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Committee on the Budget

Committee Hearing on

"Beyond the Breaking Point: The Fiscal Consequences of Climate Change on Infrastructure"

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Introduction

Good morning, Chairman Whitehouse, Ranking Member Grassley, and Members of the Committee.

My name is Susan Tierney.[1] I am a Senior Advisor at Analysis Group, an economic consulting firm where I specialize in policy, regulation, economics, environmental, and innovation issues associated with the electric and gas industries.

Thank you for inviting me to testify at this important hearing to explore the implications of climate change on the nation's critical energy infrastructure. I am testifying on my own behalf at today's hearing and it is an honor to share my thoughts and observations with you.

I have two main points to share with you today:

- First, the nation's energy infrastructure is already being adversely impacted by the changing climate and related extreme weather events. Extreme cold and hot weather, droughts, flooding, wildfires, hurricanes, tornadoes, derechos, and other events are leading to power outages and fuel shortages.
- Second, given the nation's dependence on well-functioning energy systems and the energy markets enabled by that infrastructure, the power outages and fuel shortages we are experiencing are producing great human suffering and costs. This happens both directly – by disrupting access to heating and cooling of buildings and by sometimes leading to loss of life – and indirectly – by disrupting electricity supply to other critical services (like water supply, wastewater treatment, transportation, phone, internet and other telecommunications) and causing energy prices to spike and to increase the costs and energy burdens on millions of households.

[1] I have provided my bio at the end of this testimony.

In recognition of the Budget Committee's jurisdiction, I have focused on describing these circumstances rather than talking about solutions to them (including reducing GHG emissions from the energy systems), although I spend the lion's share of my work on the latter in hopes that the former impacts do not continue to worsen in the years ahead.[2]

Overview: Impacts of the changing climate on U.S. energy infrastructure

We are already witnessing the many ways in which the regions of the country are being hit by extreme weather events in our daily news.

The circumstances we face are not surprising, but they are challenging.

Let's review the types of ways in which such extreme weather events are impacting critical energy infrastructure. For example:

- Winter storm Elliott in December 2022 not only wreaked havoc on air and ground travel; it also took out power to hundreds of thousands of consumers in the Central and Eastern U.S.[3] PJM, the 13-state grid operator in the MidAtlantic/Midwest region, reported that a quarter of the region's electric generating capacity was offline, with gas-fired power plants accounting for 70% of unplanned outages due to equipment problems and lack of gas supply.[4] Before it could no longer do so, PJM had been exporting power to neighboring utilities in the Tennessee Valley Authority region and the Carolinas where rolling blackouts were underway.[5]

- Winter Storm Uri brought severe, sustained cold temperatures, snow and ice to Texas and other Central and Southwest states in February 2021. Many oil and natural gas production facilities froze, disrupting fuel supplies to power plants, homes and businesses, blacking out the grid across much of the state, and causing loss of heating, medical, water, and other basic services of the state's most vulnerable people. Outages occurred at all types of power plants, but freezing issues and fuel supply issues led to 75% of all of the unplanned outages or failures, with the majority of outages at fossil units.[6] The Texas grid operator instituted the largest set of deliberate rolling blackouts

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[2] I have worked for four decades on economics, markets, regulation, and policy affecting the nation's energy industries, particularly the power sector. During the past two decades in particular, my work has focused on issues related to reliable, economical and clean electricity supply, including on several committees of the National Academies of Sciences, Engineering and Medicine (with the following committee reports: *The Future of Electric Power* (2021), *Enhancing the Resilience of the Nation's Electricity System* (2017), *The Role of Net Metering in the Evolving Electricity System* (20221), and *Accelerating the Decarbonization in the United States* (2021)).
[3] "Timeline: 2022 Winter Storm Elliott," Homeland Security Digital Library, https://www.hsdl.org/c/tl/2022-winter-storm-elliott/.
[4] Ethan Howland, "Gas-fired generation accounted for 70% of unplanned outages in Winter Storm Elliott: PJM," Utility Dive, July 18, 2023, ttps://www.utilitydive.com/news/pjm-winter-storm-elliott-report-gas-generation/688217/.
[5] PJM, "Winter Storm Elliott Event Analysis and Recommendation Report," July 17, 2023, https://pjm.com/-/media/library/reports-notices/special-reports/2023/20230717-winter-storm-elliott-event-analysis-and-recommendation-report.ashx.
[6] The investigation by the Federal Energy Regulatory Commission and the North American Electric Reliability Corporation concluded that 44% of the unplanned outages, equipment deratings and start-up failures were due to freezing issues, another 31% were related to fuel issues and 21% were due to mechanical/electrical issues. The majority (58%) of the affected generating units were gas-fired units (604 units in total); another 27% were at wind facilities (285 units), 6% were at 58 coal units, 2% were at 22 solar units, and 7% were at other units. Staff of the FERC and NERC, "The February 2021 Cold Weather Outages in Texas and the South

ever introduced in the country in order to prevent full collapse of the electric grid. Electricity prices spiked to over 100 times the "normal" price averages, leaving many consumers with unbearable electricity bills. At least 246 people died, and estimates of the financial losses range from $80-$130 billion.[7]

- During 2022, four severe weather events – frigid winter conditions in New England in January, heat waves in Texas in July, September heat wave in much of the West, and cold weather in the Pacific Northwest in December – led to major energy supply constraints, demand increases, and price spikes in natural gas and electricity.[8]

- The on-going, decades-long drought in the Southwest has gradually reduced Hoover Dam's electric generating capacity by one-half,[9] and greatly constrained power allocations to consumers in Arizona, California and Nevada. (The last time that Hoover dam was close to capacity was in 1999.[10]) A recent study more generally estimated that the "overlooked consequence of droughts dramatically increase carbon emissions, methane leakage, and local air pollution and deaths" amounted to $20 billion between 2001 and 2021 as a result of the power generated by fossil fuels when drought decreases the availability of hydropower. Across the West, this has cost "tens of billions of dollars over the past decade," and in "California alone, the increase in fossil generation caused by drought between 2012 and 2016 led to more than $5 billion in damages, two-and-a-half times the direct economic cost of switching from cheap hydropower to pricey fossil fuels."[11]

- The combination of extreme heat, high and erratic winds and catastrophic wildfires in Northern California (sometimes ignited by electric transmission equipment) have also stressed large sections of the California power grid. Over several years, hundreds of

Central United States," November 2021, c.gov/media/February-2021-cold-weather-outages-texas-and-south-central-united-states-ferc-nerc-and.

[7] Jess Donald, "Winter Storm Uri 2021: The Economic Impact of the Storm," Fiscal Notes, published by the Texas Comptroller of Public Accounts, October 2021, citing a survey by the University of Houston ("The Winter Storm of 2021" survey), https://comptroller.texas.gov/economy/fiscal-notes/2021/oct/winter-storm-impact.php. 70% of Texas had no electricity, 49% had no running water for days in February 2021. Patrick Svitek, "Texas puts final estimate of winter storm death toll at 246," The Texas Tribune, January 2, 2022, updated January 2, 2022, https://www.texastribune.org/2022/01/02/texas-winter-storm-final-death-toll-246/.

[8] EIA, "Wholesale U.S. electricity prices were volatile in 2022," *Today in Energy*, January 10, 2023, https://www.eia.gov/todayinenergy/detail.php?id=55139.

[9] Rachel Ramirez, "The West's historic drought is threatening hydropower at Hoover Dam," CNN, August 16, 2022, https://www.cnn.com/2022/08/16/us/hoover-dam-hydropower-drought-climate/index.html; Umair Irfan, "How the Western drought is pushing the power grid to the brink," Vox, August 16, 2022, https://www.vox.com/23292669/drought-2022-power-energy-grid-lake-mead-climate-heat-hoover-dam; Sonal Patel, "Drought-Crippled Hoover Dam, Glen Canyon Hydropower Plants Operating at Substantially Decreased Capacity," Power Magazine, September 2, 3021, ttps://www.powermag.com/drought-crippled-hoover-dam-glen-canyon-hydropower-plants-operating-at-substantially-decreased-capacity/.

[10] Justine Calma, "What record-low water levels at the Hoover Dam reservoir look like from space," The Verge, July 22, 2022, https://www.theverge.com/2022/7/22/23274082/lake-mead-record-low-nasa-satellite-images-hoover-dam-reservoir.

[11] Emily Halnon, "Droughts in Western states drive up emissions and threaten human health," Stanford News, July 17, 2023, https://news.stanford.edu/2023/07/17/western-droughts-drive-emissions-costs/, reporting on the new study by Stanford researchers: Minghao Qiu, Nathan Ratledge, Ines M.L. Azevedo, Noah Diffenbaugh, and Marshall Burke, "Drought impacts on the electricity systems, emissions, and air quality in the United States," Proceedings of the National Academy of Sciences (PNAS), July 6, 2023, https://www.pnas.org/doi/10.1073/pnas.2300395120.

people died. Hundreds of thousands have been impacted by widespread, repeated power outages and price spikes. The utility has now instituted anticipatory Public Safety Power Shutoffs during high wildfire risk conditions, shutting off power to more than 1 million customers in 2019 with an estimated economic cost of $2 billion.[12]

- The impacts on energy systems of some of the more notorious hurricanes in recent years are stunning in their consequences: Hurricane Katrina: "In the initial days of the August 2005 storm, approximately one-third of domestic oil production, one-sixth of domestic natural gas production, and nearly 10 percent of the nation's refinery capabilities were taken offline, and an estimated 4.5 million customers in Louisiana and Mississippi lost electrical power... [S]everal major refineries are expected to be out of commission for months as a result of structural damage."[13] U.S. oil and gas prices spiked and remained at double their normal level for months,[14] and raised the cost of natural gas on the order of $50 billion during the 10-month period after the hurricane.[15]

- Even a decade ago, the Council of Economic Advisors and the Department of Energy estimated that power outages due to severe weather were costing the nation "between $18 billion and $33 billion per year. In a year with record-breaking storms, the cost can be much higher. For example, weather-related outages cost the economy between $40 billion and $75 billion in 2008, the year of Hurricane Ike."[16] In inflation adjusted terms, those amounts would be between $24 billion and $44 billion per year on average, or between $53 billion and $99 billion in 2008.[17]

I could go on and on. But beyond the loss of life, the economic impacts on utilities, other energy companies, their residential and business customers, and the economy at large are staggering. The broad range of these impacts are illustrated in the figure 1 below (from the 2018 National Climate Assessment[18]).

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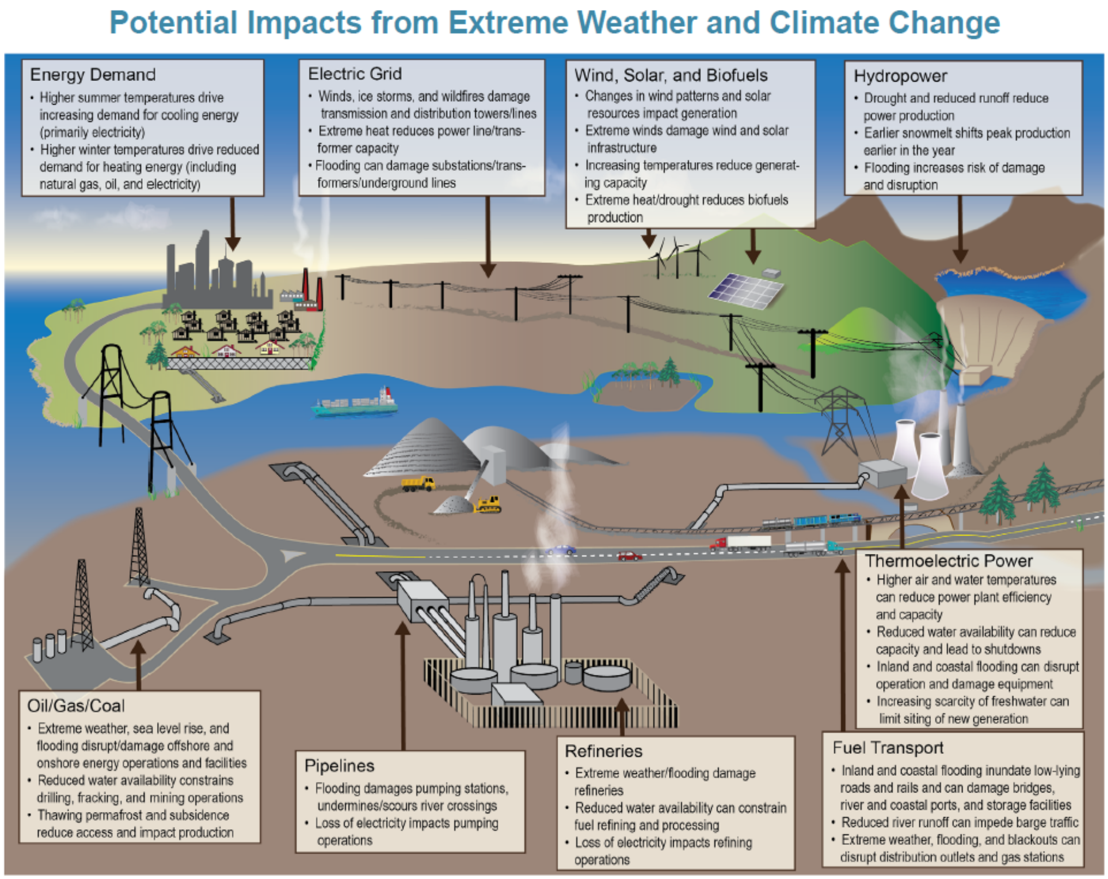
[12] Rocky Mountain Institute, "Reimagining Grid Resilience," 2020, cited by Frank Rusco of the General Accountability Office in testimony before the Senate Environment and Public Works Committee, "Electricity Grid Resilience: Climate Change Is Expected to Have Far-reaching Effects and DOE and FERC Should Take Actions," March 10, 2021, https://www.gao.gov/assets/gao-21-423t.pdf.
[13] Carrie Conway, "The Challenge of Energy Policy in New England," Federal Reserve Bank of Boston Working Paper 05-2, https://www.bostonfed.org/-/media/Documents/Workingpapers/PDF/neppcwp0502.pdf.
[14] Energy Information Administration, https://www.eia.gov/dnav/ng/hist/rngwhhdm.htm.
[15] This is calculated based on a comparison of (a) actual average monthly natural gas prices at Henry Hub times actual monthly gas deliveries for the 12-month period of August 2005 through July 2006, and (b) the same monthly natural gas delivery volumes for the August 2005-July 2006 period times the average price of natural gas (Henry Hub) for the prior year (i.e., August 2004-July 2005). EIA data for monthly gas deliveries (http://www.eia.gov/oil_gas/natural_gas/data_publications/natural_gas_monthly/ngm.html) and spot prices (http://www.eia.gov/dnav/ng/hist/rngwhhdm.htm).
[16] Executive Office of the President, "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages," August 2013, https://www.energy.gov/articles/economic-benefits-increasing-electric-grid-resilience-weather-outages.
[17] This is calculated using a 1.32 change in the Consumer Price Index between 1/2012 and 1/2023. https://data.bls.gov/cgi-bin/cpicalc.pl?cost1=1&year1=201201&year2=202301.
[18] Energy Chapter of the Fourth National Climate Assessment https://nca2018.globalchange.gov/chapter/4/ (hereafter "2018 NCA").

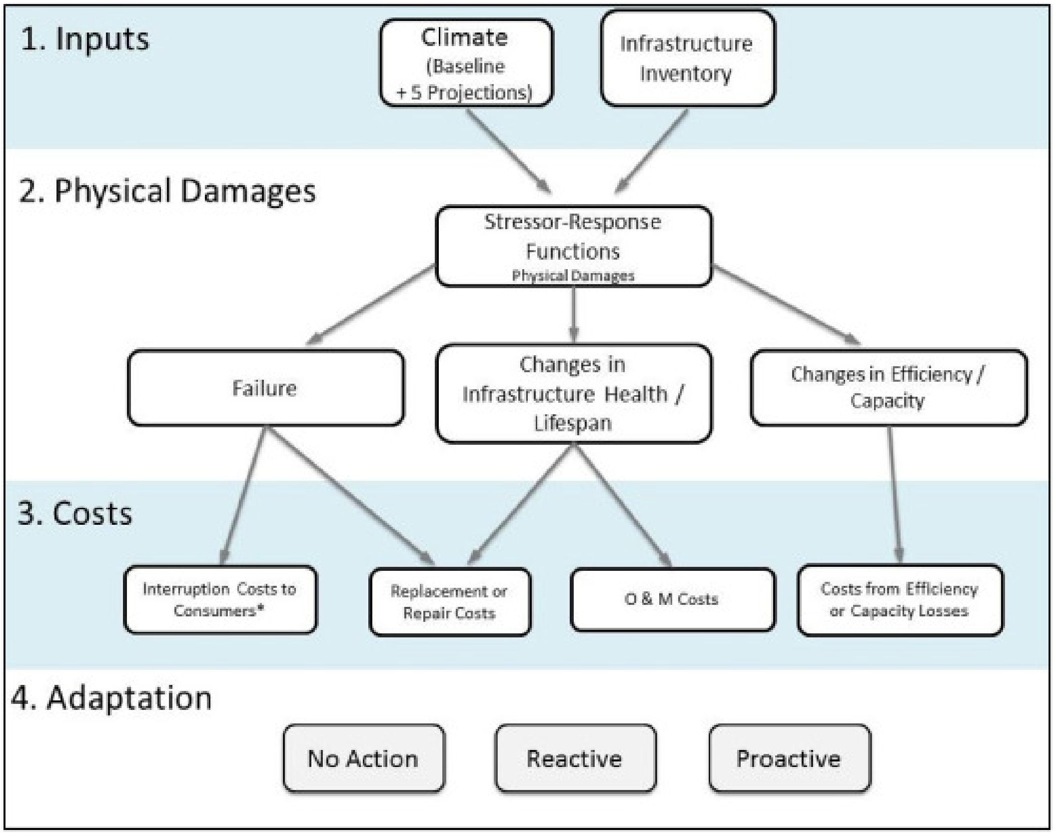


Extreme weather and climate change can potentially impact all components of the Nation's energy system, from fuel (petroleum, coal, and natural gas) production and distribution to electricity generation, transmission, and demand. *From Figure 4.1 (Source: adapted from DOE 2013* [23]*).*
2018 National Climate Assessment (Energy Chapter).

The recent Stanford study that estimated the impacts of drought on increased fossil generation to replace lost hydropower potential used the following type of analytic framework, which could be adapted to assess the costs of climate change on other energy infrastructure as well.[19] Using this framework, the authors of that 2023 study estimated that although there is great uncertainty about the location and timing of climate impacts vis-à-vis particular infrastructures, the direct impacts resulting from capacity degradation, increased operations and maintenance (O&M) costs and decreased longevity of equipment could be between $3.8 billion to $7.6 billion (in inflation adjusted dollars[20]) each year by 2030 – and this did not include either the direct

[19] Emily Halnon, "Droughts in Western states drive up emissions and threaten human health," Stanford News, July 17, 2023, https://news.stanford.edu/2023/07/17/western-droughts-drive-emissions-costs/, reporting on the new study by Stanford researchers: Minghao Qiu, Nathan Ratledge, Ines M.L. Azevedo, Noah Diffenbaugh, and Marshall Burke, "Drought impacts on the electricity systems, emissions, and air quality in the United States," Proceedings of the National Academy of Sciences (PNAS), July 6, 2023, https://www.pnas.org/doi/10.1073/pnas.2300395120.
[20] The original study indicates that costs ranged between $3 billion and $6 billion in 2017$. Using an inflation adjustment factor of 1.26x, the costs on 2023$ would be as indicated above.

infrastructure destruction from extreme events or the economic impact of outages or prices spikes to consumers and the economy.



M. Qiu et al, "Drought impacts on the electricity systems, emissions, and air quality in the United States," PNAS, July 6, 2023.

Electric utilities experiencing actual or expected storm damage to infrastructure are having to arrange and pay for new and different insurance coverage (at higher cost) and/or undertake system hardening investments. S&P Global's 2018 report on the risk of climate changes on energy infrastructure stated that: "When purchasing insurance to protect their assets, utilities must balance the level of insurance against the cost to the ratepayers. The higher level of insurance purchased, the more protected the utility may be from climate change and related natural disasters. Yet that increased cost would eventually be reflected on customers' bills. While the industry has always had to balance these conflicting risks, the pendulum may be swinging toward retaining a higher level of insurance because of more frequent and destructive weather-related events. The 'one-in-100-year' storm or wildfire has become a more commonplace occurrence and insurance decisions simply based on past performance may not be indicative of today's environment."[21]

[21] Gabe Grosberg, "Can U.S. Utilities Weather the Storm," S&P Global, November 8, 2018, https://www.spglobal.com/en/research-insights/articles/can-u-s-utilities-weather-the-storm.

These are not isolated conditions, because climate change is impacting energy infrastructure everywhere around the country – and in unpredictable time frames. The intensity and character of heat waves, extreme cold snaps, severe winds, ice storms, hurricanes, and other climate change-related conditions are affecting all parts of the country. The costs to maintain, repair or replace destroyed, degraded or damaged energy infrastructure are real and are showing up in the energy bills of energy consumers and the expenditures of governments. Increasingly, such costs are also needing to be incurred even before future events, in order to harden infrastructure and make it more resilient and to ensure that other critical infrastructure and services can still be maintained.

Clearly, one of the problems in Texas a during Winter Storm Uri (which also affected other parts of the South and Central/Midwest regions of the country) is that energy companies had not hardened their facilities (e.g., for very cold weather), even in spite of recommendations from federal energy/reliability regulators that they do so.[22] Although the Texas Public Utility Commission has adopted and enforced new weatherization rules for power plants, the Texas Railroad Commission (which regulates intrastate natural gas lines) has reportedly not taken similar enforcement steps[23] – in spite of the freezing and fuel supply issues that affected power plant outages during Uri.

This situation points to the interrelated nature of the nation's critical energy infrastructures, and the acute need to avoid being penny wise and pound foolish in light of the exceedingly high costs of climate-related events on consumers' and the public's safety and welfare.

More detail: Impacts of the changing climate on U.S. energy infrastructure

The effects of the changing climate have been detailed and explained in the energy chapters of the two most recent National Climate Assessment (2014 and 2018). Because these assessments offer so much relevant information to the topic of the Committee's hearing today, I have pulled extensive excerpted quotes[24] from them (and I was co-lead author of the Energy Chapter in the 2014 National Climate Assessment[25]).

> The Nation's energy system is already affected by extreme weather events, and due to climate change, it is projected to be increasingly threatened by more frequent and longer-lasting power outages affecting critical energy infrastructure and creating fuel

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[22] "Despite multiple prior recommendations by FERC and NERC [in 2011 and 2018], as well as annual reminders via Regional Entity workshops, that generating units take actions to prepare for the winter (and providing detailed suggestions for winterization), 49 generating units in SPP (15 percent, 1,944 MW of nameplate capacity), 26 in ERCOT (7 percent, 3,675 MW), and three units in MISO South (four percent, 854 MW), still did not have any winterization plans, and 81 percent of the freeze-related generating unit outages occurred at temperatures above the unit's stated ambient design temperature. Generating units that experienced freeze-related outages above the unit's stated ambient design temperature represented about 63,000 MW of nameplate capacity." Staff of the FERC and NERC, "The February 2021 Cold Weather Outages in Texas and the South Central United States," November 2021, c.gov/media/February-2021-cold-weather-outages-texas-and-south-central-united-states-ferc-nerc-and.
[23] Corbin Hair, "Politico Power Switch," July 20, 2023.
[24] The excepts below do not include the footnotes with their citations to the original source documents.
[25] See: Energy Chapter of the Third National Climate Assessment, https://nca2014.globalchange.gov/report/sectors/energy (hereafter "2014 NCA").

availability and demand imbalances. The reliability, security, and resilience of the energy system underpin virtually every sector of the U.S. economy. Cascading impacts on other critical sectors could affect economic and national security. (2018 NCA, with a similar finding in the 2014 NCA.[26])

Disruptions in services in one infrastructure system (such as energy) will lead to disruptions in one or more other infrastructures (such as communications and transportation) that depend on other affected systems. Infrastructure exposed to extreme weather and also stressed by age or by demand that exceeds designed levels is particularly vulnerable. (2014 NCA.) (See Figure below from the 2014 NCA.)

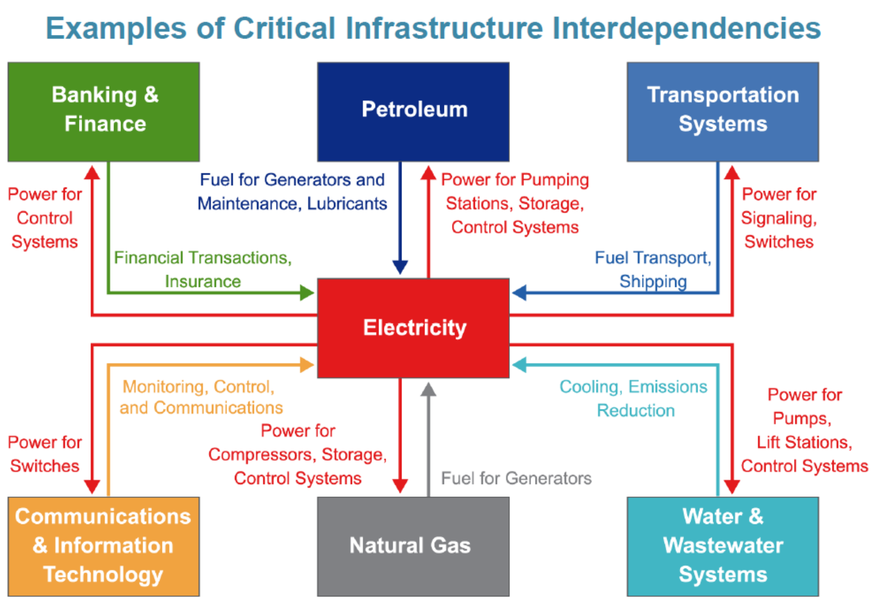

Figure 4.4: The interdependence of critical infrastructure systems increases the importance of electricity resilience, as disruptions to energy services are projected to affect other sectors. Shown above is a representative set of connections, and the complex relationships are analogous to other systems (Ch. 17: Complex Systems). A more complete listing of these linkages can be found at DOE.[2] Source: adapted from DOE 2017.[2]

2014 National Climate Assessment (Energy Chapter)

Energy systems and the impacts of climate change differ across the United States, but all regions will be affected by a changing climate. (2018 NCA.)

The principal contributor to power outages, and their associated costs, in the United States is extreme weather. Extreme weather includes high winds, thunderstorms, hurricanes, heat waves, intense cold periods, intense snow events and ice storms, and extreme rainfall. Such events can interrupt energy generation, damage energy resources and infrastructure, and interfere with fuel production and distribution systems, causing fuel and electricity shortages or price spikes. Many extreme weather impacts are

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[26] "Much of America's energy infrastructure is vulnerable to extreme weather events. Because so many components of U.S. energy supplies – like coal, oil, and electricity – move from one area to another, extreme weather events affecting energy infrastructure in one place can lead to supply consequences elsewhere." (2014 NCA.)

expected to continue growing in frequency and severity over the coming century, affecting all elements of the Nation's complex energy supply system and reinforcing the energy supply-and-use findings of prior National Climate Assessments. (2018 NCA.)

Extreme weather can damage energy assets—a broad suite of equipment used in the production, generation, transmission, and distribution of energy—and cause widespread energy disruption that can take weeks to fully resolve, at sizeable economic costs. High winds threaten damage to electricity transmission and distribution lines, buildings, cooling towers, port facilities, and other onshore and offshore structures associated with energy infrastructure and operations. Extreme rainfall (including extreme precipitation events, hurricanes, and atmospheric river events) can lead to flash floods that undermine the foundations of power line and pipeline crossings and inundate common riverbank energy facilities such as power plants, substations, transformers, and refineries. River flooding can also shut down or damage fuel transport infrastructure such as railroads, fuel barge ports, pipelines, and storage facilities. (2018 NCA.)

The petroleum, natural gas, and electrical infrastructure along the East and Gulf Coasts are at increased risk of damage from rising sea levels and hurricanes of greater intensity…This vulnerable infrastructure serves other parts of the country, so regional disruptions are projected to have national implications… More frequent and intense extreme precipitation events are projected to increase the risk of floods for coastal and inland energy infrastructure, especially in the Northeast and Midwest. (2018 NCA.)

Temperatures are rising in all regions, and these increases are expected to drive greater use of air conditioning…. [H]igher temperatures reduce the thermal efficiency and generating capacity of thermoelectric power plants and reduce the efficiency and current-carrying capacity of transmission and distribution lines. (2018 NCA.)

Energy systems in the Northwest and Southwest are likely to experience the most severe impacts of changing water availability, as reductions in mountain snowpack and shifts in snowmelt timing affect hydropower production… Drought will likely threaten fuel production, such as fracking for natural gas and shale oil; enhanced oil recovery in the Northeast, Midwest, Southwest, and Northern and Southern Great Plains; oil refining; and thermoelectric power generation that relies on surface water for cooling. (2018 NCA.)

If greenhouse gas emissions continue unabated (as with the higher scenario [RCP8.5]), rising temperatures are projected to drive up electricity costs and demand. Despite anticipated gains in end use and building and appliance efficiencies, higher temperatures are projected to drive up electricity costs not only by increasing demand but also by reducing the efficiency of power generation and delivery, and by requiring new generation capacity costing residential and commercial ratepayers by some estimates up to $30 billion per year by mid-century. (2018 NCA.)

> Most generation technologies have experienced fuel deliverability challenges in the past. Coal facilities typically store enough fuel onsite to last for 30 days or more, but extreme cold can lead to frozen fuel stockpiles and disruptions in train deliveries. Natural gas is delivered by pipeline on an as-needed basis. Capacity challenges on existing pipelines, combined with the difficulty in some areas of siting and constructing new natural gas pipelines, along with competing uses for natural gas such as for home heating, have created supply constraints in the past. Renewables supplies are not immune from storage issues, as hydropower is particularly sensitive to water availability and reservoir levels, the magnitude and timing of which will be influenced by a changing climate. (2018 NCA.)
>
> While the Nation's energy system is changing, it is also aging, with the majority of energy infrastructure dating to the 20th century: 70% of the grid's transmission lines and power transformers are over 25 years old, and the average age of power plants is over 30 years old. The components of the energy system are of widely varying ages and conditions and were not engineered to serve under the extreme weather conditions projected for this century. Aging, leak-prone natural gas distribution pipelines and associated infrastructures prompt safety and environmental concerns. (2018 NCA.)

The upcoming Fifth Assessment[27] will surely point to the broad impacts on energy infrastructure and systems, and the disparate impacts on poor, disadvantaged communities in both rural and urban areas in the states represented by every member of this community and across the United States.

Conclusion;

Climate change is impacting energy infrastructure everywhere around the country – and in unpredictable time frames. But when such impacts happen, they predictably involve high costs – incurred after the fact to repair the infrastructure, increasing the energy bills of consumers and the expenses of governments. Increasingly, such costs are also being incurred before future events, in order to harden infrastructure and make it more resilient and to ensure that other critical infrastructure and services can still be maintained.

I appreciate that the Budget Committee has given me this opportunity to share information with the Senate. Given the kinds of impacts I have described with you today, I conclude by encouraging Congress to act as swiftly as possible to address the emissions that are the root cause of the changing climate.

[27] Fifth National Climate Assessment, https://www.globalchange.gov/nca5.

Bio of Susan F. Tierney, Ph.D.

I am a Senior Advisor at Analysis Group, an economic consulting firm headquartered in Boston, with other U.S. offices in California, Colorado, Illinois, New York, Texas, and Washington, D.C.

I have been involved in issues related to public utilities, ratemaking and electric industry regulation, electric system reliability and resilience, and energy and environmental economics and policy for over 35 years. During this period, I have worked on electric and gas industry issues as a utility regulator and energy/environmental policy maker, consultant, academic, and expert witness. I have been a consultant and advisor to private and publicly owned energy companies, grid operators, government agencies, energy consumers, environmental organizations, foundations, Indian tribes, and other organizations on a variety of economic and policy issues in the energy sector.

My clients have been located in places across the U.S., from California (where I was raised), to New England (where I lived for 35 years), to other states in all regions of the nation.

Before becoming a consultant, I held several senior governmental policy positions in state and federal government, having been appointed by elected executives from both political parties. I served as the Assistant Secretary for Policy at the U.S. Department of Energy. I held senior positions in the Massachusetts state government as Secretary of Environmental Affairs; Commissioner of the Department of Public Utilities; Executive Director of the Energy Facilities Siting Council; and chair of the Board of the Massachusetts Water Resources Authority.

My Masters Degree and Ph.D. in regional planning are from Cornell University. I previously taught at the University of California at Irvine and at MIT. I am a member of the advisory councils at New York University's Institute for Policy Integrity and the National Academies of Sciences, Engineering and Medicine's Climate Crossroad Initiative.

I currently sit on several non-profit boards and commissions, including as: chair of the board of Resources for the Future; a director of World Resources Institute; and a trustee of the Barr Foundation and of the Alfred P. Sloan Foundation. I currently chair the National Academies' Board on Energy and Environmental Systems and am a member of the Academies' Committee on Accelerating the Decarbonization of the U.S. Energy System. I chair the National Renewable Energy Laboratory's External Advisory Council; I previously chaired the U.S. Department of Energy's Electricity Advisory Committee and was a member of the National Academies' committees on resiliency of the U.S. electric system and on the future of the nation's electric system. I serve on the NYISO's Environmental Advisory Council. I was co-lead convening author of the energy chapter of the Third National Climate Assessment. I previously served on the Secretary of Energy's Advisory Board and chaired the Policy Subgroup of the National Petroleum Council's study of the North American natural gas base.

After 35 years in Boston, I moved with my husband to Colorado in 2016 and recently moved to Illinois.