UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Notice of Proposed Rulemaking	**)**	
Grid Resiliency Pricing Rule	**)**	**RM18-1-000**

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In language urgent without evidence[1], alarmist without cause[2], and peremptory without authority[3], the Secretary of Energy directs[4] the independent Federal Energy Regulatory Commission (FERC) to reverse the Nation's bedrock electricity policy of open wholesale competition, painstakingly evolved over four decades. Instead, he would favor and reward deregulated coal and nuclear plants over all other resources—giving uncompetitive merchant plants using those two fuels, and no others, the advantages of ratebasing regardless of need, cost, prudency, or actual use. To my knowledge, no electrical resource anywhere has ever been afforded any such subsidy by FERC, let alone resources whose owners chose and failed to compete them in open markets. For this unprecedented proposal, the Secretary invents an imaginary emergency, a fanciful rationale, and nonexistent authorities. I cannot recall any regulatory proposal so unhinged from markets, facts, logic, and legal and policy norms.

The Commission should afford the Secretary's views the due process set by law and courtesy, but is no under obligation to accept them, and indeed could not do so via a reasoned decision based on a sound evidentiary record. None of the 14 attributes lately claimed to justify out-of-market support for coal and nuclear plants, including the Secretary's central "fuel on hand" attribute, actually offers material real benefits or merits extra payment.[5]

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[1] Joint Motion of the Energy Industries Association, FERC RM18-1-000, 2 Oct 2017, https://info.aee.net/hubfs/Joint_Energy_Motion_on_DOE_Letter_NOPR_to_FERC.10.2.17.pdf.

[2] Neither the Secretary's August 2017 *Staff Report on Electricity Markets and Reliability* (from which the NOPR cherry-picks brief quotations inconsistent with its broad analysis), the reliability authority NERC (North American Electric Reliability Corporation), any regional Independent System Operator (ISO) or Regional Transmission Organization (RTO), or any other disinterested authority has acknowledged the reliability emergency that the NOPR claims. (Other discordant sources are cited on the first page of ref. 5.) The Secretary's urgency is evidently about politics, not electricity.

[3] DOE Organization Act (42 USC 84), §7171(d) and §7175.

[4] FERC, "Grid Resiliency Pricing Rule," 82 FR 46940–46948, 10 Oct 2017 (18 CFR 35); original DOE Notice of Proposed Rulemaking (NOPR) original test posted 29 Sep 2017 at https://www.energy.gov/sites/prod/files/2017/09/f37/Notice%20of%20Proposed%20Rulemaking%20.pdf.

[5] A. Lovins, "Do coal and nuclear generation deserve above-market prices?," *The Electricity Journal* **30**:2–30 (July 2017), http://dx.doi.org/10.1016/j.tej.2017.06.002. An Exelon-sponsored critique by D. Murphy & M. Berkman and my response are in press at the same journal (2017).

My experience[6] in the electricity and national-security issues the Secretary invokes leads me to believe that his NOPR is not just unjustified but backwards. His policy *would not enhance but diminish grid resilience and national security*, as this comment explains. I've sought to organize the comment as a coherent narrative, but Annex 2 also tabulates the FERC Staff questions corresponding to each part, and as Staff invites, I have also commented on many questions not asked.

The Secretary offers no argument or evidence that existing wholesale price formation is unjust or unreasonable, as FERC would need to find in order to approve his proposed rule. Moreover, taken in their context, the attributes he wants rewarded, though framed as if fuel-neutral, are effectively fuel-specifying—hence "unduly discriminatory or preferential," a prohibited practice.[7] As ref. 5 says, too, around-market interventions, including the NOPR's unique ones, "distort pool-wide prices, crowd out competitors, discourage new entrants, destroy competitive price discovery, reduce transparency, reward undue influence, introduce bias, pick winners, and invite corruption." These outcomes are all contrary to FERC's duties. The NOPR's proposals are also likely to prove discouraging to investors and very expensive to customers, though its operational details are too vague to permit economic analysis.

This comment focuses not on such economic, legal, or policy issues, but rather on the NOPR's flawed framing and fact base. I seek to contribute here some important information on why the NOPR rests on counterfactual basic assumptions about the reliability and resilience of coal and nuclear plants, other resources, and grids—thus making its prescription far less able than other, overlooked technical and policy options to achieve its stated goals.

1. The vital goal of resilient electrical service is nearly unrelated to the NOPR's demand for rewarding specific attributes of certain central power stations, chiefly the size of their onsite fuel inventories.

Resilient electrical services require that electricity be generated, delivered, and converted by an end-use device into each desired service (hot showers, cold beer, illumination, comfort, torque, computation, etc.) in a way resistant to disruption by accident or malice, capable of prompt recovery, and able to learn from disruption so it becomes more resilient against future shocks. (I prefer this definition to NARUC's thoughtful but narrower "robustness and recovery characteristics of utility infrastructure and operations, which avoid or minimize interruptions of service during an extraordinary and hazardous event." Somewhat better is the Jan. 2017 DOE *Quadrennial Energy Review*'s encapsulation: "Resilience is the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions" [p. 4–4]; but resilience is an attribute of systems, not their parts.)

[6] Please see attached Annex 1: Qualifications. I'm solely responsible for any errors, but gratefully acknowledge review comments by my RMI colleagues James Newcomb, Mark Dyson, and Ryan Laemel.
[7] 16 USC 824e(a).

The design principles and practices that create energy resilience (or, as the Secretary calls it, resiliency) were first framed for the Pentagon in 1981,[8] and still broadly guide DoD doctrine for resilient power supplies to military bases and other facilities critical to national security. These principles do *not* include continued or enhanced reliance on inherently vulnerable powerlines hauling electricity hundreds of miles from remote central power stations—a system rife with single points and modes of failure requiring costly redundancies but still not fully effective, as these comments elaborate. Such grid-dependence is the largest factor *preventing* electric resilience.

Rather, resilient design logically starts at the customer and works back up the supply chain, seeking to make that chain as short as possible and each of its links robust, redundant, with graceful failure and quick rerouting or repair. As a lay summary of *Brittle Power* explained,[9] a resilient system "has many relatively small, dispersed elements, each having a low cost of failure. These substitutable components are interconnected not at a central hub but by many short, robust links. This configuration is analogous to a tree's many leaves, and each leaf's many veins, which prevent the random nibblings of insects from disrupting the flow of vital nutrients."

The Secretary's NOPR[10] says nothing about *grid* resilience—the core security issue for the modern electricity system—but focuses exclusively on central power *plants* and intently on their onsite *fuel* inventories. He emphasizes a remark, in a cover letter from the CEO of NERC, that becomes tautologous with emphasis added—that "premature retirements of fuel-secure baseload generating stations reduces [*sic*] resilience *to fuel supply disruptions*"—but NERC nowhere says fuel-supply disrup-

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[8] A. & L.H. Lovins, *Brittle Power: Energy Strategy for National Security* (esp. Ch. 13), 499 pp., ~1,200 refs., DoD/CEQ/Brick House (Andover MA), 1982, Foreword by ADM T.H. Moorer (USN Ret, President Nixon's Chairman of the Joint Chiefs of Staff) and R. James Woolsey (ex-Undersecretary of the Navy, later Director of Central Intelligence), www.rmi.org/wp-content/uploads/2017/04/brittlepower3ptcombo.pdf; originally *Energy policies for resilience and national security: Final report to the Council on Environmental Quality, Executive Office of the President,* 1981, commissioned by FEMA's predecessor, the Defense Civil Preparedness Agency; summarized as "Reducing Vulnerability: The Energy Jugular," in R.J. Woolsey, ed., *Nuclear Arms*, Inst. for Contemp. Studies (San Francisco), 1983, https://d231jw5ce53gcq.cloudfront.net/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprts_S84-23_EnergyJugular.pdf,. For broader energy-security context, please see also A. Lovins, "How innovative technologies, business strategies, and policies can dramatically enhance energy security and prosperity," invited testimony to US Senate Committee on Energy and Natural Resources, Hearing on Energy Independence, SD-366, 7 March 2006, https://www.rmi.org/wp-content/uploads/2017/05/E06-02_SenateTestimony.pdf.

[9] A. & L.H. Lovins, "The Fragility of Domestic Energy," *Atlantic*, Nov 1983, https://www.rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprts_S83-08_FragilityDomesticEnergy.pdf.

[10] I ascribe it personally to the Secretary of Energy because, based on DOE's *Staff Report to the Secretary on Electricity Markets and Reliability* (hereinafter *Staff Report*), Aug. 2017, https://energy.gov/sites/prod/files/2017/08/f36/Staff%20Report%20on%20Electricity%20Markets%20and%20Reliability_0.pdf, his Department's professional staff do not appear to support the NOPR's analysis or findings.

tions are a dominant and urgent issue. Nor does NERC endorse the Secretary's striking assertions (NOPR section II preamble, II.I, III) that:

> The resiliency of the nation's electric grid is threatened by the premature retirements of power plants that can withstand major fuel supply disruptions…. These fuel-secure resources are indispensable for the reliability and resiliency of our electric grid…. It is time for the Commission to issue rules to protect the American people from energy outages expected to result from the loss of this fuel-secure generation capacity…. The continued loss of fuel-secure generation must be stopped. These generation resources are necessary to maintain the resiliency of the electric grid…. [C]hronic distortion of the markets [i.e., paying market prices insufficient to retain these uncompetitive resources]…is threatening the resilience of the Nation's electricity system…. [I]t is the Commission's immediate responsibility to…ensure that the reliability and resiliency attributes of generation with on-site fuel supplies are fully valued and…to develop new market rules that will achieve this urgent objective…. Immediate action is necessary to ensure fair compensation in order to stop the imminent loss of generators with on-site fuel supplies…and avoid the severe consequences that additional shutdowns [of fuel-secure generators] would have on the electric grid….

Not one of the NOPR's cited sources supports these dramatic claims nor even the Secretary's framing of the issue. The DOE *Staff Report* (section B) notes plant retirements but does not infer capacity shortages nor reduced resilience, and (in section G) calls for proper grid planning and pricing of reliability and resilience attributes but not for rewarding plants having large "fuel on hand." DOE's *Quadrennial Energy Review* (section D) discusses resilience and mentions pricing, but (Jan. 2017, p. 4–41) does not call for coal or nuclear uplifts. The IHS Markit study (section E) decries coal and nuclear retirements but does not specify the "less efficient diversity case" underlying its claims of higher cost, nor provide analysis justifying the Secretary's urgent reliability concerns. NERC (section F) rightly notes that supply shifts "must be well understood and properly managed," and describes its continued monitoring and improvement of potential fuel-supply issues for both gas and coal, but does not support the NOPR's recommendations, nor, as implied, equate "resilience to fuel supply disruptions" with resilience of the electricity *system* (including, predominantly, the grid). Even the cited Congressional letter (section H) does not support the NOPR's analysis and prescription. None of the FERC statements and proceedings quoted in Section I does so either. FERC has not previously considered the NOPR's suggested policies, as far as I know, simply because neither FERC nor others had any analytic basis for developing them or would have dreamed of proposing them.

DOE's August 2017 *Staff Report* recommends (as do I) that regulators seek better ways for competitive markets to value specific technical reliability attributes and services—chiefly frequency support, voltage support, and ramp rate. It does not suggest any requirement or reward for large onsite fuel inventories—let alone paying coal and nuclear plants' entire costs, whether they're needed or not, competitive or not, and apparently even dispatched or not.[11] That is, DOE's *Staff Report* rightly

[11] I mention dispatch because the NOPR's language is unclear about whether that reward must be earned by dispatch, making legal and economic analysis of the NOPR's implications impossible. For example, the NOPR language of §358(g)(10)(iii)(B) mandates that "each eligible resource recovers its fully allocated costs and a fair return on equity," while the more restrictive §358(g)(10)(iii)(A)(2)

suggests crafting rules to value recognized and technologically defined grid services more thoroughly—but not to advantage specific technologies, fuels, or sources. And nobody but the Secretary seems to see merit in creating a complex new set of inter-regional financial disparities between markets with little coal or nuclear capacity (e.g. NE-ISO, CAISO), those with a lot (e.g. MISO, FERC-free ERCOT), and those with a lot that wouldn't get an uplift due to widespread State regulation or no capacity market (e.g. Southeast)—plus further distortions from putting merchant generation owners in a more favorable earning posture than state-rate-regulated owners, up-ending traditional risk/reward relationships and capital markets' risk perceptions.

Unlike "reliability"—a concept long rigorously defined, already rewarded and required, and soundly managed under rational and evolving policies—the Secretary relies on the undefined and unquantified concept of "resiliency," for which the *Quadrennial Energy Review* (Jan. 2017, p. 4–3) confirms there are "no commonly used metrics." We turn next to the Secretary's unprecedented concept of how to achieve this vague Rorschach-like attribute.

2. The NOPR focuses on "fuel-secure" generators with at least 90 days' onsite fuel inventories, when in fact dependence on fuel burned in large, remote power stations is part of the problem, not a promising solution.

Utilities have reported to DOE[12] that over the past five years, inadequate or interrupted fuel supply to power stations caused just 0.00007% of the 3.4 billion customer-hours of major US power failures—and of those fuel-caused failures, 83% were from a single coal-fired power plant in northern Minnesota. Thus the issue on which the NOPR focuses—fuel inventories on hand—is only infinitesimally related to utility-reported causes of the lights' going out. Generation inadequacy from all causes except fuel inadequacy was reported to have caused only 0.0086% of power failures. Severe weather caused 96.2% (a third of it from Superstorm Sandy alone), and all other factors 3.8%. Taken at face value, the NOPR's central focus (inadequate fuel inventories at power plants), and its mitigations that sections 2.3–2.4 below will show are often ineffectual, could appear to have caused less than a ten-millionth as many customer-hours of 2012–16 US power failures as severe weather did, i.e. 0.00007% divided by roughly 90 percent as discussed in the next two paragraphs.

Such DOE Form OE-417 data need careful interpretation because they reflect each utility's role, perspective, and attribution of an outage's "primary cause." A utility whose power plant fails because its coal or gas supply has frozen may apparently ascribe the outage to weather, not to fuel interruption. That event report also does

provides those payments "for such resource dispatched during grid operations." Either way, how and when those payments would be triggered, for how long, and how they'd affect bid prices is unclear.
[12] T. Houser, J. Larsen & P. Marsters, "The Real Electricity Reliability Crisis," Rhodium Group, 3 Oct 2017, http://rhg.com/notes/the-real-electricity-reliability-crisis. Summary data are regularly reported in Tables B.1 and B.2 of EIA's *Electric Power Monthly*.

not provide a complete picture of what grid operators and customers experience: a power plant or a group or class of power plants may well fail without blacking out any customers, as section 2.3 illustrates. Other data sources too have their own limitations. NERC's GADS unit-availability data seem to offer some latitude in assigning causality. The ISO/RTOs report loss of load (which, for example, were zero for ISO New England in Jan. 2014). As LBNL's Evan Mills urged in 2012,[13] FERC should consider possible ways to clarify how each data source defines causalities—a new issue created by the Secretary's novel concepts. Today, none of these three data sources can reliably capture what fraction of customer blackouts is caused by the fuel-inventory inadequacies that the NOPR's approach claims to mitigate.

Power plants with ample fuel can fail. The lights can go out despite ample available generation because the grid cannot deliver its output. That the lights went out just when a plant failed doesn't mean its failure made the lights go out: the failure could have occurred anywhere in the supply chain, notably downstream in the grid. Conversely, the lights stayed on in the Polar Vortex thanks to reserve margins, capacity payments, and the many layers of reliability mechanisms built into organized markets, even though some plants and fuel supplies failed. But no matter how one interprets the data, *outages are caused overwhelmingly by weather, and occur through inadequacies of grid delivery, not of available generation, let alone of power plants' onsite fuel inventories.* DOE and two Executive Agencies found[14] ~87% of major 1992–2012 outages were caused by severe weather. LBNL found (ref. 13) that for 1992–2011, 66% by number and 78% by customers were weather-related, and "the grid is increasingly frail/vulnerable." Both studies found the weather-related fraction is rising, as one would expect from the rising incidence and severity of downpours, heat waves, wildfires, and violent windstorms.[15] Some estimates of the recent weather-related fraction of customer-hours of outage are much higher, *e.g.* in the high 90s of percent according to QER Analytics (2015) as quoted by DOE.[16] Robust statistical evidence confirms weather linkages and rising severity.[17] All 12 large-

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[13] E. Mills, "Electric Grid Disruptions and Extreme Weather," 3–4 May 2012, Lawrence Berkeley National Laboratory, http://evanmills.lbl.gov/presentations/Mills-Grid-Disruptions-NCDC-3May2012.pdf.

[14] President's Council of Economic Advisors, DOE, and OSTP's "Observed Outages to the Bulk Electric System 1992-2012," Executive Office of the President, "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages," 2013, p. 8, http://energy.gov/sites/prod/files/2013/08/f2/Grid%20Resiliency%20Report_FINAL.pdf.

[15] *E.g.*, S. Lacey, "Resiliency: How Superstorm Sandy Changed America's Grid," 10 Jun 2014, https://www.greentechmedia.com/articles/featured/resiliency-how-superstorm-sandy-changed-americas-grid#gs.LC5edvE.

[16] M. Kenderdine, "Policy Drivers, Challenges, & the Quadrennial Energy Review," 5 Nov 2015, 2015 C3E Women in Clean Energy Symposium, , http://c3eawards.org/wp-content/uploads/2015/11/2015Kenderdine.pdf.

[17] P. Larsen, K. LaCommare, J. Eto, & J. Sweeney, "Assessing Changes in the Reliability of the U.S. Electric Power System," LBNL-188741, Aug 2015, https://emp.lbl.gov/sites/all/files/lbnl-188741.pdf.

scale power outages in 2015 were weather-related, though weather caused only half of *small*-scale 2015 outages.[18]

Thus the NOPR's obsession with continuity of fuel supply to generators—even if 2.1–2.4's rebuttals below were invalid—ignores the grid. Yet any rational treatment of electric reliability and resilience must focus *primarily* on the grid.

The Electric Power Research Institute long ago estimated, and modern data agree, that roughly 98–99% of power failures *originate in the grid*, and ~90–95% of those in the distribution grid.[19] As the NOPR's §II(A) rightly notes, America's grid comprises 707,000 miles of high-voltage transmission lines, 55,800 substations, and 6.5 million miles of local distribution lines. All are interruptible by high winds, lightning, ice storms, tree limbs, cars crashing into power poles, squirrels, birds, operator errors, fires, solar storms, electromagnetic pulses, cyberattacks, or rifle bullets.[20]

As I write this, about three million Puerto Rican American citizens face months of further blackout, with only 16% returned to service after three weeks, because a hurricane destroyed their grid, even though their 98%-fossil-fueled utility has ample and available generating capacity with adequate fuel on hand. The NOPR is irrelevant to them and to the other Americans blacked out in Texas by Harvey, Florida by Irma, the Virgin Islands by Irma and Maria, etc. Hurricane Maria's grid destruction in Puerto Rico alone has already about doubled in 2017 the total outage customer-hours experienced nationwide in 2016.

Yet the NOPR says and does nothing about the brittle grid connecting power plants to customers—only the virtual non-problem of how big a pile of coal sits at each plant. The NOPR does vigorously seek to prevent and reverse the competitive market exit of outdated plants typically sited half to several states away from customers, hence inherently vulnerable to *grid* failure. The NOPR's effort to reverse the market-driven decentralization and diversification of historic grid dependence would weaken national security: since grid failures dominate total failures, any electricity strategy that perpetuates and increases reliance on remote central power plants, *no matter how reliable they are*, will increase vulnerability and reduce resilience. Section 5 below suggests practical, profitable ways to make electricity supply so resilient that major failures become impossible by design—rather than, as now, inevitable by design—but those options rely less on faraway giant plants and hence on the grid.

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[18] DOE, *Year-in-Review: 2015, Energy Infrastructure Events and Expansions,* pp. 11 & 14, http://energy.gov/sites/prod/files/2016/06/ f32/2015-YIR-05122016.pdf .

[19] A. Lovins *et al.*, *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*, Rocky Mountain Institute, 2002, at p. 241, www.smallisprofitable.org. The 2017 *Quadrennial Energy Review*'s Second Installment confirms >90% at p. 4–2. LBNL's J. Eto and K. LaCommare confirm ≥94% by SAIDI and ≥92% by SAIDI in 2014: "A Preliminary Evaluation of Loss of Supply as a Contributor to SAIDI/SAIFI," IEEE Distribution Reliability Working Group (Memphis), 12 Jan 2016.

[20] Conversely, the grid can create other dangers: the California PUC is investigating whether a cluster of unusual failures of PG&E power lines (designed to withstand 56-mph winds but reportedly felled by less) might have helped trigger the wine district's extraordinarily destructive Oct 2017 wildfires.

Thus the NOPR proposes not to improve but to retain or worsen the grid's unmentioned lack of resilience. Coal and nuclear plants, by definition, are remote central stations, averaging hundreds of miles from their customers, while the distributed and renewable supplies the NOPR would disadvantage can be built at an almost infinite range of sites and scales. Coal and nuclear plants can't serve your community or neighborhood through short local powerlines, as distributed resources can. Coal and nuclear plants can't sit on your roof and need no powerlines, as solar modules can. Though lessons learned from Sandy helped soften Irma's blow and speed recovery in Florida, much of the grid was destroyed despite Florida Power and Light's prior multi-billion-dollar smart-grid and grid-hardening investments.

Demand-side resources are even more vital for resilient electrical services: not only are they onsite (*no* grid) and ~90–100% available, but they relieve precisely the peak loads that stress the grid and the fleet of generators. As ref. 8 and Alex Wilson's Resilient Design Institute's publications explain, end-use efficiency provides the most "bounce per buck" by buying time to fix what's broken or improvise new supplies; it shrinks those needed supplies; and efficient buildings can keep temperatures comfortable (and stay daylit in the daytime) for longer without power. Yet the NOPR does not recognize any resilience value for demand-side resources.

2.1. The NOPR contradicts the electric resilience strategy of its premier practitioners—America's Armed Forces.

Our Nation's foremost experts on energy security have reached the opposite conclusion to the Secretary's. To ensure its mission continuity,[21] the Pentagon aims to achieve electric resilience for its bases and facilities by relying chiefly on renewable generators (solar, wind, geothermal, etc.) onsite or nearby, able to run the base and the surrounding community even if the grid fails. Renewables are generally also cheaper than grid power, expanding military budgets, and are constant-price, derisking those budgets. That's why the Department of Defense is the Federal Government's unrivaled leader in vigorously deploying renewable power sources. Our Armed Forces need their stuff to work, but so do we citizens whom they're defending. The logic is identical, and the details differ surprisingly little. The Department of Defense's resilience initiatives seek to *replace* precisely the *un*resilient power-supply arrangements that DOE's NOPR seeks to *perpetuate* nationwide. Thus DOE's NOPR would undercut DoD's national-security mission.

2.2. The NOPR's narrow core criterion for "fuel-secure generation" (thereby qualifying for its new subsidies) as having at least 90 days' "fuel on hand" disqualify and hence

[21] Defense Science Board, *More Fight—Less Fuel*, Task Force report to US Department of Defense, Feb 2008, www.acq.osd.mil/dsb/reports/ADA477619.pdf, summarized in A. Lovins, "DoD's Energy Challenge as Strategic Opportunity," *Joint Force Quarterly* **57**:33–42 (Feb 2010), ndupress.ndu.edu/portals/68/Documents/jfq/jfq-57.pdf.

disadvantage resilient modern renewables precisely because they use no fuel—*avoiding the very vulnerability of which the NOPR complains.*

Renewables cannot stockpile fuel because by definition *they need no fuel*[22]—handily sidestepping any arbitrary requirement for "fuel on hand"—but the NOPR irrationally insists on *diversifying* fuels, rather than *displacing* fuels with an even more diversified portfolio that eliminates vulnerable fuel logistics.

The NOPR aims to shield specifically coal and nuclear plants from the market competition their owners chose, bet on, but lost. This destruction of competitive markets would disadvantage precisely the cheapest *and* most resilient competitors that are beating coal and nuclear plants in markets nationwide—efficiency and flexible demand (which are allowed to compete head-to-head with supply in about half the markets or a third of the country), cogeneration, and the modern renewables that added 62% of 2016's US new capacity (nearly twice gas) and 55% globally. This is why virtually all energy sectors except coal and nuclear oppose the NOPR (ref. 1). The Secretary's wish to reverse renewables' market victories is especially odd because he takes proper Texas pride in having as Governor helped make his state by far the national leader in windpower with over 20 GW and 15% of 2016 generation, bringing Texas over 25,000 jobs and helping bring its 2016 wholesale electricity prices to record lows. Wind and solar power harness natural energy flows that are reliably delivered free of charge, with accurately forecastable variations but virtually no risk of long interruptions.[23]

Natural gas passed coal in 2016 to make 34% of US electricity, *vs.* 30% coal and 20% nuclear. Almost the only fueled power plants still being added in the US are gas-fired, though renewables are rapidly taking their market share. But though a few gas-fired plants have associated gas storage and many are fed by multiple pipelines to increase the resilience of their fuel supplies, nearly all rely on just-in-time delivery from the national pipeline network. That network is highly reliable—*more reliable than the electric grid*[24]—and has extensive storage spread over more than 400 underground sites (DOE *Staff Report*, p. 93). Like coal logistics (section 2.3

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[22] Other than the small fraction of modern renewables that burn municipal, industrial, or agricultural wastes. These made 1.5% of 2016 US electricity, typically from major onsite sources like pulp mills, sawmills, refineries, livestock facilities, and landfills. Whether hydroelectric dams' stored water, underground geothermal heat, and solar and wind energy flows are a "fuel" is unclear. Oddly, DOE's *Staff Report* at p. 86 adopts a PJM graphic that shows neither renewables nor storage as "Not Fuel Limited" and having "On-site Fuel Inventory"—outmoded requirements they avoid and transcend.

[23] Not quite zero because of major but unlikely events like a postwar "nuclear winter" or a world-scale volcanic eruption akin to Krakatoa. Cheap insurance in an all-renewable grid could come from a "strategic capacity reserve" of existing gas-fired power plants, mothballed and hardly ever run: T.W. Brown *et al.*, "Response to 'Burden of Proof: A comprehensive review of the feasibility of 100%-renewable electricity systems.'" arXiv:1709.05716v1 [physics.soc-ph], 17 Sep 2017.

[24] C. Page (Nevada PUC), "How Reliable Is Natural Gas? An Historical Interview of Natural Gas Transmission's Outage Track Record," 2017, http://www.usaee.org/usaee2017/submissions/OnlineProceedings/Natural%20Gas%20Reliability%20paper%20CJP%20Final.pdf.

below), it remains vulnerable in principle to extreme weather, sabotage, and cyber-attack[25], but gas transmission outages are due vastly more to simple (and mostly quick-to-fix) mechanical failures than to weather[26], making its failure modes largely complementary to and milder than the electric grid's. DOE in 2015 found no particular grounds for concern about natural-gas deliverability to power stations, and good grounds for comfort about the slowing pace of US gas infrastructure additions.[27]

The NOPR seeks to disadvantage gas-fired generation as insecure—despite the Administration's fondness for fracking, which provides two-thirds of the Nation's gas—perhaps because, as the *Staff Report* found, cheap gas is the main reason many coal and nuclear plants can't compete. As the caption to the *Staff Report*'s Fig. 3.28 correctly says, "While concerns exist about the impact of widespread deployment of renewable energy on the retirement of coal and nuclear plants, the data do not suggest a correlation." In fact, they show the opposite: cheap gas is the main cause of coal retirements, followed by slack or falling electricity demand, then renewables.

To try nonetheless to exclude and suppress renewables and natural gas without naming them, the NOPR adopts the Secretary's ingenious but disingenuous new term "fuel on hand"—a notion so novel when he introduced it that in mid-April 2017 a Google search found no relevant entries. The NOPR uses the equivalent concept of "fuel-secure plants." Unfortunately for the NOPR's thesis, analysis reveals this notion to be almost entirely unrelated to electric resilience, as we'll see next.

2.3. Fuel interruption is an insignificant cause of power failures. Even if that were not so, "fuel on hand" cannot ensure that the adjacent power plant will operate at need, but on the contrary often creates new vulnerabilities.[28]

DOE's *Staff Report* rightly says on p. 91, "While having fuel onsite reduces the risk that a generator will be unable to operate when needed, every type of fuel and power generation source has known vulnerabilities that can compromise its ability

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[25] Detailed in ref. 8. Another risk—occasional Gulf hurricanes' shutdown of upstream gas platforms—is buffered by extensive underground and in-pipe storage. At significant capital and carrying cost, gas-fired power plants could add onsite liquid fuel storage—liquefied natural gas (LNG, which slowly boils off if not used), liquefied petroleum gas (LPG), or oil. Many older "dual-fueled" gas-fired power plants can already switch between gas and oil, but oil's world market price is volatile and its supply logistics, like any other fuel's, not fully reliable. In the 2014 Polar Vortex event, 2–3 GW of dual-fueled plants in the Northeast had such fuel constraints as limited inventories or trucks, gelled fuel, or frozen fuel lines and injectors. As section 2.3 describes, many coal-fired power plants had analogous problems, which the NOPR systematically and asymmetrically ignores.

[26] Ref. 24.

[27] DOE, "Natural Gas Infrastructure Implications of Increased Demand from the Electric Power Sector," Feb 2015, https://energy.gov/sites/prod/files/2015/02/f19/DOE%20Report%20Natural%20Gas%20Infrastructure%20V_02-02.pdf.

[28] Most facts and data in sections 2.3–2.5 not specifically sourced are hyperlinked in my 1 May 2017 *Forbes* article "Does 'Fuel on Hand' Make Coal And Nuclear Plants More Valuable?," https://www.forbes.com/sites/amorylovins/2017/05/01/does-fuel-on-hand-make-coal-and-nuclear-power-plants-more-valuable/, from which some of those sections' text is also adapted.

to operate reliably." The NOPR does not mention that those vulnerabilities are substantial for both coal and nuclear power, as summarized next.

No matter how big the pile of coal outside a coal-fired power plant, extreme weather can and sometimes does make the coal unloadable or unburnable or both. The NOPR features the 2014 Polar Vortex event to emphasize that some of the coal and nuclear plants called upon when other plants failed have since retired or are planned to retire. Of course, that's not an analysis claiming, as implied, that the 65 million people in the PJM power pool who "could have been affected" by those retirements actually would have been. NOPR section C's claim that "current and scheduled retirements of fuel-secure plants could threaten the reliability and resilience of the electric grid" is speculative and disputed, and cannot be justified by evidence in or behind DOE's *Staff Report*. It's also inconsistent with NERC's and the regional grid operators' continuing 2017 declarations of adequate reliability, based on detailed region-by-region analyses that explicitly include such extreme weather events.

The retired plants were of course replaced by other demand- and supply-side resources, often (as explained in sections 2.3–2.5) providing greater resilience. US generating capacity is larger[29] and more diverse (DOE *Staff Report*, p. 89) than in 2014 (or in 2002, as shown *id.*, p. 90). Bulk power system reliability "is adequate today despite the retirement of 11 percent of the generating capacity available in 2002," and "overall, at the end of 2016, the system had more dispatchable capacity capable of operating at high utilization rates than it did in 2002"[30]—hardly a declaration of a power emergency. *Practically every reliability metric has improved over the past five years*, and in particular, the Bulk Power's System's "resilience to severe weather" improved in 2016 for the second consecutive year.[31] Indeed, the same NERC CEO who told the Commission in June 2017 that "the state of reliability in North America remains strong, and the trend line shows continuing improvement year over year" is repeatedly cited in the NOPR as impliedly supporting the Secretary's warning of an imminent grid emergency. He did no such thing. The specific issues raised by the Polar Vortex have already been intensively addressed. No grid operator or reliability authority has suggested, requested, or endorsed the kind of radical reversal of market trends that the NOPR directs.[32] The Secretary's Polar

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[29] EIA data show 18 GW of utility-scale net capacity additions during 2014–16, with higher-than-historic fuel diversity: https://www.eia.gov/todayinenergy/detail.php?id=30112.

[30] The DOE draft report's forthright statement that "the grid is in good shape despite the retirement of many baseload power plants…. The power system is more reliable today due to better planning, market discipline, and better operating rules and standards" was removed, but the retained quotation, on p. 63, confirms that the grid had more flexibility in 2016 than in 2002.

[31] NERC, *State of Reliability 2017*, June 2017, p. 5 & Ch. 4, http://www.nerc.com/pa/RAPA/PA/Performance%20Analysis%20DL/SOR_2017_MASTER_20170613.pdf.

[32] For example, NERC's latest (Dec 2016) *2016 Long-Term Reliability Assessment* notes at p viii that although New England's "recent winter experiences have created challenges in both maintaining back-up fuel inventories and successfully switching from gas to oil…emerging market rules in ISO-NE, beginning in 2018, are expected to support reliability and the resilience of the generation fleet."

Vortex argument is a red herring, and more closely examined, is contradicted by that event's facts, as we explore next.

2.3.1. Coal vs. *gas vulnerabilities in extreme weather*[33]

The NOPR omits material but highly discordant facts about the 2014 Polar Vortex event. NERC found[34] that of the disabled 19.5 GW of generating capacity, some 91% failed as equipment froze in so many ways they take three pages to list (pp. 14–16). Weather as much as 35F° below normal disabled 8 of 11 GW of New England gas plants, mainly because their expected gas supplies were preempted by extraordinary space-heating demand (houses have priority over utilities) or blocked by contractual limitations, notably non-firm gas delivery—a correctable procurement-practices issue, not a power-plant deficiency. (Regional gas supplies were available throughout the period, but not all users had the right delivery arrangements. Much of the gas deliverability that could not assure supply did turn out to be available, but not in time to schedule dispatch of gas-fired units that thus had to be passed over.[35]) As the Commission well knows, the gas and electric industries have since been at pains to fix those unforeseen problems to prevent recurrence. But in the PJM power pool, as loads soared, record cold disabled nearly 30% of generating capacity —one-fourth for lack of gas, but the rest *mainly because coal-fired plants had frozen coal piles or coal-handling equipment*. Thus the Secretary illogically cites the Polar Vortex to support his claim that giant coal piles will protect coal plants from the Polar Vortex cold that in fact often made their coal piles unusable.

As the DOE *Staff Report* says (p. 98), "Many coal plants could not operate due to conveyor belts and coal piles freezing…." Its cited reference[36] states (p. 4): "Equipment issues associated with coal and natural gas units caused the greatest proportion of forced outages. Natural gas interruptions comprised approximately 25 percent of the forced outages." PJM's 9.7 GW of gas-plant outages *not* caused by natural-gas interruption (9.3 GW) *were exceeded by coal's lost 13.7 GW* (p. 26), and that figure

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http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2016%20Long-Term%20Reliability%20Assessment.pdf.

[33] C. Ji *et al.*, "Large-scale data analysis of power grid resilience across multiple US service regions," *Nature Energy* 1(16052), doi:10.1038/nenergy.2016/52 (2016), found that "extreme weather does not cause, but rather exacerbates, existing vulnerabilities, which are obscured in daily operations." That point is beyond the scope of these comments but should be examined.

[34] NERC, *Polar Vortex Review*, Sep 2014, http://www.nerc.com/pa/rrm/January%202014%20Polar%20Vortex%20Review/Polar_Vortex_Review_29_Sept_2014_Final.pdf, and *2014–2015 Winter Reliability Assessment*, Nov 2014, http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/2014WRA_final.pdf.

[35] New England ISO, 10 Jan 2014 response to FERC data request, https://www.iso-ne.com/static-assets/documents/pubs/spcl_rpts/2014/iso_ne_response_ferc_data_request_january_2014.pdf.

[36] PJM Interconnection, *Analysis of Operational Events and Market Impacts during the January 2014 Cold Weather Events*, 8 May 2014, www.pjm.com/E%7E/media/library/reports-notices/weather-related/20140509-analysis-of-operational-events-and-market-impacts-during-the-jan-2014-cold-weather-event.ashx.

doesn't include failures of non-gas fuel supplies. The NOPR fails to mention this, omits too the 1.4-GW nuclear plant disabled by cold, and criticizes only gas.

The NOPR's section II.C implies that PJM was barely able to sustain supply in the 2014 Polar Vortex by virtue only of coal plants now retiring. Yet both those units *and non*-retiring coal and nuclear units remain prone to the same extreme-weather vulnerabilities; PJM has other, more resilient, demand- and supply-side resources (including many GW of demand response as noted below); and PJM predicts adequate supply even in future extreme weather, despite all planned retirements.

In the Southeast, where many plants weren't designed for such cold, 9.8 GW of supply was lost, often for similar reasons. In the Midwestern MISO pool, only a fifth of the 31% of capacity lost was due to lack of gas; most of the rest was coal. Similarly, the February 2011 Southwest cold snap blacked out 4.4 million customers in three states, and in the Secretary's native Texas, 210 of 550 electric generating units—nearly all coal- or gas-fired—couldn't start, or stopped, or put out less than their rated power. Fifty Texas fossil-fueled plants totaling 7 GW couldn't withstand frozen coal piles, burst pipes, and other foreseeable consequences of a deep freeze. In the similar 1989 Texas cold snap, the largest lost capacity (4.7 GW, 8 units) was from coal plants, while in 2011, wind, gas-steam, simple-cycle gas, and coal were equally failure-prone.[37] NERC notes[38] that Texas lignite is ~30–40% water, so it readily freezes (*id.*), just as damp natural gas can. The NOPR mentions none of this.

Even in normally cold states like Wisconsin and Pennsylvania, cold snaps have repeatedly frozen coal piles, stranded fuel barges on frozen rivers, and prevented power-plant startups. A repetition of the winter of 1917/18, which locked Baltimore Harbor in three feet of solid ice, cannot be excluded as weather and climate become more volatile. NERC summarized a key reliability finding in 2014[39] (p. 7, emphasis added): "Prolonged cold weather events in parts of North America may cause an increase in generator unavailability due to natural gas *and coal* constraints"—not just gas.

The same is true of other extreme weather events. Hurricane Harvey left large coal piles in Texas so waterlogged they couldn't be moved to the boilers, forcing two coal plants to switch to gas for the first time in eight years[40]. Hurricanes Harvey and Irma also forced staff evacuations from coal and nuclear plants, shutting them down

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[37] FERC/NERC, *Report on Outages and Curtailments During the Southwest Cold Weather Event of February 1–5, 2011*, Aug 2011, pp. 143 & 176, http://www.nerc.com/pa/rrm/ea/February%202011%20Southwest%20Cold%20Weather%20Event/SW_Cold_Weather_Event_Final.pdf.
[38] Ref. 37, Appendix "Power Plant Design for Ambient Weather Conditions," p. 5.
[39] NERC, *2014–2015 Winter Reliability Assessment*, Nov. 2014, https://studylib.net/doc/13609546/2014–2015-winter-reliability-assessment-november-2014.
[40] See https://www.platts.com/latest-news/electric-power/houston/harveys-rain-caused-coal-to-gas-switching-nrg-21081527.

despite their "fuel on hand."[41] DOE's Energy Information Administration summarized:[42] "Power plant outages were largely caused by rain or flooding affecting generator fuel supplies, outages of transmission infrastructure connecting generators to the grid, and personnel not being able to reach generating facilities." In contrast, efficiency, demand response, and most renewable resources were unaffected; even utility-scale renewables seldom need staff onsite and are often run remotely.

Both gas and coal fuel logistics are aging[43] and exhibit some deficient maintenance, as illustrated by a 2000 New Mexico pipeline explosion that worsened California's electricity crisis, the 2010 San Bruno pipeline explosion, and the 2015 Aliso Canyon gas storage disaster. The coal, gas, and electricity industries also depend on each other in both supply and demand, so power failures could ultimately crimp gas supplies. But NERC has expressed concerns about *both coal and gas* deliverability and resilience, not just gas. To be sure, 55% of the generator outages in the 2014 Polar Vortex were gas-fired—inflated by poor inter-industry coordination later corrected—but 26% were coal-fired, and as noted earlier in this section, *PJM lost more capacity to equipment failures at coal plants than at gas plants.*

Even without such extreme weather events, the average U.S. coal-fired plant breaks down about 6–10% of the time, and for various reasons is unavailable for about 15% of its theoretical output (which was only 53% used in 2016, and falling, since it's often uncompetitive; gas power generally beat it and ran at 56% of theoretical output). For modern combined-cycle gas plants, unavailability is only about 5%, one-third the level typical of coal plants. The highest technical availability is achieved by demand-side and renewable resources (section 2.5 below).

2.3.2. Coal supply-chain vulnerabilities

Roughly doubling coal plants' typical existing fuel stocks to 90 days would be a boon and price-booster for the struggling coal industry—if limited rail capacity could actually deliver the coal, which NERC in 2014 explicitly considered doubtful.[44] But once inventories were raised to qualify for the NOPR's rewards, a deeper and more

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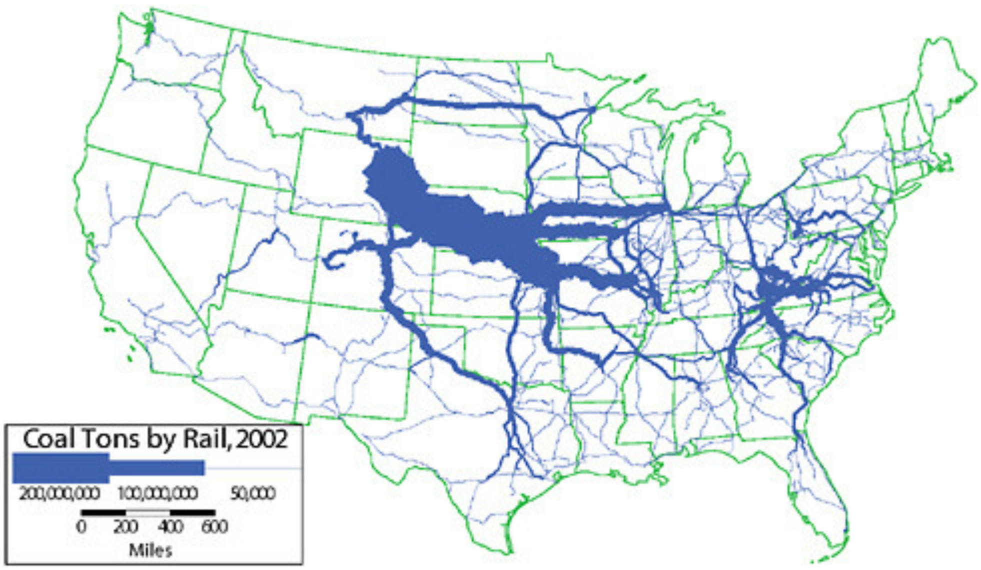
[41] This paragraph is drawn from R. Orvis & M. O'Boyle, "DOE rulemaking threatens to destroy wholesale markets with no tangible benefit," 2 Oct 2017, http://www.utilitydive.com/news/doe-rulemaking-threatens-to-destroy-wholesale-markets-with-no-tangible-bene/506289/?platform=hootsuite.

[42] EIA, "Hurricane Harvey caused electric system outages and affected wind generation in Texas," 13 Sep 2017, https://www.eia.gov/todayinenergy/detail.php?id=32892.

[43] A revival of coal-hauling assets is not in prospect. The CEO of coal-hauling railway CSX recently announced that "Coal has no future" (for economic reasons) and that his firm would buy no more coal-hauling locomotives or other equipment, nor double-track its coal-hauling rail lines. J. Voelker, "'Fossil fuels are dead,' says CSX railroad chief: no more new trains for coal, ever," 31 Jul 2017, http://www.greencarreports.com/news/1111824_fossil-fuels-are-dead-says-csx-railroad-chief-no-more-new-trains-for-coal-ever.

[44] NERC, *2014 Summer Reliability Assessment*, May 2014, http://www.nerc.com/files/2014SRA.pdf, pp. 5–6, section "Coal Supply Impacts Caused by Constrained Rail Service Could Create Reliability Impacts."

troublesome issue would come into sharper view. Worryingly, the gas industry's historic focus around the Gulf Coast is matched by the extraordinary reliance of coal on Wyoming's Powder River Basin (PRB). That region mines two-fifth of the Nation's coal and, says DOE's *Staff Report* at p. 97, had trouble serving its 166 power plants with 172 GW of capacity during winter 2013/14. It depends on specific rail and bridge chokepoints at least as concentrated as major gas pipelines. This 2002 government map reveals nothing less than an all-American Strait of Hormuz:



Nearly all that Wyoming coal goes through one 103-mile, 24/365 rail corridor. In May 2005, heavy precipitation and compromised drainage triggered two derailments in two days, requiring a year's rebuilding, curtailing shipments for most of the rest of 2005, and more than doubling coal's spot price in five months. Later that year, two hurricanes further disrupted Midwestern railways as grain shipments shifted from Mississippi River barge to rail, and a foot of October rain in Kansas City roiled major coal-rail routes for two weeks. In 2006, DOE's Energy Information Administration's Deputy Administrator testified[45]: "Hardly a month goes by that delivery of PRB coal somewhere in the supply chain is not interrupted by a derailment, freezing, flooding, or other natural occurrence" (which more-volatile weather will make more frequent and severe). At the end of the cited repost, a Georgia utility executive said his PRB coal is hauled 2,000 miles, then the unit trains immediately shuttle back to Wyoming for the next load. He added: "Our experience suggests that the supply chain is very fragile and any event[,] weather related or otherwise[,] that disrupts this supply line could quickly cause a major reduction in supply and inventory levels during the time of greatest needs and highest replacement costs."

[45] H. Gruenspecht, Senate Committee on Energy & Natural Resources, 109-601, 25 May 2006, "Coal-based generation reliability," https://www.energy.senate.gov/public/index.cfm/hearings-and-business-meetings?ID=C30108B1-0B1A-41FC-A66C-A3849ED54C60, reposted 18 Feb 2017 at http://energyskeptic.com/2017/interdependency-coal-power-plants-depend-on-railroad-delivered-coal-to-keep-running/.

In 2007, the National Academies concurred[46]: "The rail networks that transport the nation's coal—like air traffic control and electric transmission networks—have an inherent fragility and instability common to complex networks. Because concerns about sabotage and terrorism were largely ignored until recently, existing networks were created with potential choke points [like some rail bridges over major rivers]… that cause vulnerability…[and] the potential for small-scale issues to become large-scale disruptions." That's hardly a ringing endorsement of coal's resilience. Yet the NOPR baldly assumes that coal and nuclear plants, and no other resources, are resilient and merit major mandatory subsidy for that attribute. The available evidence, none of it mentioned in the NOPR, does not support that assumption.

2.3.3. Gas supply-chain vulnerabilities

This is not to say that the national gas network, or particular gas facilities, are not also vulnerable to disruption. The 1981 Pentagon study *Brittle Power* (ref. 8) found that a handful of people could, at that time, turn off three-fourths of the oil and gas supply to the Eastern States in one evening without leaving Louisiana—though it also found the power grid was even more vulnerable. (Since then, fracking, new pipelines, and LNG have greatly diversified U.S. gas flows, while grid vulnerabilities have persisted and, with cyberthreats, risen relative to gas.) The Secretary's concern about supposedly unreliable and unresilient gas supplies to power plants is thus illogical. A physical assault or cyberattack would be far more effective on the electricity system than on its gas supplies (*id.*), hence more attractive to adversaries, due to fundamental differences between these two systems. What are those differences?

2.3.4. Comparing gas supply-chain vulnerabilities

Gas has largely underground and protected infrastructure, has extensive and widely distributed bulk storage both underground and in the pipelines ("linepack"), has a mix of grid-dependent and self-powered compressors, uses increasingly diversified geographical sources and sub-networks, has relatively fewer cybervulnerabilities, and changes pressure over hours or days. In contrast, the electricity system uses largely aerial and accessible infrastructure, is highly interconnected within just three subnational grids, has ubiquitous cyberattack entry points and numerous scarce or unique critical facilities, and (most importantly) requires exact synchrony within roughly a thousandth of a second across enormous distances. These attributes *make the electric grid inherently more vulnerable than the gas grid* both to attack and to natural disaster.[47] Thus the NOPR's urgent prescription to discrimin-

[46] *Coal: Research and Development to Support National Energy Policy*, p. 83, https://www.nap.edu/read/11977/chapter/7, from which the map above is copied (p. 82); its original is from Oak Ridge National Laboratory's Center for Transportation Analysis. No update is available, but if redrawn today, the degree of concentration would probably be greater.

[47] See ref. 24. History amply confirms this, e.g. in the 22–24 Jan 2016 Eastern winter storm, which brought extensive power outages but "relatively stable" gas deliveries with no reported freeze-offs:

ate in favor of coal and nuclear plants and, unavoidably, the giant and inherently vulnerable grid on which they depend would increase relative reliance on the least resilient and most brittle elements of our Nation's energy supply.

2.3.5. Less-vulnerable options the NOPR ignores

That directive is not only backwards; it deliberately ignores available solutions that are empirically faster, cheaper, and more resilient than continued coal and nuclear operation. These options—faster deployment of efficiency, demand response, co-generation[48], and renewables—are not proposed or discussed in the NOPR. Yet a recent economic analysis found that because distressed nuclear plants have very high operating costs (averaging \$62/MWh in the industry's latest published data—the reason they can't clear in wholesale markets), closing them and reinvesting in average-cost electric efficiency would save ~2–3 times more electricity than the displaced nuclear generation. The example of Vermont Yankee illustrates how lost nuclear capacity can be displaced by efficiency and renewables in about a year (ref. 5, section 2.7). The planned orderly closure of the Diablo Canyon nuclear units shows how well-planned nuclear closure can indeed save both carbon and money.[49]

Yet the NOPR doesn't compare any option except coal and nuclear power. That is a very material omission: energy efficiency is now the world's largest energy "source," bigger than oil,[50] and renewables dominate the world market in new generating capacity, with solar power now the world's fastest-growing energy source.[51] The International Energy Agency's Executive Director now expects (*id.*) renewables will grow "by about 1,000 GW by 2022, which equals about half of the current global capacity in coal power, which took 80 years to build." The NOPR indirectly alludes to electric end-use efficiency only in noting that the downward drift of US electricity demand, even as the economy grows, has contributed to retirement of coal and nuclear plants. Yet it doesn't mention that the National Academies' *America's Energy Future* (2009) found electric efficiency could be profitably doubled by 2030, nor that

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EIA, "Winter storm knocks out power for more than a million customers," 29 Jan 2016, https://www.eia.gov/todayinenergy/detail.php?id=24752.

[48] The DOE *Staff Report* (p 9) ignores geothermal, biomass, and cogeneration because they are "not as prevalent or widespread as gas, coal, and nuclear plants," but in fact, EIA's *Monthly Energy Review* data show they respectively produced 63, 17, and ~117 TWh in 2016—collectively 5% of US electricity, nearly all "baseload," or three-fourths as big as solar and windpower combined.

[49] A. Lovins, "Closing Diablo Canyon Will Save Money And Carbon," *Forbes*, 22 Jun 2016, https://www.forbes.com/sites/amorylovins/2016/06/22/close-a-nuclear-plant-save-money-and-carbon-improve-the-grid-says-pge/.

[50] International Energy Agency, *Energy Efficiency 2017*, 5 Oct 2017, https://www.iea.org/publications/freepublications/publication/market-report-series-energy-efficiency-2017-.html.

[51] International Energy Agency, *Renewables 2017*, 4 Oct 2017, https://www.iea.org/newsroom/news/2017/october/solar-pv-grew-faster-than-any-other-fuel-in-2016-opening-a-new-era-for-solar-pow.html.

a later and deeper assessment found potential savings twice as big and four times cheaper,[52] largely via well-proven but uncounted "integrative design" methods.[53]

2.4. Nuclear plants typically have ample "fuel on hand," but suffer from at least six serious vulnerabilities—besides their unique value as a target for physical or cyber-attack (ref. 8).

The average U.S. nuclear plant has a forced outage about 1–2% of the time, plus 6–7% scheduled downtime for refueling and planned maintenance (ideally every 1.5–2 years), together making it somewhat less available than a gas-fired combined-cycle plant (the most modern and efficient kind) and much less available than modern renewables (section 2.5 below). However, when assessing nuclear power's prospects and the wisdom of retiring reactors that now average 37 years old, with 37 of the 97 operating units over 40 years old, it's important to recall that today's nuclear fleet exhibits a strong "survivor bias." Of the 259 US power reactors ordered in 1955–2016, 128 (49%) were abandoned before startup and 34 (13%) were prematurely closed later. At mid-2017, 97 remained in operation (37%), of which 49 are uneconomic to run[54], and 35 have suffered a total of 45 safety-related outages lasting a year or more. Just 28 units (11%), some now slated for closure, remain competitively operable and have not yet had a year-plus outage[55]—an ever-present risk. Indeed, nuclear plants face six further shutdown risks that are largely or wholly unique to this demanding technology:

1. Once the roughly 35-day (nominal) refueling begins, it must be completed, so guessing wrong about when to schedule it can put supply adequacy at risk.
2. In the US and Europe, heat waves and droughts have closed or derated multiple nuclear plants simultaneously when their cooling water becomes too warm. DOE's *Staff Report* (p. 95) cites the 2010 example of Brown's Ferry, and other examples abound in the US and abroad.[56]
3. By federal regulation, any nuclear plant must shut down in sustained (for a minute or more) winds of at least 74 mph, *i.e.* the weakest kind of hurricane (Category One). Wind gusts, however, remain a gray area. Some observers

[52] A. Lovins & Rocky Mountain Institute, *Reinventing Fire*, Chelsea Green (VT), 2011, www.rmi.org/reinventingfire. Summaries at *Procs. Am. Inst. Phys.* **1652**:100–111, doi:10.1063/1.4916173, https://www.rmi.org/wp-content/uploads-2017/05/AIP_RF.pdf and *Foreign Affairs* **91**(2):134–146 (Mar/Apr 2012).
[53] A. Lovins, "How Big Is the Energy Efficiency Resource?," invited 16 Sep 2017 Essay in review, *Climatic Change*, 2017.
[54] J. Polson. "More Than Half of America's Nuclear Reactors Are Losing Money," Bloomberg New Energy Finance, 14 Jun 2017, https://www.bloomberg.com/news/articles/2017-06-14/half-of-america-s-nuclear-power-plants-seen-as-money-losers.
[55] These (along with seven more year-plus outages in now-closed units) totaled 138 reactor-y costing ~$82 billion (2005 $). D. Lochbaum analysis from USNRC data, http://www.ucsusa.org/nuclear-power/whos-responsible-nuclear-power-safety/no-more-fort-calhouns (2015), and my analysis of overlap between those data and the previous reference.
[56] S. Röhrkasten, D. Schäuble, & S. Helgenberger, "Secure and Sustainable Power Generation in a Water-Constrained World," 2015, doi:10.2312/iass.2015.023.

felt that the St. Lucie plant, which experienced sustained 71-mph winds with 100-mph gusts, should have been shut down in Hurricane Irma.[57]

4. A major attack, credible threat, or nuclear accident, even abroad, could cause most or all other reactors to be shut down. Falsified safety data in Japan shut all 17 TEPCO reactors (the same owner as Fukushima Daiichi) for many months of safety checks in 2002–04; an earthquake bigger than thought possible when designing seven TEPCO units at the world's biggest nuclear complex closed it completely for 21 months, disrupting national power and global fuel markets and costing TEPCO probably over $20 billion (the units still struggle to restart); and the more than tenfold larger cost of the 2011 Fukushima disaster then bankrupted that utility in all but name and closed *all* of Japan's nuclear plants. About 34 remain shut after an average of 5.5 years, with few expected to restart. Of that lost output, 70% was replaced by cheaper and more-resilient efficiency, renewables, and other distributed resources in the first five years, so it's hard to see how many shut-down units could restart before their market disappears.
5. Radiation exposure and special techniques and rules to reduce its risk tend to make nuclear repairs long, complex, and costly. At multi-reactor sites, a problem with one unit can also make the others inaccessible to keep safe.
6. Regional blackouts automatically and instantly shut down operating reactors to ensure their safety. But then certain fission products that trap neutrons needed to sustain the chain reaction unavoidably build up, complicating stable restart. Thus the nine reactors that had been running perfectly at 100% output before the 14 August 2003 Northeast blackout took two weeks to restore fully, producing less than 3% of their rated power over the first three days and 41% in the first week. (Ref. 28 graphs the Nuclear Regulatory Commission data. Canada's restart was even tougher: Toronto was near grid collapse for days amid frantic appeals to turn everything off.) This little-known nuclear-physics attribute makes nuclear plants "anti-peakers," guaranteed unavailable when we need them most—right after a blackout.

The NOPR mentions none of these issues. It also claims that "overall, nuclear reactors performed extremely well during the Polar Vortex, with an average capacity factor of 95 percent." True, but NRC data also show that during the nine days around Hurricane Irma, three of four Florida reactors lost a total of 11.91 reactor-days or one-third of their potential output, with Turkey Point 3 completely down for 4 days, Turkey Point 4 for 6, and St. Lucie 2 for 1, and two-thirds of their total capacity down on the worst day.[58] NRC doesn't say whether this was due to technical

[57] L. Daprile, "Hurricane Irma nearly forced FPL to shut down St. Lucie Nuclear Plant; should it have?," *TCPalm*, 5 Oct 2017, http://www.tcpalm.com/story/weather/hurricanes/2017/10/05/hurricane-irma-nearly-forced-fpl-shut-down-st-lucie-nuclear-plant-should-have/724802001/.

[58] See www.nrc.gov/reading-rm/doc-collections/event-status/reactor-status/2017/20170908ps.html and following dates through the period 9–18 Sep 2017. EIA says one Turkey Point unit was pre-closed as a precaution and the other closed later for a mechanical issue.

problems or impaired operator access, but it does not appear to be due to transmission failures such as those that disabled some Texas windfarms.

2.5. Modern renewable generators are largely free of the vulnerabilities of coal and nuclear plants, and have consistently helped to keep the lights on when those plants failed.

Solar cells have almost no moving parts—just inverter fans and tracker motors, all easily maintained at night from ground level—so their forced outage rate is typically less than 1%. (For a leading brand of utility-scale PV inverter, nearly the only source of failure in such systems, the guaranteed maximum is 0.15%.) Modern wind turbines do nearly as well—1.8% for more than 20,000 performance-guaranteed Vestas turbines in 2016, 1.1% in a Sandia National Laboratory database. Although these modern renewables are 98–99+% technically available, varying sun and wind held their 2016 average capacity factor (the fraction of full-time full-rating output actually produced, per EIA *El. Monthly*, Table 6.7.B) to 34.7% for windpower (cut several percentage points by transmission or market curtailments) and 27.2% for solar photovoltaics, both improving with technologies and operating techniques.

Do these capacity factors, lower than those of coal and nuclear plants, mean these two kinds of "variable" renewables—sometimes misnamed "intermittent" or "volatile"[59]—are unreliable? Not at all. Their output can generally be predicted more accurately than electricity demand. When properly designed, built, run, and dispatched, as most now are, they are *more* reliable and resilient generators than fossil-fueled or nuclear plants, for two main reasons.[60] First, a portfolio of renewables, diversified by type and location, can exploit different sites' simultaneous solar and wind conditions, which are often complementary. Second, roughly half the world's renewable electricity (excluding big hydro dams) isn't variable—it's neither wind nor photovoltaic.[61] Therefore at least ten nations not mainly hydro-reliant now get many times the fraction of their annual electricity use from renewables that the US did in 2016 (9% without or 16% with hydropower), with at least six surpassing 37%-windpowered Iowa: Iceland 100%, Costa Rica 99%, Portugal 63% (2016), Denmark 62% (2015), Scotland 59% (2015), and peninsular Spain 40% (2016).

Yet such high-renewables countries generally achieve superior reliability. Denmark on many days of the year gets all its electricity from renewables; Germany in all of

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[59] "Intermittent" is best reserved for unpredictable (forced) outages, not for predictable variations. "Volatile" is pejorative but meaningless. "Unreliable" is simply wrong, as these comments show.
[60] This paragraph is documented in an invited paper by A. Lovins, "Reliably integrating variable renewables: a systems view," *The Electricity Journal*, in review (2017), available from the author under embargo upon request to lpauli@rmi.org. See also the International Energy Agency's Mar 2017 nontechnical primer "Getting Wind and Sun Onto the Grid: A Manual for Policy Makers," https://www.iea.org/publications/insights/insightpublications/Getting_Wind_and_Sun.pdf.
[61] E. Goldfield, R. Laemel, & A. Lovins, "Micropower Database 2017," Rocky Mountain Institute, https://d231jw5ce53gcq.cloudfront.net/wp-content/uploads/2017/08/RMI_Micropower_Database_2017.xlsm.

2016 was 32% powered by nonhydro renewables, and 82% for several days in May 2017; yet both nations averaged 23–24 minutes of customer outage per year, while the US averaged 198.[62] To be sure, much Danish and German electric infrastructure is underground, but for them as for Europe as a whole, rapid renewable growth has been accompanied by *rising* reliability of power supply[63] even though I'm aware of no data showing an increased underground fraction of lines.

Some pundits still claim that renewables can provide little electricity reliably unless backed up by comparable storage capacity in giant batteries. Yet none of the high-renewables countries just mentioned does that, nor feels any need to. Eight kinds of "grid flexibility resources" *other than* bulk storage of electricity[64] now permit largely or wholly renewable power supply at attractive costs and with unchanged or improved reliability and resilience.[65] That is where both domestic and global markets are rapidly headed and what the NOPR seeks to block. The Secretary seems unaware that the ultrareliable former East German utility 50Hertz got 49% of its 2015 electricity from renewables—three-fourths of them variable—and has stated[66] the variable renewable share could rise to 60–70% without a need to add bulk storage.

American and global experience confirm that modern renewables are exceptionally important in helping keep the lights on during grid emergencies. For example:

- In the February 2011 Texas cold snap, which was accompanied by high winds, windpower reliably generated about 3.5 GW in the morning peak.
- In the 2014 Polar Vortex, consistent windpower output helped save mid-Atlantic and Great Lakes customers more than $1 billion in two days, and PJM reported 4 GW of peak load met by windpower's outperforming its norm[67]. In New England, where renewables' "Cold weather related equipment issues did not cause any operational issues," the total renewable contribution to 7 Jan 2014 peak supply, though unmentioned in the NOPR,

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[62] D. Hochschild & D. Olson, "Renewable energy no threat to electric grid, as Trump aides claim," *San Francisco Chronicle*, 16 Jun 2017 gives 240 minutes, but the *Quadrennial Energy Review*, p. 45, Jan. 2017, gives ~198 minutes for 2016.
[63] C. Morris, "SAIDI: German grid keeps getting more stable." 2015. http://www.renewablesinternational.net/german-grid-keeps-getting-more-reliable/150/537/89595; S. Amelang, J. Schlandt, "Germany's electric stable amid energy transition," *Clean Energy Wire*, 20 Oct 2016, https://www.cleanenergywire.org/factsheets/germanys-electricity-grid-stable-amid-energy-transition; S. Lacey, "Countries With the Most Wind and Solar Have 10 Times Fewer Outages Than America," 19 Jun 2017, https://www.greentechmedia.com/articles/read/the-countries-with-the-most-wind-and-solar-have-far-fewer-outages#gs.2IiSoS4.
[64] Described in ref. 60 and its numerous citations.
[65] As exhaustively analyzed by the National Renewable Energy Laboratory, ref. 52, ref. 5 §6's citations, other DOE National Labs, and dozens of regional reports listed in App. B of DOE's *Staff Report*.
[66] G. Parkinson, "German grid operator sees 70% wind + solar before storage needed," 7 Dec 2015, http://www.energypoint.eu/german-grid-operator-can-handle-70-wind-solar-storage-needed/.
[67] PJM, ref. 36, pp. 21–22. PJM states: "The wind power produced had a positive impact on supply and contributed to PJM's ability to maintain reliability."

equaled coal's 14% in the morning and exceeded it (by 15% *vs.* 11%) in the afternoon.[68] Moreover (*id.*, p. 15), "There was no need to call on demand response/ interruptible load" during 6–8 Jan 2014, leaving 282 MW of that highly reliable resource unused—over six times the reported 44-MW peak supply margin.

- In the surrounding cold winter of 2013/14, windpower was important to grid support in TX, NE, CA, and the PJM and New England power pools. In spring 2014, CAISO told FERC that "renewables helped to get us through the winter," and ISO-New England told the House Energy and Commerce Committee that renewables "were an important part of the [winter] energy mix."[69]
- New York's Indian Point 3 shutdown in December 2015 was offset by the state's wind turbines plus two gas plants.
- Hurricane Harvey destroyed powerlines but reportedly no windfarms.[70] Some automatically shut down for self-protection (sustained winds reached 130 mph, twice most turbines' design cutout speed), but outside those peak-wind periods, wind overproduced, supplementing failed fossil-fuel plants.[71]
- Hurricane Irma didn't stop solar power from serving homes equipped with batteries and special arrangements to avoid the main Florida utility's strange monopoly and anti-resilient-hookup rules[72] (*cf.* section 5 below).
- Rural Haitian PVs, some temporarily taken down and quickly put back up, solidly withstood Hurricane Irma.[73]
- In South Australia's 28 Sep 2016 statewide blackout—wrongly blamed on windpower, the Australian Energy Market Operator's March 2017 Final Report found, when the problem arose from tornado-downed transmission lines and incorrect grid settings—grid faults stopped six windfarms but three others kept running. With proper grid settings (now in place) to accept more windpower, another 445 MW of wind could have averted the blackout.
- Solar power is so ultrareliable that each of the US Armed Services is installing a billion watts of it on or near military bases, with more to come. Portable

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68 Ref. 35.

69 J. Moore & A. Clements, "The Polar Vortex and the Power Grid: What really happened and why the grid will remain reliable without soon-to-retire coal power plants," 29 Apr 2014, https://www.nrdc.org/experts/john-moore/polar-vortex-and-power-grid-what-really-happened-and-why-grid-will-remain.

70 R. Kessler, "Most Texas coastal wind farms avoid Harvey storm damage," 29 Aug 2017, http://www.rechargenews.com/wind/1335924/most-texas-coastal-wind-farms-avoid-harvey-storm-damage.

71 EIA, ref. 42.

72 L. Gilpin, "After the Hurricane, Solar Kept Florida Homes and a City's Traffic Lights Running," 15 Sep 2017, https://insideclimatenews.org/news/15092017/after-hurricane-irma-solar-florida-homes-power-gird-out-city-traffic-lights-running; M. Rozsa, "Florida's largest power company made installing solar panels much harder," 18 Sep 2017, http://www.salon.com/2017/09/18/floridas-largest-power-company-made-installing-solar-panels-much-harder/.

73 W. Steel, "Haitian Solar PV Weathers Hurricane Irma," 13 Sep 2017, http://www.renewableenergyworld.com/articles/2017/09/haitian-solar-pv-weathers-hurricane-irma.html.

> solar power is also widely and successfully used in expeditionary power supply to reduce dependence on vulnerable fuel logistics—an "attack magnet" that has killed more than a thousand Servicemembers, making it among the highest causes of combat risk in Iraq and Afghanistan (refs. 21).

Weather-related renewable outages are not unknown[74] but are rare, brief, and seldom repeated. Demand-side resources are also important for grid support, as demand response proved in the Southeast pool SEC during the January 2014 cold snap. Demand response outperformed in the Polar Vortex too, when voluntary and paid-for demand reductions "were a valuable part of maintaining reliability" but no customers were ordered to cut back.[75] These demand-side resources and storage likewise supported California's grid during 2016 and 2017 heat waves when the Aliso Canyon storage leak cut gas supplies.[76] Dozens of diverse studies confirm that high renewable fractions and demand-side resources strongly support resilient grid operations.[77] But under the NOPR, these resilient resources would be discriminated against, while the underperforming and costlier coal and nuclear plants would get special rewards, even if their coal piles were frozen and their operators gone.

2.6. The NOPR provides no evidence—perhaps because there is none—that the "fuel-secure" plants it aims to subsidize actually provide unique and valuable "resiliency benefits," let alone that they provide high economic or unique operational value.

Sections 2.2–2.5 above show that coal and nuclear plants have significant direct, and in the case of coal also fuel-logistics, vulnerabilities. Those make them dubious substitutes for the inherently more-resilient demand-side, cogeneration, and renewable resources that the NOPR would have them supplant. The Secretary's view that they are essential to reliable and resilient power-system operation is most simply refuted by the exceptional performance of very-high-renewables countries (2.5) and indeed by the NERC reliability statistics for US regions with unusually low fractions of coal and nuclear generation. The "baseload"-centric view of electricity systems that seems to animate the Secretary's claims is familiar to the Commission as an outmoded view long abandoned by most experts as no longer useful or needed.[78] However, specific technical attributes needed for power-system reliability

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[74] E.g. NERC's 2012 Texas case-study of avoidable cold-related windpower interruptions, http://www.nerc.com/pa/rrm/ea/February%202011%20Southwest%20Cold%20Weather%20Event/20120901_Wind_Farm_Winter_Storm_Issues.pdf, and 2017 California case-study for PVs shut down by wildfire interruption to transmission due to overly sensitive inverter trip settings, http://www.nerc.com/pa/rrm/ea/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_/1200_MW_Fault_Induced_Solar_Photovoltaic_Resource_Interruption_Final.pdf.

[75] ISO-New England, quoted in ref. 40, p. 9.

[76] Orvis & O'Boyle, ref. 41.

[77] *E.g.*, http://blogs.edf.org/energyexchange/files/2017/06/DOE-Baseload-Study-Letter-Attachment.pdf.

[78] *E.g.*, S. Straub & P. Behr, "Energy regulatory chief says new coal, nuclear plants may be unnecessary," *N.Y. Times*, 22 Apr 2009, http://www.nytimes.com/gwire/2009/04/22/22greenwire-no-need-to-build-new-us-coal-or-nuclear-plants-10630.html; K. Beckman, "Steve Holliday, CEO National Grid, 'The idea of large power stations for baseload is outdated,'" 11 Sep 2015,

and traditionally provided by large rotating machines in central thermal stations *are* important, and can be reliably provided, often at lower cost, by distributed energy resources (DER) such as solar and windpower at utility scale. NERC says[79] these

…are now required to ride through disturbances, to provide reliability services, and to have active power management capability to respond to dispatch or automatic generation control…signals. Many DER will also have such capabilities, [which]…may be used either directly or through aggregators for numerous emerging services (*e.g.* demand response, micro-grids, virtual power plants, etc.)…. Technology advances have the potential to alter DER from a passive "do no harm" resource to an active "support reliability" resource. From a technological perspective, modern DER units will be capable of providing ERS [Essential Reliability Services—primary frequency response, voltage support, and ramping capability] and supporting BPS [Bulk Power System] reliability. These technologies are likely to become more widely available in the near future, and they present an opportunity to enhance BPS performance when applied in a thoughtful and practical manner.

NERC then illustrates aggregating DER into a large frequency-response, voltage-support, system-balancing, demand-response, reserve, and ramp-rate resource.

DOE's *Staff Report* acknowledges many of these same points, and its team leader valuably amplifies the newer options for providing frequency response comparable to *or better than*[80] was traditionally provided by fueled power plants:[81]

Frequency response provision – Not all inertia is created equal. While rotating mass-based generation was the only source of frequency response decades back in the days of a slow grid, such sources are no longer the only way to get frequency response. DOE, NERC and others should conduct immediate research to determine the capabilities and limits of rotating mass-based inertia, inverter-based synthetic inertia, and a variety of storage and automated demand response sources to provide primary and secondary frequency response.

If there is unique value to rotating mass-based inertia, we need to know the value of that resource relative to other frequency response sources, and how much and where (topologically) such rotating mass-based resources must be located for maximum effectiveness. Early studies suggest that inverter-based resources can be used to great advantage to manage frequency control and response and voltage, if we first identify the necessary performance expectations on a technology-neutral basis and build those into grid participation requirements.

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http://www.energypost/eu/interview-steve-holliday-ceo-national-grid-idea-large-power-stations-baseload-power-outdated/; ref. 5 §6 and its citations.

[79] NERC, Distributed Energy Resources Task Force Report, Feb 2017, http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/Distributed_Energy_Resources_Report.pdf.

[80] G. Parkinson (GE), "Why grids don't need to rely on 'synchronous' generation," 16 Dec 2016, http://reneweconomy.com.au/ge-grids-don't-need-rely-synchronous-generation-89161/; H. Trabish, "California solar pilot shows how renewables can provide grid services," *Utility Dive*, 16 Oct 2017, http://www.utilitydive.com/news/california-solar-pilot-shows-how-renewables-can-provide-grid-services/506762/, proving solar ancillary services are better and cheaper than from gas plants.

[81] A. Silverstein, "If I'd written the DOE grid study recommendations," 2 Oct 2017, http://www.utilitydive.com/news/silverstein-if-id-written-the-doe-grid-study-recommendations/506274/. If, contrary to the second ref. 90, mechanical inertia did prove to have special value, markets might simply elicit an old motor-generator set with a giant flywheel.

Grids can and do run reliably without the large thermal power plants the Secretary calls "baseload" plants.[82] Reliability then comes from a diverse portfolio of resources so designed and run that customers' needs are met at all times. Many utilities have done this for many years (see examples in section 2.5) as renewables have gradually replaced traditional thermal plants, and some parts of the United States, such as Iowa and California, are moving rapidly in this direction. Low-cost battery storage would help such operation but is not required for its success (ref. 60). For example, the Southwest Power Pool averaged 21.5% windpowered in March–May 2016 and has at times approached 40%, but found it could handle up to 60%, with lower cost and lower price volatility, by straightforward conventional improvements.[83]

3. The NOPR correctly states that many coal and nuclear plants, generally old and amortized and often paid for twice or more already[84]*, have recently retired or are slated for retirement, but it provides no evidence that these retirements have endangered or will endanger grid reliability.*

The NOPR selectively quotes NERC, the DOE *Staff Report*, and other authoritative sources out of context to try to make what they actually say sound like support for the NOPR's thesis. Of course the shifting generating mix is causing electricity system changes that "must be well understood and properly managed in order to assure continued reliability and ensure resiliency." Practically everyone in the industry understands this need for understanding and management, and is intently engaged in achieving it. But that is a very far cry from the unfounded implication that this multi-decade evolution must be urgently *reversed* and its old, uneconomic, fading generating assets (which NERC agrees are "economically marginalized") must be bailed out and restored to their former dominance because further retirements imminently threaten system reliability and resilience. There is no evidence for that proposition. The full *Staff Report*, NERC studies, and power-pool and National Laboratory studies cited above consistently show the opposite. They do show that the industry must continue to adapt its technical and institutional arrangements, in thoughtful and orderly fashion, to the changing needs and opportunities of new

[82] This term has at least five meanings (ref. 5 n. 58). The proper and longstanding industry definition, accepted by NERC, rests on operational role derived from least marginal cost—long-term for resource acquisition, short-term for dispatch. Silverstein (*id.*) correctly notes that "baseload" is an operational mode, not a type of power plant, and that many recently retired thermal plants were by then no long running that way because cheaper-to-run renewables shrank their operating hours.
[83] DOE, *Quadrennial Energy Review*, Jan. 2017, p. 4–10, paraphrasing Southwest Power Pool (SPP), *2016 Wind Integration Study* (Little Rock, AR: SPP, January 2016), 38, https://www.spp.org/documents/34200/2016%20wind%20integration%20study%20(wis)%20final.pdf.
[84] Ref. 5's section 2 notes (with citation omitted) that many nuclear plant owners were "compensated first for building their assets (with subsidies around 0.8–4.6¢/kWh for shareholder-owned and 1.7–6.3¢/kWh for public utilities, excluding ~8.3¢/kWh of historic subsidies that originally launched the nuclear enterprise), then for transition costs of the restructuring they later demanded (notably 'stranded-asset' allowances), sometimes yet again by some ISO-RTOs' additional capacity payments favoring large thermal units, and now (they hope) for a fourth time via new state payments and competitive boosts for alleged unrecognized virtues. Once is enough."

kinds of generators. But not a single such study by those entrusted with analyzing and operating the grid supports the NOPR's view that our Nation must slam on the brakes of electricity reform, accelerate in reverse, and effectively abandon competitive wholesale markets.

On the contrary, DOE's *Staff Report* cites in its Appendix B a partial list of 35 studies of considerably higher variable renewable penetration (up to 80–90%, *vs.* the 2016 US average of 6.7%) with same or better reliability, greater resilience, and often lower cost. The NOPR ignores that literature and instead cites in its ref. 14–15 a tendentious and unreviewed new study[85], by the consultant IHS Markit, whose content does not inspire analytic confidence. For example, the statement in the NOPR's section E that a grid mix much costlier than a coal-and-nuclear-centric case can be devised (as IHS Markit does without specifying that case's content) does not mean any such case must be far costlier, nor that a cheaper one could not also be devised. In fact, an exhaustive and heavily peer-reviewed 2012 analysis[86] by the National Renewable Energy Laboratory found exactly that when updated[87] to the renewable costs of 2014, far higher than today's, and ref. 52 found an even cheaper, half-distributed solution using the same NREL model. A newer analysis shows how distributed renewables could nearly halve California's electricity prices while improving resilience.[88] The IHS Markit study also decries the increasing diversity of the U.S. generating mix without explaining why it has accompanied lower outage rates (before the 2017 hurricanes) and lower costs. And DOE's *Staff Report* agrees (p. 123) that renewables stabilize electricity prices, making electricity more affordable.

It is therefore not surprising that over 80% of North American utility employees in a survey of over 600 professionals expect moderate-to-significant increases in renewable energy in their services territories over the next decade.[89] Their reported concern about grid integration has fallen by half in the past year, to less than half the fraction of respondents listing [post-election] regulatory and market uncertainty as their most pressing concern. This matches the ever-increasing weight of analysis, such as the National Renewable Energy Laboratory's finding that the Eastern

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85 IHS Markit, *Ensuring Resilient and Efficient Electricity Generation*, Sep 2017, https://www.globalenergyinstitute.org/sites/default/files/Value%20of%20the%20Current%20Diverse%20US%20Power%20Supply%20Portfolio_V3-WB.PDF. This report faithfully reflects the lobbying positions of its sponsors—Edison Electric Institute, the Nuclear Energy Institute, and the Global Energy Institute of the US Chamber of Commerce.

86 NREL, *Renewable Electricity Futures Study*, 2012, http://www.nrel.gov/analysis/re_futures/.

87 T. Mai, D. Mulcahy, M. Hand, S. Baldwin, "Envisioning a renewable energy future for the United States," *Energy* **65**:374–386 (2014), summarized at https://gcep.stanford.edu/pdfs/events/workshops/Mai_2015-04-01%20GCEP%20Net%20Energy%20-%20public.pdf.

88 R. Jain, J. Qin, & J. Rajagopal, "Data-driven planning of distributed energy resources amidst socio-technical complexities," *Nature Energy* **2**(17112), 2017, doi:10.1038/nenergy.2017.112.

89 H. Trabish, "Why utilities are more confident than ever about renewable energy growth," 25 Apr 2017, http://www.utilitydive.com/news/why-utilities-are-more-confident-than-ever-about-renewable-energy-growth/440492/.

Interconnection (by some measures the world's largest power system) can reliably increase its renewables by more than tenfold.[90]

What has kept the US electricity system a world leader is the continuous innovation driven by open markets, innovative regulation, and advanced technologies. The NOPR's effort to pick fuels under a spurious national-security pretext puts all that at risk. As Jeff St. John correctly paraphrases the R Street Institute's Devin Hartman[91], "the much deeper analysis presented in [DOE's *Staff Report*] built on existing work at FERC and [the ISOs/RTOs]…calling for improvements in energy price formation and valuation of [E]ssential [R]eliability [S]ervices such as voltage support and frequency response"—not of onsite fuel inventories. And as the DOE *Staff Report* (pp. 90–91) quotes the R Street Institute, which later found the NOPR "deeply troubling"[92] and hostile to competitive markets:

> Fuel neutrality is essential for both monopoly-utility resource planning and competitive markets to manage risk and achieve reliability efficiently. Interventions to promote specific fuel types—such as bailouts for coal and nuclear or mandates and subsidies for renewables—skew investment risk and can undermine incentives for reliability-enhancing behavior…. For regulators, attempts to achieve fuel diversity in market designs explicitly would likely result in inefficient and potentially discriminatory practices that are inconsistent with the Federal Power Act.

4. Resilience is best achieved through efficient and timely use of electricity generated by diverse, distributed, and preferably renewable resources.

Ref. 13's evidence, much of it paraphrased in sections 2.3–2.5, suggests six lessons that it summarizes thus and that are highly relevant to this docket:

1. Without exception, all sources of electricity sometimes fail. Their failures differ widely in cause, size, abruptness, predictability, frequency, duration, and importance. Big, lumpy failures are more awkward than small, granular ones.

2. Coal- and gas-fired plants' often-farflung fuel logistics are particularly vulnerable…. Gas and electricity supplies are also interdependent.[93]

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[90] A. Bloom *et al.*, *Eastern Renewable Generation Integration Study*, NREL/TP-6A20-64472, Aug 2016, https://www.nrel.gov/docs/fy16osti/64472.pdf.

[91] J. St. John, "Behind the Backlash to Energy Secretary Rick Perry's Demand for Coal-Nuclear Market Intervention," 5 Oct 2017, https://www.greentechmedia.com/articles/read/behind-the-backlash-to-energy-secretary-rick-perrys-demand-for-coal-nuclear#gs.e6Upvd0.

[92] R Street Institute, "DOE proposal misframes grid resiliency," 1 Oct 2017, http://www.rstreet.org/2017/10/01/doe-proposal-misframes-grid-resiliency/.

[93] E.g., NERC's Southwest 2012 case-study at http://www.nerc.com/pa/rrm/ea/February%202011%20Southwest%20Cold%20Weather%20Event/LL20120905_Gas_and_Electricity_Interdependency.pdf. NERC's interdependency reports are at http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/Gas_Electric_Interdependencies_Phase_I.pdf and http://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_PhaseII_FINAL.pdf.

3. Coal and nuclear power plants, the two kinds that keep "fuel on hand," are particularly prone to "common-mode failures" that can stop their output over large areas for substantial periods.

4. Though nuclear plants require only infrequent delivery of fresh fuel, and accounted for only 3% of the forced outages in the Polar Vortex, they can suffer relatively infrequent but unusually long outages, can be shut down at a national scale (or more) after certain uncontrollable events, and can be slow and hard to restart after a sudden and widespread blackout, so they too have reliability shortcomings.

5. Renewable power has less frequent and briefer technological failures than fueled generation, but windpower and PVs do vary (albeit very predictably) with wind and sun. (Other renewables, delivering half the 2016 global output of all renewables other than big hydropower, are "dispatchable"—you can have them whenever you want.) Especially when integrated into microgrids, renewables are more resilient than generators that need fuel—even windpower and PVs if their forecastable variability is properly managed. That need is analogous to but probably cheaper than managing the intermittence of large thermal plants through reserve margin and spinning reserve. Making largely or wholly renewable power supply highly reliable typically needs little or no bulk electricity storage, but combines proven techniques[94] for forecasting, diversification, integration, demand flexibility, thermal storage, and electricity storage worth buying anyway (such as in parked electric vehicles).

6. All these comparisons between generators overlook a very important factor. Whether it comes from a renewable or a nonrenewable power plant, the average electron moves several hundred miles through the transmission and distribution grids before it reaches your meter. But no faraway power plant can serve you if that grid fails. *Grid failures, not generator shortfalls, cause roughly 98–99% of US power failures.* So if you want the most reliable supply, use a nearby generator, like PVs on your roof, to bypass the grid altogether. If you can't do that, at least consider a local microgrid to minimize the distance your electricity must travel. If you really want reliable and resilient power, no kind of remote central power station is a suitable choice (ref. 8).

Whatever the virtues of fueled central power stations, "fuel on hand" is not one of them. The commendable impulse to diversify power sources does not require substituting one particularly brittle and costly source for another, any more than diversifying a financial portfolio will make it perform better if you unwisely choose costly and risky investments. To manage both cost and risk, both reliability and resilience, a diverse portfolio of efficiency, load flexibility, and renewables is sufficient, smart, and winning in the marketplace—while also advancing free markets, national security, and Creation care.

Both conservatives and progressives who share Secretary Perry's goals of "reliability, affordability, and fuel assurance"—where fuel is needed at all, and not otherwise—will find this a winning formula. Its prudent management of other risks is a free byproduct.

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[94] *E.g.* https://www.agora-energiewende.de/fileadmin/projekte/2014/integrationskosten-wind-pv/agora-integration-cost-wind-pv-web.pdf.

Thus as my colleagues Miranda Ballentine (previously a top Wal-Mart official, then Assistant Secretary of the Air Force) and Mark Dyson put it,[95] the NOPR "looks backward, not forward. Any serious attempt to improve the country's energy resilience needs to take advantage of emerging solutions rather than prop up 20th century ones." Building on FERC's longstanding and expert leadership in fuel-neutral and technology-neutral markets, improving resilience should use innovation and competition to enable the new energy system, not protect the old.

5. For the foregoing reasons, FERC should reject the NOPR as unsupported by evidence of record. But grid resilience is important and needs more attention. FERC should therefore intensify its examination of grid resilience by diligent, orderly, unhurried, and inclusive means that consider the following four classes of suggestions.

5.1. Distributed resources' grid interconnections should become resilient by default.

Distributed renewable generators can power your house through disasters—but not if crippled by obsolete utility rules. When Superstorm Sandy blacked out more than two million New Jersey households, many for days, that state had the second-highest home solar power capacity, over a thousand megawatts. Over 90% of those solar panels survived the storm and even many that flew away with their roofs were OK when they landed. But by utility rule, that "grid-tied" gigawatt had all been wired not to work without the grid, making renewables so irrelevant to restoration that NERC's analysis doesn't mention them.[96] Even backup engine-generators couldn't get fuel and soon became useless—an issue addressed below in section 5.3. Now PSE&G and ConEd are starting to rethink that no-islanding policy, as the whole industry should. Sandy should have been a wakeup call[97], and was for a few utilities, but most hit the snooze button. In a recent industry seminar, I asked representatives of dozens of utilities how many allowed resilient hookup. Only two did. The issue hasn't even been on EEI's agenda, and few state PUCs have yet paid attention. But a proven and preapproved solution is readily at hand.

The nationwide industry consensus standard IEEE-1547 on distributed generators' grid interconnection, approved in 2003 and enshrined in the Energy Policy Act signed by President George W. Bush in 2005,[98] automatically makes the hookup

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[95] M. Ballentine & M. Dyson, "Rick Perry's plan to subsidize coal and nuclear plants does nothing to fix the U.S. power grid," 6 Oct 2017, http://www.latimes.com/opinion/op-ed/la-oe-ballentine-dyson-energy-resilience-power-grid-rick-perry-20171006-story.html.

[96] NERC, "Hurricane Sandy Event Analysis Report," Jan 2014, http://www.nerc.com/pa/rrm/ea/Oct2012HurricanSandyEvntAnlyssRprtDL/Hurricane_Sandy_EAR_20140312_Final.pdf; D. Levitan, "Rooftop Solar Stood Up to Sandy," *IEEE Spectrum*, 16 Nov 2012, https://spectrum.ieee.org/green-tech/solar/rooftop-solar-stood-up-to-sandy/.

[97] S. Lacey, "Resiliency: How Superstorm Sandy Changed America's Grid," 10 Jun 2014, https://www.greentechmedia.com/articles/featured/resiliency-how-superstorm-sandy-changed-americas-grid#gs.Ofrl_g0.

[98] B. Reppert, "Energy Act Includes Provisions Championed by IEEE-USA," *Today's Engineer*, Sep 2005, http://te.ieeeusa.org/2005/Sep/energy_act.asp.

resilient while protecting lineworkers—even if they ignore their own safety rules *and* if they fail to activate the utility-operable shutoff switches (now often two separate switches) mandated by the National Electrical Code. There is no technical reason for most US utilities to forbid modern renewables' owners from activating the IEEE-1547-compliant "islanding" feature built into most modern inverters. Such rules are only an artifact of a knife-switch mentality persisting in the age of power electronics. If allowed to, 1547-compliant solar power can isolate from the failing grid and keep critical loads running, not endangering lineworkers but letting foresighted customers and their neighbors carry on uninterrupted. Increasingly, too, behind-the-meter batteries (often cost-effective now due to many valuable benefits[99]) are firming rooftop solar power, further increasing resilience.

The state-of-the-art solar system atop a major new convention center where I spoke in North Carolina a few years ago wouldn't even be able to light its parking garage's tornado shelter in the daytime if the tornado tore down the powerlines. The inverters were fully IEEE 1547-compliant, but old utility rules wouldn't let that feature be activated. And such needless gaps in public safety aren't isolated flukes; they're the norm. Such shamefully backward restrictions persist unnoticed in most of the United States, sacrificing vital benefits to family, community, and national security.

That's backwards. "Resilient hookup" should be not the exception but the rule. Utilities shouldn't forbid any customer from adopting the same hookup that DoD doctrine requires to sustain its military bases' resilient power. FERC should take up this issue and encourage grid operators and their market actors to make "resilient hookup" permissible and encouraged everywhere. Then the gradual deployment of distributed generators can build from the bottom up a resilient grid, including nucleation of blackstart and continuity of vital local services. Sandy's victims should have had power immediately, not days later, and so should everyone in America's hurricane-afflicted zones today.

5.2. Grid architecture should be allowed and encouraged to shift to netted islandable microgrids.

Next, to make power supplies resilient nationwide, we need to reorganize distributed renewables into local microgrids that normally interconnect but can split apart fractally at need, stand alone and serve critical loads as best they can, then detect grid restoration (after a pause to ensure it's real and not a recloser transient), resynchronize, and reconnect seamlessly. That's the Pentagon's strategy for military power supplies. It's how my own house works. It's how Denmark is reorganizing its grid in a "cellular" architecture that makes cascading blackouts impossible, as proven by regular stress-tests. At about the same cost as business-as-usual, resilient

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[99] RMI, "The Economics of Battery Energy Storage," Oct 2015, https://rmi.org/insights/reports/economics-battery-energy-storage.

grid architecture[100] could maximize national security, customer choice, entrepreneurial opportunity, and innovation.

Resilient grid architecture plus efficient end-use form the strongest known route to resilient power supply. When a 2007 wildfire disrupted San Diego's grid, the University of California campus's islandable microgrid,[101] providing 92% of the campus's annual electricity at $8 million lower annual cost, switched in under ten minutes from importing 4 MW to exporting 3 MW of power from its onsite sources, including PVs.[102] When 14 transmission trips in Hurricane Gustav (2008) isolated a Baton Rouge–New Orleans zone for 33 hours, Entergy, using 21 phasor measurement units, was able to improvise islanded operation that sustained service across four states by balancing three large generating units without access to the larger grid.[103]

The world now has on the order of 2,000 microgrids, ranging in America from Ocracoke Island in North Carolina to Borrego Springs in California and Sterling in Massachusetts.[104] Several powered their institutions through Sandy.[105] The hurricane-beset Caribbean, where my organization had already undertaken substantial efforts to switch several island nations from diesel generators to efficiency and renewables, is naturally very interested in microgrids. Cuba[106] used microgrids and several complementary reforms to cut its serious blackout days from 224 in 2005 to zero in 2007, then sustained vital services in 2008 when two hurricanes in two weeks shredded the eastern grid—a feat reportedly repeated in this year's hurricanes despite immense destruction. Why did sophisticated US grids perform worse in the 2017 hurricanes than some parts of Cuba? Might our utilities, while emphasizing hardening and smartening of the traditional grid, have not taken seriously enough the need to evolve its architecture and distribute its resources?

5.3. FERC should encourage regional and industry actors to undertake prompt special initiatives to enable motor-fuel filling stations to run even without the grid.

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100 A. Lovins, How To End Blackouts Forever," *Time*, 2012, http://ideas.time.com/2012/11/15/how-to-make-blackouts-history/.

101 UCSD, "The Magic of the Microgrid," 2017, https://sustainability.ucsd.edu/highlights/microgrids.html; for the Princeton equivalent, see M. Fitzgerald, "When the Power Goes Out, Microgrids Keep Electricity Flowing," *Wall St. J.*, 18 May 2014, https://www.wsj.com/articles/when-the-power-goes-out-microgrids-keep-electricity-flowing-1400272693.

102 M Miller et al, "Status Report on Power System Transformation," May 2015, NREL/TP-6A20-63366, for Clean Energy Ministerial, at p. 58, https://www.nrel.gov/docs/fy15osti/63366.pdf.

103 Ref. 14, p. 16.

104 All hyperlinked in ref. 95.

105 Ref. 14, p. 15n; see also ref. 102.

106 A. Lovins, "Efficiency and Micropower for Reliable and Resilient Electricity Service: An Intriguing Case-Study from Cuba," memo prepared for senior DoD theater commanders, RMI, 31 Jan 2010, https://www.rmi.org/wp-content/uploads/2017/05/RMI_Document_Repository_Public-Reprts_2010-23_CubaElectricity.pdf. See also Y. Zhao, "Power Shift in Cuba," 10 Feb 2017, http://www.renewableenergyworld.com/articles/2017/02/power-shift-in-cuba-seven-reasons-to-watch-the-renewable-energy-sector-in-the-post-fidel-and-trump-era.html.

FERC could encourage the ISO/RTOs and their market actors to work with local gasoline-station owners (often major oil companies) to equip every station with rooftop solar power, a battery, and slightly revised breaker-box wiring so the submerged gasoline pumps and the point-of-sale terminal are disentangled from the rest of the convenience store. (Currently they're often combined so the entire 20–30-kW store needs to be powered up before you can pump any gas—and modern pumps lack the old socket for a manual crank, so that option is gone unless a resourceful owner kept the old pump-head and can reinstall it in an emergency.) As long as we have remote power plants connected to customers by frail wires strung through the air, storms will continue to take down powerlines and black out customers. But at least first responders, genset owners, and everyone else should still be able to get gasoline and diesel fuel to keep vital mobility services running throughout post-disaster recovery. DOE actually pioneered a solar-powered gasoline station in West Chicago, where the Secretary of Energy cut the ribbon in 1980. It's time to repeat that good idea.

5.4. FERC should enhance wholesale competition by requiring proper valuation of fuel-price volatility and by at least shadow-pricing and emulating energy desubsidization.

Finally, FERC should add to its existing policies for full and fair competition between all resources—both supply- and demand-side—two new elements:

1. Economic competitions and comparisons between fueled and nonfueled resources should include the fair market value of fuel-price volatility—risk-equalizing for fair comparison with efficiency and renewables, which have no fuel and hence constant prices. Ref. 5 §12 summarizes this basic but currently ignored foundation of financial economics. Its effect would be to roughly double the effective price of natural gas (and probably somewhat increase that of coal, oil, LPG, and perhaps biofuels). That would help nuclear power compete against fossil-fueled generation, notably gas, without distorting competition between all carbon-free resources.
2. FERC should consider ways to encourage across-the-board desubsidization of the entire electricity (and energy) system so that all options can compete on their merits. In general, fossil and nuclear electricity is more heavily subsidized than renewable electricity or efficiency, both on current account[107]

[107] DOE's *Staff Report*, p. 53, cites a fallacious nuclear-industry study as showing that in a year of very atypical renewable subsidies, they got more subsidy than nonrenewables (particularly nuclear). The opposite is true: the cited 2015 EIA study (https://www.eia.gov/analysis/requests/subsidy/pdf/subsidy.pdf) is unhelpful because its Congressional sponsors carefully excluded most subsidies to nonrenewables. See *e.g.* D. Koplow, "The Nuclear Solution? The Role of Subsidies and Market Distortions," Mar 2017, https://sustainability.ucsd.edu/highlights/microgrids.html; —, "EIA Energy Subsidy Estimates: A Review of Assumptions," 2010, https://earthtrack.net/sites/default/files/uploaded_files/EIA%20subsidy%20review%20final_17Mar20.pdf; —, "Subsidies to conventional energy in the PJM region: An initial listing," May 2017,

and (even more) historically over decades—for some subsidies even for a century or more. I believe comprehensive, orderly, fair desubsidization (which I have long favored[108]) would tend to help the most resilient resources, enhancing both our wealth and our community and national security while respecting the sound tenets of conservative market economics. FERC should explore whether shadow pricing could emulate desubsidization even if Congress is not yet ready to implement it, thus achieving more-efficient market outcomes and reducing market distortions.

Together, these approaches should better achieve the NOPR's resilience goals, not by backwards-looking emphasis on the size of a pile of fuel that the market is rejecting and the power system no longer needs, but by a forward-looking, market-friendly focus on how competition and innovation can best provide the reliable and resilient power supply our Nation's security and prosperity require.

I thank the Commission for kindly accepting and considering these ideas, and stand ready to help discuss and elaborate them if desired. The thoughtful consideration and public participation required by law seems to me impossible within the extraordinarily short timeframe proposed in the NOPR. Indeed, the NOPR does not meet the basic Administrative Procedure Act requirement of sufficient specificity for interested parties to comment and FERC to consider. For both reasons, the NOPR should be rejected in its entirety. However, as perhaps the person involved most early and deeply in raising the whole issue of grid resilience over the past 37 years, I am excited and grateful that this existentially important issue is now firmly on the Commission's agenda and can benefit from its proud legacy of evidence-based, nonpartisan rulemaking.

Respectfully submitted,

Amory B. Lovins

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https://earthtrack.net/documents/siubsidies-conventional-energy-pjm-region-initial-listing; —,"Nuclear Power: Still Not Viable Without Subsidies," 2011, http://www.ucsusa.org/nuclear-power/cost-nuclear-power/nuclear-power-subsidies-report#.WeKLIa2ZOis. D. Roberts's 7 Oct 2017 fossil-fuel lay summary "Friendly policies keep US oil and coal afloat far more than we thought" (https://www.vox.com/energy-and-environment/2017/10/6/16428458/us-energy-subsidies) is an excellent introduction, and one of the three studies it describes was just published in *Nature Energy* (P. Erickson *et al.*, "Effect of subsidies to fossil fuel companies on United States crude oil production," 2 Oct 2017, doi:10.1038/s41560-017-0009-8).

[108] A. Lovins, "Nuclear socialism," *Weekly Standard*, 25 Oct 2010, http://www.weeklystandard.com/nuclear-socialism/article/508830.

ANNEX 1: QUALIFICATIONS OF AMORY B. LOVINS

Amory B. Lovins (1947–) is Chief Scientist and Chairman Emeritus of Rocky Mountain Institute (RMI)—an independent, apolitical, nonprofit, ~200-person energy think-and-do tank he cofounded in 1982. An American consultant physicist, he is an innovator in energy and its links with economy, environment, resources, security, and development. He has advised the energy and other industries for over four decades in more than 65 countries. He has received the Volvo, Zayed, Blue Planet, Onassis, Nissan, Shingo, and Mitchell Prizes, the Benjamin Franklin, Happold, and Spencer Hutchens Medals, MacArthur and Ashoka Fellowships, 12 honorary doctorates, and the Right Livelihood ("Alternative Nobel"), Heinz, Lindbergh, *Time* Hero for the Planet, World Technology, and National Design Awards. A Swedish engineering academician, US honorary architect, former Oxford don, and member of the National Petroleum Council, he has briefed more than 30 heads of state, advised major firms and governments worldwide, taught at ten universities (most recently Stanford's School of Engineering), and written 31 books and more than 600 papers. In 2009, *Time* named him one of the 100 most influential people in the world, and *Foreign Policy*, one of the 100 top global thinkers. In 2016, the President of Germany awarded him that nation's highest civilian award for national service, the Officer's Cross of the Order of Merit (*Bundesverdienstkreuz 1. Klasse*).

A hands-on practitioner, Lovins has led the superefficient redesign of more than $40 billion worth of industrial facilities in 30 sectors, scores of buildings, and various land and sea vehicles. His trademark "integrative design" techniques often make very large energy savings cheaper than small ones. His 1999 business book *Natural Capitalism* (1999) with Paul Hawken remains a best-seller. *Small Is Profitable*, the foundational work on the scale economics of electricity systems, was an *Economist* 2002 Book of the Year. His Pentagon-cosponsored 2004 synthesis *Winning the Oil Endgame* roadmapped how to eliminate U.S. oil use by 2040 and revitalize the economy, led by business for profit; so far it's ahead of schedule. His 2011 *Reinventing Fire* synthesis expanded that agenda to include coal and save $5 trillion, and so far is on track in the marketplace. (These books had respectively 2, 6, 4, and 60 coauthors.) In 2012–16 he co-led a consortium with the Chinese government's top energy modelers (NDRC's Energy Research Institute) and Lawrence Berkeley National Laboratory, drawing similar conclusions to inform China's 13th Five Year Plan. In 2017 he co-led with Prime Minister Modi's NITI Aayog the officially adopted *India Leaps Ahead* reframing of India's personal mobility strategy.

In the 1980s, Lovins formed many of the basic concepts that underlie today's electricity industry and led the most detailed studies so far of electric end-use efficiency, then in the 1990s, founded and spun off as E SOURCE what remains the leading technical and strategic information service for such efforts. He has given expert testimony to ten state utility commissions. In March 2013, the Editor of *Public Utilities Fortnightly* devoted nine pages to his electricity prescience,[109] and in

[109] "Turning Energy Inside Out," https://www.fortnightly.com/fortnightly/2013/03/turning-energy-inside-out; "Saving Gigabucks with Negawatts,"

June 2016 listed him first among utilities' Top 10 Most Influential people since 1990.[110] *Power Engineering International* likewise singled him out for the best foresight among 20 electricity experts it had interviewed 20 years earlier.[111]

His clients have included the US Congress, 13 state and 5 foreign governments, dozens of major firms, major real-estate developers, and more than 100 electric and gas utilities. He long taught at Camp NARUC and has addressed such groups as the National Academies, Association of Energy Engineers, seven DOE National Laboratories, UK Royal Academy of Engineering, National Science Foundation, Council of Scientific Society Presidents, ASHRAE, Institution of Electrical Engineers, Edison Electric Institute, Electric Power Research Institute and its Japan counterpart CRIEPI, NARUC, American Gas Association, American Petroleum Institute, American Association of Petroleum Geologists, Urban Land Institute, Industrial Development Research Council, CoreNet, American Institute of Architects, American Physical Society, Highlands Forum, World Energy Conference, Goldman Sachs, Merrill Lynch, JPMorgan, Morgan Stanley, Swiss Re, Allen & Co., Bloomberg New Energy Finance, News Corporation, Council on Competitiveness, CSIS, Hoover and Brookings Institutions, Council on Foreign Relations, Conference Board, Keidanren, World Economic Forum, World Bank, International Monetary Fund, Royal Society, and Royal Society of Arts.

Newsweek called Lovins "one of the western world's most influential energy thinkers"; Dr. Alvin Weinberg, former Director of Oak Ridge National Laboratory, "surely the most articulate writer on energy in the whole world today"; and *Car* magazine, the 22nd most powerful person in the global automotive industry. Dr. John Ahearne, then Vice President of Resources for the Future, said "Amory Lovins has done more to assemble and advance understanding of [energy] efficiency opportunities than any other single person."

Lovins's national-security background includes devising the first logically consistent approach to nuclear nonproliferation (many papers and two books, 1979–83); performing for DoD in 1981 the still-definitive unclassified study of domestic energy critical infrastructure and resilience (*Brittle Power: Energy Strategy for National Security*); codeveloping a "new security triad" of conflict prevention, conflict resolution, and nonprovocative defense; lecturing at OSD, NDU, DAU, USMA, USNA, NWC, NPS, STRATCOM, etc. on least-cost security and on how new technologies will transform missions and force structures; leading for VADM Lopez the 1995–98 overhaul of NAVFAC's design process; leading a 2000–01 analysis for SECNAV Danzig of how to save up to half the hotel-load electricity aboard *USS Princeton* CG-59; addressing ASNE 10 and the USMC Commandant's 2010 expeditionary energy symposium; keynoting SECNAV Mabus's 62th Current Strategy Conference; serving in 1980–81 on DOE's Energy Research Advisory Board; and serving on 1999–2001

https://www.fortnightly.com/fortnightly/1985/03/saving-gigabucks-negawatts-1985; "Scratching the Surface," https://www.fortnightly.com/fortnightly/2013/03/scratching-surface.

[110] S. Mitnick, "Most Influential Since 1990," *Public Utilities Fortnightly* (**151**(3):3,28–36), https://www.fortnightly.com/fortnightly/2016/06/most-influential-1990.

[111] D. Flin, "Back to the Future: European power predictions," *Power Engineering International*, 26 May 2016, http://www.powerengineeringint.com/articles/print/volume-24/issue-5/features/back-to-the-future.html.

and 2006–08 Defense Science Board panels, finding cost-effective DoD fuel-saving potential later estimated by RMI to total ~66% plus avoided lift, and first explicating the modern threat spectrum of power-grid disruptions that he foresaw pre-Internet in *Brittle Power*. Lovins continues to help DoD with energy strategy, electricity resilience, and platform efficiency, and has been tasked by COMNAVSEA to help transform the Naval design process. Having helped drive DoD's energy agenda for three decades, he joined CNO's Advisory Board (CAB) in 2013, and since 2011 has served as Professor of Practice at the Naval Postgraduate School.

Andy Bochman's authoritative DoD Energy Blog kindly stated:[112] "Rocky Mountain Institute founder Amory Lovins has been in this long game longer than anyone, and much of the credit for DoD's current momentum on energy can be traced directly to his decades-long leadership and perseverance." Bochman added[113], with some hyperbole: "He's a thought-leading outsider who knows more about DoD and energy—where it's been and where it needs to go—than maybe all the readers and writers of this blog put together." VADM (Ret.) Dennis McGinn, former Deputy Chief of Naval Operations and an energy-resilience partner for 21 of his 35 years of Naval service (then during his 2014–17 term as Assistant Secretary of the Navy), wrote that "as a direct result of his unmatched knowledge, effective engagement and tireless effort, Dr. Lovins has almost singlehandedly shaped the energy and environmental security awareness and sustainability perspectives of the most senior leaders in the Department of Defense and Armed Services, as well as security leaders in key foreign nations," and has "had a profound and direct influence on military operational designs and practices."

[112] A. Bochman, 15 Mar 2010 blog, http://dodenergy.blogspot.com/2010/03/lovins-on-dod-energy-opportunities-in.html.
[113] A. Bochman, 12 May 2010 blog, http://dodenergy.blogspot.com/2010/05/lovins-addresses-new-nuclear-power-for_12.html.

ANNEX 2: CONCORDANCE TO FERC STAFF'S 30 QUESTIONS

This table matches my submission's page numbers (and line numbers in parentheses) with categorized, numbered staff questions from FERC RM18-1-000.

Page	FERC Question(s) Answered
1	Implementation #3 (14–20); Need for Reform #4, 90-day Requirement #2 (26–29)
2	Need for Reform #4 (2–4, 10–16); Implementation #1&5 (8–10); Other #4 (16–18); 90-day Requirement #2, Fuel Supply Requirement #2 (28–30); Need for Reform #1 (32–42)
3	Need for Reform #1 (2–22), 90-day Requirement #2 (22–25)
4	90-day Requirement #2 (1–36); Need for Reform #4, Fuel Supply Requirement #2 (18–27); General Eligibility Questions 3–5 (38–40)
5	General Eligibility Questions #4 (1–2); Need for Reform #4 (3–9); General Eligibility Questions #6 (5–9); Need for Reform #1 (11–15); 90-day Requirement #2, Fuel Supply Requirement #2 (19–35); Need for Reform #3 (30–31)
6	Need for Reform #2&3 (15–28)
7	Need for Reform #3 (1–2, 8–23); Need for Reform #4&5 (27–33)
8	Need for Reform #2–4 (2–11), Other #3 (4–6, 13–20), 90-day Requirement #2 (39–40)
9	90-day Requirement #2 (1–7); Need for Reform #5 (5–7); Need for Reform #1, Other #3 (10–15)
10	90-day Requirement #2 (3–5, 24–30)
11	Need for Reform #2 (4–15, 24–26), Need for Reform #5 (18–24)
12	Need for Reform #2, 90-day Requirement #2, Fuel Supply Requirement #2 (6–30)
13	Need for Reform #2, 90-day Requirement #2, Fuel Supply Requirement #2 (1–2, 11–36); Need for Reform #4 (4–9)
14	Need for Reform #2 (14–17), Other #3 (4–6, 24–25), Need for Reform #4 (29–31)
15	Need for Reform #4 (1–7); Need for Reform #3, Fuel Supply Requirement #2 (11–26)
16	Need for Reform #3, Fuel Supply Requirement #2 (2–11)
17	Need for Reform #1, Other #3 (7–30)
18	Other #3 (1–2), Fuel Supply Requirement #3 (24–25), Fuel Supply Requirement #2 (26–32)
19	Need for Reform #3, Fuel Supply Requirement #2 (1–2, 6–10, 21–26, 34–38); Other #3 (13–16); Need for Reform #2 (32–34)
20	Need for Reform #1, Other #3 (4–6, 20–36)
21	Need for Reform #1, Other #3 (1–3, 8–13, 19–29); Need for Reform #2 (24–27)

22	Need for Reform #1, Other #3 (6–11, 21–26); Need for Reform #3 (12–20)
23	Need for Reform #1, Other #3 (6–17); General Eligibility Questions #3 (33)
24	Need for Reform #1, General Eligibility Questions #3, Other #3 (1–33)
25	Need for Reform #5 (2–3), Need for Reform #4 (13–16, 24–32)
26	Need for Reform #4, Other #3 (1–4, 14–20)
27	Need for Reform #5 (18–20), Other #3 (23–24), 90-day Requirement (28–32)
28	90-day Requirement (1–3), Need for Reform #2&3 (4–8), Other #3 (9–21), General Eligibility Questions #3 (22–31)
29	Other #3 (9–34)
30	Other #3 (1–41)
31	Other #3 (1–29)
32	Other #3 (2–36)
33	Other #3 (1–8)