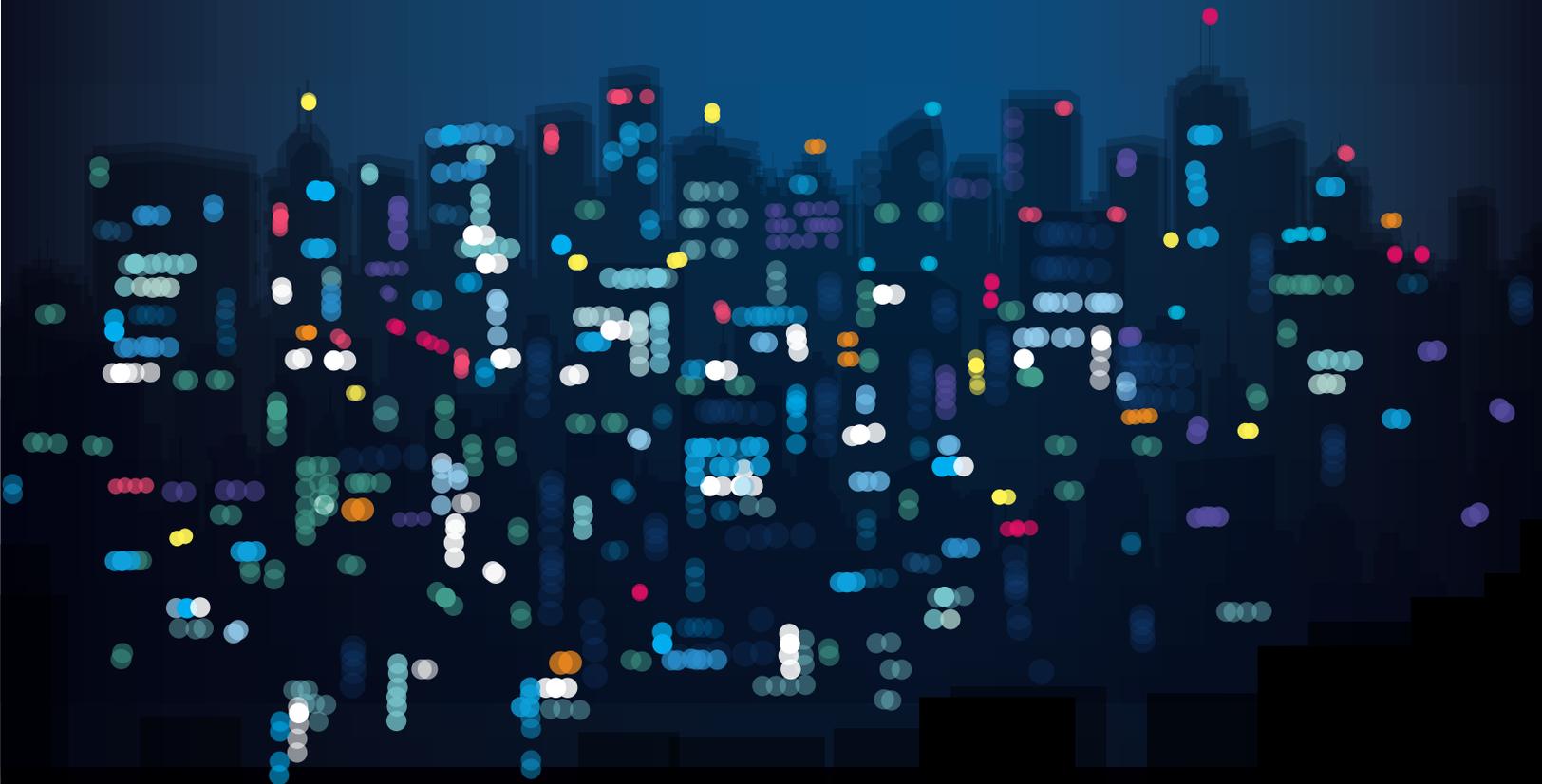


KEEPING THE LIGHTS ON 24/7:

THE VALUE OF COAL AND THE NATION'S COAL FLEET

SECOND EDITION
AUGUST 2020



AMERICA'S POWER

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Coal and the nation's fleet of coal-fueled power plants have been the backbone of the U.S. electricity grid for decades. However, this grid that produces and delivers electricity is undergoing profound changes. The retirement of baseload sources of electricity and an increasing reliance on natural gas and renewable energy sources (mostly wind and solar) affect—and can even impair—the reliability and resilience of the grid and, therefore, create challenges for electricity generators; state public utility commissions; independent system operators (ISOs) and regional transmission organizations (RTOs); the U.S. Federal Energy Regulatory Commission (FERC); the U.S. Department of Energy (DOE); the North American Electric Reliability Corporation (NERC); and others with a stake in ensuring the grid is able to produce and deliver affordable electricity 24/7. Despite these challenges, the coal fleet and coal continue to be a critical part of the U.S. power grid.

To assist policymakers in better understanding the value of coal and the coal fleet, America's Power wrote this paper to explain the fleet's role in —

- Helping to assure the grid is both reliable and resilient,
- Providing fuel security,
- Serving as an insurance policy at critical times,
- Producing affordable electricity,
- Contributing to fuel diversity, and
- Supporting national security.

To preserve this value, steps must be taken to prevent the premature retirement of more coal-fueled electricity generating capacity, as well as establishing policies that lead to the deployment of more efficient and lower emitting coal-fueled electricity sources.

Background

Coal was the second-largest source of electricity during 2019, providing approximately 24 percent of U.S. electricity needs¹ and is projected to provide 18 percent of U.S. electricity in 2020 and 22 percent in 2021.² The coal fleet provides electricity to consumers in 47 states. The states with the largest coal fleets (in order of size) are Texas, Indiana, West Virginia, Ohio, Kentucky, Pennsylvania, Missouri, Illinois, North Carolina, Michigan, Georgia, Florida, Wyoming, and Tennessee.³

The U.S. has vast supplies of coal. As of 2018, EIA estimates that recoverable coal reserves total slightly more than 253 billion tons.⁴ At current rates of consumption, the nation's coal reserves would last for roughly 500 years. Natural gas is the other leading fuel for electricity generation. At current rates of consumption, the nation's gas resources would last from 14 years (proved reserves) to 92 years (technically recoverable reserves).⁵

Some 92 percent of domestic coal is consumed for electricity generation in the U.S., which means that coal demand and prices are not influenced by other uses.⁶ By contrast, almost two-thirds of natural gas is either consumed for non-electricity purposes or exported.⁷ Therefore, overall demand and prices for natural gas are influenced by demand in the industrial, residential and commercial sectors of the economy, which are highest during winter months due to residential and commercial space heating (together 27 percent of overall gas demand). At the same time, gas demand in the winter for electricity generation continues to increase, with its share of December-February gas demand rising from 21 percent in 2007-08 to 25 percent in 2018-19.⁸

Natural gas prices tend to be volatile, typically spiking during winter months when gas demand increases. For example, gas prices in PJM Interconnection (PJM) exceeded \$96 per million British thermal units (MMBtu) on January 5, 2018, during the polar vortex.⁹ On the other hand, the price of coal is relatively stable. From 2016 through 2019, the monthly average cost of coal delivered to power plants ranged from \$1.92 to \$2.17/MMBtu, a range of \$0.25/MMBtu.¹⁰ Over the same period, the average cost of natural gas delivered to power plants ranged from \$2.23 to \$5.06/MMBtu, a range of \$2.83/MMBtu.¹¹

Approximately two-thirds of the coal fleet's generating capacity is located in RTO/ISO regions (wholesale electricity markets). Therefore, wholesale market rules have a significant effect on the coal fleet. The regions with the largest coal fleets are Midcontinent Independent System Operator (MISO) (56,500 MW); PJM (49,100 MW); Southwest Power Pool (SPP) (23,700 MW); and the Electric Reliability Council of Texas (ERCOT) (14,000 MW).¹²

Emissions per kilowatt-hour of three major air pollutants—sulfur dioxide, nitrogen oxides, and particulate matter—emitted by coal-fueled power plants have been reduced by 93 percent over the period 1970–2019.¹³ Owners of coal-fueled power plants will have spent almost \$100 billion to install emission control technologies over the period 2000–2020 to reduce these three air pollutants, as well as emissions of mercury.¹⁴

According to EIA, coal is the third-largest source of energy-related carbon dioxide (CO₂) emissions in the U.S.¹⁵ Over the period 2017–2021, petroleum (mostly transportation) is responsible for 46 percent of emissions, natural gas is responsible for 32 percent, and coal represents 21 percent. For perspective, CO₂ emissions from the U.S. coal fleet represent approximately 19 percent of U.S. greenhouse gas (GHG) emissions and less than 2 percent of global GHG emissions.¹⁶ In addition, CO₂ emissions from the U.S. electric power sector have declined from 2005 levels by nearly 33 percent, which exceeds the economy-wide commitment (26 to 28 percent reduction) of the Obama administration to meet the goals of the Paris Agreement.¹⁷

The coal fleet is necessary for reliability, resilience, and fuel security

A reliable grid means having an adequate supply of electricity 24/7 under relatively normal circumstances. NERC, which is responsible for ensuring the reliability of the nation's bulk power system, has objective standards for reliability.¹⁸ Failure to comply with these reliability standards can result in fines. There are at least 16 distinct attributes that contribute to grid reliability.¹⁹ The coal fleet possesses almost all of these attributes, especially those that are defined as “essential reliability services” (voltage control, frequency response, and regulation). A resilient grid means that the grid can withstand and recover quickly from unusual disturbances—such as extreme weather, cyber threats, or physical threats—that can have severe consequences. However, there are no criteria or standards yet for resilience, despite its importance.

If the grid is not both reliable and resilient, the cost of electricity outages can be substantial. According to the National Academy of Sciences, “... a large-scale blackout could result in billions of dollars in economic impact, and risk injury or death.”²⁰ In 2018, DOE estimated that power outages cost American businesses \$150 billion per year.²¹ In addition, the Obama administration cited annual costs of power outages ranging from \$59 billion to \$209 billion.²²

Fuel security is essential for grid resilience because it enables the grid to absorb and recover quickly from major disturbances. PJM emphasizes the potential disruption of fuel supplies in its definition of fuel security: "... the ability of the system's supply portfolio, given its fuel supply dependencies, to continue serving electricity demand through credible disturbance events ... that could lead to disruptions in fuel delivery systems ... which could impact the availability of generation over extended periods of time."²³ Both PJM and ISO New England (ISO-NE) have conducted fuel security analyses because of concerns about fuel security and grid resilience, with ISO-NE ultimately enacting an "operational fuel-security" payment to generators that maintain firm fuel supplies during critical winter periods.²⁴

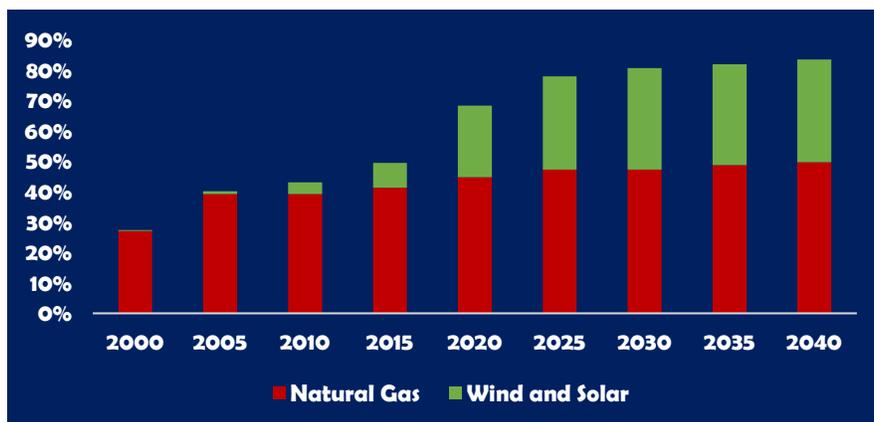
Maintaining a supply of coal at each coal-fueled power plant provides fuel security because on-site stockpiles of coal minimize the potential impact of fuel supply disruptions. The average U.S. power plant burning bituminous coal has a 127-day stockpile. Plants burning subbituminous coal have an average 114-day stockpile.²⁵ Thus, the average coal-fueled power plant could operate for more than three months, even in the extremely unlikely event that coal deliveries were interrupted for an extended period making coal one of the two most fuel-secure sources of electricity. This high degree of fuel security contrasts with renewables that cannot generate electricity without wind or sunshine and natural gas-fueled power plants that rely on just-in-time fuel delivery from gas pipelines.

A study conducted by EVA analyzed the resilience of coal deliveries via barge, rail and truck to PJM power plants.²⁶ Among other findings, the study concluded that disruptions of coal deliveries are "extremely infrequent" and have never affected the ability of PJM's coal fleet to generate electricity because of coal stockpiled at each plant.

The electricity grid is becoming less fuel secure

Although there are no standards for grid resilience, there is general agreement that fuel security is important to resilience. However, premature coal retirements mean the nation's electricity supply is becoming increasingly dependent on sources that provide little fuel security (natural gas) or no fuel security at all (renewables). Since 2010, more than 200,000 MW of natural gas-fueled generation, wind, and solar have been added to the grid.²⁷ In 2000, nearly 70 percent of the nation's electricity generating capacity was comprised of fuel-secure sources. In 2020, the percentage represented by fuel-secure sources has fallen to 32 percent (chart below²⁸).

Share of generating capacity by resource type



The grid's increasing dependence on natural gas and the retirement of coal-fueled and nuclear power plants have raised concerns that these trends may be jeopardizing the reliability and resilience of the grid. Such concerns have been raised by DOE, FERC, NERC, ISO/RTOs, the National Academy of Sciences, and the National Energy Technology Laboratory (NETL), among others.²⁹

Analysis by Quanta Technology illustrated the negative impacts on the PJM grid of premature coal retirements and the lack of sufficient natural gas-fueled generation that could be caused by disruption or curtailment of fuel supplies.³⁰ Quanta modeled nine scenarios (different combinations of retirements and interruption of gas supplies) and determined that the PJM grid would not meet reliability criteria for transmission security, resource adequacy, or both under seven of the nine scenarios. Quanta concluded that PJM would lose its resilience to gas outages if coal retirements continue.

Other experts have raised concerns about the vulnerabilities associated with overreliance on natural gas for electricity generation. For example, NERC assessed the potential threats to the grid posed by disruptions to natural gas pipelines and other parts of the natural gas delivery system.³¹ Their assessment listed at least 17 vulnerabilities that could interrupt the delivery of natural gas to power plants.

One of these vulnerabilities is just-in-time gas delivery via pipeline because natural gas cannot be stored easily at power plant sites. (As noted previously, coal-fueled power plants stockpile enough coal on site to last for two or more months.) NERC points out that in many cases, several gas-fueled power plants are served by the same natural gas pipeline. Therefore, disruption of a single pipeline system could interrupt gas deliveries to multiple gas-fueled power plants. This gas vulnerability is referred to as a "single point of disruption."

Another vulnerability is the lack of dual fuel as a backup if natural gas supplies are interrupted. Having a backup fuel (either fuel oil or diesel) stored on site at gas-fueled power plants can help mitigate at least some, but not all, of the risks associated with natural gas deliveries because it can provide backup fuel to generate electricity in case of disruptions. However, NERC indicated that only 27 percent of gas-fueled generating capacity built over the past two decades has dual-fuel capability. This means that roughly 275,000 MW of gas-fueled generating capacity—approximately one-fourth of the entire U.S. electricity supply—lack dual-fuel capability and, therefore, have no backup in case gas deliveries are interrupted. (The cost to add dual-fuel capability to the existing gas fleet to improve fuel security could be as much as \$110 billion or more.³²) Even for plants that have dual-fuel backup, air quality requirements can restrict operations if it becomes necessary to use higher-polluting fuel oil or diesel as a backup.

Many gas-fueled power plants opt for less expensive interruptible service that is available only when pipeline capacity is not being used by customers with firm delivery contracts. NYISO, ISO-NE, MISO, and PJM have the smallest proportions of gas delivered to power plants via firm transportation, ranging from 23 to 52 percent.³³ New pipeline and storage capacity would be needed if more gas-fueled power plants sign firm supply contracts, an additional cost that would increase power prices. Even without more firm gas contracts, the capital cost to add new natural gas infrastructure over the period 2017-2035 is estimated to be \$370 billion to \$465 billion, assuming that regulatory and other hurdles can be overcome.³⁴

NERC also evaluated the impacts of accelerated coal and nuclear retirements on resource adequacy, fuel assurance, fuel diversity, and transmission reliability.³⁵ NERC concluded that “a significant shift to natural-gas-fired generation could leave the [bulk power system] more vulnerable to natural gas supply and transportation disruption events or curtailments” unless gas deliveries are based on firm contracts and new pipeline capacity is added. NERC also recommended that “policymakers should consider the potential for increased reliability risk from declining fuel diversity.” To that end, NERC recently issued reliability guidelines that it developed to assist grid operators in identifying and mitigating the risks that arise from insecure fuel supplies.³⁶

The nation’s electricity supply is becoming less diverse

Forty-two states have coal-fueled generating units that have retired or are planning to retire.³⁷ The top 15 states for coal retirements are Ohio, Pennsylvania, Indiana, Illinois, Alabama, Texas, Missouri, Michigan, Kentucky, Virginia, Georgia, Florida, North Carolina, Minnesota, and Tennessee. In total, 45 percent (141,520 MW) of the U.S. coal fleet has retired or announced plans to retire. For perspective, these coal retirements are equivalent to shutting down the combined electricity supplies of Georgia, Michigan, Ohio, Indiana, and Kentucky. At least 11,500 MW are expected to retire in 2020 and 2021.³⁸

As coal retirements mount, fuel diversity is declining. To illustrate the value of fuel diversity, IHS Markit published “Ensuring Resilient and Efficient Electricity Generation: The Value of the Current Diverse U.S. Power Supply Portfolio.”³⁹ According to the study, the U.S. is “moving away from the cost-effective mix of fuels and technologies and toward a less reliable, less resilient, and less cost-effective power supply portfolio.” Within the next decade, some regions of the country could end up with a “less efficient diversity” portfolio with virtually no coal or nuclear, a smaller contribution from hydro, more renewables, and a majority of generation coming from natural gas.

IHS compared today’s electricity generation mix to a less diverse portfolio and found that the cost of electricity production with a less diverse portfolio would increase by \$114 billion per year; the average retail price of electricity would increase by 27 percent; and impaired reliability from a less resilient portfolio could increase electricity outages, resulting in added costs as high as \$75 billion per outage hour. According to IHS, its overall results are conservative because the value of fuel diversity would be even greater if IHS had used a longer time frame for its analysis. IHS recommended steps to prevent further premature retirements that include defining criteria for resilience and implementing reforms to wholesale electricity price formation.

Preserving the coal fleet makes economic sense

The levelized cost of electricity (LCOE) has been used in the past to make comparisons between new, but not existing, electricity resources. Other things being equal, the resource, whether existing or new, with the lowest levelized cost is the most economic choice. In contrast to dispatch costs that reflect only variable costs, LCOE is a more comprehensive measure because it includes all of the costs (variable, fixed, capital, and financing) associated with constructing and operating an electricity source over its lifetime. Therefore, levelized costs are useful in helping to determine whether it is less expensive either to continue operating an existing power plant or to replace it with a new resource (e.g., natural gas or renewables).

Analysis of levelized costs by America’s Power and the Institute for Energy Research (IER) illustrates the economic advantage of the existing coal fleet compared to new natural gas, wind, and solar.⁴⁰ On average, the LCOE for an existing coal-fueled power plant (yellow in the chart below) is less than the levelized cost of new natural gas combined cycle (NGCC), new wind or new solar (blue). (These costs are based on national averages. Actual costs can vary based on case-specific circumstances). New generators have higher costs because of the debt and equity obligations they incur during construction, while existing power plants have already paid off some or all of those obligations.

LCOE (\$/MWh) for electricity sources in 2020



Other analyses have reached the same conclusion that, on average, new resources are more expensive on a levelized cost basis than existing coal-fueled generation. IHS Markit found that the levelized cost of existing coal-fueled generation (\$40/MWh) is less than the levelized cost of new NGCC (\$68/MWh) and renewables (\$82/MWh).⁴¹

In addition, the PJM system illustrates the potential cost of prematurely retiring existing coal-fueled generation. (PJM has had more coal retirements—36,100 MW—than any other ISO/RTO, and even more coal-fueled generation in the region is at risk of retirement.) Analysis by EVA shows that the cost of power in the PJM market would increase by \$1.92 billion annually due to the higher costs of energy and capacity if three at-risk coal-fueled power plants were retired and replaced by new NGCC.⁴² In addition, the capital cost of replacing these coal retirements with NGCC generation would be \$5.7 billion.

The coal fleet helps prevent higher electricity prices and shortages

The coal fleet mitigates spikes in the price of other fuels and ensures against the possibility of electricity shortages during critical times, such as extreme weather, when other electricity sources may be unable to obtain fuel, or the price of other fuels is extremely high. The 2018 bomb cyclone winter storm is a case study.

NETL analyzed the performance of different electricity sources in PJM during 2018’s bomb cyclone.⁴³ Their analysis concluded that PJM would have experienced “interconnect-wide blackouts” if coal-fueled generation had not been available to meet the increased electricity demand caused by unusually cold weather.

PJM maintained that natural gas-fueled power plants could have met the increased demand for electricity but were not dispatched because natural gas was too expensive.⁴⁴ The price of natural gas in PJM exceeded \$20/MMBtu during several days of the storm (\$96/MMBtu on January 5), well above the \$4 to \$5/MMBtu price that prevailed before and after the storm. If coal-fueled generation had not been available, NETL determined that power prices from incremental gas-fueled generation to meet the higher electricity demand would have been 25 to 70 times higher than normal (i.e., power prices would have been \$650-\$1,800/MWh). In short, both NETL and PJM agreed the PJM coal fleet was important but for different reasons: NETL because of the lack of sufficient natural gas and PJM because natural gas was too expensive.

PJM’s CEO testified before the Senate Energy and Natural Resources Committee shortly after the bomb cyclone: “The reality is ... 45,000 MW of the electricity that PJM delivered, which is 40 percent or more, was coal-fired. We could not have served customers without coal-fired resources.”⁴⁵

NETL continued to study the grid’s response to the 2018 bomb cyclone, finding that coal unit retirements led to significant increases in the price of electricity and natural gas in the regions comprising the four largest grid operators.⁴⁶ This is because reliance on natural gas-fueled generation during cold weather leads to significant simultaneous spikes in gas demand for both electricity and space heating markets. These spikes can lead to gas supply shortages, drastic increases in the price of natural gas, and corresponding increases in electricity prices. The table below shows the price increases NETL observed for these four regions during the bomb cyclone.

Market price increases during 2018 bomb cyclone

	ISO-NE	PJM	NYISO	MISO
Natural Gas	1,900%	2,200%	2,200%	300%
Electricity	500%	500%	700%	300%

In a wider look at recent winter storm events, NETL found that natural gas price “excursions” caused by high demand for both heating and electric power generation caused electricity prices paid by utility customers to increase by \$27.6 billion over just three cold snaps—in 2014, 2015, and 2018.⁴⁷

During the January 2019 polar vortex, MISO relied heavily on its coal fleet to meet the increased demand for electricity caused by the extreme cold. MISO’s coal fleet was able to provide 44 percent of the region’s electricity during the extremely cold weather. In contrast, electricity output from wind dropped by two-thirds when it was needed most.⁴⁸ Similarly, SPP issued its very first energy emergency alert in August 2019 due to wind generation shortfalls. Despite high electricity demand, only seven percent of SPP’s wind capacity was operating. Having lost over 5,000 MW of coal capacity to retirement since 2010, SPP required emergency power imports from Texas. SPP Operations Director C.J. Brow commented, “We had no other generators.”⁴⁹

A Texas heat wave in August 2019 saw electricity demand reach record levels. In the prior ten years, wind capacity had grown from 10 percent to 26 percent of capacity in ERCOT.⁵⁰ The low marginal cost of subsidized wind power depressed market prices to the point where over 5,000 MW of coal generation chose to retire in 2018 rather than continue losing money. These retirements combined with an

unpredicted drop in wind generation forced ERCOT to enact emergency procedures to avoid blackouts. Although blackouts were avoided, electricity prices that were under \$20/MWh in the morning of August 13, 2019 rose to \$9,000/MWh in the afternoon.⁵¹

Coal retirements could be jeopardizing national security

The retirement of coal-fueled and nuclear plants also has prompted national security concerns. A 40-page draft White House paper explained that “... resources that have a secure on-site fuel supply ... including coal-fired power plants ... are essential to support the nation’s defense facilities, critical energy infrastructure, and other critical infrastructure ... The Department of Defense (DOD) relies on the electric grid to support military operations at home and abroad.” The paper went on to say that “... retirements of fuel-secure electric generation capacity across the United States are undermining the security of the electric power system because the system’s resilience depends on these resources.”⁵²

National security expert Dr. Paul Stockton sent several recommendations to PJM because the grid operator is evaluating fuel security.⁵³ (Dr. Stockton served as an Assistant Secretary of Defense during the Obama Administration.⁵⁴) His comments highlighted the growing risks of overreliance on natural gas: “U.S. reliance on natural gas for power generation has been increasing along with adversary capabilities to attack pipelines and storage sites in the PJM region and beyond ... given the critical military installations and other national security facilities in the PJM service area, this area will be ground zero if Russia, China, or other potential adversaries launch comprehensive attacks to disrupt the flow of natural gas for power generation.”

In addition, past Director of National Intelligence Dan Coats testified in 2019 before the Senate Intelligence Committee that “China has the ability to launch cyberattacks that cause localized, temporary disruptive effects on critical infrastructure — such as disruption of a natural gas pipeline for days to weeks.”⁵⁵

Technology and the future of coal

The development of advanced coal technology represents an opportunity to improve the efficiency and flexibility of the nation’s coal fleet, while reducing its carbon intensity. Carbon capture, utilization and storage technology (CCUS) continues to advance, with declining costs that suggest promise for widespread commercial deployment. CCUS removes CO₂ at the source of combustion and either injects it into long term geologic storage or delivers it as a commodity for commercial use.

Globally there are 19 large scale carbon capture projects, with 10 of those in the U.S. The Global Carbon Capture Institute is monitoring approximately 40 more potential large scale projects.⁵⁶ Facilities in the U.S. capture approximately 25 million metric tons (tonnes) of CO₂ annually and represent 80 percent of global carbon capture capacity.⁵⁷ There are currently two operational coal plants with carbon capture systems: the Petro Nova project in Texas⁵⁸ and the Boundary 3 project in Saskatchewan, Canada.

Current cost-effectiveness estimates for CCUS installed at coal-fueled generators range from \$43/tonne of CO₂ to \$120/tonne of CO₂ (table below).

Cost estimates of carbon capture from coal-fueled generation

Source	\$/tonne
DOE—Current Estimate⁵⁹	\$60
DOE—Anticipated Goal⁶⁰	\$30
Global CCS Institute⁶¹	\$60
Goldman Sachs Carbonomics⁶²	\$50-\$120
IEA Clean Coal Centre⁶³	\$43-\$45

These costs reflect increased government support for CCUS. Tax credits under Section 45Q of the Internal Revenue Code also offer support for CCUS investment. The credits currently amount to \$35/tonne of CO₂ that is utilized for enhanced oil recovery or other commercial utilization and \$50/tonne for CO₂ that is permanently stored in a geologic formation. The National Petroleum Council estimates that 45Q tax credits could lead to a doubling of CCUS deployment in the next five to seven years.⁶⁴

High efficiency, low emissions (HELE) coal-fueled electric generating technology is well-developed and has been successfully operating in many countries, including Japan, Germany, and China.⁶⁵ HELE technology includes supercritical and ultrasupercritical boilers, fluidized bed combustion, and integrated gasification combined cycle generators.

Sound policies would help preserve the coal fleet and its value

Past EPA policies have caused or contributed to more than half of all coal retirements.⁶⁶ Most of these policies are being revisited by the current administration. For example, EPA has repealed the Clean Power Plan that was promulgated in 2015 and replaced it with the Affordable Clean Energy rule to reduce CO₂ emissions from coal-fueled power plants, and the agency is in the process of revising regulations promulgated in 2015 for coal combustion residuals and effluent discharges.

Federal tax subsidies for renewables, state out-of-market subsidies for nuclear generation, and state renewable portfolio standards give other electricity sources an advantage over the coal fleet. In wholesale electricity markets, subsidies for other electricity sources suppress energy prices and make coal-fueled generation less competitive. Reforming wholesale market rules could remedy some of these problems.

This year at the direction of FERC, PJM revised its Minimum Offer Price Rule (MOPR) to mitigate the effects of state subsidies for certain electricity sources in its 13-state footprint. The MOPR prohibits electricity generators from offering generating capacity into PJM's capacity market at below-competitive prices caused by state subsidies. However, the MOPR alone does not resolve other flaws in PJM's market or in other electricity markets.

Establishing resilience criteria would enable wholesale electricity markets to value resilience attributes and fuel security in the same manner they currently value reliability attributes. For regulated utilities, integrated resource planning should consider fuel diversity and the adequacy of fuel infrastructure for natural gas to the extent they are not already factored into retirement decisions.⁶⁷ Also, the LCOE for

both existing and new resources should be given careful consideration in decisions about whether to retire coal-fueled generating units. These are some, but not all, of the policies that need to be addressed in order to preserve the value of the nation's coal fleet.

* * *

This paper provides mostly summary-level information. More detail or additional information can be obtained by contacting America's Power at info@americaspower.org.

¹ U.S. Energy Information Administration (EIA), "Short Term Energy Outlook," August 11, 2020.

² *Ibid.*

³ S&P Global Market Intelligence, SNL Energy Data. Accessed April 2020.

⁴ EIA, "How large are U.S. coal reserves?," Categories and estimated amounts of U.S. coal reserves as of January 1, 2018. Last updated October 3, 2019.

⁵ Estimates of natural gas resources vary widely. According to EIA (2020), proved reserves of natural gas total 438.5 trillion cubic feet (Tcf) as of 2018. Proved reserves are "the most certain gas resource category," according to EIA. Technically recoverable resources (TRR) of natural gas total 2,828.8 Tcf. However, "estimates of TRR are highly uncertain," according to EIA. Moreover, the actual number of years will depend on the amount of natural gas consumed each year, natural gas imports and exports, and additions to natural gas reserves. Annual gas production of 30.6 Tcf in 2018 is used to estimate how long gas reserves would last. EIA, "Annual Energy Outlook 2020."

⁶ EIA, "Coal Quarterly Report October-December 2019," release date July 1, 2020.

⁷ EIA, "Natural Gas Monthly Data for May 2020," release date July 31, 2020.

⁸ *Ibid.*

⁹ S&P Global Market Intelligence, Tetco M3 Spot Natural Gas Index.

¹⁰ EIA, "Electric Power Monthly," June 2020.

¹¹ *Ibid.*

¹² S&P Global Market Intelligence, SNL Energy Data. Accessed August 2020.

¹³ EIA, "Electric Power Monthly," May 2020, Table 1.1. Net Generation by Energy Source: Total (All Sectors); U.S. EPA, "Air Pollutant Emission Trends, National Air Emissions Trends 1970-2019;" U.S. EPA, "National Emissions Inventory, Air Pollutant Emissions Trends Data, 1970-2019, Fuel Combustion Electric Utilities," queried July 2020.

¹⁴ Energy Ventures Analysis (EVA), "Capital Investments in Emission Control Retrofits in the U.S. Coal-fired Generating Fleet through the Years 1970-2016," January 26, 2016.

¹⁵ EIA, "Short-Term Energy Outlook," release date March 11, 2020. Over the period 2019-2021, U.S. energy-related CO₂ emissions average 5.2 billion tonnes per year. Petroleum averages 2.37 billion tonnes per year (46 percent), natural gas averages 1.60 billion tonnes (31 percent), and coal averages 1.22 billion tonnes (23 percent).

¹⁶ Global GHG emissions were estimated to be 51.8 billion tonnes in 2018. "Trends in Global CO₂ and Total Greenhouse Gas Emissions: 2019 Report," PBL Netherlands Environmental Assessment Agency, The Hague, 2019. U.S. GHG emissions were 6.67 billion tonnes in 2018. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018," February 12, 2020. According to EIA, CO₂ emissions from the coal fleet totaled 1.26 billion tonnes in 2018. EIA, "Short-Term Energy Outlook," release date February 12, 2019.

¹⁷ The electric sector emitted 2.42 billion tonnes of CO₂ in 2005. In 2019, the sector emitted 1.6 billion tonnes of CO₂. EIA, "How much of U.S. carbon dioxide emissions are associated with electricity generation?" May 26, 2020.

¹⁸ Section 215 of the Federal Power Act requires NERC to develop mandatory and enforceable reliability standards, which are subject to FERC review and approval. After reliability standards are approved by FERC, they become mandatory and enforceable in the U.S. and eight Canadian provinces.

¹⁹ These reliability attributes include, but are not limited to, dispatchability, frequency response, inertia, voltage control, reactive power, contingency reserves, spinning reserves, ramp capability, regulation, load following, black start capability, fuel security/on-site fuel, resource availability (non-intermittency), flexibility (cycling and short start-up times), vulnerability to single points of disruption, and price stability. The coal fleet provides 13 of these 16 attributes.

²⁰ National Academy of Sciences, "Enhancing the Resilience of the Nation's Electricity System," 2017.

²¹ DOE, "Department of Energy Report Explores U.S. Advanced Small Modular Reactors to Boost Grid Resiliency," January 25, 2018.

²² Executive Office of the President, "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages," August 2013.

²³ PJM, "Valuing Fuel Security," April 30, 2018. ISO-NE says that "... the most significant resilience challenge is fuel security – or the assurance that power plants will have or be able to obtain the fuel they need to run ..." For that reason, ISO-NE has undertaken a study of fuel security. PJM takes a similar view of fuel security and has undertaken an initiative to value fuel security: "PJM now seeks to isolate one type of resilience risk: fuel security. Fuel security focuses on the vulnerability of fuel supply and delivery to generators and the risks inherent in increased dependence on a single fuel-delivery system ... To define potential fuel-security criteria, PJM needs to understand the fuel-supply risks in an environment trending towards greater reliance on natural gas supply and delivery."

²⁴ ISO New England Tariff, III.13.2.5.2.5A, https://www.iso-ne.com/static-assets/documents/regulatory/tariff/sect_3/mr1_sec_13_14.pdf.

²⁵ EIA, "Electricity Monthly Update," "Electric Power Sector Coal Stocks: March 2020," release date June 24, 2020.

²⁶ EVA, "Coal Supply Security in PJM," November 2018.

²⁷ EIA, "Electric Power Annual," October 2019.

²⁸ *Ibid* and EIA, "Annual Energy Outlook 2020," January 29, 2020.

²⁹ These include DOE "Notice of Proposed Rulemaking, Grid Resiliency Pricing Rule," Docket RM17-3-000, Sept. 28, 2017; NERC "Generation Retirement Scenario Special Reliability Assessment," Dec. 18, 2018; NETL "Reliability, Resilience and the Oncoming Wave of Retiring Baseload Units, Volume I: The Critical Role of Thermal Units During Extreme Weather Events," DOE/NETL-2018/1883, Mar. 13, 2018; FERC "Grid Resilience in Regional Transmission Organizations and Independent System Operators," Docket AD18-7-000, announced January 8, 2018; National Academy of Sciences "Enhancing the Resilience of the Nation's Electricity System," 2017; Western Electricity Coordinating Council "Western Interconnection Gas – Electric Interface Study," prepared by Wood Mackenzie, June 2018; and PJM "Fuel Security: Analyzing Fuel Supply Resilience in the PJM Region, Summary of Results, Conclusions and Next Steps," Nov. 1, 2018.

³⁰ Quanta Technology, "Ensuring Reliability and Resilience – A Case Study of the PJM Power Grid," April 23, 2018.

³¹ NERC, "Special Reliability Assessment: Potential Bulk Power System Impacts Due to Severe Disruptions on the Natural Gas System," November 2017.

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³⁵ NERC, "Generation Retirement Scenario - Special Reliability Assessment," December 18, 2018.

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³⁸ *Ibid*.

³⁹ IHS Markit, "Ensuring Resilient and Efficient Electricity Generation – The Value of the Current Diverse US Power Supply Portfolio," September 2017. IHS also concluded that the resulting increase in retail electricity prices would reduce U.S. GDP by \$158 billion per year; cause the loss of one million jobs; and reduce the disposable income of each U.S. household by \$845 per year.

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⁴⁴ PJM, "Perspective and Response of PJM Interconnection to National Energy Technology Laboratories [sic] Report Issued March 13, 2018," April 13, 2018.

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- ⁵³ Paul Stockton, “Valuing Fuel Security: Recommendations on Study Scope and Simulated Disruptions,” Sonecon, LLC, June 8, 2018.
- ⁵⁴ Dr. Stockton is Managing Director of Sonecon, LLC. Before joining Sonecon, Dr. Stockton served as Assistant Secretary of Defense for Homeland Defense and Americas’ Security Affairs from June 2009 until January 2013. He currently serves on the Homeland Security Advisory Council for the Department of Homeland Security and is Co-Chair of the Council’s Cybersecurity Subcommittee.
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- ⁵⁷ Carbon Utilization Research Council, “Capitol Hill Day 2020 Asks and Advocacy Message,” March 11, 2020.
- ⁵⁸ As of May 1, 2020, the Petra Nova CCUS facility has stopped operations due to low oil prices and reduced oil production, preventing the plant from supplying CO₂ for enhanced oil recovery. NRG has indicated that the project will be restarted when economics improve.
- ⁵⁹ United States Department of Energy, Fossil Energy, Carbon Capture, Utilization, and Storage R&D Programs, 10/2019.
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