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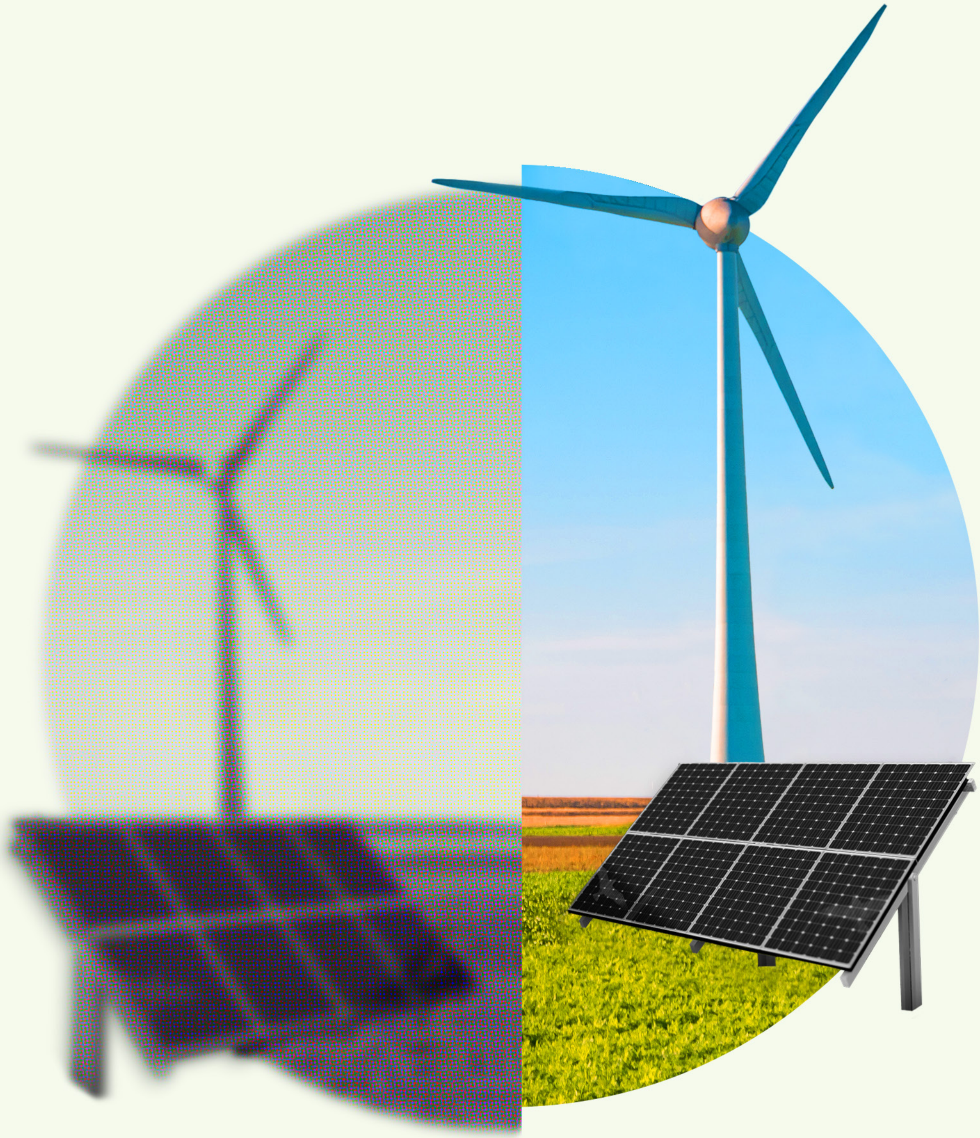

Renewable transition

Separating perception from reality

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Contents

Introduction

IN JUST 10 years, renewable energy's share of US electricity generation has doubled—from 10% in 2010 to 20% in 2020.[1] The overwhelming majority of that growth has been in solar and wind energy, which rose at compound annual growth rates of 84% and 15%, respectively, over the decade.[2] Despite these impressive gains, the pace will have to accelerate significantly for the United States to achieve clean energy goals. At the end of 2020, the country had more than 100 gigawatts (GW) of solar[3] and 122.5 GW of wind power capacity,[4] but will need to add as much as 70–100 GW each of solar and wind per year to decarbonize the power sector between 2035 and 2050.[5]

Most countries are targeting net-zero emissions by 2050, and the US administration supports a goal of emission-free electricity by 2035.[6] How difficult will it be to get there? This report explores five of the most commonly raised challenges: comparing costs of wind and solar versus conventional generation, integrating variable renewables, managing supply chain constraints, addressing disaster vulnerability, and meeting future electricity and renewable electricity demand. We also examine the perceptions often voiced, and some industry perspectives, facts, and data around the issues, and what's required to solve them.

Comparing costs of wind and solar versus conventional generation

Common perception: *Solar and wind are too expensive, or they are only competitive with conventional generation plants because of government incentives, such as tax credits.*

Reality and industry perspectives: Solar and wind have become the cheapest power generation sources across most of the United States and the world, even without tax incentives and with integration costs included. In many cases, these resources are competitive even with battery storage included. And costs continue falling.

The cost of electricity from wind and solar generation has declined sharply in the past decade, by about 55% for onshore wind and 85% for utility-scale solar photovoltaics (PV) in the United States and globally.[7] Figure 1 compares the revenue required to build and operate a generation source over a 30-year period for several types of generation technologies, or the levelized cost of energy (LCOE). The LCOE ranges indicate that even without the benefit of tax credits, wind and solar LCOEs are still cost-competitive.

Since wind and solar are variable renewable energy (VRE) resources, ongoing investment is required to integrate them smoothly on the grid, such as new transmission, energy storage, and further digitalization[8] to add flexibility. But even adding industry estimates of US$5 per megawatt hour (MWh) for integration costs still leaves wind and solar LCOEs competitive with gas and coal-fired plants.[9]

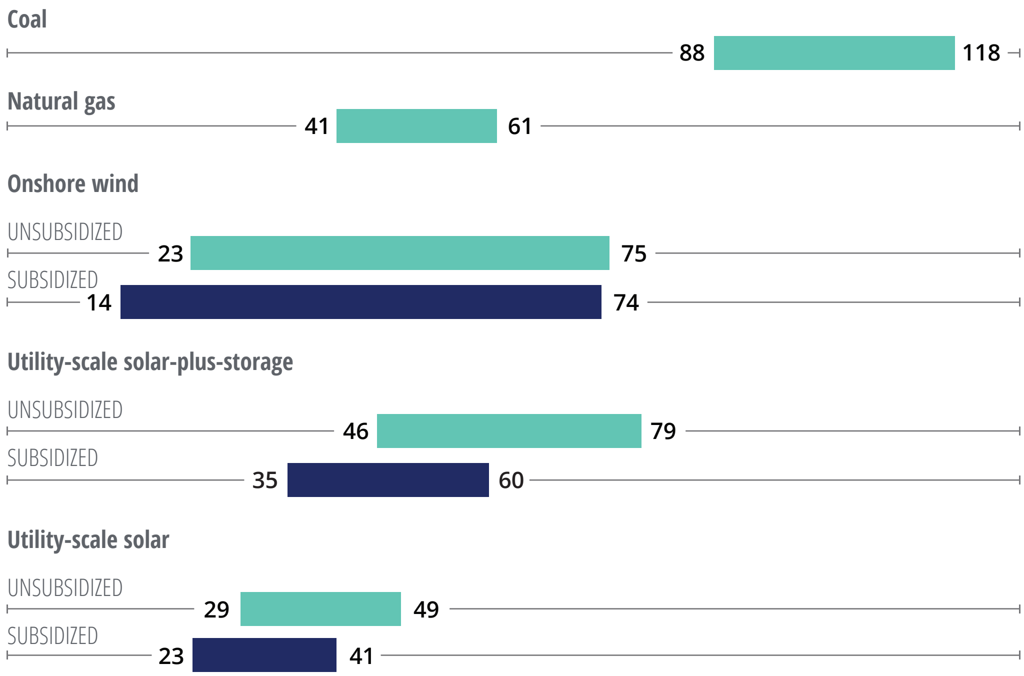
Given the variability of wind and solar, plants are increasingly being built with battery storage, which can make them more dispatchable. The average LCOE for solar-plus-storage “hybrid” plants is not yet competitive with combined cycle gas turbines (CCGT) across the entire United States (figure 1). But in some states with high renewable penetration, such as California, market forces make hybrid plants more cost-effective than CCGT, and this trend is expected to spread to other states as renewable market penetration increases.[10]

Power purchase agreement (PPA) prices for wind and solar power are also competitive with other resources. The weighted average US price for the first half of 2021 from auction and PPAs for solar PV is US$31/MWh, while for onshore wind it is US$37/MWh.[11] This compares to a weighted average wholesale electricity price of about US$34/MWh across US markets during the same period.[12]

FIGURE 1

Levelized cost of energy for generation resources in the United States

(US$/MWh)



Sources: Wind and solar: National Renewable Energy Laboratory, "2021 electricity ATB technologies and data overview," 2021; coal and natural gas: International Energy Agency, "Levelized cost of electricity calculator," December 9, 2020.

In many cases, it costs less to build new solar and wind plants than to continue running existing coal-fired plants. In fact, between 77% and 91% of existing US coal-fired capacity in 2021 has operating costs that are estimated to be higher than the cost of new solar or wind power capacity.[13] And that trend may increasingly apply to nuclear and natural gas-fired plants. Figure 2 compares the levelized cost of energy from new-build wind and solar plants with the marginal costs of existing conventional generation.

In Deloitte's recent survey of power industry executives (see sidebar "About the Deloitte Renewable Transition Survey"), nearly three-quarters of respondents perceive renewables' low costs as well as the need for investment to smoothly integrate them.

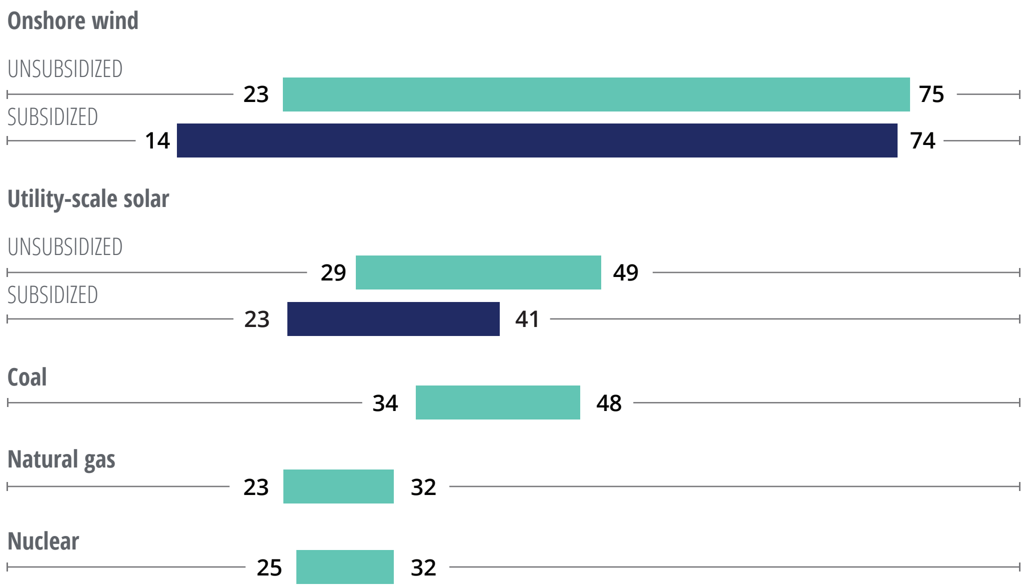
73% of power industry respondents agree that wind and solar power are cheaper than many other sources of electricity, but there is a need to continue to invest in modernizing the grid and adding transmission and storage to integrate these resources.

35% of power industry respondents believe wind and solar costs have fallen so far that they are increasingly competitive with other generation sources, even when they are combined with battery storage.

FIGURE 2

New build renewable energy vs. marginal cost of existing conventional generation

(US$/MWh)



Source: Wind and solar LCOE: National Renewable Energy Laboratory, "2021 electricity ATB technologies and data overview," 2021; coal, natural gas, and nuclear marginal cost: Lazard, *Lazard's levelized cost of energy analysis - version 14, October* 2020, p. 7.

The electric power industry, consumers, and the investment community appear to be voting for renewable growth with their wallets, as wind and solar development pipelines have expanded to 119.4 GW and 67.4 GW for solar and wind, respectively, through 2025.[14] And these two technologies will likely become even more attractive as their costs are projected to fall to half of what they are today by 2030.[15]

ABOUT THE DELOITTE RENEWABLE TRANSITION SURVEY

To understand the perspectives of electric power industry executives on the five challenges discussed in this report, Deloitte fielded a survey in July 2021 to more than 40 power industry executives and senior leaders. The findings were supplemented by interviews with executives and leaders in utilities and other electric power providers.

Integrating variable renewables

Common perception: *Intermittency is a major obstacle and more than 10% penetration of variable wind and solar power on the grid could destabilize it. Wind and solar must be backed up 1:1 with conventional generation, which is too expensive.*

Reality and industry perspectives: Power systems in some countries and states are already operating with more than 50% penetration of wind and solar generation annually without impacting reliability. There is an expanding set of operational and technical solutions to help integrate these resources and building new conventional power plants to back them up has not been necessary.[16]

The challenges of integrating VRE resources[17] are real, but US VRE penetration is already 11% nationwide and has reached more than 58% in Iowa and 43% in Kansas, without impacting reliability.[18] Twelve states generated more than a quarter of their electricity from VRE in 2020 (figure 3)[19] and European countries have seen even higher penetrations, with Denmark topping 61% annually in 2020 (figure 4)—all without major supply shortages or outages associated with renewable variability. Many projections show VRE penetration rising to over 40% across the United States by 2035 and up to 70%–80% in 2050.[20]

FIGURE 3

Share of annual electricity generation from VRE

0–20% 21%–40% 41%–60% 61%–80% 81%–100%

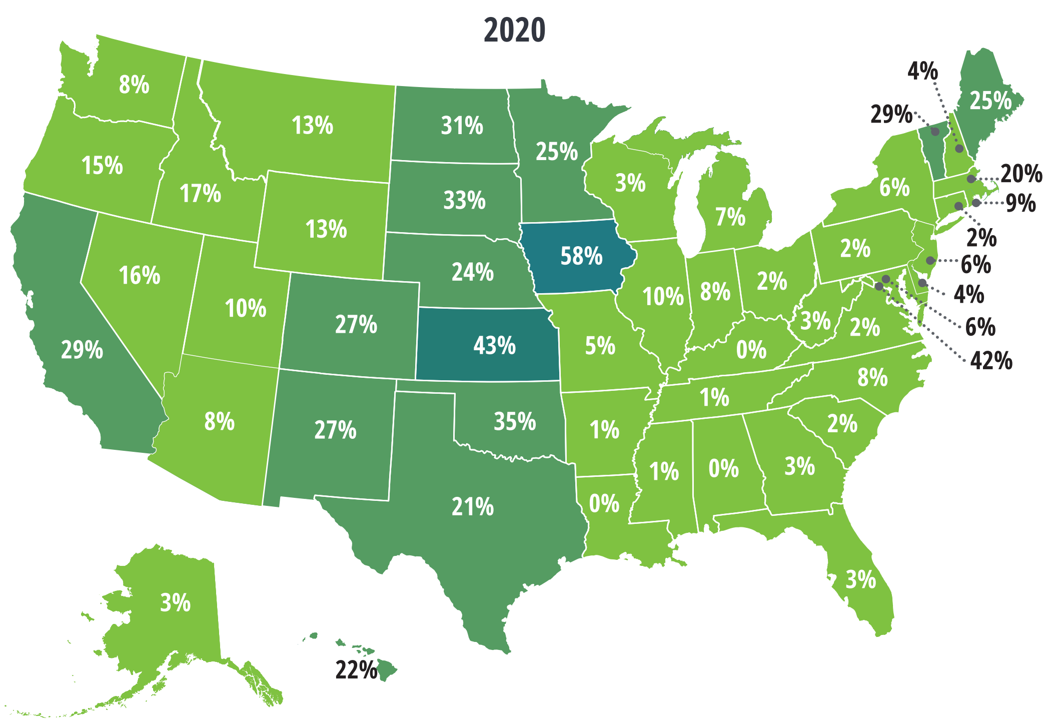
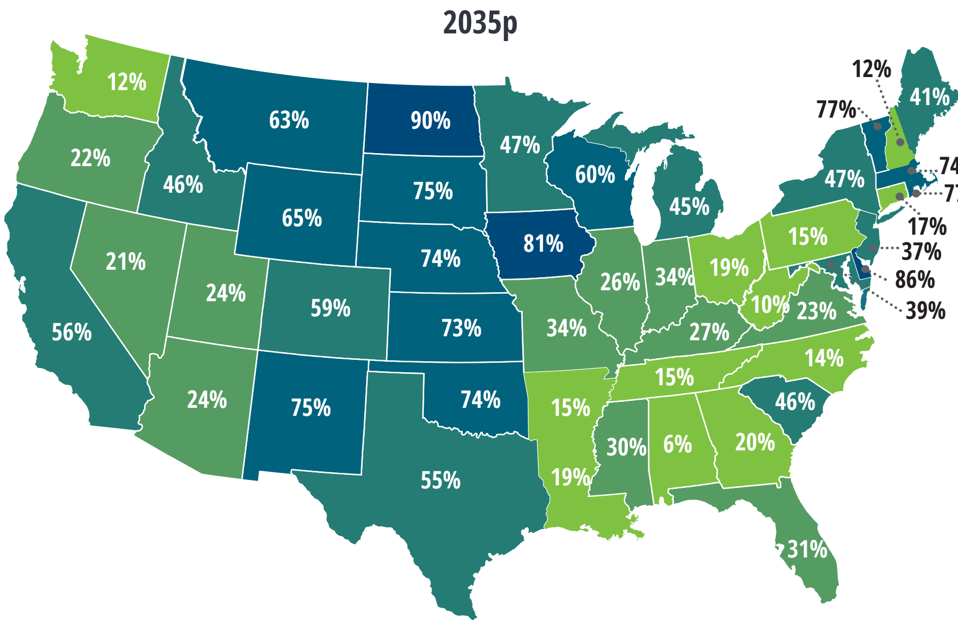
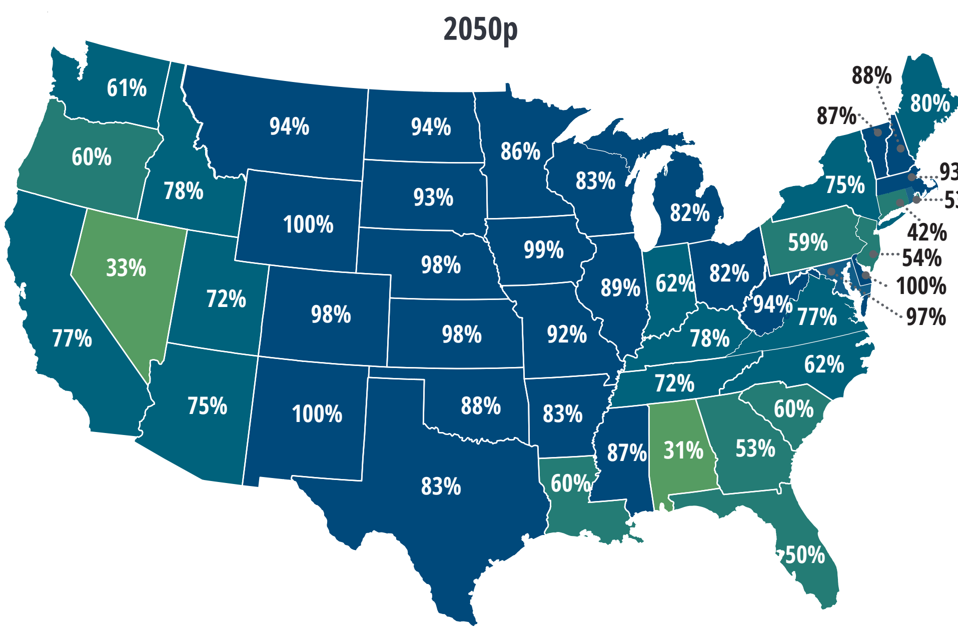


FIGURE 3 (CONTINUED)

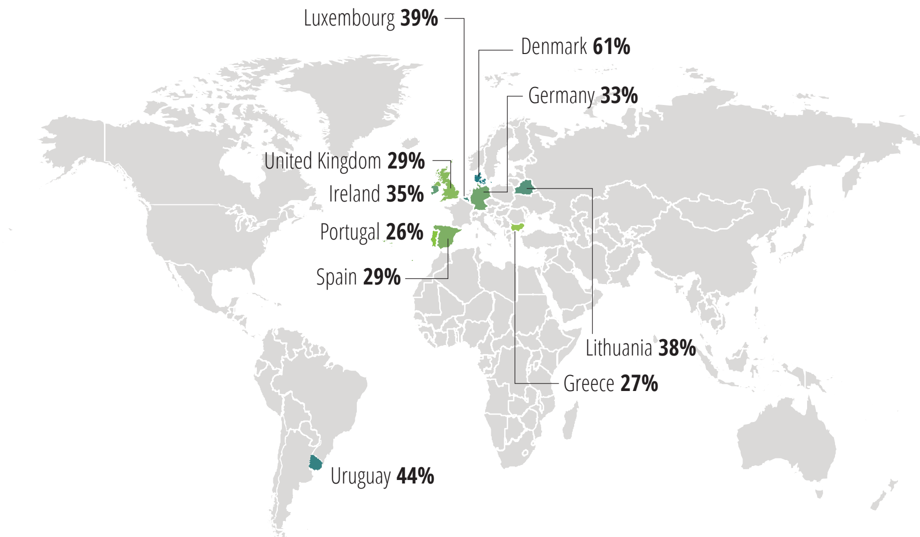




Note: Projections for Hawaii and Alaska are unavailable.
Sources: 2020 data: U.S. Energy Information Administration (EIA), which includes generation from utility-scale wind and solar as well as small-scale solar (<1MW); 2035 and 2050 data: National Renewable Energy Laboratory, North American Renewable Integration Study (NREL/NARIS), which includes utility scale wind and solar as well as distributed solar; 2035 data is the average of 2034 and 2036 NREL/NARIS data; Deloitte analysis.

FIGURE 4

Top 10 countries' share of annual electricity generation from VRE, 2020



Sources: Ember, *Global electricity review 2021.*

Planning and flexibility are often key to smoothly integrating VRE, and solutions typically fall into 10 categories: [21]

Redesigning markets—Wholesale market operators are revising rules and innovating market design to provide more flexibility to integrate variable resources.

Improving forecasting—Advanced weather forecasting can more accurately determine when and where the sun will shine or the wind will blow to forecast VRE output. On the demand side, operators are also working to forecast load more accurately.

Accessing dispatchable centralized generation resources—Operators can access output from fast ramping resources such as CCGT and hydropower plants with reservoirs to address intermittency.

Tapping into dispatchable DER—DER can either reduce demand (e.g., demand response) or increase supplies (e.g., fuel cells) to help reduce grid impacts from VRE.

Deploying energy storage—Fast ramping capability makes energy storage a particularly useful resource in countering VRE intermittency.

Expanding/optimizing transmission—Adding transmission capacity through expansion or technology upgrades allows access to resources in neighboring regions for balancing.

Increasing regional coordination—Coordinating resource dispatch across regions can facilitate VRE integration as weather patterns vary across larger areas.

Planning/optimizing location of DER—Analyzing existing grid resources, capacity, and current and future load patterns can help determine where DER can be most valuable.

Testing new technologies—Utilities and grid operators are testing new technologies for integrating VRE around the world. For example, operators are applying AI/machine learning to weather and power plant output data to increase the accuracy of renewable output forecasts.[22]

Modernizing the grid—Boosting the grid's flexibility to integrate growing volumes of VRE requires deployment of a host of supporting technologies to enhance visibility and control. Utilities are already including many of these same technologies in grid modernization plans because they facilitate overall grid reliability and operational efficiency.

The following examples highlight some key strategies employed by the country with the highest VRE penetration globally, Denmark, and by two high-penetration US states with different approaches, Iowa and California. For additional examples, see *Managing variable and distributed energy resources: A new era for the grid*.

DENMARK (VRE PENETRATION: 62%)

Key strategies

Redesigning markets: In 1999–2000, Denmark cocreated the Nord Pool power exchange, a market that helps its 16 member countries balance electricity supply and demand.[23] The country also maintains four ancillary/balancing markets. In 2006, Denmark began requiring its combined heat and power (CHP) plants to settle at market prices, effectively transforming them into flexible resources to balance increasing wind output.

Tapping into dispatchable distributed energy resources (DER): Denmark has a sophisticated demand response market based largely on CHP systems, which produce nearly half of the country's power. Fueled by gas, biomass, and waste, the CHP systems can respond to market pricing and balance output against varying wind generation. The country also encourages new DER, such as heat pumps and electric vehicles (EVs), to provide storage for excess wind output.[24]

Expanding/optimizing transmission: Denmark has interconnections that allow it to sell excess wind output to neighboring countries, or source its entire peak load from them if needed.[25] Its electricity system operator proactively plans new transmission capacity anticipating future interconnection of wind farms.

Accessing dispatchable centralized generation resources: Denmark's conventional power plants are designed for hourly ramping and daily cycling to quickly adjust to fluctuating output.[26]

IOWA (VRE PENETRATION: 58%)

Key strategies

Regional and interregional coordination: Iowa is part of the Midcontinent Independent System Operator (MISO), which delivers power and operates a wholesale electricity market across 15 states and one Canadian province. MISO's real-time and day-ahead markets help balance electricity supply and demand throughout the midcontinent.

Expanding transmission: MISO's 66,000 miles of transmission lines connect Iowa to resources across the region and to neighboring grids,[27] enabling operators to send excess wind output or access additional energy as needed. The proposed SOO Green HVDC Link would link wind resources across Iowa to northern Illinois and connect MISO to mid-Atlantic grid operator PJM, further expanding those capabilities.[28]

Accessing centralized generation: Iowa's 11.7 GW of wind generation capacity[29] are part of 199 GW of generating capacity of all types within MISO.[30] Diversified resources across a large geographic region help enable smooth integration of Iowa's wind output. Studies show that MISO needs almost **no additional fast-acting power reserves** to back up the wind power on the system.[31]

Deploying energy storage: Iowa has approximately 6.9 MW of utility-scale battery storage[32] and another 415 MW in the queue as of May 2021, while MISO has 5,625 MW in the queue.[33] Green hydrogen producers are exploring production potential in Iowa, due to the abundance of low-cost wind and increasing solar output needed to produce this long-term energy storage resource.[34]

CALIFORNIA (VRE PENETRATION: 29%)

Key strategies

Improving forecasting: Recent extreme heat waves have caused electricity demand to exceed resource adequacy and planning targets. The California Independent System Operator (CAISO), the California Public Utilities Commission (CPUC), and the California Energy Commission (CEC) are collaborating to modernize load forecasting and resource planning to anticipate extreme climate events, while accounting for the state's transition to a cleaner but potentially more variable energy resource mix.*[35]

Planning/optimizing location of DER: The CPUC requires the state's investor-owned utilities (IOUs) to file and update distribution resource plans annually, which identify optimal locations for deploying DER.[36] This helps the CPUC assess where DER, such as EV charging stations, can be added without costly upgrades and/or lengthy interconnection studies.[37]

Regional coordination: CAISO offers the Energy Imbalance Market as a real-time, energy-only market for participants anywhere in the western United States to buy and sell energy when needed. CAISO can send excess solar output to other states and potentially tap their resources when needed through this market.[38]

Deploying energy storage: The CPUC set targets for California's three largest IOUs to procure and install 1.325 GW of energy storage by the end of 2020 and 2024, respectively. The IOUs exceeded the target, procuring 1.5 GW of storage by end 2020. The state set an additional target for IOUs to procure 500 MW of distributed energy storage systems.[39] Additional storage can help integrate growing VRE generation.

Note: *While some have attributed California's electricity supply shortages to VRE, the causes appear more related to demand surges from unprecedented multistate heat waves coinciding with wildfires that constrained transmission and triggered systemwide failures (for more details, read Ken Silverstein, "Green energy is not among the culprits behind California's energy crisis," *Forbes*, September 8, 2020). Nevertheless, California's plans to prevent future shortages include accounting for the state's changing generation mix.

These solutions can serve as building blocks and their value will likely grow as VRE penetration rises across the United States and globally. The good news is that the required technologies and capabilities are advancing and their costs are falling. Battery storage costs, for example, have dropped 89% over the last decade.[40] US states and other countries should plan and forecast in detail, strengthen and modernize their grids in advance, and consider retaining the resources needed to fill in gaps, however seldom used, until they have been replaced with robust, low-carbon solutions.

When surveyed on this topic, power industry executives appeared optimistic about meeting integration challenges with long-term planning and innovative solutions—and that DER can help:

73% of power industry respondents think the United States can integrate far more wind and solar power than it has now without compromising reliability as long as we build flexibility into the grid and plan ahead to use resources such as energy storage to manage intermittency.

70% of power industry respondents think DER will form a big component of the clean electricity grid that will help balance intermittent resources.

Managing supply chain constraints

Common perceptions: *There is concern that renewable energy, battery storage, and EV growth could be hampered by supply chain disruptions—from manufactured components to critical minerals and materials.*

Reality and industry perspectives:
Constraints on manufactured components, key materials, and critical mineral supply chains are real and can potentially slow growth, at least temporarily, as they have during the pandemic. But longer-term solutions exist and are being explored and implemented to address longer-term postpandemic constraints.

Most clean energy components are manufactured abroad, with the United States most exposed in the solar, battery storage, and wind sectors. US-China trade tensions (including issues around production using forced labor) and pandemic-driven supply chain vulnerabilities have raised concerns about supply chain resiliency.[41] About 85% of the solar panels sold in the United States are imported from China and Chinese companies operating in Southeast Asia.[42] As for lithium-ion battery manufacturing, the United States manufactures 10% or less of global supplies of key battery components such as anodes, while 42%–65% of these and other components come from China (figure 5).

FIGURE 5

Share of total manufacturing capacity for lithium-ion battery components, by country

Country	Cathode manufacturing (3M ton)	Anode manufacturing (1.2M ton)	Electrolyte solution manufacturing (339,000 tons)	Separator manufacturing (1,987M sq.m)
United States	–	10%	2%	6%
China	42%	65%	65%	43%
Japan	33%	19%	12%	21%
Korea	15%	6%	4%	28%
Rest of world	10%	–	17%	2%

Source: Federal Consortium for Advanced Batteries, *National blueprint for lithium batteries 2021–2030*, June 2021, p. 19.

In the wind sector, the United States has increased the domestic content of turbines with more than 500 manufacturing facilities in 40 states.[43] Still, it imports nearly three-quarters of wind power generating sets from Spain, 64% of wind towers from three Asian countries, and 22% of blades and hubs from China.[44] Record demand and the COVID-19 pandemic strained the global supply chain in 2020, triggering shortages of blades, bearings, and core materials used in blades.[45] As the world economy reignites, shortages are also emerging for everything from semiconductors, to steel, to flatbed trucks. Record-high freight rates and port congestion are further straining clean energy supply chains.[46]

Efforts to support US solar, battery, and wind supply chains are addressing not just the clean energy components themselves, but also the materials that go into them, such as aluminum, steel, polysilicon, and critical minerals. The International Energy Agency describes a "looming mismatch between the world's strengthened climate ambitions and the availability of critical minerals that are essential to realizing those ambitions."[47] The need for critical minerals and rare earth elements (REEs) could increase by as much as six times by 2040.[48] Constrained access to these commodities may hamper the United States' ability to reach ambitious renewable energy and decarbonization targets.[49] Lithium-ion battery production requires lithium, nickel, cobalt, manganese, and graphite, while wind turbines and EV motors require REEs such as neodymium, praseodymium, and dysprosium for permanent magnets, and solar PV requires polysilicon and silver. Electricity networks overall need significant amounts of both copper and aluminum.[50] Figures 6 and 7 illustrate critical mineral needs for clean energy technologies and global supply sources.

Many of these materials are not scarce, but it takes time, investment, expertise, and commitment to start or restart mining operations to extract and process them.[51] For more details on the mining sector's potential role, read *Meeting demand for green and critical minerals.*

Governments, end-user industries, and individual companies are working to address these supply chain issues. Solutions include developing domestic manufacturing and sustainable mining, working with allies and partners to secure additional supplies, committing to future demand to incentivize investment, recycling materials, and changing designs to limit use of scarce resources. For example, wind turbine developers are exploring a move to smaller and lighter permanent magnet generators that use fewer REEs, gearless design for wind turbines that are REE-free, and replacing permanent magnets with high-temperature superconductors.[52] The alternative pathway for solar PV (with silicon) could be scaling up perovskite solar cell manufacturing in tandem with existing silicon cells to reduce silicon demand and boost efficiency. And EV manufacturers are working to develop low- or no-cobalt cathodes due to price spikes and ethical concerns around current cobalt mining.[53]

A recent executive order supports the development of an end-to-end domestic supply chain for advanced batteries and seeks to strengthen supply chains for multiple critical production materials.[54] In addition, some manufacturers are lobbying for the reinstatement of advanced energy manufacturing tax credits.[55]

Deloitte Renewable Transition Survey respondents were somewhat optimistic about the impact of

FIGURE 6

Degree of criticality by industry*

High | Moderate | Low

	SOLAR PV	WIND	EVs AND BATTERY STORAGE
ALUMINUM *70%–80% recycled* Can be substituted with some loss of performance (steel, plastic)	High	High	High
COPPER *About 34%–90% recycled* Challenging to substitute in most applications	High	High	High
DYSPROSIUM *Not currently recycled* Shift to alternative motor or magnet types using ferrite or copper, or non-PMG** wind	Low	High	High
NEODYMIUM *Not currently recycled* Shift to alternative motor or magnet types using ferrite or copper, or non-PMG** wind	Low	High	High
MANGANESE *Limited recycling* Efficiency increasing; can shift to other battery types (LFP, NCA**)	Low	Moderate	High
NICKEL *90% recycled* Efficiency increasing; possible shift to LFP**	Low	Moderate	High
SILVER *Not currently recycled* Efficiency increasing; possible shift to copper but not commercialized	High	Moderate	Low
LITHIUM *5%–10% recycled* Efficiency increasing; possible shift to zinc in batteries	Low	Low	High
COBALT *90% recycled* Efficiency increasing; possible shift to LFP and NCA**	Low	Low	High

Notes: *Criticality is determined by factors such as use in multiple technologies or being hard to replace; **LFP = Lithium iron phosphate; NCA = Lithium nickel-cobalt-aluminum oxide; PMG = Permanent magnet generator.

Sources: International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions*, p. 45, May 2021; Claudiu C. Pavel et al., *Substitution of critical raw materials in low-carbon technologies: lighting, wind turbines and electric vehicles*, European Commission, 2016; Deloitte analysis.

manufactured components' supply chain constraints on renewable growth, and more concerned about the impact of critical minerals shortages:

MANUFACTURED COMPONENTS

59% of power industry respondents said supply constraints for wind and solar components manufactured abroad will likely impact renewable growth only temporarily because renewable developers can find alternative suppliers of wind and solar manufactured components.

31% of power sector executives surveyed said manufactured components' supply constraints could significantly slow renewables' growth.

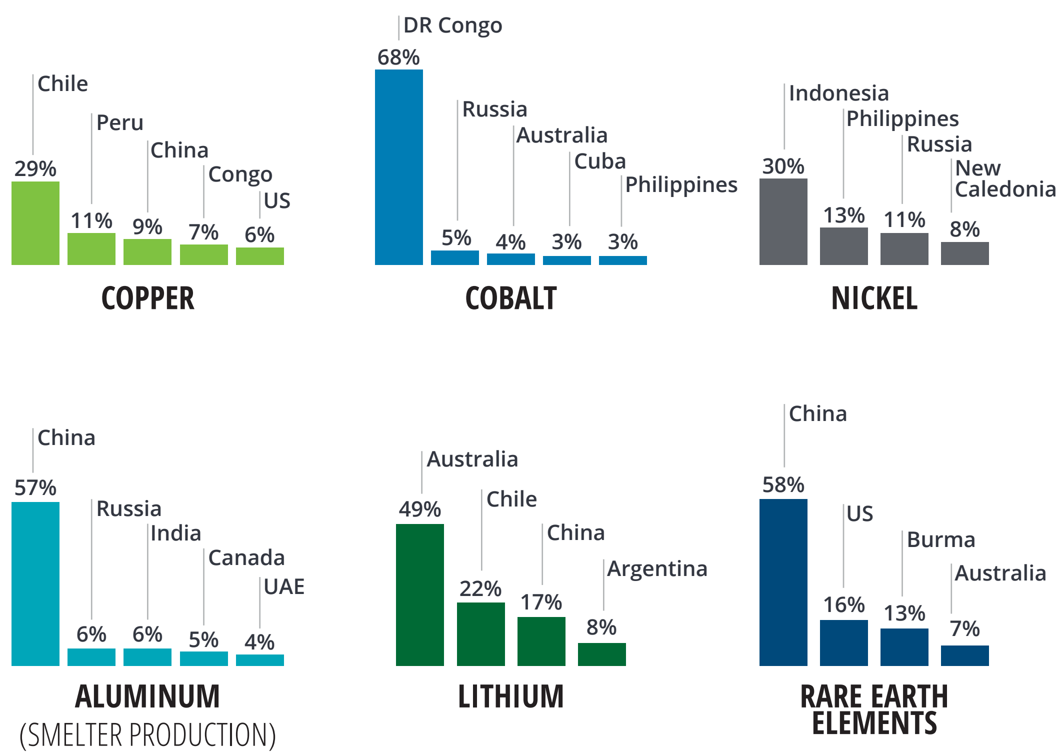
CRITICAL MINERALS

51% of power sector executives surveyed said constrained supplies of critical minerals will likely slow renewable energy growth.

41% of power industry respondents said critical mineral shortages are unlikely to significantly slow renewable energy growth because industries and governments are taking steps to boost production, identify alternative materials, recycle, or develop processes that require smaller quantities.

FIGURE 7

Share of global critical mineral supplies from top suppliers, 2020



Sources: US Geological Survey, *Mineral commodity summaries* 2020, January 21, 2020.

Addressing disaster vulnerability

Common perceptions: *Renewables are sometimes perceived as more vulnerable to extreme weather than conventional generation plants. There is also a misconception that renewables are more apt to fall prey to another type of disaster, cyberattacks.*

Reality and industry perspectives: Renewables have sometimes come under scrutiny after severe weather-driven power outages. However, nearly all types of power generation can be impacted by storms, extreme temperatures, and other natural disasters.[56] Weatherization to reduce this vulnerability can often be economically justified and should be evaluated, especially given recent severe weather trends. Diversifying energy sources, expanding interregional connections, and adding DER such as onsite solar, battery storage, microgrids, and demand response can also help ensure against weather-related outages and provide resilience. In addition, all types of generation assets face the risk of cyberattacks and require cyber risk management.

Weather vulnerability: The United States experienced 22 weather or climate disasters in 2020 that each caused at least US$1 billion in damage, breaking the previous annual record of 16 events, which occurred both in 2017 and in 2011.[57] With more extreme weather events, both renewable and conventional energy sources face increased risk from climate-related disasters.

In the case of coal and natural gas–fired plants, extreme weather can impact fuel delivery and storage. Subzero temperatures can freeze coal stockpiles as well as natural gas wellheads and pipelines.[58] Similarly, wind turbine parts can become brittle under cold temperatures, which can impact output and longevity. To address these issues, operators can invest in weatherization packages that include heaters and special lubricants. Solar plants typically do not require winterization, although fewer daylight hours and heavy snow on panels may reduce energy output.[59] Wildfires can also cut solar production as particulate matter from the smoke may reduce the amount of sunlight absorbed. One remedy is to spray panels with water to remove the grime.

For most generation assets, particularly in areas that typically have milder winters, it may be difficult to determine when weatherization packages are economically justified. Figure 8 highlights weatherization solutions for different assets with typical costs.

Our survey results reinforce the perspective that renewable assets are not more vulnerable to extreme weather than conventional generation:

68% of power sector executives surveyed believe that wind and solar plants are no more vulnerable to extreme weather than other types of power generation plants; all types of generation may need to be "weatherized" to withstand potential weather extremes in certain climates.

Cyber vulnerability: Recent highly publicized cyberattacks across industries suggest that not only are nearly all types of power generation vulnerable,

FIGURE 8

Options and costs for weatherizing assets

Asset type	Weatherization options	Costs
Natural gas production, delivery, processing, and storage infrastructure	• Prioritize electricity delivery to gas infrastructure during a crisis • Winterize gas production, delivery, processing, and storage infrastructure with solutions such as methanol injection, enclosures, heaters, insulation, and dehydration	Capex for winterizing a typical gas well: US$42,000 + US$8,000 annual opex[a]
Natural gas-fired plants	Install insulation, wind breaks/enclosures, heaters, heat tracers, temperature and dew point monitors, sensors, and alerts	US$60,000–600,000 per plant[b]
Coal-fired plants and coal storage		Winterization of thermal plants typically costs < 1% of the initial capital cost of the plant, while retrofits are more costly[c]
Nuclear plants		
Wind turbines/plants	Solutions to prevent ice buildup include:[d] 1. Heaters and blowers 2. Carbon fiber coating to prevent ice buildup 3. Embedded warming equipment in blades, turbine, and gear box (allows production at temperatures down to -22F)	Cost of solutions:[e] 1. Heaters and blowers: US$80,000–150,000 2. Coating: US$40,000 + US$5,000 annual opex 3. Embedded warming: US$150,000–450,000 Winterization packages add about 5% to turbine cost[f]

Sources:

[a]Federal Energy Regulatory Commission and North American Electric Reliability Corporation, *Report on outages and curtailments during the Southwest cold weather event of February 1-5, 2011*, August 2011, p. 36. Costs converted to 2021 USD using the Bureau of Labor Statistics inflation calculator.

[b]Ibid., p. 179.

[c]Charlotte Huffman and Jason Trayhan, "Winterizing Texas power plants could cost between $5B and $20B," WFAA, May 2, 2021.

[d]American Clean Power Association, Asset management and standard development department.

[e]Ibid.

[f]Baker Institute, "Winterization and the Texas blackout: Fail to prepare? Prepare to fail," *Forbes*, February 19, 2021.

but assets and systems across other energy infrastructure could also be susceptible.

Natural gas and coal are both, to varying degrees, dependent on supply chain interfaces that are exposed to cyberthreats. Sensors, valves, and pressure within pipelines and leak detection systems may be vulnerable to attack in gas plants.[60] Although nuclear plants are not connected to unsecured networks, effectively creating "air gaps" that provide some level of cyber protection, they could be vulnerable to a targeted attack perpetrated by a well-resourced adversary using USB sticks.[61]

In solar plants, inverters have been identified as a source of cyber risk due to their two-way communications with the grid and a perceived lack of strong standards to protect those communications. Likewise, operators' remote access to wind, solar, and storage systems may also pose cyber risk. Researchers in Oklahoma demonstrated that their wind turbines could be hacked in less than one minute through a single lock on the door to gain access to their servers.[62] Distributed solar and wind, like other DER, may expand the potential attack surface. And, as with other assets, increasing dependence on digital communications and control, without cyber risk management, could increase vulnerability.

However, Deloitte Renewable Transition Survey results suggest wind and solar are not more vulnerable to cyberattacks than other assets:

80% of power industry respondents said it's not clear that wind and solar assets add any more vulnerability to cyberattacks than other types of assets.

The power industry and government have increased efforts to address growing cybersecurity threats. The nonprofit North American Electric Reliability Corporation (NERC) mandates cybersecurity standards for the bulk power system and operates a data sharing and incident management center for the industry. The Energy Sector Coordinating Council (ESCC) helps industry members coordinate with the government to prepare for and respond to disasters or threats. A recent executive order outlines several initiatives, including improving software supply chain security.[63] And the Department of Energy (DOE) is working to establish wind industry-specific guidelines for cyber incident reporting, event response, and recovery.[64] Integrating cybersecurity measures into new renewables projects from the start can help manage cyber risk.

Meeting future electricity and renewable electricity demand

Common perceptions: *As the United States further electrifies the transportation, heating, and industrial sectors, there is sometimes concern about whether there will be enough electricity to power it all—in particular, enough renewable electricity to meet US needs.*[65]

Reality and industry perspectives: Overall power supplies will likely be sufficient as electrification boosts consumption, as long as the industry continues long-term, holistic system planning, grid modernization, demand side management, and integration of DER. As for renewable supplies, meeting a 100% clean electricity standard between 2035 and 2050 will require doubling or tripling the 35 GW of wind and solar capacity that was added in 2020, every year. This is an ambitious goal and would be more likely with federal policy support, such as a Clean Energy Standard (CES). It will also likely require accelerated grid interconnection rates.

Electricity supply: Utilities are already planning and preparing for electrification. Electricity supplies will likely be sufficient if the timing of demand, such as EV charging, can be managed. Many utilities are implementing grid modernization plans, which involve harnessing advanced analytics and digital technologies to forecast demand and consumption, monitor and manage load, and match supplies to it (or, increasingly, vice versa). In 2020, the North American market for digital grid solutions, such as sensors, meters, and communications technology, was estimated to be US$1.16 billion, and that's expected to grow at a compound annual growth rate (CAGR) of 3.5% over the decade, to reach US$1.64 billion in 2030.[66]

Despite the ability to plan and manage the growth of electrification and renewables, some are still concerned about electricity supplies due to other factors. In some areas, climate change is having unpredictable effects on consumption patterns and on the grid itself.[67] Recent infrastructure and supply challenges in the US West due to record-breaking heat and wildfires, and in Texas and other states due to an unprecedented winter freeze, illustrate this trend. This is likely behind the split in power industry respondents' attitudes on the issue. Despite the ambiguity, nearly three-quarters of respondents see DER as a key potential solution:

53% of power industry executives surveyed said as long as the industry can project increased consumption, build the necessary infrastructure to support it, and manage usage to avoid spiking peak demand, supply shortages are unlikely.

At the same time, more than half of power industry respondents said as additional end-uses are increasingly electrified, there's a risk of not being able to meet increased electricity demand by 2035.

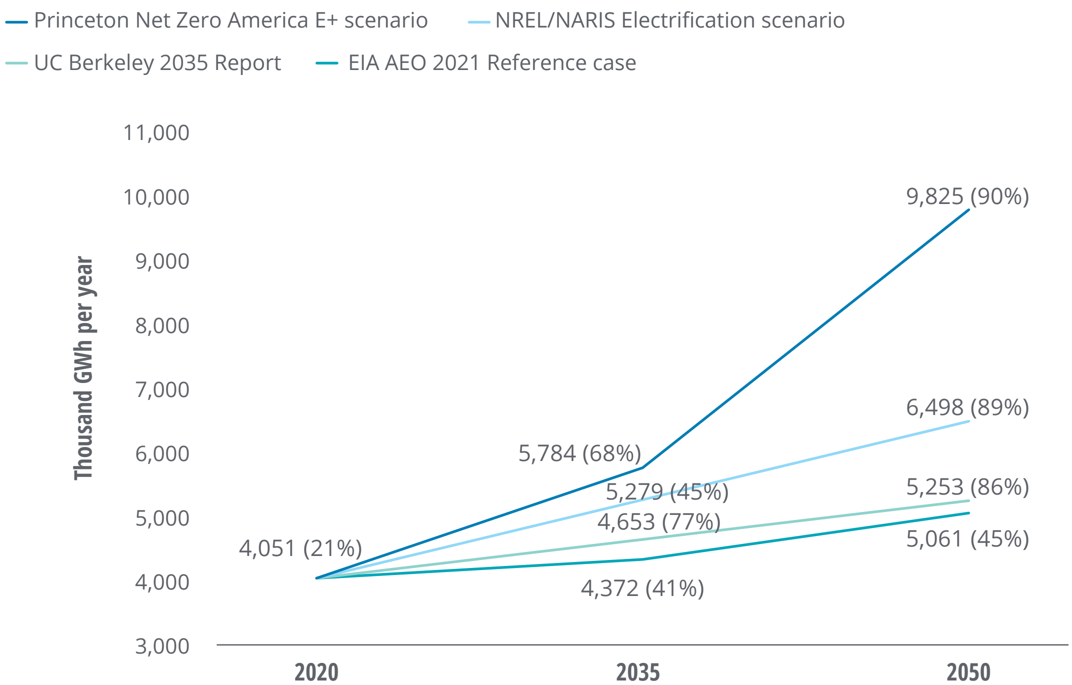
73% of power industry respondents think DER will play a key role in fulfilling increased electricity demand by 2035.

Renewable/clean electricity supply: While the power industry is committed to leading the clean energy transition,[68] the 2035 deadline is sooner than some had planned. Nearly two-thirds of power industry respondents were skeptical of reaching the target in 2035. Utilities continue to announce decarbonization goals, but most of their targets extend closer to 2050.[69] In addition, while renewable developers already have 187 GW of wind and solar in project pipelines through 2025,[70] interconnection has become a bottleneck, with average wait times rising to 3.5 years over 2010–2020, up from 1.9 years in the previous decade.[71]

To understand how much electricity and renewable electricity the United States may require in 2035 and 2050, consider the EIA's most recent data (2020) and projections to 2050, as well as three alternative scenarios that model different degrees of electrification and carbon reduction (figure 9).

FIGURE 9

US electricity generation in select carbon reduction scenarios



Notes: The values in parentheses are the share of generation from renewable resources, including wind, solar, hydro, geothermal, and biomass. Other "clean" or carbon-free sources, such as nuclear power and fossil fuels with carbon capture, are not included in the percentages.

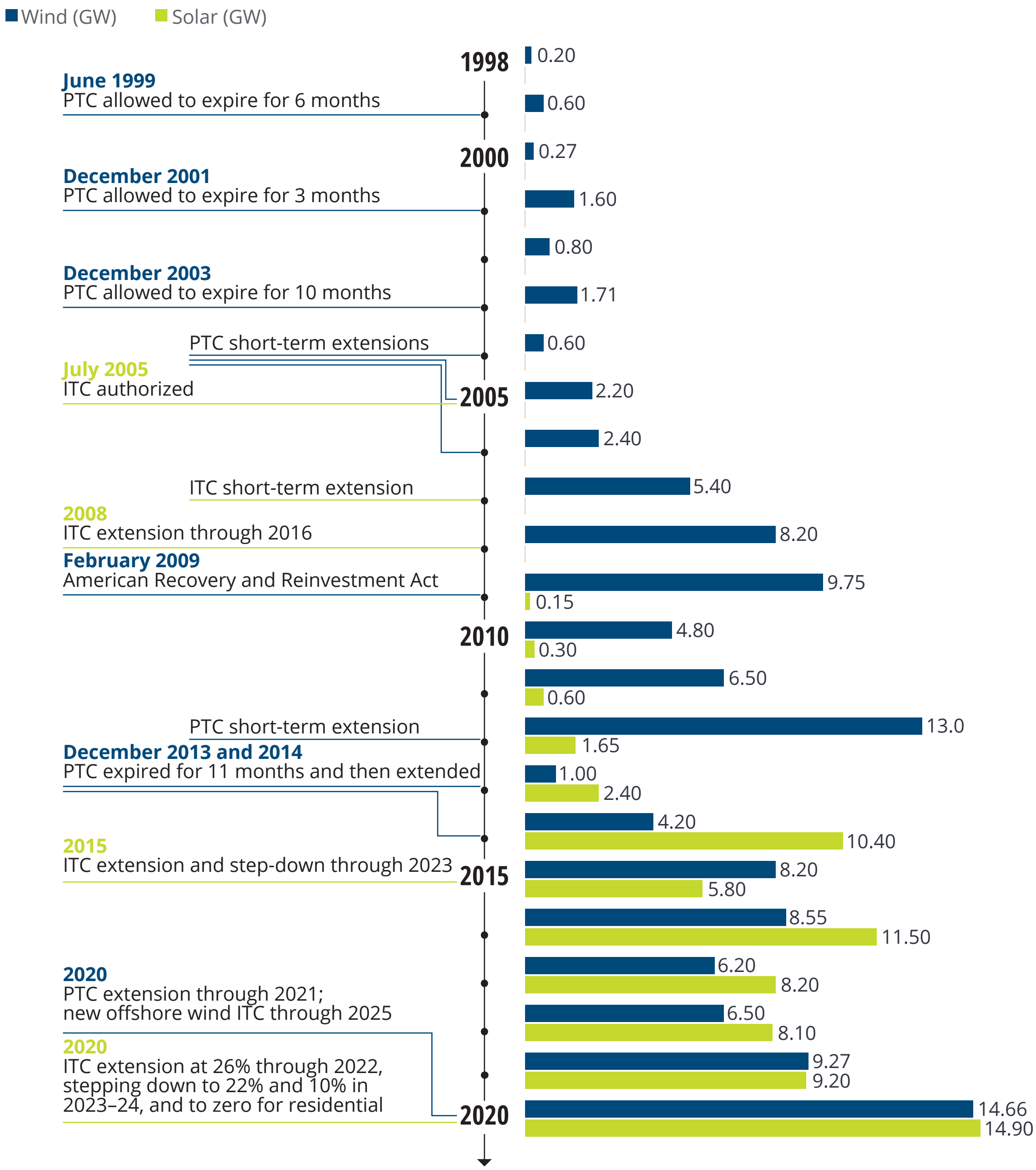
Sources: E. Larson et al., *Net-Zero America: Potential Pathways, Infrastructure, and Impacts, interim report*, Princeton University, Princeton, NJ, December 15, 2020; (the E+ scenario assumes aggressive end-use electrification to reach net-zero carbon emissions economywide by 2050); NREL/NARIS, June 24, 2021 (the Electrification scenario assumes electrification of new transportation and heating demand and reduces power sector carbon emissions 80% by 2050; 2035 data point is the average of 2034 and 2036 data); Center for Environmental Public Policy, University of California, Berkeley, The 2035 Report: *Plummeting solar, wind, and battery costs can accelerate our clean energy future*, June 9, 2020 (The 2035 Report models a pathway to 90% carbon-free electricity by 2035); US Energy Information Administration, *Annual energy outlook 2021*, February 3, 2021 (the reference case assumes no policy changes and current laws and regulations, including current expiration dates, apply); Deloitte analysis.

US wind and solar installations hit an all-time high of 35 GW in 2020.[72] But the scenarios depicted in figure 9 require 70–100 GW to be added annually to meet clean electricity goals by 2035–2050. Many factors are driving strong renewable growth, from declining costs for wind, solar, and storage; to efficiency advances; corporate and public sector decarbonization goals; and stakeholder pressure from employees, shareholders, insurers, and financiers. Another key driver is policy. State Renewable Portfolio Standards (RPS) and federal renewable tax credits have boosted renewable growth. Roughly half of all growth (45%) in US renewable electricity generation and capacity since 2000 is associated with state RPS requirements.[73] The investment tax credit (ITC) for solar and the production tax credit (PTC) for wind have also contributed significantly to growth. But their impact has been inconsistent as the tax credits were allowed to expire and then reextended numerous times in the last 20 years (figure 10).

To meet the most ambitious clean electricity goals, many electric utilities and renewable developers are advocating for a federal CES, renewable tax credit extensions plus new credits for transmission and standalone storage, and permitting reform. The power industry also seeks federally funded research in technologies such as low-carbon hydrogen, long-duration energy storage, advanced nuclear, and carbon capture. The current administration supports a CES or similar policy and has initiated and/or proposed legislation to fund new research programs for these technologies.[74]

FIGURE 10

Impact of tax credits on wind and solar annual capacity additions



Note: PTC = wind production tax credit, ITC = solar investment tax credit.

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Conclusion

AT THE START of this report, we noted goals to reach net-zero emissions by 2050 and emission-free electricity by 2035 and asked how difficult it will be to get there. Exploring these five challenges demonstrates that although some common perceptions sound like showstoppers that could halt renewable energy growth, that's not likely. Some perceptions are actually misperceptions, or the reality is that solutions are already being explored and implemented. Several of the challenges are difficult and require planning, coordination, and potentially, new policies. And getting there by 2035 may be a tall order. But progress will likely continue, buoyed by innovation and the proliferation of DER. Innovations such as cost-effective technologies for long-term energy storage could make affordable renewables increasingly reliable and dispatchable, speeding their penetration. And, as more than 70% of our survey respondents indicated, DER can play a key role both in fulfilling increased electricity demand and in helping to balance intermittent renewables. In sum, reality is often more encouraging than perceptions imply.

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