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Institute for Energy Economics and Financial Analysis
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U.S. 2022 Power Sector Outlook

The Renewable Energy Transition Takes Off

Executive Summary

Surging global energy prices have been a central theme over the past year, as rebounding economic activity vied with new waves of COVID infections, and the shock of Russia's invasion of Ukraine has roiled oil and gas markets in particular. But the soaring cost of fossil fuels and unexpected disruptions in energy security are now supercharging what was already a torrid pace of growth in solar, wind and battery storage projects.

IEEFA predicted last year that wind, solar and hydro's share of the U.S. electric power market would approach 30 percent by the end of 2026. IEEFA now believes the forecast reflected the low end of possible growth, given the significant acceleration in expected solar and wind (particularly offshore) capacity installations through 2026. We now expect that clean energy's share of the electric generation market could hit 33 percent or more. Together with existing nuclear generation, this would push the U.S. share of carbon-free electricity to well over 50 percent—a massive transition from just five years ago.

Some of the most notable recent developments include:

- Construction has begun on the first two commercial-scale **offshore wind farms** in the U.S., which has lagged far behind development efforts in Europe. A recent federal lease auction brought in a record $4.4 billion for development areas off the New Jersey/New York coasts, and underscored investor enthusiasm for the resource's economic potential over the coming decade. Offshore wind will have an increasing impact on power markets up and down the East Coast.

- A significant shift among several of the largest, traditionally coal-based utilities to completely move away from the fuel. Georgia Power, Duke Energy, and the Tennessee Valley Authority have all recently embraced plans for a 2035 **coal plant phaseout.**

- An end to the decade-long run of annual increases of gas-fired electric generation. IEEFA projected last year that the increase in gas-fired capacity had plateaued; we now think that total annual **gas-fired electricity generation has peaked** as well. IEEFA believes that gas-fired generation in the U.S. peaked in 2020, and we expect it to decline this year and into the future as rapid growth in solar and wind output displaces both coal and gas generation. The challenges for gas have been exacerbated by the recent runup in prices and growing concerns about methane emissions from gas production and distribution, which significantly reduce the fuel's supposed environmental benefits.

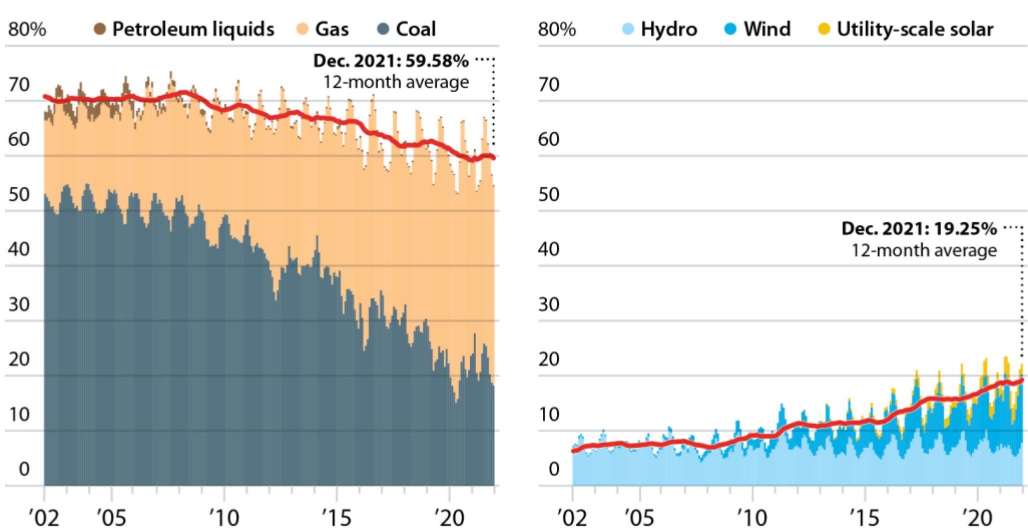
- **Corporate renewable energy demand** is climbing quickly as American businesses embrace net-zero goals, pushed by consumer demand, higher electricity prices and the rise in fossil fuel costs. This could drive the construction of as much as 94 gigawatts of renewable energy capacity by 2030.

- Real-world experience and research increasingly show that high levels of **green energy with battery storage can be integrated into the U.S. power grid while maintaining system reliability.** A recent report from the National Renewable Energy Laboratory concluded that with sufficient storage, renewable generation (including solar, wind, hydropower, geothermal and biofuel resources) could meet as much as 94% of demand on an annual basis with "no unserved energy and low reserve violations, indicating no concerns about hourly load balancing through the end year of 2050."[1]

The compelling economics and proven reliability of renewable energy and storage have changed perceptions in utility and corporate boardrooms across the U.S., driving a buildout of wind and solar generation portfolios and prompting businesses and consumers to push for greater access to green energy. With fossil fuel price volatility and energy security currently among the top concerns of executives and policymakers, IEEFA finds the energy transition is tipping even more strongly toward renewables and battery storage, and expects this trend will continue to drive fossil fuels out of the power market.

Figure 1: Declining Share of Fossil Fuels in U.S. Power Generation

In the power sector, the overall market share for fossil-fuel generation—coal, gas, and petroleum liquids—has been shrinking, while renewables—utility-scale solar, wind, and hydro—continue to rise.



Source: U.S. Energy Information Administration

[1] National Renewable Energy Laboratory. Grid Operational Impacts of Widespread Storage Deployment. National Renewable Energy Laboratory. 2022.

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Solar/Wind Capacity Buildout Will Break Records

Installed utility-scale clean energy capacity hit a milestone in 2021, passing 200 gigawatts (GW). It took the sector 16 years to hit the 100 GW capacity mark, but just five to double that total. The next 100 GW likely won't even take that long.[2]

According to estimates from the American Clean Power Association, there are 120 GW of renewable energy capacity in the development pipeline. Of that total, 37.8 GW is already under construction, with the remainder in advanced development.

Looking just at solar, the Solar Energy Industries Association, in conjunction with Wood Mackenzie, projects that 123 GW of utility-scale solar will be added to the gird by 2027 and 244 GW by 2032.[3] The estimates do not include the potential impact of the Build Back Better incentives now stalled in Congress. Should those be adopted, SEIA says an additional 210 GW of solar would be installed by 2032, pushing the total increase for the decade to 454 GW.[4]

On the storage side, the outlook is just as positive. The Energy Storage Association, also in conjunction with Wood Mackenzie, expects 63.4 GW of battery storage capacity, the bulk in utility-scale projects, to be installed by the end of 2026.[5]

Even the Energy Information Administration expects that 66 GW of utility scale clean energy will be added to the U.S. grid just in the next two years. EIA estimates are conservative since they only include projects that have officially filed with the agency's monthly electric generator inventory and do not track corporate announcements on future developments or power purchase agreements.

In other words, the clean energy sector is booming, and will be for years. This is going to have a major impact on the U.S. grid, with the new clean generation pushing out fossil fuels essentially on a one-for-one basis.

For example, from 2019-21, wind and utility-scale solar rose by 127 million megawatt-hours (MWh); during the same period, coal and gas generation fell 77 million MWh. The fossil slide would have been worse, but the increased renewable generation also had to cover for declining nuclear output and falling hydro generation.

If the current projects in the wind and utility-scale solar pipelines come online by the end of 2026, renewable generation would rise by an estimated 444 million MWh, almost doubling 2021's total. Given the lack of electricity growth in the U.S.—net generation was 4.125 trillion kilowatt-hours (kWh) in 2010 and 4.115 trillion kWh in 2021—the rise in clean energy will almost certainly lead to an equal drop in fossil fuel generation.

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[2] These totals include utility scale solar, wind and battery storage, but not rooftop solar.
[3] SEIA/Wood Mackenzie. U.S. Solar Market Insight: Executive Summary. December 14, 2021.
[4] *Ibid*.
[5] ESA/Wood Mackenzie. U.S. Energy Storage Monitor 2021 Year in Review Executive Summary. March 2022.

This would push clean energy's market share close to 30%, even assuming hydro generation remains at its depressed 2021 level. However, this understates the likely growth, since this figure does not include small-scale or rooftop solar, which has been growing quickly. Indeed, a new analysis from the Institute for Local Self-Reliance shows that the 5.4 GW of distributed solar added to the grid in 2021 almost matched that of the 5.7 GW new gas capacity.[6] Given the trends of the past several years, 2022 could see distributed solar outpace new gas additions.

EIA data shows that small-scale solar rose 40 percent from 2019-21, climbing to 49 million MWh by the end of the period. A similar increase for the next five years would push small-scale solar output to an estimated 264 million MWh—roughly 6% of total generation in 2021.

This estimate also does not include the impact storage will have on the system, enabling utilities and other users to charge batteries with renewable energy during periods of lower demand and then discharge that power during higher demand periods. This time-shifting function, particularly suited for solar generation which otherwise could be curtailed during the mid-day, is likely to put significantly more pressure on fossil generation.

Finally, none of these estimates can keep up with the rapid changes reshaping the market overall. In January, for example, well after the forecasts above were prepared, Iowa's MidAmerican Energy announced plans to build more than 2,000MW of wind, plus a small solar project. The utility said it could have the $3.9 billion project online by the end of 2024 if it receives the needed state approvals by the end of October.[7] Similarly, and much less expected, Peabody Energy announced a partnership with two private equity firms in March to develop 3.3 GW of solar capacity and 1.6 GW of battery storage during the next five years. The projects would be located at or near former Peabody mines in Indiana and Illinois, the company said.[8]

Clearly, when one of (if not the largest) coal mining companies in the U.S. turns to solar and battery storage, big changes are afoot.

[6] ILSR. New Power Generation Quarterly: Annual Update—2021. March 24, 2022.
[7] S&P Global Market Intelligence. MidAmerican Energy proposes $3.9B renewables investment in Iowa. January 19, 2022.
[8] S&P Global Market Intelligence. U.S. coal producer Peabody to pursue solar, energy storage development. March 1, 2022.

Offshore Wind Becomes a Commercial Reality

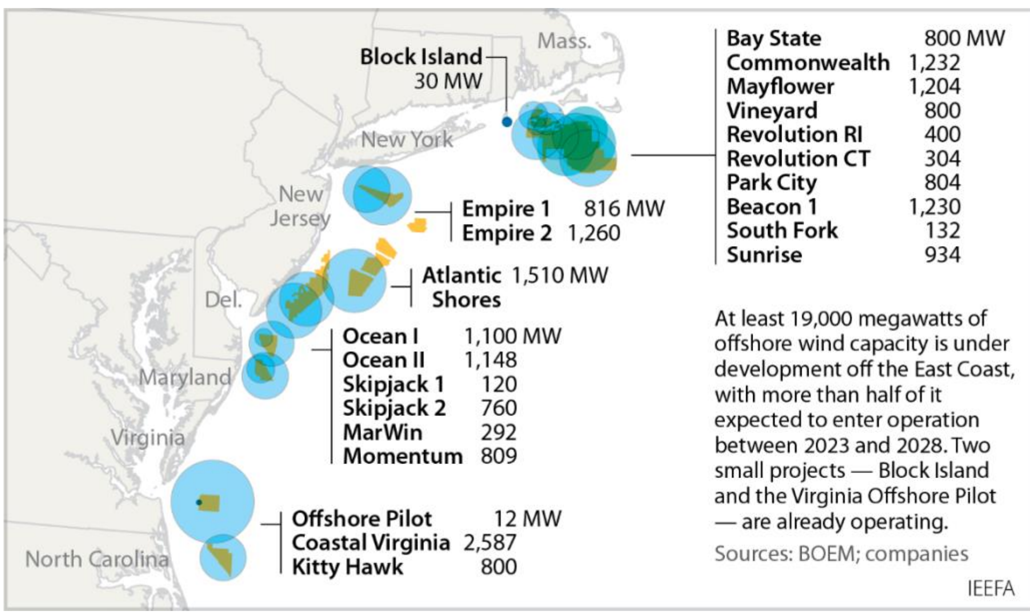
30-Gigawatt Goal by 2030 Is Achievable

Recent developments have changed the conversation regarding offshore wind in the U.S., which has badly lagged the ongoing buildout in Europe and the recent surge in capacity installations by China

In a milestone, construction work is now underway on two large-scale projects in the Atlantic, finally moving the sector from talk about future potential to near-term commercial operation. The first project, Vineyard Wind I, is being built by Avangrid and Copenhagen Infrastructure Partners (CIP) off the Massachusetts coast. Work on the 800 MW project began in November, with full commercial operation expected in late 2023 or early 2024. The second project, South Fork Wind, is being built by Orsted and Eversource off the New York coast. Groundbreaking for the 132 MW project was in February; it is expected online in 2023.

The record-shattering federal auction for several leases off the New Jersey/New York coasts in an area known as the New York Bight cemented the change in tenor. The February auction attracted winning bids totalling $4.37 billion for six areas with an estimated generation potential of 7,000 MW.

Figure 2: Planned U.S. Offshore Wind Capacity



The result speaks for itself, but as important is the level of interest throughout the bidding process. According to the Interior Department, 25 companies prequalified for the auction, including major players in offshore wind, the utility arena and the oil and gas sector. Among the participants were: Orsted, Equinor, Avangrid, RWE, National Grid, Engie SA, EDP Renewables, Shell, EDF, TotalEnergies, CIP and

Invenergy. The serious corporate interest also was manifest in the 64 rounds of bidding spread over the three days it took before winners were selected for the separate lease areas.

As one commentator noted following the auction's conclusion: "It is [hard] to get a stronger signal than the type of signal we got today. The commitments are there."[9]

The 30-GW Goal

These developments give backing to the Biden administration's push to have 30 GW of offshore wind capacity installed in the U.S. by 2030. A project tracker compiled by IEEFA (see Table 1 below) shows there are 21 projects already in active development (including the two mentioned above). The installed capacity of the projects is estimated at more than 19 GW, and could well be more if turbines with higher rated capacities than originally planned are used during construction and if already noted expansion plans are added to the current announced project sizes. Coupled with the 7 GW of capacity in the recently concluded auction, this puts the country on a path to reach 30 GW.

Table 1: Offshore Wind Projects in Active Development

Project Name	Location	Size (MW)	Lead Partner(s)	Online
Bay State Wind	MA	800	Orsted/Eversource	
Commonwealth Wind	MA	1232	CIP/Avangrid	
Mayflower Wind	MA	1204	Shell/Engie	
Vineyard Wind	MA	800	Avangrid/CIP	2023/2024
Block Island	RI	30		Operational
Revolution Wind	RI	400	Orsted/Eversource	2025
Revolution Wind	CT	304	Orsted/Eversource	2025
Park City	CT	804	Iberdrola	
Beacon Wind	NY	1230	Equinor/BP	
Empire Wind	NY	816	Equinor	
South Fork Wind	NY	132	Orsted/Eversource	2023
Sunrise Wind	NY	934	Orsted	2025
Empire Wind 2	NY	1260	Equinor/BP	
Ocean Wind	NJ	1100	Orsted	Q4 2024
Ocean Wind II	NJ	1148	Orsted	2028
Atlantic Shores	NJ	1510	EDF/Shell	2028
MarWin	MD	292	US Wind	2025
Momentum	MD	809	US Wind	2026
Skipjack Wind	MD/DE	120	Orsted	2026
Skipjack Wind 2	MD	760	Orsted	2026
Offshore Pilot	VA	12	Dominion	Operational
Coastal Virginia Offshore Wind	VA	2587	Dominion	2026
Kitty Hawk	NC	800	Avangrid	
Total		19084		

[9] Climate Wire. $4.4B wind auction broke records. Here's why it matters. February 28, 2022.

If it doesn't happen by 2030, it almost certainly will happen soon thereafter. Nationally, states have set offshore wind capacity targets that now top 44 GW and include areas both in the Gulf of Mexico and on the Pacific Coast. But Atlantic Coast projects will drive this first round of U.S. offshore activity, with announced state targets totalling almost 40 GW. New York and New Jersey alone have plans to install 16.5 GW of offshore wind by 2035; of that total, 8 GW is already under contract.

The System Impact

As IEEFA has noted, this new capacity is going to have a major impact on the energy markets along the Atlantic coast, particularly in the organized wholesale markets in New England, New York and the PJM area.

Offshore wind farms tend to have relatively high capacity factors. The existing 29 MW Block Island project posted a 44.7% capacity factor from 2016-20, and Dominion's two-turbine, 12 MW demonstration project recorded a 47.2% capacity factor during its first full year of operation. The average lifetime capacity factor for 5,326 MW of offshore wind farms in the UK that are less than five years old is 45.5%. On top of these strong capacity factor values, wind along the Atlantic coast tends to pick up speed in the afternoon and evening hours, matching periods of higher onshore electricity demand.

Beyond this, by pushing out coal (PJM) and gas (all three markets), offshore wind will reduce local air pollution problems, an oft-overlooked value for these projects. In addition, offshore projects will avoid the bitter siting disputes that frequently stall land-based transmission infrastructure proposals.

Coupling these attributes with continued expectations for low/no growth in electricity demand creates a situation where new gas plants will not be justifiable, particularly in those states with strong decarbonization plans such as New Jersey, New York and Virginia. In addition, the economics of existing fossil-fueled generation facilities are likely to face increasing challenges as new offshore wind projects come online.

A closer look at Massachusetts highlights the future impact offshore of wind. Gas-fired generators in the state produced 14.9 million MWh of electricity in 2021. The four offshore wind projects currently being developed in the state have a planned capacity of 4,036 MW. If those projects operate with a capacity factor of just 43%,[10] they would produce 15.2 million MWh of electricity annually—more than the current output from the state's gas-fired generators.

It won't be a simple one-for-one substitution, given the multistate capacity market operated by ISO New England, but the threat posed by offshore wind is real and coming soon.

[10] IEEFA believes this is a conservative estimate given the performance of new projects in Europe and the two smaller operating facilities in the U.S.

Massive Land-Based Economic Benefits

On top of the environmental benefits of offshore wind, the buildout of the industry will have significant positive economic impacts in the host states. For example, Equinor and the New York Economic Development Corporation are redeveloping the South Brooklyn Marine Terminal as the main supply hub for the two offshore wind farms, Empire Wind 1 and Beacon Wind, being built by the Norwegian firm. The redevelopment is expected to generate 13,000 local jobs and result in $1.3 billion in average annual investment in the city.[11]

Similar investments are occurring up and down the East Coast as the announced offshore projects move closer to construction.

In Massachusetts, for example, the former coal plant at Brayton Point, which was closed in 2017, is being redeveloped to serve the offshore wind market. The Prysmian Group, a leading manufacturer of undersea cabling, recently announced plans to purchase part of the site and build a manufacturing facility there to serve the growing offshore wind market. The company estimated its investment in the site at $200 million.[12]

In Virginia, Siemens Gamesa is making a $200 million investment to improve the port of Portsmouth and enable it to use land there as a blade assembly facility.[13] When complete, the new facilities are expected to create 260 jobs.

The American Wind Energy Association projected in 2020 that the buildout of 30 GW of offshore wind capacity could lead to a $57 billion investment in the U.S. economy by 2030 and support 83,000 jobs.[14]

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[11] CNBC. NYC to turn Brooklyn port into a hub for offshore wind farm construction. March 3, 2022.
[12] Prysmian Group. Prysmian Group: new submarine cable plant in the USA. February 17, 2022.
[13] Siemens Gamesa. Global leadership grows: Siemens Gamesa solidifies offshore presence in U.S. with Virginia blade facility. October 25, 2021.
[14] American Wind Energy Association. U.S. Offshore Wind Power Economic Impact Assessment. March 2020.

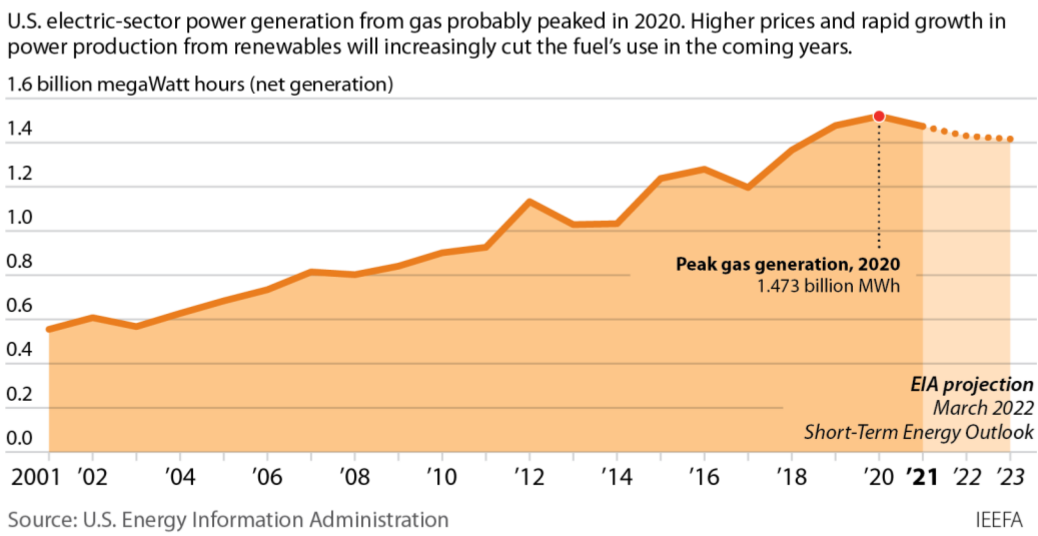
Natural Gas Hits a Plateau

The massive renewable buildout outlined above is the driving factor behind IEEFA's prediction that gas use for electricity generation has peaked in the U.S.

Gas use in the electricity sector has soared since the fracking boom began in the mid-2000s. According to EIA data, gas use in the power sector in 2005 was about 15 billion cubic feet (bcf) per day. The total grew steadily over the next 15 years, climbing to almost 32 bcf/day in 2020.

This growth pushed total gas-fired generation up from 848.8 million MWh in 2009 to 1.62 billion MWh in 2020, when the onset of the pandemic pushed gas prices down significantly. EIA statistics show that gas generation dropped to 1.57 billion MWh in 2021 as gas prices rose significantly. The agency's latest short-term outlook, which provides forecasts for 2022 and 2023, expects the decline to continue, with gas generation dropping to 1.4 billion MWh.

Figure 3: U.S. Electric Power Sector Generation From Gas



This turnaround is being driven in part by higher prices, but another key element is the extremely rapid buildout of renewable energy capacity now underway across the U.S. EIA, which is generally conservative in its outlooks given the agency's reliance on official corporate reporting, expects that 46 GW of new solar capacity will be built in the next two years. Other forecasters expect similar near-term increases and more. Wood Mackenzie, for example, sees total solar installation (utility scale and distributed) averaging almost 30 GW annually through 2026. Even more aggressive, S&P late last year estimated that more than 44 GW of new solar could be installed in 2022.[15]

[15] S&P Global Market Intelligence. The Big Picture: 2022 Electric, Natural Gas and Water Utilities Outlook. October 2021.

Regardless of the exact installation numbers, the point is clear: Renewables, particularly solar, are going to eat into the gas generation market in the years ahead.

The other contributing factor to our projection that the usage of gas for electric generation has peaked is the sharp decline in the number of gas plants in development queues nationwide, particularly the combined cycle gas turbine (CCGT) units that are responsible for the vast majority of gas use for electric power generation. Since 2010, 67,000 MW of new CCGT generation capacity has been added across the U.S. But looking ahead, EIA reports that just 25 GW of new CCGT capacity is under development, and it is not certain how much of that will be built. IEEFA has previously identified about 8 GW of planned capacity in EIA's database that is unlikely to be completed.[16]

In addition, significant public opposition to new natural gas pipeline proposals has thwarted efforts to add transportation capacity, which in turn makes it difficult for utilities in many areas to add new gas-fired generation since firm fuel supplies may not be available without new capacity.

Finally, with utilities increasingly committing to net-zero plans, most commonly with a 2050 target date, gas plant additions are at significant risk of being stranded before the end of their economic lives. Regulators are likely to carefully question such proposals to ensure that ratepayers are not left responsible for millions of dollars of worthless utility investments.

Unlike the precipitous drop in coal-fired generation in the 2010s, the decline in gas generation is likely to be more gradual. Nonetheless, we believe that decline has begun.

[16] IEEFA. IEEFA U.S.: Gas-fired power plant cancellations and delays signal investor anxiety, changing economics. November 18, 2021.

A Decade of Retirements Loom for Coal Sector

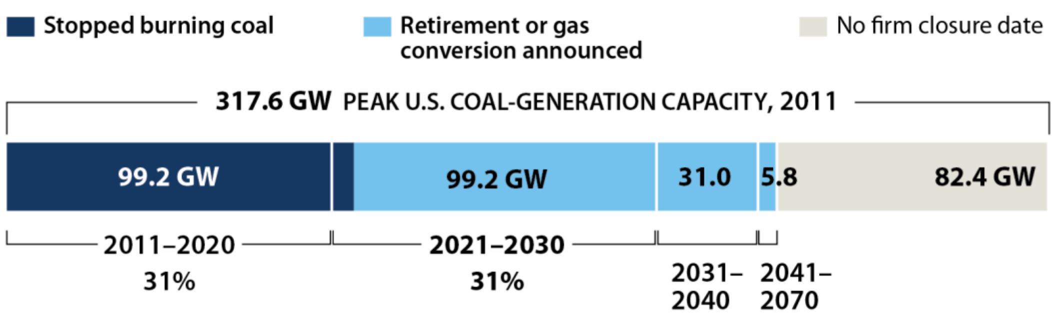
The decline of the coal industry over the past 10 years has been pronounced, but perceptions die hard. It is worth stressing how significant the decline has been: Almost 120 GW of coal-fired generation has been closed since 2011, when capacity peaked at 317.6GW. As important, coal's share of the electricity market has fallen sharply, from 42 percent to 22 percent.

These trends will accelerate through 2030.

IEEFA research shows that companies already have announced retirement plans for almost 100 GW of coal-fired capacity through the end of the decade. Given recent developments, particularly the accelerating electric utility movement away from the fuel toward cleaner alternatives, this retirement figure is likely to go much higher. For example, analysts at IHS Markit expect operating coal-fired capacity in the U.S. to drop well under 100 GW by 2030.[17]

Figure 4: Status of U.S. Coal Generation Capacity Since 2011 Peak

Coal-fired electric generation capacity peaked in the United States at 317.6 gigawatts in 2011. Ten years later, 99.2 GW, or 31%, of that capacity had retired. This decade (2021 through 2030), another 99.2 GW is already scheduled to retire or convert to gas, and IEEFA expects more closures to be announced in the years ahead.



Sources: EIA (Electric Power Monthly); company announcements; IEEFA research As of March 22, 2022

Here, a spate of recent announcements tells the tale of the sweeping move away from coal at utilities across the country.

In February, Duke Energy said it planned to reduce its reliance on coal-fired generation to less than 5% of the sprawling company's electric needs by 2030 and retire all its coal plants by 2035. Duke, which has roughly 7.8 million customers across six states, still has almost 16,000 MW of coal-fired capacity in its generation fleet. These plants account for more than a quarter of the utility's installed generation capacity. In other words, this is a big deal.

The rationale behind the decision was spelled out by Regis Repko, Duke's senior vice-president for generation and transmission market transformation: "The driver for that is really our customers. Our customers have told us—and continue to tell

[17] IHS Markit. U.S. Coal Market Briefing. February 2022.

us—they want their energy from cleaner resources. So those views of the customers translate really to policymakers and investors."[18]

A similar transition was laid out by Georgia Power in its latest long-term resource plan filed with state regulators in January. The company is proposing to close most of its coal plants by 2028.[19] Its remaining capacity, two units at Plant Bowen, now the largest operating coal plant in the U.S., would be retired no later than 2035.

The decision was a simple one of economics, the company said: "As coal-fired generation continues to be less economically viable, the company is proposing to retire and decertify all Georgia Power-controlled coal units, except for Plant Bowen Units 3 & 4, which will continue to operate no later than 2035. The company's plan includes retirement of a total of 12 generating units, or more than 3,500 megawatts (MW), by 2028."[20]

The announcement caps a decade-long shift at Georgia Power and its parent, Southern Company. In 2013, as Southern was seeking to build its now-cancelled Kemper coal gasification facility, Tom Fanning, Southern's CEO, was quoted saying: "We are the Saudi Arabia of coal—very high-quality stuff. We've got to find a way to continue to preserve that important national energy resource to be used for the benefit of our citizens."[21]

Clearly, that era has ended.

In addition to the corporate-wide coal exit announcements, which IEEFA expects to see more of in the next couple of years, there is a growing body of evidence showing the vulnerability of individual coal plants to any additional new cost (due to extra required maintenance or environmental compliance measures) or reduced revenue (particularly in the PJM capacity market).

IEEFA highlighted this first point in our 2021 outlook, when several plants were closed due to unexpected maintenance costs. That threat has not gone away.

Indeed, as the case of Xcel's Comanche 3 coal plant in Pueblo, Colo., illustrates, the impact of any unplanned-for costs is magnified once a retirement date has been set. Last year, IEEFA reported the utility had moved up the planned retirement for the 750MW unit to 2040 from the original 2070 (the unit only entered commercial service in 2010). In addition, the company said it would reduce output at the plant after 2030.

Since then, the plant's problems have continued. Last November, the company filed a plan with state regulators to move the retirement date forward again, to 2035, and agreed to cut generation at the plant beginning in 2025. Under that plan, by 2029, the plant's output would be capped at 33%.

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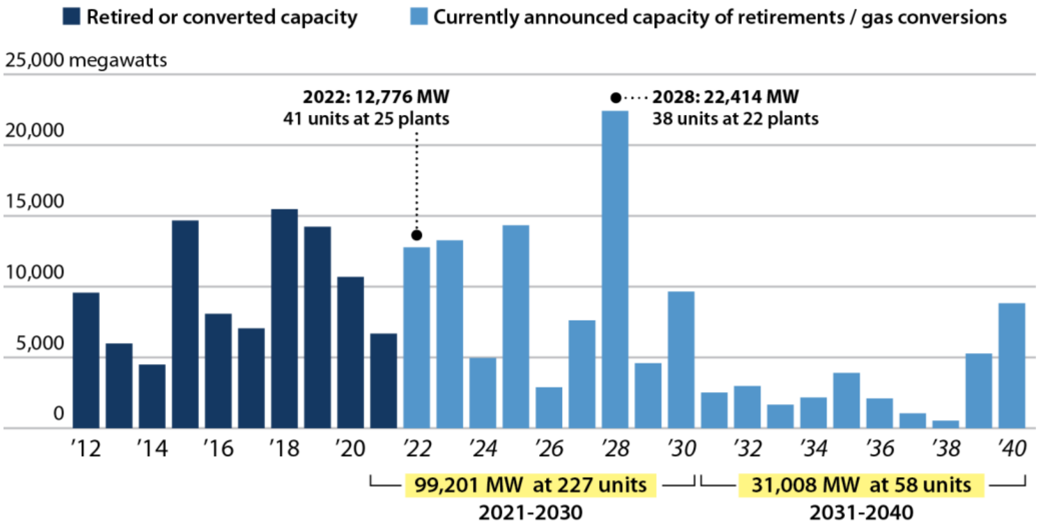
[18] Financial Times. U.S. coal companies defy obituaries with 'amazing' results. February 17, 2022.
[19] The two-unit Wansley facility, Unit 3 at the Scherer plant and Units 1 and 2 at Plant Bowen.
[20] Georgia Power. Georgia Power files plan preparing for future energy landscape, building upon solid foundation to meet needs of customers and state. January 31, 2022.
[21] Charleston Gazette-Mail. Coal plant closures and Southern Co.'s 'big bet'. January 7, 2013.

Figure 5: Coal-Fired Electric Generation Retirements and Conversions

At least 227 coal-fired units are currently expected to end coal use between the start of 2021 and the end of 2030, with a total capacity of 99.2 gigawatts, according to utility announcements.



Sources: EIA; PJM; S&P Global; IEEFA research (2017-2040) As of March 22, 2022

Whether that latest plan will hold is uncertain, particularly given new mechanical problems that forced the unit offline in January, with repairs expected to take at least until April. As of this writing, the extent of the problem and the cost to repair it was unclear. But given that staff at the Colorado Public Service Commission have already found the plant to be uneconomic during certain months of the year, any additional costs are only going to worsen the unit's competitive problems.

More broadly, the Environmental Protection Agency just released a plan to require cuts in ozone-forming nitrogen oxide emissions at fossil fuel plants in 25 states. To comply with the new rules, coal- and certain oil- and gas-fired plants will be required to install selective catalytic reduction (SCR) technology, a widely available emissions control option already installed on most of the coal plants in the targeted states. Because of the cost of the pollution control upgrades, EPA expects many owners to opt to retire their affected units instead of retrofitting them with the new equipment. All told, EPA said the rule could push 18GW of coal-fired capacity off the grid.[22]

The second issue is new this year, but is likely to become a more prominent concern as an influx of energy efficiency measures, demand-side management and new renewable generation works to depress capacity payments. Last year's capacity auction in the PJM market saw prices fall across the board, with the base price for the bulk of the system falling to $50/MW-day from $140/MW-day in the prior auction. That had an immediate impact, with two of the larger market participants,

[22] S&P Global Market Intelligence. U.S. EPA expects cross-state air pollution plan to drive 18 GW in coal retirements. March 11, 2022.

NRG Energy and Vistra Corp., announcing new coal plant retirements shortly after the results were released.

Vistra, for example, said it would close its 1,425MW Zimmer coal plant in May 2022—five years ahead of schedule. The reason? Economics.

“The Zimmer coal-fueled power plant has recently struggled economically due to its configuration, costs, and performance. The PJM capacity revenues are critical to Zimmer, and unfortunately, without them, the plant simply doesn’t make money,” said Vistra CEO Curt Morgan. “… the disappointing auction results, along with other challenging factors, make continued economic operation impossible. We’re left with a difficult but necessary decision of retiring the plant.”[23]

IEEFA expects this to become a key trigger point for the retirement of even more coal plants in the organized capacity markets, particularly PJM.

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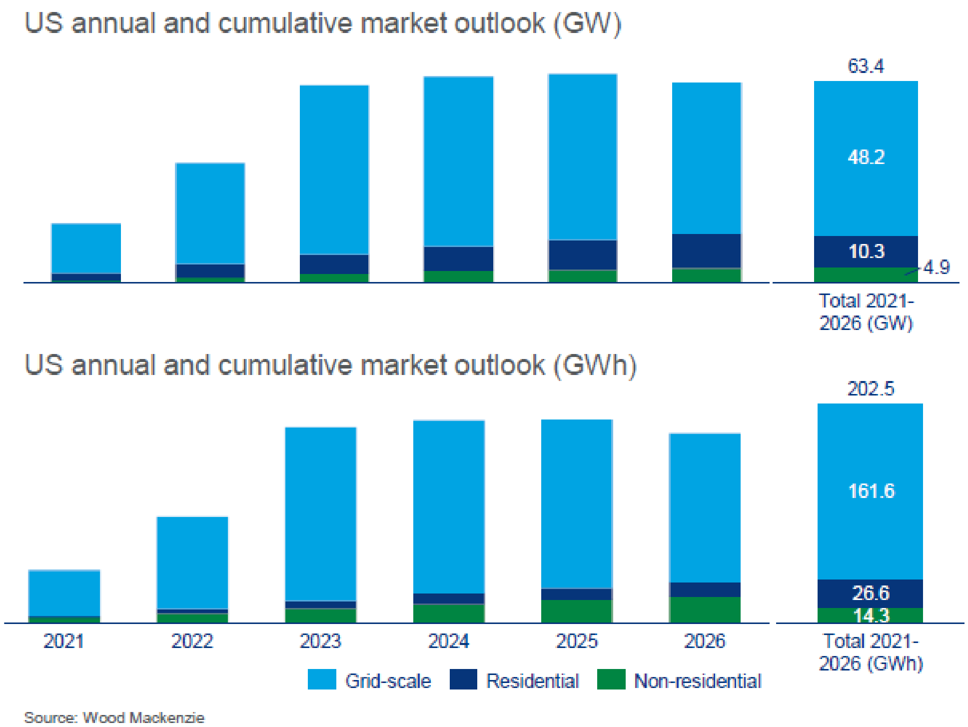
[23] Power Engineering. Vistra moving Zimmer coal-fired plant closure up to May 2022. July 20, 2021.

Energy Storage
Growth Takes Off

Battery storage hit the big time in 2021, shattering the 2020 annual installation record of 1 GW in the third quarter alone. By the end of the year, EIA says that 4,648MW of utility-scale battery storage was online across the U.S.[24] And this is just the beginning of a projected steep ramp-up over the next five years.

EIA predicts the doubling of battery storage capacity that occurred in 2021 will be matched in 2022, with capacity at the end of the year projected to top 10.7GW.[25] The Energy Storage Association expects annual battery storage capacity additions to top 10GW by 2023 and continue at that level through 2026—pushing total installed battery capacity to more than 63 GW.

Figure 6: ESA/Wood Mackenzie Battery Storage Forecast



Source: Energy Storage Association.
Note: This forecast assumes a standalone investment tax credit and the extension of the existing solar ITC.

Regardless of whether these exact installation forecasts come to fruition, the trend is clear. Utilities and other major participants in the electricity sector are

[24] EIA. Electric Power Monthly. February 2022.
[25] *Ibid.*

increasingly confident in turning to battery storage as a means of firming renewables, paving the way for a cleaner grid.

The Development of Longer-Duration Storage

In addition to the growth in overall capacity, a key development has been the push for longer duration storage, which will play a central role in enabling the transition away from fossil fuels.

CC Power, which represents a group of community choice aggregators in California, recently announced two key longer duration storage contracts. Under the first, LS Power subsidiary REV Renewables will supply eight hours of storage to the CCA group through its planned Tumbleweed project—a 69MW/552MWh facility scheduled to come online in 2026. The second project, dubbed Goal Line, is a 50MW/400MWh facility being built by Onward Energy that is slated for commercial operation in 2025.[26]

In addition to their eight-hour duration, the contracts are precedent-setting for two other reasons.

First, the projects will both use lithium-ion batteries. Cost concerns had prompted many observers to speculate that lithium-ion would be limited to projects of no more than four hours. These projects show otherwise, since the key metric used by CC Power in picking the winners in its solicitation was cost-effectiveness.[27] Developers using lithium-ion technology clearly are not simply going to cede the longer-duration market to new entrants, which should sharpen the economic competition among all the battery storage technologies, enabling a more cost-effective transition.

Second, the industry response was overwhelming. According to CC Power, it received 51 responses totalling 9,000 MW for its request for offers (RFO).[28] The RFO was the outgrowth of the state's 2021 Mid-Term Reliability rule, which requires power providers across the spectrum to contract for 11,500 MW of battery storage, including 1,000 MW of eight-hour storage. The participating members of CC Power have a total obligation of 125MW. Clearly, there is plenty of market interest.

Another major development in the long-duration storage sector is the agreement announced early this year between Georgia Power and Form Energy to collaborate on a battery project with as much as 100 hours of storage—a game-changing duration.

The project will use Form Energy's iron-air battery technology, an electro-chemical process that the company describes as reversible rusting.[29] As the company explains it, the battery takes in oxygen when it discharges, which converts the metallic iron

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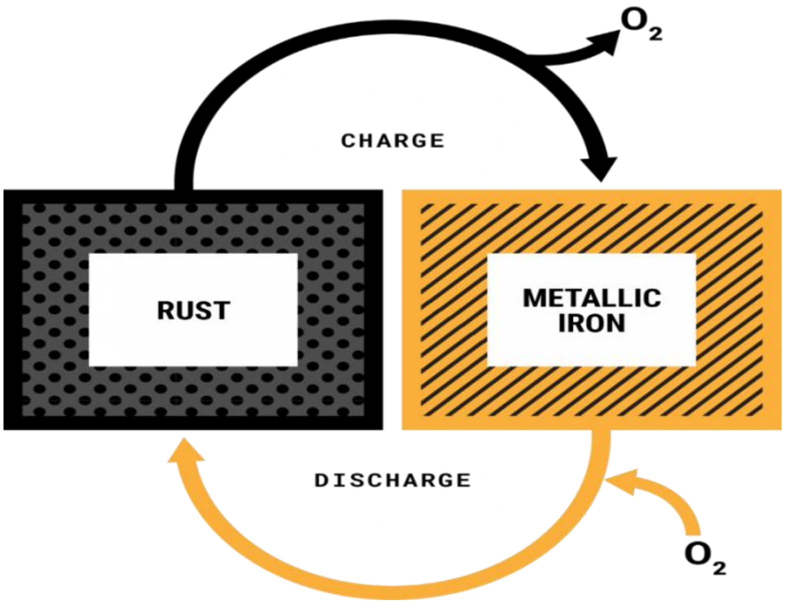
[26] Energy Storage News. Second eight-hour lithium-ion battery system picked in California long-duration storage procurement. March 8, 2022.
[27] Energy Storage News. Lithium-ion chosen first, but not the only option for California's long-duration energy storage needs. February 9, 2022.
[28] *Ibid.*
[29] Form Energy. Battery Technology.

to rust (iron oxide). Then, when the battery charges, the electric current converts the rust back to metallic iron as the oxygen is removed.[30]



Source: Form Energy.

The simplicity of the process and the easy availability of the required iron ore have prompted company officials to predict that its first battery will be cost-competitive with existing fossil fuel-based options and significantly lower cost than lithium-ion options.[31,32]

The company does not yet have a commercially operating unit, but is scheduled to bring a small pilot online in 2023 in conjunction with Great River Energy, a cooperative based in Minnesota. The project is sized at 1MW/150MWh.

That duration "will get you through a couple of cold nights**,"** said Jon Brekke, Great River's vice president and chief power supply officer. "And that's the kind of solution that we think is going to be important to maintain reliability and affordability as we transition the power grid."[33]

Looking further out, a recent study by the National Renewable Energy Laboratory (NREL) concluded that storage can play a central role in facilitating the transition to a clean energy grid. In one scenario targeting zero carbon emissions by 2050, NREL's modelling found that even with renewable generation accounting for as much as 94% of annual generation, which included 70% of the generation coming from wind and solar resources, NREL found "no unserved energy and low reserve

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[30] *Ibid.*
[31] *Ibid.*
[32] WBUR. Rusting batteries could help power the electric grid of the future. February 24, 2022.
[33] *Ibid.*

violations, indicating no concerns about hourly load balancing through the end year of 2050."[34]

Digging into some of the specifics, the report found storage can:

- Reduce carbon dioxide emissions across the board by storing overgeneration of zero-emissions wind and solar and using it to displace fossil fuels during higher demand periods;

- Cut down on the number of start-ups at fossil fuel plants, thereby improving operating efficiency and reducing emissions of local air pollutants;

- Improve the efficiency of the transmission grid by reducing congestion—that is, taking local generation off the system during periods of high output; and

- Putting downward pressure on prices by enabling entities to use the lowest-cost available resource mix.

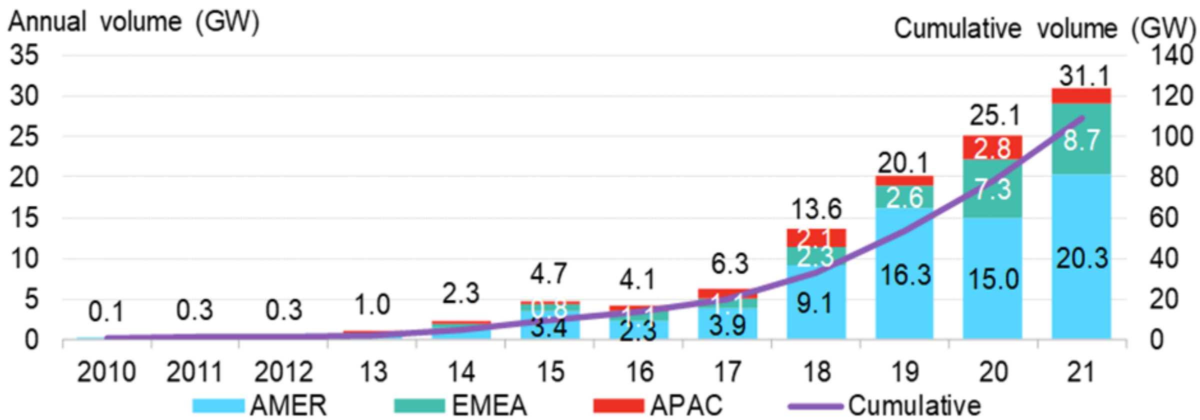
[34] National Renewable Energy Laboratory, *op. cit.*, p. 2.

Corporate Green Energy Demand Drives Development

The corporate sector is becoming an increasingly important driver in the transition away from fossil fuels. Pushed by consumer demand and internal clean energy goals, businesses worldwide signed power purchase agreements for a record 31.1 GW of green power in 2021.[35] Of the total, contracts topping 20 GW of capacity were signed in the U.S.

The 2021 results continue a run that has seen the volume of renewable energy PPAs climb to 120 GW from essentially zero less than a decade ago.

Figure 7: Global Corporate Green Energy Contracts



Source: BNEF.

Importantly, this growth is set to continue. The RE100 group, a global initiative by corporations pledging to transition to 100% renewable energy, reported recently that its membership climbed by 58 in 2021. The group now has 349 members using a combined 340 terawatt-hours of electricity annually—more than the total consumption in the UK, the world's 12th-largest consuming country.[36] Currently, according to RE100, its members obtain 45% of their electricity from renewable resources. In other words, there will be significant continued growth in the group's demand for clean electricity.

BNEF estimates that an additional 94 GW of wind and solar capacity would be needed just to transition the current RE100 membership to 100% clean electricity.[37] As the number of RE100 members grows, the amount of new renewable energy capacity will grow as well.

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[35] BNEF. Corporate Clean Energy Buying Tops 30GW Mark in Record Year. January 31, 2022.
[36] RE 100. 2021 Annual Disclosure Report.
[37] BNEF, *op. cit.*, p. 22.

As Kyle Harrison, the head of sustainability research at BNEF, noted: "It is no longer a matter of whether corporate clean energy procurement will grow each year, it's a matter of how much."[38]

Another measure highlighting corporate America's growing interest in clean energy is the rising amount of private investment in the sector. According to the Business Council for Sustainable Energy, a record $105 billion in private capital flowed into clean energy in 2021, up 11% from the previous year and 70% over five years.[39]

"Clean energy is thriving," the council said. "The record levels of public and private sector investment in both the U.S. and around the world in 2021 point to the durability of the energy transition, despite Covid-19 business conditions. Corporate demand, coupled with public sector injection of capital into U.S. infrastructure, will accelerate the expansion of the clean energy transition…"[40]

[38] *Ibid.*
[39] Business Council for Sustainable Energy. Sustainable Energy in America 2022 Factbook.
[40] *Ibid.*

Renewable Resources and Battery Storage Can Provide Essential Grid Reliability and Resilience

A grid that offers secure access to power supplies is the goal of everyone working in the electric power sector. Unfortunately, renewable critics too often try to undercut the push for a cleaner grid with hyperbole. Grid operators and developers both know that the sun doesn't sun every day, that the wind doesn't always blow, but also that weather events and unexpected breakdowns (like at the Comanche 3 coal plant in Colorado or the Eagle Valley gas-fired unit in Indiana) can force fossil fuel and nuclear power plants offline. And they plan for all those events.

The renewable-based grid that is now being built will certainly operate differently than the ones of the past, but that does not mean it will be any less reliable or resilient. First, the development of advanced inverter power controls has enabled standalone wind and solar resources to respond almost instantaneously to threats to grid stability posed by imbalances between supply and demand that arise, for example, when a large generator goes offline or when a portion of a solar farm stops producing electricity due to the passage of a cloud bank.[41] In fact, the technical ability of stand-alone wind and solar resources to provide essential reliability services has been extensively demonstrated through studies, tests and operating experience.[42]

Testing by the California independent system operator (CAISO) and NREL showed that commercial-scale wind and solar PV resources could provide essential grid reliability resources such as voltage support, ramping, frequency response and load following.[43, 44] The testing also showed that the performance of these resources was comparable to or better than conventional resources.[45]

At the same time, the dramatic increase in storage capacity being added to the grid that we discussed earlier will further enhance grid reliability because fast-acting grid-scale battery storage can provide essential services that include firming the variability in solar and wind generation and providing essential grid reliability support. A 2020 global survey by the IEEE Power & Energy Society found that "Energy storage is one of the most important strategic technologies for power system operators around the world and is also the first priority of technical

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[41] Stand-alone means that the solar or wind facility is not partnered with on-site battery storage.
[42] Berkeley Lab. Variable Renewable Energy Participation in Ancillary Services Markets: Economic Evaluation and Key Issues, slide 6. October 2021; Wind Energy Science. Ancillary services from wind turbines. 2020; and NREL. Variable Renewable Generation Can Provide Balancing Control to the Electric Power System. September 2013.
[43] CAISO. FAQ: Using Renewables to Operate a Low-Carbon Grid, California ISO, NREL, and First Solar. January 2017.
[44] CAISO. Using Renewables to Operate a Low-Carbon Grid: Demonstration of Advanced Reliability Services from a Utility-Scale Solar Plant, 2017, pp. 5, 55; and CAISO, NREL, Avangrid Resources, and General Electric. Avangrid Renewables Tule Wind Farm: Demonstration of Capability to Provide Essential Grid Services. March 2020.
[45] CAISO, *op. cit.*

standards and regulatory support needs."[46] The president and CEO of the North American Electric Reliability Corporation (NERC) in testimony before the U.S. Senate Energy and Natural Resources Committee called energy storage "a game changer."[47]

For example, the battery can be charged when loads and prices are low and discharged during more expensive hours when loads are higher.[48] This can both act as a hedge against renewable variability and reduce the curtailment of emissions-free renewable energy generation.[49] Battery storage also can be used to ensure that there is adequate firm or peaking capacity during periods when variable solar or wind energy is unavailable.[50]

In addition, battery storage can be a suitable resource for short-term reliability services, such as primary frequency response and regulation, due to the ability of batteries to charge or discharge very quickly, faster than conventional resources.[51] The U.S. power grid is designed to operate at a frequency of 60 Hertz, with tolerances for levels slightly over or under. Beyond that, however, resources are needed to rebalance the system. These services traditionally have been provided by fast response thermal generation, but battery energy storage systems are a better option due to their faster response times.

As NREL noted in a recent study: "BESS can rapidly charge or discharge in a fraction of a second, faster than conventional thermal plants, making them a suitable resource for short-term reliability services, such as primary frequency response (PFR) and regulation."[52] Increase the size, NREL added, and battery storage systems "can also provide longer-duration services, such as load-following and ramping services, to ensure supply meets demand."[53]

NREL also has noted that "deploying battery storage also can help defer or circumvent the need for new grid [transmission and distribution system upgrades] by meeting peak demand with energy stored from lower-demand periods, thereby reducing congestion and improving overall transmission and distribution asset utilization."[54]

Utility-scale battery storage can be deployed in the transmission network, the distribution network near load centers, or co-located with variable renewable energy generators, depending on the need and economics. For example, Rocky

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[46] IEEE Power & Energy Society. Maintaining Electric Reliability with Changing Resource Mix; Testimony at FERC 2021 Reliability Technical Conference, p. 6. September 2021.
[47] NERC. Testimony of James B. Robb before the Committee on Energy and Natural Resources, United States Senate. March 11, 2021.
[48] NREL. Grid-Scale Battery Storage: Frequently Asked Questions and IEEE Power & Energy Society. Maintaining Electric Reliability with Changing Resource Mix; Testimony at FERC 2021 Reliability Technical Conference.
[49] *Ibid.*
[50] *Ibid.*
[51] *Ibid.*
[52] NREL. Grid-Scale Battery Storage: Frequently Asked Questions. September 2019.
[53] *Ibid.*
[54] NREL, *op. cit.*

Mountain Power is seeking to develop distributed solar-plus-storage grid assets in Utah, first by participating with solar and battery developers in building a new 600-unit all-electric and energy efficient apartment complex. Each apartment will have its own solar panels and storage battery. Each battery will be controlled by the utility, and all 600 batteries will work together to provide power to the grid, as needed.[55]

Rocky Mountain Power also is partnering with a battery manufacturer and a solar contractor to offer incentives for its 50,000 current solar customers in Utah to add a battery system to create a virtual power plant.[56] The power from the new batteries would increase the distributed power capacity that the utility can dispatch to the grid in the same way that solar-plus-storage assets dispatch their storage batteries.[57] The company also has filed a version of the incentive program in Idaho and is evaluating it for all six states in which its parent company, PacifiCorp, operates.

[55] Utility Dive. The future of energy storage is here: An inside look at Rocky Mountain Power's 600-battery DR project. September 30, 2019.
[56] Utility Dive. Rocky Mountain Power's distributed battery grid management system puts Utah 'years ahead' of California. October 14, 2021.
[57] *Ibid.*

Developments To Watch

Green Hydrogen

The potential for green hydrogen, which is hydrogen produced via electrolysis powered by renewable energy, to play a major role in the transition away from fossil fuels increased significantly in the past year. IEEFA mentioned it briefly in our 2021 power outlook, and developments since have shown that green hydrogen is likely to be a key option for meeting at least some of the power needs of a decarbonized grid.

The cost of green hydrogen is derived largely from two factors—the capital cost of the electrolyzer and the price of the renewable energy used to run it. Current green hydrogen projects are small and the electrolyzer costs are high, but those prices are expected to drop significantly in the coming years, benefiting from a development curve similar to that of the wind and solar industries.

Emanuele Taibi, head of the power sector transformation strategies group at the International Renewable Energy Agency (IRENA), projected in late 2021 that "the pipeline for green hydrogen projects is on track for a halving of electrolyzer cost before 2030."[58]

BloombergNEF said essentially the same thing in early January: "Although expensive today, green hydrogen costs are expected to plummet 75 percent by 2030, as the price of electrolyzers rapidly declines. Chinese companies already sell electrolyzers at one-quarter the price of their Western peers. The price decline means that green hydrogen will be cheaper to make than blue hydrogen from natural gas across the world by 2030."[59]

Other experts are even more optimistic about green hydrogen's cost curve. The consulting firm Rethink Energy, for example, said in January that it expected green hydrogen "to become cost-competitive with existing fossil-fuel-based [grey] hydrogen in just two years."[60]

All these projections were made well before the Russian invasion of Ukraine sent oil and gas prices skyward, raising the price of fossil fuel-based hydrogen.

As green hydrogen's costs decline, it becomes possible to envision it playing a role offering long-term and perhaps even seasonal storage for the grid—answering critics' concerns about the variability of wind and solar. One such project is already being planned in Mississippi. Last year, Hy Stor Energy announced plans to build a major green hydrogen hub in the state with backing from Canadian investment firm Connor, Clark & Lunn Infrastructure. The first phase of the project is scheduled to

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[58] World Economic Forum. What is green hydrogen and why do we need it? An expert explains. December 21, 2021.
[59] Renew Economy. Renewable hydrogen costs "expected to plummet" by 2030 – here's how. January 19, 2022.
[60] Recharge. 'Violent shakedown': Green hydrogen to become cheaper than grey within two years, says analyst. January 18, 2022.

enter commercial service in 2025 and be capable of producing as much as 110 million kilograms (kg) of green hydrogen annually and storing more than 70 million kg in underground salt caverns.[61,62]

Laura Luce, Hy Stor's CEO, said the project and others like it would enable a full transition away from fossil fuels: "…[I]t's imperative to have the ability to store large quantities of renewable energy capable of providing multiple days of power over long periods of high demand. We believe the approach we're taking in Mississippi will become the blueprint for future green hydrogen projects ..."[63]

Other projects are also in the development phase, including one announced by Southern California Gas in early March to build a green hydrogen hub in California. The company said it would be the largest such project in the U.S., cutting regional diesel consumption, lowering smog-forming nitrogen oxides emissions and allowing several gas-fired power plants to convert to hydrogen.[64] Details on the project's timing and cost are uncertain, but the fact it has even been proposed shows the dramatic changes that have occurred in the past year.

Electric Vehicles

Sales of EVs soared in the U.S. last year, almost doubling to 608,000 vehicles (see figure below) despite continued supply chain issues that slowed parts deliveries across the sector. In contrast, overall vehicle sales rose just 3% during the year.

Continued sharp sales increases are expected. Ford, for example, sold roughly 27,000 of its first all-electric vehicle in 2021, the Mustang Mach-E. But it plans to be able to produce 200,000 EVs of all kinds, including the much-anticipated F-150 Lightning, in 2022 and more than 600,000 by 2023.[65,66]

Rising EV sales will clearly have an impact on the electric utility sector. As with the sales forecasts, the effects on the grid remain highly uncertain. Conventional wisdom holds simply that rising EV sales will lead to higher energy demand. What is likely to matter much more is how and when those new EVs are charged.

A 2018 study for the Department of Energy found that managed charging would have a number of major benefits for the grid. The study, which looked at the impact of having 3 million EVs on the road in California by 2030, found that managing the how/when of charging those vehicles could:

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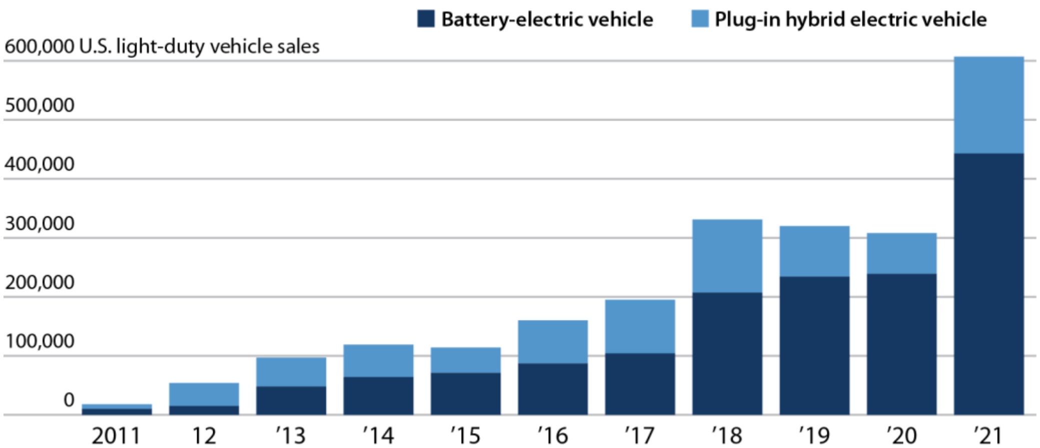
[61] Hy Stor Energy press release. Hy Stor Energy Developing First-Ever U.S. Zero-Carbon Green Hydrogen Storage Hub. October 19, 2021.
[62] The U.S. produces about 10 million metric tons of hydrogen annually.
[63] Hy-Stor, *op. cit.*, p 28.
[64] Sempra Energy press release. SoCalGas Proposes to Develop United States' Largest Green Hydrogen Energy Infrastructure System to Help Decarbonize LA Basin and Accelerate California's Climate Goals. March 2, 2022.
[65] FordAuthority.com. Ford Mustang Mach-E Helped U.S. EV Sales Grow 89 Percent In 2021. January 31, 2022.
[66] Engadget.com. Ford starts 2022 with its highest EV sales numbers to date. February 3, 2022.

- Reduce curtailment of renewable resources by as much as 12.8%, or 7,400 gigawatt-hours, annually;
- Cut peak load by between 1.2 GW and 1.8 GW;
- Lower carbon dioxide emissions by as much as 2.4 million metric tons annually; and
- Lead to lower overall production costs.[67]

Figure 8: U.S. Light-Duty Plug-In Electric Vehicles Sales

Light-duty all-electric and plug-in hybrid vehicle sales in the U.S. doubled in 2021 compared with 2020. With gasoline prices high so far in 2022, some auto analysts think sales could double again this year.



Source: U.S. Department of Energy IEEFA

At this point, the questions about the grid effects of EVs outnumber the answers. But it is clear that EVs can be a grid resource, not just a new load. For example, time-of-use rates enable utilities to push charging into peak solar production hours, maximizing use of this resource and cutting curtailments while also keeping customer costs down. Similarly, utilities are investigating programs to help EV owners use their vehicles as backup power sources during grid outages. Using EVs to help meet peak demand needs on the grid could eventually become a reality as utilities and owners become more comfortable with nascent vehicle-to-grid (V2G) technology options.

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[67] IEEE. Value to the Grid from Managed Charging based on California's High Renewables Study. 2018.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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