# CHANGING THE POWER GRID FOR THE BETTER

Diverse, Flexible Resources Are Key to Reducing Costs and Enhancing Reliability in Today's Electric Power System

By Advanced Energy Economy Institute

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# EXECUTIVE SUMMARY

A successful transition to a more diverse energy resource mix has been underway for at least a decade. Ten years ago, nearly half of U.S. electricity was produced by a single resource: coal. Today, coal and natural gas each supply about one third of our electricity, nuclear one fifth, and hydro and non-hydro renewables another one fifth. Greater fuel diversity has provided us with more options to meet our energy needs while maintaining, if not improving, reliability.

Despite the real-world examples of greater fuel diversity improving reliability, there are concerns that a shift away from coal and nuclear, so-called "baseload" resources, and toward more flexible natural gas, demand-side resources, and renewable energy threatens to undermine reliability. While there is a place for all resources, including baseload, in our current energy mix, these concerns stem from a misunderstanding of how the grid works today. More importantly, these concerns fail to recognize the ways that new technologies and services are helping us keep the lights on every moment of every day.

This paper sheds light on what is driving our changing resource mix and how it is improving reliability and lowering costs for businesses and consumers. Specifically, it shows that:

- **The transition to a more diverse resource mix is driven primarily by consistently low natural gas prices**, followed in order of significance by flat electricity demand and competition from renewables.

- With operational techniques and technologies currently available and in widespread use today, **the grid can continue to reliably integrate much higher levels of natural gas, variable renewables, and demand-side re-sources**.

- **These changes will improve – not undermine – the reliability and resilience of the electric power system**, as demonstrated by extreme weather events. During the 2014 Polar Vortex, extreme cold caused onsite coal piles to freeze, power plant control equipment to fail, and natural gas pipelines to become constrained. But grid operators were able to turn to demand-side resources and wind energy to keep the lights on during the emergency.

This paper argues that incorporating more renewable energy, fast-ramping natural gas generation, a range of demand management techniques, and new resources like energy storage – rather than a return to a singular reliance on baseload resources – is the foundation of electric power system reliability. Better understanding of how these resources contribute to reliable grid operations will better enable policymakers to maximize the benefits they can provide.

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# INTRODUCTION

Access to affordable, reliable energy is fundamental to modern life and commerce, as consumers and businesses alike depend on uninterrupted power, unrestricted mobility, and constant connectivity. The increased need for reliability, the rising economic cost of blackouts, and the need to replace ageing infrastructure can all be addressed through a more flexible and responsive energy system that draws on a variety of resources and provides consumers with more choices and lower costs. Fortunately, the technologies needed to build a modern, high-performing, and affordable energy system already exist, and bring with them huge opportunities for economic growth in the United States and global leadership in energy innovation.

Electric power markets have changed dramatically in the last decade. These markets are more competitive today than ever before. Natural gas prices have fallen and are projected to remain low for the foreseeable future. Meanwhile, renewables have experienced rapidly declining costs, which are also expected to continue, and have reached price parity with other resources in some regions. These changes in the supply side of the industry have occurred during a period that has also seen a rising demand for more flexible resources, greater fuel diversity, and consumer choice and control. The deployment of highly cost-effective energy efficiency technologies, relatively slow pace of economic growth following the Great Recession, and loss of some energy intensive industry in the United States has kept energy demand growth relatively flat for some time and projections indicate that the situation is likely to continue for the foreseeable future. Together, these changes in supply and demand economics are putting competitive pressure on aging and relatively inflexible resources like some of the large coal and nuclear plants that are sometimes referred to as "baseload resources".

Some people have raised questions about whether the challenges facing some of these baseload resources will create problems for our energy system. As context, it is helpful to realize that the concept of baseload resources is an accident of history and energy economics. *Baseload* simply refers to the minimum system-wide demand for power that exists around the clock (refrigeration, street lighting, etc.). For a period of time, some of the lowest-cost way to meet baseload demand happened to be resources that had the operational characteristic of performing best when operated continuously – namely, coal and nuclear power. So, it made sense that baseload demand would be met with baseload resources that generated power continuously, while peaking resources, such as generators using (at the time) higher-cost natural gas fuel would be dispatched as demand increased over the course of the day.

But that does not describe the mix of resources available today to meet electricity demand, nor does it reflect today's energy economics. Baseload resources will undoubtedly continue to play an important—

and substantial—role in our energy mix. But natural gas is cheaper than coal, and natural gas-fired electricity is cheaper than nuclear power. So generators using natural gas are more competitive in many parts of the country for meeting both baseload demand and peaking demand. Meanwhile, wind and solar energy are not only competitive with more traditional generation resources, their zero-fuel-cost character make them valuable hedges against fuel price volatility, and they are increasingly being deployed based purely on their economic value.

According to the North American Electric Reliability Corporation (NERC), reliability in the bulk power system can be broadly separated into two main categories: *resource adequacy,* or the availability of sufficient resources to meet demand at all times; and *operating reliability*, or the ability of the electricity system to withstand disturbances ranging from storms to mechanical failures to voltage disturbances.[1] Given the operating characteristics of baseload described above, it is no surprise that concerns about the loss of baseload resources focus mainly on resource adequacy. However, all generation resources contribute to ensuring resource adequacy as long as they are properly accounted for by grid operators.

Two complementary developments provide additional tools for enhancing grid reliability and performance. First, grid management technologies and operational techniques have become far more sophisticated, and are being used to manage the growing diversity of resources on the grid. Grid operators are now routinely managing high levels of wind and solar generation, sometimes exceeding 50% of load, without compromising reliability, levels that would have been viewed as impossible just a few years ago. Second, energy demand, once viewed as inelastic, is becoming much more flexible and responsive to price and other market signals. With the ability to manage demand, rather than just matching supply to meet whatever level of demand occurs, it is now possible to take more dynamic control of both, which reduces costs and enhances reliability, while also giving customers more control over their own energy use and costs s.

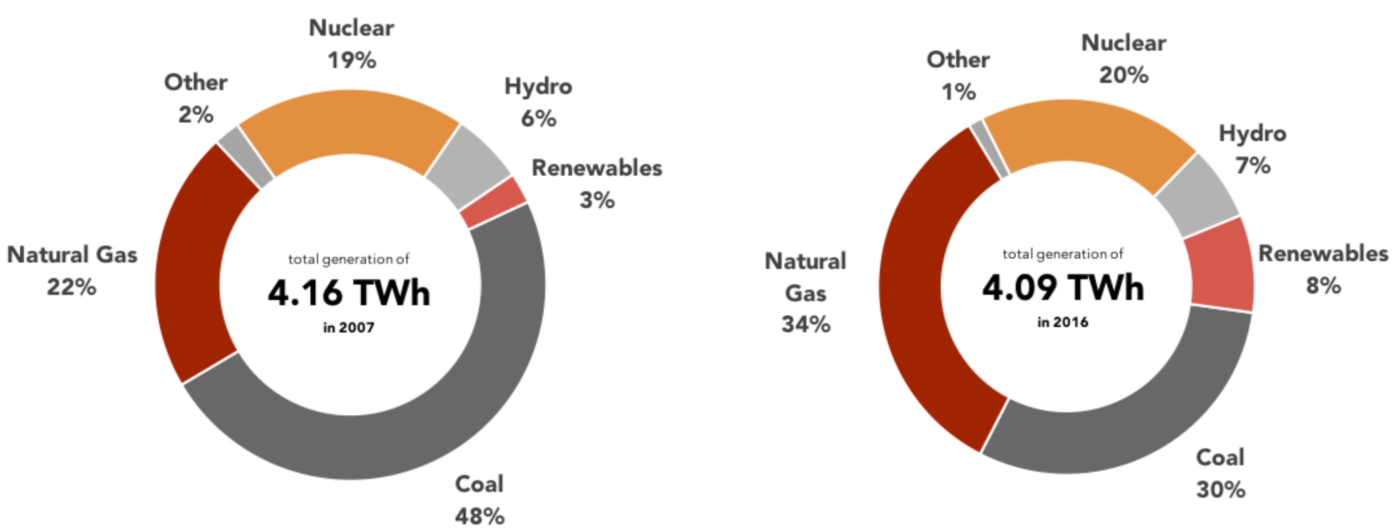
**Modernizing the aging energy infrastructure that has supported American prosperity for decades and moving toward a more diverse and dynamic energy system is the key to maintaining a reliable grid in the future. It** can also foster the competition and innovation that will drive down costs while meeting our energy needs as they evolve. To date, this process has not only improved the overall functioning of the grid but acted as an economic engine as well. In 2016, advanced energy was a $200 billion industry in the United States and employed more than 3 million Americans. Allowing these resources to contribute to and compete in the U.S. energy system has resulted in growth and prosperity, and will continue to do so going forward.

# CHANGING RESOURCE MIX IS DRIVEN BY COMPETITION, NOT SUBSIDIES

## U.S. Generation Mix Has Become More Diverse

Over the past decade, the U.S. generation mix has changed substantially. In 2007, coal accounted for nearly half (49%) of total U.S. generation.[2] Today it makes up less than 30%. Natural gas supplanted coal as the largest source of electricity in the United States for the first time last year, rising from less than a quarter (22%) of generation in 2007 to 34% today. Renewables have also grown in the last decade, rising at a faster rate than gas but still accounting for a significantly smaller share of the generation mix. Non-hydro renewable generation more than doubled from 3% in 2007 to 8% in 2016. Nuclear generation, which does not fluctuate significantly year-to-year in the absence of major capacity additions or retirements, has provided a fairly constant 20% of U.S. generation for the last decade. The result is a more diverse energy mix today than ever before in U.S. history.

### Generation Mix 2007 vs. 2016




**Source: EIA**

At the same time, demand has been relatively flat nationally, declining slightly from 4,150 TWh in 2007 to 4,080 TWh in 2016. In the electric power sector, and especially the competitive wholesale energy markets, competition among generating sources has become more intense.[3]

While national generation and demand data give us a sense of how today's resource mix compares to that of the past, data on new capacity additions and planned retirements tell us what utilities and investors see as the energy mix of tomorrow. For the past five years, over 80% of all new capacity additions annually have been renewables and natural gas.[4] There has been no notable addition of coal generating capacity since 2013.

At the same time, retirements of coal-fired power plants have accelerated, and some nuclear units have retired or announced plans to retire if the market for their resources does not become more favorable soon. Relatively modest economic growth has been one factor, but below the surface, there is an important trend underway. The particular units in question are some of the oldest resources on the grid, with many having already recovered their capital costs from years of operation. As these resources retire, they are being replaced with a diverse set of resources on both the supply side and demand side of the grid.

## Low Natural Gas Prices Are the Primary Driver of Changing Resource Mix

These changes are driven by a number of factors, chief among them low natural gas prices, followed in order of importance by flat electricity load growth and then competition from renewables.[5]

Driven by the abundance of domestic shale gas, natural gas prices have fallen from an average price of $8.86/MMBtu in 2005 (and spiking above $12/MMBtu in two months of 2005 and one month of 2008) to an average of $3.20/MMBtu for the last five years.[6]

A March 13, 2016, report from Moody's wrote that natural gas prices have "by far…the most dominant effect on the unregulated power sector," especially as "gas-fired power plants often serve as the marginal plant during times of peak power demand."[7] This is especially true in regions that do not have capacity markets, like Texas and the Midwest, where underutilized power plants are not getting paid to ensure their availability to meet future demand.

The R Street Institute, a free market think tank, conducted a similar analysis, with a focus on the nuclear industry.[8] The study identified similar trends pressuring nuclear, coal, and older natural gas-fired plants: flat demand growth, competition from renewables, transmission challenges, post-Fukushima regulations to ensure safety, and uranium price spikes. Most importantly, the study found that low and stable natural gas prices "are setting new standards for what electricity should cost."

These studies are backed up by anecdotal evidence from announced coal plant retirements across the country. For example, the utility owners of the Navajo Generating Station in Arizona decided to close the plant "based on the rapidly changing economics of the energy industry, which has seen natural gas prices sink to record lows and become a viable long-term and economical alternative to coal power."[9] The reasons that natural gas prices have such a dominant impact on the competitiveness of other resources are twofold. First, natural gas has the largest market share of all the generating technologies. With a large and growing share of U.S. capacity, low natural gas prices are encouraging grid operators to dispatch this capacity at increasing rates, resulting in over one-third of U.S. generation coming from natural gas. Second, natural gas often sets the clearing price of electricity in wholesale power markets. In these markets, the price of electricity is set by the marginal resource as grid operators dispatch power supply in economic merit from the cheapest to the most expensive, and that marginal resource is frequently natural gas. For example, in the Midcontinent Independent System Operator (MISO), the grid operator for most of the Midwest region, natural gas set the price of electricity in the market 75% of the time while coal set the price 23% of the time and wind only 1%.[10]

## Monthly Natural Gas Prices, 2006 – Present ($/Million Btu)

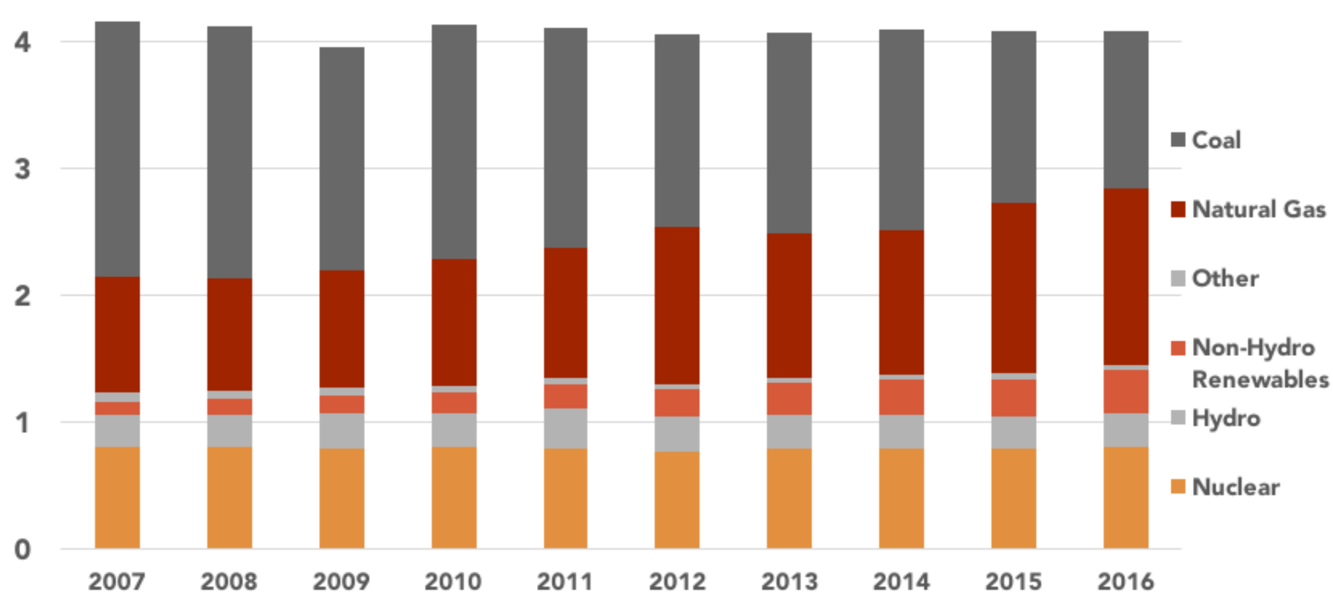

**Source: EIA**

## Flat and Declining Load Growth Is Also a Major Factor

As described above, demand for electricity has been flat or declining in most regions of the country for at least the past decade. Economic growth is no longer synonymous with increased energy use. A shift away from energy-intensive industries like manufacturing, vast improvements in the energy efficiency of buildings and devices, and the increased deployment of demand-side and behind-the-meter resources have all helped to effectively decouple U.S. economic growth from energy use.[11] As a result, total retail electricity sales fell by about 1% between 2010 and 2014 even as the economy grew by 9% in real terms.[12]

In PJM Interconnection, where over one fifth of U.S. GDP is produced annually, the relationship between load growth and economic growth has been weakening since the end of World War II.[13] Behind the meter resources like combined heat and power (CHP), energy storage, and rooftop solar and demand control resources like demand response and energy efficiency are contributing as well.

### Annual Electricity Generation by Resource (TWh)




Source: EIA

Flat load growth has created fewer transmission constraints and pushed prices down. Energy efficiency is often the least-cost option for meeting new and existing electricity needs and is already participating in electricity markets across the country PJM Interconnection operates a capacity market based on auctions held three years in advance of the time when the capacity is needed. In one recent auction, a total of 12,314 megawatts of demand response and energy-efficiency resources were committed as capacity resources for the 2017-2018 delivery year, with over 99% of energy efficiency bids clearing the market.[14] Similarly, in the ISO-New England region, energy efficiency is being officially forecast and incorporated into the Regional System Plan, while growing amounts of energy efficiency are clearing the market in each auction.[15]

Energy efficiency's cost-competitiveness has driven growth in energy performance-based contracting services offered by Energy Service Companies (ESCOs). Analysts expect the $6 billion ESCO market to double in size by 2020.[16] Utility efficiency programs, which are roughly equal in size to the ESCO market nationally, will also continue to grow due in part to Energy Efficiency Resource Standards (EERS), which exist in nearly half of U.S. states. These trends will likely continue as innovations in technologies and services give customers greater control over their energy use and make energy efficiency even more cost-competitive with generation for meeting electricity needs.

Behind the meter resources, which include distributed energy storage and rooftop solar, have a similar effect on the demand curve as energy efficiency. They modify the net load shape that is "visible" to wholesale electricity markets, which has implications for the mix of generating assets needed to meet demand. Several states have recognized the transformational effect that these resources are having on the grid and have initiated regulatory proceedings to facilitate greater adoption of behind the meter and distributed resources for the benefit of customers and the electric system as a whole. The most notable of these include the Massachusetts Grid Modernization proceeding (DPU 12-76), New York State's Reforming the Energy Vision proceeding (Case 14-M-0101), and various proceedings in California, including the Distributed Resources Plan proceeding (R.14-08-013). Minnesota has also initiated an investigatory proceeding into Grid Modernization (E999/CI-15-556). While the scope of these proceedings differ, they are all in response to the evolving nature of the utility business model and the increasing complexity and interconnectedness of the electricity system. As consumers seek more control over their own energy use, this trend is likely to continue and accelerate.

## Cost Declines Are Driving Renewable Deployment Today

Federal tax incentives and renewable portfolio standards (RPS) in a majority of U.S. states are responsible for giving non-hydro renewable energy technologies, especially wind and solar power, their start in the U.S. electricity marketplace, and with many states raising their targets for renewable energy, continue to support development. But as these technologies have matured and reached scale, their adoption is increasingly being driven by cost.

The most basic indicator of power technology competitiveness is the levelized cost of energy (LCOE), which measures the average cost of electricity over the life of a project, including the costs of upfront capital, operations and maintenance, fuel, and financing. Lazard, an independent financial advisory and asset management firm, has tracked the unsubsidized LCOE of power technologies for the past decade.[17] Lazard's annual analyses show that, from 2008 to 2015, the unsubsidized LCOE for utility-scale wind and solar power declined by 64% and 81%, respectively. Those decreases have made renewable-energy technologies competitive with other power sources purely on the basis of cost. As a result, renewables are increasingly deployed purely on economic grounds, without regard for subsidies or mandates.

This is already evident in stateslike Texas and Iowa, which have greatly exceeded their renewable energy targets. As grid operators have become more sophisticated and experienced at managing a more diverse portfolio of resources, including variable renewables, utilities are increasingly investing in wind and solar purely on the basis of cost and as a hedge against fuel price volatility. In 1999, the Public Utility Commission of Texas (PUCT) adopted an RPS that called for 10,000 MW of renewables by 2025.[18] In 2009, Texas had already surpassed its 2025 target and installed over 13,000 MW of renewables, mostly wind. And the Lone Star State continues to add more wind every year without the RPS as a driving force. In the neighboring service territory of the Southwest Power Pool (SPP), a new record for wind penetration was set last year when wind generation, early one February morning, peaked at 52% of total output on the SPP system.[19] As grid operators grow more accustomed to higher penetrations of renewables, states are increasingly eyeing higher RPS policies without fear of cost or operational impacts.

Although wind and solar power receive tax credits to encourage their development, so do most other resources on the grid. For the past 100 years, federal policy has supported the resources necessary to meet U.S. energy needs, from the Revenue Act of 1913 (which allows oil drillers to write off the cost of dry holes and depletion) to DOE-funded development of large-scale hydraulic fracturing techniques in the 1970s.[20,21] The U.S. Department of the Treasury identified 11 federal fossil fuel production tax provisions that cost the Treasury an estimated $4.7 billion per year.[22] Any new nuclear power plant put in service today could benefit from a 2005 production tax credit, which is now being considered for extension,[23] while existing nuclear reactors were developed with other direct and indirect subsidies, such as federal limits on liability for potential accidents.[24]

The total cost of the wind and solar tax credits is small compared to the similar support that fossil fuels and nuclear power have received over a much larger time frame.[25] In contrast to many of these policies, the Production Tax

Credit (PTC), primarily supporting wind development, and the Investment Tax Credit (ITC), primarily supporting solar, have already begun to ramp down, or will by 2020. The potential market impact of these tax benefits on wind and solar investment will be short-lived, while any action to end these credits prior to the scheduled phase-out would be disruptive to these industries, which DOE estimates currently support nearly a half million jobs between them.[26]

Critics of the ITC and PTC often point to the phenomenon of negative pricing (when generators offer to pay customers to take their energy) as evidence that they are distorting the market. However, negative pricing events are extremely rare. In the Electric Reliability Council of Texas (ERCOT), the grid operator for most of Texas, market-wide average prices were only negative in 0.64% of cases in 2015. Of those, the vast majority were negative by only a few dollars per megawatt hour.[27]

For reasons outlined above, renewables generally do not set the clearing price of electricity.

Even if a renewable resource bids into the market at zero or negative prices, the clearing price is set by the marginal resource, which is most commonly natural gas. Moreover, renewables are not the only resources that cause negative pricing. Nuclear and coal also sometimes bid at negative prices because they find it more costly to reduce their output than to pay a customer to take it. Some coal power plants may also face penalties for failing to purchase a minimum amount of coal required in their delivery contract. Hydro-electric resources also bid at negative prices from time to time if, for example, they need to lower water levels.

In the rare cases where wind and solar set the market clearing price, it is usually in remote parts of the grid, where there are no other generators available, rather than because of bidding price. This means that renewables' bidding prices also don't impact the competitiveness of other resources in the same way as natural gas prices. For example, when wind set the clearing price in 2016 PJM Interconnection, the grid operator for the Mid-Atlantic region, it only impacted prices by $0.05/MWh, or 0.2% (1/500$^{th}$) of total prices.[28] Wind and solar, which have low marginal operating costs, do impact market prices indirectly because, when operating, they reduce the need for more costly generation from other. But with less than one-tenth of the market share of natural gas, the impact is negligible in comparison.

# LOW-COST, FLEXIBLE RESOURCES ARE THE FUTURE OF THE ELECTRIC GRID

## Grid Operators Increasingly Value Flexibility Over "Always On" Power

Economic forces are causing the resource mix used to meet our electricity needs to shift from capital-intensive, centralized baseload resources that operate full-time to flexible resources that are currently lower cost, and likely to remain so. This raises concerns in some quarters that replacing baseload resources with variable renewable energy or flexible natural gas will jeopardize the reliability of the grid. But such concerns are stem from a misunderstanding of how the grid works today.

The operation of the grid requires moment-by-moment management as well as forward-looking design and planning that looks many years into the future. While sudden, unexpected events always create reliability challenges, regardless of the resource mix, power plant retirements and the steady growth of natural gas and renewables are neither sudden nor unexpected. Grid operators have been successfully managing these changes for years, and can continue to do so using technology and operating techniques widely available and already in use today.

Baseload resources, like coal and nuclear, tend to have high fixed capital and operating and maintenance costs. Owners of baseload resources bring down their unit energy costs by running for extending periods of time. In addition, baseload resources typically generate power with steam turbines, which take many hours to turn on and off, do not ramp up and down easily, and are expensive to restart. The "always on" nature of baseload resources offered an element of reliability when it was beneficial for the grid to have some generators running continuously, but today it is simply is an operational characteristic like any other.

In the past, grid operators could use these resources to meet baseload needs – the portion of demand that exists even in the middle of the night – because running continuously helped to make them cheaper than other options. But when baseload resources like coal or nuclear are no longer the cheapest resources available, grid operators cease to use them to meet baseload demand – and as their utilization falls, their unit costs rise, making them less competitive. That leaves coal and nuclear power struggling to compete.

## Grid Operators Are Successfully Managing More Gas and Renewables

Reducing reliance on baseload resources does not mean that the grid is compromising reliability. As the grid changes, system planners and policymakers increasingly turn to flexible resources like natural gas generation, demand side management, smart grid, and now storage, to maintain reliability.[29] Even in the case of wind and solar, variability does not make such resources unreliable. To use an analogy to transportation, imagine that you have two choices to get to work in the morning: a bus, which is cheaper, or a taxi, which is more expensive. The bus officially departs every 10 to 15 minutes, though it is sometimes delayed, while taxis can be hailed almost immediately. You, the commuter, can make the bus your first choice, to save money, but if it is unexpectedly late, you can hail a cab and, though you pay more, will still get to work on time.

Grid operators do much the same thing. They use variable resources like wind and solar effectively by forecasting weather conditions, with increasing sophistication and accuracy, but can also respond to unpredicted changes by calling on fast-starting natural gas generators, demand response, and energy storage to make sure demand is met.[30]

Grid operators already have tools at their disposal to integrate variable renewables. Indeed, they have been reliably integrating ever increasing levels of renewables over the last two decades while maximizing the flexibility and low price impacts of new and existing gas generation. A report by The Brattle Group describes in detail how grid operators are doing this in two states, Texas and Colorado.[31] ERCOT and Xcel Energy have both managed to integrate variable renewables at 10% to 20% of total generation on average, and above 50% at times.

Texas is a good example of this trend in action. Texas has more wind capacity than any other state and its grid is isolated, leaving it unable to call on electricity from neighboring states to maintain reliability. ERCOT, which operates the transmission system and competitive wholesale power markets for most of Texas, updates its six-hour wind forecast every 15 minutes to let operators know whether they will need additional resources to meet demand.  ERCOT has also started to redesign its market to make use of flexible resources like demand response and energy storage, as part of its Future Ancillary Services (FAS) proposal.[32] The creation of new reliability products in ERCOT will help the grid operator procure the capabilities it needs to maintain reliability.

During the Polar Vortex, on January 6, 2014, freezing conditions caused multiple baseload generators to trip offline, derate, or fail to start, leading ERCOT to declare an emergency event and activate over 600 MW of emergency demand response for approximately one hour.[33] In its official assessment of the event, ERCOT noted that wind resources were not affected and did not contribute to creating the emergency. Driven by advances in smart meters, home energy managements systems, and smart appliances, more customers are able to participate in demand response programs, increasing the ability of the grid to integrate renewables in non-emergency situations.

Colorado has also successfully integrated high levels of variable renewables. Xcel has a peak load of 6,700 MW and an off-peak load of about 2,700 MW. With 2,600 MW of wind generation, Xcel's service territory could potentially be served by nearly all wind generation at times of low demand, which often correspond to high winds. Xcel has developed an advanced weather forecasting system with the National Center for Atmospheric Research to improve wind forecasts by 35%. Over time, Xcel has improved its integration by also tadding more gas-fired generation, increasing its storage capacity, and installing automatic generation control systems.

## With Current Grid Capabilities and Continued Innovation, There is No Physical Limit To the Reliable Renewables Integration

On top of these case studies, The Brattle Group also found that operational techniques and renewable energy technology itself will allow the integration of even higher penetrations of renewables in coming years:

> Ongoing technological progress and ongoing learning about how to manage the operations of the electric system will likely allow the integration not only of the levels of variable renewable capacity now in places like Texas and Colorado but even significantly larger amounts in the future.

Numerous studies show that greater levels are possible with technologies commercially available and in widespread use today. In 2012, NREL examined how much of U.S. energy needs could be met with renewable energy technology available at the time and found that by 2050, 80% of U.S. electricity needs could be met by variable renewables, in combination with a more flexible grid, in every region of the country.[34, 35] Subsequent analysis by NREL has drawn similar conclusions.[36] A recent review of the available literature found that renewables "can supply, on an hourly basis, a majority of a country's or region's electricity demand."[37] GE's Energy Consulting Group has conducted multiple studies on potential renewable penetration in North America. Last year, it released an interactive web tool that consolidates some of these studies and shows that "there is not a hard limit" to the level of renewables that could be deployed on the grid.[38]

In addition to the examples of ERCOT and Xcel energy cited above, California Independent System Operator (CAISO) is also exploring ways to enhance its grid's flexibility as it significantly expands the renewable penetration on its grid to 50% by 2030.[39] As technology such as energy storage improves and costs further decline, it will be even cheaper and easier to manage these resources.

# CONSUMERS BENEFIT FROM RESOURCE DIVERSITY

Today's electric power grid is served by a changing mix of resources, which provides benefits in multiple ways. Ten years ago, nearly half of U.S. power generation was supplied by a single resource: coal. Today, coal and natural gas each supply about one third of our electric power, nuclear one fifth, and hydro and non-hydro renewables another one fifth. This greater fuel diversity gives us more options for meeting electric power needs, increases competition, and drives down prices.

It has also improved reliability and resilience, as demonstrated by recent winter storms. During the 2014 Polar Vortex, the extreme cold caused a winter-record demand for electricity while also contributing to the failure of 22% of the generation in PJM Interconnection. NERC conducted an assessment of the Polar Vortex event and found that, of unplanned power plant outages, coal plants accounted for 26% and natural gas 55% of the total. Outages due to extreme cold were caused by the freezing of on-site fuel supplies like coal piles, frozen control and sensor equipment, and the inability to receive fuel from outside providers due to natural gas pipelines constraints.[40,41] Facing this situation, grid operators were able to turn to demand response and wind energy were able to meet the electric power needs of PJM even when baseload resources failed.

America is blessed with an abundance of energy resources – both natural and technological. A well-balanced mix of flexible and renewable resources, including natural gas, biomass, solar, wind, geothermal, hydropower, and other distributed resources like fuel cells, can work with traditional resources to provide electricity that is both low-cost and reliable. Advanced grid technologies are helping to integrate variable generation, increasing the output from these resources and amplifying their contribution to resource adequacy, and providing the grid with a number of other operational benefits. These technologies include energy storage, advanced metering infrastructure, demand response, distribution automation, microgrids, high voltage direct current transmission, and smart grid management technologies.[42] Meanwhile, demand-side management technologies, such as energy efficiency and demand response, reduce peak demand, thus lowering necessary reserve capacity and improving resource adequacy. Lawrence Berkley National Laboratory (LBNL) cites load shifting, energy efficiency, and renewable energy as viable strategies to improve overall grid reliability without adding more generating capacity that is used only at times of peak demand.[43]

The contribution of renewables themselves to reliability is growing every year. Voltage must remain within a stable range, and variations in voltage are monitored on very short timescales to ensure the continued reliability of the grid. Transmission operators have experience in maintaining voltage support, even in states with high levels of renewable generation. They utilize voltage support not only from coal generating units, but also from gas turbines, energy storage, variable frequency drives,[44] solar PV with smart inverters,[45] and newer (Type 3 and 4) wind turbines.[46] With the continued retirement of inefficient older generating units, these widely-available advanced energy technologies can be deployed to provide voltage support and ensure continued grid reliability.

The role of advanced energy such as wind turbines in maintaining grid reliability will only increase with technological and operational improvements. The National Renewable Energy Laboratory (NREL) found that, with the proper equipment and incentives, wind power can provide important power system control services, often on timescales much faster than conventional generation.[47] Earlier this year, in California, CAISO, First Solar, and NREL conducted a series of tests on a 300 MW solar PV facility to see if it could provide ancillary services as well as natural gas peaker plant.[48] The tests determined that, in every category of ancillary service, the solar plant performed as well or better than a conventional resource.

Rather than create reliability concerns, wind power and other advanced energy technologies can actually improve both resource adequacy and operating reliability. This argues for continued change in power system resources – incorporating more renewable energy, fast-ramping natural gas generation, demand management techniques, and new resources like energy storage – rather than a return to baseload resources as the foundation of electric power system reliability.

# CONCLUSION

Driven by low and stable natural gas prices, flat electricity demand, and falling renewable costs – in that order – the electric power system in the United States is undergoing a dramatic change. But with the advent of a more flexible, fuel diverse, and dynamic energy system, consumers and businesses are poised to reap the benefits. We have already seen new resources like wind and demand response perform under emergency conditions like the 2014 Polar Vortex. These resources kept the lights on when traditional baseload generation failed. We have also seen states like Colorado and Texas reliably integrate levels of renewable energy that would have been unimaginable 10 years ago. And we have seen that, with technologies and operating techniques available today, there is no physical limit to how much more flexible the grid can become. With all the benefits that come with a more flexible, fuel diverse, and dynamic energy system, these changes should be embraced.

# NOTES

[1] North American Electric Reliability Corporation (NERC). "Definition of "Adequate Level of Reliability" (2007) available online at http://www.nerc.com/docs/pc/Definition-of-ALR-approved-at-Dec-07-OC-PC-mtgs.pdf.

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