

DOE study: Markets and infrastructure key to electric reliability and resilience

American Wind Energy Association | www.awea.org

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The U.S. Department of Energy's (DOE) [new report on the U.S. electric grid](#) makes valuable recommendations for expanding access to reliable, low-cost electricity by streamlining approval of electric transmission infrastructure and using markets to procure essential reliability services. As a low-cost source of energy that can provide reliability services as well as or better than conventional power plants, wind energy will flourish with the expansion of markets and infrastructure.

I. Markets for essential reliability services will benefit renewables

We welcome the Department of Energy report's focus on resilience and strongly support the recommendation to value essential reliability services, as wind energy is making critical contributions to a more reliable and resilient power system. The [following table](#) documents the reliability and resilience services provided by different energy sources, demonstrating that renewables perform well on most if not all metrics. The fact that no resource excels at providing all services demonstrates the value of a diverse power system, as well as the importance of essential reliability services markets for sorting out which resources can most cost-effectively provide those services at any point in time.

Reliability Service	Wind	Solar PV	Gas	Coal	Nuclear	Recent Reliability Events Where a Lack of this Service was a Significant Factor
Disturbance ride-through	Excellent, cost-free, and free-ridethrough due to inherent electronic, existing generator from grid disturbances. Wind meets no economic ride-through requirement (FERC Order 2000) plus other generation.	Can add to power electronics, but, needs to have unmet need of capacity.	Generators often taken offline by grid disturbances.	Generators and essential plant equipment, like pumps and condenser belts, often taken offline by grid disturbances.	Generators and essential plant equipment, like pumps, often taken offline by grid disturbances.	The lack of conventional generation capacity during extreme weather events has been a contributing factor in several recent reliability events, including the DC and Florida blackouts.
Note: For the following reliability services, yellow in color the resource can provide the service but during many hours it may not be the most economic choice to do so.						
Reactive and voltage control	Provides, and can provide while not generating by using power electronics.	Provides, and can provide while not generating by using power electronics.	Must be generating to provide.	Must be generating to provide.	Must be generating to provide.	
Frequency regulation	Fast and accurate response. Can provide but often costly, particularly for upward response. Provides a fast Xcel system.	Fast and accurate response. Can provide but often costly, particularly for upward response.	Provides	MISO data shows a large share of coal plants cannot regulate (negative).	Does not provide	
Flexibility	Fast and accurate response. Can be often costly, particularly for upward response. Provides an Xcel system.	Fast and accurate response. Can be often costly, particularly for upward response.	Most gas generators are operated flexibly.	Many coal plants have limited flexibility, with slow ramp rates, high minimum generation levels, and lengthy start-up and shutdown times.	Almost never provides	
Primary frequency response and inertia response to disturbances	Wind rapidly provides fast and accurate PFR in ERCOT today. Can be economic to provide upward response if curtailed. Can provide synthetic inertia at economic to do so.	Can provide deserved frequency response today, can provide upward frequency response and fast power injection if curtailed.	Only 15% of conventional generators provide sustained primary frequency response.	Only 15% of conventional generators provide sustained primary frequency response.	Nuclear plants are exempted from providing frequency response, but they do provide inertia.	
Resilience Service	Wind	Solar PV	Gas	Coal	Nuclear	
Note: For the following resilience services, score reflects risk of common mode unavailability reducing fleetwide output below capacity value during challenging time period.						
Cold weather resilience	Wind plants typically have high output during periods of extreme cold, as seen during January 2011 and much of the country in 2012.	Solar plants have lower output during the winter.	As noted below, high gas demand can cause low gas system pressure, forcing some gas plants to curtail or switch fuel capability or firm pipeline contracts.	Many coal plants failed due to cold in ERCOT in February 2011, polar vortex in 2014, and other events.	Some failures due to extreme cold.	Polar vortex event in 2014 and ERCOT February 2011 event.
Hot weather resilience	In many regions, wind output is lower during hot summer days, though it can be higher than its capacity value. In some regions, like coastal areas or mountain passes, wind output is higher on hot summer days.	Solar plants have high output on hot summer days.	Gas plants experience large output de-rates when air temperatures are high.	As noted below, coal plants experience de-rates when cooling water temperatures are high.	As noted below, nuclear plants experience de-rates when cooling water temperatures are high.	
Fuel delivery resilience	No fuel to deliver.	No fuel to deliver.	High gas demand can cause low pressure, forcing some gas plants to curtail or switch fuel capability or firm pipeline contracts.	Rail connection, lesser coal piles, and other disruptions prevent large delivery are all fuel supply risks.	Large amount of fuel in reactor.	
Cooling water resilience	No cooling water.	No cooling water.	Gas combined cycle plants require cooling water, while combustion turbines do not.	Generators have been forced offline or de-rated due to insufficient cooling water or cooling water being too hot.	Generators have been forced offline.	
Impact on System Variability	Wind	Solar PV	Gas	Coal	Nuclear	
Impact on operating reserves and reliability needs of other generation						
	Modest increase in system variability at higher penetrations, though can mostly be accommodated through less expensive, slower-responding	Modest increase in system variability at higher penetrations.	Compliance issues, gas scheduling limit the rate can introduce intermittency.	Compliance issues, restrictions on power system burden on other resources.	Compliance issues, inflexible, limited cooling burden on other resources.	

NERC (the North American Electric Reliability Corporation, the entity responsible for electric reliability), [confirms](#) that “wind energy... offers ride-through capabilities and other essential reliability services.” For example, sophisticated power electronics allow modern wind turbines to exceed the ability of conventional power plants to ride through grid disturbances, improving system resilience.

As we've [explained](#), those power electronics and output controls also allow wind and solar plants to provide voltage and reactive power control and dispatchable flexibility for regulating power system frequency. The DOE report notes that "manufacturers have designed electronic controls for newer model wind turbines that can provide automatic generation control, primary frequency response and synthetic inertia" (page 73).

Grid operators in Texas and Colorado [regularly dispatch wind plants to regulate power system frequency](#), and most wholesale electricity markets dispatch wind generators under the same market rules as other power plants. In contrast, many coal and nuclear power plants are not dispatchable and do not help regulate power system frequency. NERC recently noted that [power system frequency response is noticeably higher when wind output is high in Texas](#).

AWEA has long supported market-based compensation for those services and technology-neutral reliability standards, so we strongly support DOE's call for "creating fuel-neutral markets ... that compensate grid participants for services that are necessary to support reliable grid operations" (page 126).

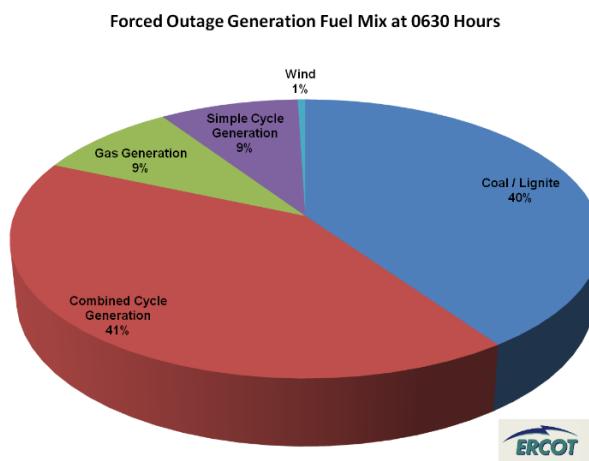
Markets for grid reliability services, called ancillary services markets, are the most efficient way to procure these needed services. Wind and solar will continue to increase their participation in such markets, particularly as technologies like smart inverters and fast controls expand the reliability services they can cost-effectively provide. DOE's study cites another recent DOE report that lists the four main needs for the reliable operation of the power system (page 67-68). As [that report explains](#), renewable resources make valuable contributions to providing all of those services.

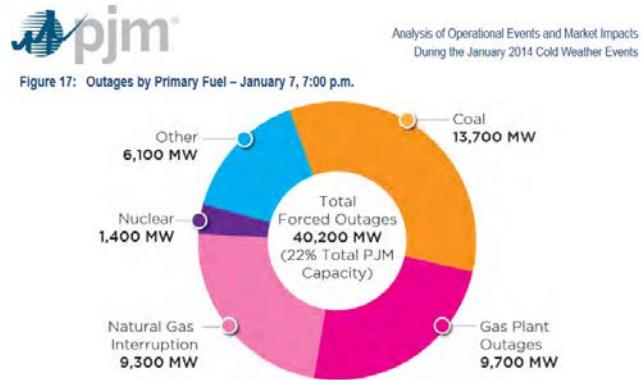
As illustrated in the table above, many resources, including wind and solar plants, are capable of providing those services. Wind plants will not always be the most economic resource to provide all of those services, just as coal and nuclear plants do not typically provide flexibility or other reliability services. That's fine; in fact, that's the beauty of markets. Markets find which resource can provide a service at the lowest cost at that moment, and use a division of labor across a diverse energy mix to keep the lights on.

Renewables build resilience

By increasing the ability of the power system to withstand disturbances, many caused by the sudden failure of large conventional power plants, wind plants are helping to build a more resilient power system. As [NERC defines](#) it, "Operating resiliency is the ability of the electric system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system components."

Cold snap events in [Texas in 2011](#) and during the [Polar Vortex event](#) across much of the country in 2014 showcased wind's resilience, while also highlighting the importance of diversifying the energy mix because all energy sources can be affected by reliability challenges. During each event a large share of the coal fleet failed simultaneously due to extreme cold, as noted in DOE's report (page 98) and shown in the grid operator charts below. In contrast, [wind energy output was well above expectations](#) for its contribution during a peak demand period, helping keep the lights on for millions of customers.





A study by the nation's largest grid operator, PJM, also recently found that scenarios in which wind energy provided the majority of electricity were [some of the most resilient](#) to unexpected weather events. PJM's [study](#) also notes that coal and nuclear plants are susceptible to cooling water shortages due to [drought](#).

Coal supplies have also been disrupted by events ranging from sustained rail network congestion to droughts preventing barge deliveries to coal piles freezing in extreme weather, as the DOE report explains in noting that "most generation technologies have experienced fuel deliverability challenges in the past" (page 11). With no need for fuel or cooling water, wind and solar plants are immune to those challenges.

Recent [analysis](#) confirms that simultaneous fleet-wide failures of conventional power plants occur many times more frequently than expected. [Grid operator data](#) also show that the gradual and predictable variability of wind output is far less costly for grid operators to accommodate than the abrupt failures of large conventional power plants. Because no energy source is 100 percent reliable or resilient, diversifying the energy mix with wind energy improves reliability and resilience.

DOE prudently focuses on reliability services, not onsite fuel or “baseload”

Because no resource is immune to reliability challenges, it is more prudent to focus on fleet diversity and creating markets for needed grid services to achieve resilience, rather than on having specific types of generating resources.

As noted above, resources with onsite fuel, like coal and nuclear, have been affected by extreme weather, cooling water constraints, fuel delivery disruptions, or other unexpected fleet-wide failures. A power system that relied almost entirely on coal and nuclear would not be reliable, as it would lack flexibility and the ability to regulate frequency.

The term "baseload" has driven some confusion in discussions of grid reliability. As a wide range of [experts have explained](#), "baseload" is a mostly [obsolete term](#) that has no relationship to the reliability services the grid needs. Rather, "baseload" referred to power plants that ran most of the time for the simple fact that they provided the lowest-cost energy due to their low fuel cost. However, now that renewable resources are able to provide energy with zero fuel cost, some utility executives and grid operators say they view [wind and solar as "the new baseload."](#)

As the [Brattle Group](#) concluded in June, "As some of the coal and nuclear power plants face retirement decisions, focusing on their status as baseload generation is not a useful perspective for ensuring the cost-effective and reliable supply of electricity." Instead, as DOE and a wide range of [experts have explained](#), [we](#) should focus on creating markets for the actual grid reliability [services](#) that are [needed](#).

II. DOE calls for streamlining transmission investment

The DOE report identifies infrastructure development as a key solution. Among the report's primary recommendations are that "DOE and related Federal agencies should accelerate and reduce costs for the licensing, relicensing, and permitting of grid infrastructure," and that "DOE should review regulatory burdens for siting and permitting for generation and gas and electricity transmission infrastructure and should take actions to accelerate the process and reduce costs" (page 127).

Transmission benefits all low-cost generation resources as it allows their low-cost power to reach customers, much like the interstate highway system allowed the most efficient producers and retailers to get their low-cost products to market. For example, the Quad Cities nuclear plant on the border between Illinois and Iowa is facing economic challenges because power prices there are \$8/MWh lower on average than those just 100 miles to the east in Chicago. Upgrading the grid to allow more power to be delivered from Quad Cities to Chicago would be a win-win for both the nuclear plant and consumers in Chicago.

Like any market, electricity markets are more competitive when there are fewer barriers to entry. For this exact reason, Texas has always had some of the strongest pro-transmission policies in the country. As ERCOT board member Peter Cramton [recently explained](#), "One thing in favor of strengthening transmission ... is that it's pro market. It allows a larger set of generators to compete in a more robust marketplace. You don't always want to throw money at transmission, but at same time, you have to recognize it's transmission that's enabling the market."

Grid operators and other experts have explained that [transmission is a key solution for making electricity more reliable and affordable](#). The benefits to consumers are even greater when transmission helps access low-cost, stably-priced clean energy resources, as Texas has successfully demonstrated with its Competitive Renewable Energy Zone power line projects in West Texas.

As DOE's report documents, "Transmission investments provide an array of benefits that include providing reliable electricity service to customers, relieving congestion, facilitating robust wholesale market competition, enabling a diverse and changing energy portfolio, and mitigating damage and limiting customer outages (resilience) during adverse conditions. Well-planned transmission investments also reduce total costs. SPP analyzed the costs and benefits of transmission projects from 2012–2014 and found that the planned \$3.4 billion investment in transmission was expected to reduce customer cost by \$12 billion. This yielded an estimated benefit of \$3.50 for every dollar invested in the region. A robust transmission system is needed to provide the flexibility that will enable the modern electric system to operate. Although much transmission has been built to enhance reliability and meet customer needs, continued investment and development will be needed to provide that flexibility" (page 75).

DOE accurately diagnoses the constraints limiting transmission development and identifies the solutions: "The challenge for building transmission continues to revolve around the three traditional steps involved, each of which can be time-consuming, involved, and complex: (1) demonstrating a need for the transmission project, also known as transmission planning, (2) determining who pays for the transmission project, also called cost allocation, and (3) state and Federal agency siting and permitting. FERC has taken steps to help with the first two, with reforms such as Order No. 1000, which remains a work in progress." (75) DOE also explains that "natural gas pipelines can be built more quickly than electric transmission lines (in most states) because they have a comparatively streamlined permitting process" (page 37).

A more robust transmission system would prevent almost all occurrences of negative prices, whether caused by nuclear, coal, or renewables. The DOE report accurately notes that most instances of negative pricing have been observed at "constrained hubs that feature a relatively large amount of VRE and/or nuclear generation" (page 114). As explained previously, any instances of wind-related negative prices are typically caused by transmission constraints on isolated parts of the grid. Because there are few if any conventional power plants on these remote parts of the grid, these events have little to no impact on other generators.

Negative prices are a red herring

The DOE report accurately notes that many types of power plants occasionally cause negative prices, including nuclear and fossil plants, as “Conventional generators also face economic factors that lead them to submit negative bids. Existing nuclear plants in the United States, as well as some fossil units, may bid in during these periods to avoid costly start-ups and shutdowns” (pages 114-115). As [explained previously](#), the limited flexibility of fossil and nuclear plants is a primary cause of negative prices, and some coal plants also offer negative prices to avoid penalties in coal supply contracts. The DOE report also explains that negative pricing events are rare, and “have had almost no impact on annual average day-ahead or real-time wholesale electricity prices.”

AWEA recently released [comprehensive analysis](#) proving that renewable energy policies account for an extremely small share of the already negligible occurrences of negative prices at retiring coal and nuclear power plants.

This analysis builds on work we completed three years ago to [rebut](#) arguments that occurrences of negative prices at nuclear plants in Illinois were frequently caused by wind energy. That “compelling” data led then-[FERC Commissioner John Norris](#), who had previously discussed his concerns about negative prices, to affirm that “the focus on negative prices is a distraction.”

Our new analysis examines full-year 2016 price data for all retiring power plants in the main wholesale electricity markets that have a large amount of wind generation: PJM, MISO, SPP, and ERCOT. Across more than 1.8 million data points, which cover all 2016 pricing intervals in the day-ahead electricity market for all retiring power plants in those regions, only 55 instances of negative prices were found (0.003% of prices) that could have been set by a wind project receiving the PTC. The analysis includes market price data for all power plants that have retired since 2012 or have announced plans to retire according to DOE.

Our analysis focused on the day-ahead electricity market (the results bolded below), as that is where nuclear and coal generators sell most if not all of their generation. However, the results show that wind plants almost never set prices in the real-time electricity market as well. For more on electricity markets and how prices are set, see the last header under this section.

In PJM and MISO, which account for a large share of all power plants in wholesale markets that are retiring nationwide, only 0.003% of day-ahead market prices at retiring power plants were in a range that could be set by a wind project receiving the federal Production Tax Credit (PTC), as shown on the left side of the table. Occurrences of negative prices that could be wind-related were even less frequent in SPP, at 0.0017% of day-ahead market price intervals. Those occurrences were slightly more common at retiring plants in ERCOT, at 0.06% of price intervals, but it should be noted that there is only one retiring coal power plant in ERCOT.

Market prices at retiring generators, by ISO	Real-Time or Day-Ahead Market	Share of prices that are negative	Prices between -\$20 and -\$40 /MWh (offer range for PTC + REC wind project)	Average market price	Average price if all -\$20 to -\$40/MWh prices were \$0/MWh	Price change if wind offered \$0/MWh
PJM	Real-Time	0.88%	0.12%	\$26.41	\$26.44	\$0.03
	Day-Ahead	0.18%	0.003%	\$26.8811	\$26.8818	\$0.0007
ERCOT	Real-Time	1.62%	0.03%	\$21.7825	\$21.7888	\$0.0063
	Day-Ahead	0.08%	0.06%	\$22.635	\$22.649	\$0.014
SPP	Real-Time	2.04%	0.54%	\$21.32	\$21.49	\$0.17
	Day-Ahead	0.59%	0.0017%	\$21.9965	\$21.9969	\$0.0004
MISO	Real-Time	1.20%	0.14%	\$25.413	\$25.451	\$0.038
	Day-Ahead	0.22%	0.003%	\$25.6803	\$21.6810	\$0.0007

To underscore the trivial impact of the PTC in setting market prices, the right side of the table shows how prices would change if wind projects receiving the PTC no longer received the credit. In PJM and MISO, conservatively assuming that all negative prices in that range were set by wind projects receiving the PTC, Day-Ahead Market prices at retiring power plants would increase by an average of \$0.0007, or 1/13th of a penny per MWh, if operating wind projects no longer received the PTC. Retiring power plants in SPP saw an even smaller impact at 1/25th of a penny, while the one retiring coal power plant in ERCOT saw an impact of around one penny per MWh.

It is important to clarify that the PTC does directly reduce consumer electricity costs outside of the electricity market. The PTC and other incentives allow wind projects to offer lower long-term contract prices to customers and the utilities who serve them, which translates into lower electric bills for consumers on a 1:1 basis. However, those contract payments are outside of the wholesale electricity market, so they are not directly factored into the wholesale electricity market prices received by other generators.

The facts about energy incentives

In reality, the wind PTC has been a remarkable success in driving the American innovation and efficiency that have driven a two-third reduction in the cost of wind energy since 2009.

The more than 100,000 Americans working in the wind industry today are creating a new industry with a bright future, bringing tens of billions of dollars in investment to rural areas and tens of thousands of manufacturing jobs to America. As the DOE report notes, “the solar and wind workforce increased by 25 and 32 percent, respectively, in 2016” (page 53).

Production-based incentives like the PTC have driven efficiency increases that make U.S. wind projects some of the most productive in the world, while giving developers access to capital from investors so they have the funds they need to break ground on more projects.

Regardless, Congress voted in December 2015 to phase down the wind PTC, and we are now in Year 3 of that 5-year phasedown period. Despite the recent focus on incentives for renewables, cumulatively wind energy has received less than [3% of federal energy incentives](#), versus 86% for fossil and nuclear sources, according to the Nuclear Energy Institute and other experts. DOE notes that all energy sources have received incentives, writing that “subsidies are spent on different technologies at different times” (page 51). Given that the wind industry’s “tax reform” is already in place with the PTC phasedown legislation, we would welcome a comprehensive look at all forms of subsidies for all electricity sources.

Market dynamics are driving retirements

Market changes are benefiting consumers by driving retirement of older, less efficient resources in favor of more efficient resources. The DOE report agrees with a wide range of [experts that the primary](#) factors [driving](#) power plant retirements and economic challenges for generators of all types are cheap natural gas and flat electricity demand (page 13).

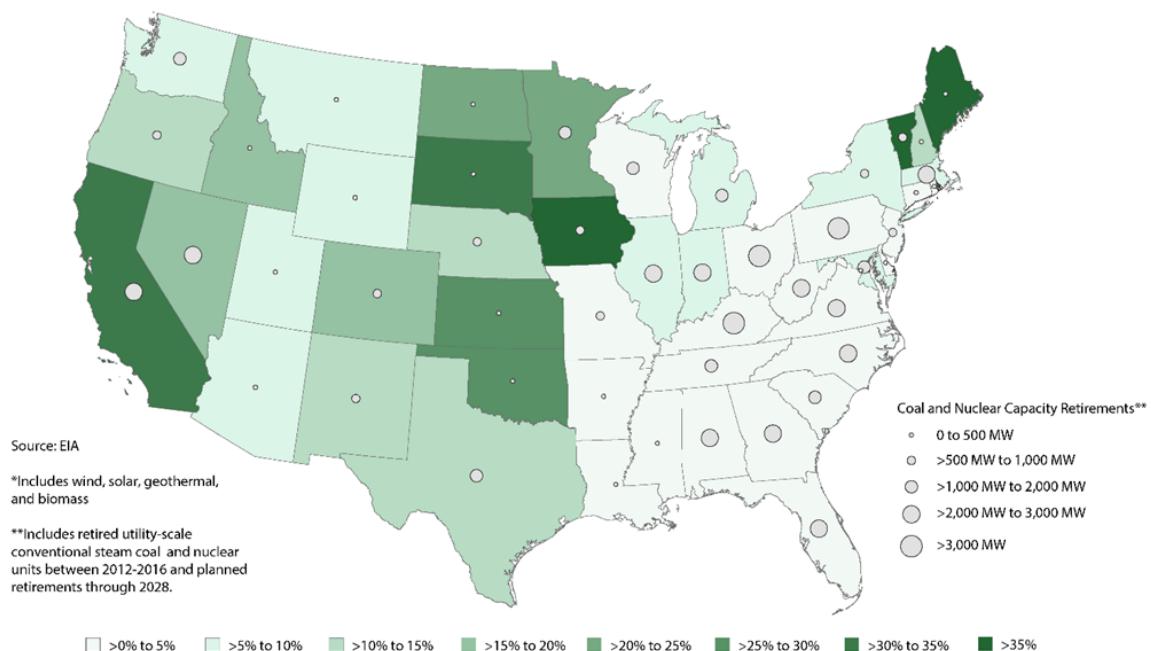
As the report notes, “With the sustained drop in natural gas prices, for example, natural gas-fired combined-cycle (NGCC) plants are currently a less costly source of baseload generation than coal or nuclear power in many regions of the country” (page 6).

Competition from lower-cost gas generation is a primary cause of the reduced capacity factors and greater cycling observed at the nation’s coal fleet. Quoting PJM, DOE’s report notes that “due to low energy prices and the overall efficiency of the units, combined cycle natural gas units are dispatched as baseload with coal units more often being cycled” (page 58). As DOE also notes, “The biggest contributor to coal and nuclear plant retirements has been the advantaged economics of natural gas-fired generation” (page 13).

The DOE study also explicitly exonerates renewable generation as a primary cause of retirements, noting that “the data do not show a widespread relationship between VRE penetration and baseload retirements...While concerns exist about the impact of widespread deployment of renewable energy on the retirement of coal and nuclear power plants, the data do not suggest a correlation”(page 50).

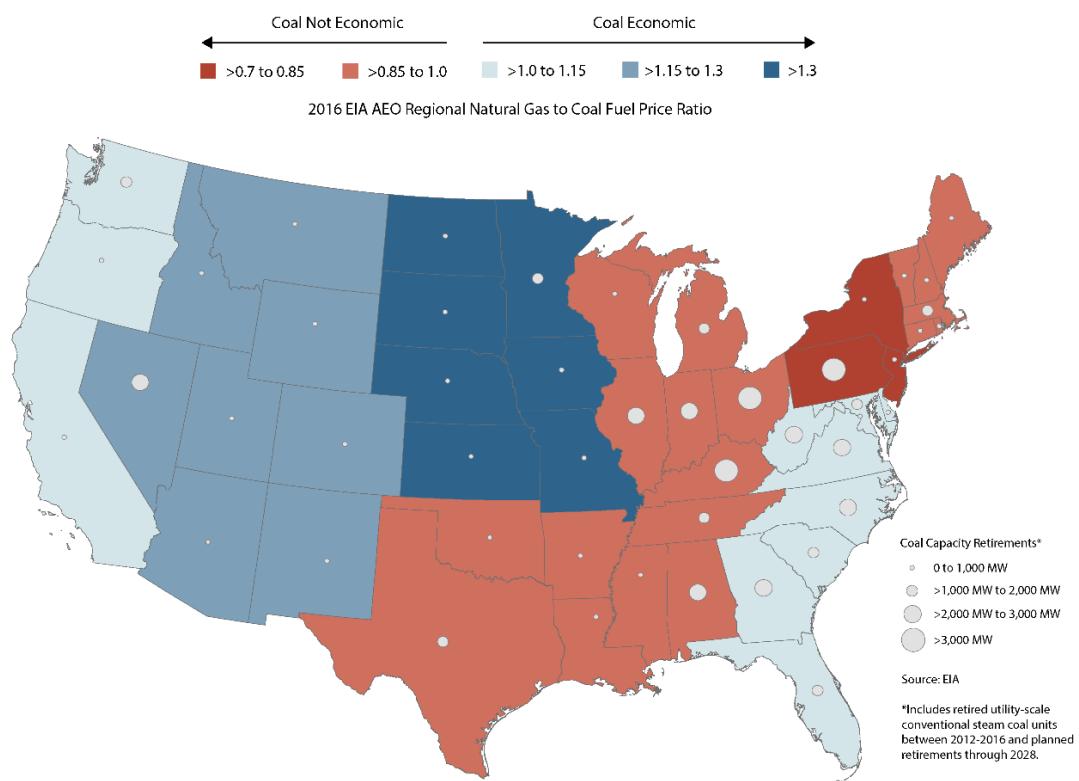
The following map, compiled from Department of Energy data, shows that most retiring coal and nuclear plants are in regions that have little to no renewable generation, confirming that renewable energy or pro-renewable policies cannot be the primary factor driving those retirements.

Recent and Planned Coal and Nuclear Retirements
and 2016 U.S. Renewable Energy* Share of Electricity Generation, by State



Rather, the primary factor driving power plant retirements appears to be low-cost shale gas production undercutting relatively high cost Appalachian and Illinois Basin coal in the Eastern U.S., as shown below. In the regions shaded red in the map, the fuel cost of producing electricity from natural gas is significantly lower than the fuel cost of coal power plants, explaining why utilities in those regions are moving from coal to natural gas generation.

Recent and Planned Coal Retirements and Economics of Coal versus Natural Gas, by Region



III. DOE's study confirms electric reliability is strong

Electricity markets, and the multiple layers of regulatory checks already in place at the state, regional, and federal level, are successfully working to ensure that electric reliability remains strong. As the North American Electric Reliability Corporation (NERC) and other experts have concluded, ongoing and planned power plant retirements do not pose a reliability threat. In June, the CEO of NERC testified to the Federal Energy Regulatory Commission that "[the state of reliability in North America remains strong, and the trend line shows continuing improvement year over year.](#)"

DOE and NERC both note that reliability is continuing to increase across a range of metrics, with DOE explaining that "All regions have reserve margins above resource adequacy targets" (page 66), and that "BPS reliability is adequate today despite the retirement of 11 percent of the generating capacity available in 2002, as significant additions from natural gas, wind, and solar have come online since then" (page 63).

The chart below, compiled from grid operator data and included in [NERC's Long-Term Reliability Assessment](#), confirms that all regions greatly exceed their targeted level of reserve power plant capacity through at least 2021. Moreover, the regions experiencing the most coal plant retirements, PJM and SERC, exceed their capacity reserve margins by double digits even under the most conservative planning standard.

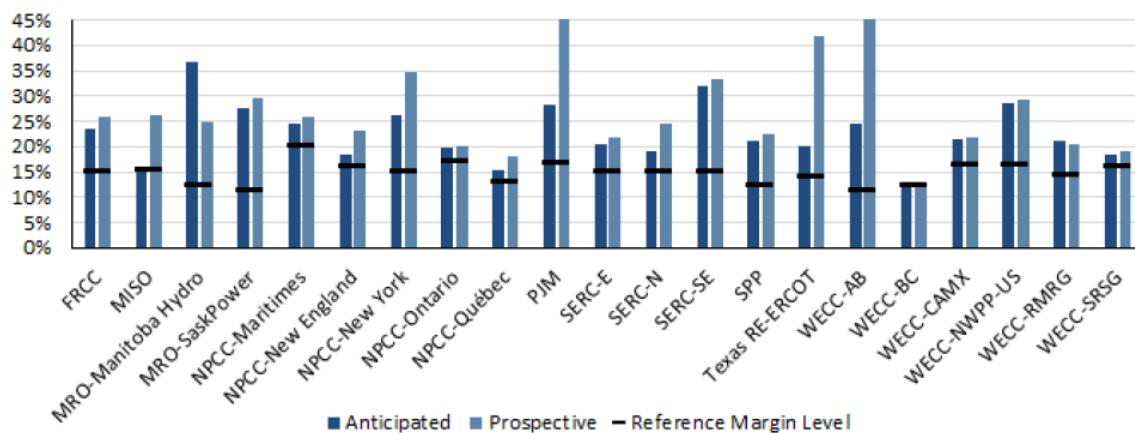


Figure 1.2: Planning Reserve Margins for Year 5 (2021)

In short, electricity markets and renewable energy are working well to ensure electric reliability, and we support DOE in its proposals to use market-based solutions to ensure electric reliability will continue to increase.