The Impacts of Exponential Renewable Generation Growth Across the Energy Ecosystem

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Renewable generation will continue significant growth over the coming decade, disrupting all core utility processes. Energy CIOs should understand and prepare for the implication of renewables on IT and OT portfolios across the industry value chain.

Overview

Impacts

- Renewable energy (RE) growth impacts the four core utility life cycle processes (commodity, asset, revenue and customer), requiring changes to a broad array of IT and OT applications.
- Different actors, including utilities, independent power producers (IPPs), community organizations and electricity consumers, have diverging objectives and approach renewables with distinctly different ambitions and expectations.
- The variability, unpredictability and lack of dispatchability of renewable sources, in particular, wind and solar, are stressing the existing commodity management processes and their supporting IT and OT applications such as generation optimization and automated generation control.
- Grid operations with increasing renewable resources require new business models, as well as new ways of operating infrastructure, compelling CIOs of grid operating companies to assess readiness of their grid technology portfolios to match evolving business needs.
- Pricing and incentives that encourage renewable energy deployment, utilization and market integration of customer-deployed renewable sources impact revenue and customer management life cycles and require new metering, billing and customer engagement capabilities.

Recommendations

CIOs in the energy sector focused on digitally enabled transformation must:

- Work with line of business (LOB) leaders to evaluate the impact of renewables on existing and planned IT and OT applications by utilizing Gartner's matrix of renewable power impacts on core
Analysis

The journey toward a cleaner and sustainable energy future is fueled by renewable energy. According to the IEA Conservative Stated Policy Scenario (see World Energy Outlook 2020), renewables will constitute about 80% of the electricity generation growth over the next decade.

The growth of renewables is driven by the need to decarbonize power generation, and thus, reduce the energy sector's impact on climate change. However, the growth of renewables has profound and disruptive implications across the utility value chain. Renewable generation sources tend to be several orders of magnitude smaller and installed both centrally and at the grid edge. Consequently, they promote decentralization and have a significant impact on existing grid architecture and operations. An increasing number of renewables are owned by consumers or their agents and are deployed on consumer premises in order to act as dedicated consumer resources. This democratization of energy provisioning challenges the established position of traditional energy providers. As the percentage of renewables rises and ownership of renewable generation becomes more diverse, the impact on energy provisioning business models and the consequence to operating models become more pronounced.

The most significant renewable impact on utilities comes from the fact that utilities are losing their grip on generation sources due to the unpredictable and intermittent nature of renewable generation. The loss of controllability/dispatchability of generation sources breaks one of the foundational utility operational tenets in which controllable generation follows variable load. Consequently, traditional OT systems, which were put in place to maintain demand supply equilibrium via load frequency control, and commercial systems such as generation scheduling and nomination are unable to meet the new challenge, from both complexity and time latency requirements.

The growth of renewable energy is not a unified phenomenon. Rather, it is an eclectic mix of varying incentives, ownership and operating models, adoption rates, and emerging energy technologies. Renewable technologies range from intermittent wind and solar energy, which are experiencing the most significant growth, to more traditional, and to some extent controllable, sources such as hydropower,

utility life cycle processes.

- Provide the people, knowledge and tools to support the LOB development of generation resource planning analytical tools that can model utility- and customer-owned renewable and traditional resources within a common framework.

- Advise LOB leadership to expand distribution engineering and operations capabilities to design and manage distributed energy resources (DERs) and leverage DERs for grid control, and support the transition to new business and operating models, including transformation from distribution network operator (DNO) to distribution system operator (DSO).

- Task IT managers who support new renewable energy pricing schemes to adopt new billing technology architecture to augment core billing systems with new tariff such as net metering and feed-in-tariffs and potentially online-to-offline (O2O) peer-to-peer energy exchange settlement.
geothermal and biomass. Utility CIOs can learn many lessons from tracking progress in regions with high renewable energy adoption rates. These include, for example, Germany, Australia, and Arizona and Southern California in the U.S. for solar power, or Denmark, the U.K. and the U.S. Texas panhandle for wind energy. CIOs must also consider a range of variables unique to their own situation when assessing the impact on their existing IT and OT portfolios, as well as long-term investment in new IT and OT assets.

Depending on the penetration of consumer-owned renewable sources, a utility may consider offering different products with pricing plans such as feed in tariffs or net metering to support customer-owned renewable integration. In other cases, depending on the specific composition and mix of renewable power in their service territory, including the ownership and operating models, energy companies may consider how to integrate nonutility renewable resources in overall market operation. They might do this via digital platforms such as flexibility markets or virtual power plants. As energy becomes a tradable product outside of bulk power markets, other models such as transactive markets or peer-to-peer energy exchange should be considered by utilities to add new capabilities and to become digital business platform providers (see Industry Vision: Utilities as Platform Providers for the Energy-Sharing Economy).

This research explores the impacts of intermittent renewable power (predominantly wind and solar power) across the utility value chain. We accomplish this by exploring renewables’ impact on four utility core business process life cycles (commodity, asset, customer and revenue) with consequent implications for corresponding IT and OT applications (see Table 1). Future research will provide further detail in each of these areas, as well as deeper analysis of different RE ownership models and the unique set of challenges they pose and the opportunities they create.
### Table 1: Impacts and Recommendations for Exponential Renewable Generation Growth Across the Energy Ecosystem

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<td>Use Gartner’s RE impact matrix to gauge the impact of renewable power growth on IT and OT.</td>
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<td>The intermittent and variable nature of renewables increasingly stresses existing commodity management processes.</td>
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Source: Gartner

### Impacts and Recommendations

**Renewable Energy Resources Impact All Four Core Utility Life Cycle Processes**

The characteristics of renewable energy have a cross-cutting transformational impact on the utility industry. The utility value chain is composed of three distinct domains:

1. In a supply domain, participants engage in production/generation and trading of electricity on the wholesale market.

2. In a delivery domain, participants operate transmission and distribution infrastructure to deliver electricity to customers’ premises.

3. In a retail (aka customer) domain, participants service and sell energy to customers.

In addition to breaking the energy provisioning value chain into three distinct domains, for the purpose of determining required technical capabilities for energy companies, we can look at key activities across the business process life cycles. In the energy utility sector, companies deal with four major business process life cycles. Those are the commodity (energy) life cycle, the asset (plant and linear) life cycle, the
customer life cycle and the revenue life cycle. The business activity processes that utilities address in these life cycles are:

- **Commodity**: Forecast energy need, acquire fuel, optimize generation, produce and balance demand and supply, and trade energy.
- **Asset**: Design, procure, construct, maintain, operate and retire generation and deliver physical asset.
- **Customer**: Acquire, enroll, engage, retain, service and switch/transfer customers.
- **Revenue**: Meter consumption, calculate bills, process payments, manage credit collection.

Utilities operating across different value chain domains are focused on different business process life cycles. Merchant generators are focused on commodity and asset life cycles. Transmission system operators (TSOs) and distribution network operators (DNOs) are focused primarily on the asset life cycle. Local distribution companies and integrated utility companies are focused on all four business process life cycles, while competitive retailers deal primarily with the customer and revenue business process life cycles (see Figure 1). Each of these business process life cycles requires a set of capabilities that is addressed by a number of IT and OT applications.
Unique characteristics associated with the dominant sources of intermittent renewable power across the four utility industry life cycle processes include:

- **Commodity** — The large-scale deployment of renewables has impacted the utility commodity life cycle, primarily as a consequence of the intermittent, variable and uncertain nature of renewables. Solar and wind are expanding the share in electricity supply, mainly at the expense of electricity generated through coal, which could be easily controlled, dispatched, scheduled and delivered. Renewables, which depend on weather, need to be forecast and "scheduled" to meet load requirements, while requiring grid operators to be proactively flexible on the storage, demand and supply sides.

- **Asset** — Large, centralized, scaled-up fossil fuel plants are increasingly being retired and replaced by scaled-out renewable units. Large-scale renewable energy installations such as offshore wind farms have a large distributed surface footprint of assets that are instrumented and operated remotely. Scaled-out renewable resources tend to be located in remote regions away from population centers.
Unlike traditional generation sources that are built, owned and operated by utility companies, renewable deployment has introduced new actors. These include both industrial and residential customers, as well as their agents such as IPPs and renewable community providers—community solars and CCAs. Those different actors tend to focus on different types of renewables, in particular from the scale perspective, and tend to have diverse business models with a different impact on their business process life cycles.

Figure 2 depicts six different types of generalized renewable deployments (utility scale, IPP, community, CCA, industrial and residential) with the qualitative assessment of impact using Harvey balls across the four utility life cycle processes (commodity, asset, customer and revenue).

**Customer** — Exponential innovation in consumer energy technologies, in particular renewables such as rooftop solar, have resulted in grid parity in many regions, resulting in a growth of prosumers. Consumers that can meet most if not all of their energy needs through self-generation, is one of the most disruptive phenomena in the utility sector. Growth of prosumers challenges current business and operating models and opens doors for new entrants in the utility sector such as consumer technology vendors and digital dragons. It requires utilities to explore their customer engagement strategies and apply a new set of capabilities, including advanced analytics, to identify owners of renewable sources and their production/consumption patterns. It also requires utilities to create better segmentation with more personal customer experience offerings.

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Customer-owned installations appear at the edge of the distribution grid and need to be orchestrated to manage impacts on the grid.

**Revenue** — Renewable “green” energy is a relatively new product that creates new financial relationships between utilities and renewable power owner-operators. Integrating renewable sources, in particular those that are outside of utility companies’ ownership, creates new opportunities for utilities to monetize use of their infrastructure and create new product and service offerings. These can range from:

- A simple tariff structure that will encourage owners of renewable sources to respond to utility needs for commodity or grid operations
- More sophisticated models such as virtual power plants
- Revenue models for advanced IoE or peer-to-peer energy exchange operating models
- Monetization of the grid infrastructure for use in community solar or community choice aggregation (CCA) models

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Different actors involved in various deployment models in renewable development in utility sectors are:

- **Utility-scale renewable infrastructures**, often termed “farms,” are large installations. As an example, wind farm turbines have scaled up to a 222 meter swept rotor area delivering up to 14 megawatts with hundreds of structures consolidated into gigawatts of capacity. Depending on jurisdiction and energy policy, farms are owned and operated most commonly by third-party developers or utilities. They have a significant impact on the commodity and asset processes, given their increasing scale and remoteness from population centers. This energy needs to managed and transported over significant distances, requiring upgrades to high-voltage transmission and distribution networks and physical systems. High voltage direct current (HVDC) is emerging as a useful technology to derisk ISO operational zones across jurisdictions.

- **Independent power producers (IPPs)** develop, own and operate renewable energy plants to generate electricity to meet utilities’ power demand, through contractual agreements called power purchase agreements (PPAs). IPPs played a dominant role in laying the foundation for utility-scale renewable energy deployments across the globe. However, the growth in DERs, regulatory mandated subsidized renewables, changing consumer preferences and volatile commodity prices have impacted IPPs. Having said that, utilities still rely on IPPs to ensure they meet their renewable energy targets.
Additionally, IPPs have a significant impact on utility commodities and assets, given their increased ownership of large-scale renewable assets.

- **Community choice aggregation (CCA)** or citizen-driven renewable energy (CRE) projects in European countries, also known as municipal aggregation, are programs that allow local governments or third-party aggregators to procure renewable (green) power from an alternative supplier. They do this on behalf of their members while still receiving network delivery service from their existing utility provider. These collaborative choice aggregation models have a similar goal as community solar programs. They provide renewable power options to community members, such as apartment dwellers who may not have access to suitable sites, or low-income customers, who may not have sufficient economic means for full ownership. CCA municipalities use aggregate buying power to purchase green energy directly from a provider (an IPP or a merchant generator) that owns and operates renewable generation assets. Utilities become network operators and provide metering and billing service on behalf of CCAs, while CCAs take ownership of customer engagement.

- **Community solar projects** (solar gardens) typically range from a few hundred kilowatts up to a few megawatts, where generation output is allocated to participants (typically customers) on a pro rata basis, based on a shared ownership model. According to the Solar Energy Industry Association (SEIA), in the U.S. alone, 2.6 GW of community solar was installed in 2020. Examples include a distributed rooftop solar program by Arizona Public Service's Community Solar or the Cow Power offering from Green Mountain Power. In addition to utilities that have created targeted offerings for this segment, community solar programs across the world are addressed by a host of new entrants such as Sunseap Group in Singapore. Due to the smaller capacity of community solar programs, impacts on commodity and asset processes are not as high as those of utility-scale projects. Impacts on revenue and customer processes are more significant, given the need to allocate bill credits proportionally based on ownership shares.

- **Commercial and industrial sectors** either produce or procure a portion of all of their on-site power requirements via renewables and sell the excess to the national or local grids. With generation of on-site renewables, the impacts on commodity and assets range from medium to high. Feeder penetration ranges from 20% to 30% and higher as reverse power flows from periodic localized overproduction move up from distribution feeders to the substation level. The impacts on revenue and customer aspects are high due to the increasing regulatory and investor pressures, combined with customer preferences, to deploy renewables in order to reduce greenhouse gas emissions and offer viable pricing structures. In the case of procuring renewables through a leasing model, stakeholders often enter into long-term PPAs that guarantee a rate of return to the lessor. The lessor may then aggregate generation and enter into a PPA with a load-serving entity. Outright owners have two choices. They can sell back power they don’t use via a net metering arrangement that enables surplus generation to be carried by the owner as a credit. Or they can sell all power generated to their local load-serving entity at a premium rate, typically called a “feed-in” tariff. In addition, by participating in renewable programs, owners earn green certificates or renewable energy certificates (RECs), which can be used to offset carbon footprint and contribute to net zero commitment.
Residential renewable projects are those initiated and deployed by residential consumers interested in meeting their own “green power” needs. These are installed on consumer premises and range from 5 to 20 kw. The growth of renewable energy at the grid edge is a consequence of exponential innovation and significant price performance improvement in consumer energy technology (rooftop solar and batteries), which has achieved grid parity even without subsidies.

The residential renewable sector has attracted new entrants. These range from service companies like SunPower that are focused on residential solar installation to advanced models of leasing and operating as PPAs to gridless utilities such as Tesla (formerly Solar City). Utility companies, in particular DNOs and LDCs, are participating in this segment via unregulated subsidiaries that get into residential solar installation, maintenance and operation (such as Iberdrola). From an impact standpoint, although the individual installations are small, aggregated prosumer impact is significant. As an example, in South Australia, more than 30% of customers export excess production to the grid, affecting all business process life cycles of the local utilities, in particular commodity and revenue life cycle. Owners can usually sell back power they don't use via a net metering arrangement that enables surplus generation to be carried by the owner as a credit. Or they can sell all power generated to their local load-serving entity at a premium rate, typically a feed-in tariff. The more advanced market models allow prosumers to trade energy directly to interested parties via peer-to-peer platforms.

Recommendations

Utility CIOs must:

- Work with LOB leaders to gauge the impact of renewable power growth on IT and OT applications using Gartner’s matrix of renewable power impacts by utility life cycle process.
- Use Gartner’s RE impact matrix to assess the effort and high-level budgetary requirements to modernize existing capabilities and acquire new capabilities.

The Intermittent and Variable Nature of Renewables Increasingly Stresses Existing Commodity Management Processes

Increasing deployment of renewables, coupled with newer digital technologies, has transformed utility commodity management needs. Renewables are decentralized sources of electricity generation. They create benefits around grid resilience, but also present challenges in transmission and siting, compared to coal and nuclear, which are centralized sources. Energy markets must evolve to keep pace, and move from a traditional bulk participants-only market structure to a devolved model by introducing new generation and transaction products even at consumer levels. As part of the utility commodity portfolio management process, utilities procure commodities, fuels and natural gas under traditional or restructured market structures. Forecasting is a pivotal element of renewable energy generation, given the variable and intermittent nature of these sources. There are a multitude of software solutions — such as weather data input — that provide the capabilities required for accurate forecasting of renewables.
and enable more accurate forecasts. Utilities will have to invest in robust weather data solutions for observational data—meteoro-logical (weather) data, critical for forecasting of renewables.

Utility resource planning departments assess generation portfolios, typically on an annual cycle. Integrated resource planning assesses both supply-side (conventional and renewables) and demand-side (energy efficiency) resources. Resources are assessed in terms of their potential contribution, dispatchability, reliability of results, term of benefit and persistence over time. Resource planners are charged with optimizing the resource mix against financial and operational constraints. Dispatchable resources (that is, resources that grid operators can control to manage fluctuations in supply requirements) that have greater persistence and firmness (such as coal-fired, nuclear or hydropower plants) can be reasonably relied on as a base resource for planning purposes. Supplies with less persistence and firmness, but that are dispatchable (such as natural gas peaker plants) are more suited to reliability purposes. For example, they are used to avoid outages or high resource costs as a result of weather conditions, plant outages, market price swings or unanticipated system failures. Also, as the share of renewables increases in the utilities’ resource mix, the long-run marginal cost (LRMC) of renewables will outperform traditional source planners, and utilities will have to modify their conventional planning methods, too.

While renewables are favorable from an emissions and cleaner energy standpoint, power output from renewable sources depends on variable natural resources, which makes these plants more difficult to control and presents challenges for traditional utility business models. Renewable energy sources such as solar and wind require flexible energy systems and more responsive markets that will require new investments in smart digital capabilities. The consequent loss of dispatchability of energy sources will also require more flexible enterprise-wide solutions. It will likely stimulate cross-border, regional trade in electricity — not only changing conventional energy system planning and business boundaries, but also potentially realigning social and geopolitical interests across regions and subcontinents. Additionally, managing flexibility requires sophisticated capacity management for planning, scheduling and dispatching renewables.

Technology options to reduce the impact of intermittency include rapid response generation (typically, gas), decentralized generation, storage, AC and DC interconnectors, disconnection and DERs, including generation, storage, demand response and energy efficiency. While some resources are utility-owned, the majority of DERs will be customer-owned at the edge of the grid. Flexibility requires the balancing of sources, which need to be identified, prequalified and contracted so that a market can function on a real-time basis using the flexibility resource register. Resources might need to be aggregated by a third party into biddable blocks that can be matched, scheduled, dispatched, verified and settled in a multiparty market.

When large volumes of renewables are injected into the grid, complexities around variability, uncertainty and intermittency do not just impact the grid. They also affect the trading and risk management dynamics of the utility business models. Renewables impact spot prices, trading patterns and also the dispatch of conventional energy sources. The lack of technology maturity and the inadequate flexibility-related capabilities of trading platforms for utilities need to expand extensively to meet the evolving
flexibility requirements to trade, balance and manage renewables. Utilities will have to upgrade and enhance the capabilities of their energy trading and risk management (ETRM) platforms to bridge the gap in order to accommodate automated and algorithmic trading functionalities required to support trading in short-duration intervals.

Additionally, the growth in regional and local trading markets has created complexities for utilities around resource management, trading, flexibility and balancing. Traditional utility systems are designed to support large-scale centralized generation to consumers rather than a decentralized generation system to integrate the growing numbers of prosumers. Additionally, prosumers need to be managed by DSOs. DSOs need to coordinate and manage their loads in parallel with the TSO's activities. Local energy markets created via peer-to-peer trading create both operational and market challenges for utilities. Local energy markets are subject to transmission constraints and will need to interoperate across market boundaries. Utilities will have to enhance congestion management and balancing techniques in order to ensure reliability of power. The existing trading platforms are conformed to support trading of power generated via coal, which could be easily scheduled and dispatched in forward markets, but now need to support bilateral contracts, auctions and trading in short-interval durations.

Renewables also come with contractual obligations between the owner and the grid, embodied by PPAs. PPAs define a wide variety of financial and operational obligations on both parties, creating significant compliance and execution challenges. PPAs are also a financial instrument with valuation, analysis and risk management consequences. These concerns could be solved either by enhancing the PPA management capabilities of existing ETRM systems, or by investment in stand-alone PPA management solutions.

Grid operations have always focused on system stability, but renewables have changed the boundary of the problem and introduced low-inertia resources to the generation mix. Grid operations require access to fast response resources through an evolving flexibility market. Fast response resources in the flexibility pool need to be identified, and incentives located, contracted, instrumented and dispatched. This requires a new market operating within short time frames and low latency in response to evolving operational practices.

Recommendations

- Collaborate closely with business leaders to quantify the business value of forecasting with critical utility operations.
- Explore and identify advanced forecasting and weather data solutions that will use advanced AI and analytics in order to enhance forecasting capabilities.
- Devise a detailed plan for developing and enhancing flexibility platform capabilities that address lack of adequate ancillary services and spinning reserves in order to address growing market volatility.
- Support LOB leadership in developing a long-term strategy for enhancing capabilities in trading platforms in order to accommodate trading of power generated by renewables and support trading in
Renewables Will Drive Grid Modernization Requiring New Business Capabilities and New IT and OT Software

As the adoption of intermittent renewable resources rises, grids start to exhibit changes in their behavior. Intermittency can trigger changes to energy flow and load swings, causing network switching and changing fault levels. Intermittency triggers transient and sustained drifts in key operational power quality metrics such as frequency and voltage. This, in turn, will drive demand for additional investment in infrastructure and operational controls such as assets with rapid switching capabilities, with a consequential impact on grid costs.

Intermittent renewable resources create significant challenges for business users across the delivery domain, impacting assets and operations across planning, engineering, and operating transmission and distribution networks. As RE penetration rises in response to decarbonization pressures, planning groups must revise their steady-state and dynamic stability assessments and pivot the grid to support new generation resources at new locations. In extreme cases, this could trigger a fundamental reconfiguration of the grid to support the new dominant energy flows.

Wind and solar resources have light inertia characteristics, reducing the ability of the grid to ride through disturbances that were previously dampened by large mechanical flywheels (fossil-fueled generators). New asset classes and devices with embedded software will be needed to support new energy services in real time. An example is energy storage with fast response curves that are needed to support operations. Rapid AI models processing validated data will be needed in the operational environment in production to support and eventually manage the grid in real time, as the decision time frames are not achievable by a human operator. This will have a significant impact for system operators and their control strategies (see How Utility CIOs Can Use Intelligent Operations to Achieve Resilience During the Energy Transition).

A similar conversation applies to distribution grids where customer- and utility-scale renewable resources introduce power quality challenges, such as voltage perturbations and frequency harmonics. DERs will require a pivot from a passive unidirectional grid to an active, dynamic, bidirectional, reconfigurable grid. Active control will be achieved by intelligent operations, supported by model-based engineering across the asset life cycle. DERs will require a revision of system design approaches across standards, controls and operations. Real-time analytic models will need to span customers, assets and control layers to be able to model real-time topology, dynamic fault levels, reconfiguration and backfeeds. Operations will pivot to include control and dispatch of loads and prosumer devices. The IEEE 2030.5-2018 — IEEE Standard for Smart Energy Profile Application Protocol introduces a range of functional controls based on a DER “passport.” This will allow the utility to interrogate a device, understand both its performance characteristics and its owner’s opt-in choices before issuing a control signal to a compliant device. Simulation-based mathematical models have been used for years by engineers across generation, transmission and distribution. But these individual single-purpose models need to morph into digital twins of the network. The digital twin has to be valid across a range of operational scenarios and
be applicable across the asset life cycle. Digital twins need to become reusable and configurable, supporting real-time simulation, before executing operational decisions.

Within the operations arena, worker safety, equipment tagging and equipment relay protection must all be revisited in light of increased safety risks from two-way power flows. Operating procedures must be revised to accommodate a more dynamic field environment. Substation technicians and line workers must be trained to work with equipment that injects power flow to distribution networks. Feeders will need to be upgraded to resectionalize networks to isolate faults during outages. Protection relays will need to become adaptive to accommodate shifting topology and fault levels. Communication technicians will deal with new communication equipment that extends beyond the utility-owned network to include customer-owned devices.

As the device and sensor footprint explodes, operational systems will need to move from legacy monolithic systems to modular focused systems to improve resilience and manage processing volumes. Supervisory control and data acquisition (SCADA) systems will need to accommodate a significant increase in phasor measurements. Operators must be trained in new advanced distribution management system (ADMS) software capabilities (see Market Guide for Advanced Distribution Management Systems).

Distributed energy management systems (DERMS) will extend direct-load control systems to generic load, generator and storage capabilities (see Market Guide for Distributed Energy Resource Management Systems). New role players such as aggregators, virtual power stations and electricity markets will need to be integrated into the operations platform. Outage planning and scheduling will be supported by switching to execute asset maintenance that could include customer-owned devices, meaning that work management and execution will become a lot more complex.

A common complaint within utility operations is that planning engineers deliver infrastructure improvements that meet engineering criteria, and project management decisions during the build phase can invalidate the original design, creating significant operational impacts. This challenge will only grow with the inherent complexity and intermittency of renewables. Gartner has noted an increase in client initiatives aimed at better integration of engineering and operations data — developing a "single source of truth" to mitigate the risk of unintended operational impacts. This is especially true with the introduction of ADMS applications; higher-quality data is required for more sophisticated applications. Discrepancies in equipment data and modeling conventions among field design applications, GIS, and feeder analysis applications can be difficult to unravel and will require strong coordination between the engineering and OT organizations, supported by a common information model.

Regulatory organizations have flipped through various incentives and tariff decisions including, feed-in, net metering, across to real-time wholesale tariffs, which have created long queues of interconnection applicants and backlogs of engineering studies. As software-defined assets proliferate across the grid, OT systems will need to evolve to include services such as discovery, authentication, patching, and even automatic model generation. This will drive efforts to align and integrate OT and IT across issues such as security, disaster recovery and standards.
Geographical information systems (GISs) are increasingly critical for all types of renewables because of the multiplicity of factors involved in siting and operations. Utilities can leverage spatial models to assess the most favorable locations for setting up wind- and solar-based plants based on multiple factors. These factors include irradiation, transmission cost, road access, load center location, and environmental factors (for example, avian impacts or protected species).

**Recommendations**

CIOs of energy companies owning and operating grid assets must:

- Influence and guide LOB leadership to expand engineering and operations capabilities to include model-based engineering across the asset life cycle.
- Upgrade engineering and operations systems to support use cases triggered by the rising penetration of renewables.
- Work with LOB sponsors of enterprise asset management to review potential impacts of new equipment types and safety and maintenance procedures.
- With LOB leadership, consolidate engineering data into more accessible data repositories with measurable and consistent data quality and modeling conventions that will support digital twins.

**Integration of Consumer Energy Resources Requires New Revenue Models and Customer Engagement Platforms**

Exponential innovation on the grid edge and consequent growth in deployment of consumer-owned renewable sources are disrupting the utility sector and forcing utilities to explore different business and revenue models. Traditional utility business models, in the majority of developed markets, include a regulated utility with an obligation to serve, operating under a guaranteed rate of return or a competitive energy retail. However, some utilities are now exploring different customer value propositions and revenue models to address challenges, as well as opportunities, created by prosumerization. One example is the new value proposition for affluent consumers/prosumers that are fleeing the grid, enabled by grid parity advancement in many developed markets. In that example, utilities can monetize use of the grid by charging customers for utilizing the network as a peer-to-peer exchange infrastructure. Alternatively, utilities can leverage prosumer-owned renewable resources to address commodity fluctuation, reduce their exposure to wholesale market volatility and defer investment in the new infrastructure capacity. That can be achieved via different digital business models such as VPP platforms, flexibility platforms or O2O peer-to-peer platforms (see *Industry Vision: Utilities as Platform Providers for the Energy-Sharing Economy*). In each of those cases, a utility will have to enhance capabilities in the metering, billing and consumer engagement areas.

In an effort to encourage customer adoption of renewable energy, policymakers around the world have structured various financial incentives that grant favorable treatment for renewable energy investments and energy production. These policies are subject to ongoing changes as renewable power advocates
continue to lobby for favorable treatment, resulting in new legislation and changing policymaker rulings. Many of these incentive structures have a direct impact on utility revenue streams, as well as impacts on revenue and customer life cycle processes. Specifically, net energy metering, the predominant model in the U.S., and feed-in tariffs, which are popular in the EU — in particular Germany — drive new requirements that span metrology, utility product design, pricing, billing and CRM. In addition, in some jurisdictions, customers may receive renewable power credits that utilities can purchase to receive credit toward renewable portfolio standards — a form of indirect subsidy to renewable power owners. A REC trading platform is another new requirement created as a result of prosumerization.

From the metering standpoint, the common denominator for business and revenue models that are either triggered by or align to needs of prosumers is more sophisticated metering technology. Smaller intervals and lower latency are required to support new revenue models that span from fixed connection charges for consumer-owned renewables via net metering, feed-in-tariff to metering that supports just-in-time billing and settlement. These new metering requirements are challenging technology offerings from legacy revenue metering vendors, forcing utilities to deploy new metering solutions based on IoT components, cloud and data lakes.

As customer participation in renewable energy increases, it also creates challenges in administrative tracking of the interconnection process. Though in most cases, prosumers are required to register and ask permission for connecting their sources on the grid, in some cases, utilities need to deploy advanced algorithms to identify customers with self-generation capabilities. To streamline the interconnection process, IT leaders need to establish requirements and IT solutions for tracking the status of customer applications, interconnection workflow and documentation. Engaging prosumers for participation in programs such as demand response or VPP or to be able to model their contribution into distributed network operation requires extension of the exciting CRM and customer experience platforms.

Feed-in tariffs create challenges with the overall meter-to-cash cycle, including gathering data (billing determinants) and calculating bills for specific rate structures. Feed-in tariffs typically require a separate meter attached between the inverter and the utility. Most U.S. states now require utilities to issue and track bill credits for excess power production for customers in net metering plans. Rules vary from state to state as to the rate for compensating excess production and the eventual disposition of the credits. But the impact on billing systems is significant, since many were not designed to issue and track credit balances from excess power production.

Deployment of new revenue opportunities such as IoE O2O platform also requires the addition of completely new billing and settlement processes — customer information systems (CISs) — that cannot be addressed with legacy utility billing systems. Instead, those new billing models are addressed in the system of innovation layer as a packaged business capability (PCB) that can be composed to achieve a specific business outcome and support different revenue models.

Recommendations

Utility CIOs should:
- Rearrange revenue management portfolios by using composable architecture to handle varying rate structures for different types of renewable products and services.

- Push their CIS and CRM system vendors to share their roadmaps for addressing new billing and business relationships for customer-owned renewable power.

- Implement new capabilities within customer engagement to document the interconnection process and develop technical capabilities to address increased interconnection requests.

**Evidence**

1. Siemens Gamesa

2. Dogger Bank Wind Farm

3. Noor Ouarzazate Solar Complex


5. Solar Partner Program, Arizona Public Service

6. Cow Power, Green Mountain Power

7. Sunseap Group

8. Impact of Rooftop Photovoltaics on the Distribution System, Hindawi

9. SunPower

10. Tesla

11. Iberdrola


**Recommended by the Authors**

- Top 10 Trends Driving the Utility Industry in 2021
- Predicts 2021: Get Ready for the Energy Transition
- Industry Vision: Utilities as Platform Providers for the Energy-Sharing Economy
- Market Guide for Advanced Distribution Management Systems