United States House of Representatives
Select Committee on the Climate Crisis

Hearing on April 30, 2019
"Solving the Climate Crisis: Drawing Down Carbon and Building Up the American Economy"

Questions for the Record

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Dear Representative Castor,

I appreciate the chance to respond to questions from yourself and Congressman Ben Ray Luján. Your questions and our responses follow, but please note that we would be happy to elaborate on any point, or consider other issues.

The Honorable Kathy Castor

1. **In your written testimony, you say the following about cleaning up the electricity sector: "We have the technology (and it's increasingly cheaper to deploy clean rather than polluting power plants), we have the know-how, we just need to get this moving—and quickly." What are the primary barriers standing in the way of faster deployment of clean energy technology?**

Technology and cost are no longer major barriers to deep electricity sector decarbonization—institutions and information are. Conventional wisdom that wind and solar require 100 percent redundancy from dispatchable power plants is not accurate. Numerous studies including some by federal agencies[1] and our national laboratories[2] show we can reliably operate very high penetrations of renewable electricity using today's technologies at a similar cost as today's electricity system. Further advancements in energy storage and renewable energy technologies, coupled with digitized devices able to respond to real-time grid needs, hold tremendous promise to further reduce costs as we decarbonize the electric grid. With such technological tailwinds, we now must turn our attention to overcoming four barriers: slow infrastructure development, incumbents preventing uneconomic fossil retirement, market barriers to renewable energy, and fossil fuel-dependent communities impacted by transition.

Our **grid infrastructure** has been slow to adapt to the fundamentally new characteristics of clean electricity technologies. Renewable energy is always available somewhere, and long-

[1] https://research.noaa.gov/article/ArtMID/587/ArticleID/542/Rapid-affordable-energy-transformation-possible
[2] https://www.nrel.gov/analysis/re-futures.html, https://www.nrel.gov/docs/fy18osti/71465.pdf

distance transmission lines enable excess in one part of the country to compensate for deficits elsewhere. Despite clear consumer benefits from expanding transmission lines to access low-cost renewables and sharing resources over large areas, developing new long-distance transmission lines often takes more than 10 years, and many promising projects never materialize.[3] At the local distribution level, demand-side resources like storage are unable to participate meaningfully in grid management, restricting a crucial source of flexibility[4] to support renewable energy. New data management systems and advanced rate designs are needed, yet monopoly distribution utilities lack proper incentives to innovate and improve efficiency under conventional cost-based revenue regulation.

Legacy rules, procurement, and market products also favor incumbent fossil fuel-based technologies and make it more challenging for new technologies to participate in energy markets. Uneconomic fossil generators are not retiring as fast as they should, as backward-looking market designs (described in more detail in the answer to Question Two below) keep inefficient coal and natural gas units online. At the state level, utilities owning these assets resist retirement, and regulators lack the financial tools to accelerate retirement of uneconomic coal assets without harming customers[5].

Grid operators including utilities stack the deck against new renewables. In electricity markets, renewable energy, demand-side resources, and storage face significant barriers—in the form of obsolete rules—to participation and often cannot provide their full range of value to the market. In monopoly jurisdictions, utilities use outdated cost assumptions and trumped-up integration cost estimates to prevent competition from renewables in procurement processes. As evidence of the market potential, 280 gigawatts of wind and solar projects are stuck in queues for interconnection wholesale markets alone, enough to *treble* U.S. renewable generation capacity. Developers and financiers are ready, but cannot access the market.

A rapid renewable energy transition risks leaving behind entire communities dependent on coal mining and fossil power plants. These communities often rely on mining and power plants for both jobs and local tax revenue to support social services. But viable local clean alternatives exist – *local* wind or solar could replace three quarters of existing U.S. coal capacity at a lower cost to consumers,[6] and the federal government could support this just transition with financing and worker retraining programs in partnership with local utilities.

2. **In your testimony, you say: "The first policy I would recommend is to require that the Federal Energy Regulatory Commission be a merit driven, technology neutral, adjudicatory body required to run the power system at the lowest cost." Would Congress need to make changes to authorizing statues to implement the technology neutral FERC idea? Describe.**

[3] See answer to Question three below for ideas on how to jumpstart transmission development.
[4] https://energyinnovation.org/wp-content/uploads/2018/07/OrvisAggarwal-WholesaleMarketsFlexibility-June2018.pdf
[5] https://energyinnovation.org/publication/managing-the-utility-financial-transition-from-coal-to-clean-2/
[6] https://energyinnovation.org/publication/the-coal-cost-crossover/

Congress does not need to make changes to the Federal Power Act, which provides FERC's legal authority, but it does need to insist that FERC actually satisfies its obligations to ensure just and reasonable rates and avoid undue discrimination. In other words, Congress needs to hold FERC accountable to its obligation to be merit-driven and technology neutral while ensuring fair prices and reliability. As Commissioner Glick recently pointed out,[7] FERC has historically interpreted its just and reasonable rate authority and obligation to avoid undue discrimination as requiring technology neutrality.

FERC precedent and court interpretations clearly maintain that FERC's duty is to create a level playing field for all grid resources to compete on their technological and cost merits. Of course, if Congress wants to emphasize a certain aspect of that duty, for example, that FERC require grid operators to take proactive steps to develop (as transmission assets) and deploy (as grid services) distributed energy resources when they are the lowest cost option, additional legislation could accelerate those changes.

One recent FERC decision approving a pernicious policy in two FERC-regulated wholesale electricity markets[8] punishes states taking action on greenhouse gas emissions. These markets impose a Minimum Offer Price Rule (MOPR), the original intent of which is to mitigate against buyer-side market power, on renewable power plants receiving state support through a renewable portfolio standard (RPS). In effect, the MOPR requires renewables to bid in at an administratively determined price greater than the actual cost of running these plants, which is zero. This in turn raises the wholesale electricity price and supports fossil-fueled plants which otherwise would retire.

The MOPR undermines state choice – states are being forced to pay for fossil-fueled power plants that constituents don't want and market operators don't need for reliability. Congress should clarify that the MOPR should not be applied to resources receiving state policy support.

The root of these backward-looking market design policies is institutional lag behind the economic and political realities driving the U.S. toward more renewable energy. Markets using the MOPR still see renewables as undermining the integrity of markets, rather than redesigning the markets to fairly accommodate these resources. Reliability services markets are based upon, such as peak capacity needs, respond to the existing system's performance attributes. MOPR ensures that fossil resources receive revenues through capacity markets, even when a high renewables system would not need that same service. As renewable energy output varies with weather, complementary resources can and should provide flexibility, especially the underused resources of responsive demand, efficiency, and storage. Rather than defining new services to accommodate state constituents' preferences for low-cost renewables, market operators have kept one foot in the past, and FERC has been loath to correct them.

Serious technological changes are hitting the electricity grid, but the concomitant changes in market incentives and rules are lagging behind, as are the mechanisms to allow more demand side participation. FERC and the ISOs/RTOs wholesale electricity markets have done little to accelerate this transformation, instead in many cases setting rules prejudiced against clean

[7] page 15 https://www.eba-net.org/assets/1/6/%5BGlick_and_Christiansen%5D%5BFinal%5D.pdf
[8] PJM Interconnection and ISO-New England.

energy. As new technologies come online at lower prices and higher volumes, Congress should consider examining whether existing wholesale electricity market structures are equipped to handle today's technology.

3. **During Q&A, you stated the following in response to a question from Rep. McEachin: "One element I would propose is expanding transmission lines across the country to help balance renewables and balance the whole system. In fact, I think we should look at ways to streamline permitting. I advocate pre-zoning into red, yellow, and green zones, where red, you are just not going to build anything; green, you get a permit in 90 days if you meet the proper specs; and yellow is like everything today, it is an all-out war. So we just need to clean that up and save a lot of time and a lot of trouble." Can you provide more detail on how to design a red/yellow/green zoning process for transmission?**

The National Renewable Energy Laboratory (NREL) recently completed a study[9] of the value of interconnecting the entire country with high-voltage direct current (HVDC) transmission, modern transmission technology widely used by China to build out and improve the efficiency of its grid. NREL's study calculated up to a 3-to-1 benefit to cost ratio from a transmission overlay connecting East and West so that clean energy can reach cities and factories anywhere across the nation.[10] A similar study from the National Oceanic and Atmospheric Administration (NOAA) found that reducing carbon emissions 80 percent using today's technologies was possible at negligible incremental cost if we build out a national HVDC grid to support renewable development and integration.[11]

In the U.S., a HVDC transmission overlay linking the country's three electric grids and remote high-quality wind and solar resources with demand centers would reduce overall costs to consumers, open up massive opportunities for new renewable resources to access the market, and provide grid operators with additional tools to balance an increasingly variable electricity mix.

Reducing permitting and siting problems by pre-screening federal and state lands for transmission corridor suitability is crucial to enabling this transmission overlay. This is already ongoing in the Western U.S., through the federal West-wide Energy Corridors[12] planning process, and should be expanded to the rest of the country. The planning process identifies continuous strips of federal land across jurisdictional boundaries suitable for transmission development. Robust stakeholder engagement minimizes environmental, cultural, and other stakeholder conflicts. Eventually, this process will streamline federal siting, review, and permitting processes for transmission developers. Parallel efforts to engage with private landowners crucial to completing many of the corridors will increase the likelihood of success.

Data is also key to pre-screening transmission. The Western Electricity Coordination Council has developed the Environment Data Viewer,[13] a tool that should be expanded for the rest of the U.S.

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[9] https://cleanenergygrid.org/wp-content/uploads/2018/08/NREL-seams-transgridx-2018.pdf
[10] Unfortunately, DOE has refused to release the study. https://cleanenergygrid.org/interconnections-seam-study/
[11] https://research.noaa.gov/article/ArtMID/587/ArticleID/542/Rapid-affordable-energy-transformation-possible
[12] http://corridoreis.anl.gov/
[13] https://ecosystems.azurewebsites.net/WECC/Environmental/

to enable smart infrastructure development. The tool uses Geographic Information Systems (GIS) data for different land conflicts, enabling users to create maps of low-conflict land. For example, lowest conflict existing rights of way are green; low-conflict undeveloped land is yellow; and land with explicit environmental, infrastructure, or cultural conflicts ranges from orange to red. The tool uses professional judgment of transmission planners, Bureau of Land Management and U.S. Forest Service, environmental leaders, and even archaeologists to build the tool's classifications .

Some obvious "green" zones exist—along existing transmission corridors or highways, for example. These should be promptly identified and so-designated. Some places should be labelled "red," such as wilderness study areas, or areas with ecologically important biota. Making these strictly off limits can reduce time and money spent on fruitless pursuits.

Note that this recommendation does not contemplate relaxing environmental standards, but instead doing the work to designate these three classes in advance to reduce uncertainty, time, and money.

Besides providing corridors and data, the federal government can also facilitate inter-state cooperation on transmission development. Though all consumers should benefit from a more robust HVDC transmission network, these benefits are often not distributed equally among states. The largest beneficiaries of HVDC transmission are likely the producer state and the load center on the other end of the line, making states between the two reticent to accept transmission development without compensation. The federal government can facilitate dialogue between states involved.

4. **During the hearing, Rep. Palmer stated the following: "In California right now, there is a lawsuit that has been filed by minority group against the California Air Resources Board, because of the harm that it is doing to low income people. Since the effective date of California's greenhouse gas reduction law, the Global Warming Solutions Act, 41 states have reduced their per capita greenhouse gas emission more than California, but it had enormous negative impact on the people in California. So, I think, we have got to look at this in the broader spectrum of how this affects everybody, and the U.S. obviously I think we continue the best in the technologies to reduce our carbon emissions." As an energy expert living and working in California, what is your response to this statement?**

As the world's fifth largest economy, California is a global leader on climate change and a model of successful greenhouse gas reduction policy. As of 2016, only New York and the District of Columbia have lower per capita energy-related carbon dioxide emissions than California.[14] Rep. Palmer cites data related to per capita emissions reductions that ignores California's thirty-plus years of environmental leadership before enacting the Global Warming Solutions Act. In 2006 when the bill passed, California was already a national leader in renewable energy and used virtually no coal-fired power, the reduction of which accounts for the vast majority of U.S. emissions reductions since 2006. California has much work left to reduce emissions to meet its goals, but is well on its way to creating an equitable, affordable, low-carbon future.

[14] https://www.eia.gov/environment/emissions/state/analysis/pdf/stateanalysis.pdf at page 4.

Low-income community opposition to California's Global Warming Solutions Act is vastly overstated. The lawsuit takes issue with proposed measures in a planning document from the California Air Resources Board specifying measures that can reduce greenhouse gas emission in line with the state law – 40 percent below 1990 levels by 2030. The group backing the lawsuit, the Two Hundred, is represented by a law firm whose work has focused on fighting environmental protections in California for the last 30 years. Masquerading as a civil right issue, this lawsuit creates a pretext for removing the very environmental protections low-income residents depend on.

Recent polling[15] indicates low-income residents are more likely to support cap-and-trade than not. Disadvantaged communities and the organizations representing them recognize that climate change and pollution pose a real threat to the lives and economic security of low-income communities, and California has built vital protections for our communities into our climate laws. That's why dozens of disadvantaged community representatives support California's climate change policies and work constantly to ensure that they address poverty and pollution at the same time.

Of course, the revenue stream that pays for these programs is California's cap-and-trade program, which some have argued has a negative impact on the very same priority populations where climate investments are being made. The latest data show $1.9 billion (more than 57 percent) of all implemented dollars raised by cap-and-trade are benefiting state-identified disadvantaged communities and low-income communities. [16] These investments are creating new affordable housing, improving accessible and affordable mobility, lowering energy bills, and creating new jobs, while also reducing greenhouse gases. Legislation established parallel programs to improve air quality in historically disadvantaged communities[17] and study low-income barriers to adopting clean energy technologies.[18]

5. **During the hearing, members raised Chinese carbon pollution levels on numerous occasions. China's emissions now, and their future trajectory, are critical to addressing the climate crisis. Given your experience working in China, is the Chinese government implementing policies that will curb and ultimately reduce Chinese carbon pollution? Please Explain.**

It is true that without continued heroic public investment from the Chinese government, the world will fail to meet international emissions reduction goals necessary to limit warming to safe levels. It is also true that China has experienced rapid economic growth dependent on burning coal for industrial processes and electricity, resulting in citizens with higher incomes who now

[15] 44 percent of California residents with incomes under $40,000 favor cap-and-trade, while 39 percent oppose it. https://www.ppic.org/wp-content/uploads/ppic-statewide-survey-july-2018.pdf at 21.

[16] https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/2019_cci_annual_report.pdf?_ga=2.14451895.1868598449.1553707432-2139052204.1553538057 at viii.

[17] AB 617 is the most recent effort by the state to improve air quality, particularly in EJ communities. The law is in the early stages of implementation but it was achieved due to a high level of engagement by priority communities on the issue of air pollution.

[18] SB 350

drive gasoline-powered cars. One cannot be sanguine or naïve about the environmental problems China faces, nor the vast Chinese contribution to climate change.

But in many ways, China's efforts to combat climate change have dwarfed those of the U.S. Despite its rapid rise to the world's largest greenhouse gas emitter, the Chinese government has systematically implemented policies to curb its greenhouse gas pollution for more than a decade, and remains committed to doing so in the future.

The Chinese government began including explicit climate change targets in its Five-Year Plan (FYP) in 2011. China's initial greenhouse gas reduction goals were aimed at reducing carbon intensity (carbon per unit of GDP). By 2017 China had cut carbon intensity 46 percent from 2005 levels, honoring its voluntary international commitment to reduce carbon intensity 40 to 45 percent from the 2005 level by 2020 - three years ahead of schedule. Under the Paris Accord, China agreed to further reductions of carbon intensity 60-65 percent below 2005 levels by 2030, and will make "best efforts" to peak carbon emissions by or before 2030.

Through ambitious policy and public investment, China is now the world leader in two key clean energy technologies – renewable electricity and electric vehicles (EVs). Almost 30 percent of the world's renewable power capacity is in China, and in 2017, China added almost half the world's renewable power capacity. In China's 13th Five-Year Renewable Energy Development Plan, the government announced $373 billion in total renewable energy investment by 2020. This historic renewables investment played an outsized role in driving down the global solar module costs 90 percent since 2008.

China is also responsible for more EV sales annually than the rest of the world combined, and boasts the only city in the world with all-electric bus and taxi fleets: Shenzhen. BYD, the international leader in electric bus manufacturing, trails only Tesla in EV sales. As the world economy continues toward low-carbon development, China's industries are well positioned to take advantage.

China is evolving its command and control economic and emissions policy centered on mandates and subsidies into more sophisticated market approaches, starting with the world's largest carbon market, which will launch later this year (2019). Its current first phase only covers power generation accounting for some than 3.5 gigatons of annual carbon dioxide emissions, more than half of U.S. total annual emissions. The Chinese government plans to expand the market to cover other energy-intensive sectors.

Despite these policies, without more action China's emissions will continue to rise. Chinese climate goals are deeply influenced by international norms and leadership by other nations, and the loss of U.S. leadership in controlling greenhouse gases is definitely softening China's ambition. China begins designing new policies first by learning the best practices of other countries, often seeking to emulate innovative U.S. market design. U.S. leadership on low-carbon technology development and emissions reduction goals provides strong motivation for the Chinese government to continuously push for more aggressive goals.

The Honorable Ben Ray Luján

1a. How does a Clean Energy Standard, such as the Clean Energy Standard Act of 2019, put the United States on a trajectory towards producing electricity with net-zero carbon emissions by mid-century?

A clean energy standard (CES) such as the CESA of 2019 is an excellent way to decarbonize the power sector. The CESA of 2019 is a particularly good example of a CES, in that it allows for all types of clean energy technologies, and sets long-term targets with continuous improvement along the way, which will drive and sustain innovation. Such a bill would help rapidly decarbonize the power sector, and would incentivize clean energy companies to accelerate research and development, to meet a clear and aggressive long-term target.

By including all zero-carbon technologies, a CES provides a high degree of flexibility that helps decarbonize the power sector at the lowest cost. Additionally, it is already cheaper[19] in much of the country to build and run new clean energy than to simply pay for the operating costs of fossil plants, so a CES would actually help lower costs—right from the start.

An initial analysis of the bill using the Energy Policy Simulator (EPS)[20] – assuming the share of clean electricity increases linearly to reach 90 percent in 2040, then pushes toward 100 percent by 2050 – suggests the CESA of 2019 would reduce power sector emissions from 2005 levels by about 75 percent in 2035. By 2030, according to the EPS, this CES would save around 20,000 lives due to cleaner air. By 2040, that number rises to about 38,000; by 2050, it reaches about 70,000.

1b. How would it stimulate good, well-paying jobs? How can a clean energy standard help to promote U.S. technological leadership and R&D efforts and how would leading on this the climate benefit domestic businesses?

The renewable energy industry has become a major U.S. employer. E2's recent Clean Jobs America report[21] found nearly 3.3 million Americans working in clean energy – outnumbering fossil fuel workers by 3-to-1. Nearly 335,000 people work in the solar industry and more than 111,000 work in the wind industry, compared to 211,000 working in fossil fuel extraction, of which only 50,000 are coal miners. Clean energy employment grew 3.6 percent in 2018, adding 110,000 net new jobs (4.2 percent of all jobs added nationally[22] in 2018), employers expect 6 percent job growth in 2019.

Clean energy jobs offer higher wages than the national average, and are widely available to workers without college degrees, according to new Brookings Institution research.[23] Landing a clean energy job can equal an 8-19 percent increase in income, and 45 percent of all workers in

[19] https://energyinnovation.org/wp-content/uploads/2019/04/Coal-Cost-Crossover_Energy-Innovation_VCE_FINAL2.pdf
[20] https://us.energypolicy.solutions/
[21] https://www.e2.org/wp-content/uploads/2019/03/E2-2019-Clean-Jobs-America.pdf
[22] https://www.whitehouse.gov/articles/2018-ends-312000-jobs-created-december-strong-year-job-market/
[23] https://www.brookings.edu/research/advancing-inclusion-through-clean-energy-jobs/

clean energy production (e.g. electricians, installers, repairers, and power plant operators) have only a high school diploma, while still receiving higher wages than similarly educated peers in other industries.

E2 reports the fastest-growing jobs across 12 states were in renewable energy during 2018, and the U.S. Bureau of Labor Statistics already forecasts[24] the country's two fastest-growing jobs through 2026 will be solar installer (105% growth) and wind technician (96% growth) [25]. While we have no jobs estimate from this CES, it is reasonable to expect significant acceleration of these already encouraging trends, since the CES requires more than doubling current annual installations of wind and solar. Because the best wind and solar resources are available in the Great Plains, Southeast, and Southwest, opportunities abound for economic development in rural as well as urban areas.

1c. What other policies would complement a clean energy standard?

Congress should focus on three policy areas to enable a cheaper, faster clean electricity transition: Maximize existing transmission while streamlining future development, spur investment in flexible zero-carbon resources, and invest in building and end-use efficiency and electrification.

Maximize existing transmission while streamlining future development – Transmission is the platform that allows our nation's electricity system to function. As renewables provide increasing amounts of electricity in the U.S., we need to move it from the places with the greatest sun and wind resources to the places where people and businesses need to use it. We can do that by getting more out of our existing system[26], and by adding new lines. The federal government could build on the National Interest Electric Transmission Corridors[27] to overlay priorities for greenhouse gas reduction goals, reforming and aligning transmission incentives with greenhouse gas objectives.[28] The federal government could then partner with states to increase capacity on existing rights of way, as well as build new lines. President Lyndon Johnson provided a model for this in the 1960s with the build-out of the Pacific Intertie.[29] Texas also provides a model – pre-approving and building out transmission to "Competitive Renewable Energy Zones," where clean energy resources are abundant. Market mechanisms can then be used to select the lowest cost projects to build clean power in those zones.

Spur investment in flexible zero-carbon resources and get more out of existing assets - Solar and wind power are the cheapest new zero-carbon generation sources today, but their production varies with the availability of sunlight and wind, so they require a more flexible power system to realize their value as power system decarbonizers. Fortunately, many options are already available to draw additional flexibility out of the power system, including improved grid and

[24] https://www.bls.gov/ooh/fastest-growing.htm
[25] https://www.bls.gov/ooh/fastest-growing.htm
[26] Dynamic line rating gets more out of the system than existing practices in much of the country (for more, see https://issues.nawindpower.com/article/using-grid-weve-got). Where needed, we can beef up transmission capacity on existing rights of way.
[27] https://www.energy.gov/sites/prod/files/edg/media/NIETC_Fact_Sheet.pdf.
[28] See also transmission answer for Rep. Castor
[29] http://www.orkas.com/the-future-of-electric-transmission/.

transmission operations. Grid flexibility can also come from physical assets, such as batteries and fast-ramping natural gas plants, better co-optimization power supply and power demand.[30] Congress incentivize the investment in storage and demand response needed to balance a high-renewables grid, while also leveraging the national labs to partner with system operators to integrate better weather forecasting and market optimization software.

Invest in building and end-use efficiency and electrification - Using electricity more efficiently is a key policy for reducing the overall cost of a national CES. Because the majority of U.S. buildings standing today will still be standing in 2050, Congress must find ways to incentivize whole-building efficiency retrofits. To reduce overall costs and leverage the clean grid to decarbonize building heating, retrofits should combine appliance electrification and on-site clean power generation (e.g., rooftop solar), if practical and applicable.

A program with financial incentives including low-interest loans,[31] on-bill financing,[32] property tax financing,[33] and cash rebates at the point of equipment sale[34] for building decarbonization retrofitting could improve economics and stimulate investment. Programs should also encourage pay-for-performance, increasing the incentive for efficiency measures that reduce grid costs.[35] Incentives should cover electrification for the big end-uses – building heat, water heat, and clothes drying, while implementing appliance standards that ensure maximum efficiency and customer savings.

2. **Would a low-carbon grid be as reliable and resilient as a predominately fossil fuel driven grid? Please explain.**

Cleaning up the electricity supply brings different but manageable resilience and reliability problems. To reduce outages and improve security, policymakers should focus on the main causes of outages – the aging and vulnerable transmission and distribution systems.

A more distributed and decentralized grid relying on local solar and storage can be more resilient to centralized threats. Relying on smaller, uncorrelated power generators over a larger footprint improves reliability. At the same time, widening grid balancing areas and strengthening interregional transmission connections also reduce the risk associated with single generator or transmission failures.

With respect to a low-carbon power generation mix, the transition from fuel-based power to higher shares of renewable energy affects bulk power system reliability and resilience in a blend of both positive and negative ways.

For human-caused events, such as cyber or physical attacks, renewables can help to reduce fuel supply risk. Coal relies on rail delivery, which is subject to physical attacks, since roughly 40

[30] https://energyinnovation.org/wp-content/uploads/2017/10/A-Roadmap-For-Finding-Flexibility-In-Wholesale-Power-Markets.pdf
[31] https://www.energy.gov/savings/low-interest-energy-loan-programs
[32] https://aceee.org/blog/2019/04/bill-financing-gains-ground-faces
[33] https://www.energy.gov/eere/slsc/property-assessed-clean-energy-programs
[34] https://www.smud.org/en/Rebates-and-Savings-Tips/Improve-Home-Efficiency
[35] https://www.brookings.edu/research/advancing-inclusion-through-clean-energy-jobs/

percent of U.S. coal comes from Wyoming's Powder River Basin, and nearly all via the 103-mile Joint Line rail corridor.[36] And natural gas pipelines are vulnerable to cyber and physical attacks.[37] As demonstrated during the recent polar vortexes, coal piles on-hand can freeze[38], and co-dependence on natural gas for heating and generation during extreme cold can threaten resource availability. Prolonged heat waves can leave nuclear unusable[39] if cooling water is too hot.

But renewable energy sources are not automatically resilient. A robust grid requires strategies to deal with natural events, such as adverse weather. Hydroelectric generation is drought-vulnerable, while cloud cover from intense storms and hurricanes can threaten solar availability. Extreme winds may force partial wind curtailment for short periods of time.

Resilience can be achieved first by strengthening the distribution system for utilities—which causes by far the most power interruptions. [40] Second, by making the transmission grid more "islandable," meaning that grids can automatically isolate blackouts in small areas so they do not cascade through the system. Third, having a heterogenous set of clean energy sources and geographically dispersed supplies provides insurance against failures. Smart strategies to manage demand via demand response technologies gives many more options to grid operators. And of course, energy efficiency dramatically reduces stresses on the grid, and allows for more "ride through" in the case of disruption.

The upshot is that with smart operations and policy, the grid can be made more resilient and more reliable, even as we move to clean energy at scale.

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[36] https://www.nap.edu/read/11977/chapter/7
[37] http://docs.house.gov/meetings/HM/HM07/20160419/104773/HHRG-114-HM07-Bio-ParfomakP-20160419.pdf
[38] https://www.greentechmedia.com/articles/read/as-extreme-weather-forces-coal-to-falter-where-will-resilience-come-from#gs.frgowa
[39] http://www.unisdr.org/files/1145_ewheatwave.en.pdf
[40] https://rhg.com/research/the-real-electricity-reliability-crisis-doe-nopr/