Atlantic Council
GLOBAL ENERGY CENTER

ISSUE BRIEF
JANUARY 2021

Ensuring Energy Security in a Renewables World

BEN HERTZ-SHARGEL

Introduction

The march toward a decarbonized generator fleet, anchored by renewables, has begun. Despite the destabilizing effects that renewables have on electricity supply and demand balance, as well as electricity prices, their emissions-free profile and low cost are increasingly winning them market share. Six of the sixteen US states that have committed to 100 percent clean energy targets require that the clean energy be renewable.[1] Large corporations are increasingly securing power purchase agreements with renewables projects, with high-visibility initiatives such as RE100 putting brand pressure on corporations to commit to 100 percent renewable energy targets.[2] In tandem with this sustainability-driven demand, the cost of renewable supply continues to fall. The overnight installed cost of renewables is projected to decline faster than that of any other resource, with the exception of the combined-cycle gas turbine (CCGT), a competitor freighted with both fuel costs and, likely, carbon costs (see Figure 1).

While direct carbon capture remains an option for natural gas–fired generation to compete with renewables as an emissions-free source, the cost of retrofits today is prohibitive, at $1,000 per kilowatt—doubling the installed cost of the resource—and the marginal production costs by 2035 are expected to be in the vicinity of 5.3 cents per kilowatt-hour, barely below today's cost.[3]

Other low-carbon technologies seeking to compete with renewables face similar challenges from a levelized cost of energy perspective. While hydrogen holds promise as a lightweight energy storage alternative to batteries—for example, to power construction and commercial fleet vehicles—it will require massive

The Global Energy Center promotes energy security by working alongside government, industry, civil society, and public stakeholders to devise pragmatic solutions to the geopolitical, sustainability, and economic challenges of the changing global energy landscape.

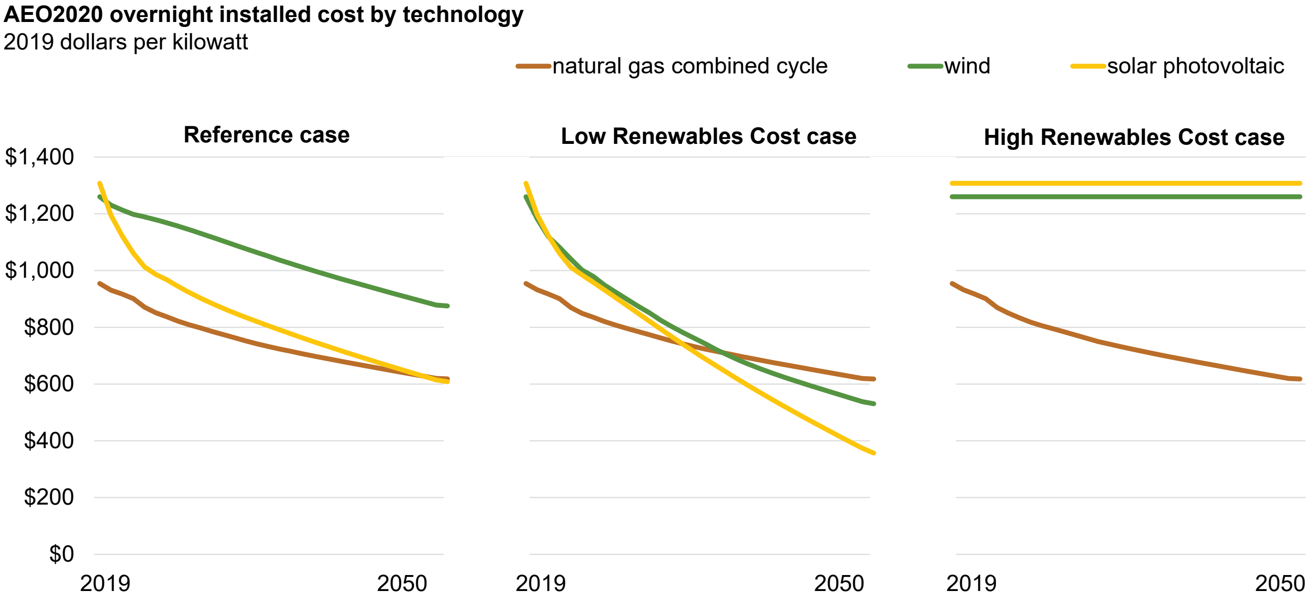
---

[1] Spencer Fields, "100 Percent Renewable Targets," *EnergySage*, May 5, 2019, https://news.energysage.com/states-with-100-renewable-targets/.

[2] "About Us," RE100, https://www.there100.org/about-us; High Lantern Group, "2020 Brand Pressure Index: Climate Change #1 Corporate Issue," November 27, 2019, http://www.highlanterngroup.com/news-insights/2019/11/27/hlg-analytics-note-aw9n5.

[3] Amol Phadke, Sonia Aggarwal, Mike O'Boyle, Eric Gimon, and Nikit Abhyankar, "Illustrative Pathways to 100 Percent Zero Carbon Power by 2035 without Increasing Customer Costs," Energy Innovation, September 2020, https://energyinnovation.org/wp-content/uploads/2020/09/Pathways-to-100-Zero-Carbon-Power-by-2035-Without-Increasing-Customer-Costs.pdf.

Figure 1.



NOTE: Excluding a bearish scenario in which the cost of renewables falls minimally over the coming three decades—an outcome inconsistent with all evidence to date—the overnight installed cost of renewables (which excludes interest payments during construction) is set to decline as fast, if not faster, than that of the most efficient fossil fuel technology. Renewables have the added advantage of zero fuel cost as well as no exposure to carbon costs.

SOURCE: Reproduced from US Energy Information Administration, Annual Energy Outlook 2020 with Projections to 2050, January 29, 2020, https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf, 69.

transmission and storage investment, mitigated only by reusing today's natural gas infrastructure, if it is to be used as a fuel for power generation.[4] Green hydrogen, moreover, which is produced from water through hydrolysis using renewables, can never reach cost parity with renewables as a power source, as these resources are used to produce it. Blue hydrogen, which is extracted from natural gas through a process known as steam methane reformation, has a long way to go down the cost curve to be viable, and is dependent upon carbon capture advancements as well.[5] Advanced nuclear faces similar cost uncertainties, which will govern whether it plays a supporting or a leading role in a future decarbonized grid.[6] None of these resources is likely to match the low-cost, low-technology risk and zero-carbon profile of solar and wind generation in the next decade, during which the North American Electric Reliability Corporation (NERC) forecasts 330 gigawatts (GW) of wind and solar capacity will be installed in the United States and Canada, representing 65 percent growth over these countries total installed capacity in 2019, inclusive of all resources.[7] Europe is even more bullish on renewables: In its most recent Ten-Year Network Development Plan, the European Network of Transmission System Operators for Electricity estimated that between 48 and 58 percent of demand will be met by renewable generation.[8]

The question, therefore, is not whether renewables will

---

[4] National Renewable Energy Laboratory, *Hydrogen Energy Storage: Grid and Transportation Services*, February 2015, https://www.nrel.gov/docs/fy15osti/62518.pdf.

[5] Jason Deign, "Utilty Global Comes Out with Bold Claims for Cheaper, Cleaner 'Blue' Hydrogen," *Greentech Media*, September 4, 2020.

[6] Karen D. Tapia-Ahumada, John Reilly, Mei Yuan, and Kenneth Strzepek, *Deep Decarbonization of the U.S. Electricity Sector: Is There a Role for Nuclear Power?*, Massachusetts Institute of Technology Joint Program on the Science and Polity of Global Change, Report 338, September 2019.

[7] North American Electric Reliability Corporation, 2019 Long Term Reliability Assessment, 2019, https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2019.pdf; US Energy Information Administration, Annual Energy Outlook 2020 with Projections to 2050, January 29, 2020, https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf.

[8] European Network of Transmission System Operators for Electricity, *Connecting Europe: Electricity*, ENTSO-E 2025, 2030, 2040 Network Development Plan 2018, 2018, https://eepublicdownloads.blob.core.windows.net/public-cdn-container/clean-documents/tyndp-documents/TYNDP2018/consultation/Main%20Report/TYNDP2018_Executive%20Report.pdf.

play a dominant role in the coming decarbonized grid but rather how energy security can be ensured with renewables playing such a role. The prospect of a generator fleet that is directly subject to the sun, wind, and other forces of nature, under a backdrop of unpredictable climate change, has provoked anxiety. Some have gone as far as to lay the blame for the blackouts that beset California in August 2020 at the feet of renewables, raising the question of whether the state has become a cautionary tale of transitioning too quickly toward renewable power.[9] The reality is more nuanced: it is not the rate of adoption of renewables that poses risks, in and of itself, but the failure to maintain sufficient capacity of complementary flexible resources, such as battery storage, demand response, and gas-fired peaker plants, which can be dispatched during the inevitable dips in renewable supply.[10] Nevertheless, the unique cost and physical profile of renewables have taken the electric power system into uncharted territory, posing novel challenges to energy security. While daunting, these challenges can be understood and addressed to ensure that the coming decarbonized electric power system is a viable one.

Energy security challenges

Intermittence and the need for flexible capacity

The intermittence of renewables has undermined a key dynamic that has governed power markets since their inception in the 1990s. Despite the volatility of electricity prices, which is greater than that of any other commodity price, far less price-sensitive demand has arisen in wholesale power markets than market designers anticipated. A vast majority of commercial and residential customers consume electricity regardless of price, enabled by the largely fixed rates offered by utilities and retail energy providers, which charge a premium to shield them from price volatility. As a consequence, the supply side is relied upon to be fully flexible to meet demand, meticulously following its ebbs and flows to maintain balance. Put simply, supply follows demand, and not the other way around. Turbines cannot follow the wind and system load at the same time, however, which is a conflict that poses tremendous risks for system stability in a fully decarbonized power system.

The physical laws governing electricity distribution are unforgiving. Supply and demand must be balanced at every instant; otherwise, the frequency of the grid's alternating current will diverge from its target (60 hertz in the United States), causing devices to malfunction and ultimately the grid's voltage to collapse. Renewables tend to peak when there is low to moderate load on the system—midday for solar, and overnight for wind—and are not always present in force when load does peak, such as on weekday evenings in the summer, or during a deep freeze in the Northeast. When renewables cause generation to exceed load, excess generation that cannot be consumed by load or storage resources must be curtailed to achieve balance—an action without risk to system stability, but one that induces waste. California curtailed 318 gigwatt-hours (GWh) of wind and solar in April 2020 alone, enough to power roughly 380,000 homes during that period.[11]

The opposite case, in which renewable supply fails to meet demand, has significant energy security implications. In these times, the system must rely on complementary resources to fill in the gap, sometimes in a matter of minutes. Figure Two illustrates the "duck curve" phenomenon in California, in which solar production winds down just as evening residential load ramps up, requiring complementary resources to ramp up dramatically. Bulk power systems are designed to support worst-case scenarios, which include days with minimal sun and wind.[12] Resource adequacy may therefore require energy storage and flexible capacity on the same order as the renewables they cover for even if they are infrequently dispatched, a costly duplicate investment in capacity. While today's flexible generation capacity is largely fossil-based (with the notable exception

---

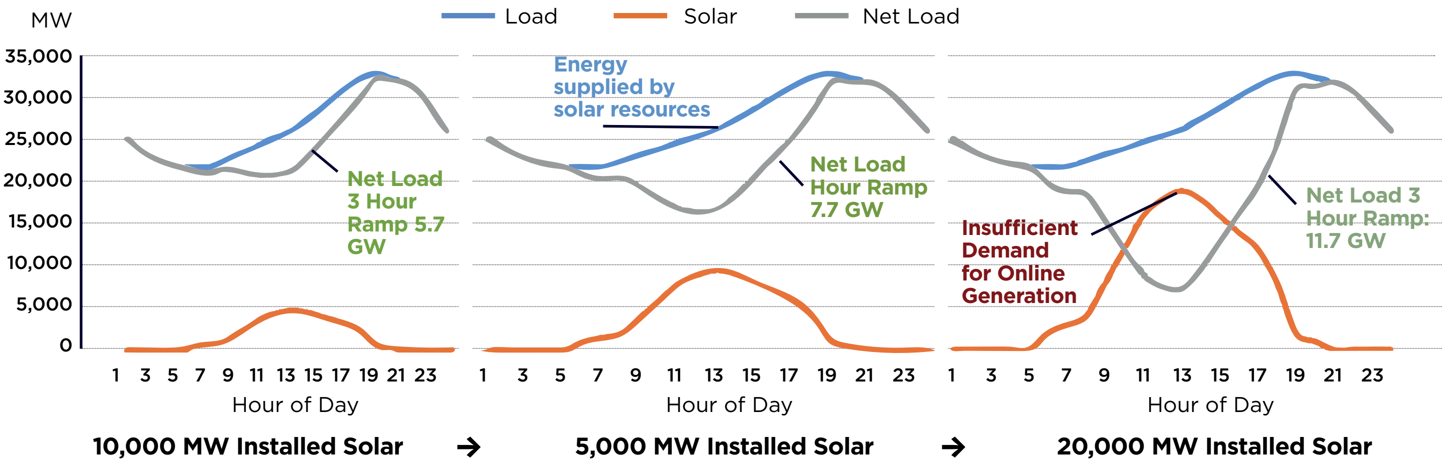
[9] Katherine Blunt, "California Blackouts a Warning for States Ramping Up Green Power," *Wall Street Journal*, August 17, 2020.

[10] Cailifornia Independent System Operator, "Preliminary Root Cause Analysis: Mid-August 2020 Heat Storm," October 6, 2020. Demand response refers to loads that act as supply, earning revenue in wholesale markets by reducing consumption when called upon by the system operator. Like CCGS, gas-fired peaker plants can be outfitted with carbon capture equipment to reduce emissions.

[11] "Managing Oversupply," California Independent System Operator, May 5, 2020, http://www.caiso.com/informed/Pages/ManagingOversupply.aspx. The typical single-family residence consumes roughly 10 MWh of power per year, a quantity termed a Residential Customer Equivalent.

[12] Bulk power systems refer to transmission systems and the generation and energy storage resources directly connected to them. They do not include distribution systems, the last mile of delivery to residential and small commercial and industrial customers.

Figure 2. Duck curve illustration.



NOTE: Duck curve illustration. Solar production during the day masks load on the system, resulting in minimal net load that must be met by other resources. As late-day solar production declines, other resource must ramp quickly to replace it, even as demand itself is ramping toward the evening peak.

REPRODUCTION: NERC 2019 Long Term Reliability Assessment

of hydroelectric power), emissions-free technologies that are ultimately unable to compete with renewables on cost may find a new lease on life by providing this valuable grid service. Flexible nuclear is a leading contender, as are hydrogen fuel cells: Green hydrogen can be produced when there is excess renewable capacity and consumed as fuel when renewable capacity is insufficient.[13]

Accenture estimates that Europe will require 55-90 GW of flexible capacity by 2030 across six markets: France, Great Britain, the Netherlands, Germany, Spain, and Ireland.[14] At that time, the latter three countries may require flexible capacity exceeding 70 percent of total generating capacity.[15] Supply imbalance fluctuations will be shorter than they are today, but their amplitudes 55-95 percent greater, requiring increased ramping capability as well as generating capacity.[16]

The loss of inertia: The grid's stabilizing force

A second energy security vulnerability imposed by renewables arises from their intermittence: not in regard to following load, but in regard to the grid's sensitivity to sudden changes in load. The stability of bulk power systems relies on the synchrony of their generators, many of which—known as synchronous generators—consist of a massive magnet rotating in the vicinity of a stationary magnet, driven by steam, water, or wind. The collective mass of these rotating magnets, known as rotors, provides inertia for the grid, enabling it to withstand sharp fluctuations in load and supply. Inverter-based generators such as solar photovoltaic (PV) and battery storage (including batteries in electric vehicles) do not have a rotating mass, and therefore do not naturally contribute inertia to the grid.[17] While wind turbines do, the variability of wind makes their inertial response intermittent, and therefore less dependable. A key challenge for a

---

[13] Rita Baranwal, Mollie Johnson, Kihara Shinichi, and Stephen Speed, Flexible Nuclear Energy for Clean Energy Systems, National Renewable Energy Laboratory Technical Report, NREL/TP-6A50-770, September 2020, https://www.nrel.gov/docs/fy20osti/77088.pdf; National Renewable Energy Laboratory, Hydrogen Energy Storage.

[14] Sander van Ginkel, Wytse Kaastra, Sanda Tuzlic, and Sytze Dijkstra, *Flex and Balances Unlocking Value from Demand-Side Flexibility in the European Power System*, Accenture, 2018, https://www.accenture.com/_acnmedia/accenture/conversion-assets/dotcom/documents/global/pdf/dualpub_26/accenture_flex_balances_pov.pdf.

[15] Ibid.

[16] Ibid.

[17] Samuel C. Johnson, Dimitri J. Papageorgiou, Dharik S. Mallapragada, Thomas A. Deetjen, Joshua D. Rhodes, and Michael E. Webber, "Evaluating Rotational Inertia as a Component of Grid Reliability with High Penetrations of Variable Renewable Energy," Energy 180 (2019): 258-271.

power system driven primarily by renewables, therefore, is determining where to source inertia for the system or, more improbably, how to operate stably without it.[18]

An increased reliance on long-distance transmission

The physical characteristics of renewables are not the only impact these resources have on a bulk power system. Utility-scale renewable plants are frequently sited far from population centers, due to the cost of land and the availability of the relevant natural resource. Bringing this power to population centers necessitates increased and sometimes dedicated long-distance transmission lines, which implicitly add to the cost of the power. Today's transmission capacity provides insufficient headroom for the anticipated growth in renewables, however, and transmission planning processes have not been up to the task, most notably in the context of multi-region projects.[19] Only fifteen thousand circuit miles of transmission are planned in the next six years, for instance, compared with forty thousand built in the last decade, despite the increased need.[20] In the Southwest Power Pool (SPP) and the Electric Reliability Council of Texas (ERCOT), a regional transmission organization (RTO) and independent system operator (ISO), respectively, renewables are already reaching transmission capacity.[21] This limitation does not apply to distributed solar, which is sited on the distribution system, conveniently proximal to loads. But for utility-scale solar projects, which have grown faster than residential- and commercial-scale projects from 2015 through 2020, as well as utility-scale wind, transmission capacity limitations generally imply generation capacity limitations.[22]

Cybersecurity

Cybersecurity is a perennial risk to power systems, but it will take on a new character in a world powered to a large degree by customer-owned distributed energy resources (DERs), such as residential and community solar, stationary batteries, electric vehicles (EVs), and smart thermostat-enabled air conditioners and heat pumps. Unlike centralized resources, isolated on proprietary utility and energy market communication networks, these resources are exposed to the public internet, and reliant on commercial software platforms and device owners to maintain their security. Botnet attacks have already demonstrated the vulnerability of Internet of Things (IoT) devices to cyber exploits, but the capability of DER botnets to deploy electrical power as well as computational power introduces novel energy security risk.[23]

Not all exploits of DERs will originate from internet hacks. Global supply chains represent significant vulnerabilities for device manufacturers, whose hardware components and firmware programming are exposed to the risk of backdoor infiltration and sabotage. NERC has focused on the risk to bulk power system equipment, such as that used in transmission lines and within substations, leading to reliability standards that address supply chain risk management.[24] But the risk persists—and is, in fact, wider and more decentralized—for IoT devices, which are produced by countless manufacturers and parts vendors across the globe, and whose role in grid operations may not even be known to ISOs and utilities.[25]

---

[18] Paul Denholm, Trieu Mai, Rick Wallace Kenyon, Ben Kroposki, and Mark O'Malley, *Inertia and the Power Grid: A Guide without the Spin*, National Renewable Energy Laboratory, NREL/TP-6120-73856, May 2020, https://www.nrel.gov/docs/fy20osti/73856.pdf.

[19] Advanced Energy Economy, Wholesale Market Barriers to Advanced Energy—and How to Remove Them, May 2019, https://info.aee.net/wholesale-market-barriers-to-advanced-energy.

[20] North American Electric Reliability Corporation, 2019 Long Term Reliability Assessment.

[21] Ibid. ISOs are system operators that manage the bulk power system and power markets within a single state. RTOs are system operators that manage such entities across multiple states.

[22] US Energy Information Administration, "Table 1.1.A. Net Generation from Renewable Sources: Total (All Sectors), 2010-August 2020" in Electric Power Monthly, February 2020, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_1_01_a.

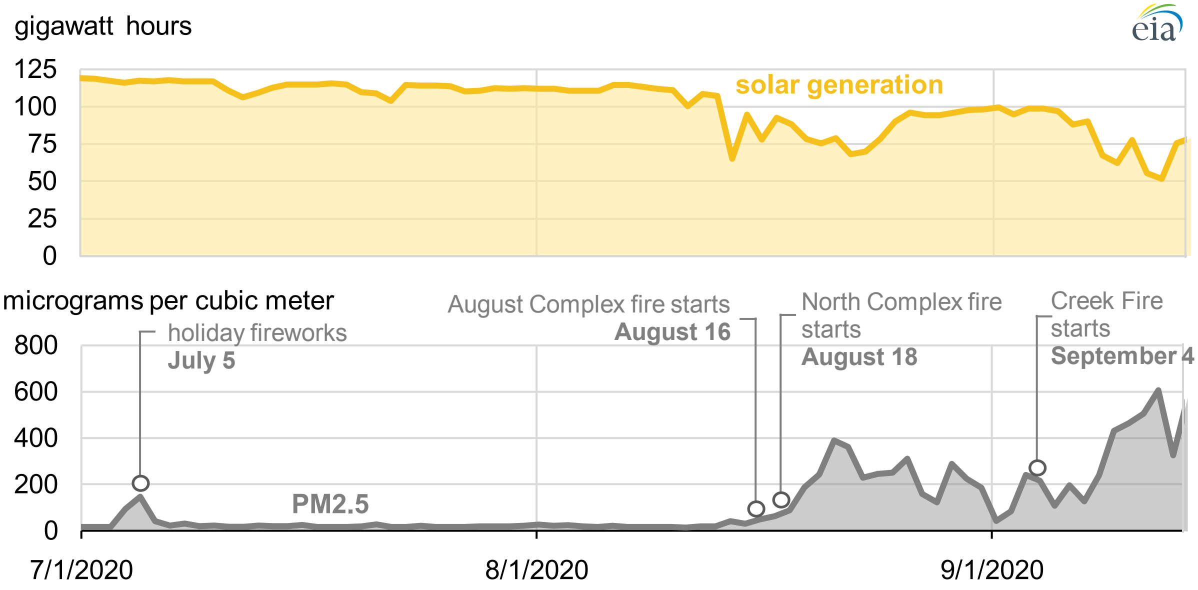
[23] Josh Fruhlinger, "The Mirai Botnet Explained: How IoT Devices Almost Brought Down the Internet," CSO Online, March 9, 2018, https://www.csoonline.com/article/3258748/the-mirai-botnet-explained-how-teen-scammers-and-cctv-cameras-almost-brought-down-the-internet.html; Lindsey O'Donnell, "Security Glitch in IoT Camera Enabled Remote Monitoring," Threatpost, July 27, 2018, https://threatpost.com/security-glitch-in-iot-camera-enabled-remote-monitoring/134504/.

[24] North American Electric Reliability Corporation, "Cyber Security Supply Chain Risks," May 17, 2019.

[25] Muhammed Junaid Farooq and Quanyan Zhu, "IoT Supply Chain Security: Overview, Challenges, and the Road Ahead," via arXiv.org, Cornell University, July 21, 2019, arXiv:1908.07828v1.

Figure 3.

Daily CAISO solar generation and California peak air particulate matter (PM2.5) level



NOTE: CAISO: California Independent System Operator; PM2.5: particular matter of 2.5 micrometers or less in diameter.

SOURCE: Reproduced from US Energy Information Administration, "Smoke from California Wildfires Decreases Solar Generation in CAISO," September 30, 2020, https://www.eia.gov/todayinenergy/detail.php?id=45336.

Wildfires and extreme weather

Extreme weather events represent a perennial risk to the grid and will persist in a decarbonized system. Conventional thermal generation can fail in both the extreme hot and cold: High temperatures prevent power plants from evacuating sufficient heat during the steam cooling cycle, causing the plant to trip offline, and cold temperatures can cause mechanical failures and even fuel to freeze. For example, coal piles froze during the Polar Vortex of 2014, and both gas- and coal-fired plants were forced offline due to cold-induced mechanical failures during the Polar Vortex of 2019.[26]

Renewables are not immune to extreme weather, of course: the efficiency of solar PV systems decays with increased ambient temperatures, and smoke from forest fires has a particularly acute effect on production. Power forecasting firm Amperon, in coordination with the Australian Energy Market Operator, studied the effect of bush fires on twenty solar plants during the summer of 2019-2020 and found a 4.1 percent mean decrease in production over a two-month period—a massive loss in energy.[27] The California Independent System Operator (CAISO) saw a loss of up to a third of solar production at points during the wildfires that plagued California during September 2020.[28] A recent study in Nature Energy examined the effects of extreme weather on renewable generation and demand under various climate change scenarios, and found up to a 16 percent drop in power supply reliability.[29] These are reminders that there is no free lunch for grid reliability, whether the grid is powered by legacy resources or advanced renewables.

---

[26] North American Electric Reliability Corporation, "Polar Vortex Review," September 29, 2014; Emma Foehringer Merchant, "Surviving the Polar Vortex: A Look at How the Electricity System Fared," *Greentech Media*, February 6, 2019, https://www.greentechmedia.com/articles/read/polar-vortex-electricity-system-fared#gs.dyyQeQ8W.

[27] Geert Scholma and Ydo Wexler, "Attenuation of Large-Scale Solar PV Production by Bushfire Smoke in South-East Australia," Amperon Holdings, 2020, https://amperon.co/case-studies/Attenuation-of-Large-Scale-Solar-PV-Production-by-Bushfire-Smoke-in-South-East-Australia.pdf?.

[28] Peter Behr, "Solar Power Plunges as Smoke Shrouds Calif.," *E&E News*, September 11, 2020, https://www.eenews.net/stories/1063713459.

[29] A.T.D. Perera, Vahid M. Nik, Deliang Chen, Jean-Louis Scartezzini, and Tianzhen Hong, "Quantifying the Impacts of Climate Change and Extreme Climate Events on Energy Systems," Nature Energy 5, no. 2 (2020): 150-159.

Extreme weather impacts demand as well as supply. One of the chief factors underlying the two-day rolling blackouts that CAISO imposed during the heat storm in August 2020 was the unpredicted swell of air conditioning demand it induced.[30] Residential electricity demand is highly weather-sensitive, primarily due to air conditioning in the summer and electric heating in the winter, sensitivity that will only grow with the electrification of space heating through heat pumps. Failure to predict demand spikes hour-ahead, or even day-ahead, can cause a grid contingency even if sufficient supply exists to meet it. Such supply does no good if it is sitting idle on the sidelines, not having been dispatched early enough to come online to assist. A notable finding from the California blackouts was that certain virtual power trading strategies contributed to the failure by masking the underestimation of demand.[31]

Missing money and economic insecurity for generators

Not all energy security challenges are physical in nature. Renewables have exacerbated what is known as the "missing money" problem in power markets, which refers to the insufficiency of real-time energy prices to drive the efficient entry and exit of resources in the long run.[32] Real-time prices in markets are often capped below prices that customers are willing to pay in order to prevent the exercise of market power by generators when supply is tight. It is precisely the margin made during such scarcity periods that recovers resources' fixed costs, however. At other times, renewables depress real-time prices due to their near-zero variables costs, displacing conventional resources in the merit order of supply bids and reducing the market clearing price paid to all resources. This dynamic is entirely consistent with the principle of locational marginal pricing, upon which power markets are based, by which all resources are paid the marginal total system cost of serving the next increment of load. It calls that principle into question, however, as an increasing percentage of the fleet have no marginal cost. All power markets, including the bilateral market for power purchase agreements through which renewable projects are typically financed, are ultimately based on real-time (spot) market prices, and therefore the economic viability of the entire fleet—clean and dirty resources alike—is dependent on solving the missing money problem.

Understanding renewable "cannibalization"

The low cost of renewables only begins to characterize the financial effect they have on power markets. Without variable costs, and often with long-term power purchase obligations to satisfy, renewables can bid into markets at zero or even negative marginal cost (in the case of production tax credits). This behavior lowers the market clearing price paid to all generators, as well as the costs paid by consumers, ostensibly a straightforward market efficiency. The reduced market payments threaten the financial viability of otherwise-economic resources, however, pushing the generator fleet toward an unstable technology mix and increasing blackout risks for customers. The expectation of depressed future spot market prices also has the effect of reducing futures prices for electricity, the market on which long-term renewables financing is based. The low cost by which renewables win today, therefore, reduces their viability to obtain long-term financing tomorrow.

---

[30] Cailifornia Independent System Operator, "Preliminary Root Cause Analysis: Mid-August 2020 Heat Storm."

[31] Ibid.

[32] Roy J. Shanker, "Comments on Standard Market Design: Resource Adequacy Requirement," Federal Energy Regulatory Commission, Docket RM01-12-000, 2003, http://elibrary.ferc.gov/idmws/common/opennat.asp?fileID=9619272.

Wind turbines in California, United States. *Unsplash / Cameron Venti (@ventiviews)*

Approaches to energy security

Effective transmission development

Increased transmission capacity is a clear requirement for the continued development of utility-scaled renewable projects. These projects leverage economies of scale to produce power at lower cost than residential- and commercial-scale facilities, and will therefore play an important role in meeting clean energy targets.

In addition to bringing far-flung generation to load centers, such as metropolitan areas, transmission development can address local energy availability and prices in these areas as well. Even when a transmission path exists between regional resources and a load center, the capacity of the transmission lines may not be sufficient to carry the needed power during peak times, leading to congestion in the network. Congestion raises energy prices in the constrained area and can become a bottleneck to such a degree that the system operator is compelled to take out-of-market actions to address it, such as dispatching a polluting and uneconomic resource, or even initiating a long-term arrangement with such a resource, known as a reliability-must-run (RMR) contract. Such actions are costly to consumers and exacerbate the missing money problem for economic generators, as a supply scarcity opportunity has been addressed outside of the competitive market. In September 2019, the Federal Energy Regulatory Commission (FERC) approved a request from CAISO for unprecedented flexibility in procuring RMR resources, but only under the condition that CAISO would consider transmission investments as a lower-cost alternative, and that RMRs would be "a measure of last resort."[33]

There are important questions regarding how transmission capacity is developed. Transmission facilities are typically procured through administrative planning processes, such as PJM's Regional Transmission Expansion Plan or Europe's Ten-Year Network Development Plan, which look at system needs over various time horizons to identify needed investments. Once a need is identified and approved by the system operator's board, competitive project bids are solicited and paid on a cost basis. Long-term planning over horizons

---

[33] Federal Energy Regulatory Commission, "Order Accepting Tariff Revisions," 168 FERC ¶ 61,199, September 27, 2019.

of five years or more can increase energy security, but often fail to take into account alternative, comparatively short-term investments in local generation capacity.[34] It may be most cost effective to develop a solar plant or a grid-scale battery storage facility in a congested area, for instance, or even solicit demand response, rather than investing in transmission to import additional power. It is therefore important that market transmission planning processes evolve to work around, rather than preempt, market-driven generation investments, and let energy market price signals do their work.

A limitation of transmission planning processes is that they centralize transmission investment. While ISOs and RTOs provide a vital public good by assessing and addressing reliability-based transmission needs, they do not facilitate economic-based transmission project development—for instance, a transmission line introduced between load zones to arbitrage congestion-based price differences between them, which provides market value. In a 2013 policy statement, FERC made clear its support for decentralized, market-based investment, enabling transmission developers to contract directly with loads or generators that stand to benefit from their investment.[35] In situations where the beneficiaries of a transmission investment may be too broad to contract with directly, developers might instead contract with the ISO/RTO directly, through standard transmission operating agreements. In either case, the impetus for the transmission investment is a market opportunity, rather than a reliability exigency. Facilitating such merchant transmission investments—which, unlike administrative planning processes, are closely in tune with energy markets prices and alternative investment options—should be a tenet of power market reform. Market-based transmission investment is not a substitute for reliability-driven centralized procurement, but it is a valuable complement.

Regionalization: Security through market size

Transmission networks enable long-distance power flow, but their effectiveness is limited by the reach of the markets they serve. The US power grid is legally segmented into so-called balancing authority areas, each administered by a balancing authority—such as an ISO, RTO, or monopoly utility—tasked with ensuring stability through the balance of supply and demand. Imports and exports of power across balancing authority areas are permitted but are not optimized like power flows within a wholesale market territory. This limits the effectiveness of excess generation in one area to serve excess demand in another, an opportunity enabled by long-distance transmission.

Regional power markets, such as CAISO's Western Energy Imbalance Market (EIM), address this deficiency by co-optimizing load and generation across balancing areas. As an imbalance market, the EIM was designed as a real-time market only, optimizing power flows that are not committed by day-ahead schedules or long-term bilateral agreements. This includes facilitating the purchase of excess wind generation in the mountainous Northwest by customers on the California coast, and the export of excess California solar to loads in Arizona. Since its inception in 2014, the EIM has avoided more than 1.2 million megawatt-hours of renewables curtailment, reduced close to 550,000 tons of carbon dioxide, and generated over $1.1 billion in gross benefits for its members.[36]

Regional markets offer energy security benefits in addition to cost savings. Their wide footprint increases the likelihood that a lull in wind or solar in one locale will be offset by a surplus in another, given natural variations in weather. By the same token, they enable higher penetrations of renewables than would otherwise be possible in fragmented and less-coordinated networks.[37] Additionally, the impact of a generator tripping offline or a sudden

---

[34] William W. Hogan and Susan L. Pope, Priorities for the Evolution of an Energy-Only Market Design in Texas, FTI Consulting, May 2017.

[35] Federal Energy Regulatory Commission, "Allocation of Capacity on New Merchant Transmission Projects and New Cost-Based, Participant-Funded Transmission Projects," 142 FERC ¶ 61,038, January 17, 2013.

[36] California Independent System Operator, Western EIM Benefits Report, Third Quarter 2020, October 29, 2020, https://www.westerneim.com/Documents/ISO-EIM-Benefits-Report-Q3-2020.pdf.

[37] David Newbery, Michael Pollitt, Robert Ritz, and Wadim Strielkowski, "Market Design for a High-Renewables European Electricity System," Cambridge Working Paper in Economics 1726, June 2017, https://www.eprg.group.cam.ac.uk/wp-content/uploads/2017/06/1711-Text.pdf.

spike in demand is reduced when there is a vast network of regional generators from which to import. For these reasons, the regional market model has become popular outside of the United States as well, including the European Union's Internal Electricity Market, the Central American Electricity Market, the Australian National Electricity Market, and the West African Power Pool.[38] Islands such as Great Britain, Ireland, and Hawaii cannot enjoy the benefit of regionalization, however, owing to their predominant (or complete) electrical isolation.

Despite early successes, there is opportunity for this model to evolve and expand. CAISO is planning to extend the EIM with a day-ahead market to better coordinate regional unit commitment and power scheduling based on day-ahead load forecasts.[39] Ironically, day-ahead markets have a much greater impact on real-time power flows than real-time markets do, given how much power flow is scheduled day-ahead, so this extension may significantly amplify the EIM's cost savings and energy security benefits. The market continues to grow, with numerous utilities scheduled to join from 2020 through 2022, including major providers Xcel Energy in Colorado and Avista in Washington State and Idaho. It is being challenged, however, by a new Western Energy Imbalance Service Market, led by SPP.[40] Further regionalization in the West must continue, however, as lack of coordination between wholesale markets will introduce severe flexibility costs by the 2030s.[41] Greater transmission capacity will likely also be required to meet long-term decarbonization goals.[42]

As regionalization in the West increases, by contrast, the absence of basic deregulation and wholesale competition in the Southeast becomes even more glaring. This could be addressed by an expansion of the Midcontinent ISO (MISO) and/or PJM, both of which border the region, either via full market integration or as a real-time imbalance market, similar to the EIM. Another possibility is a new RTO. A recent study found that over two decades such an RTO could generate $384 billion in cumulative economic savings and 285,000 additional jobs compared with business as usual, with the jobs driven by the construction of new battery storage and renewables assets.[43] Either option will require the support of state lawmakers and regulators in the Southeast, who would be best served by opening public utility commission dockets to study the potential benefits of regionalization to their ratepayers.

Market product and technology innovations for flexibility

The averaging effects of regional markets can mitigate the intermittence of renewables, but they cannot make them self-sufficient. Complementary flexible resources will be required to cover the gap between system load and renewable supply, consuming power when renewables overproduce and injecting it when they underproduce. These swings from consumption to production will occur over the span of seconds, minutes, and hours, with little warning—an exacting requirement for energy resources, few of which can ramp up and down so quickly.

Much of this flexible capacity will be procured in ancillary service markets, whose products require much greater flexibility on the part of assets than real-time energy products. Examples include frequency regulation, which requires assets to follow production setpoints that change every few seconds, and CAISO's and

---

[38] Arina Anisie, Elena Ocenic, and Francisco Boshell, "Regional Markets: Innovation Landscape Brief," International Renewable Energy Agency, 2019, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Regional_markets_Innovation_2019.pdf?la=en&hash=CEC23437E195C1400A2ABB896F814C807B03BD05.

[39] California Independent System Operator, "2020 Draft Three-Year Policy Initiatives Roadmap and Annual Plan," Market and Infrastructure Policy, September 30, 2019; Unit commitment is the process by which the system operator determines which generators should be producing in a future time window, and then instructs them in advance to come online.

[40] Robert Walton, "Xcel, 3 Other Colorado Utilities Choose California's Imbalance Market over Southwest Power Pool," *Utility Dive*, December 18, 2019, https://www.utilitydive.com/news/xcel-3-fellow-colorado-utilities-choose-californias-imbalance-market-over/569361/.

[41] Keegan Moyer, "Western Flexibility Assessment," Energy Strategies, NW Energy Coalition Clean & Affordable Energy Conference, December 2, 2019.

[42] Ibid.

[43] Eric Gimon, Mike O'Boyle, Taylor McNair, Christopher T.M. Clack, Aditya Choukulkar, Brianna Cote, and Sarah McKee, "Economic and Clean Energy Benefits of Establishing a Southeast U.S. Competitive Wholesale Electricity Market," Energy Innovation, August 2020, https://energyinnovation.org/wp-content/uploads/2020/08/Economic-And-Clean-Energy-Benefits-Of-Establishing-A-Southeast-U.S.-Competitive-Wholesale-Electricity-Market_FINAL.pdf.

Figure 4. Actual and forecasted upward ramps in CAISO.

Solar supply, 2018	11,800 MW
1-hour upward ramp record set in March, 2018	7,545 MW
3-hour upward ramp record set in March, 2018	14,777 MW
3-hour upward ramps forecasted by March, 2021	17,000 MW
Total demand forecasted in 2021	54,629 MW

SOURCE: NERC 2019 Long Term Reliability Assessment

NOTE: In 2021, 3-hour ramps are expected to exceed 30% of total system demand, requiring significant flexible ramping capacity.

MISO's flexible ramping products, which compensate assets for the number of megawatts (MW) they are able to ramp up or down from their current economic dispatch setpoint within a five- or fifteen-minute timeframe, respectively. Flexible ramping products are viewed as a key tool in managing renewable variability: The New York ISO (NYISO) and ISO New England (ISO-NE) have carefully studied the current implementations, and both SPP and its independent market monitor have concluded that SPP should develop its own product.[44]

ISO-NE has settled on a product, known as Energy Imbalance Reserve (EIR), that is similar to a flexible ramping product but fits within a new framework for ancillary services developed within the RTO's Energy Security Improvements (ESI) initiatives, filed with FERC in April of 2020.[45] All day-ahead ancillary services in the new framework would be procured as call options on real-time energy. In the case of EIR, that energy corresponds to the upward ramping capacity of the resource, and the total reserves procured are equal to the difference (if positive) between the day-ahead forecasted load and the day-ahead cleared load. This protects against load serving entities, such as utilities, collectively underestimating day-ahead demand, and procuring less capacity than the ISO forecasts will be needed. While FERC has rejected ISO-NE's ESI proposal, that rejection was not based on the merits of the novel call option-based framework, or EIR.[46] While an empirical comparison may not be possible, other ISOs and RTOs would do well to consider EIR as an alternative to flexible ramping products. Like other ESI products, it has the potential to offer resources greater revenue than traditional products if they are prepared to meet their obligations.

It is worth noting that flexible demand could be a tremendous source of flexible ramping capacity. Aggregations of heating and cooling loads, EVs, and commercial and industrial loads can be surgically dialed up at the individual kilowatt level, offering more than the precision needed for demand response ramping products. In September of 2020, FERC issued a landmark order establishing aggregations of distributed energy resources (DER) as first-class participants in wholesale markets, with dedicated participation models that respect their unique characteristics.[47] FERC acknowledged in its order that market participation today would require complex and sometimes costly market communications integration, however, which must be streamlined to make participation feasible for many DERs.[48] In the meantime, flexible load resources bidding their demand in a manner that reflects their price sensitivity can offer similar flexibility value to markets as supply-side participation, and even earn these resources capacity payments for

---

[44] Southwest Power Pool Market Monitoring Unit, "State of the Market 2018," May 15, 2019.

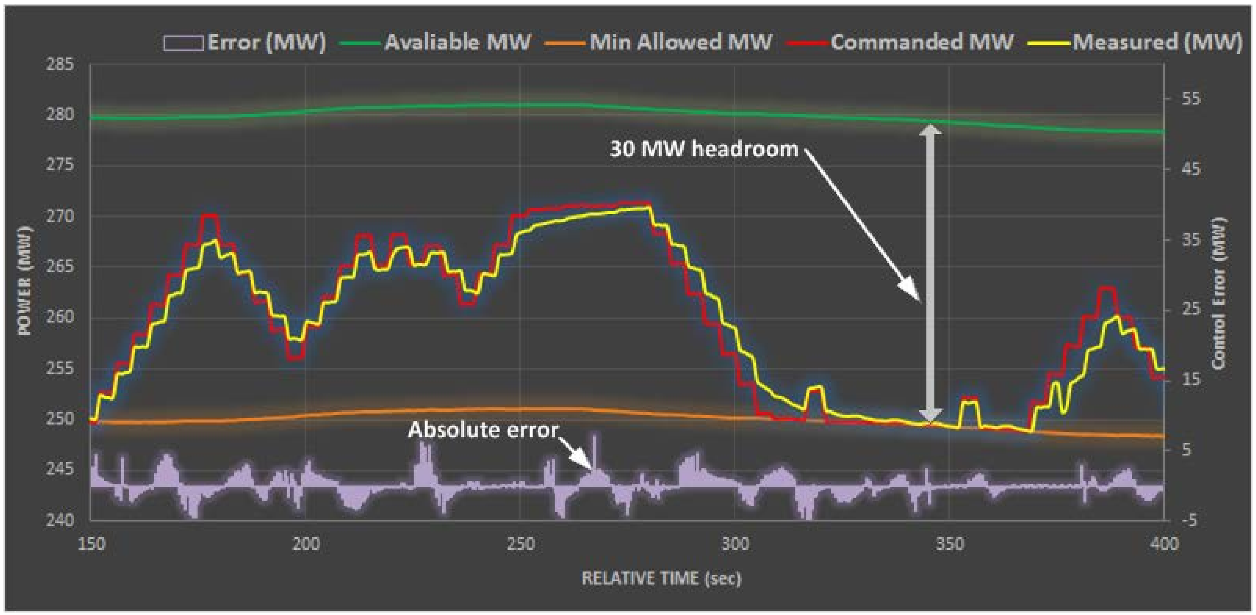
[45] ISO New England Inc., "Compliance Filing of Energy Security Improvements," Docket No. ER20-1567, April 15, 2020.

[46] Order Rejecting Proposed Tariff Revisions, 173 FERC ¶ 61,106.

[47] Order No. 2222, 172 FERC ¶ 61,247.

[48] Ibid.

Figure 5. Demonstration of utility-scale solar performing frequency regulation.



NOTE: Results of a demonstration showing that a utility-scale solar plant can follow an Automatic Generation Control (AGC) sequence, required for providing frequency regulation. While the maximum power of solar plants is limited by solar irradiation, below that limit they have surgical, low-latency control.

SOURCE: Reproduced from Clyde Loutan, Peter Klauer, Sirajul Chowdhury, and Stephen Hall, Demonstration of Essential Reliability Services by a 300-MW Solar Photovoltaic Power Plant, National Renewable Energy Laboratory, Technical Report NREL/TP-5D00-67799, March 2017, https://www.nrel.gov/docs/fy17osti/67799.pdf.

committing to responsiveness during emergencies.[49]

Despite their value in high-variability environments, markets have not adequately priced ancillary services. In PJM, ancillary services account for less than 7 percent of the revenue brought in through capacity markets, despite the absence of any flexibility requirement in capacity products, merely the commitment to be available.[50] In MISO that percentage is higher, but ancillary services still account for only 0.3 percent of the all-in price of electricity.[51] Markets' under-allocation of revenue to ancillary services due to an overreliance on forward capacity and out-of-market dispatch is problematic: It may fail to incent sufficient investment in flexible capacity, locking in today's uneconomic (and frequently high-emitting) backup resources for years to come. While adequate today, these resources may not be adequate in a high-variability future driven by high penetrations of renewables, compromising energy security.

Beyond managing price signals, there are other actions markets can take to encourage greater flexibility from resources by adjusting market rules. Some involve creating new participation models and market products to enable advanced technologies such as dispatchable renewables, DER aggregations, flexible load, and advanced nuclear to leverage their full physical capabilities. It is an underappreciated fact that while renewable generators cannot control their maximum output capacity at any given moment, due to their weather dependence, they have near-surgical control over their production below that level. This fact should guide ancillary service market reforms to leverage that capability, taking into account the opportunity cost when a MW of energy production is withheld as a MW of ancillary service capacity. A recent study has shown, moreover, that flexible nuclear

---

[49] PLM, "Price Responsive Demand," Factsheet, 2017, https://www.pjm.com/-/media/about-pjm/newsroom/fact-sheets/price-responsive-demand.ashx.

[50] Monitoring Analytics, LLC, State of the Market Report for PJM, Q1 2020, May 14, 2020, https://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2020/2020q1-som-pjm.pdf.

[51] Potomac Economics, 2018 State of the Market Report for the MISO Electricity Markets, June 2019, https://cdn.misoenergy.org/2018 State of the Market Report364567.pdf.

would be expensive to develop, but advanced reactors capable of cycling to meet load could result in nuclear being the largest or second-largest form of capacity in several major regions, including New England, California, and Florida.[52] This scenario is predicated on nuclear reaching costs of $50 per megawatt hour (/MWh) in 2006 dollars, however, with the potential of nuclear being phased out if prices remain above $76/MWh.[53] While its future is uncertain, advanced nuclear must remain a part of the conversation around deep decarbonization planning.

Improving coordination with natural gas markets is a simple but effective tactic that system operators can take. By posting day-ahead unit commitments further in advance of the natural gas day-ahead window, power markets would enable generators to bid their full flexible capacity, in the knowledge that they will have time to estimate and procure exactly as much fuel is necessary to support however much of their bid clears the market.[54]

Another rule change would be to limit or even eliminate the practice of resources self-scheduling their generation, rather than participating in economic dispatch.[55] Resources typically self-schedule if they have already contracted with a buyer, such as through a power purchase agreement, or if they have long lead times to start up and cannot wait for the day-ahead market to close. These resources are inflexible in several respects: They are price-taking, rather than price-responsive; they increase the risk of network congestion, as their dispatch cannot be optimized; and they frequently have preferred treatment with respect to curtailment. Reducing self-commitment was one of the reasons the SPP's Market Monitoring Unit recommended extending its day-ahead market to two days ahead.[56] Requiring contracted units to participate in economic dispatch would coerce greater flexibility from them, but potentially at the expense of the otherwise-beneficial practice of long-term contracting; this requirement must therefore be carefully studied, both from market and participant perspectives. Carve-outs would be required for truly inflexible resources such as conventional nuclear, which provides clean baseload generation, as well as resources such as hydroelectric plants whose actions must prioritize environmental considerations above market ones.

Leveraging smart inverters and market competition to create synthetic grid inertia

Incremental improvements in resource flexibility and ramping will support decarbonization in the near term, but as renewable capacity eclipses that of conventional resources, the ultimate challenge will be a lack of grid inertia. Inverters today that enable batteries and renewables to deliver power to the grid are grid-following, in that they simply follow the alternating current of synchronous generators. In an environment with few synchronous generators, inverters will need to operate in a more challenging grid-forming mode, as they do in an islanded microgrid, in which they act as leaders rather than followers in establishing alternating current synchrony.[57] Beyond that, their power electronics will need to react near-instantaneously to power transients, mimicking physical inertial response.[58] This feat is analogous to what a Segway scooter accomplishes in staying upright, despite the movements of its rider. Inverter designs capable of such "synthetic" or "virtual" inertial response are still in the developmental stage, however, and will need to prove themselves capable of stabilizing the grid at scale, to the exacting requirements of NERC and other regulators.[59]

To incentivize the development of this technology while

---

[52] Tapia-Ahumada et al., Deep Decarbonization of the U.S. Electricity Sector.

[53] Ibid.

[54] Robbie Orvis and Sonia Aggarwal, "A Roadmap for Finding Flexibility in Wholesale Markets," Energy Innovation, October 2017.

[55] Ibid.

[56] Southwest Power Pool Market Monitoring Unit, "Self-Committing in SPP Markets: Overview, Impacts, and Recommendations," December 2019.

[57] Benjamin Kroposki, Brian Johnson, Yingchen Zhang, Vahan Gevorgian, Paul Denholm, Bri-Mathias Hodge, and Bryan Hannegan, "Achieving a 100% Renewable Grid," IEEE Power & Energy Magazine, March 1, 2017, https://ipu.msu.edu/wp-content/uploads/2018/01/IEEE-Achieving-a-100-Renewable-Grid-2017.pdf.

[58] National Renewable Energy Laboratory, "When the Gears Stop Turning: NREL and PG&E Collaboration Demonstrates Synthetic Inertia," May 30, 2018, https://www.nrel.gov/news/program/2018/when-the-gears-stop-turning.html.

[59] Roy Kuga, Mark Esguerra, Bennet Chabot, and Alejandro Avendaño Ceceña, EPIC 2.05: Inertia Response Emulation for DG Impact Improvement, EPIC Final Report, Pacific Gas and Electric Company, February 20, 2019.

it remains inessential, markets should consider valuing inertial response as an ancillary service. This action would have the added benefit of initiating the long and complex discussion between markets, regulators, and stakeholders of how to measure and compensate for grid inertia. The Australian Energy Market Commission has begun such an investigation, and found that while requiring minimum levels of inertial response is adequate for now, in higher variable energy resource environments a market for inertial response might be needed in the future.[60] In parallel to such market testing, the federal government can accelerate the development of synthetic inertia through Department of Energy research grants and national laboratory research partnerships, such as the one between the National Renewable Energy Laboratory and Pacific Gas & Electric.[61]

Conclusion

The falling cost and minimal technology risk of renewables has established them as the anchor of tomorrow's decarbonized grid. A key issue for policy makers, regulators, and grid operators is determining how to accommodate these resources at scale without compromising energy security or raising costs. As intermittent resources, renewables will require a substantial investment in flexible complementary resources, such as battery storage and combined-cycle gas turbines, and eventually clean generation sources, such as advanced nuclear, geothermal, and hydrogen fuel cells. These resources must work together to follow loads, and to recreate the physical inertia the grid will lose with the retirement of conventional resources. Flexible loads will have a grid-stabilizing role to play as well, both as supply-side demand response resources and demand-side price-sensitive consumers of electricity. System operators must do their part by creating participation models for advanced resources, such as renewables and DER aggregations, enabling them to participate to their full physical potential. They must also create markets for ancillary services such as flexible ramping reserves and perhaps even grid inertia, services which are technology agnostic and create price signals for flexibility, driving innovation.

Increased transmission capacity will be key to bringing far-flung renewable resources to population centers and to decreasing transmission congestion. Transmission investment that is driven by market opportunities as well as societal needs, and that works around rather than preempts generation investment, can boost grid stability while reducing customer costs. The value returned by physical infrastructure depends on how efficiently it is used, however. Regionalization of markets enables transmission equipment to serve a wider territory, carrying renewable generation to where it is needed—and compensated—the most. Regional markets have averaging effects as well, increasing the likelihood that renewable generation deficits in one territory will be offset by surpluses elsewhere. The Southeast United States, which lags behind much of the country in deregulation and access to competitive markets, could benefit by either joining PJM or MISO, or by forming its own regional transmission operator.

---

[60] Australian Energy Market Commission, Frequency Control Frameworks Review, Final Report, July 26, 2018, https://www.aemc.gov.au/sites/default/files/2018-07/Final%20report.pdf.

[61] National Renewable Energy Laboratory, "When the Gears Stop Turning: NREL and PG&E Collaboration Demonstrates Synthetic Inertia," May 30, 2018, https://www.nrel.gov/news/program/2018/when-the-gears-stop-turning.html.

Ben Hertz-Shargel is head of data science and demand management at Rhythm, a retail clean electricity provider combining technology and humanity for an effortless experience with energy. Previously, he was vice president, advanced grid services and analytics at EnergyHub, where he was responsible for analytics within the company's distributed energy resource management system (DERMS) and energy market operations. At EnergyHub, Ben managed the forecasting and optimization of some of the largest virtual power plants in the world, comprised of electric vehicle (EV) chargers, stationary batteries, grid-interactive water heaters, and connected thermostats. Ben came to EnergyHub from ThinkEco, where he was vice president, technology, and prior to that was a member of the Quantitative Strategies group at Credit Suisse.

Ben is an expert on the intersection between advanced energy technology and energy markets, contributing to reports on the digitalization and decarbonization of the power system published by the Atlantic Council Global Energy Center and the Council on Foreign Relations. He is a Nonresident Senior Fellow at the Atlantic Council Global Energy Center and serves on the external Advisory Committee of the Alfred P. Sloan Foundation's Energy and Environment Program. He is also a contributor to Axios.

Ben holds a bachelor of arts in computer science from Northwestern, a master of science in mathematics from the Courant Institute at New York University, and a PhD in mathematics from UCLA.

Acknowledgments

The Atlantic Council wishes to thank the MacArthur Foundation.

Atlantic Council

Board of Directors

CHAIRMAN
*John F.W. Rogers

EXECUTIVE CHAIRMAN EMERITUS
*James L. Jones

PRESIDENT AND CEO
*Frederick Kempe

EXECUTIVE VICE CHAIRS
*Adrienne Arsht
*Stephen J. Hadley

VICE CHAIRS
*Robert J. Abernethy
*Richard W. Edelman
*C. Boyden Gray
*Alexander V. Mirtchev
*John J. Studzinski

TREASURER
*George Lund

DIRECTORS
Stéphane Abrial
Todd Achilles
*Peter Ackerman
Timothy D. Adams
*Michael Andersson
David D. Aufhauser
Colleen Bell
*Rafic A. Bizri
*Linden P. Blue
Philip M. Breedlove
Myron Brilliant
*Esther Brimmer
R. Nicholas Burns
*Richard R. Burt
Michael Calvey
Teresa Carlson
James E. Cartwright
John E. Chapoton
Ahmed Charai
Melanie Chen
Michael Chertoff
*George Chopivsky
Wesley K. Clark
*Helima Croft
Ralph D. Crosby, Jr.
*Ankit N. Desai
Dario Deste
*Paula J. Dobriansky
Joseph F. Dunford, Jr.
Thomas J. Egan, Jr.
Stuart E. Eizenstat
Thomas R. Eldridge
*Alan H. Fleischmann
Jendayi E. Frazer
Courtney Geduldig
Thomas H. Glocer
John B. Goodman
*Sherri W. Goodman
Murathan Günal
Amir A. Handjani
Katie Harbath
Frank Haun
Michael V. Hayden
Amos Hochstein
*Karl V. Hopkins
Andrew Hove
Mary L. Howell
Ian Ihnatowycz
Wolfgang F. Ischinger
Deborah Lee James
Joia M. Johnson
*Maria Pica Karp
Andre Kelleners
Astri Kimball Van Dyke
Henry A. Kissinger
*C. Jeffrey Knittel
Franklin D. Kramer
Laura Lane
Jan M. Lodal
Douglas Lute
Jane Holl Lute
William J. Lynn
Mark Machin
Mian M. Mansha
Marco Margheri
Chris Marlin
William Marron
Neil Masterson
Gerardo Mato
Timothy McBride
Erin McGrain
John M. McHugh
H.R. McMaster
Eric D.K. Melby
*Judith A. Miller
Dariusz Mioduski
*Michael J. Morell
*Richard Morningstar
Dambisa F. Moyo
Virginia A. Mulberger
Mary Claire Murphy
Edward J. Newberry
Thomas R. Nides
Franco Nuschese
Joseph S. Nye
Ahmet M. Ören
Sally A. Painter
Ana I. Palacio
*Kostas Pantazopoulos
Alan Pellegrini
David H. Petraeus
W. DeVier Pierson
Lisa Pollina
Daniel B. Poneman
*Dina H. Powell McCormick
Robert Rangel
Thomas J. Ridge
Lawrence Di Rita
Michael J. Rogers
Charles O. Rossotti
Harry Sachinis
C. Michael Scaparrotti
Rajiv Shah
Wendy Sherman
Kris Singh
Walter Slocombe
Christopher Smith
James G. Stavridis
Michael S. Steele
Richard J.A. Steele
Mary Streett
*Frances M. Townsend
Clyde C. Tuggle
Melanne Verveer
Charles F. Wald
Michael F. Walsh
Gine Wang-Reese
Ronald Weiser
Olin Wethington
Maciej Witucki
Neal S. Wolin
*Jenny Wood
Guang Yang
Mary C. Yates
Dov S. Zakheim

HONORARY DIRECTORS
James A. Baker, III
Ashton B. Carter
Robert M. Gates
James N. Mattis
Michael G. Mullen
Leon E. Panetta
William J. Perry
Colin L. Powell
Condoleezza Rice
George P. Shultz
Horst Teltschik
John W. Warner
William H. Webster

**Executive Committee Members*

List as of February 2, 2021

Atlantic Council

The Atlantic Council is a nonpartisan organization that promotes constructive US leadership and engagement in international affairs based on the central role of the Atlantic community in meeting today's global challenges.

Atlantic Council
1030 15th Street, NW, 12th Floor,
Washington, DC 20005
(202) 778-4952
www.AtlanticCouncil.org