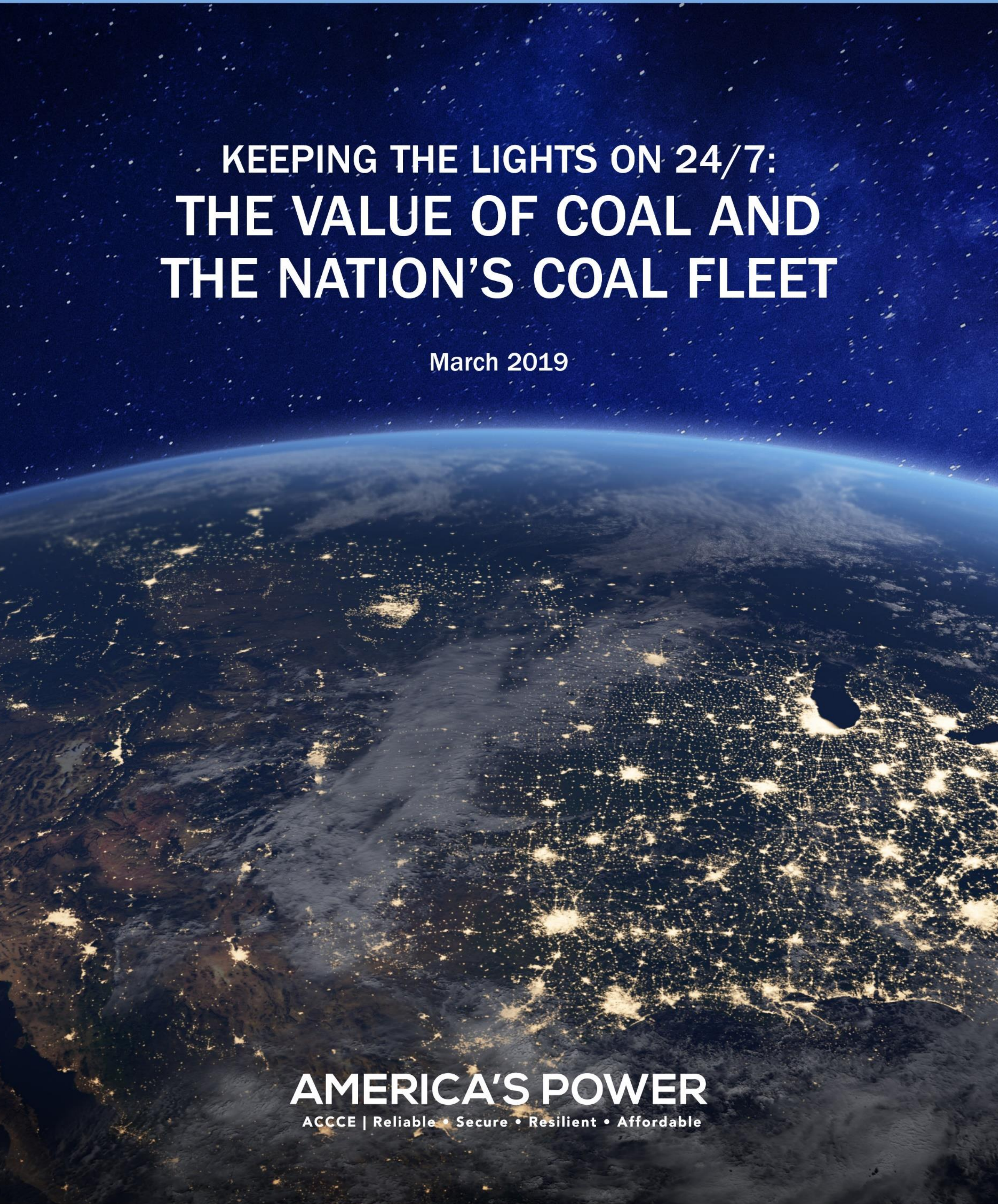
KEEPING THE LIGHTS ON 24/7:
THE VALUE OF COAL AND THE NATION'S COAL FLEET

March 2019



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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 a long time. However, this grid that produces and delivers electricity to consumers is undergoing profound changes that include the retirement of baseload sources of electricity, as well as increasing reliance on natural gas and renewable energy sources (mostly wind and solar). These changes can affect—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 grid.

To assist policymakers in better understanding the value of coal and the coal fleet, America's Power developed this paper to highlight 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 maintain this value, steps must be taken to prevent the premature retirement of more coal-fueled electric generating capacity, as well as establishing policies that provide a bridge to the next generation of high efficiency, low emissions (HELE) coal-fueled generating units.

Background

Coal was the second largest source of electricity during 2017, providing approximately 30 percent of U.S. electricity needs.[i] Coal is projected to provide 28 percent of U.S. electricity in 2018 and 24 percent in 2020.[ii] The coal fleet provides electricity to consumers in 48 states. The 15 states with the largest coal fleets (in order of size) are Texas, Indiana, Illinois, West Virginia, Ohio, Kentucky, Missouri, Pennsylvania, North Carolina, Georgia, Michigan, Florida, Wyoming, Wisconsin and Arizona.

The U.S. has vast supplies of coal. As of 2018, EIA estimates that recoverable coal reserves total slightly more than 250 billion tons.[iii] At current rates of consumption, the nation's coal reserves would last for more than 300 years. Natural gas is the other leading fuel for electricity generation. At current rates of consumption, the nation's gas resources would last from 17 years (proved reserves) to 90 years (technically recoverable reserves).[iv]

Some 95 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.[v] By contrast, almost two-thirds of natural gas is consumed for non-electricity purposes and exported.[vi] 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 31 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 27 percent in 2017-18.[vii]

Natural gas prices tend to be volatile, typically spiking during winter months when gas demand increases. For example, gas prices in PJM exceeded $96 per million British thermal units (MMBtu) on January 5 during last year's polar vortex.[viii] On the other hand, the price of coal is relatively stable. From 2016 through 2018, the monthly average cost of coal delivered to power plants ranged from $2.02 to $2.17 per MMBtu, a range of $0.15/MMBtu.[ix] Over the same period, the average cost of natural gas delivered to power plants ranged from $2.23 to $5.02/MMBtu, a range of $2.79/MMBtu.

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 impact on the coal fleet. The regions with the largest coal fleets by megawatts (MW) are Midcontinent Independent System Operator (MISO) (63,000 MW); PJM (57,400 MW); Southwest Power Pool (SPP) (26,400 MW); and the Electric Reliability Council of Texas (ERCOT) (15,500 MW).

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 1970-2017.[x] 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.[xi]

According to EIA, coal is the third largest source of energy-related carbon dioxide (CO_2) emissions in the U.S.[xii] Over the period 2017-2020, petroleum (mostly transportation) is responsible for 46 percent of emissions, natural gas is responsible for 31 percent, and coal represents 23 percent. For perspective, CO_2 emissions from the U.S. coal fleet represent approximately 20 percent of U.S. greenhouse gas (GHG) emissions and 2.5 percent of global GHG emissions.[xiii] In addition, CO_2 emissions from the U.S. electric power sector have declined from 2005 levels by 28 percent, which was the economy-wide commitment (26-28 percent reduction) of the previous administration to meeting the goals of the Paris agreement.[xiv]

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, who is responsible for ensuring the reliability of the nation's bulk power system, has objective standards for reliability.[xv] Failure to comply with these reliability standards can result in fines. There are at least 16 distinct attributes that contribute to grid reliability.[xvi] 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."[xvii] Lawrence Berkeley National Laboratory estimated that power outages and blackouts cost some $79 billion per year.[xviii] In addition, the Obama administration cited annual costs of power outages ranging from $59 billion to $209 billion.[xix]

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."[xx] Both PJM and ISO New England are conducting fuel security analyses because of concerns about fuel security and grid resilience.

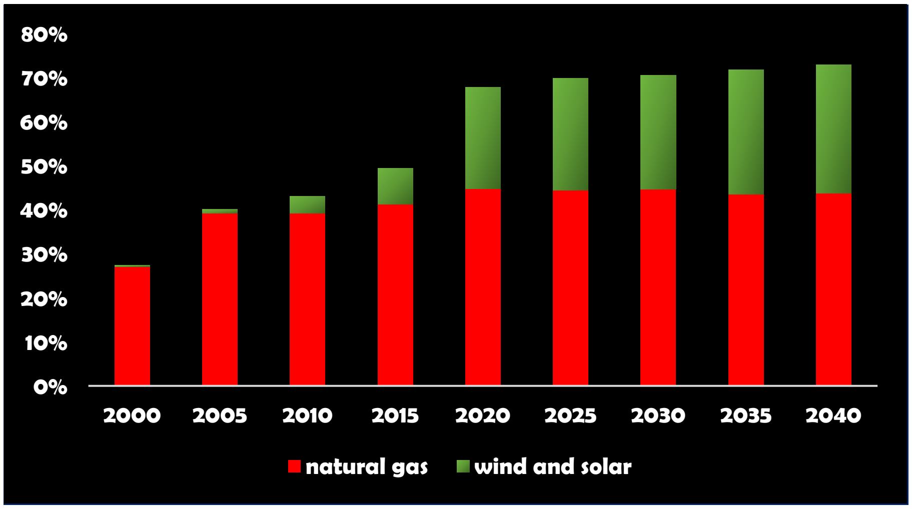
Maintaining a supply of coal at each coal-fueled power plant provides fuel security because on-site stockpiles of coal minimize the potential impact of fuel supply disruptions. Over the past five years, the average coal-fueled power plant using subbituminous coal had a stockpile that could last 75 days without being replenished. The average plant using bituminous coal had a supply of 81 days.[xxi] In short, the average coal-fueled power plant could operate for more than two months, even in the extremely unlikely event that coal deliveries were interrupted for an extended period. This high degree of fuel security contrasts with renewables that cannot generate electricity without wind or sunshine and with natural gas-fueled power plants that rely on just-in-time fuel delivery from gas pipelines.

A recent report by EVA analyzed the resilience of coal deliveries via barge, rail and truck to PJM power plants.[xxii] 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.

Occasionally, statements are made that coal piles freeze in extreme weather and interfere with power plant operations. Unable to find data to support these claims, the authors of this paper surveyed electricity generators that operate in cold climates, as well as consultants familiar with the operations of coal-fueled power plants.[xxiii] We confirmed that a number of steps are taken to mitigate coal supply problems during extreme weather, and we were unable to document instances where frozen coal piles had caused outages or de-rates at coal-fueled power plants.

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). Over the past 13 years, more than 160,000 MW of natural gas-fired generation, wind and solar have been added to the grid.[xxiv] In 2000, more than 70 percent of the nation's electric generating capacity was comprised of fuel-secure sources. By 2020, the percentage represented by fuel-secure sources drops to 30 percent (chart below[xxv]).



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.[xxvi]

Analysis last year by Quanta Technology illustrated the negative impacts on the PJM grid of premature coal retirements and the lack of sufficient natural gas-fired generation that could be caused by disruption or curtailment of fuel supplies.[xxvii] Quanta modeled nine scenarios (different combinations of retirements and loss of gas) 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.[xxviii] 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. (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 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 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 cannot be delivered. (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.[xxix]) Even for plants that have dual-fuel backup, air quality requirements can restrict operations if it becomes necessary to use higher-emitting 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, ISONE, MISO and PJM have the smallest proportions of gas delivered to power plants via firm transportation, ranging from 39 percent to 65 percent.[xxx] 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.[xxxi]

NERC also evaluated the impacts of accelerated coal and nuclear retirements on resource adequacy, fuel assurance, fuel diversity and transmission reliability.[xxxii] 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."

The nation's electricity supply is becoming less diverse.

Forty-three states have coal-fueled generating units that have retired or are planning to retire.[xxxiii] The top 15 states for coal retirements are Ohio, Pennsylvania, Indiana, Texas, Illinois, Alabama, Michigan, Florida, North Carolina, Kentucky, West Virginia, Georgia, Arizona, Virginia and Wisconsin. In total, almost 40 percent (121,000 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 supply of Michigan, Ohio, Kentucky, Indiana and Iowa. At least 14,000 MW are expected to retire in 2019 and 2020.

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."[xxxiv] 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

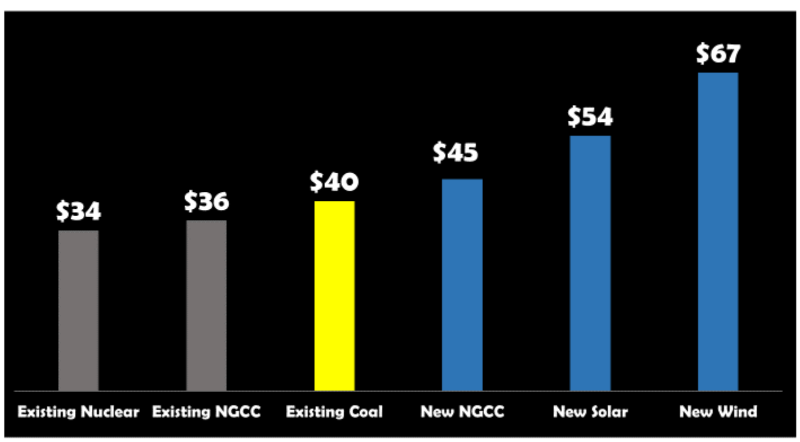
$114 billion per year; the average retail price of electricity would increase by 27 percent; and impaired reliability from a less resilient portfolio could increase electricity outages, resulting in added costs as high as $75 billion per outage hour. According to IHS, its overall results are conservative 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 included 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 which 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 new a new resource (e.g., natural gas or renewables).

Analysis of levelized costs by EVA illustrates the economic advantage of the existing coal fleet compared to new natural gas, wind and solar.[xxxv] 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.)

LCOE ($/MWh) for electricity sources in 2020 per EVA model



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 also 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).[xxxvi] The Institute for Energy Research (IER) also estimated a levelized cost of $40/MWh for existing coal, compared to $55/MWh for new NGCC, $107/MWh for wind and $140/MWh for PV solar.[xxxvii] As the IER report put it, "The primary reason new power plants have higher LCOE is because they begin their operational lives with a full burden of construction debt and equity investment to repay. Since existing power plants have already repaid some or all of those obligations, their fixed costs going forward are lower."

In addition, the PJM system illustrates the potential cost of prematurely retiring existing coal-fueled generation. (PJM has had more coal retirements—35,000 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.[xxxviii] 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 electricity 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. Last year's bomb cyclone is a case study.

NETL analyzed the performance of different electricity sources in PJM during last year's bomb cyclone.[xxxix] 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. In addition, NETL found that electricity prices would have been higher without the coal fleet.

On the other hand, 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.[xl] 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-$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 President and CEO Andy Ott testified before the Senate Energy and Natural Resources Committee last year 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 the coal-fired resources."[xli]

During this year's 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, while electricity output from wind dropped by two-thirds when it was needed most.[xlii]

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."[xliii]

National security expert Dr. Paul Stockton sent several recommendations to PJM because the grid operator is evaluating fuel security.[xliv] (Dr. Stockton served as an Assistant Secretary of Defense during the Obama Administration.[xlv]) 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, Director of National Intelligence Dan Coats testified earlier this year 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."[xlvi]

Sound policies would help preserve the coal fleet and its value.

So far, past EPA policies have caused or contributed to the majority of coal retirements.[xlvii] Most of these policies are under review or are being revised by the current administration. Federal tax subsidies for renewables (production tax credits and investment tax credits), state out-of-market subsidies for nuclear generation (zero emission credits, or ZECs), and state renewable portfolio standards give other electricity sources a significant 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. In addition, establishing resilience criteria would enable wholesale markets to value resilience attributes—especially fuel security—in the same manner they currently value reliability attributes. For regulated utilities, integrated resource planning and resource adequacy should consider fuel diversity and the adequacy of fuel infrastructure to the extent they are not already factored into retirement decisions.[xlviii] Also, the LCOE for both existing and new resources should be given full consideration in making decisions about coal retirements. These are some of the most significant policies that need to be addressed to preserve the nation's coal fleet.

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

[i] U.S. Energy Information Administration (EIA), "Electric Power Monthly," Electric Power Monthly Data for October 2018, release date December 26, 2018.
[ii] EIA, "Short Term Energy Outlook," August 7, 2018.
[iii] EIA, "How large are U.S. coal reserves?," Categories and estimated amounts of U.S. coal reserves as of January 1, 2017. Last updated December 3, 2018.
[iv] Estimates of natural gas resources vary widely. According to EIA (2018), proved reserves of natural gas total 464 trillion cubic feet (Tcf) as of the end of 2017. Proved reserves are "the most certain gas resource category," according to EIA. Technically recoverable resources (TRR) of natural gas total 2,459 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. Current annual gas consumption of 27 Tcf is used to estimate how long gas reserves would last.
[v] EIA, "Quarterly Coal Report, July-September 2018."
[vi] EIA, "Natural Gas Monthly," release date February 28, 2019.
[vii] *Ibid.*
[viii] S&P Global Market Intelligence, Tetco M3 Spot Natural Gas Index.
[ix] EIA, "Electric Power Monthly," January 2019. 2018 data are through November.
[x] Emission reductions are based on EIA "Electric Power Monthly," February 2018; U.S. EPA "National Emissions Inventory, Air Pollutant Emissions Trends Data, 1970-2016, Fuel Combustion Electric Utilities"; and EPA Air Markets Program data queried March 7, 2018.
[xi] 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.
[xii] EIA, "Short-Term Energy Outlook," release date February 12, 2019. Over the period 2017-2020, U.S. energy-related CO_2 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).
[xiii] Global GHG emissions were estimated to be 49.3 billion tonnes in 2016. "Trends in Global CO_2 and Total Greenhouse Gas Emissions: 2017 Report," PBL Netherlands Environmental Assessment Agency, The Hague, 2017. U.S. GHG emissions were 6.5 billion tonnes in 2016. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2017," February 12, 2019. According to EIA, CO_2 emissions from the coal fleet totaled 1.2 billion tonnes in 2017.
[xiv] According to EIA, the electric sector emitted 2.42 billion tonnes of CO_2 in 2005. In 2017, the sector emitted 1.74 billion tonnes of CO_2.
[xv] 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.
[xvi] 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 startup times), vulnerability to single points of disruption, and price stability. The coal fleet provides 13 of these 16 attributes.
[xvii] National Academy of Sciences, "Enhancing the Resilience of the Nation's Electricity System," 2017.
[xviii] Lawrence Berkeley Laboratory, "Cost of Power Interruptions to Electricity Consumers in the United States," February 2006.
[xix] Executive Office of the President, "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages," August 2013.
[xx] 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."
[xxi] EIA, Electricity Monthly Update, "Electric Power Sector Coal Stocks: March 2018," release date May 28, 2018.
[xxii] EVA, "Coal Supply Security in PJM," November 2018.
[xxiii] ACCCE, "Frozen Coal Piles — Myth or Real Problem?", March 2, 2018.
[xxiv] EIA, "Electric Power Annual," October 22, 2018.
[xxv] EIA, "Electric Power Annual," October 22, 2018, and EIA, "Annual Energy Outlook 2019," January 24, 2019.
[xxvi] These include DOE's "Notice of Proposed Rulemaking, Grid Resiliency Pricing Rule," Docket RM17-3-000, Sept. 28, 2017; NERC's "Generation Retirement Scenario Special Reliability Assessment," Dec. 18, 2018; NETL's "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's "Western Interconnection Gas – Electric Interface Study," prepared by Wood Mackenzie, June 2018; and PJM's "Fuel Security: Analyzing Fuel Supply Resilience in the PJM Region, Summary of Results, Conclusions and Next Steps," Nov. 1, 2018.

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

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

[xxix] We used an estimated capital cost of $200-$300/kW to provide dual-fuel capability based on a 900 MW NGCC unit with 90 days of on-site fuel.

[xxx] Data provided by EVA, June 26, 2017.

[xxxi] The INGAA Foundation, Inc., "North America Midstream Infrastructure through 2035 - Significant Development Continues," prepared by ICF, June 18, 2018.

[xxxii] NERC, "Generation Retirement Scenario - Special Reliability Assessment," December 18, 2018.

[xxxiii] ACCCE, "Retirement of Coal-Fired Electric Generating Units as of February 7, 2019."

[xxxiv] 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.

[xxxv] ACCCE, "Are Existing Coal Plants Less Expensive Than New Gas, Wind or Solar?", August 2018.

[xxxvi] IHS Markit, "Ensuring Resilient and Efficient Electricity Generation – The Value of the Current Diverse US Power Supply Portfolio," September 2017.

[xxxvii] Institute for Energy Research, "The Levelized Cost of Electricity from Existing Generation Resources," July 2016. The LCOE values for new wind and PV solar include the costs "imposed" by non-dispatchable resources on baseload resources. "Non-dispatchable resources impose costs on dispatchable resources by causing them to run fewer hours without substantially reducing their fixed costs."

[xxxviii] EVA, "Impact of Coal Plant Retirements on the U.S. Power Markets – PJM Interconnection Case Study," July 2018. The three at-risk coal plants are Pleasants, Sammis and Bruce Mansfield, which total 5,260 MW.

[xxxix] NETL, "A Review of PJM Interconnection's April 13, 2018, Response to National Energy Technology Laboratory's Report on Reliability, Resilience and the Oncoming Wave of Retiring Baseload Units," November 7, 2018.

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

[xli] Senate Energy and Natural Resources Committee, "Full Committee Hearing to Examine the Performance of the Electric Power System Under Certain Weather Conditions," January 23, 2018.

[xlii] *Energy Wire*, "Turbine shutdowns in polar vortex stoke Midwest debate," Jeffrey Tomich, February 27, 2019.

[xliii] The leaked paper was dated 5/29/18. It was referred to in trade press as a "memo," although it's styled as an addendum to another document.

[xliv] Paul Stockton, "Valuing Fuel Security: Recommendations on Study Scope and Simulated Disruptions," Sonecon, LLC, June 8, 2018.

[xlv] 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.

[xlvi] U.S. Senate Select Committee on Intelligence hearing on "Worldwide Threats," January 29, 2019.

[xlvii] Base on announcements by their owners, retirements attributed in whole or in part to EPA policies total over 78,000 MW of coal-fueled generating capacity.

[xlviii] NERC, "Special Reliability Assessment: Generation Retirement Scenario," December 18, 2018.


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