Future Dispatch of U.S. Coal and Natural Gas-Fired Power Plants


In the United States, based on relative economics, coal-fired power plants have generally been dispatched ahead of natural gas-fired plants to generate electricity, although regional variations in fuel prices and variable operating costs can lead to exceptions. Since 2009, natural gas combined-cycle plants, in particular, have come into dispatch-level competition with existing coal plants due to declining natural gas prices.

Record low natural gas prices in 2012 resulted in coal’s share of total U.S. electricity generation dropping to 37%, compared with 50% in 2005, while natural gas’s share grew from 19% in 2005...
to 30% in 2012. Total carbon dioxide (CO₂) emissions in the power sector fell 16% in this same period, while demand for electricity was fairly flat. This decline was due largely to the decrease in the level of coal-fired plant operation in favor of increased generation from natural gas-fired combined-cycle plants, which emit about 40% of the CO₂ of a coal plant per megawatt hour (MWh). Coal has regained some market share since 2012 as natural gas prices have increased, but in the long term, coal generation is not expected to reach historical levels as coal plant retirements occur and few new coal plants are expected to be built.

The U.S. Energy Information Administration (EIA) publishes projections for the energy sector in its Short-Term Energy Outlook¹ (STEO) and Annual Energy Outlook 2014² (AEO2014) reports. The STEO produces monthly projections over a 13–24 month forecast horizon, and reflects the seasonality in the use of different generation fuels, regional differences in generation patterns, and the responsiveness of power generators to changes in relative fuel costs. It does not explicitly model environmental regulations, but does reflect recent trends in generation patterns that may be driven in part by the industry’s reaction to expected shifts in policy. The AEO2014 contains annual projections through 2040 and includes assumptions regarding current laws and regulations, including environmental rules such as the Clean Air Interstate Rule³ (CAIR) and the Mercury and Air Toxics Standards⁴ (MATS).

The June 2014 edition of the STEO forecasts that the total level of U.S. generation this year will be 1.9% higher than in 2013, primarily because colder winter temperatures in the early part of the year led to higher electricity demand. However, the use of natural gas for electricity generation is projected to decline in 2014 due to rising natural gas prices. While the AEO2014 also projects a near-term dip in natural gas generation, in the longer-term almost three quarters of new capacity added through 2040 will be natural gas-fired, and total natural gas generation surpasses coal generation by 2035. Power sector CO₂ emissions are projected to grow by 11% between 2012 and 2040 in the AEO2014, slower than the 25% increase in total electric power generation, indicating a shift
to less carbon-intensive generating resources or improved efficiency. Uncertainty surrounding future natural gas prices and potential greenhouse gas (GHG) legislation and regulation will influence these projections.

**Background**

Generally, operators dispatch power plants based on their variable costs of generation, of which a key input is the cost of fuel. Figures 1–3 show dispatch supply curves for the Southeastern states representing the summer months of 2010, 2011, and 2012, respectively. The dispatch curves are formed by ranking all plants by their variable operating costs (as measured in dollars per MWh) and accumulating the plants’ summer generation. Plants at the lower end of the dispatch curve run more frequently, since they are more economic to operate. When comparing across the three figures, the curves show some natural gas-fired generating plants moving down and to the left on the curve, shifting ahead of some coal-fired plants as a result of changing relative fuel prices, particularly in 2012. Although not included in the figures, in 2013, the average delivered price of natural gas rose 27% above 2012 levels, causing the dispatch order to shift back to favor coal-fired plants. As a result, coal generation rose 5% while natural gas generation fell 9% in 2013. However, in the long term, impending environmental legislation and uncertainty surrounding the longer term fuel prices will affect the future market share for coal generation.

**Short-Term Outlook**

Despite an expected increase in total generation in 2014, EIA’s June 2014 STEO projects a continued decline in the use of natural gas-fired power plants as the forecast average U.S. cost of natural gas grows at a much higher pace (28.6%) than the forecast cost of coal (0.7%) (see Figure 4). Operators are substituting coal for natural gas this year to supply the increase in total generation and to offset a slight decline in nuclear-powered generation resulting from the recent retirement of a few nuclear units. This substitution between fuels translates to changes in each fuel’s relative share of total generation. The June 2014 STEO projects the U.S. share of generation fueled by coal will average 40.5% this year, up from 39.1%
in 2013. This projected share for 2014 is still lower than coal’s 42.3% share of generation in 2011. In contrast, the share of U.S. generation fueled by natural gas in 2014 averages 26.5%, down from 27.4% last year.

In 2015, EIA expects an increased supply of natural gas, which should lower the cost of the fuel for power generators. Figure 4 shows the average per MWh fuel cost of operating natural gas combined-cycle plants and coal-fired steam turbines, based on the average efficiencies of the current fleet. During 2015, the STEO projects that natural gas prices will fall 7.1%, while the cost of coal stays relatively steady. In addition to fuel prices favoring natural gas generation, the retirement of some coal capacity in recent years leads to other fuels such as natural gas needing to meet the generation formerly supplied by coal.

**Long-Term Outlook**

EIA’s AEO2014 Reference case presents projections for the U.S. energy sector through 2040, assuming current laws and regulations. In the electric power sector, the environmental regulations modeled include CAIR; MATS; the Regional Greenhouse Gas Initiative (RGGI), which sets a cap on power sector CO\textsubscript{2} emissions across nine Northeastern and Mid-Atlantic states; and California’s Assembly Bill 32\textsuperscript{6} (AB32), which restricts carbon emissions in the state across several sectors, including electric power.

In the AEO2014, to comply with MATS, it is assumed that all qualifying coal-fired power plants must be equipped with either flue gas desulfurization (FGD) scrubbers or dry sorbent injection (DSI) systems and activated carbon injection, if warranted, for mercury control by 2016, or else the plant must be retired. In the AEO2014 Reference case, 46 gigawatts (GW) of existing coal plants are projected to retire by 2016, while 30 GW will add FGD controls and 45 GW will add DSI systems. This equipment also reduces emissions of sulfur dioxide (SO\textsubscript{2}); by 2016 SO\textsubscript{2} emissions are projected to be below the cap specified by CAIR. Between 2012 and 2016, total power sector nitrogen oxides (NO\textsubscript{X}) emissions fall 14% and SO\textsubscript{2} emissions decline by 61%.

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**Figure 4. Average U.S. delivered fuel costs and electricity generation by fuel.**

*Notes:* Labels show percentage share of total generation provided by coal and natural gas. *Source: Short-Term Energy Outlook, EIA, June 2014.*
EIA’s Annual Energy Outlook 2014 predicts that natural gas generation grows by 50% between 2012 and 2040 and surpasses coal as the largest source of U.S. electricity generation by 2035.

MATS would also result in SO\(_2\) emissions below the CSAPR limits.

In the AEO2014 Reference case, once the 2016 coal plant retirement decisions are made, the remaining coal plants are projected to increase output over several years as capacity factors reach relatively high levels and then maintain a consistent output throughout 2040. Competition with existing natural gas plants along the dispatch curve is limited, as natural gas prices are projected to rise through 2040. However, little new coal capacity is projected to be added through 2040, while significant amounts of new natural gas-fired capacity is built to replace retired units and meet demand growth. As a result, natural gas generation grows by 50% between 2012 and 2040, and surpasses coal as the largest source of U.S. electricity generation by 2035.

The AEO2014 does not directly model any federal GHG legislation or regulation, including the recent U.S Environmental Protection Agency proposals on standards for either new or existing sources, because there still is no final rule promulgated. However, to examine the impacts of uncertainty surrounding future legislation, as well as surrounding future costs, resource availability or commodity prices, the AEO2014 includes a number of side cases. While several cases are highlighted here, the full report includes many additional cases, such as alternate electricity demand and plant retirement assumptions, which also impact the fuels used for power generation and the resulting emissions.

Three cases are discussed in this article relative to the AEO2014 Reference case:

- **The Low Oil and Gas Resource Case** assumes less supply for oil and natural gas through lower estimated ultimate recovery per well, resulting in higher costs to develop these resources. Delivered natural gas prices to the electric power sector are 33% higher in 2040 than in the Reference case.

- **The High Oil and Gas Resource Case** assumes greater supply for oil and natural gas through higher estimated ultimate recovery per well and increased development. Delivered natural gas prices to the electric power sector are 37% below the Reference case in 2040.

- **The GHG10 Case** imposes a fee on energy-related CO\(_2\) emissions to represent policies that explicitly or implicitly place a value on GHG emissions. The GHG10 case assumes an initial CO\(_2\) value of $10 per metric ton in 2015, rising by 5% per year through 2040. This fee is applied economy-wide, to all energy sectors, and is passed through the delivered fuel prices based on the average carbon content of the fuel.

As seen in recent history, the opportunities for competition between existing coal and natural gas generation depend primarily on the relative fuel prices. Because natural gas combined-cycle plants are more efficient to operate than the average coal plant, the natural gas delivered prices generally need to be within 35–40% more than coal delivered prices for the average fuel cost per unit of generation to be competitive. Figure 5 shows the ratio of average per MWh fuel costs for natural gas combined-cycle plants and coal plants, across the Reference case and three side cases. It illustrates the relative competitiveness of the two plant types, taking into account the differences in efficiencies.

In 2012, when delivered natural gas prices averaged $3.42 per million British thermal unit (MMBtu) and delivered coal prices average $2.38 per MMBtu, the resulting fuel costs per MWh of coal and natural gas combined-cycle plants were almost equal, reflecting the greater efficiency of the combined-cycle technology. In the High Oil and Gas Resource case, the lower natural gas...
prices result in the ratio moving closer to 1.0, where the fuel prices are identical on a dollar-per-MWh basis and there are more opportunities for natural gas plants to displace coal. Similarly, in the GHG10 case, because the carbon fee is applied through the fuel prices and the coal price will see a larger impact based on its higher carbon content, the ratio again moves closer to 1.0.

Conversely, if natural gas prices were higher, as in the Low Oil and Gas Resource case, the coal plants remain cheaper to operate throughout the forecast, based solely on fuel costs. However, this relationship primarily reflects the competition for dispatch of existing units and not the relative cost effectiveness of new capacity expansion. Because of higher construction costs and uncertainty surrounding GHG standards, new natural gas-fired plants are generally more economical than new coal plants regardless of the natural gas prices in the scenarios examined in the AEO2014. If natural gas prices are higher, other non-fossil technologies may then be more economical than both coal and natural gas-fired plants.

**Electricity Generation by Fuel**

The projected levels of coal and natural gas generation are impacted in these alternate cases. Figure 6 shows electricity generation by fuel in 2012, 2025, and 2040, across four cases. In general, any shift in coal generation occurs early in the projection, when MATS becomes effective, and coal generation tends to remain steady after that point. The exception is when a carbon price is added, where the increasing carbon fee throughout the forecast period results in additional retirements after the 2016 MATS compliance date. By 2040, the coal share has dropped in all cases, and ranges between 19% in the GHG10 case and 35% in the Low Oil and Gas Resource case.

Natural gas generation varies significantly across the cases, particularly by 2040, where the natural gas generation ranges from 1,231 billion kilowatthours (24% share) in the Low Oil and Gas Resource case to 2,399 billion kilowatthours (44% share) in the High Oil and Gas Resource case. In the High Oil and Gas Resource case, natural gas generation surpasses coal generation before 2025, more than 10 years earlier than in the Reference case. In the GHG10 case, by 2040 total generation from natural gas-fired plants is slightly below the Reference case, while increases in generation are seen from new nuclear and renewable capacity additions. Under an increasing carbon fee, eventually natural gas-fired plants...
become less economic to build and operate than the more capital intensive but carbon-free generating options.

**CO₂ Emissions across Cases**

Carbon dioxide emissions in the power sector are affected by the relative levels of coal- and natural gas-fired generation, as well as changes in the overall generation levels of nuclear and renewable generators. In Figure 7, CO₂ emissions in the power sector increase relative to 2012 levels in all cases shown except the GHG10 case. In the High Oil and Gas Resource case, CO₂ emissions are initially lower than the Reference case, as natural gas generation displaces coal generation, but in the long term, the greater growth in natural gas generation results in total CO₂ emissions that are very similar to the Reference case.

Total power sector electricity generation is higher in the High Oil and Gas Resource case as the lower gas prices lead to lower electricity prices and greater demand growth. The average carbon intensity in tons per kilowatthour is about 5% below the Reference case value in 2040. With the higher projected natural gas prices in the Low Oil and Gas Resource case, total CO₂ emissions in 2040 are below the level of CO₂ emissions in Reference case—in this case, the decreased natural gas generation is not replaced by the more carbon intensive coal units, because existing units were already operating at high levels and new builds are primarily nuclear and renewable plants. In the GHG10 case, the CO₂ emissions drop significantly in 2016, when 65 GW of coal plants are retired, and continue declining throughout the forecast, due to the increasing price placed on CO₂ emissions. By 2040, CO₂ emissions are 29% below 2012 levels, and the average carbon intensity in the power sector is 34% below the Reference case.

**Conclusion**

In EIA’s AEO2014 Reference case, existing coal plants remain a large source of future generation, but the market share for coal generation will decline as most of the generation produced to meet incremental demand growth comes from natural gas. Further federal and state action to address GHG emissions in the United States could greatly alter the outlook for coal generation and the resulting mix of fuels used for electricity generation. If natural gas prices are higher than projected in the Reference case or if an explicit price is placed on carbon emissions, then growth in natural gas generation could be lower. This article focused on the national trends; however, variations exist across the country in fuel prices, operating costs, and the available mix of capacity and resources, all of which could lead to differing results in some regions of the country.

**References**

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