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Managing variable and distributed energy resources:
A new era for the grid

Deloitte Center *for* Energy Solutions

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Executive summary

The ongoing electric power industry transformation has ushered in a wave of variable and distributed energy resources on electric grids across the US and globally. Wind and solar installed capacity soared 85 and 1,169 percent, respectively, in the US from 2010 to 2015.[1] And now resources such as battery storage, home energy management systems, and electric vehicles appear poised for strong growth. Forces propelling the overall power industry transformation seem to be some of the same ones prompting this flood of new resources—the drive to reduce carbon emissions from the power supply; to deploy rapidly improving technologies as they travel down the cost curve; and, to respond to changing customer needs and expectations.

US deployment of variable and distributed energy resources accelerated from 2008-2015, with a surge of utility-scale wind power in wind-rich areas such as the Midcontinent. It then gathered momentum with grid-scale solar plants in the West and Southwest, and it is now spreading swiftly down the electric power value chain, as grids in many regions become increasingly decentralized and host a growing number and variety of distributed energy resources (DER).[2] Wind and solar power are variable energy resources (VER), labelled "non-dispatchable" since their output is dependent on weather conditions. While they bring many benefits, integration of these resources can be challenging for grid operators, who must ensure generation and load remain in constant balance and power quality is not compromised. Fortunately, there is a large and growing toolbox of solutions to manage wind and solar variability, including the increasingly promising potential of dispatchable DER, such as energy storage, demand response, and (non-variable) distributed generation sources like fuel cells, natural gas-fired turbines, and combined heat and power systems (CHP).

Whether variable, non-dispatchable resources reside at the transmission or distribution level, the industry's capacity to integrate them is evolving rapidly. Those who see their potential as limited because they are difficult or costly to integrate may be underestimating the capacity for electric systems and markets to innovate. So far, US utilities and grid operators in some regions have successfully integrated annual VER penetration levels of up to 30 percent, with 13 states generating more than 10 percent of their power from VER in 2015, eight states above 15 percent, and three exceeding 20 percent.[3] Short-term or "instantaneous" VER penetration levels—for hours at a time—have surpassed 50 percent and even reached 60 percent in some areas, while maintaining a high standard of reliability.[4] Some European countries have supported even higher levels. Costs have generally not been prohibitive in the US, with the Electric Reliability Council of Texas (ERCOT) estimating integration of its first 10,000 megawatts (MW) of wind capacity at roughly $0.50 per megawatt hour (MWh) of generation.[5] Early forecasts that substantial new generation must be built to back up variable resources like wind and solar power are also not playing out, as the industry innovates and modernizes the grid to increase its responsiveness and flexibility.

How are grid operators handling the growing influx of variable resources? By deploying a broad set of solutions such as expanding transmission; tapping dispatchable, centralized generation resources as well as DER; and deploying energy storage. This paper focuses on the growth path of VER in selected US states and countries with the highest current or projected penetration of these resources, and the benefits and challenges they pose for grid operators. It explores the variety of solutions being implemented across regions with high or rapidly increasing VER penetration, and discusses how dispatchable DER can play a growing role in those solutions.

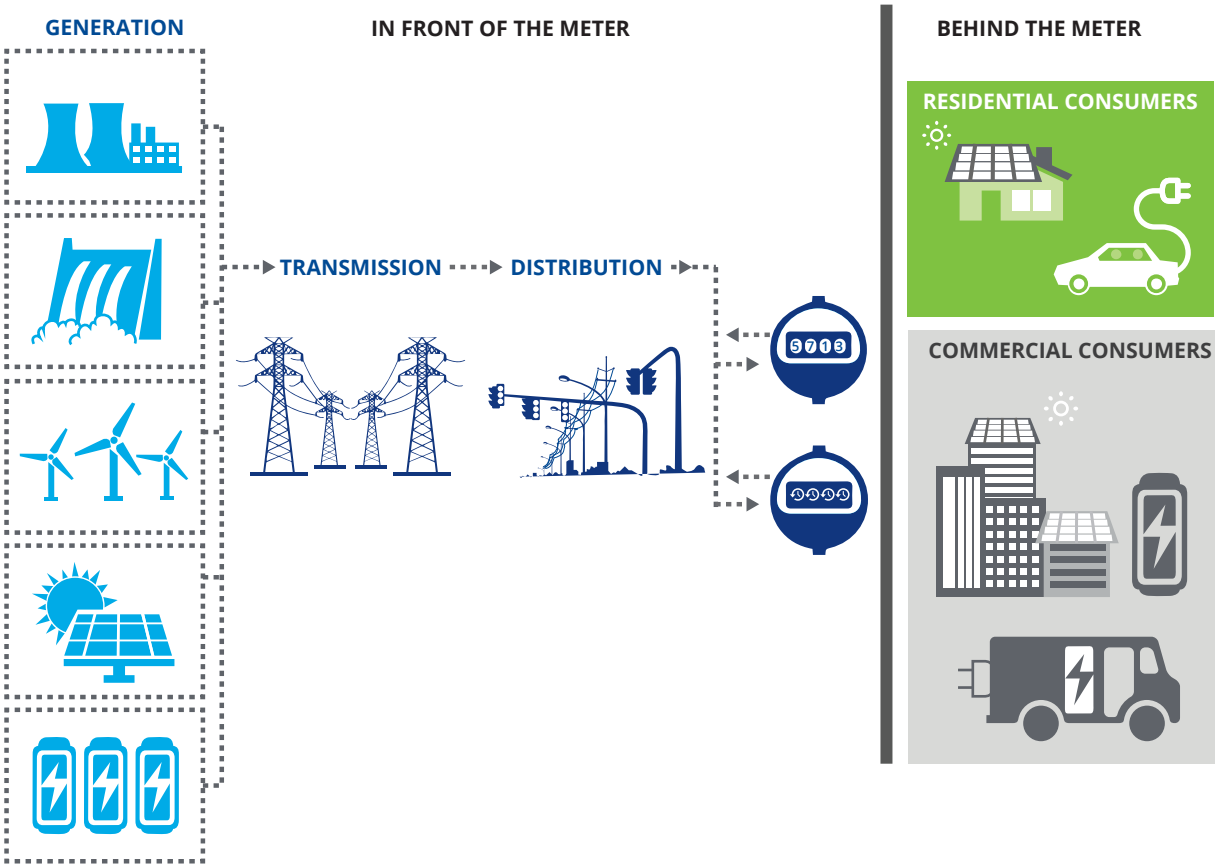
The discussion concludes that building new generation or transmission assets are not the only solutions for integrating VERs, and they may not be the most cost-effective ones either. Greater potential may lie in redesigning and expanding markets, improving coordination across regions, and most of all, taking advantage of the vast, often unused potential of DER. A growing legion of power-generating or load-reducing resources resides on the distribution system, often behind the customer's meter—and new tools and market designs to help utilities harness them are continually being developed. In many instances grid modernization investments will be needed to enable greater deployment of DER. As utilities add smart sensing, communications, and control technologies to the grid, the system gains the flexibility to incorporate DER both operationally and economically, and this in turn may enable smoother VER integration.

VER: What are variable energy resources and which areas have the highest penetrations?

United States

VER are resources whose output may be difficult to predict because they are subject to passing clouds, storms, and other climatological influences, as well as the time of day. Wind and solar power fit this category, and are therefore considered non-dispatchable.* Other renewable resources, such as geothermal and hydroelectric plants, may have output that varies seasonally and with longer term climatic or geological phenomena, but they are far less subject to intraday output volatility, and are considered dispatchable. Wind and solar installations can be located at the transmission or the distribution level, either *in front of or behind the meter,* though behind the meter wind power is less common (see diagram in figure 1).

Figure 1. Energy resources may be located *in front of* or *behind the meter*



* **Dispatchable** energy sources are those that can be turned on and off by utilities and grid operators in a relatively short amount of time. This could refer to time intervals of a few seconds up to a couple of hours. In contrast, **non-dispatchable** refers to everything else. This includes all current nuclear power plants, most coal power plants, and run-of-river hydroelectric plants. It also includes intermittent energy sources such as wind, solar photovoltaics, and wave energy. These power sources cannot be relied upon to meet demand in a short amount of time, so they are non-dispatchable. Source: Vision of Earth, Electricity Grid Key terms and definitions, https://www.visionofearth.org/industry/electricity-grid-key-terms-and-definitions/#Non-Dispatchable.

In the decade from 2006-2015, the annual share of US electricity generation from wind and solar combined grew from 0.8 percent in 2006 to nearly 6 percent in 2015.[6] But some states had much higher VER shares of total generation, such as Iowa, with nearly 31 percent, which was virtually all wind generation. The ten US states with the highest percentage of electricity generated annually by wind and solar in 2015 are shown in figure 2, along with projected VER shares for 2020, 2025, and 2030. The map in figure 3 shows VER share of total electricity generation in 2015 for all 50 states, and figure 4 maps VER penetration projections for 2030.

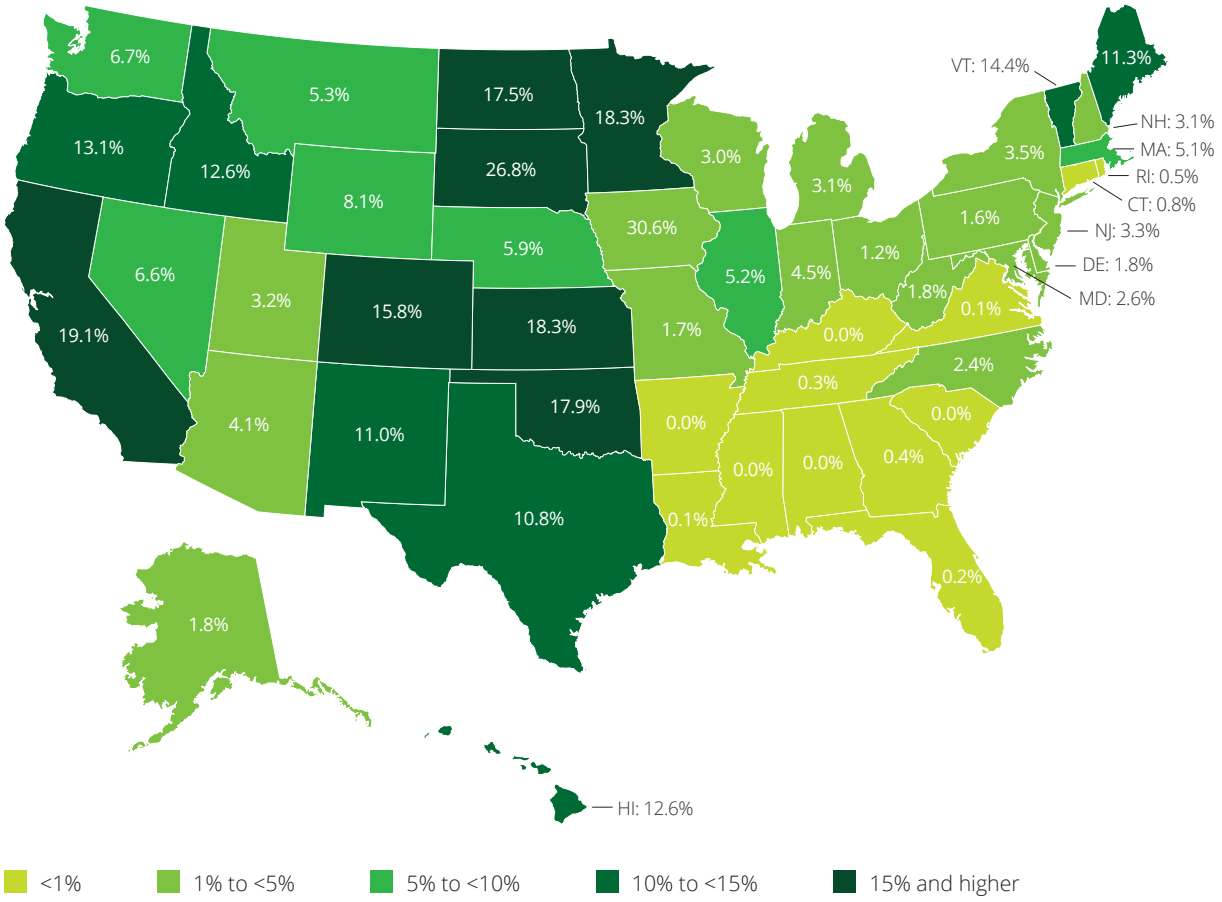
Figure 2. Top 10 US states for variable energy resource generation (VER), 2015-2030
(percent of annual electricity generation)

State	2015 Wind	2015 Solar	2015 VER (wind + solar)	Projected 2020 VER (wind + solar)	Projected 2025 VER (wind + solar)	Projected 2030 VER (wind + solar)
Iowa	30.6%	0.1%	30.6%	36.3%	37.9%	40.6%
South Dakota	26.8%	0.0%	26.8%	38.6%	50.8%	64.5%
California	8.5%	10.6%	19.1%	33.0%	44.4%	52.0%
Minnesota	18.1%	0.2%	18.3%	27.2%	30.5%	34.7%
Kansas	18.3%	0.0%	18.3%	26.4%	30.9%	37.8%
Oklahoma	17.9%	0.0%	17.9%	25.7%	27.7%	32.4%
North Dakota	17.5%	0.0%	17.5%	25.0%	26.7%	29.5%
Colorado	14.1%	1.7%	15.8%	21.8%	24.8%	29.4%
Vermont	6.5%	7.9%	14.4%	26.2%	35.9%	42.7%
Oregon	12.8%	0.2%	13.1%	13.7%	16.7%	20.0%
US Total	4.9%	1.1%	5.9%	10.9%	14.6%	18.7%

Note: Includes utility-scale (solar thermal and PV) and distributed PV
Total may be subject to rounding error

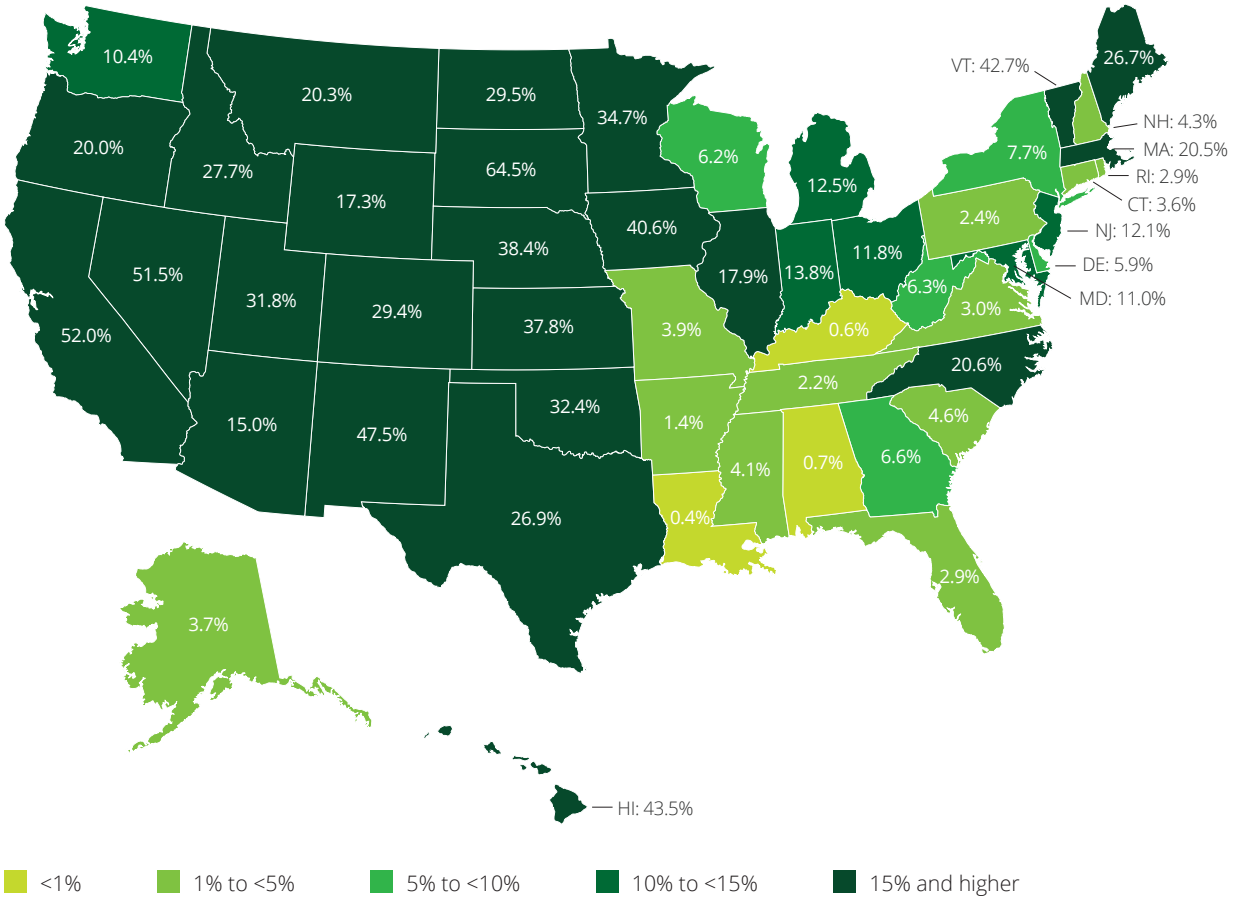
Source: GlobalData

Figure 3. VER penetration across the US, 2015



Source: GlobalData

Figure 4. Projected VER penetration across the US in 2030



Source: GlobalData

Global

Globally, the top ten countries for VER share of annual electricity generation are shown in figure 5, with Denmark and Portugal in the lead, at about 44 percent and 26 percent, respectively. Both within and outside the US, the regions typically cited in discussions of this topic are not always the ones with the highest VER penetration. Germany's VER integration challenges and solutions are commonly highlighted, while US discussions often focus on California (#3), but also on Hawaii (#12), Texas (#15), and New York (#25). These areas are important because they have either rapidly growing penetration of VER, and/or ambitious goals for VER growth, as in the case of Hawaii, which increased its Renewable Portfolio Standard (RPS) in 2015 to 100 percent by 2045. The areas may also be countries or states where a large portion of the existing or planned VER resides on the distribution system, such as Germany or New York (planned), which can add to the complexity of integrating these resources. In some of the states and countries that top the lists, such as Iowa, the Dakotas, and Portugal, the VER currently reside largely on the transmission system, into which large volumes of VER are being integrated successfully, using some of the tools discussed in this report.

Figure 5. Top 10 countries for variable energy resource generation (VER), 2015-2030
(percent of annual electricity generation)

Country	2015 Wind	2015 Solar	2015 VER (wind + solar)	Projected 2020 (wind + solar)	Projected 2025 (wind + solar)	Projected 2030 (wind + solar)
Denmark	42.2%	1.7%	43.9%	51.7%	56.1%	60.8%
Portugal	24.1%	1.6%	25.8%	31.1%	31.8%	31.6%
Spain	17.9%	4.9%	22.8%	22.8%	23.1%	23.8%
Germany	14.8%	6.5%	21.2%	28.6%	35.3%	41.3%
UK	12.8%	2.4%	15.1%	21.7%	28.6%	31.8%
Italy	5.4%	8.2%	13.6%	16.1%	17.5%	18.5%
Australia	4.1%	2.3%	6.3%	11.3%	15.3%	16.3%
US	4.9%	1.1%	5.9%	10.9%	14.6%	18.7%
France	3.9%	1.4%	5.2%	8.9%	12.5%	14.9%
Canada	4.6%	0.5%	5.1%	7.7%	9.4%	10.3%

Note: Includes utility-scale (solar thermal and solar PV) and distributed PV; wind includes onshore and offshore
Total may be subject to rounding error

Source: GlobalData

DER: What are distributed energy resources and how do they impact the electric grid?

DER are any energy resources that are connected to the grid at the distribution level. This encompasses many resource types and technologies, which may be located in front of or behind the meter. Many types of DER are dispatchable, such as energy storage, demand response, or natural gas turbines, and these resources can play a growing role in balancing variable resources on the grid. DER can present planning challenges for grid operators since the distribution system was not designed for two-way power flow, the flow itself may be intermittent, and the resources may be owned and controlled by the customer or a third party. Some of the most common types of DER include:

- **Solar photovoltaics (PV)**—Includes resources such as rooftop solar installations, which are typically small and have intermittent power output. These resources are widely dispersed on the grid and grid operators have little visibility or control over them. In addition to residential solar PV, community solar programs are growing fast likely due to strong consumer demand and program design innovation, according to the Deloitte Center for Energy Solution's *Unlocking the value of community solar: Utilities find opportunity in the inevitable growth of distributed energy.*[7] The Solar Energy Industries Association projects US community solar installations will rise from 66 MW at the end of 2014 to about 1.8 GW by the end of 2019.[8]

- **Other distributed generation**—In addition to solar PV, there are many other types of distributed generation resources connected to the grid, from combined heat and power (CHP) systems, which are prevalent in California and New York, to natural gas turbines, micro-turbines, wind turbines, biomass plants, and fuel cells.

- **Energy storage**—Energy storage includes many technologies, such as pumped hydro, thermal storage, and batteries, with the latter two more likely to be deployed as DER. Storage resources can help provide grid flexibility since they can either draw power from or send power to the grid and provide grid services that help balance the system. GTM Research expects the US energy storage market to reach $1.5 billion by 2018, and the market for increasingly popular solar-plus-storage systems to reach $1 billion by 2018.[9]

- **Demand response**—Includes a number of technologies and applications that adjust energy load to reduce peak demand and provide electricity services to the grid, such as frequency regulation. Demand response applications can be automated or manual and may control residential, commercial or industrial load. They are another source of flexibility that can help balance the grid, maintain reliability and reduce the need for new infrastructure. GTM Research expects the US demand response market to be worth $1 billion by 2018.[10]

- **Electrical vehicles (EV) and EV chargers**—Since they use batteries, electric vehicles can either draw electricity from the grid or provide stored electricity back to the grid to help balance resources. Several utilities are testing these capabilities on their systems through pilot programs. One estimate projects the market for grid services provided by EVs will exceed $3 billion annually by 2020, focusing on demand response programs.[11]

- **Energy efficiency/energy management systems**—Includes residential home energy management (HEM) systems that use smart thermostats to control energy use, sometimes in conjunction with demand response programs, as well as increasingly sophisticated building energy management systems for commercial and industrial (C&I) customers. These can be combined with solar PV or other generation sources plus storage to form a "nanogrid." Utility respondents to a 2016 Utility Dive survey see energy management and efficiency services as the top emerging revenue stream.[12]

- **Microgrids**—Essentially a small-scale power grid, a microgrid is a group of distributed generation resources connected to load in a defined geographic area (e.g. a hospital, military base, or college campus), controlled by a networked energy management system and often including energy storage resources. The system can typically connect or disconnect from the larger grid as needed, though some are completely self-contained off-grid. GTM forecasts US microgrid capacity will reach 4.3 GW by 2020, from the current 1,649 MW of capacity (169 microgrids).[13]

Moving forward, providers aim to enhance the value proposition of DERs by combining them. Recently, the solar-plus-storage combination has gained traction with residential and commercial customers overseas and in selected US markets where economically feasible, and this area is expanding as technology costs decline. Solar and other providers are also beginning to offer "suites of DER," which include not only solar-plus-storage, but also energy management applications (including rate optimization intelligence), and the smart inverters that grid operators are starting to require with these systems.[14] In addition, system operators in organized markets are developing rules that enable small-scale DER providers to aggregate resources for sale into wholesale markets.[15]

Benefits: Why are variable and distributed resources proliferating?

Utilities and other service providers, renewable developers, technology providers, electricity customers, and others are typically adding VER and DER to electric grids for one or more of the following reasons, including:

- Reduced carbon emissions/cleaner energy portfolio for utilities; reduced carbon footprint for residential and business customers
- Opportunities to use tax credits
- Fulfillment of state Renewable Portfolio Standards (RPS)
- Compliance with EPA regulations, such as those promulgated under the Clean Air Act
- Deferral or avoidance of investment in large-scale transmission, distribution or generation infrastructure
- Responsiveness to customer preferences for renewable energy and energy management services
- Access to new revenue streams for utilities and other providers, including customers who provide energy or services to the grid
- Increased reliability and resiliency at grid level and/or at the customer site due to flexible distributed resources
- Greater grid efficiency and asset utilization for utilities and customers
- Declining technology costs
- Improved communications and control technologies that help enable integration

Challenges: What makes VER and DER integration challenging?

The operational challenges posed by VER are familiar: they require system operators to deploy other resources to serve load when the sun isn't shining or the wind blowing and to protect the grid against power quality issues that may arise from intermittent output. Most wind and utility-scale solar plants connect to the grid at the high-voltage transmission level, which is typically equipped with protection, control, and communications technology to support intermittent two-way power flows that can help operators manage their variability.[16] However, as VER volumes increase, we expect that utilities and grid operators will need to plan and employ new tools and strategies to integrate these resources successfully while maintaining reliability. At the distribution level, where the majority of solar PV installations reside, integration can be even more challenging because the medium voltage distribution grid is less likely to be technically and operationally ready to host such technologies.

The distribution grid was not designed to accommodate intermittent output, fluctuations in power quality, and two-way power flows. Surges, spikes, or sags in supply can impact voltage and frequency and potentially impair grid stability, and in turn cause stress and premature aging of distribution assets. In addition, the sun sets as electricity consumption is reaching its daily peak, so net load can rise sharply, requiring other assets to ramp up rapidly. Baseload generation plants, such as coal and nuclear facilities, were not designed to ramp up and down quickly. However, a new generation of combined cycle gas turbines (CCGT) can ramp up in 30-40 minutes, and retrofits are available to improve the operational flexibility of older CCGT plants, as well as gas-fired combustion turbines (CT) and coal-fired steam turbines.[17]

In the case of dispatchable DER, resources such as storage, back-up gas or diesel generators, demand response, fuel cells, and electric vehicles and their chargers can help manage the impact of wind and solar variability. However, some of the hurdles that apply to variable DER may still apply to dispatchable DER, such as lack of visibility or control over the resources, as noted above. In addition, some of the challenges cited by the Electric Power Research Institute (EPRI) apply to dispatchable resources too: "utilities may face large numbers of interconnection requests; distributed generation on some circuits will exceed the load; and many operating challenges involving feeder voltage regulation, hosting capacity limits, inverter grid support and grounding options are brought to bear."[18]

Another set of challenges involves utilities' efforts to plan, simulate, quantify and monetize the value created by DER. These efforts would enable them to assign value and compensate resource owners according to location and to optimize their own investments in grid upgrades and distributed resources. For example, a GTM study found that 7 in 10 regulators, utilities, and solar industry providers surveyed expect customer-sited solar to be compensated based on locational factors in 2020.[19] However, this paper is focused on technical and operational challenges and solutions, rather than economic ones.

Strategies for integrating variable and distributed energy resources

US states and countries that host high and/or rapidly increasing volumes of VER on their electric grids are deploying a wide variety of tools and strategies to integrate these resources without compromising reliability, safety, or affordability. Discussions frequently focus on electricity storage as the Holy Grail—the most indispensable solution, without which VER cannot be integrated. Others emphasize the need to build new transmission lines to connect VER-rich areas with electricity demand centers, or to construct newly flexible gas-fired plants to fill in for VER intermittency—often with estimates of prohibitive costs. But these are just a few tools in the toolbox, and in practice, they may not be the most important strategies for successfully integrating VER into electric grids. As technology progresses, new tools are becoming available.

The solutions generally fall under one of ten categories, including:

- Redesigning markets
- Improving forecasting
- Accessing dispatchable centralized generation resources
- Tapping into dispatchable DER
- Deploying energy storage
- Expanding transmission
- Increasing regional coordination
- Planning/optimizing location of DER
- Testing new technologies
- Modernizing the grid

The following sections describe these solutions in more detail and explore how utilities, grid operators, regulators, and other stakeholders are using them to integrate VER and DER into electric grids.

Redesigning markets

As VER and DER have proliferated, grid operators in organized wholesale markets are revising market rules and innovating market design to provide the flexibility needed to integrate variable resources. In some cases, the Federal Energy Regulatory Commission (FERC) has issued rulings that lend support to these efforts. Below are some examples:

- **MISO**—With wind power increasing rapidly across its territory, the Midcontinent Independent System Operator (MISO) in 2011 began allowing wind resources to register as Dispatchable Intermittent Resources (DIR), enabling them to participate fully in its automated real-time market system that dispatches power every five minutes. Previously, wind power had to be manually curtailed when transmission was constrained. Participation in the automated real-time system allows wind resources to be dispatched more efficiently, which can result in more economic and reliable grid operations.[20]

- **CAISO**—The California Independent System Operator (CAISO) developed rules that allow small-scale providers of DER such as rooftop solar, energy storage, plug-in electric vehicles, and demand response to aggregate and participate in California's energy and ancillary markets as Distributed Energy Resource Providers (DERPs).[21] These resources are typically below the 500 kilowatt (kW) minimum size required to sell into CAISO, and aggregation into DERPs enables them to participate. The rule also opened the way for new types of resources in the future, located either in front of or behind the meter.[22] For example, rapidly evolving demand response services may now include a variety of behind-the-meter resources, such as batteries, solar PV, HVAC, smart lighting systems, industrial equipment, refrigeration, and smart water heaters, which are controlled remotely and aggregated in various ways to serve different grid needs.[23]

- **FERC**—Recent FERC rulings have helped enable some of these regional market innovations. For example, FERC order 745 essentially allows markets to treat demand response resources similar to generation, with customers being able to bid or submit offers to reduce demand at a given price.[24] In addition, FERC order 792 allows energy storage to be treated as a small generator. Furthermore, orders 755 and 784 enable energy storage technology to be compensated in ancillary services markets for its speed and accuracy as a generation source.[25]

Improving forecasting

The ability to accurately forecast when and where the sun will shine or the wind will blow are critical to managing the impact of variable resources, and almost every region with high VER penetration is trying to improve its forecasting abilities. Here are some examples:

- **CAISO**—This independent system operator has taken steps to improve load and weather forecasting, using current and historical data on weather conditions such as wind speed, temperature, barometric pressure, and solar irradiance. In addition, CAISO is incorporating renewable resources into its forecasts, including factors such as behind-the-meter distributed solar and its impact on net load.[26]

- **Germany**—Forecasting errors, due to the unforeseen impact of distributed PV, served as a wake-up call for grid operators in Germany as they were forced to activate all of the system's contracted operating reserves for several hours in 2010.[27] Now, they are using improved PV forecasting tools at the distribution and transmission level, and they have begun modeling a forecasting system like the one developed by the National Center for Atmospheric Research (NCAR) and Xcel Energy (see sidebar). The next step is to equip wind and solar facilities to transmit data in real time, which will likely be necessary in order for German system operators to adjust production accurately.[28]

- **ERCOT**—In 2015, ERCOT enhanced its wind forecasting capabilities, added a 7-day forecast, and began a project to provide utility-scale solar forecasting. At the same time, it improved its wind capacity forecasts by basing generation estimates on actual observed capacity factors during peak load conditions. This increased wind's estimated contribution to resource adequacy, which in turn increased expected reserve margins by about 2 percent in 2015.[29]

Advanced forecasting helps integrate wind more efficiently

Xcel Energy, one of the largest utilities serving the US Midcontinent, helped develop an advanced wind-production forecasting system through cooperation with Global Weather Corp (GWC), an affiliate of the NCAR. Using real-time, turbine-level operating data to forecast wind output for a week ahead every 15 minutes, the system has increased Xcel's wind forecasting accuracy by more than 35 percent since 2009 and saves customers several million dollars yearly.[30] The system forecasts wind output across Xcel's service territory from Minnesota to Texas, and the company also licenses it to other utilities. It helps them make wind commitment and dispatch decisions, and identify opportunities to power down less efficient power plants when forecasted wind output is sufficient to meet customer electric demands.[31]

Accessing dispatchable centralized generation resources

One solution for managing intermittent resources is to access centralized generation resources, especially those that can start, stop, and ramp up and down quickly to adjust to fluctuating output. The latest generation of flexible CCGT plants serves this purpose well, and older gas and coal-fired plants can be retrofitted to better enable fast starts and ramping. In addition, hydropower plants with reservoirs can ramp up and down instantaneously to provide power to the system when needed.[32]

Midcontinent—As winds strengthen or subside, grid operators in this region can increase or decrease the output of flexible generators such as hydroelectric or fast-ramping natural gas plants. The reserves required to cover incremental wind variability are far less than the amount required to respond to a conventional power plant failure, since the region is large and wind output changes are relatively gradual and predictable. Changes can be managed with the use of non-spinning reserves—power plants that are not operating but are standing by ready to provide power within about 30 minutes.[33] The region has integrated significant amounts of wind largely *without adding power plants* to back up VER, partly because it is a large balancing area with many available energy resources.[34] When companies do add new plants, they favor those that can ramp up and down more efficiently, such as CCGT.

- **New York**—To meet its Clean Energy Standard (CES), which calls for 50 percent of the state's power to be sourced from clean and renewable energy by 2030, New York plans to keep its existing baseload, emissions-free nuclear plants open and to use fast-starting gas-fired turbines to help balance variable wind and solar. The state's 2015 generation mix included 31 percent nuclear power and 44 percent power from gas-fired plants or plants that can burn gas or other fuels.[35]

Tapping into dispatchable DER

One of the fastest growing solutions for managing VER intermittency is an increasingly sophisticated set of DER services that is introducing new flexibility into energy markets.[36] Often enabled by new technologies or market design, these resources can either reduce demand or increase supplies to fill in for variable resources. As noted earlier, DER includes demand response and energy management programs and applications, microgrids, distributed energy storage, and many forms of distributed generation. DER adoption is likely rising due to a growing desire to save money, ensure resilience, and/or reduce carbon emissions among both consumers and businesses, according to the *Deloitte Resources 2016 Study*.[37] Most of these resources reside behind the meter and are owned by the customer or a third party. Distributed PV may even be part of the equation, since its variability diminishes when enough resources are coordinated over a large area, and tools like smart inverters can provide increased control over output.

Considering the rapid growth of customer installations and program participation, DER could develop into a significant tool for managing VER. For example, operators could increasingly reach behind the meter to tap into customers' largely unused backup generators or storage devices to smooth out fluctuations in VER output (see sidebar). But first, the industry will need to harness the technology and develop the regulatory and market structures necessary to access, monitor, control, and manage these resources. Examples of ongoing programs include:

New York—In 2014, New York announced its groundbreaking electricity market restructuring plan, *Reforming the Energy Vision* (REV). Developed by the New York Public Service Commission (PSC), REV aims to enhance grid resiliency and energy efficiency; reduce greenhouse gases; and enable increased customer choice and participation in energy markets while preserving affordability. Much of this is expected to be achieved with regulatory changes and market initiatives that facilitate the role of DER and help to integrate these resources into the system.

- **Distribution System Platform (DSP)**—REV calls for utilities to transform the distribution system into a platform to enable greater participation by third-party DERs. Part of the effort requires grid modernization, including increased penetration of Advanced Metering Infrastructure (AMI) and enablement of two-way power flows.

Using customer resources to balance the grid

The Wyoming Public Service Commission recently approved an innovative corporate tariff that enables utilities to use large customers' backup energy resources for grid balancing. The tariff was a solution developed by the local utility and a technology company that is building a large data center in its territory. If the utility needs additional power during peak demand periods, it can access the data center's gas-fired backup generators, essentially as it would a peaker plant. The technology company would boost utilization from an otherwise largely idle asset, while the utility would gain access to energy balancing and ancillary services without having to build costly new generation or transmission infrastructure. With its fast ramp up capabilities, this type of installation could be used in the future to help integrate renewables on the grid.[43]

- **DER Roadmap**—In August 2016, the New York Independent System Operator (NYISO) released a roadmap outlining changes to wholesale electricity markets to enable additional DER integration.[38] These initiatives include aligning market incentives and compensation for DER providers based on resource flexibility and measured performance, and enhancing measurement and verification methodologies.[39]
- **Demand response**—Currently, demand response programs developed in New York's competitive wholesale markets provide more than 1,200 MW of resources to address peak demand. REV initiatives would enable more demand response, which would help balance intermittent resources.[40]

- **Texas**—ERCOT has been using demand response programs to maintain reliability in emergency situations, such as unplanned outages. It is now creating price-responsive programs to allow customers to react quickly and be compensated accordingly for reducing peak load.[41] Retail Energy Providers (REP) in the ERCOT system are also enabling customers to save money by being price-responsive. Through the remote-control capabilities of smart meters and smart thermostats, electric heating and air conditioning systems or pool pumps can be programmed to power down in response to signals from Time of Use (TOU) pricing programs. While these programs are still in the early stages, they may eventually enable demand response to be used more robustly, which would help operators to integrate more VER.

- **Denmark**—This nation has the highest penetration of VER in the world, at nearly 44 percent of electricity generated in 2015, yet system reliability surpasses that in the US. Denmark's variable power comes primarily from wind energy, and is integrated through a number of the strategies described in this report. Its strategy for leveraging distributed energy resources to better integrate VER involves a sophisticated demand response market currently based largely on distributed CHP. Most of Denmark's CHP units have flexible capacity to respond to market pricing. When local power prices are low or negative due to high wind output or other factors, the CHP units can bypass power production and produce only heat; when prices rise again they can resume producing both heat and power. Grid operators are transferring that flexibility to other distributed resources, such as distributed wind turbines and solar panels, and testing local control systems that can anticipate grid instability and disconnect from the grid for islanded operation in the event of a disturbance.[42]

Deploying energy storage

As VER penetration grows, regulators, grid operators, and other stakeholders have encouraged the deployment of energy storage, both at grid-scale and as a DER, to store excess electricity and help balance the grid. Its fast ramping capability makes energy storage a particularly useful resource in countering VER intermittency. Storage technologies vary widely—from large pumped hydro plants to the lithium-ion batteries increasingly used in home backup systems and electric vehicles. The cost of some of these technologies has been relatively high, but it is declining with technological advances and new market designs that help compensate energy storage technologies for the full slate of services they provide. These services may include frequency regulation, voltage support, and transmission and distribution upgrade deferral, among others, rather than solely being a backup for variable renewables.[44] The following storage initiatives are currently being pursued:

- **California**—In 2013, the California Public Utilities Commission (CPUC) mandated that the state's three largest investor-owned utilities (IOUs) add 1,325 megawatts (MW) of energy storage to the electric grid by 2020.[45] The Commission concluded storage was one of the tools necessary to help balance variable wind and solar resources and keep the grid stable. As a result, stationary storage installations have increased by 340 percent between 2014 and 2015 and have continued to grow in 2016.[46] In September 2016, the state passed four more bills that will likely boost energy storage investment. Overall, the legislation will increase funding incentives for self-generation, require the state's three IOUs to invest in an additional 500 MW of distributed energy storage, expedite dispute resolution for behind-the-meter DERs attempting to connect to the distribution network, and require the CPUC and the California Energy Commission (CEC) to analyze the potential of various types of storage for integrating variable renewables into the grid.[47]

- **PJM Interconnection**—The PJM RTO, which covers 13 states and the District of Columbia, is increasingly deploying electricity storage technologies. At grid level, the RTO currently has nearly 250 MW of battery storage projects, including a 2 MW battery on its campus. It also has a flywheel storage facility in Pennsylvania and is evaluating compressed air storage and thermal storage using large water heaters. At the distribution level, PJM is testing vehicle-to-grid regulation services using electric vehicle batteries.[48]

- **Hawaii**—As the state with the highest RPS goal in the US and no access to neighboring grids to help balance VER, Hawaii is pursuing a number of home-grown solutions, including energy storage. Hawaiian Electric Company deployed its first grid-scale battery energy storage system in 2016, and is exploring how to leverage the growing number of behind-the-meter batteries at customer sites.[49] One experiment in Maui involves shifting the charging time of 200 electric vehicles to off-peak hours to help absorb late-night supplies of wind power and reduce customers' bills. Vehicles in this project are also able to discharge energy and help households adjust their supply and demand.[50]

Expanding transmission

Being able to tap into generation resources in neighboring regions or send excess output to them can help grid integrators balance supply and demand on systems with increasing VER. However, this sometimes requires building new transmission lines to connect regions, which can be a complex, time-consuming, and costly process. But the benefits may outweigh the costs, and they may extend beyond VER integration. Almost all regions with increasing VER are considering transmission-system expansions—or they are already implementing them.

- **ERCOT**—Texas spent $6.8 billion on transmission lines to connect Competitive Renewable Energy Zones (CREZ), or areas with high wind potential, to demand centers. Although the lines are not limited to wind use, they have helped alleviate supply-demand mismatches that sometimes caused negative prices and wind curtailment.[51]

- **Europe**—European countries are considering a number of transmission expansion projects to better link their grids and balance VER. Two projects that are likely to move forward are a 460-mile undersea cable linking the Danish grid with the UK's, and a new 400 kilovolt (kV) overhead line linking Denmark and Northern Germany.[52] The UK and Norway have also agreed to build a $2.2 billion subsea link across the North Sea, which would enable the UK to import Norwegian hydropower. The UK's grid is already connected to grids in Ireland, France, and the Netherlands.[53]

- **New York**—NYISO's 2016 annual report called for transmission upgrades to move hydro and wind power from upstate to the metropolitan demand centers in the southeastern region.[54]

Increasing regional coordination

Utilities, system operators, and other stakeholders are increasingly seeking to coordinate the dispatch of resources across borders to reduce costs and improve market efficiency. Coordination across a larger geographic area with diverse resources and weather patterns facilitates VER integration. Even systems that aren't part of organized markets can benefit from regional coordination. Below are a few examples:

- **Western Interconnection**—CAISO is part of the Western Interconnection, which consists of 38 energy balancing authorities that are not organized into regional markets like those in the East (e.g., PJM, NYISO, and ISO-New England).[55] But, partly due to the need to integrate variable wind and solar resources, CAISO and PacifiCorp formed an Energy Imbalance Market (EIM) in late 2014 to dispatch the lowest cost energy to serve load across 14 western states. NV Energy participates, and four other utilities are set to join the EIM, which automatically balances supply and demand in 5-minute intervals (see sidebar).

To take it one step further, CAISO and PacifiCorp proposed a full Regional Transmission Organization (RTO) in 2015, with markets for day-ahead energy and ancillary services. The proposed RTO would be expected to save billions of dollars and facilitate renewable energy development throughout the region, according to a study commissioned by CAISO and PacifiCorp.[56] Nonetheless, CAISO and stakeholders across this diverse group of states will need to work out governance and other issues before the plan can move forward.

Western EIM Partnership provides renewable integration benefits:

"As the nation's energy supply becomes more diverse, regional coordination and finely tuned dispatches become more important because of changing weather conditions that produce variability in wind and solar power generation. The EIM improves the ability to manage resource deviations, smoothing out power flows so that renewable energy is effectively integrated onto the grid. By capturing a wider portfolio of resources, the EIM optimizes available resources reducing the quantity of reserves required to ensure electricity shows up where and when it is needed. By leveraging geographic diversity, the EIM will make it possible to share intermittent renewable resources such as wind and solar during times of under or over-generation."[61]

- **Eastern Interconnection**—This interconnection covers the US states east of the Rockies, except Texas. The 2016 Eastern Renewable Generation Integration Study, completed by the National Renewable Energy Laboratory (NREL), found that the system could feasibly integrate up to 30 percent variable wind and PV generation (with up to 50 percent instantaneous penetration).[57] To do this, the study suggests greater regional coordination will likely be needed, along with incentives for transmission operators and generators to provide ramping, energy, and capacity services.[58]

- **Joint Dispatch Agreement (JDA)**—On a smaller scale, utilities operating outside of RTOs or ISOs can also coordinate operations to reduce generation costs, serve load more efficiently, and help balance VER across a larger geographical area. In 2014, Xcel Energy Colorado entered into a JDA with neighboring Platte River Power Authority and Black Hills Colorado Electric Utility Company.[59] The agreement, similar to the western Energy Imbalance Market, allows the three parties to coordinate the intra-hour dispatch of generation resources.

- **Europe**—Abundant wind energy from countries like Denmark can help decarbonize and secure power supplies across Europe, but more regional coordination is needed, according to a spokesperson for the European Wind Energy Association. "If we want to see this happening on a European scale, it is essential that we upgrade the continent's aging grid infrastructure, ensure that countries open up borders, increase interconnection, and trade electricity on a single market."[60]

Planning/optimizing location of DER

Part of the process of leveraging more DER to help balance the grid involves identifying the optimal location for these resources on the distribution system and communicating those locations to resource developers. Analyzing existing grid resources, capacity, and current and future load patterns can help determine the locations where DER can contribute the most value on the system. Utility planners in California, Vermont, and New York have mapped out the areas on their systems with available capacity or strong congestion to help developers site new projects.[62]

California, in particular, seems to be moving forward quickly on this front. Under California energy law AB 327, passed in 2013, the state's IOUs must file Distributed Resource Plans (DRP) with the CPUC and update them annually, starting in 2015.[63] The companies were asked to analyze and map their distribution systems to identify optimal locations for DERs; propose tariffs or mechanisms to support DER deployment, as well as barriers that could limit it; propose methods of coordinating existing programs, incentives and tariffs to maximize locational benefits and minimize incremental costs of DERs; and identify any utility spending necessary to integrate cost-effective DERs into distribution planning while yielding net benefit to ratepayers. The plans were submitted in July 2015 as the first step in integrating DERs into utility distribution operations and long-term planning. Much work has yet to be done, especially in terms of valuing these resources, as well as potentially adjusting the regulatory structure to support DER deployment as a less costly alternative to investment in traditional transmission, distribution and generation assets.

Testing new technologies

New technologies for integrating VER are being tested around the world. In the US, Hawaii in particular has become somewhat of a laboratory for grid integration technologies, partly because the state hosts a growing volume of VER and DER, due to abundant wind and solar resources and the most ambitious RPS goal in the country. In addition, Hawaii offers opportunities to test new tools on isolated, islanded grids. Plus, retail electricity prices in the state are more than double the US average, which leaves room to experiment with new technologies that might be cost-prohibitive elsewhere.[64] These pilot projects are being watched by operators in high VER penetration regions around the world. Here are a few examples of those being conducted in Hawaiian Electric Company's (HECO's) territory:[65]

- **Distributed Resource Energy Analysis and Management System (DREAMS)**—This effort combines high-tech weather forecasting, distribution automation, and control system integration. Funded by the Department of Energy's SunShot program, it aims to determine the effect of weather on output from both utility-scale and behind-the-meter distributed generation and to use the data to inform operational decisions.
- **System to Edge-of-Network Architecture and Management (SEAMS)**—This project aims to provide HECO with more visibility and control over customer load both in front of and behind the meter. For example, using inline power regulators (IPRs) provided by a technology partner, the utility was able to stabilize voltage and prevent back-feed from rooftop solar installations.
- **Storage**—The utility is hosting a storage pilot with a partner who is deploying onsite batteries to help customers reduce demand charges. In return, the utility has the ability to call on those batteries to reduce system load when necessary for an hour at a time. Other demand-side pilots involve utility-controllable hot water heaters and air conditioners.
- **Smart inverters**—A project with NREL and SolarCity tested smart inverters with distributed solar installations. These inverters adjust operations to minimize potential grid disturbances on either side of the meter, and the utility now requires them in all installations.

Modernizing the grid

Leveraging the flexibility of DER to integrate growing volumes of VER on grids across the globe typically requires deployment of a host of supporting technologies. The good news is that these are often the same technologies being adopted in grid modernization programs in many areas of the world. And in the US, these investments can potentially be rate-based since they help ensure overall grid reliability and operational efficiency.

Grid modernization includes the transformation of the electric grid from a one-way system where power flows from centralized generation stations to consumers, to a platform that can detect, accept, and control decentralized production and consumption assets, so that power can flow in multiple directions as needed. The end result is an "intelligent grid."[66] Achieving this vision typically requires deploying "Internet of Things" (IoT) technology, such as Advanced Metering Infrastructure (AMI), a two-way communications network of smart devices both in front of and behind the meter. These devices include sensors, smart meters, and in-home displays, as well as DERs, such as demand response and energy management systems, smart inverters connected to distributed PV, and interfaces with other distributed generation resources.

These networked devices are linked to increasingly advanced information and analytics software, such as Advanced Distribution Management Systems (ADMS). ADMS provide situational awareness on a holistic, system level and enable the monitoring and control of DER. With these tools, utilities, customers, and other stakeholders can eventually optimize DER as they increasingly gain visibility into fluctuating output and demand, and in some areas, prices. Grid modernization is discussed further in Deloitte's *The power is on: How IoT technology is driving energy innovation*.[67]

Fortunately, states with high VER and DER penetration, such as California and Texas, ranked among the top ten in the 2016 Grid Modernization Index published by Gridwise Alliance and CleanEdge.[68] The Index ranks states on criteria such as penetration of AMI and transmission and distribution automation devices; integration of AMI with outage management and distribution management systems; state policy support; and customer engagement. States with high RPS goals, such as Hawaii, Vermont, and New York, will likely continue to add VER rapidly. They also appear to be on track with grid modernization efforts, as they ranked #12, #13, and #16, respectively.

Conclusion

As states and countries continue down the path toward low or no-carbon energy supplies, the role of variable and distributed energy resources will likely grow and VER integration tools are expected to become increasingly critical. While integrating VER can be challenging for grid operators, in reality these resources have been integrated at higher levels than expected,[69] reaching nearly 44 percent of power generated annually in Denmark without impacting reliability. In the US, costs of VER integration have generally been lower than analysts predicted, largely thought to be because the set of tools for integrating them has been expanding. We expect it to be increasingly important to deploy VER integration solutions as penetration rises. In some European countries, such as Germany, rapid VER adoption occurred before some of the solutions described here could be implemented, which contributed to supply-demand imbalances and rising electricity prices. Germany is now pursuing policies to slow VER growth and implement DER solutions such as demand response, CHP, and storage. Another area with rapid VER adoption, the Australian state of South Australia, is reviewing its integration strategies and particularly its wind plant settings that interface with the electric grid, after a recent storm-related blackout that involved, though was not caused by, several of the state's wind farms.[70]

Across the globe, solutions that were originally thought to be the primary tools for VER integration, such as building backup power plants, have not been used extensively. Instead, operators are relying more heavily on solutions like improved weather forecasting, expanded regional and inter-regional coordination, and perhaps most significantly—on a growing wave of DER that is becoming increasingly accessible to operators as the grid is modernized and new market services and technologies become available. Grid modernization seems particularly critical to unlocking the potential of DER, just as it is to improving efficiency and cutting costs across all grid operations. An "intelligent grid" would allow operators to monitor, analyze, manage and control the VER and DER on the system.

While once viewed primarily as a threat to utility business models, DER are beginning to be seen as valuable tools to add flexibility to the grid and integrate growing volumes of VER cost effectively. As grids evolve into two-way energy platforms, electricity markets are also evolving, and may increasingly acquire characteristics of the new "sharing economy," as customers make their DER available to utilities and grid operators to balance the grid. In this environment, utility planners are starting to see DER more as enablers, rather than competition, and increased coordination across systems, markets, and resource owners as the most effective and efficient solution for integrating VER and DER.

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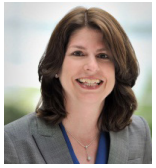
Let's talk



Marlene Motyka
US Renewable Energy Leader
Deloitte Transactions and Business Analytics LLP
mmotyka@deloitte.com
+1 973 602 5691
@MarleneMMotyka

Andrew Slaughter
Executive Director
Deloitte Center for Energy Solutions
Deloitte Services LP
anslaughter@deloitte.com
+1 713 982 3526

John McCue
Principal
Deloitte Consulting LLP
jmccue@deloitte.com
+1 216 830 6606
@JMcCue624

Key contributors

Suzanna Sanborn
Senior Manager, Market Insights
Deloitte Services LP

Kartikay Sharma, Senior Analyst, Deloitte Support Services India Pvt. Ltd.
Deepak Vasantl Shah, Senior Analyst, Deloitte Support Services India Pvt. Ltd.

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Through the Center, Deloitte's Energy & Resources group leads the debate on critical topics on the minds of executives — from the impact of legislative and regulatory policy, to operational efficiency, to sustainable and profitable growth. We provide comprehensive solutions through a global network of specialists and thought leaders.

With locations in Houston and Washington, DC, the Center offers interaction through seminars, roundtables and other forms of engagement, where established and growing companies can come together to learn, discuss, and debate.

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