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Thank you, Chairman Weber, Ranking Member Veasey, and Members of the Sub-Committee for inviting me to testify on the electric grid of the future. Since modern society requires affordable, clean, and reliable electricity for most commercial and personal pursuits, there is no infrastructure more important than the interstate electric network.

I serve as Executive Director of the WATT Coalition (Working for Advanced Transmission Technologies), on the board of the Americans for a Clean Energy Grid coalition, and have a consulting practice called Grid Strategies LLC that provides analysis and regulatory policy support for clean energy integration and delivery. I have served as a member of the Electricity Advisory Committee of the DOE Office of Electric Delivery and Energy Reliability from 2008 through 2012, as Senior Vice President of the American Wind Energy Association, as Economic Advisor to FERC Chairman Pat Wood III, and as a Senior Economist at PJM Interconnection LLC.

I. The power system has never been more reliable and no emergency exists

The grid is currently very reliable. There is no crisis or emergency. The grid is experiencing rapid changes as more clean, low-cost resources come on-line to serve customers and crowd out higher-cost, less flexible generation, at the same time that Americans' demand for electricity is flattening. There are also some new and emerging threats that should be addressed, as there always are over time. Reliability and grid authorities are on top of these issues.

DOE and its Office of Electricity can best support reliability and resilience through continuing RD&D, promoting grid expansion and innovations to better use the existing grid, and by following through on recommendations from expert sources such as grid operators, national laboratories, and the National Academies of Science, Engineering & Medicine. The Department should refrain from pursuing misguided support for certain favored generators and technologies, since such subsidies will ultimately harm rather than help customers -- including defense facilities and taxpayers – and harm rather than improve overall grid reliability, security, flexibility and costs.

Over the past decade, authorities including the Department of Energy have consistently reported that the electric system is reliable and becoming more reliable. The North American Electric Reliability Corporation (NERC) reported through its then-CEO to the Federal Energy Regulatory Commission (FERC), "I am pleased to report that the state of reliability in North America remains strong, and the trend line shows continuing improvement year over year."[1] In the region with the most recent and potential future retirements of coal and nuclear plants, grid operator PJM stated, "Our analysis of the recently announced planned deactivations of certain nuclear plants has determined that there is no immediate threat to system reliability."[2] PJM continued, "The PJM electrical grid is more reliable than ever, with 23 percent reserve margins and billions of dollars of new investment. All of this is occurring while emissions are decreasing and wholesale prices are at historic lows for the 65 million consumers we serve. From 2008 to 2017, wholesale prices in PJM fell by more than 40 percent. Competition has required generators to operate more efficiently while also attracting new, more efficient technology, resulting in more than $1.4 billion in annual savings."[3]

Competitive power markets have been key to continued and growing reliability. PJM stated, "Markets have helped to establish a reliable grid with historically low prices. Any federal intervention in the market to order customers to buy electricity from specific power plants would be damaging to the markets and therefore costly to consumers."[4]

II. The electric sector faces evolving threats and opportunities

The electric sector faces a new set of challenges every decade. In the 1990s the industry introduced competition through open access transmission, independent regional grid operation, and the development of an independent power producer sector. In the 2000s, the industry reversed the prior downward trend in infrastructure investment to build up transmission and distribution capability across the country, and implemented mandatory reliability standards after the 2003 Northeast blackout.[5]

This decade seems to have two major defining characteristics: the opportunity to use more low-cost wind, solar, batteries, and natural gas, and the growing threats from severe weather and cyber and physical attack.

Renewable energy costs have fallen by over two-thirds this decade, so it is certain that wind and solar use will continue to grow based on favorable economics regardless of public policy on

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[1] https://www.ferc.gov/CalendarFiles/20170717080645-Cauley,%20NERC.pdf p.1.

[2] http://www.pjm.com/-/media/about-pjm/newsroom/2018-releases/20180601-pjm-statement-on-potential-doe-market-intervention.ashx

[3] http://www.pjm.com/-/media/about-pjm/newsroom/2018-releases/20180601-pjm-statement-on-potential-doe-market-intervention.ashx

[4] http://www.pjm.com/-/media/about-pjm/newsroom/2018-releases/20180601-pjm-statement-on-potential-doe-market-intervention.ashx

[5] http://www.eei.org/issuesandpolicy/transmission/Documents/Trans_Project_lowres_bookmarked.pdf

renewable energy or climate. This presents major opportunities for customers and utilities. It also creates new operational and planning issues related to variability, handling inverter-based technologies, and maintaining stability in some of the weaker parts of the grid. These challenges can be overcome in a safe and economical manner. Over the past decade we have moved from conventional wisdom that 5 percent annual energy from variable sources was a problem, to understand that a mix with 20 percent or more renewable energy is not a major grid management problem.[6] Some systems such as Ireland, even as an electrical island, are evaluating variable resource penetrations of up to 80 percent. Managing a system with high renewable penetration entails changes in system planning and operations, but this nation and others have been working successfully for the past decade to understand the challenges and develop effective solutions.

There is an increasing focus on resilience to certain threats. The Executive Office of the President issued a report on electric system resilience in 2013[7] and the National Academies of Sciences (NAS) did the same in 2017.[8] Severe weather events are growing in magnitude and frequency. Power systems have been challenged not only by Hurricanes Maria, Irma, Harvey, Matthew, Irene and Sandy, but also prolonged cold spells in the Northeast, drought in the South and West, ice storms in the Central region, and wildfires in the West. Intentional physical and cyber attacks are also increasingly plausible, and merit inclusion in reliability frameworks and standards. The NAS report concludes, "the risks of physical or cyber attacks pose a serious and growing threat,"[9] and the Department of Energy and others have been documenting these threats and recommending solutions. It is appropriate for NERC and other reliability authorities to undertake analyses of any new issues or risks as the power system changes, and they are doing so with respect to physical and cyber security, geomagnetic disturbances, and other operational threats.

An analysis of resilience which I recently co-authored offers some broad conclusions:[10]

1) Most outages are caused by distribution problems, not generation or fuel supply, and by routine rather than large events;

2) Budgets are limited, and investments have opportunity costs – suggesting policy makers should compare actual reliability and resilience impact per dollar spent, such as on measures that address multiple threats;

3) Spending to protect high levels of generation capacity (especially older, inflexible units with poor ride-through capability) yields little benefit, while spending on measures close to customers, such as distribution system hardening and critical spares for transmission

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[6] For example, see https://www.weforum.org/agenda/2017/02/wind-power-has-crossed-a-significant-milestone-in-the-us

[7] https://www.energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf

[8] https://www.nap.edu/read/24836/chapter/1

[9] https://www.nap.edu/read/24836/chapter/3#12

[10] Silverstein, Gramlich, Goggin, "A Customer-Focused Framework for Electric System Resilience," https://gridprogress.files.wordpress.com/2018/05/customer-focused-resilience-final-050118.pdf .

equipment, protects against a wide variety of threats and contributes more to reliability and resilience.

III. Grid needs and opportunities

The evolving resource mix and threat environment calls for attention from policy makers in certain general areas: bulk transmission infrastructure, customer-specific reliability for critical electricity needs, distribution system hardening, bulk transmission operations, developing flexible resources, distributed generation and storage, energy efficiency that protects customer survival during extended outages, and analysis and models to support inverter-based generation penetration. Generally these initiatives can be funded by ratepayers through federal and state regulatory policy (FERC and state public utility commissions), so there are very high leverage opportunities available today and emerging from federal and private sector research into better technologies and methods for power system infrastructure and operations.

A. Bulk transmission infrastructure

The transmission network is critical for reliability, resilience, efficiency, and connecting and integrating new clean energy resources. I shared a set of ideas recently at a House Energy and Commerce Committee hearing on opportunities to expand transmission.[11]

Two opportunities in particular are inter-regional planning and cost allocation to increase power flow capability between regions, and high-voltage Direct Current (DC) lines using voltage-source converter (VSC) technology. Unlike the line-commutated converter (LCC), the VSC can supply reactive power; go from no-load to full load, or reverse power flow direction, in 3 cycles instead of seconds; and black-start an area.

We must reform how transmission is planned and paid for -- particularly inter-regional transmission -- to break the current logjam limiting private investment in our grid. FERC has the authority to reform these policies, and should do so. Inter-regional transmission improves reliability and resilience and more than pays for itself by giving customers and regions access to lower-cost, diverse sources of energy.[12] Inter-regional transmission also increases power system efficiency by aggregating diverse sources of supply and demand.[13]

B. Customer-specific reliability for critical electricity needs

Some customers highly value reliable electricity. The value of uninterrupted service for water treatment plants, emergency first responders, hospitals, nursing homes, military facilities, some industrial facilities, data centers, and other critical facilities is much higher than for other customers.[14] The most cost-effective solution for increasing reliability and resilience for these customers is to deploy reliability solutions like backup generators and storage, at the customer

[11] https://docs.house.gov/meetings/IF/IF03/20180510/108283/HHRG-115-IF03-Wstate-GramlichR-20180510.pdf
[12] https://www.spp.org/documents/35297/the%20value%20of%20transmission%20report.pdf, https://cdn.misoenergy.org/MTEP17%20MVP%20Triennial%20Review%20Report117065.pdf
[13] http://www.sciencemag.org/news/2016/01/better-power-lines-would-help-us-supercharge-renewable-energy-study-suggests, https://arpa-e.energy.gov/sites/default/files/ARPA-E%20Dale%20Osborn.pdf
[14] http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=24836

site. As stated by Argonne National Laboratory and quoted in the DOE Quadrennial Energy Review, ""One hundred percent of the following assessed facility groups have an alternate or back [-up] power in place: Banking and Finance; Critical Access Hospitals; Private or Private Not-for-Profit General Medical and Surgical Hospitals; State, Local, or Tribal General Medical and Surgical Hospitals."[15]

Around 90% of outages at military facilities result from failures of equipment on the base.[16] These failures should be a primary focus of efforts to increase bases' electric reliability and resilience, including[17]:

- Increased maintenance of electrical distribution equipment serving the base (52% of base outages are caused by equipment failures).[18]
- Vegetation management to keep trees from contacting power lines serving the base (30% of base outages are caused by weather).
- Adding healthy redundancy by converting radial lines to looped networks.
- Undergrounding critical circuits.
- Investing in more backup generators and Uninterruptible Power Supplies for critical loads.
- Spare transformers and substations.
- Better maintenance and regular testing of backup generators to reduce the high rate of backup generator startup failures (only 60% of military facilities are compliant with requirements for "testing/exercising;" one senior military official noted that, "Maintenance of generators is underfunded and no one checks.").[19]
- Develop refueling plans for backup generators (only 84% of facilities are compliant).
- Microgrids can increase base resilience by aggregating the base's backup generators and loads, protecting against failures of individual backup generators;[20] this requires also hardening the base's distribution equipment, which must be intact for a microgrid to be able to share power across the base.

C. Distribution system hardening

Over 90 percent of customer outages are due to distribution system failures.[21] That share is likely to grow as severe weather threats increase, because the distribution system is more

[15] DOE QER at 4-46, and Julia Philips, Kelly Wallace, Terence Kudo, and Joseph Eto, Onsite and Electric Power Backup Capabilities at Critical
Infrastructure Facilities in the United States (Argonne, IL: Argonne National Laboratory, 2016), ANL/GSS-16/1, https://emp.lbl.gov/sites/all/files/onsite-and-electric-power-backup.pdf
[16] https://www.gao.gov/assets/680/671583.pdf
[17] See DOE QER at p. 4-46.
[18] https://www.acq.osd.mil/eie/Downloads/IE/1%20-%20Castillo%20DoD%20Energy%20Resilience%20Overview_Aug%202015.pdf, page 3
[19] http://www.pewtrusts.org/~/media/assets/2017/01/ce_power_begins_at_home_assured_energy_for_us_military_bases.pdf, pages 10-11
[20] *Ibid.*
[21] U.S. DOE, Quadrennial Energy Review, Second Installment, Chapter IV, p. 4-2 and 4-29

affected by severe weather and many natural disasters than transmission or generation infrastructure. Utilities and state regulators have principal responsibility for distribution system investments. DOE and the national laboratories can develop and share technologies, modeling techniques, and best practices for improving distribution system reliability and resilience.

D. Bulk transmission operations

As with most other forms of infrastructure, advances in monitoring and control systems can improve the reliability and efficiency of the transmission network. There is a set of cost-effective technologies that can increase the flexibility, reliability and utilization of the existing grid.[22] Technology options which can be used separately or together include dynamic line ratings,[23] advanced power flow control,[24] synchrophasor monitoring and analytics, and transmission topology optimization.[25]

E. Expanding flexible resources

Any increase or decrease in system load or generation requires system operators to ramp up or down other resources to keep supply and demand in balance at all times of day and throughout the year. Increasing penetrations of variable resources can make flexible resources that are able to respond to such system balancing needs more valuable. These include demand-side resources such as building energy management, demand response and customer-sited energy storage as well as flexible supply-side resources such as gas turbines, renewables resources themselves, and storage. System operators and market designers should remove barriers that block such flexible resources from participating in markets for flexibility services or from delivering such services in the 40% of the nation that does not have centralized competitive power markets.

F. Analysis and models to support inverter-based generation penetration

Some of the new technologies integrating into the grid such as wind, photovoltaics, and batteries are "non-synchronous," such that power electronics are used to integrate them into the bulk power system. This brings opportunities to improve reliability, such as through extremely fast response to support frequency deviations. However, these resources operate

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https://www.energy.gov/sites/prod/files/2017/02/f34/Chapter%20IV--Ensuring%20Electricity%20System%20Reliability%2C%20Security%2C%20and%20Resilience.pdf

[22] https://watttransmission.files.wordpress.com/2018/03/watt-living-grid-white-paper.pdf

[23] Dynamic Line Ratings (DLR) increase capacity on existing transmission lines by calculating capacity ratings based on actual monitored conditions rather than fixed worst-case assumptions. See DOE QER https://www.energy.gov/sites/prod/files/2017/02/f34/Chapter%20IV--Ensuring%20Electricity%20System%20Reliability%2C%20Security%2C%20and%20Resilience.pdf p. 4-44.

[24] Power Flow Control refers to a set of technologies that effectively push or pull power away from overloaded lines and onto underutilized corridors within the existing transmission network. Advanced power flow control provides this same function with advanced features such as the ability to quickly deploy, easily scale to meet the size of the need, or redeploy to new parts of the grid when no longer needed in the current location.

[25] Transmission topology optimization is a software technology that automatically identifies reconfigurations of the grid to route power flow around congested or overloaded transmission elements, taking advantage of the meshed nature of the power grid.

differently than traditional synchronous machines and their settings need to be properly set to improve system reliability and not harm it. This is particularly true on "weak" systems (where there is a high sensitivity of local system voltage to variations in current injections), which tends to occur in remote areas where the best renewable resource areas are found. NERC and RTOs are performing research in this area.[26]

IV. DOE's Office of Electricity can play a key role

DOE has contributed a great deal to advances in transmission hardware, monitoring and control systems, and sensor development and deployment. Given the importance of a reliable electric grid to modern society, and the critical role it plays in integrating new centralized and distributed resources and managing various threats, the Office of Electricity (OE) needs full funding.

A. Continue and Expand Research, Development, and Demonstration

OE can contribute through its Grid Modernization Initiative (GMI).[27] I agree with the office's focus on reliability, flexibility, efficiency, resiliency, affordability and security,[28] and the general direction of the GMI.

I would emphasize the opportunities to demonstrate and evaluate some of the technologies DOE has helped foster. The technologies mentioned above -- Dynamic Line Ratings (DLR), advanced power flow control, synchrophasors, and topology optimization -- have benefited from DOE RD&D support. They can all improve reliability, resilience, and efficiency, and are extremely affordable. The challenge is getting transmission owners to use them when they generally do not have an incentive to do so. FERC has the primary authority to address that, but DOE can help by funding local and regional studies of the benefits of these technologies.

B. Support studies of the evolving generation mix

NERC and RTOs are generally aware of the opportunities and risks of shifting to more use of inverter-based resources.[29] They could benefit from DOE support for studies to better understand what standards or guidelines to use in interconnection requirements. Better system models, generic resource models, and tools are needed, and no entity can support that better than DOE. For example, studies of weak grids with high penetrations of inverter-based resources would be extremely valuable.

DOE management has been visionary for decades in imagining new energy production, delivery and use technologies and bringing them from idea into reality. These successes include hydraulic fracturing for natural gas, wind and solar technology, natural gas-fired combustion turbines, a host of energy-efficient building and appliance designs, and the smart grid. The

[26] https://www.nerc.com/pa/RAPA/rg/ReliabilityGuidelines/Reliabilty_Guideline_-_Integrating_VER_into_Weak_Power_Systems.pdf

[27] https://www.energy.gov/grid-modernization-initiative-0

[28] https://www.energy.gov/oe/activities/technology-development

[29] https://www.nerc.com/pa/RAPA/rg/ReliabilityGuidelines/Reliabilty_Guideline_-_Integrating_VER_into_Weak_Power_Systems.pdf

power system components and balance – particularly generation fleet composition -- has changed markedly in large part to these and other technology advances. DOE-OE should continue to conduct studies of how to modernize and evolve grid architecture and how to integrate distributed energy resources (DERs), to help the electric industry and society adapt to further evolution of power system capabilities and roles.

C. Perform resilience functions as recommended by NAS

In the National Academies of Sciences study of power system resilience, 8 of the 12 recommendations to policy makers were for the Department of Energy. DOE's Office of Electricity can play a lead role in implementing these eight specific recommendations:[30]

1. "Improve understanding of customer and societal value associated with increased resilience and review and operationalize metrics for resilience."
2. "Support research, development, and demonstration activities to improve the resilience of power system operations and recovery by reducing barriers to adoption of innovative technologies and operational strategies."
3. "Advance the safe and effective development of distributed energy resources and micro-grids."
4. "Work to improve the ability to use computers, software, and simulation to research, plan, and operate the power system to increase resilience."
5. "Work to improve the cybersecurity and cyber resilience of the grid."
6. "The owners and operators of electricity infrastructure should work closely with DOE in systematically reviewing previous outages and demonstrating technologies, operational arrangements, and exercises that increase the resilience of the grid."
7. "Work collaboratively to improve preparation for, emergency response to, and recovery from large-area, long-duration blackouts."
8. "With a growing awareness of the electricity system as a potential target for malicious attacks using both physical and cyber means, DHS and DOE should work closely with operating utilities and other relevant stakeholders to improve physical and cyber security and resilience."

D. Transmission expansion

OE can play a key role in assisting with the planning and permitting of high-voltage long-distance transmission. OE can help facilitate inter-regional transmission through analytical and data support, and process facilitation to resolve differences in methodologies and metrics.

OE can also perform its roles under EPAct 2005 for congestion studies and backstop federal transmission siting. I recommend DOE engage only in very specific limited circumstances when all other options have failed.

V. Budget priorities should reflect the importance of the grid and DOE's role

[30] https://www.nap.edu/read/24836/chapter/2#6

The most critical challenges for a reliable, resilient, and clean future power system lie in the integration of diverse resources into the grid, more so than the continued cost reductions or preservation of any one generation technology. Yet OE's budget is far smaller than most generation-specific or demand-side programs within DOE. This is not surprising given its relatively short program history, but Congress and the administration have a strategic opportunity to expand resources for future needs.

a. The administration's proposed budget cuts would undermine reliability and resilience

The administration's budget states, "The mission of the Office of Electricity Delivery (OE) is to drive electric grid modernization and resiliency in energy infrastructure."[31] Yet it proposes to cut approximately 2/3 to 3/4 of the funding for transmission reliability and resiliency, resilient distribution systems, and energy storage.[32]

b. The House bill removes the cuts but does not increase funding to where it should be

The House bill puts funding back up to $45 million, $48 million, and $51 million, respectively for transmission reliability and resiliency, resilient distribution systems, and energy storage (from $13 million, $10 million, and $8 million, respectively, in the administration's proposal).[33] This is an improvement relative to the Administration's proposed budget, but does not reflect the importance of the grid and DOE's key role.

VI. OE should not support the administration's misguided initiative to bail out old, unreliable power plants

On June 1, the President stated, "impending retirements of fuel-secure power facilities are leading to a rapid depletion of a critical part of our Nation's energy mix," and directed the Secretary of Energy "to prepare immediate steps to stop the loss of these resources."[34] A leaked untitled draft memo identified "fuel-secure" units as coal, nuclear, oil and dual-fueled resources with adequate storage.[35] This draft generator bail-out plan indicates that DOE has already concluded that, "recent and announced retirements of fuel-secure electric generation capacity across the continental U.S. are undermining the security of the electric power system because the system's resilience depends on those resources."[36]

There is no basis for this directive or for DOE's findings. It ignores some basic facts:

[31] https://www.whitehouse.gov/wp-content/uploads/2018/02/doe-fy2019.pdf page 383.
[32] https://www.whitehouse.gov/wp-content/uploads/2018/02/doe-fy2019.pdf p. 382.
[33] https://docs.house.gov/meetings/AP/AP00/20180516/108312/HRPT-115-HR-FY2019-EnergyandWater.pdf p. 88.
[34] https://www.whitehouse.gov/briefings-statements/statement-press-secretary-fuel-secure-power-facilities/
[35] https://www.documentcloud.org/documents/4491203-Grid-Memo.html
[36] https://www.documentcloud.org/documents/4491203-Grid-Memo.html

- All types of power plants are vulnerable to reliability and resilience threats. Coal plants are vulnerable to disruption or congestion in rail and barge deliveries of coal.[37] During recent droughts, coal and nuclear plants have been forced to reduce their output in peak summer demand periods due to cooling water constraints.[38] On page 20, DOE's memo quotes NERC's discussion of the impact of natural gas failures during the Polar Vortex event, while omitting the surrounding sections of NERC's report that discussed the equally large failures at coal plants. During the Polar Vortex, Bomb Cyclone, and ERCOT 2011 cold snap, equipment failures and not fuel supply issues caused most generator outages; these equipment failures occur regardless of fuel source.[39]
- Although the leaked memo warns that natural gas pipelines are vulnerable to cyber-attacks, it ignores the fact that all power plants (including coal and nuclear) and control rooms are similarly vulnerable to cyber threats.
- Nuclear plants are the least flexible of all major resource types and are unable to respond to grid frequency deviations.
- Coal plants are also inflexible, and systematically fail to accurately follow frequency regulation signals.[40] NERC has found that around 90% of conventional power plants fail to provide sustained response to stabilize frequency following a grid disturbance.[41]
- 99+% of customer outage-hours are caused by distribution and transmission system failures, not by generation failures or fuel delivery problems.
- As noted above, around 90% of military base power outages occur due to failures of power lines and other electricity distribution equipment on the military base. If the goal is to improve electric reliability and resilience at military bases, the solutions discussed earlier in my testimony would be far more effective than subsidizing unneeded coal and nuclear plants.
- Most customer outages are weather-driven, and weather-driven events impact distribution systems more than generation.
- Fuel security problems have historically caused fewer than 1 out of every 1.4 million hours of customer electricity outages.[42] Nearly all U.S. power markets have a large surplus of capacity; the generation reserve margin in PJM is currently over 32%, twice the region's target level.[43] PJM[44] and other grid operators have documented[45] that increasing reserve margins above 20% provides almost no incremental benefit to power system reliability. More fundamentally, when many power plants are facing economic pressures because electricity markets are oversupplied, subsidizing coal and nuclear plants will only exacerbate their challenges by sustaining over-supply and allowing

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[37] https://www.ncac-usaee.org/resources/Documents/Presentations/2014/2014_12Heller.pdf
[38] https://www.eia.gov/todayinenergy/detail.php?id=7810
[39] https://www.aweablog.org/renewables-grid-market-based-solutions-support-reliability/
[40] https://ieeexplore.ieee.org/document/6815753/
[41] https://www.nerc.com/docs/pc/FRI_Report_10-30-12_Master_w-appendices.pdf
[42] https://rhg.com/research/the-real-electricity-reliability-crisis-doe-nopr/
[43] https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_SRA_05252018_Final.pdf, page 7
[44] http://www.pjm.com/-/media/committees-groups/committees/pc/20171012/20171012-item-03a-2017-pjm-reserve-requirement-study.ashx, page 39
[45] https://gridprogress.files.wordpress.com/2018/05/customer-focused-resilience-final-050118.pdf, page 61

expensive, inefficient and inflexible old power plants to crowd out more efficient and low-cost producers that better contribute to grid reliability and resilience.

- Coal and nuclear plants have relatively poor "ride-through" capability, meaning they drop off-line when they encounter a small disturbance on the grid. Compared to new wind plants, it takes very little to shut down coal and nuclear plants, so they are not "resilient" on their own. These frequency and voltage disturbances are likely to be among the most disruptive consequences of a physical or cyber attack on the grid. Coal and nuclear plants are just as vulnerable to attack as other resources. If anything, renewable plants tend to be smaller, which reduces the impact of any failure. Regardless, generator-specific resilience has minimal impact on customers given the reliance on transmission and distribution to serve customers.
- Keeping the lights on following the loss of large fossil and nuclear power plants is a far larger challenge and expense for grid operators than the gradual and predictable changes in wind and solar output.[46]
- New generation tends to be much more reliable than the old generation that is retiring which has approximately 3 times the outage rates in PJM.[47]
- Contrary to the claim in the DOE memo that electric resilience is not being addressed, NERC has explained that its existing reliability standards and other requirements already address electric resilience.[48] The vast majority of the 150 comments filed in FERC's resilience docket AD18-7 offer extensive detail on how power system resilience is being addressed effectively today.

The administration's leaked memo also relies on flawed studies. For example, the National Energy Technology Laboratory study referenced on page 14 calls coal power "resilient" because it increased output during the Bomb Cyclone event relative to an arbitrary time period in December 2017. All that example shows is that during the December time period many coal power plants were not operating at full output because the grid operator was properly dispatching less costly natural gas-fired and wind generation, so the coal plants had a great deal of idle capacity available to increase output when demand and prices increased during the Bomb Cyclone.[49] The NETL findings do not indicate coal plants' resilience, but rather just their poor economics. Similarly, oil-fired power plants increased their output even more than coal plants during the Bomb Cyclone. This does not mean oil generators are resilient, only that they are also expensive. This is basic power sector "economic dispatch," used since the beginning of the industry and in all countries.[50]

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[46] https://www.aweablog.org/fact-check-winds-integration-costs-are-lower-than-those-for-other-energy-sources/

[47] https://www.pjm.com/-/media/committees-groups/committees/mc/20171026/20171026-item-03-2017-irm-study-presentation.ashx slide 7. Recently retired generation has a forced outage rate of 14.56 percent while newly added generation has a forced outage rate of 4.42 percent.

[48] https://www.nerc.com/comm/PC/Agenda%20Highlights%20and%20Minutes%202013/Draft_PC_Meeting_Presentations_March_6-7_2018_Jacksonville_FL.pdf, page 57

[49] http://sustainableferc.org/fossil-lab-misses-mark-in-cold-weather-resilience-report/

[50] http://www.pjm.com/-/media/library/reports-notices/weather-related/20180413-pjm-response-to-netl-report.ashx?la=en

The NETL study also understated the large contribution of renewable resources during the Bomb Cyclone. Even though wind energy output was well above average during the Bomb Cyclone event, NETL incorrectly claimed renewable output was low because NETL's analysis only compared output against the arbitrary December 2017 time period, when renewable output was also above average.[51]

The leaked memo also cites studies by IHS Markit that assert the economic value of coal and nuclear power in the PJM region. Several articles have challenged the validity and quality of these studies' analytic methods and claims.[52]

It is noteworthy that among the long list of resilience recommendations from the National Academies of Sciences, there is no recommendation to keep old coal and nuclear plants on line. The two issues simply have nothing to do with each other.

Finally, the Administration's memo asserts national security concerns regarding the continuing loss of aging coal and nuclear plants, but as noted above there are far better ways to support defense facility reliability and resilience than keeping old coal and nuclear plants in operation. The annual cost of DOE's proposed subsidies, using either ratepayer or taxpayer money, is estimated to be in the tens of billions of dollars per year.[53] Based on an estimated cost of $65 billion per year for the DOE proposal, that money could be used to instead:

- Increase grid resilience by installing over 300,000 miles of new electricity distribution lines each year, enough to cross the U.S. more than 150 times;[54] or
- Move around 100,000 miles of existing overhead distribution lines underground each year;[55] or
- Install over 200,000 MW of backup generators each year,[56] enough to cover the Defense Department's total electricity needs more than a dozen times over; or
- Make thousands of military facilities more energy efficient, reducing the electric load that must be served and protected when a grid or national emergency event occurs.

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[51] http://www.aweablog.org/wind-energy-perform-bomb-cyclone/
[52] https://www.aweablog.org/report-ignores-renewable-technology-advances/
[53] Last fall, DOE issued a Notice of Proposed Rulemaking (NOPR) to the Federal Energy Regulatory Commission that appears to be similar to DOE's latest proposal; but the latest proposal appears to apply nation-wide rather than to just the MISO, PJM, NYISO, and ISO-NE grid operators. The PJM Independent Market Monitor estimated that the NOPR would have cost PJM customers between $3 billion and $32 billion per year, with a middle case of $13 billion per year. Since PJM accounts for about 20% of U.S. electricity demand, a central estimate is that the latest proposal would cost around $65 billion per year. See https://www.rtoinsider.com/doe-nopr-pjm-market-monitor-cost-allocation-78830/, https://www.nytimes.com/2018/06/01/climate/trump-coal-nuclear-power.html
[54] https://www.eia.gov/todayinenergy/detail.php?id=7250
[55] *Id.*
[56] Based on a backup generator cost of $300/kW https://www.acq.osd.mil/eie/Downloads/IE/Attachment%202%20-%20What%20does%20$1M%20in%20resilience%20buy%20me_v6.pdf

However, actual spending for military base electric resilience has remained flat. The budget for DOD's Energy Resilience and Conservation Investment Program has fallen from as high as $174 million in 2010 to $150 million today,[57] with no increases for inflation, and with a $150 million request for FY2019.[58] In FY2018, funding for only 7 energy resilience projects was requested (although the Senate did recommend spending an additional $15 million).[59] The FY2019 budget request also proposes cuts to assessments of military base resilience.[60]

VII. OE's modeling to support the bailout plan should be scrutinized carefully and should not divert resources from valuable OE work

A top OE priority currently is to spend two years on a continental multi-sector model. I am concerned that this model will be used to support the administration's misguided plan to bail out old uneconomic and unreliable generation sources and divert important resources and attention away from valuable OE work.

A model with so many variables can easily be adjusted to lead to certain answers. Every model is a "black box" to some extent, but this one will be murkier than most given its complexity and the confidentiality of many of the inputs. Most technical models earn credibility after extensive peer review of both input assumptions and internal mechanics. In the case of a model purporting to identify critical national energy assets and infrastructure, such review is likely to be complicated by assertions that the inputs and outputs are classified national security information that should not be aired for public or expert technical review.

It is not clear DOE will be able to gain access to the data it would need for such a model anyway. Utilities and RTOs have data on their system under confidentiality protections and they are not subject to FOIA. Utilities, RTOs and NERC run analyses and have detailed models of their own systems, and likely have as good a sense of the security-critical assets on their systems as DOE-OE may eventually develop with its emerging infrastructure model.

VIII. Conclusion

I appreciate the Subcommittee's interest in this important topic. There are some very valuable work streams in the Office of Electricity that can support reliability, resilience, efficiency, and the grid's evolution given changes in the resource mix and evolving threats. That work should be continued and expanded. At the same time, the President and DOE are undertaking a misguided program to fund the continued operation of old, uneconomic and unreliable power plants. It will be important for Congress to rigorously oversee the Department of Energy, and

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[57] https://www.acq.osd.mil/eie/IE/FEP_ECIP.html
[58] https://docs.house.gov/meetings/AS/AS03/20180418/108135/HHRG-115-AS03-Wstate-NiemeyerL-20180418.PDF, page 14
[59] https://www.congress.gov/115/crpt/srpt130/CRPT-115srpt130.pdf, page 10
[60] http://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2019/budget_justification/pdfs/01_Operation_and_Maintenance/O_M_VOL_1_PART_1/Volume_I_Part_I.pdf, page 574

the Office of Electricity specifically, to ensure that important work gets done and taxpayer dollars are not wasted on ill-conceived programs.

By driving grid expansion and better utilization of the existing grid, DOE can help provide consumers with access to more affordable and reliable power.