Independent Statistics & Analysis
U.S. Energy Information Administration

# U.S. Energy-Related Carbon Dioxide Emissions, 2014

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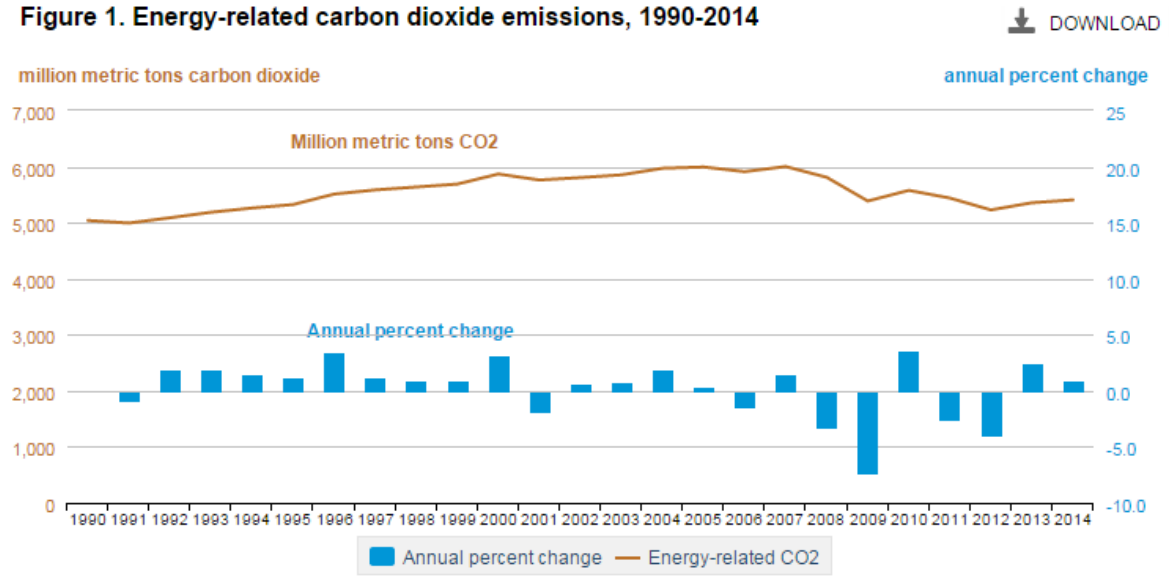
U.S. Department of Energy
Washington, DC 20585

## U.S. ENERGY-RELATED CARBON DIOXIDE EMISSIONS INCREASED 0.9% IN 2014

- Energy-related carbon dioxide (CO2) emissions increased by 50 million metric tons (MMmt), from 5,355 MMmt in 2013 to 5,406 MMmt in 2014.
- The increase in 2014 was influenced by the following factors:
  - Real gross domestic product (GDP) grew by 2.4%;
  - The carbon intensity of the energy supply (CO2/Btu) declined by 0.3%; and
  - Energy intensity (British thermal units[Btu]/GDP) declined by 1.2%.
- Therefore, with GDP growth of 2.4% and the overall carbon intensity of the economy (CO2/GDP) declining by about 1.5%, energy-related CO2 grew 0.9%.

**Figure 1. Energy-related carbon dioxide emissions, 1990-2014**




**Source:** U.S. Energy Information Administration, *October 2015 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 2015 *Monthly Energy Review*. Because of slightly differing coverage and data vintage, percent changes may differ slightly with other EIA publications.

## CARBON DIOXIDE EMISSIONS BY FUEL EXHIBIT DIFFERING PATTERNS OVER TIME

- 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 2008, coal emissions have also generally declined. While total coal emissions are below those from petroleum and other liquids, there is more CO2 released per Btu of energy. The decline in coal emissions has contributed to a lower carbon intensity of U.S. energy consumption.
- Natural gas emissions have generally increased since 2008, primarily reflecting growth in the natural gas share of electricity generation largely through displacement of coal-fired generation.

**Figure 2. Energy-related carbon dioxide emissions by fuel, 1990-2014**

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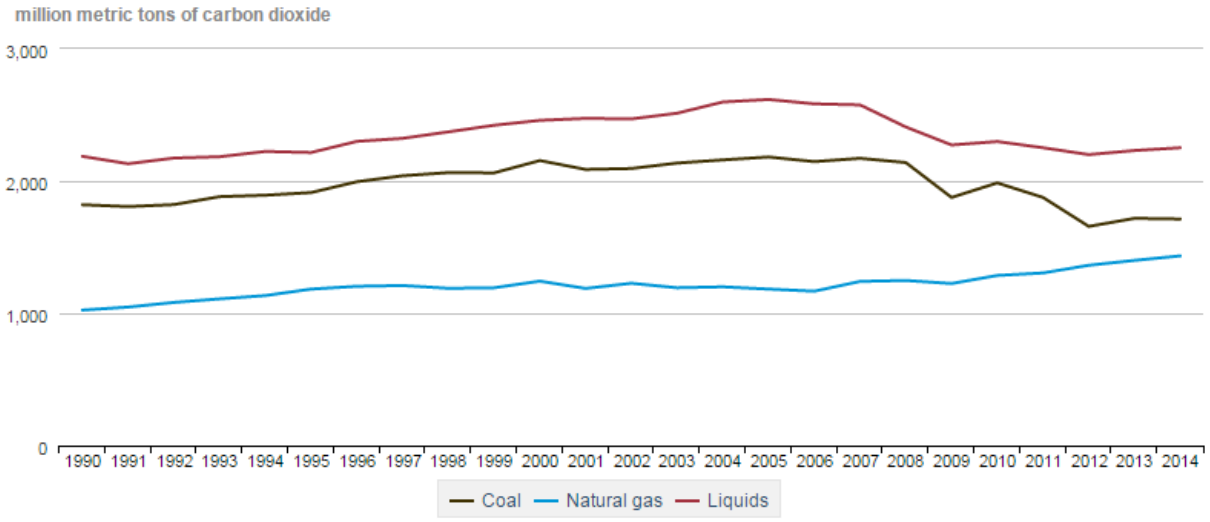


**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 12.1 Carbon dioxide emissions from energy consumption by source.

## INDUSTRIAL AND TRANSPORTATION SECTORS' ENERGY-RELATED CARBON DIOXIDE EMISSIONS FURTHER DIVERGED IN 2014

- Since the late 1990s, the transportation sector has produced the most CO2 emissions. These emissions reached their highest level in 2007.
- The industrial sector was the largest source of CO2 throughout most of the 1990s. Emissions declined between 1998 and 2008 and have flattened in recent years.
- In 2014, transportation sector CO2 increased while industrial sector CO2 declined.
- Emissions from the residential and commercial sectors, known collectively as the "building sector," are dominated by indirect emissions from electricity use. These emissions grew about 1% in 2014, which is typical for buildings since 1990. However direct CO2 emissions increased 4% in 2014.

**Figure 3. Energy-related carbon dioxide by end-use sectors, 1990-2014**

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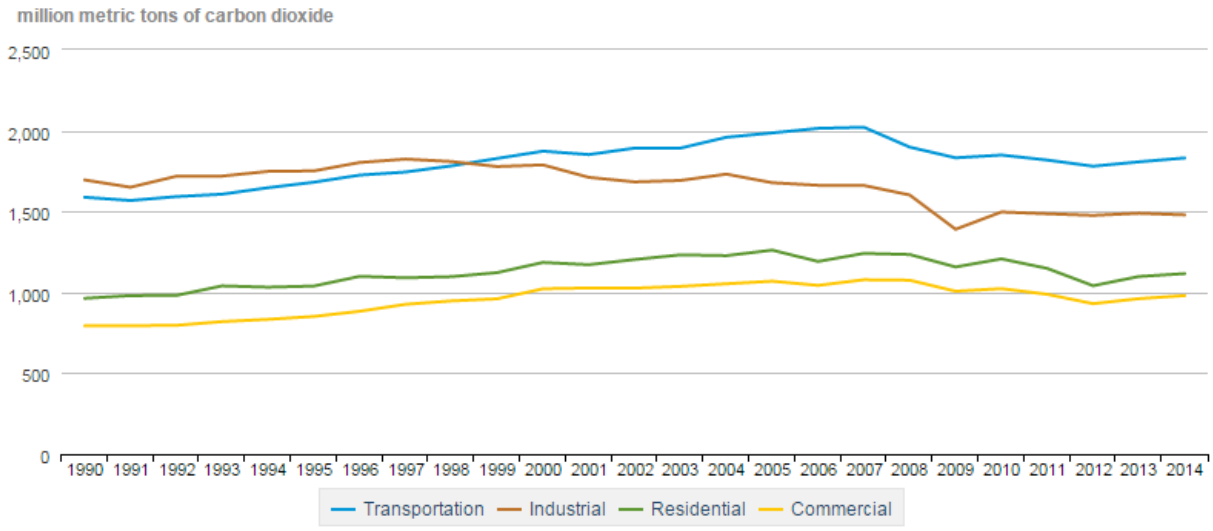


**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 12.2 Carbon dioxide emissions from energy consumption: residential sector. Table 12.3 Carbon dioxide emissions from energy consumption: commercial sector. Table 12.4 Carbon dioxide emissions from energy consumption: industrial sector. Table 12.5 Carbon dioxide emissions from energy consumption: transportation sector.

## THE LARGEST ABSOLUTE INCREASE IN 2014 ENERGY-RELATED CARBON DIOXIDE EMISSIONS WAS FROM THE TRANSPORTATION SECTOR

Price decreases in gasoline and other fuels from 2013 to 2014, along with the continued economic recovery, has induced higher fuel consumption. Transportation-related CO2 emissions increased by 24 MMmt (1.3%) in 2014, or 47% of the total emissions increase from 2013.

- Motor gasoline dominates CO2 emissions from the transportation sector, however diesel fuel emissions increased by 5% or 21 MMmt in 2014.
- Even with the recent increase, total transportation sector CO2 emissions are more than 9% below their 2007 level.

**Figure 4. Transportation-related carbon dioxide emissions by fuel, 1990-2014**

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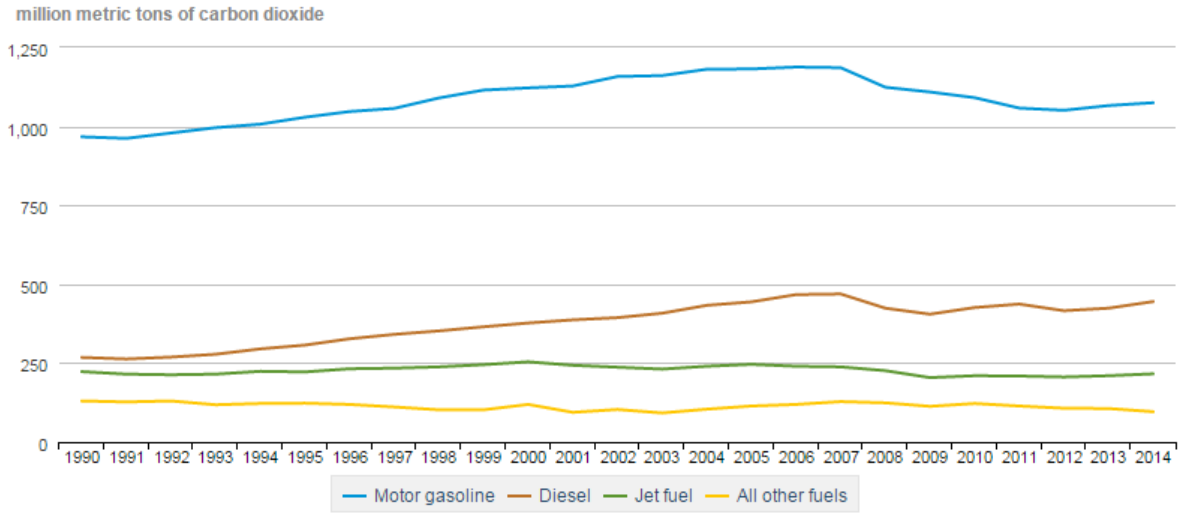


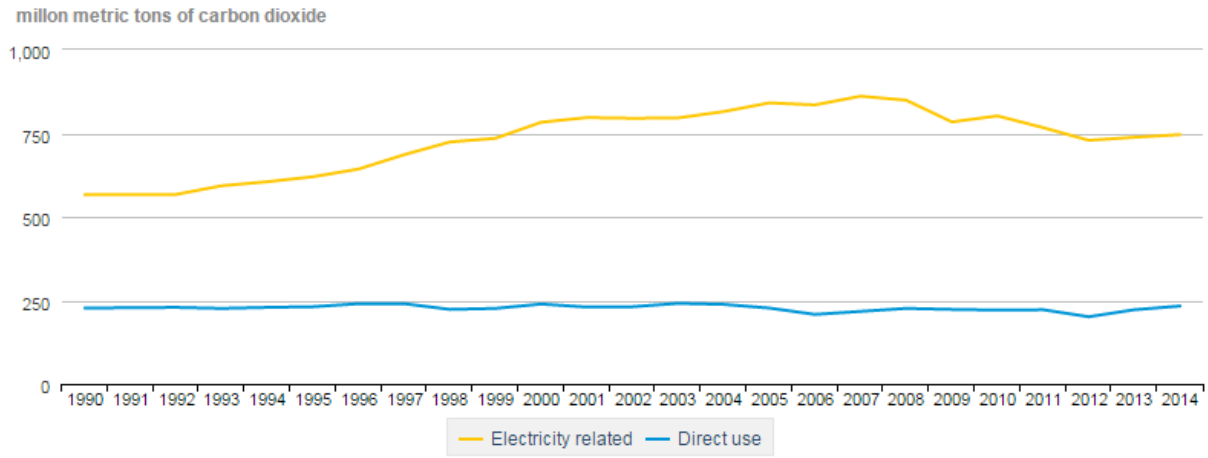

**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 12.5 Carbon dioxide emissions from energy consumption: transportation sector.

## ENERGY-RELATED CARBON DIOXIDE EMISSIONS IN THE COMMERCIAL SECTOR INCREASED BY OVER 2% IN 2014

The increase in commercial sector CO2 emissions in 2014 was 19 MMmt (2.0%), accounting for 38% of the total increase in emissions.

- Indirect CO2 emissions from the use of electricity in the commercial sector increased by 1.1% (8 MMmt), which was 41% of the sector's total increase.
- Direct CO2 emissions increased 5% (11 MMmt), 54% of the total sector's increase.
- While the commercial sector is less affected by weather than the residential sector, economic growth contributed to increased energy consumption and emissions.
- Despite the 2014 experience, indirect emissions from the purchase of electricity have historically accounted for the largest share of the increase in this sector, while direct-use emissions have remained generally flat since 1990.

**Figure 5. Commercial sector energy-related carbon dioxide emissions, 1990-2014**




**Sources:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 12.3 Carbon dioxide emissions from energy consumption: commercial sector.

## RESIDENTIAL ENERGY-RELATED CARBON DIOXIDE EMISSIONS INCREASED IN THE FIRST QUARTER OF 2014

Residential CO2 emissions increased in the first quarter of 2014 by about 12% compared with the first quarter of 2013, due largely to colder weather; heating degree days (HDD) increased 10% over the first quarter of 2013. For the year, residential CO2 emissions increased 18 MMmt (1.6%), accounting for 36% of the total increase in energy-related CO2 emissions in 2014.

- Residential CO2 emissions were similar in the second quarters of 2012, 2013, and 2014, while third quarter emissions have declined steadily since 2010, as third-quarter cooling degree days were about 16% lower by 2014 than 2010.
- In the fourth quarter of 2014, emissions declined from the same period in 2013 as HDD fell 7%, indicative of a relatively warm start to the 2014/2015 heating season.

**Figure 6. Residential energy-related carbon dioxide emissions by quarter, 2007-14**

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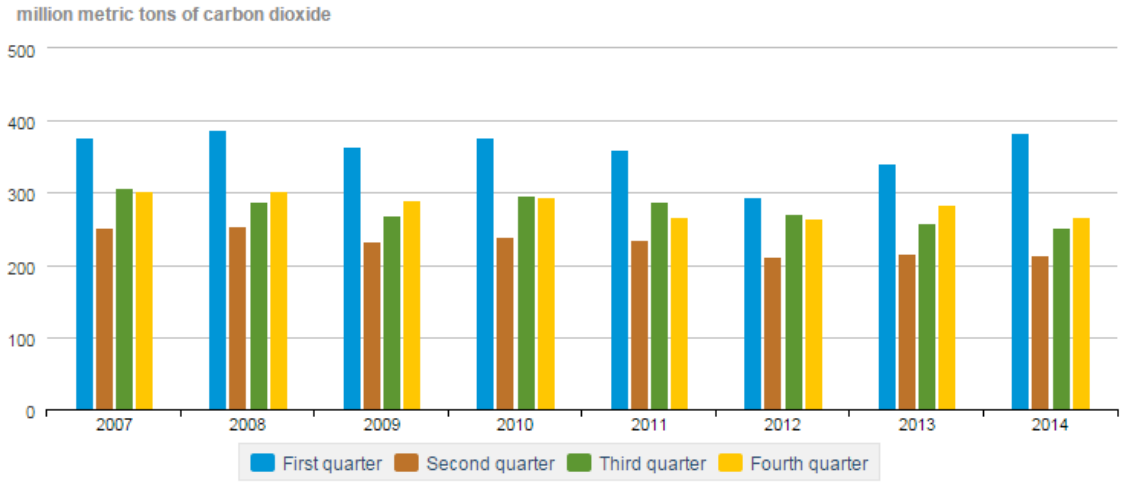


**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 12.2 Carbon dioxide emissions from energy consumption: residential sector

## INDUSTRIAL SECTOR ENERGY-RELATED CARBON DIOXIDE EMISSIONS DECLINED IN 2014

The industrial sector's CO2 emissions, which fell by 11 MMmt (0.7%) in 2014, have remained largely flat in recent years despite increasing output. Continuing growth in less energy-intensive output (such as computers) has 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 every year from 2011 to 2014.
- Emissions from petroleum use in industry have declined since 2012.
- Natural gas emissions have risen every year since 2009. Because it is the least carbon-intensive fuel, subsitution of natural gas for other fossil fuel inputs has served to mitigate overall CO2 growth in the industrial sector.

**Figure 7. Annual change in carbon dioxide emissions from industrial fuels, 2005-14**

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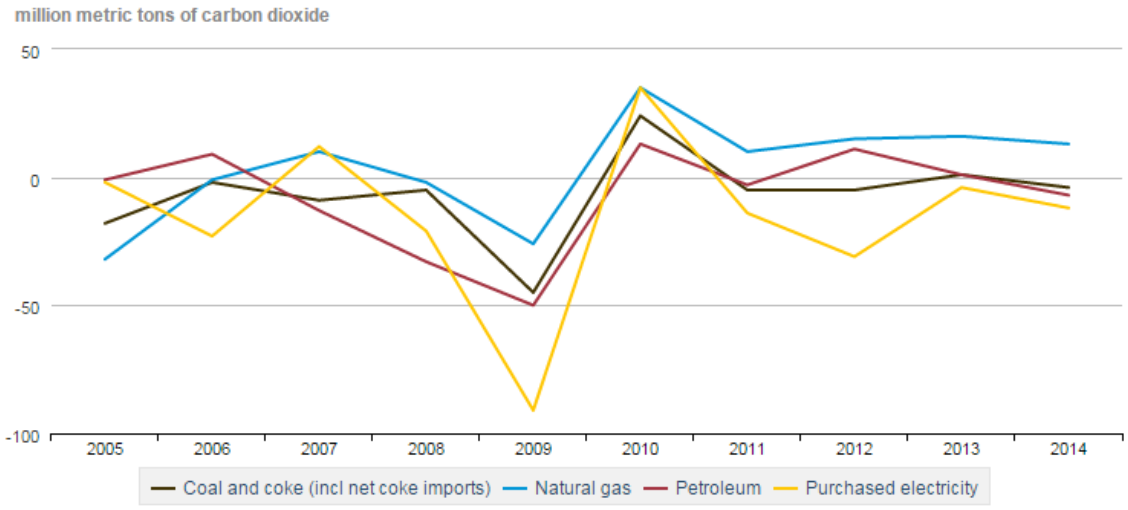


**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 12.4 Carbon dioxide emissions from energy consumption: industrial sector

## THE INCREASING SHARE OF ELECTRICITY FROM NATURAL GAS-FIRED GENERATION AND WIND AND SOLAR POWER HAS HELPED TO LOWER THE CARBON INTENSITY OF ELECTRICITY SUPPLY

The natural gas share of electricity generation grew from approximately 11% in 1990 to 29% in 2012, dipping to 26% in 2014.

- Coal's share of electricity generation fell from 54% in 1990 to 40% in 2014.
- Renewables other than hydropower have provided a growing share of generation in recent years.

**Figure 8. Share of three fossil fuels and of non-fossil fuel generation, 1990-2014**

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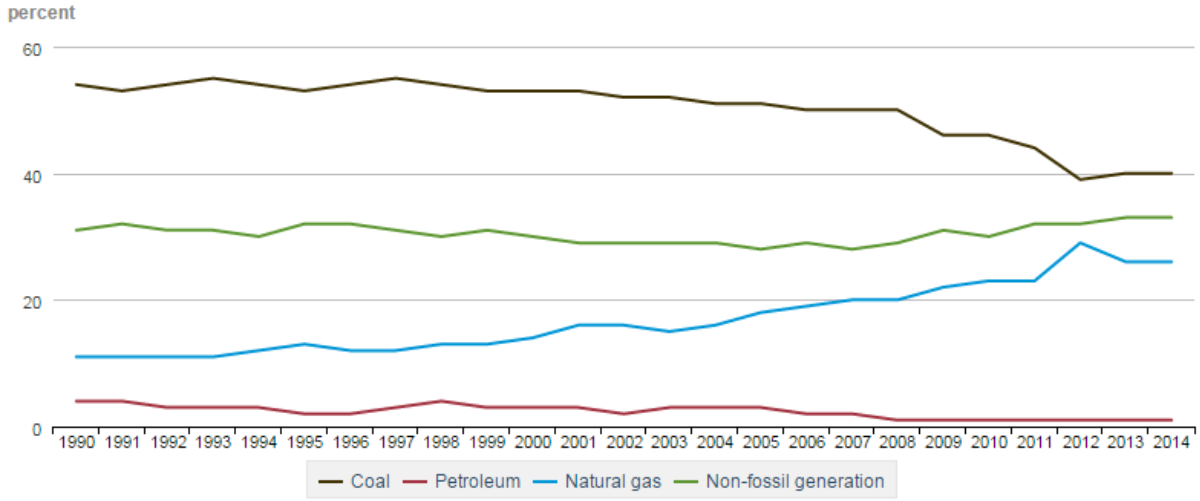


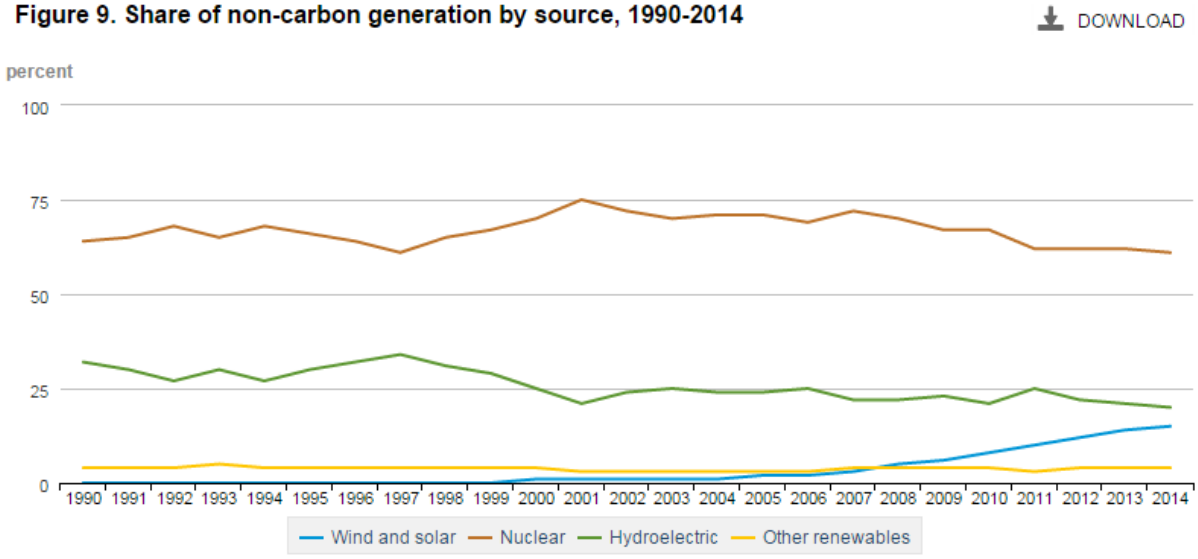

**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review* , Table 7.2b Electricity net generation: electric power sector. From 2004 to 2014, includes an estimate of distributed solar generation from the National Energy Modeling System, Table 16. Renewable Energy Generating Capacity and Generation.

## GROWTH IN WIND AND SOLAR ELECTRICITY GENERATION HAS BEEN A KEY COMPONENT IN THE DECREASING CARBON INTENSITY OF THE ELECTRICITY SUPPLY

While 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.

- Nuclear's share of non-fossil 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 about 20% in 2014.
- Wind and solar (combined) accounted about 15% of non-fossil electricity generation in 2014 after rising from less than 1% in 2000 to 2% in 2005.
- Other renewables such as biomass have remained at about 4%.

**Figure 9. Share of non-carbon generation by source, 1990-2014**




**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 7.2b Electricity net generation: electric power sector. From 2004 to 2014, includes an estimate of distributed solar generation from the National Energy Modeling System, Table 16. Renewable Energy Generating Capacity and Generation.

## ABOUT HALF OF THE INCREASE OVER TREND IN ENERGY-RELATED CARBON DIOXIDE IN 2014 WAS DUE TO GROWTH IN PER CAPITA ECONOMIC OUTPUT

In 2014, per capita output (GDP divided by population) grew by 1.7% compared with the average growth of just 0.5% from 2004 to 2013. This contributed about 62 MMmt to the increase in CO2 emissions when compared with the average shown over the previous ten years.

- Energy intensity of the economy added about 29 MMmt of CO2 relative to average energy intensity over the past decade as it fell by 1.2% in 2014 versus an average decline of 1.7%. Carbon intensity of the energy mix declined by 0.3% versus an average decadal decline of 0.9%, leading to an increase of about 31 MMmt of CO2.
- The 0.7% growth in population put downward pressure on emissions growth as compared with the previous 0.9% annual growth in the past decade (resulting in a 6 MMmt decline in CO2 emissions compared with the trend).
- The net effect for 2014 was CO2 emissions that were about 115 MMmt higher than had the previous decadal trend held.

**Figure 10. Changes in emissions attributed to key drivers from 2013 to 2014 as compared to the trend from the prior decade**

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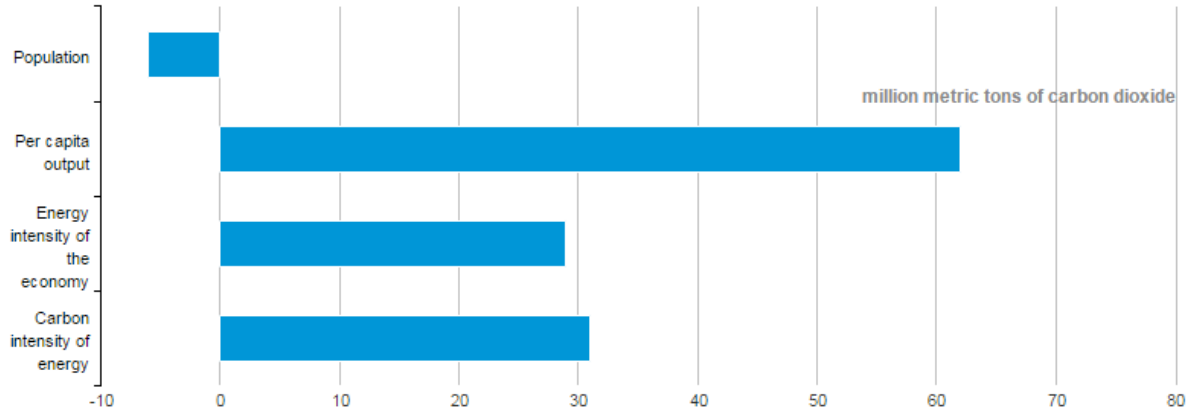


**Sources:** U.S. Energy Information Administration, October 2015 Monthly Energy Review, Table 12.1 Carbon dioxide emissions from energy consumption by source.
Bureau of economic analysis, *Current-Dollar and "Real" Gross Domestic Product.*
Bureaus of Census *U.S. Population 2014.*

## DECLINING CARBON INTENSITY OF THE ENERGY MIX SINCE 2008 HAS CONTRIBUTED TO A GENERAL DECOUPLING OF CARBON DIOXIDE EMISSIONS FROM ECONOMIC GROWTH

The carbon intensity of energy supply began declining in 2008, in step with the recession that resulted in a two-year drop in per capita economic output.

- With recovery in the economy, GDP in 2014 exceeded pre-recession levels, but the carbon intensity of the energy supply has continued to decline.
- In prior years, with relatively flat carbon intensity, it was mainly declining energy intensity that kept CO2 emissions from rising as fast as the economy. Substitution of natural gas and renewable energy for coal in the electric power sector has contributed to the decline in carbon intensity of the energy mix since 2008.
- As a result of the recent decreases in the carbon intensity of the energy supply, the overall carbon intensity of the economy has begun to decline more than the decline in energy intensity of the economy.

**Figure 11. Index of key energy-related emissions drivers, 1990-2014**

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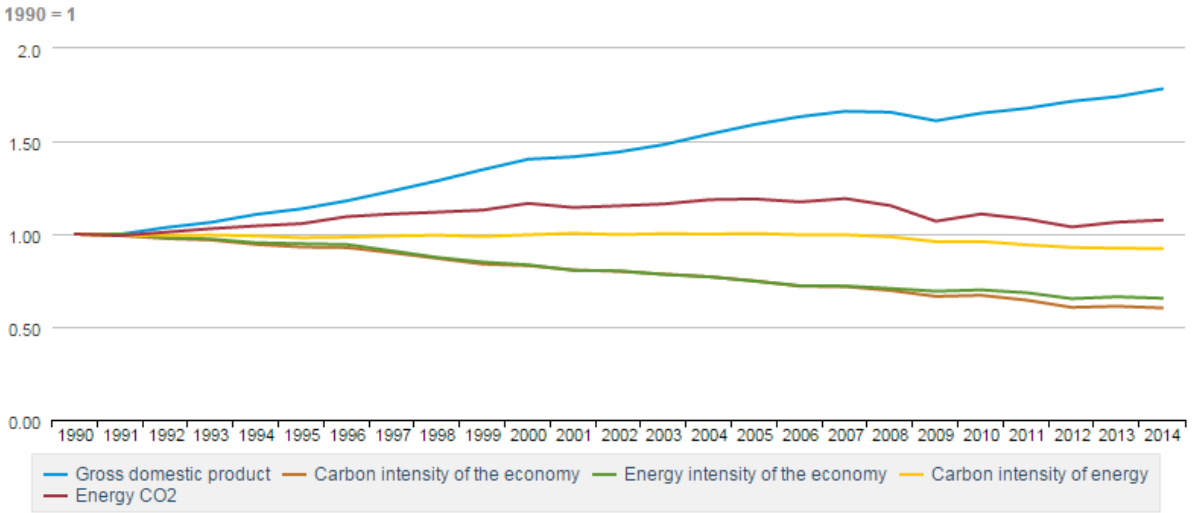


**Sources:** U.S. Energy Information Administration, October 2015 Monthly Energy Review, Table 12.1 Carbon dioxide emissions from energy consumption by source.
Bureau of economic analysis, *Current-Dollar and "Real" Gross Domestic Product.*
Bureaus of Census *U.S. Population 2014.*

## INCREASED USE OF NATURAL GAS AND THE GROWTH IN NON-CARBON GENERATION HAVE CONTRIBUTED TO THE DECLINE IN POWER SECTOR CARBON DIOXIDE EMISSIONS SINCE 2005

- Two main factors that have contributed to lower carbon intensity (CO2/kWh) since 2005 in the electric power sector: (1) substitution of less-carbon-intensive and more efficient combined cycle natural gas generation for coal and petroleum, and (2) growth in non-carbon generation, especially renewables such as wind and solar.
- While generation grew by just under 1% from 2005 to 2014, related emissions fell by 15% over that period.
- From 2005 to 2014, fossil generation declined by about 6% while non-fossil (non-carbon) generation rose by 18%.

### Figure 12. Electric power sector carbon dioxide emissions reduction from shifting to natural gas and non-carbon generation in years 2006 through 2014 relative to 2005 generation fuel mix and efficiency

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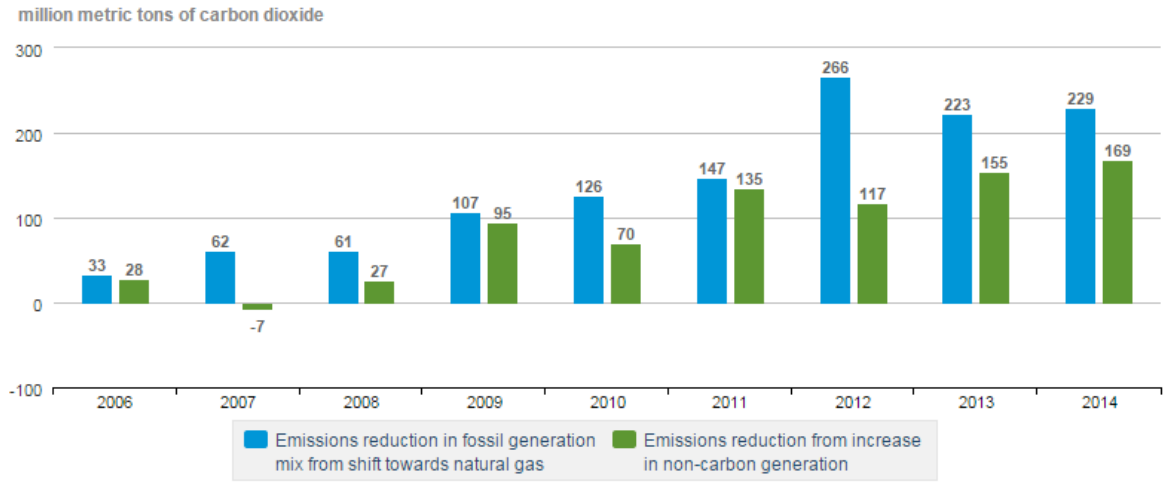


**Source:** U.S. Energy Information Administration, *October 2015 Monthly Energy Review*, Table 12.6 Carbon dioxide emissions from energy consumption: electric power sector
Table 7.2b Electricity net generation: electric power sector
From 2004 to 2014, includes an estimate of distributed solar generation from the National Energy Modeling System,
Table 16. Renewable Energy Generating Capacity and Generation,

# Implications of the 2014 carbon dioxide emissions increase

It is difficult to draw conclusions from one year of data. Specific circumstances such as the very cold first quarter of 2014 and the increase in coal generation relative to 2013 (while natural gas generation remained flat) affected the year-to-year change, as did the growth in transportation emissions influenced by lower fuel prices. In the longer term, other factors (such as improvements in vehicle fuel efficiency and increased use of natural gas and renewable generation) could help mitigate future emissions growth.

For EIA's projections on emissions and their key drivers, see the Short-Term Energy Outlook (STEO), updated monthly with projections through 2016 (2017 beginning in January of 2016) and the Annual Energy Outlook (AEO) with annual projections through 2040.

The analysis of energy-related carbon dioxide emissions presented here is based on data in the Monthly Energy Review (MER). Chapter 12 of the MER reports monthly U.S. energy-related carbon dioxide 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 measured 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 that 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 that are 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.

For other definitions see the EIA glossary.

## Methodology used in this analysis

Most of the data presented in the slides require no explanation. However, slides 10 and 12 involve some underlying complex calculations. The methodology for those slides is as follows:

Slide 10 entitled: About half of the increase over trend in energy-related carbon dioxide in 2014 was due to growth in per capita economic output – This slide 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 output (GDP/population), energy intensity of the economy (Btu/GDP), and carbon intensity of the energy supply (CO2/Btu). The changes in these key parameters determine changes in energy-related carbon dioxide. By comparing the rate of change for each parameter for the 2013 to 2014 time period to the average rate of change for that parameter for the previous decade, the contribution of each 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 and the larger the negative value the lesser the increase in emissions.

| Parameter | Previous decade % chng. | 2013-14 % chng. |
|---|---|---|
| Population | +0.9 | +0.7 |
| Carbon intensity (CO2/Btu) | -0.9 | -0.3 |
| Per capita output (GDP/pop.) | +0.5 | +1.7 |
| Energy intensity (Btu/GDP) | -1.7 | -1.2 |
| Change in energy CO2 | -1.2 | +0.9 |

Slide 12 entitled: 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 slide shows graphically the emissions savings from two factors in the generation of electricity that have allowed emissions to decrease in recent years 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 calculated for 2005. This factor is then multiplied times the actual fossil generation for subsequent years. The difference between that value and the actual value for fossil fuel generation CO2 emissions is the reduction in CO2 generation emissions. For example the carbon factor in 2005 for fossil fuel generation was .865 metric tons per megawatthour. By 2014 the carbon intensity had declined to .778 metric tons per megawatthour. Using the 2005 value times the 2014 level of generation would yield 2,275 MMmt, versus the actual value of 2,046 MMmt. Therefore the savings was 229 MMmt. 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. 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 2014 was 398, so the amount allocated to non-carbon generation is 398 – 229 = 169.