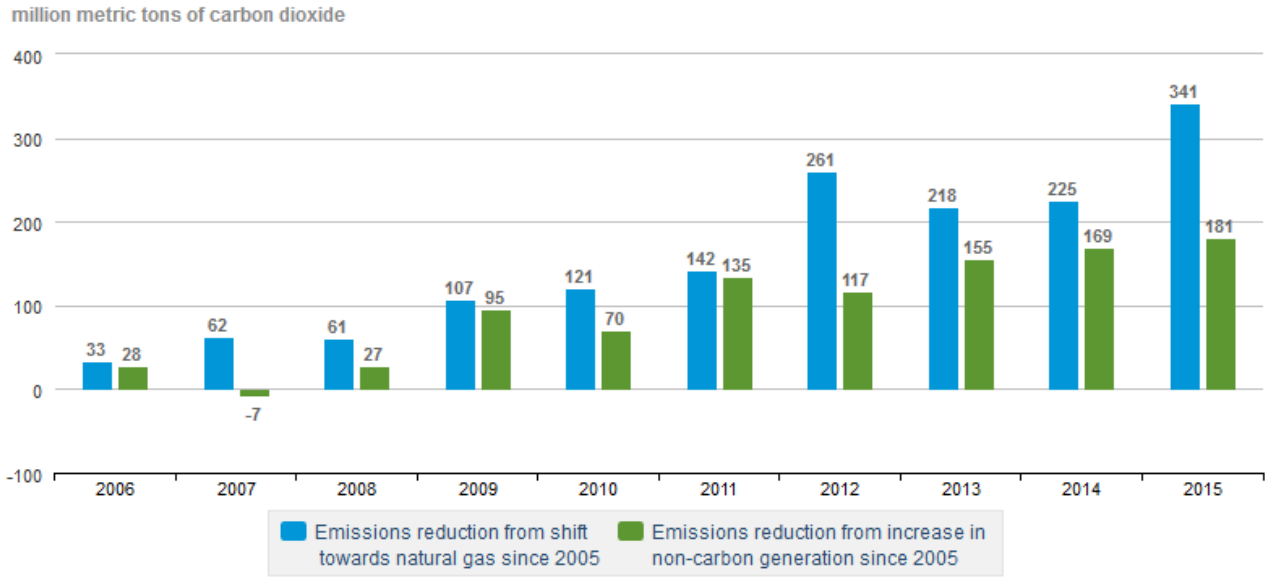
Sources: U.S. Energy Information Administration, October 2016 Monthly Energy Review, Table 12.1 Carbon dioxide emissions from energy consumption by source.
Bureau of economic analysis, *Current-Dollar and "Real" Gross Domestic Product.*
Bureaus of Census *U.S. Population 2014.*

Increased use of natural gas and the growth in non-carbon generation has contributed to the decline in electric power sector* carbon intensity since 2005

- Two basic factors contributed to lower electric power sector carbon intensity (CO2/kWh) since 2005: (1) substitution of the less-carbon-intensive and more efficient combined-cycle natural gas generation for coal-fired generation, and (2) growth in non-carbon generation, especially wind and solar.
- Between 2005 and 2015, CO2 emissions dropped by a cumulative 2,533 MMmt as a result of these two factors.
- As a result, although electricity generation grew by 1% from 2005 to 2015, related CO2 emissions fell by 21% over that period.
- From 2005 to 2015, fossil-fuel electricity generation declined by about 6%, while non-fossil (non-carbon) electricity generation rose by 20%.

* Note: includes data on distributed generation from U.S. Energy Information Administration, Monthly Energy Review, Table 10.6 Solar electricity net generation, October 2016.

Figure 11. Electric power sector carbon dioxide savings from changes in the electricity generation mix since 2005



Source: U.S. Energy Information Administration, *October 2016 Monthly Energy Review*, Table 12.6 Carbon dioxide emissions from energy consumption: electric power sector
Table 7.2b Electricity net generation: electric power sector
From 2004 to 2015, includes an estimate of distributed solar generation from the National Energy Modeling System,
Table 16. Renewable Energy Generating Capacity and Generation,

Table 1. Weighted factors for electricity and primary energy by sector for the energy-related carbon dioxide emissions percent change from 2014 to 2015

	Electricity change 2014-15	Change in carbon intensity of electricity 2014-15	Electricity share of sector CO2 2015	Change in electricity-weighted CO2 2014-15
Residential	-0.8%	-5.1%	69.3%	-4.1%
Commercial	0.2%	-5.1%	76.3%	-3.8%
Industrial	-4.2%	-5.1%	34.3%	-3.2%
Transportation	-1.3%	-5.1%	0.2%	0.0%

	Primary energy change 2014-15	Change in carbon intensity of primary energy 2014-15	Primary energy share of sector CO2 2015	Change in primary energy-weighted CO2 2014-15
Residential	-9.1%	1.4%	30.7%	-2.4%
Commercial	-6.5%	-0.4%	23.7%	-1.6%
Industrial	-0.1%	-1.0%	65.7%	-0.7%
Transportation	2.2%	-0.1%	99.8%	2.1%

	Sector CO2 change MER tables 2014-15	Electricity & primary energy CO2 change times sector share 2014-15	Sector share of total CO2 2015	Sum of change in electricity and primary energy-weighted CO2 2014-15
Residential	-6.5%	-1.3%	19.8%	-6.5%
Commercial	-5.4%	-0.9%	17.4%	-5.4%
Industrial	-4.0%	-1.1%	27.3%	-3.9%
Transportation	2.1%	0.7%	35.4%	2.1%
Total all sectors	-2.7%	-2.6%		

Sources: U.S. Energy Information Administration, Monthly Energy Review, October 2016:
Table 12.1 Carbon Dioxide Emissions From Energy Consumption by Source,
Table 12.2 Carbon Dioxide Emissions From Energy Consumption: Residential Sector,
Table 12.3 Carbon Dioxide Emissions From Energy Consumption: Commercial Sector,
Table 12.4 Carbon Dioxide Emissions From Energy Consumption: Industrial Sector,
Table 12.5 Carbon Dioxide Emissions From Energy Consumption: Transportation Sector,
Differences in percent changes are calculated using unrounded numbers.

Table 1 decomposes the rates of change by sector for electricity (indirect) and primary (direct) energy consumption and separates them from the changes in the respective carbon intensities. The sums of

those changes multiplied by the share of CO2 emissions from each energy type approximates the sectoral changes in CO2.

Using the residential sector as an example—the drop in electricity consumed between 2014 and 2015 of 0.8%, added to the decline in carbon intensity of the electricity supply (-5.1%) yields a total of -5.9% (not shown in the table). When -5.9% is multiplied by the electricity emissions share of 69.3% the resulting electricity-weighted change is -4.1%. When this is added to the residential sector's weighted change of primary energy (-2.4) the result is the largest total sector change of -6.5%. Finally, when weighted by the residential share of total CO2 emissions (19.8%), the weighted sector share of -1.3% is about half the total change in energy-related CO2 emissions in 2015. In the commercial sector, the slight increase in electricity consumption somewhat offsets the drop in carbon intensity. Because energy use in the residential and commercial sectors is primarily electricity, their overall rate of CO2 change is largely determined by changes in power sector fuel consumption and the carbon intensity of the electricity supply. By contrast the transportation sector is not significantly affected by electricity changes in 2015 and is almost totally dominated by primary energy consumption.

The industrial sector, while still dominated by primary energy consumption, has a large enough electricity share that large changes in electricity supply mix (as happened in 2015) can outweigh the relatively small change in primary energy consumption and produce a total sector change of -3.9%

When weighted by each sector's share of the total, as indicated above, the largest change in CO2 emissions (-1.3%) is fromchange in the residential sector. The industrial sector is the next largest contributor to the decline (-1.1%), followed by the commercial sector (-0.9%). The transportation sector's growth offsets the total CO2 decline by +0.7%.

Future Implications of the 2015 decline in carbon dioxide emissions

Specific circumstances, such as the very warm fourth quarter of 2015 and relatively low natural gas prices, put downward pressure on emissions as natural gas was substituted for coal in electricity generation. The downward pressure on emissions was slightly offset by an uptick in transportation energy consumption that was influenced by lower fuel prices that put upward pressure on emissions. These conditions do not necessarily reflect future trends.

For EIA's forecasts and projections on emissions and their key drivers, see the Short-Term Energy Outlook (STEO), with monthly forecasts through 2018 and the Annual Energy Outlook (AEO) with annual projections through 2050. EIA's International Energy Outlook (IEO) contains projections of international energy consumption and emissions through 2040. Full-length versions of the AEO and IEO are on a biennial schedule. Summary versions of these publications appear in alternating years.

The analysis of energy-related CO2 emissions presented here is based on data in the *Monthly Energy Review* (MER). Chapter 12 of the MER reports monthly U.S. energy-related CO2 emissions derived from EIA's monthly energy data. For the full range of EIA's emissions products, see the Environment webpage.

Terms used in this analysis

British thermal unit(s) (Btu): The quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density (approximately 39 degrees Fahrenheit).

Carbon intensity (economy): The amount of carbon by weight emitted per unit of economic activity. It is most commonly applied to the economy as a whole, where output is measured as the gross domestic product (GDP). The carbon intensity of the economy is the product of the energy intensity of the economy and the carbon intensity of the energy supply. Note: this value is currently expressed in the full weight of the carbon dioxide emitted (CO2/GDP).

Carbon intensity (energy supply): The amount of carbon by weight emitted per unit of energy consumed. A common measure of carbon intensity is weight of carbon per Btu of energy. When there is only one fossil fuel under consideration, the carbon intensity and the emissions coefficient are identical. When there are several fuels, carbon intensity is based on their combined emissions coefficients weighted by their energy consumption levels. Note: this value is currently measured in the full weight of the carbon dioxide emitted (CO2/energy or CO2/Btu).

Cooling degree days (CDD): A measure of how warm a location is over a period of time relative to a base temperature, most commonly specified as 65 degrees Fahrenheit. The measure is computed for each day by subtracting the base temperature (65 degrees) from the average of the day's high and low temperatures, with negative values set equal to zero. Each day's cooling degree days are summed to create a cooling-degree-day measure for a specified reference period. Cooling degree days are used in energy analysis as an indicator of air conditioning energy requirements or use.

Energy intensity: A measure relating the output of an activity to the energy input to that activity. It is most commonly applied to the economy as a whole, where output is measured as the gross domestic

product (GDP), and energy is measured in Btu to allow for the summing of all energy forms. On an economy-wide level, it is reflective of both energy efficiency as well as the structure of the economy. Economies in the process of industrializing tend to have higher energy intensities than economies in their post-industrial phase. The term energy intensity can also be used on a smaller scale to relate, for example, the amount of energy consumed in buildings to the amount of residential or commercial floor space.

Gross domestic product (GDP): The total value of goods and services produced by labor and property located in the United States. As long as the labor and property are located in the United States, the supplier (that is, the workers and, for property, the owners) may be either U.S. residents or residents of foreign countries.

Heating degree days (HDD): A measure of how cold a location is over a period of time relative to a base temperature, most commonly specified as 65 degrees Fahrenheit. The measure is computed for each day by subtracting the average of the day's high and low temperatures from the base temperature (65 degrees), with negative values set equal to zero. Each day's heating degree days are summed to create a heating-degree-day measure for a specified reference period. Heating degree days are used in energy analysis as an indicator of space heating energy requirements or use.

See the EIA glossary for other definitions.

Methodology used in this analysis

With the exception of figures 10 and 11, the data in this report are directly from the published values in the MER or based on relatively simple calculations such as CO2/Btu of energy. The methodology of figures 10 and 11 is as follows:

Figure 10. *The decrease compared to trend in energy-related carbon dioxide emissions in 2015 was due primarily to a decline in energy intensity*: This figure gives context to the most recent year-to-year change by comparing it to the average change for key parameters over the previous decade. The key parameters are population, per capita GDP (GDP/population), energy intensity, and carbon intensity of the energy supply. The changes in these key parameters determine changes in energy-related carbon dioxide. By comparing the rate of change for each parameter from 2014 to 2015 to the average rate of change for that parameter for the previous decade, the contribution of each parameter towards the overall deviation from trend can be calculated. The table below summarizes the rates of change that drive the results. The larger the positive value, the greater the increase in emissions. The larger the negative value, the lesser the increase in emissions.

Parameter	Previous decade % change	2014–15 % change
Population	+0.8	+0.7
Carbon intensity (CO2/Btu)	-0.9	-1.8
Per capita output (GDP/pop.)	+0.5	+1.9
Energy intensity (Btu/GDP)	-1.5	-3.4
Change in energy CO2	-1.1	-2.7

Figure 11. *Increased use of natural gas and the growth in non-carbon generation have contributed to the decline in power sector carbon intensity since 2005*: This figure shows the emissions savings from two factors that have allowed emissions to decrease from 2005 to 2015 while generation has risen slightly. The first factor is the shift within fossil fuel generation from coal to natural gas. To capture this shift, the fossil fuel carbon factor (fossil fuel CO2/fossil fuel generation) is frozen at the 2005 level. This factor is then multiplied by the actual fossil fuel generation for subsequent years. The difference between that value and the actual value for fossil fuel generated CO2 emissions is the savings in that year. For example, the carbon factor in 2005 for fossil fuel generation was 0.865 metric tons per megawatthour. By 2015 the carbon intensity had declined to 0.735 metric tons per megawatthour. Multiplying the 2005 value times the 2015 level of generation would yield 2,259 MMmt, versus the actual value of 1,919 MMmt. Therefore, the savings was 341 MMmt in 2015. Because non-carbon generation (the second factor) has a zero-carbon factor for direct emissions, the overall reduction in total carbon intensity was applied to total generation, i.e., multiplying total generation by the 2005 value of 0.619 metric tons per megawatthour. The savings in fossil fuel generation was subtracted from the total and the difference was credited to non-carbon generation. For example, the total savings in 2015 was 522, so the amount allocated to non-carbon generation is 522 minus 341 = 181.