Assessing Emerging Policy Threats to the U.S. Power Grid

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Executive Summary

Reliable, affordable electricity is critical to our well-being and essential to modern life. But today, threats to the reliability of the power grid are numerous: cyber-attacks, weather, and accidents. Fortunately, the most significant threat is also the most avoidable—bad policy. Federal and state policies are already increasing electricity bills around the country, and the worst effects are yet to come. The federal government, and particularly the U.S. Environmental Protection Agency, is promulgating regulations that will reduce the reliability of the power grid with little thought of the consequences. In fact, these policies threaten to take offline 130 gigawatts of reliable electricity generation sources—enough to meet the electricity needs of more than 105 million Americans, or one-third of the population of the entire United States. Reforming policies that threaten grid reliability should be a top priority for policymakers.

Overview

American homes and businesses depend on reliable electricity. We use it to energize everything from our lights and appliances to our computers and the data centers that give us the Internet. Because so much of what we do every day depends on having access to reliable power, threats to the consistent delivery of electricity put modern life itself at risk.

Such threats take many forms. Some originate from things beyond our control—such as cyber attacks and extreme weather—and we can seek to defend against and mitigate those threats. Others result from accidental error, such as the transmission line failure that resulted in a major blackout of the Northeastern U.S. in 2003. Smart planning and the use of best practices in the electricity industry can minimize these accidents, but they are an unavoidable part of a society powered by a complex system of electricity delivery.

In contrast, some emerging threats are completely avoidable. These threats come from a different kind of error—bad policy. Currently, a host of federal and state regulations, subsidies, and mandates threaten to undermine the reliability of the U.S. power grid by taking offline over 130 gigawatts of reliable power, which is enough to meet the residential electricity needs of more than 105 million Americans.

New stresses on the electricity delivery system are coming primarily from two types of policies:

> 1) Regulations that directly shut down reliable sources of electricity, such as coal and nuclear power, and
> 2) Subsidies and mandates that force increased amounts of unreliable sources of electricity on the grid, such as wind and solar power, and undermine the normal operation of reliable power plants.

Together, these two types of policies create a much less reliable grid and increase the chances of a major blackout.

This year, the Environmental Protection Agency (EPA) is slated to finalize a regulation that closes reliable power plants and forces the use of unreliable sources of electricity. With this wide-ranging carbon dioxide regulation under Section 111(d) of the Clean Air Act—called the Existing Source Rule—EPA threatens simultaneously to shut down vast swaths of reliable electricity generation across America and impose a federal mandate for renewable energy.

Affected utilities and grid operators are pushing back on the rule and asking for extra time to comply. However, pushing back deadlines does not solve the most important problem with the Existing Source Rule, which is EPA's disregard for electric reliability. With this one regulation, EPA will be able to exercise unprecedented control over the electric grid. In turn, grid reliability will suffer because reliability is neither a priority for EPA nor one of EPA's statutory obligations. Some have referred to the Existing Source Rule as a federal takeover of the electric grid because EPA is proposing to turn electricity markets on their head by mandating a radical shift away from economic dispatch (the tried-and-true method of balancing the grid while minimizing costs by selecting reliable generators on a least-cost basis) and towards environmental dispatch (choosing generation sources based on their carbon dioxide emissions rather than their reliability and cost).

EPA is charging ahead with the Existing Source Rule and other grid-threatening regulations despite vocal opposition from independent grid experts. The North American Electric Reliability Corporation—the group of reliability experts designated by the federal government to oversee the power grid—continues to raise questions about the effect of EPA rules on the grid. It is unclear whether EPA will address these reliability problems before finalizing its rules.

Electricity policy in the U.S. deserves to be reevaluated. In fact, if federal and state policymakers intentionally set out to cause havoc for grid operators and hurt grid reliability, they would be hard pressed to do better than the current policy trajectory. Dozens of policies handicap electric reliability by favoring unreliable sources of power, undercutting reliable sources, or both. From state-level renewable energy mandates, to the wind production tax credit, to multiple EPA rules targeting coal-fired power plants, to—yes—blocking the Keystone XL pipeline, bad policy threatens to wreck America's power grid. Fortunately, policymakers have every opportunity to address these threats. For those who want to ensure that Americans have access to reliable electricity long into the future, the time has come to push back against policies that hurt grid reliability. It is time to repeal regulations that shut down reliable sources of power and to remove massive subsidies for unreliable power sources.

Today's electricity policy is a risky nation-wide experiment in burning the candle at both ends— something has to give. That means reliability problems and blackouts if emerging policy threats go un-checked. Policymakers should choose now to put the U.S. power grid back on track and to ensure reliable electricity for years to come.

Reliable Electricity is Indispensable

Access to reliable electricity is a fundamental part of American life. We may take it for granted, but when the power goes out, everything grinds to a halt. Inside the house, we lose everything from the lights, heat pump, refrigerator, television, and Internet to chargers for phones and computers. Outside, the stoplights and streetlights stop working. It's impossible to get any work done inside offices and in factories. In short, our daily lives depend on a reliable source of electricity.

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> I want you to try to imagine what it's like to live without electricity. It's boring, for one thing—no television, no MP3 player, no video games. And it's lonely and disconnected as well—no computer, no Internet, no mobile phone. You can read books, of course—but at night you won't have light, other than the flicker of firewood. And about that firewood—you or someone in your family had to gather it during the day, taking you away from more productive work or schooling, and in some parts of the world, exposing you to danger. That same firewood is used to cook dinner, throwing off smoke that can turn the air inside your home far more toxic than that breathed in an industrial city. You may lack access to vaccines and modern drugs because the nearest hospital doesn't have regular power to keep the medicine refrigerated. You're desperately poor—and the lack of electricity helps to ensure that you'll stay that way.
>
> That's life for the 1.3 billion people around the planet who lack access to the grid.[2]

Recognizing electricity’s central role in society, IER recently launched *The Story of Electricity*, an initiative focused on educating policymakers and voters on how the power grid works and raising awareness of the importance of electricity.[3] We detail the history of electricity in America[4] as well as the technical and economic aspects of electricity generation,[5] transmission,[6] and distribution.[7] This report is an extension of our efforts to improve the policy discussion surrounding America’s power grid.

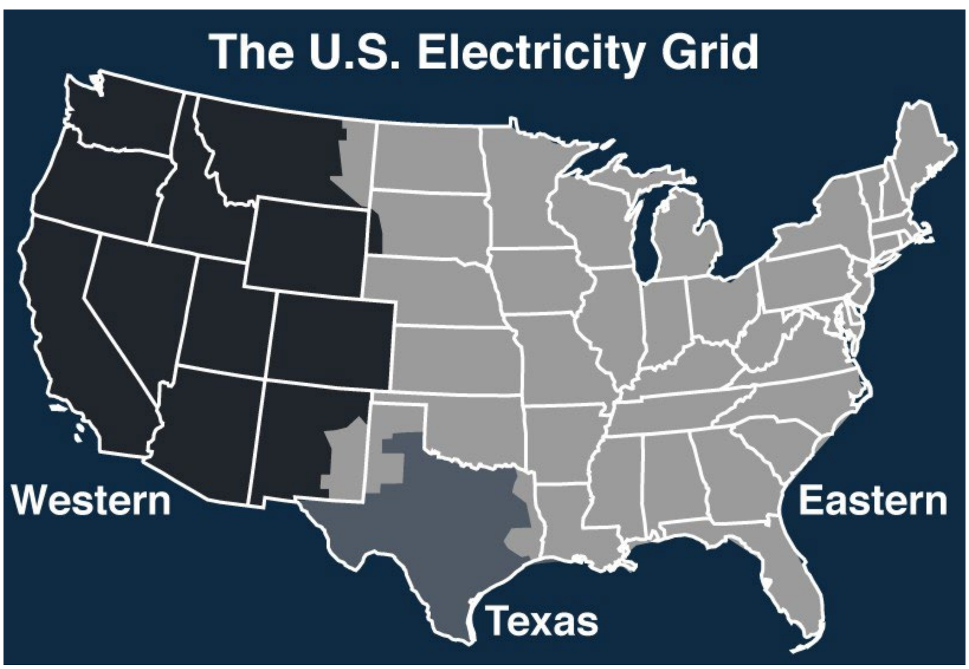
Electric reliability in the U.S. is excellent overall, which is a testament to the men and women working in power plants and control rooms across the country. Aside from two major blackouts (1965 and 2003), electricity consumers in the U.S. have not been subjected to persistent, region-wide blackouts[8]—unlike less developed nations with less reliable electric systems.[9]

Given the positive track record of America’s power grid, it is no surprise that some experts characterize the grid as “underrated.”[10] According to a 2014 report by the North American Electric Reliability Corporation (NERC)—which is the U.S.’s federally designated electric reliability organization—the grid remains stable:

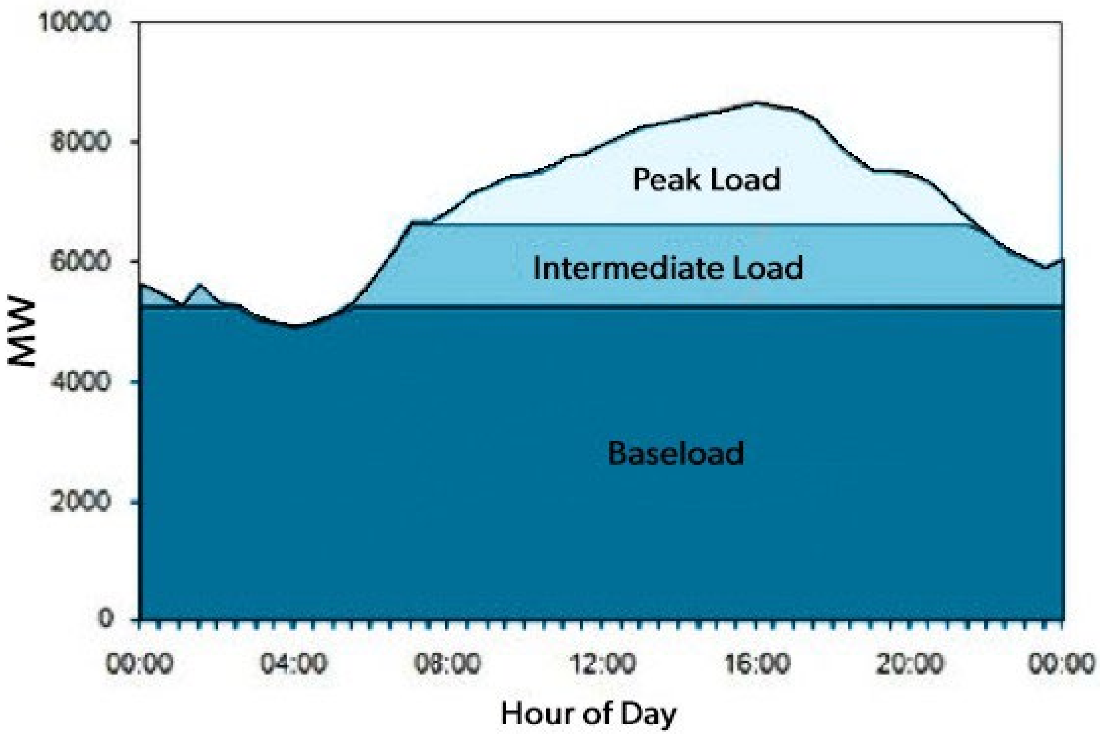
> The availability of the bulk transmission system remained high from 2008 to 2013. The [alternating current] transmission circuit availability remained above 97 percent, and transmission transformer availability was above 98 percent for the 2010 to 2013 period (unavailability includes both forced and planned outages). High transmission availability demonstrates that the [bulk power system] is able to perform reliably over a variety of operating conditions.[11]

This report focuses on the power plants and high-voltage transmission lines that make up the *bulk power grid*.[12] Even with a top-notch bulk power grid covering the U.S., consumers will experience outages on local distribution lines from time to time.[13] This is due largely to the fact that many of our neighborhood power lines are on overhead poles and thus vulnerable to damage from storms, ice, falling trees, etc. The alternative—burying distribution lines underground—is impractical and would be incredibly expensive.[14] For the purposes of this report, statements about grid reliability refer to the bulk power grid.

The U.S. power grid actually consists of three region-wide interconnections: the Eastern Interconnection, the Western Interconnection, and the Texas Interconnection. When we refer to the American power grid, we refer to these interconnections collectively, with a special focus on their generation and transmission infrastructure.



To keep these interconnections up and running (and to keep the lights on), electricity generators must meet the total demand on the system at all times and do so within tight margins of error. Electricity is a unique good in that it must be produced at the moment it is consumed, and grid supply must match demand during every second of every day. As people demand higher or lower amounts of power throughout the day (shown below), reliable generators adjust their output accordingly. "Baseload" plants run consistently at nearly all hours, whereas other plants come online to satisfy higher levels of demand or "load." Having a reliable grid means matching supply to demand in real time, all the time.



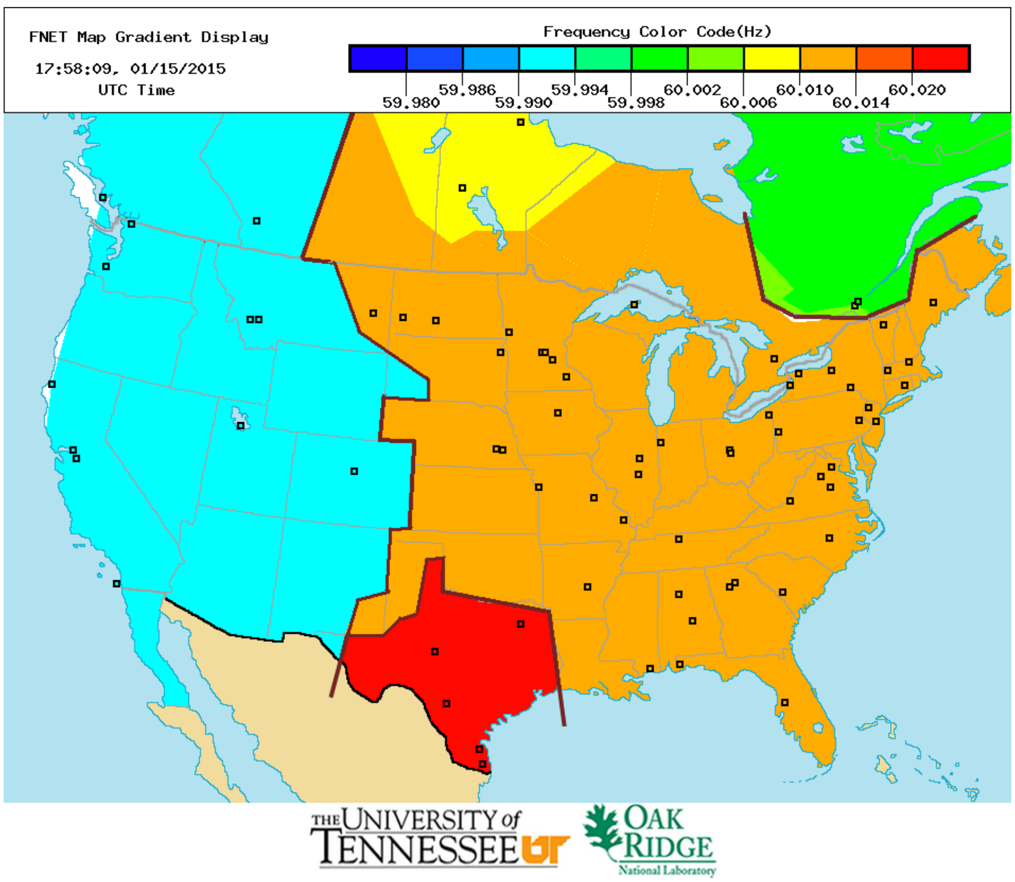
The technology that makes large electricity grids possible in the first place—the alternating current (AC) system—presents some operating challenges. For example, in an AC system, all generators and devices running on the grid are synchronized to the same frequency (in the U.S., grid current alternates at 60 cycles per second or 60 hertz). If demand outstrips supply (or vice versa), the whole system experiences a dangerous drag (or boost) in frequency that can cause blackouts across a large area. Diverging from 60 hertz is dangerous for some of the equipment on the grid, including generators, so power plants will shut themselves off when the frequency changes too much.

For example, in the 2003 blackout that spread across the Eastern U.S., grid operators were slow to realize that a generator had failed and transmission lines had tripped offline, causing other transmission lines to overload, which, in turn, caused other generators to trip offline, further losing power and exacerbating the frequency collapse.

The cascading effect continued until much of the Eastern U.S. and Canada suffered a major blackout.[15] The 2003 blackout demonstrated that, even in good conditions, the power grid is susceptible to system-wide disruptions.

To understand how fragile the balance of the grid truly is—and how well operators manage the grid—look no further than the second-by-second frequency fluctuations across the three interconnections.

Below is a screen capture of the real-time, color-coded frequency map maintained by the Power Information Technology Laboratory at the University of Tennessee.[16] Blue areas are experiencing lower grid frequency (less than 60 hertz), indicating that overall electricity supply is lagging demand in that moment, and red areas are the opposite. Green areas indicate that the system is balanced at 60 hertz.



Source: http://fnetpublic.utk.edu/gradientmap.html

Grid planners and operators go to great lengths to make sure the grid's delicate supply/demand balance is stable, not just minute to minute, but also five and ten years into the future. In those long-range plans, having enough reliable supply to meet demand in many different situations is key.

These conditions change in real time, cycling second-by-second through the rainbow of colors. As total demand on the system changes (as lights, electric motors, air conditioners, computers, etc. turn on and off), hundreds of generators respond by increasing or decreasing their power output at a moment's notice. The blues and reds reflect the fact that generators require some reaction time to respond to changing power demand. Minor deviations in frequency are normal—extreme deviations or "frequency excursions" can cause serious reliability problems.[17]

Grid planners and operators go to great lengths to make sure the grid's delicate supply/demand balance is stable, not just minute to minute, but also five and ten years into the future. In those long-range plans, having enough reliable supply to meet demand in many different situations is key. Planners pay special attention to peak demand forecasts, ensuring there will always be enough reliable generation to match demand at its highest. The buffer or cushion above peak demand provided by reliable sources of electricity is called the "reserve margin," and it is absolutely crucial in grid planning. Planners also take into account the potential loss of equipment such as transmission lines, substations, generators, and so on. That is why this report stresses the importance of having enough reliable generators up and running.

The U.S. Energy Information Administration (EIA) is careful to distinguish between "dispatchable" generation—power plants that can be controlled, i.e., turned on and off, ramped up and down—and non-dispatchable generation.[18] In the U.S., power plants fueled by coal, natural gas, and nuclear power are the largest sources of dispatchable generation. Non-dispatchable sources include wind, solar, and hydroelectric power.[19] This distinction is important because dispatchable generation is absolutely essential to grid reliability.

According to the most recent data from the EIA, the U.S. is home to an amazing 875 gigawatts (GW) of dispatchable generation from coal, natural gas, petroleum, and nuclear power.[20] That is more installed capacity than all of Central and South America, Eurasia, and the Middle East combined.[21]

Existing Threats

Today's electric grid is built to be resilient and secure against a variety of external threats. Given the complex nature of the power grid and the extreme stresses often placed on it, the reliability of the U.S. electricity system that we currently enjoy is something to be celebrated. Major blackouts are extremely rare, which indicates that today's skilled grid operators can effectively manage the day-to-day stresses of the grid. Still, many external factors pose significant threats, such as unruly weather and electromagnetic disturbances from the sun.

The human element also comes into play, not only in terms of accidental errors but also in terms of planned attacks. When it comes to these threats, Congress is already paying close attention.[22] To their credit, members of Congress from both parties are genuinely interested in grid reliability and security.[23] Policymakers should continue to take grid reliability into account when considering known threats and challenges. To that end, and to provide some context for assessing new threats, we provide a brief review of existing threats to the grid below.

Natural Disturbances

Extreme weather places immense stress on the electricity system. In fact, bad weather remains the number one cause of power outages.[24] Extreme cold can put pressure on fuel supply by diverting natural gas to direct heating purposes rather than to natural gas-fired power plants, or by freezing stockpiles of coal stored on-site at coal-fired power plants.[25] Equipment, especially pipes carrying water, can also fail in freezing temperatures.

That is precisely what happened during the January 2014 "polar vortex" in the Northeast. Cold weather increased demand for natural gas beyond the supplies that customers in New York and New England could procure and resulted in forced power outages. During the cold spell, the Midwest, Northeast, and Southeast regions set records for natural gas demand. Meanwhile, other regions reached their all-time peaks for gas demand.[26] Extremely high temperatures can also spike demand for power and strain the grid, underscoring the importance of having an adequate supply of reliable power. In Los Angeles, for example, a September 2014 heat wave caused demand for electricity to skyrocket, breaking a record set in 2010 for power demand. Neighborhoods in L.A. experienced blackouts, and grid operators urged customers to cut back on their electricity usage to avoid further straining the grid.[27]

Solar flares and "coronal mass ejections" can also disrupt the electrical grid by giving off high-energy particles that can interfere with the Earth's magnetosphere and set off a geomagnetic storm. These high-energy particles can overload power lines and damage electrical equipment, particularly in higher latitudes. In 1989, for example, a geomagnetic storm caused a temporary power outage in Quebec. Thankfully, disruptive geomagnetic storms occur so infrequently that they do not constitute a major ongoing threat to the electrical grid.[28]

Source: NASA[29]

Human Attacks

Human attacks on the grid are always a threat. However, history shows that their impacts are fairly limited, and harmful attacks are very infrequent. Doomsday scenarios greatly exaggerate the magnitude of human threats, particularly from attacks that require sophisticated or military-grade technology.

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A recent example illustrates the limited scope of non-military attacks. As documented in the *Wall Street Journal*, in April of 2014, unidentified assailants carried out a sniper attack on an unmanned substation near San Jose, California.[31] The snipers slipped into an underground vault, cut phone cables, and shot out electrical transformers that help supply power to Silicon Valley. As unfortunate as that attack was, the important takeaway is that the grid continued to function normally even after the substation went offline.

It is true that if multiple such attacks were carried out simultaneously at critical points in the grid, they could produce a blackout.

However, there is no evidence that such an attack currently looms over the U.S. power grid. While attacks are theoretically possible, the likelihood of any individual event is typically low, and we should not over-prioritize catastrophic but improbable events. Even so, the Federal Energy Regulatory Commission (FERC) and NERC are already working together on this issue. In November 2014, FERC passed a new Physical Security reliability standard which helps protect the grid from physical attacks.[32] Policymakers have responded to the threat.

Electromagnetic pulse (EMP) attacks are also unlikely. In theory, terrorists or other rogue actors could carry out an EMP attack by detonating a nuclear weapon at an extremely high altitude. In practice, though, there are significant deterrents to launching such an attack with nuclear weapons. Nuclear weapons have not been used in an attack anywhere in the world since 1945. Since an EMP attack would represent a nuclear attack against the U.S., any actor would be well aware that the U.S. would respond in kind—with nuclear weapons. In short, if we are talking about nuclear war, the grid—as vital as it is—may become an afterthought. It is also unclear whether terrorists in particular have access to nuclear weapons.[33]

Cyber attacks are becoming increasingly common. Even though cyber threats do exist and are concerning, fears of catastrophic damage from a cyber attack are likely overblown. In large part, this is because the threats are well known and Congress and FERC have already made efforts to secure America's critical cyber assets.[34] Policymakers are not ignoring the issue.

Further, a sophisticated cyber attack on vital pieces of grid infrastructure likely would require a military-caliber effort.[35] Similar to the EMP threat, the guaranteed in-kind response to a cyber attack remains a strong deterrent to this type of attack. Thus, although cyber attacks are a real threat, there is little reason to believe that they will grow significantly worse or that our agencies tasked with overseeing grid reliability will be unable to deal with the attacks.

Emerging Policy Threats

The single greatest emerging threat to reliable electricity in the U.S. does not come from natural disturbances or from human attacks. Rather, the host of bad policies now coming from the federal government—and, unfortunately, from many state governments—is creating far greater and more predictable problems with grid reliability. Current policies are shuttering unprecedented amounts of reliable power sources while simultaneously forcing increasing amounts of intermittent, unreliable power onto the grid.

In total, we estimate that the policies highlighted in this report are responsible for closing or threatening the reliable operation of over 130 GW of reliable (dispatchable) generation from power plants that run on coal (103 GW), natural gas (19 GW), and nuclear power (8.6 GW). This figure—over 130 GW of reliable power—should be treated as a lower bound because we simply cannot estimate the full impact of each policy on reliable generators.[36] And to put 130 GW in perspective, that's enough power to supply Great Britain's National Grid twice over.[37]

Fortunately, because harmful policies are within the control of policymakers, reliability problems that are policy-driven can be solved by repeal or reform of the offending policies. Below, we highlight the ways in which the current administration has pursued a set of policies that undermine grid reliability. Policymakers should weigh the purported benefits of these policies against their risks, which include bringing greater uncertainty to the power sector and increased chances of a major blackout.

On their face, the point of these regulations is to limit emissions from power plants. However, the administration under President Barack Obama has been openly hostile to coal-fired power plants from the beginning. In 2008, Presidential candidate Obama threatened to bankrupt coal-fired power plants with his cap-and-trade scheme for carbon dioxide. Congress refused to pass cap-and-trade legislation, but Obama's EPA is having the same effect—bankrupting coal-fired power plants by imposing uneconomic regulations and mandating impossible standards.

EPA Regulations

The EPA has promulgated dozens of regulations that directly impact power plants, and is currently finalizing many more. Unprecedented new rules under the Clean Air Act are cumulatively threatening the reliability of the electric grid by forcing reliable power plants to close early. Taken together, EPA's carbon dioxide regulations shut down existing plants—closing 103 GWs of coal-fired power plants by 2020—and ban any potential new coal-fired power plants.

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Existing Source Rule

The EPA's proposed rule regulating carbon dioxide emissions from existing power plants threatens to shutter reliable sources of power while encouraging unreliable ones. For public relations purposes, EPA refers to the rule as the "Clean Power Plan."[39] However, the purpose of the EPA rule is to reduce carbon dioxide emissions from power plants. The problem with calling it the "Clean Power Plan" is that carbon dioxide is not dirty but rather a clear, odorless gas. Furthermore, the nation's electricity generation fleet is already very clean and getting cleaner—electric utilities have reduced the six common pollutants known as the "criteria pollutants" by 68 percent since 1970.[40] With that in mind, we refer to this rule as the Existing Source Rule rather than the Clean Power Plan.

Some observers have called the Existing Source Rule a "federal takeover" of the electric grid because the EPA rule represents a jurisdictional trespass into state-level affairs.[41] But the problems with EPA's proposal go beyond legal issues. With the Existing Source Rule, EPA is proposing a radical shift away from traditional *economic dispatch* of power generators—the tenet of modern electricity markets that the lowest-cost reliable electricity is chosen first—and towards a new model of *environmental dispatch*, which would be a new system designed to select generation sources based on their carbon dioxide emission levels rather than their reliability and cost.

A fatal flaw in the Existing Source Rule and its environmental dispatch framework is that it is completely incompatible with electricity markets. As Harvard electricity expert William Hogan points out, the Existing Source Rule "embeds contradictions of the Clean Air Act, carbon policy, and a collision with electricity market design." He explains that "wholesale power markets depend on the economic dispatch framework," and that the Existing Source Rule cannot be integrated with economic dispatch.[42]

Others have noted that the Existing Source Rule is the regulatory proxy for a carbon tax or cap-and-trade—just one of President Obama's "many ways to skin a cat."[43] However, by making an end-run around Congress with the Existing Source Rule—a regulation that is even more costly than an equivalent carbon tax[44] or cap-and-trade scheme[45]—this administration threatens to turn electricity markets on their head.

Perhaps the larger problem with the Existing Source Rule is that it threatens grid reliability by promoting the least reliable sources of generation and demoting the most reliable. It assumes grid operators will use intermittent sources of electricity such as wind and solar power while forcing reliable coal plants to reduce output. If EPA were an office manager, its plan would give a huge raise to the least effective workers, who only show up when they feel like it, and would substantially reduce the wages and work hours of the most effective workers.

Likewise, the Existing Source Rule threatens to reduce the overall effectiveness and reliability of the power grid.

How much of a demotion are reliable power plants getting? Analyses by EPA, IER, and NERC—our non-partisan, non-ideological national "grid doctor"[46]—reveal that 49 GW or more of coal generation capacity could go offline because of this single rule. For comparison, that's enough reliable power to meet the residential electricity needs of 40 million Americans.[47] The result of this rule will necessarily be an increasing strain on the reliable supply of electricity, which means an increased risk of blackouts.

NERC notes that the effects of the Existing Source Rule are magnified when layered on earlier rules, such as the Mercury and Air Toxics Standards (MATS):

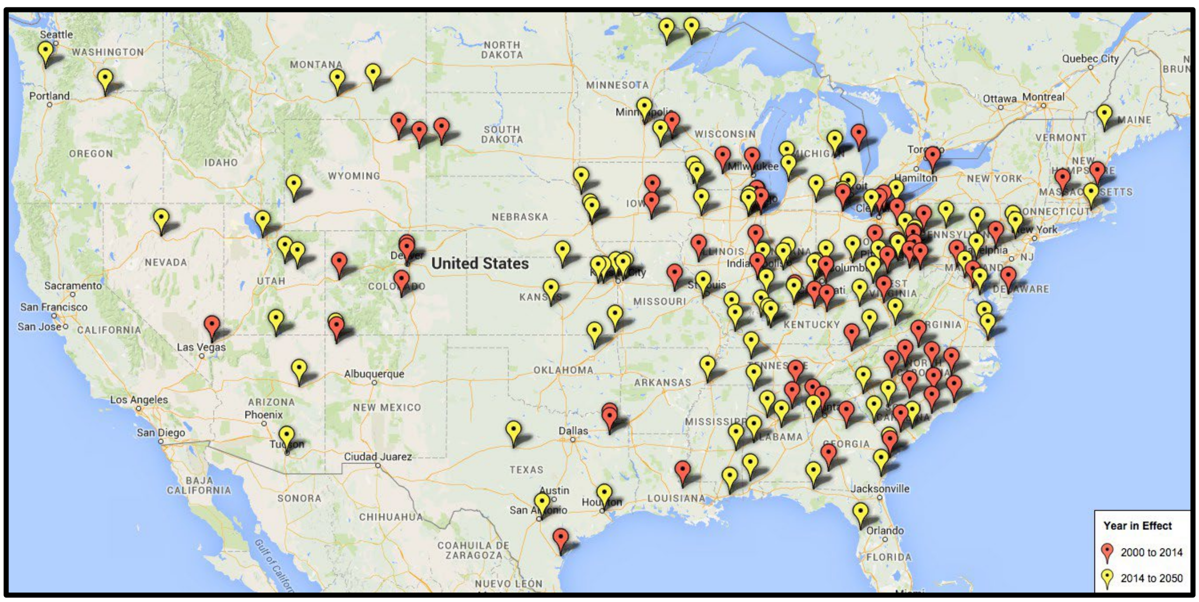
> The EPA estimates that an additional 49 GW of nameplate coal capacity will retire by 2020 due to the impacts of the proposed [Existing Source Rule]. When including the 54 GW of nameplate coal capacity already announced to retire by 2020 (mostly due to MATS), **the power industry will need to replace a total of 103 GW of retired coal resources by 2020**.[48] [emphasis added]

For comparison, 103 GW can power the entire country of France.[49]

IER also analyzed EPA's modeling and coupled it with actual announcements from electricity generators to estimate the number of power plants that are certain to close as a result of the combination of the Existing Source Rule and other regulations. Our initial findings are an underestimate because they only capture the early effect of the Existing Source Rule:

> ...the combined impact of the MATS rule along with that of the Cross State Air Pollution Rule (with some early influence of this GHG rule) would shutter more than 72 gigawatts (GW) of reliable electricity generation. To put this figure in perspective, 72 GW is enough to power every home in every state west of the Mississippi River, excluding Texas.[50]

The following map from IER also demonstrates the scope of 72 GWs of power plant closures across the country. The red dots show power plant retirements that occurred between the years 2000 and 2014, while the yellow dots indicate power plants that are projected to close after 2014:



Source: Institute for Energy Research[51]

Why do NERC and IER urgently warn about the grid reliability impacts of the Existing Source Rule while EPA remains dismissive? One reason is because EPA makes assumptions about the electricity system that do not comport with reality. For example, EPA anticipates a sizable reduction in overall electricity demand in the coming years—for each year between now and 2030—which NERC found to be an unsupported assumption.[52] If EPA is wrong about electricity demand steadily falling over time (and NERC—our grid doctor—is right), then EPA's predictions about grid reliability will be woefully off the mark.

Officials at FERC have also warned of reliability impacts stemming from the amount of coal-fired power that may retire. FERC's analysis is particularly important because FERC is the federal agency that is tasked with ensuring grid reliability. In fact, FERC's Office of Electric Reliability was formed in 2007 to address the agency's growing role in electric reliability.[53] FERC Commissioner Philip Moeller has warned Congress of the grid reliability issues stemming from EPA rules:

> We are really in for a wild ride for five to six years because of the amount of coal shutting down in such a short amount of time and the transformation toward more gas being used to generate electricity.[54]

FERC Commissioner Tony Clark also lamented the practical problems with the Existing Source Rule, noting in Congressional testimony that "it is not hard to envision a future jurisdictional train wreck" between EPA and FERC.[55]

FERC is holding a series of technical conferences in February and March of this year to investigate the reliability problems posed by the Existing Source Rule.[56] EPA should pay close attention to FERC's recommendations.

Other grid overseers, such as regional grid operators, have also expressed serious reservations about the Existing Source Rule. The Midcontinent Independent System Operator (MISO) suggests that the rule would jeopardize an additional 14,000 MW of coal-fired power, on top of the 12,600 MW already about to retire by 2016 in that region because of the MATS rule.[57] In fact, John Bear, MISO's chief executive, noted that "the clean power plan will cause reliability problems...."[58] His concern is that coal-fired plants will shut down before replacement generation can come online, reducing the supply of electricity available and risking blackouts.

The Electric Reliability Council of Texas echoes MISO's concerns about the costs and time required to build new transmission infrastructure to comply with the proposed rulemaking. The operators also worry about the impacts of retiring coal-fired generation on reliable baseload power.[59]

The Southwest Power Pool (SPP), a neighboring transmission organization, said in an October 2014 reliability assessment that the power plant closures caused by the EPA rule essentially broke SPP's model:

> As a result of the assumed EPA retirements with no resource additions, the SPP network was so severely stressed by large reactive [power] deficiencies that the software used in the analysis was unable to produce meaningful results, which is generally indicative of **voltage collapse and blackout conditions**.[60] [Emphasis added]

Regulating power plants assuming that they will comply by employing CCS puts the grid at risk. The New Source Rule's ban on coal deprives the country of much-needed energy from an abundant, domestic source. Like the Power Plant and Industrial Fuel Use Act of 1978, which banned the use of natural gas and petroleum in electricity generation from 1978 until 1987, this unwise regulation should be repealed.

EPA's New Source Rule, proposed in early 2014, is another threat to grid reliability. One of the largest problems with the New Source Rule is that it essentially requires that any new coal-fired power plant use Carbon Capture Sequestration (CCS) technology in order to comply. Asking plants to use CCS, however, is a de facto ban on new coal plants because the technology has not been adequately demonstrated to be commercially viable.[61] The 2014 National Climate Assessment (to which EPA contributed) notes:

> CCS facilities for electric power plants are currently operating at pilot scale, and a commercial scale demonstration project is under construction. Although the potential opportunities are large, many uncertainties remain, including cost, demonstration at scale, environmental impacts, and what constitutes a safe, long-term geologic repository for sequestering carbon dioxide.[62]

Regulating power plants assuming that they will comply by employing CCS puts the grid at risk. The New Source Rule's ban on coal deprives the country of much-needed energy from an abundant, domestic source. Like the Power Plant and Industrial Fuel Use Act of 1978, which banned the use of natural gas and petroleum in electricity generation from 1978 until 1987, this unwise regulation should be repealed.[63]

Mercury and Air Toxics Standards

The EPA finalized the Mercury and Air Toxics Standards (MATS) rule in 2012. The MATS rule—also called Utility MACT because it requires the "maximum achievable control technology"—mandates limits on mercury emissions from all coal- and oil-fired power plants. [64]

The compliance deadline is April 2015. To comply with the rule, power plants have three options, all of which hurt grid reliability: reconfigure the plant to use natural gas, install costly scrubbers, or shut down.

The reason why MATS threatens grid reliability is simple—it is extremely difficult, expensive, and, in some cases, impossible for plants to reconfigure themselves to run on other fuels or to install new scrubbers. Using EPA's own figures,[65] NERA Economic Consulting (NERA) estimates that just the capital costs for a single wet scrubber for a 100 MW power plant can be as much as $85 million (in 2010 dollars).[66]

The EIA likewise estimates that scrubber capital costs[67] for a plant less than 100 MW could reach up to $896 per KW, which translates to $89.6 million for a 100 MW coal plant.[68]

According to NERC, the MATS rule is responsible for the bulk of the 53 GW of coal-fired capacity that was slated to close even without the Existing Source Rule.[69] With so much coal-fired power taken offline, grid operators may struggle to find sources of baseload power.[70]

Anti-Nuclear Policies

A bevy of anti-nuclear policies jeopardize grid reliability as well. These include actions taken by the Nuclear Regulatory Commission (NRC), state policies threatening existing nuclear plants, and subsidies for renewable energy sources that work at cross-purposes with nuclear power.

Taken together, Fitch Ratings estimates that anti-nuclear policies will force an additional 8.6 GW of nuclear power to retire.[71] Five nuclear units have already been decommissioned.

Nuclear power is incredibly important because it is a large source of reliable power and provides about a fifth of our electricity.[72] As energy expert Robert Bryce notes, "if you are anti-carbon dioxide and anti-nuclear, you are pro-blackout."[73]

Bureaucratic hurdles at the NRC have threatened the existence of a number of nuclear plants. As many plants in the existing fleet of nuclear reactors are scheduled to retire soon, insufficient plans have been made to renew or replace them.

A few years ago, nuclear companies assumed that the NRC would easily grant 20- or 30-year life extension grants to plants. Lately, however, long delays and bureaucratic hurdles at the agency have not provided sufficient certainty that the life of existing nuclear plants will be extended into the future, contributing to the decision of some nuclear companies to start closing their plants.[74] One example is the Vermont Yankee power plant in New England. After serving New Englanders for 42 years, the plant closed in December 2014 and will be decommissioned over the course of the next decade because of over-reliance on natural gas and because of NRC policies. As IER has recently noted, the closure of the plant will significantly raise electricity costs for families and put them at risk of suffering from price volatility.[75]

Another example is the San Onofre nuclear power plant located between San Diego and Los Angeles in California. In 2013, Southern California Edison announced that it would stop operating Units 2 and 3 of the plant because a small leak prompted the need for repairs in one of the units while the other was down for a routine outage. The NRC, however, had been dragging its feet on issuing a life extension license for one of these units and for approving the company's plans to restart the other unit. Without certainty that it could even continue to operate the units in the future, Southern California Edison found it uneconomical to pay for repairs and the natural gas generation it needed to purchase while the units were down. The company chose instead to decommission Units 2 and 3 of the plant. Other examples of closing plants include the Kewaunee Power Station in Wisconsin and the Crystal River Nuclear Generating Plant in Florida.[76]

These closures are perfect examples of reliable electricity sources shutting down in a policy environment that favors unreliable sources. While natural gas has added an inexpensive and flexible dimension to electricity generation, over-reliance on natural gas as a consistent baseload source of power in New England has had deleterious effects on customers, as evidenced during the Polar Vortex.[77] As nuclear power expert Rod Adams notes on the closure of Vermont Yankee, alternative energy optimism will not produce energy on "cold, snowy, dark New England days."[78]

It is not just the outright closure of nuclear power plants that is problematic. A larger but less noticeable problem stems from the subsidies for unreliable sources of energy that work at cross-purposes with reliable nuclear power. One such example is the federal Wind Production Tax Credit (PTC).

The size of the subsidy is so large that wind producers can actually pay the grid up to $35 per MWh to take their electricity, even during off-peak hours. This situation—called "negative pricing"—causes unwanted wind power to flood wholesale electricity markets and forces reliable sources of electricity like nuclear power to either cut production or lose money.[79] As IER has noted before, the PTC directly harms reliable power production:

> By encouraging unreliable wind power to produce electricity at times that hurt the grid and other sources of generation, the PTC creates a "biting the hand that feeds you" scenario. This perverse incentive of the PTC is most evident in the case of nuclear energy. As baseload generators, nuclear plants are dependable, efficient, and designed to run without a lot of fluctuation of output.
>
> Both technical and cost recovery factors influence nuclear operators to continuously run their facilities at full output. An excess of wind power at off-peak times forces baseload nuclear plants to sell their electricity at uneconomical, and sometimes negative, prices. Since the PTC encourages wind generators to sell their power for negative prices, nuclear generators are adversely affected when they operate continuously.[80]

The PTC, in essence, forces nuclear plants into inefficient operation patterns depending on whether wind producers are paying the grid to take their electricity at certain times of the day. This policy-driven bias towards wind power and against nuclear power makes the grid less reliable.

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Mandates and Subsidies for Renewable Energy

In its *State of Reliability 2014* report, NERC lists the "changing resource mix" as one of the top-priority risks to reliability. Other risks identified by NERC include those listed above, such as physical attacks and extreme weather. NERC explains the hurdles facing grid planners and operators:

> Reliably integrating high levels of variable resources (wind, solar, and some forms of hydro) into the [bulk power system] will require significant changes to traditional methods used for system planning and operation. The amount of variable generation is expected to grow considerably as policy and regulations on greenhouse gas emissions are being developed and implemented by federal authorities and individual states and provinces throughout North America. Power system planners must consider the impacts of variable generation in power system planning and design and develop the necessary practices and methods to maintain long-term BPS reliability.[81]

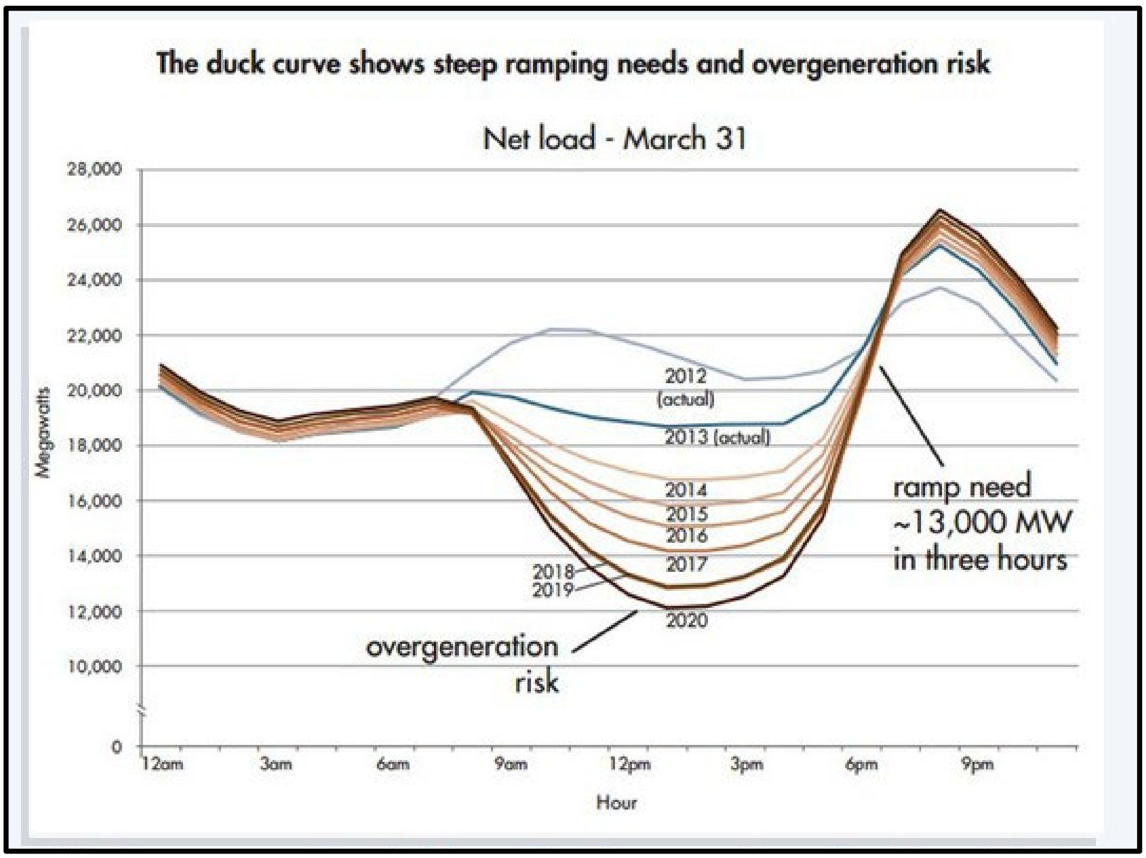
In other words, NERC sees federal and state policies supporting intermittent power sources as a "top-priority risk to reliability." Unlike extreme weather and human attacks, these threats are purely the invention of policymakers and can be undone with a simple repeal of the underlying legislation.

Unreliable sources of electricity are a nuisance on the power grid because they simply cannot be turned on and off. In other words, grid operators cannot count on them to be there when they are needed. A major problem with attempting to use wind and solar power to meet increasing shares of power demand, for example, is their intermittent nature—the wind and the sun follow their own cycles, which are different from daily fluctuations in demand. To further complicate matters, there is currently no economically feasible way to store electricity at the utility scale.[82] Therefore, electricity generated at off-peak times by wind and solar facilities cannot be used to satisfy peak demand.

It actually gets worse. Wind and solar power not only create problems when they are *not* available, but they also create problems when they *are* available because of their effect on reliable power plants. When the intermittent output of wind and solar facilities comes online, reliable plants are forced to back down their output in order to avoid a situation of oversupply. Over time, this parasitic effect can cause reliable power plants to retire early because—with the help of generous subsidies and mandates—wind and solar generation forces even the most consistent plants to reduce output, operate less efficiently, and become overall less economic.

In California, for example, where the government heavily encourages the use of wind and solar power, the grid operator has developed a graphical explanation of the problem with customer-sited photovoltaic solar systems. The graph, called the "duck curve," highlights the challenges facing the grid as more and more solar generation comes online from residential and commercial systems over the next five years. The different lines of the duck curve below show the demand for electricity from reliable sources for each year from 2012 to 2020.[83] In this case, "net load" means total demand not met by solar power.

In the graphic, "net load" bottoms out mid-day due to high output from solar power facilities. The dip is more pronounced each year as more and more solar power comes online. The darkest line—for the year 2020—shows what a solar-heavy grid might look like. Starting at about 5 PM, solar production falls off rapidly, increasing the need for electricity from reliable sources, such as natural gas-fired power plants. In the three hours leading up to peak demand, reliable sources essentially have to double their output to make up for solar power's intermittency. The "head" of the duck reflects the fact that the peak demand for electricity comes late in the day, hours after solar power's peak output.



This situation makes it more difficult to keep supply and demand in balance, increasing the risk of a blackout. Ironically, it also means that the grid will become less efficient overall. The increased output from solar facilities hurts the most efficient sources of generation (such as nuclear, coal, and combined cycle natural gas power plants) by putting them in stop-and-go traffic every day, rather than leaving them to run consistently and efficiently. To use an automobile analogy, renewables are putting "city miles" on the grid, which increase wear and tear and make a breakdown more likely.

Net Metering

Many states have incentives for solar power development.[84] One such incentive is an arrangement called "net metering." When residents of a state install solar panels on their rooftops, the utility is required to buy that electricity from them. In return, they do not have to pay a total electricity bill at the end of the month. Instead, they only pay for the "net" total of electricity used from the utility minus electricity sold back to the utility.[85]

The problem with net metering policies for grid reliability is that they require utilities to buy unwanted electricity, thus creating the same parasitic effect on reliable power sources as we observe with the wind PTC. Overpriced rooftop solar energy is accelerating the duck curve problem in California and creating a dangerous situation in terms of grid reliability. In Hawaii, for example, where net metering is prevalent, grid operators often face an overload of power into the grid and have to pay solar customers *not* to produce power in order to maintain a stable electrical system.[86]

Net metering also threatens the reliability of the grid by making the transmission and distribution of electricity much more expensive. As IER has pointed out from a report commissioned by the California Public Utility Commission:

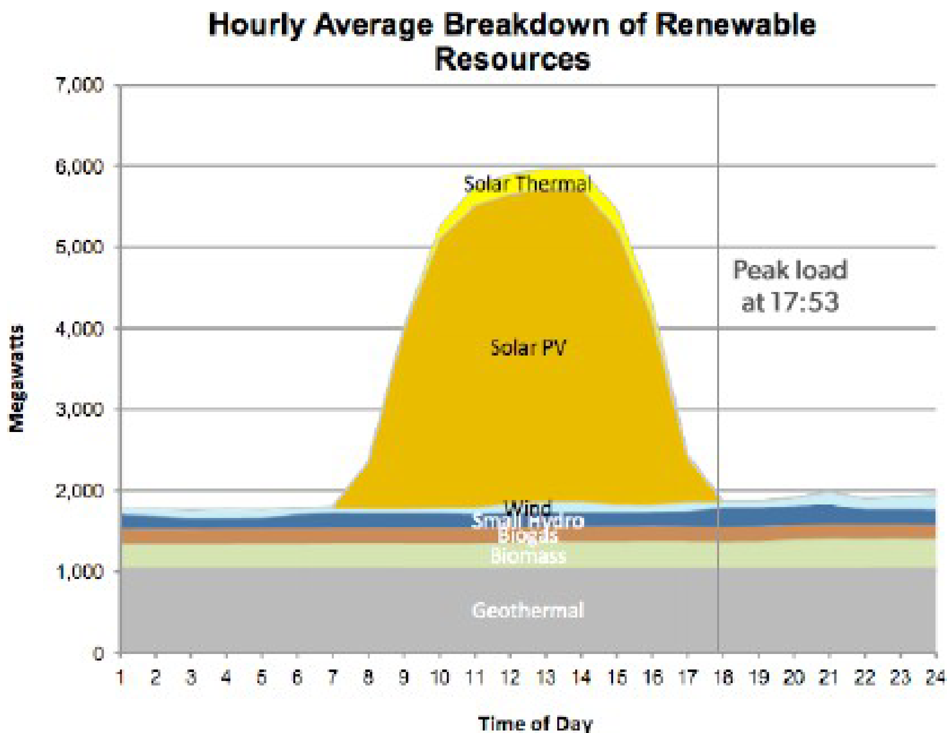
> Due to the intermittent nature of solar energy (it only works when it is sunny), solar users will have a need for backup power supplied by their utility. However, when solar owners are subsidized at high rates, and in higher than expected numbers, utilities are paying more than they would otherwise for **electricity while still being required to maintain transmission and delivery** services for these customers. The CPUC report showed that without reforms to current rate structures and net metering policies, **$359 million** in costs for utility services and maintenance to the grid will be shifted annually from rooftop solar customers to other ratepayers.[87][Emphasis added]

Utilities must recoup their transmission and distribution costs, or the reliability of the grid would be thrown into jeopardy. Consistent electricity depends on the ability of grid operators to maintain a smoothly running transmission and distribution system.

Renewable Portfolio Standards

Renewable Portfolio Standards (RPSs) at the state level mandate that the state generate a certain percentage of its electricity from renewable sources by a certain year. Currently, 29 states and the District of Columbia have RPSs. An example includes a Kansas law which requires 20 percent of its electricity to come from renewable sources by 2020.[88] The problem with such mandates is that they require utilities to choose unreliable and more expensive sources of electricity that are incapable of keeping the lights on, 24/7.

California provides a case in point for why RPSs encourage the use of energy sources that do not provide consistent power. Data from the California grid operator reveal that, on January 15, 2015, wind never produced more than 3.7 percent of its total capacity.[89] Solar power hardly fared much better, peaking only during the middle hours of the day, falling off before peak demand, and remaining nonexistent after the sun goes down.[90] The following graph reveals the hourly breakdown of renewable energy production throughout a single day in California (January 15, 2015):[91]



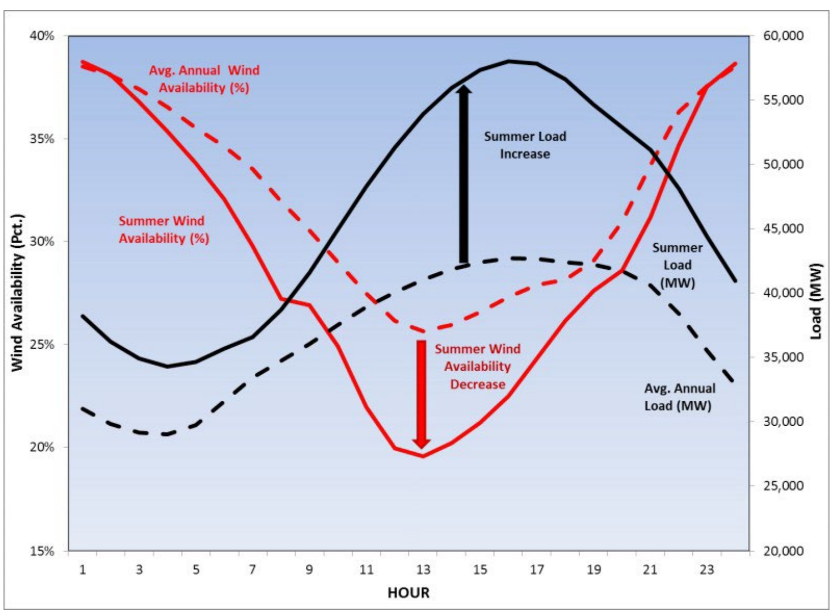
This graph shows the production of various types of renewable generation across the day.

As the chart reveals, on January 15th, wind hardly produced any electricity at all during the day, while solar peaked during the middle of the day, while peak demand (shown as a vertical line on the chart) occurred after solar had gone offline.

Not only does the wind PTC jeopardize grid reliability indirectly by harming reliable nuclear power as discussed above, it also hurts reliability directly by promoting an inherently unreliable source of energy. One of wind energy's greatest problems is that it fails to provide power during the times when it is needed most.

Not only does the wind PTC jeopardize grid reliability indirectly by harming reliable nuclear power as discussed above, it also hurts reliability directly by promoting an inherently unreliable source of energy. One of wind energy's greatest problems is that it fails to provide power during the times when it is needed most. On a yearly basis, wind production typically peaks during the spring and fall—periods of the year when demand for electricity is the lowest. On a daily basis, more wind-generated electricity is produced overnight, when demand is low, rather than during peak hours of the day.[92]

The following graph compares the supply of wind power to the overall load (total demand for power) during a 24-hour cycle in Texas. The dashed black line represents the average annual load, while the dashed red line represents annual wind availability. The graph reveals that wind power shows up when it is least needed and falls short when it is most needed. The solid lines show how the same phenomenon is far worse in summer, when more power is needed:[93]



The takeaway from this graph is that wind power is incapable of keeping the lights on, and, like solar power, actually makes it harder for reliable sources to satisfy demand because it forces them to fluctuate their output more than they would otherwise need to.

A Note on Renewables and America's "Third World Grid"

Last year, former Energy Secretary Bill Richardson claimed in an article in *Politico* magazine that America had a "third world grid." Richardson lamented the fact that wind and solar power play a limited role on America's grid and pleaded for a federal plan to remake the grid for renewables:

> We are producing a lot more energy from renewable sources than we were 10 years ago—yet it's not clear our faltering grid systems are capable of transmitting it from sites far removed from the population centers that traditional grid outlets were intended to serve.[94]

This is a strange complaint. The U.S. electric grid does a great job of providing stable, reliable electricity. But that isn't what Richardson is complaining about. He is complaining that the grid is not set up to handle large amount of unreliable electricity. This is true, but why then isn't Richardson complaining that wind and solar companies have not yet figured how to produce electricity reliably?

Here's a thought experiment: If the federal government mandated the use of some other technology with very limited use, such as 8-track tapes, would Mr. Richardson complain about CD players and iPods and ask the government to build a new fleet of 8-track players? Or would he see why that particular technology is on the sidelines in the first place? In other words, the incompatibility of wind and solar power on the grid is not a major drawback of the grid. Rather, it is a major drawback of those sources of power.

Policies Affecting Delivery of Fuel Supplies

Energy and transportation are linked in important ways. Not only does it take energy to move trains, planes, and automobiles, it also takes a robust transportation infrastructure to move energy (fuels) to the places they are most needed. At the moment, the most salient policy barrier to the vital transportation of fuel is in the area of oil and gas pipelines. Permitting delays at FERC and other agencies at the state and federal level stand in the way of much-needed pipelines that are poised to carry oil and gas to both existing and planned generating stations.

Never has the need for pipelines been more evident than during the so-called "polar vortex" of January 2014, the cold weather event that severely impacted people living in the Northeast and Midwest. Existing natural gas capacity simply could not satisfy the two-pronged increase in demand for natural gas: for direct home heating and for electricity generation from gas-fired power plants.

In response to the price spikes in both electricity and natural gas and the infrastructure problems exposed by the polar vortex, IER issued a report detailing the need to keep existing coal plants online during the winters to come. The report found, among other things:

> Policies which hurt the U.S. coal fleet are placing the reliability, affordability, and security of America's electric supply system at risk… During the winter of 2014, **coal was the only fuel** with the ability to meet demand increases for electricity, **providing 92 percent** of incremental electricity in January/ February, 2014 versus the same months in 2013.[95] [Emphasis added]

New England, for example, relies on natural gas for 50 percent of its electricity generation.[96] NERC estimated the impact of natural gas supply constraints during the polar vortex—for several regions—and found that nearly 19 GW of gas-fired capacity was lost.[97]

If EPA regulations that threaten to close coal-fired power plants are not reformed, many parts of the U.S. will be forced to take a radically different approach to electricity in order to keep the lights on. However, given the current administration's track record—and environmentalists' opposition to nearly all energy infrastructure projects from nuclear power plants[98] to natural gas pipelines[99]—it is unclear which sources of electricity might be permitted to take the place of coal.

Even the Keystone XL pipeline affects grid reliability. Because much of the new oil production from unconventional plays in North Dakota and Canada is moving by rail rather than by pipeline, other goods and materials that move by rail (including coal) are being crowded out by the congestion on rail lines. Utilities have already signaled the need for more timely transport of coal to power plants.[100] Meanwhile, President Obama is unwilling to allow the construction of the pipeline infrastructure that would relieve rail congestion.[101]

Recommendations

In a recent piece for *The Wall Street Journal*, Representative Kevin Cramer—a former grid regulator from North Dakota—asked the question, “Where will you be when the lights go out?”[102] If we make the right changes, we will not have to answer this question. Policymakers have every opportunity to address some of the largest threats to the grid, as these threats are driven not by external factors beyond our control but by bad policies within our control. Repeal or reform of flawed electricity policies would ensure that American homes and businesses have access to reliable electricity long into the future.

Our recommendations include:

- Stop EPA’s Existing Source Rule. States should resist pressure from EPA to comply with the rule, and Congress should do everything in its power to constrain EPA’s authority to enforce it.
- Allow the wind PTC to expire and stay expired. The PTC’s negative long-term impact on grid reliability makes this policy a non-starter for anyone who values reliable electricity.
- End renewable electricity mandates and subsides. These include state RPSs as well as subsidies and special rate treatment like net metering.
- Rationalize EPA’s regulations. EPA’s new regulations affecting power plants harm grid reliability and should be withdrawn as soon as possible.
- Heed the advice of grid experts, such as the electrical engineers at NERC, FERC, utilities, and regional transmission organizations. The EPA’s strategy of plowing forward with a set of regulations that threaten grid reliability flies in the face of the advice that numerous independent grid experts have offered. Instead of buckling in for EPA’s “wild ride,” policymakers should reform or repeal the policies that NERC and FERC deem to be threats to grid reliability.

Grid reliability is under attack. Unwise policies threaten to take 130 GW of reliable power offline forever—more than enough to supply Great Britain’s grid twice over. Among the many serious threats to America’s power grid, emerging policy-related threats are not only the most urgent, but also the most straightforward for policymakers to address. The time is now to make sure the future is bright for America’s power grid.

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