ACCCE
AMERICAN COALITION FOR CLEAN COAL ELECTRICITY

Displacement of Coal with Natural Gas to Generate Electricity

The American Coalition for Clean Coal Electricity (ACCCE) supports a balanced energy strategy that will ensure affordable and reliable energy, greater energy security, and continued environmental progress. The U.S. relies on coal, natural gas, nuclear power, and renewable energy sources to meet the nation's demand for electricity. Because of its affordability and other advantages, coal has been responsible historically for providing about half the nation's electricity. Currently, coal is responsible for producing more electricity than any other fuel, and that trend is projected to continue for at least the next two decades.[1]

Federal and state policies have been adopted or are being considered that would promote or incent the use of natural gas to replace coal to generate electricity. This paper provides data to explain why promoting greater use of natural gas to generate electricity is not consistent with sound energy or economic policy. In short -

- Natural gas has been and is expected to be a more expensive fuel than coal.
- Natural gas prices are highly volatile, whereas coal prices have been more stable.
- There is significant uncertainty about the amount of natural gas resources available.
- The cost of developing future natural gas resources is expected to be much higher than current prices, which suggests that natural gas prices could be substantially higher in the future.
- Promoting the use of natural gas for electric power generation decreases its availability and increases its price for other sectors of the economy.
- Substantially increasing the amount of natural gas used for electricity generation will require significant infrastructure investment.
- Dramatically increasing the use of natural gas in electricity generation may adversely impact electric reliability.

SUPPORTING DATA

All information below is sourced from third parties, primarily the federal government and academia.

Coal has been and is projected to be a less expensive fuel than natural gas.[2]

- According to data from the Energy Information Administration (EIA), the average cost of natural gas used in electricity generation was 3.6 times as expensive as coal during the period 2002-2011. Natural gas cost an average of $6.37/MMBtu over the 10-year period, whereas the cost of coal averaged $1.78/MMBtu over the same period.[3]

- During 2011, the cost of natural gas for power generation was more than double that of coal. Natural gas averaged $5.01/MMBtu over the course of the year, while coal averaged $2.41/MMBtu over the same period.[4]

- The U.S. Energy Information Administration (EIA) projects real natural gas prices to increase by 31 percent between 2010 and 2030. Coal prices are projected to rise only half as much, increasing only 15 percent over the same period**.** The table below shows EIA projections for natural gas and coal prices for the electric power sector in its *2012 Annual Energy Outlook (AEO)*.[5] Based on these projections, coal is expected to cost a fraction of the price of natural gas for the foreseeable future.

Price per MMBtu of Gas versus Coal for Electricity Generation [6]

	2011	2015	2020	2030
Natural gas	$5.01	$4.54	$4.91	$6.13
Coal	$2.41	$2.36	$2.46	$2.70
Comparison	Gas was 2.1 times as expensive	Gas is 1.9 times as expensive	Gas is 2.0 times as expensive	Gas is 2.3 times as expensive

Historically, electricity generated with coal has been considerably less expensive than electricity generated with natural gas.

- As shown in the table below, the cost of producing electricity with natural gas in 2010 was approximately one and one-half to three times as expensive as electricity generated from coal.

For the period 2001-2010, the average cost of electricity generated from natural gas combined cycle (NGCC) units was 2.4 times as much as from coal-fueled units. Electricity from natural gas combustion turbines cost 3.8 times as much as coal.[7]

2010 Electricity Production Cost

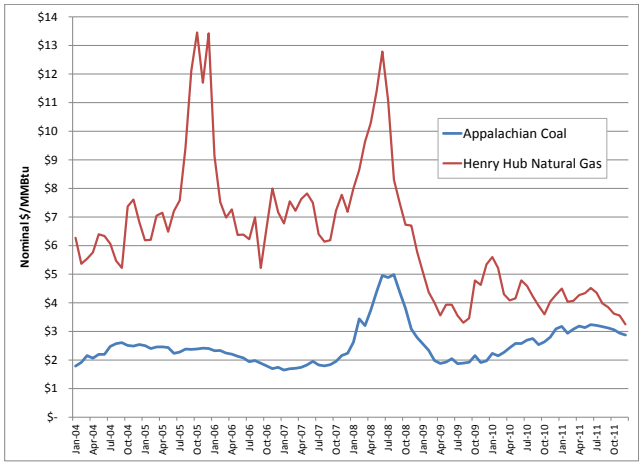
Coal	NGCC	Combustion Turbine
$33.15/MWh	$48.73/MWh	$91.62/MWh

- Generally, states that rely on coal have the lowest electricity rates. In 2011, 33 states had electricity rates below the national average retail price of 9.99 cents/kWh.[8] Coal was responsible for 50 percent or more of the electricity generated in 17 of those states.

Natural gas prices are volatile.

- Over the period 2004-2011, average annual natural gas commodity prices have fluctuated widely between a low of $4.03/MMBtu in 2011 and a high of $9.01/MMBtu in 2005, a swing of $4.99/MMBtu. Over the same period, coal commodity prices have varied more modestly from a low of $1.87/MMBtu in 2007 to a high of $3.86/MMBtu in 2008, a difference of $1.99/MMBtu. The graph below shows the volatility of gas prices compared to the relative stability of coal prices.

Historic Monthly Average Commodity Fuel Prices[9]



- U.S. natural gas prices have historically been among the most volatile of any commodity in the world.[10] This is driven in part by fundamentals of supply and demand. Suppliers increase drilling and production activity when high prices reflect increased demand, and reduce production when low prices signal lower demand. Lags between price signals and corresponding production responses lead to cyclical periods of high and low natural gas prices.[11]

- Factors that limit the ability of natural gas suppliers to adjust quickly to changes in demand include the availability of drilling rigs and skilled labor; the time required to permit, drill, gather and process gas from new wells; and weather-related disruptions to production.[12]

There is significant uncertainty about the technically recoverable quantity of U.S. natural gas resources.

- The long-term outlook for natural gas, while currently optimistic, has alternated between optimistic and pessimistic in recent decades. According to the MIT Energy Initiative, "These cycles of perceived 'feast and famine' demonstrate the genuine difficulty in forecasting the future and providing appropriate policy support for natural gas production and use."[13]

- EIA currently estimates U.S. technically recoverable natural gas resources to be 2,543 trillion cubic feet (Tcf.)[14] This is an increase of 86 percent over the 2008 forecast of 1,364.6 Tcf, much of which is attributable to an increase in shale gas resources from 125 Tcf to 861.7 Tcf.[15]

- Shale gas production is in its early stages in most of the country, and forecasters of ultimate shale gas productivity note the uncertainty. According to the MIT Energy Initiative, "Predicting the future economics of shale gas is difficult for many reasons, principal among those being the fact that shale gas production, at least in the contemporary sense, is still very much in its infancy, despite the current contribution it makes to overall U.S. production."[16]

- Estimates of the total recoverable natural gas resources in the Marcellus Shale formation highlight this uncertainty. The 2011 AEO estimated over 400 Tcf of resources in the Marcellus. However, later in 2011, the U.S. Geological Survey released an official estimate of only 84 Tcf, a reduction in resources of nearly 80 percent and an elimination of more than 12 percent of the technically recoverable resources estimated in the 2011 AEO (13 years of gas resources at 2010 U.S. demand levels).[17]

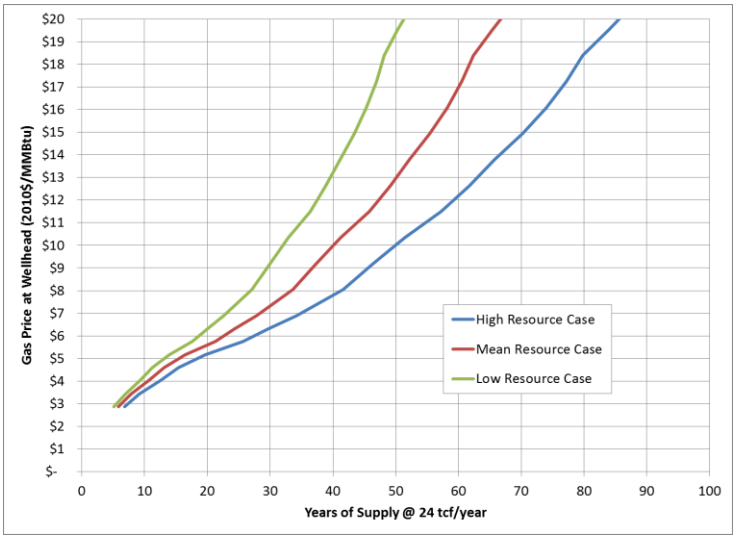
The future price of natural gas is uncertain and may be much higher than current prices.

- Natural gas prices are widely acknowledged to be difficult to forecast.[18] In assessing the forecasts it produces for the Annual Energy Outlook, EIA has noted that, "the fuel with the largest difference between the [EIA] projections and actual data has been natural gas."[19] For the years 2000-2009, EIA forecasts of wellhead natural gas prices produced 10 years earlier (i.e., 1990-1999) missed the actual observed price of gas by an average of 35 percent. Forecasts performed five years before were off by an average of 46 percent. Even forecasts of natural gas prices only three years in advance were off by an average of 36 percent.[20]

- The market price for natural gas at Henry Hub was below $4/MMBtu for much of 2011 and has begun 2012 under $3/MMBtu,[21] but these prices appear to be below the cost of production for most shale gas resources.[22] With shale gas expected to provide an increasing share of supply in the future, it is logical to expect that prices will rise in order to cover the costs of production.

- A 2011 study conducted by the MIT Energy Initiative projected the amount of domestic gas that could be economically produced at different wellhead prices.[23] The chart below presents these results as years of supply (using the 2010 U.S. consumption level of 24.13 Tcf).[24] The amount of natural gas that can be recovered at less than $4/MMBtu would satisfy only 10 years of U.S. gas demand. MIT's Mean Resource Case projects that less than 30 years of supply can be extracted at prices less than $7/MMBtu.

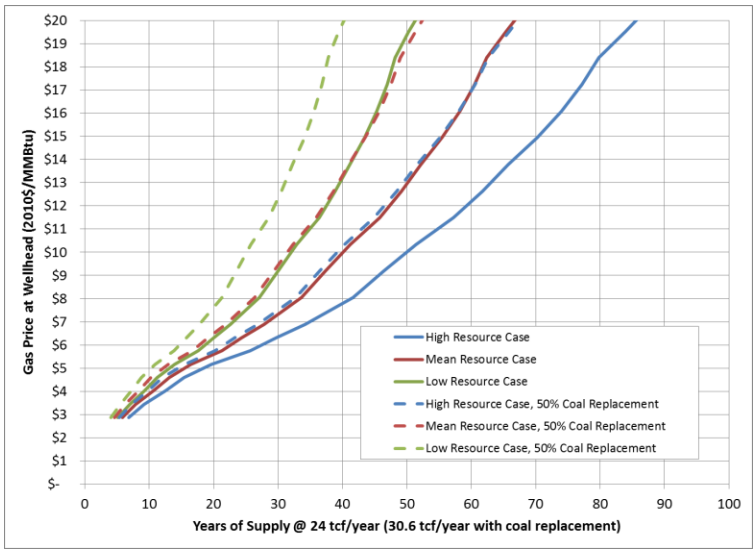
Natural Gas Supply Curve



- During 2001-2010, coal-generated electricity accounted for 48.6 percent of the electricity generated in the U.S. If half of this generation was replaced with natural gas, an additional 6.6 Tcf of natural gas would be required annually, a 90 percent increase from the 7.38 Tcf used to generate power in 2010.[25]

- Adding an additional 6.6 Tcf/year of natural gas demand to replace half of the power generated from coal will tend to consume inexpensive natural gas reserves more quickly, and lead to higher gas prices. As the chart below shows, at this rate of consumption (30.6 Tcf/year), 30 years of supply require resources that cost over $9/MMBtu to produce.

Natural Gas Supply Curve With 50 Percent Coal Replacement



The U.S. has abundant supplies of coal.

- EIA estimates that U.S. recoverable reserves totaled over 260 billion tons in 2010. The world's total recoverable coal reserves were estimated to be 948 billion tons in 2009.[26] According to EIA, the U.S. has the largest recoverable reserves of coal in the world.[27]

- At the current rate of consumption, the U.S. is capable of meeting domestic demand for coal for over 270 years (260 billion tons/954 million tons of coal consumed in 2010).[28]

- The current EIA natural gas estimate of 2,543 Tcf is equivalent to 105 years of supply (2,543 Tcf/24.13 Tcf natural gas consumed in 2010). However, the price of producing this much gas is highly uncertain (see above).

Increasing the use of natural gas for electric power generation decreases its availability and increases its price for other uses.

- Natural gas is used as fuel and feedstock in numerous industrial applications, for commercial and residential heating, and as a transportation fuel. As a finite natural resource, natural gas consumed for electric power generation cannot be used in these other sectors.

- In 2010, only 31 percent of natural gas consumption was for electric power generation. Industrial, residential, and commercial sectors accounted for 33 percent, 21 percent, and 13 percent of demand, respectively.[29] Higher natural gas prices caused by an accelerated consumption of natural gas in the electric sector will affect costs to these sectors.

- Coal is overwhelmingly used for generating electric power, which accounts for more than 93 percent of its demand.[30] Reducing the use of coal for electric power generation does not free it for use in other applications; rather, it idles a productive natural resource.

Increased reliance on natural gas for electricity generation will require substantial infrastructure investment.

- Due to the locations of existing power plants and constraints on the electric transmission system, only a fraction of the power currently generated by coal-fueled plants can be replaced by increasing the output of existing NGCC plants. The Congressional Research Service estimated this amount to be between 5 percent and 9 percent of the total output of coal-fueled plants.[31] Therefore, large-scale replacement of coal-fueled generation would require transmission line upgrades and construction of new NGCC capacity.[32]

- Most natural gas is consumed far from where it is produced, requiring significant transportation infrastructure. In 2007, 30 states were dependent on interstate pipeline deliveries to supply 85 percent or more of their natural gas demand.[33] According to the MIT Energy Initiative, $210 billion in natural gas infrastructure investment will be required over the next 20 years to supply growing gas demand.[34] Further increasing natural gas demand through replacement of coal-fueled generation should be expected to require even greater infrastructure investment.

Increased reliance on natural gas for electricity generation may impact the reliability of the electricity grid.

- The North American Electric Reliability Corporation (NERC) studied the risks to the electric system of growing reliance on natural gas and identified several areas of concern that could adversely affect electric reliability.[35] Among the risks NERC identified are the following:

  - Natural gas pipelines are built with sufficient capacity to meet only the demand of customers willing to pay for "firm" service and not in anticipation of demand growth or in coordination with additions to the electricity grid.

  - Many electricity generators do not maintain contracts for firm service from pipelines due to the unavailability or high cost of such service and, therefore, may not have access to gas during periods of peak demand.

  - Modern NGCC plants are less tolerant of variations in natural gas pressure and quality, and could be unavailable for peak demand periods if the quality of gas supply fluctuates.

  - Operation of the electricity and natural gas systems is not coordinated, and operating information is often withheld due to its proprietary nature.

This paper is updated as new data and information become available.

March 2012

---

[1] *Annual Energy Outlook 2012 Early Release Overview*, U.S. Energy Information Administration, January 2012.

[2] Natural gas can be measured based on either its volume (cubic feet) or its heat content (British thermal units or Btu). Coal can be measured based on either its weight (short tons) or its heat content (Btu). Different units of measurement are sometimes used in different reports. Typically, gas and coal are compared in millions of Btus (MMBtu). However, gas quantities are sometimes expressed in thousands of cubic feet (Mcf) or trillions of cubic feet (Tcf), rather than MMBtu.

[3] *Electric Power Monthly*, U.S. Energy Information Administration, February 2012. Monetary values are expressed in nominal dollars.

[4] *Ibid*.

[5] *Annual Energy Outlook 2012 Early Release Overview,* U.S. Energy Information Administration, January 23, 2012. Data are from the Reference Case results.

[6] *Ibid.* Coal and gas prices are for the electric power sector and are expressed in 2010$/MMBtu. 2011 prices are in nominal dollars and are from the EIA *Electric Power Monthly*, February 2012.

[7] FERC Form 1 filings for 2001 through 2010. Production cost includes fuel cost, variable operations & maintenance cost (VOM), and fixed operations & maintenance costs (FOM).

[8] *Electric Power Monthly*, U.S. Energy Information Administration, February 2012.

[9] Market prices are for prompt-month NYMEX futures contracts for 12,000 Btu/lb Central Appalachian coal and Henry Hub natural gas, as reported on the EIA web site.

[10] Austin F. Whitman. *Natural Gas Price Volatility: Lessons From Other Markets*. M.J. Bradley & Associates LLC, January 26, 2011.

[11] For example, see "Natural Gas Explained: Factors Affecting Natural Gas Prices," U.S. Energy Information Administration, http://www.eia.gov/energyexplained/index.cfm?page=natural_gas_factors_affecting_prices, accessed December 12, 2011.

[12] Natural Gas Supply Association (NGSA), http://www.naturalgas.org/business/supply.asp, accessed December 12, 2011.

[13] *The Future of Natural Gas: An MIT Interdisciplinary Study, Appendix 2D: Shale Gas Economic Sensitivities,* MIT Energy Initiative, 2011, p.6.

[14] Technically recoverable resource estimates include all natural gas that can be recovered using current technology, without regard to economic cost, and are from *Assumptions to the Annual Energy Outlook 2011*, Energy Information Administration, July 2011, Table 9-2. Technically recoverable resources are comprised of more than expected production from known reservoirs ("proved reserves"). They also include estimates of potential future production in known fields that are not currently under development ("inferred reserves") and "undiscovered resources" outside of known production fields.

[15] Forecast of 125 Tcf of shale gas resources is from *Assumptions to the Annual Energy Outlook 2008*, Energy Information Administration, June 2008, Table 9-2.

[16] *The Future of Natural Gas: An MIT Interdisciplinary Study, Appendix 2D: Shale Gas Economic Sensitivities,* MIT Energy Initiative, 2011, p.6.

[17] *Fact Sheet 2011-3092: Assessment of Undiscovered Oil and Gas Resources of the Devonian Marcellus Shale of the Appalachian Basin Province*, U.S. Geological Survey, August 2011.

[18] See, e.g., Michelle M. Foss. *The Outlook for U.S. Gas Prices in 2020: Henry Hub at $3 or $10?* Oxford Institute for Energy Studies, December 2011.

[19] *Annual Energy Outlook Retrospective Review 2008*, U.S. Energy Information Administration, September 2008, p.2.

[20] *Retrospective Review: Annual Energy Outlook 2010*, U.S. Energy Information Administration, July 2011. Calculations based on Table 8. Forecast errors have predominantly been underestimates, with actual natural gas prices being higher than the forecasts. Actual prices for the ten years 2000-2009 were underestimated eight times by ten-year forecasts, nine times by five-year forecasts, and seven times by three-year forecasts.

[21] *Henry Hub Gulf Coast Natural Gas Spot Price ($/MMBTU)*, U.S. Energy Information Administration, tonto.eia.gov/dnav/ng/hist/rngwhhdd.htm, accessed January 25, 2012.

[22] See, e.g., Neal Anderson, "Wood Mackenzie: Playing a smart shale gas hand," *Oil & Gas Financial Journal*, August 10, 2011.

[23] *The Future of Natural Gas: An MIT Interdisciplinary Study*, MIT Energy Initiative, 2011. The "high resource case" curve represents the 10th percentile of forecast supply costs, i.e., there is a one-in-ten chance that future supply costs are lower than those represented by the curve. Similarly, the "low resource case" curve represents the 90th percentile of costs, with a one-in-ten likelihood of the actual production cost curve exceeding this one. The "mean resource case" curve represents the expected future supply curve. Prices are inflated from 2004 dollars to 2010 dollars.

[24] 2010 natural gas consumption of 24.133 Tcf is taken from *Annual Energy Review 2010*, U.S. Energy Information Administration, Table 6.1.

[25] Coal generated an average of 1.94 million MWh between 2001 and 2010 according to EIA's *2010 Electric Power Annual*. Assuming half of this generation is replaced by modern NGCC units with heat rates of 7 MMBtu/MWh results in a value of 6.611 Tcf of additional natural gas demand per year.

[26] *International Energy Outlook 2011,* U.S. Energy Information Administration, September 2011.

[27] *Ibid.*

[28] Coal consumption of 1.048 billion tons in 2010 taken from EIA *Annual Energy Review 2010*.

[29] *Annual Energy Review 2010*, U.S. Energy Information Administration, Table 6.5, October 2011.

[30] *Annual Energy Review 2010*, U.S. Energy Information Administration, Table 7.1 & 7.3, October 2011. The remaining coal consumption amounts to 6.6 percent in the industrial sector, 0.3 percent in the commercial sector, and 0.03 percent for residential use.

[31] Stan Mark Kaplan, *Displacing Coal with Generation from Existing Natural Gas-Fired Power Plants*, Congressional Research Service, January 19, 2010. The CRS identified as candidates for replacement the coal plants that had nearby existing CCGT plants running at less than full output (capacity factors less than 85 percent). The low and high ends of the estimate correspond to distances of 10 miles and 25 miles, respectively.

[32] *Implications of Greater Reliance on Natural Gas for Electricity Generation*, Aspen Environmental Group, July 2010.

[33] EIA, http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/dependstates_map.html, accessed December 5, 2011.

[34] *The Future of Natural Gas: An MIT Interdisciplinary Study*, MIT Energy Initiative, 2011, p.12.

[35] *2011 Special Reliability Assessment: A Primer of the Natural Gas and Electric Power Interdependency in the United States*, North American Electric Reliability Corporation, December 2011. This report updates a 2004 NERC study addressing similar concerns.