The Future of the Grid

Evolving to Meet America's Needs

Central Region Workshop Summary

February 4, 2014

Dallas, Texas

GRIDWISE ALLIANCE

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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Introduction

The U.S. electricity system is undergoing a major transformation that will continue for the next 25–30 years. The rapid evolution of electricity supply and end use will have major implications for reliability, transmission and distribution, customer engagement, security, and integration.

Regardless of the ultimate generation mix or the policies in place, the electric grid will play a critical role in future electricity infrastructure. In fact, it is an essential, enabling platform that supports America's economic activity, similar to the cellular network, which enabled the world of smartphones and mobile applications.

Thoughtful debate and planning are needed today in order to address tomorrow's challenges and seize on tomorrow's opportunities. With this in mind, the GridWise Alliance (GWA) and the U.S. Department of Energy's (DOE's) Office of Electricity Delivery and Energy Reliability (OE) are hosting a series of workshops across the country (four regional workshops followed by an executive summit) to develop an industry-driven vision of the nation's future electricity grid. During the regional workshops, thought leaders from all stakeholder groups (utilities, regulators, state government officials, renewable energy providers, suppliers, and industry innovators) are coming together to define the needed capabilities, the changing role of grid operators, the new technologies and financial models required to drive investment, and the policy and regulatory barriers to realizing the vision.

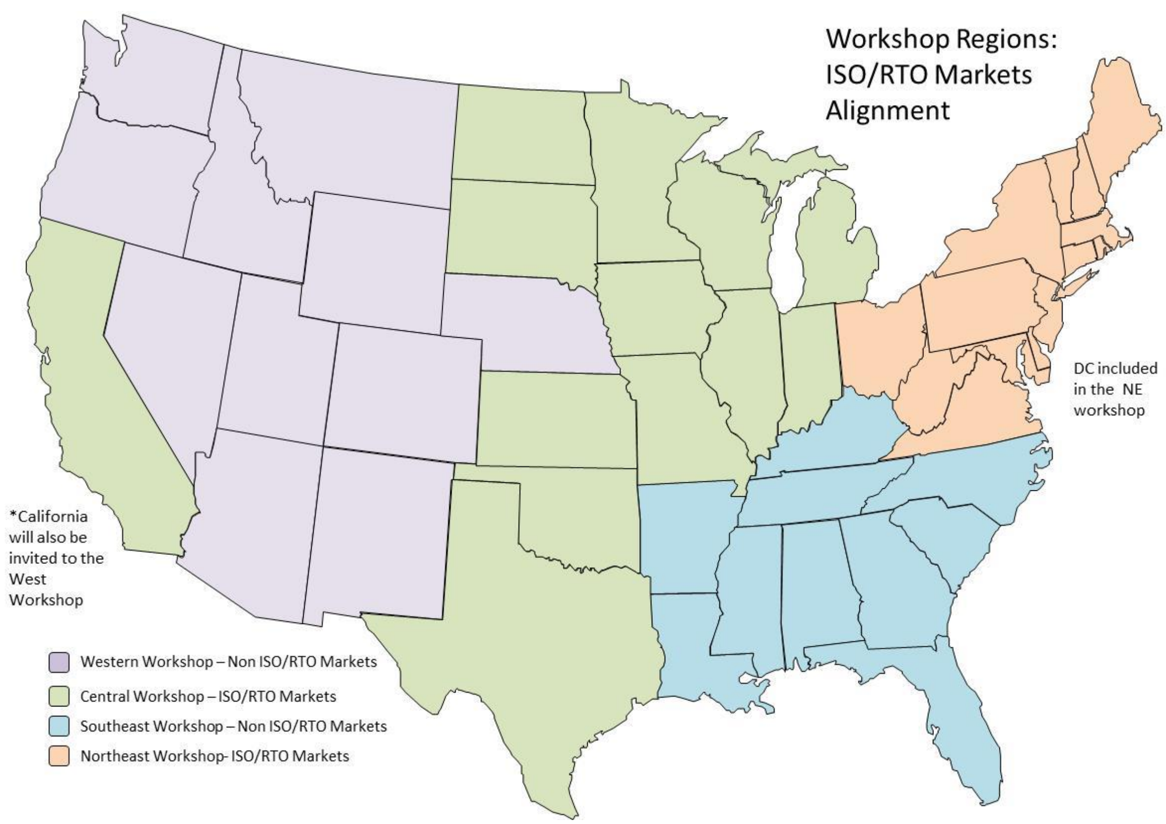

Figure 1. Workshop region designations

The region designations for the regional workshops are identified in Figure 1 and align along Independent System Operator (ISO)/Regional Transmission Organization (RTO) markets. California, due to its unique characteristics, was included in both the Western and Central Region workshops.[1]

Following the regional workshops, an Executive Summit will take place in Washington, DC, to review, synthesize, and validate the findings and themes that emerge from the regional discussions. The results from this effort will inform larger DOE efforts to help guide research and development (R&D) agendas and serve to educate all stakeholders—including state and federal policy makers and regulators—on the issues that must be addressed to ensure that the future grid is affordable, reliable, and resilient to support economic prosperity and energy security.

[1] California is geographically aligned with the Western Region and shares many renewable energy and environmental drivers common to other Western Region states. California is also aligned with the Central Region in terms of its use of an ISO to regulate its wholesale market and the nature of the utility-customer relationship.

Workshop Approach

The structure of each of the four regional workshops is the same. The day begins with a visioning exercise in which participants are asked to forget the current legacy system and think about the type of system they would design today if starting anew. Participants are then split into breakout groups, each of which is given a different scenario to discuss considering a future state of the grid in 2030. The breakout groups then participate in facilitated discussions to answer questions about grid capabilities, grid operations, business models and investments, and regulatory and policy barriers and opportunities in the context of their assigned scenario, while keeping in mind the vision for the future grid. The workshops feature open and frank discussions by employing Chatham House Rules, which permit participants to speak freely without the fear of attribution. The complete workshop agenda for the Central Region workshop can be found in Appendix B.

Although the scenarios are anchored in key factors affecting the grid, they do not represent an exhaustive examination of what is possible in 2030. Instead, they highlight the most likely scenarios and key areas that are plausible and facing industry today. The scenarios serve to guide the discussion of "2030 grid operations" from important and somewhat different perspectives. Participants are asked not to debate whether the scenario will occur, but to consider what new technologies, capabilities, or policies would be needed or what limitations might exist to transform today's system into the future vision.

The same five scenarios are discussed at each workshop:

- Balancing Supply and Demand as Grid Complexity Grows
- Involving Customers and Their Loads in Grid Operations
- Higher Local Reliability through Multi-Customer Microgrids
- Transitioning Central Generation to Clean Energy Sources—Large Wind, Large Solar, and Large Gas
- Planning for Empowered Customers

Regional differences will likely emerge from the different workshops as these scenarios are discussed throughout the country. These differences are included in each region's stakeholder-driven vision and will be captured as part of the broader national-level vision.

The Central Region workshop—the second in this series—took place in Dallas, Texas, on February 4, 2014. Forty-eight participants attended the workshop; Figure 2 shows the breakdown by stakeholder group. The complete list of attendees is provided in Appendix C.

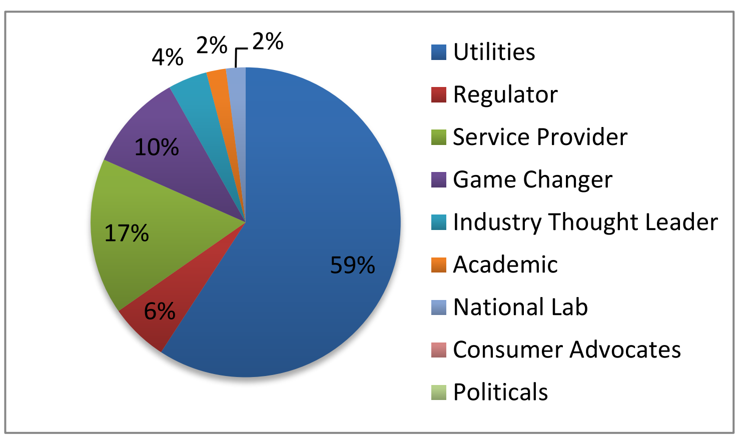

Figure 2. Breakdown of Central Region workshop participants

Participants were given an extensive set of pre-read materials before the workshop describing the scenarios and highlighting factors to consider. These materials set the stage for the workshop and provided context for the discussions. Appendix A contains a summary of the key factors participants were asked to consider.

Key Findings

Participants at the Central Region workshop noted the value of bringing together a diverse set of stakeholders in an environment that allowed for frank, open discussions. Participants appreciated the opportunity to gather with peers to talk about these important topics. Throughout the discussions, several key themes emerged:

<u>Operations</u>

- **The grid will be more complex.** While inwardly complex, its interface must be outwardly simple for customers. **It will be more plug and play**, with outwardly projected standards that are functionally based and device agnostic.
- **There will be a transactive energy component** in which customers receive and respond to price signals. Some customers will want a mechanism in place to allow them to make pricing decisions. However, accommodations must be made to meet the needs of all customers—from very interested buyers to customers who do not want to worry about tracking their electricity usage and want "set-it and forget-it" devices and electricity options.
- **The ISO, transmission, and distribution will be more closely integrated.** More coordination and interaction will be needed. **The lines between transmission and distribution will blur**, and there will no longer be a separation between the two. Overall, an integrated view and perspective on operations system-wide (transmission and distribution) will be needed. **Security will be needed across the entire system.** Security will be needed for all levels of communication to ensure reliable, secure information exchange.
- **The future distribution grid will more closely resemble today's transmission grid.** Due to cognitive computing and near-real-time **communications with devices on the system, operating the distribution grid will be more predictive, rather than reactive**, and thereby more like the current transmission system. Visibility will be needed to the edge of the grid—down to the end device.
- **A higher-bandwidth, lower-latency, and cost-effective communication system will overlay the grid.** The communication system will have to process more data and will involve getting information on a real-time basis, allowing energy providers to act on it in near real time. More standardization and consistency of communications across the entire network will be needed so that information can be transferred from the source to the distribution system, transmission system, and/or ISO.
- **Customers will have the option to be more involved as distributed generation is added**, whether they hire someone or do the work themselves. To maintain grid stability, a mechanism must be in place to control the interface with the grid as well as provide signals to end devices to produce the results desired by customers or other entities participating in the grid.
- **The grid will be operated with real-time knowledge of operational capacity.** Real-time monitoring capabilities of distribution systems will be needed; these capabilities will allow for more efficient dispatch for the transmission and ISO systems.
- **Wide-area (regional) grid operation and coordination will allow for more integration of renewable resources.**
- **There will be both physical and virtual microgrids**, and private microgrids could be nested within a utility microgrid. Microgrids could be managed and operated by private companies on behalf of others, or they could be a service provided by a utility. Virtual microgrids are an aggregation of loads and are analogous to cloud computing.

Business Models and Pricing

- **New business models will be needed to accommodate the buying or selling of power by anyone anywhere on the grid.** Rates must be flexible and the regulatory model must change to allow for this flexibility. The value to the customer must align with the cost to the customer.
- **The grid model will be market-based instead of asset-based.** Revenue should be based on what is sold, not on assets. The grid of the future will be a service-based model, not a commodity- and infrastructure-based model.
- **The grid will shift toward a performance-based model where pricing transparency will be required.** Pricing for services needs to be a part of the new rate structures/pricing models. There will be a move from a volumetric/commodity model to one based on value-added services. With value-based pricing, the positive or negative pricing level must be transparent at the customer level. Without price transparency, customers would be making investments without complete knowledge.
- **Wholesale and retail markets will be seamlessly integrated.** Price control will be driven by transactive price. Both transmission and distribution will be involved in sending these signals. A local pricing system will be possible. Price mechanisms will be clear.
- **Utilities will be able to offer a portfolio of selectable services, including ancillary services, reliability, microgrids, and others options.** Customers will have a choice of the level of reliability they want—utilities will need to be able to offer options. Customers will need to pay for these additional services. Utilities should be able to provide behind-the-meter services.

Policy

- **Regulatory clarity is needed to help utilities plan and transform.** Current rate cases are cumbersome and take too long to gain approval; they do not allow utilities to be nimble and react to changing market conditions or customer expectations. Utilities and other players need certainty regarding the rules around cost recovery in order to make investments in grid modernization that need to be made today. In addition, incentives are needed to encourage the right types of investments, such as investment in innovation and efficiency.
- **As new players enter the market, there will be a need for infrastructure and technology accountability.** If a new party provides services to customers and then leaves the market, there will be questions about how services to those customers are handled and who is accountable for providing those services. If the utility picks up the services, there will also be questions about how it will be compensated.
- **A roadmap needs to be developed that integrates policy pathways conducive to new business model formation.** The roadmap needs to provide enough detail to be useful; therefore, it should be completed at the regional, state, or company level. The roadmap will provide clarity on the path forward and help facilitate an orderly transition to the future grid. The roadmap should be stakeholder-driven but developed through frank, open discussions with all stakeholders to make sure all perspectives are taken into account. It will need to be facilitated by a trustworthy, unbiased entity.

Summary of Messages to Policy Makers

During the breakout sessions, participants identified the most important messages for policy makers to consider when developing future policies:

- **The value to the customer must accompany the cost.** The value of the service must be in concert with the cost in the future world.
  - **Transparent, unbundled rates are needed to support value discovery.** Commodity charges should not be bundled with delivery infrastructure and services charges—pricing for various services should be separate and understandable to customers.
  - **Optionality will not be free.** Any services above basic electric service will have a cost, allowing for a more customer-focused model.
  - **Safeguards should be built into services.** Regulators and generators should be open-minded to all forms of solutions instead of compartmentalizing them by technology type, etc.
- **Investment risks and benefits need to be aligned.** The risk of investments and the benefits realized from those investments need to be better aligned. Achieving this alignment would help define a better path toward investments. However, alignment can be difficult. For example, some of the benefits that result from investments made to the distribution system to modernize the grid do not go to the distribution system owner but to other players, such as the transmission grid operator or even the customer by improving system efficiencies.
- **Utilities should be allowed—but not required—to operate in a competitive market.** Utilities—or anyone who is able to provide unregulated services—should have the option to do so, but they should not be mandated to do this. Considerations will have to be made for how to prevent handicapping regulated entities versus their unregulated competitors and vice versa. Allowing the utilities to use their name and reputation to provide services in the unregulated market could have significant benefits. Benefits may include increasing innovation and enabling a faster transition to a new market structure while keeping the utility financially viable. Considerations will also need to be made regarding how regulators can facilitate the transition for customers who want to leave the grid, rather than hinder those customers. Policies should consider the need for wires infrastructure investment.
- **From a public utility commission perspective, the utility profit model needs to change so that it is based on efficiencies and efficient operations, not investment.**
- **Co-ops must be creative with rate policies. More distributed generation is coming; the co-ops need to think about the future and be flexible.** There must be creativity in rate making and in determining who gets rewarded and who does not.
- **Politics must be set aside.**
- **Managing the grid is becoming more complex.** Multidirectional communication, aggregation of loads, third-party service providers, and complex and overlapping stakeholder groups are just some of the factors that will come into play.
- **The future grid will require investment.** Utilities need assurances that these investments will be recoverable.
- **There is a manpower shortage, insufficient knowledge, and a lack of resources among policy makers.** State regulators are responsible for a number of areas but are often short-staffed. State legislatures have added new requirements for utilities—such as increasing the deployment of solar, increasing energy efficiency measures, etc.—that can add complexity to the system and will require regulatory bodies to become more specialized so that they can understand and effectively oversee the new complexity. Currently, electricity is just part of many public utility

commissions' work, and their staffs often cover multiple areas. Policy makers, both state and federal, must be more informed about technology and aware of the relevant costs, consequences, and benefits to the consumer and to the grid. They must seek input from all impacted stakeholders and welcome innovation from outside parties. As grid complexity increases, an agency (or similar entity) dedicated to electricity and its operational nuances will be needed.

- **The federal/state jurisdictional quagmire is costly.** There are many cross-jurisdictional issues that create barriers for utilities and non-utilities, and there are many entities to deal with. These issues need clarity. Questions often arise about which group has responsibility for which part.
    - **More coordination across jurisdictions (city, states, etc.) is needed.** Multiple layers of regulation (e.g., federal, state, local, air pollution control districts, and more) exist, and there is little consistency between these layers. Requirements vary from city to city, which makes doing business difficult and increases overall cost.
- **Utilities should be given the authority to create their own service models as well as perform their own "prototyping."** Utilities will need the authority—although not be required—to come up with new service offerings as they start to see competition in certain areas (e.g., microgrids). Utilities will need to be able to do more prototyping and issue requests for proposals for innovative pilots or the development of new technologies. Utilities are generally risk-averse, but innovation requires risk. Utilities should not be penalized for failures when piloting these innovations.
- **Decisions must be made regarding appropriate levels of reliability.** If reliability is offered at multiple levels for the future grid, it will be important to consider which levels are adequate. New metrics will be needed to ensure accountability.
- **Clarity will be needed regarding who is responsible for customers' choices.** If a customer contracts a third party but that company's system fails or a manufacturer's system has issues and the customer is without electricity, it is unclear who would be held accountable. If the utility must rectify the issue, it is unclear how it would be compensated.
- **Regulatory certainty will increasingly become a key point.** Transparency regarding requirements and who can participate in markets will be needed. Regulations are often short term and reactionary, which creates many unintended consequences, such as forgetting to open opportunities (such as distributed generation) to utilities.
- **Policy makers should focus on the desired outcome, rather than the specific technology.** Technology needs to serve the desired outcome (e.g., diversification of supply, emissions reduction), rather than policy dictating a specific technology.

Summary of Recommended Actions

During the breakout sessions, participants recommended actions that should be taken as well as issues that must be considered in order to facilitate the evolution of a cost-effective, reliable, and resilient grid of the future.

Overarching

- **Education of stakeholders will be critical.** Education of policy makers, regulators, businesses, shareholders, and customers will be needed throughout the transition to increase the understanding of all parties. Industry will need to proactively provide information to policy makers to help them remain informed. Customers will have more choice as the grid becomes more complex, and utilities will need to explain complex concepts such as average interruption index to customers in a simple, easy-to-understand manner. In addition, getting customers to change their behavior will be a big challenge and education will be a key component in facilitating this shift. Stakeholder education might be extensive and continuing.
- **A "roadmap" must be developed.** A stakeholder-driven roadmap is needed. It should be facilitated by a trustworthy, unbiased entity and should involve all stakeholder perspectives. In order to be useful, the roadmap needs to provide details and be completed at a more local (i.e., regional, state, or company) level.

Operations

- **ISO, transmission, and distribution operations will be more closely integrated.** More coordination and interaction will be required. **The lines between transmission and distribution will blur**, and there will no longer be a separation between the two. Overall, an integrated view and perspective on operations system-wide (transmission and distribution) will be needed.
- **Information technology (IT) and communication investment will be a very important part of the grid of the future.** Methods will have to be developed to deliver, aggregate, understand, and return information to customers. Grid operators will have to incorporate the tools and technology needed for the younger generation of consumers, which will have different expectations.
- **Technology systems must be able to accommodate an increasingly complex grid,** including data management and two-way communication.
- **Workforce education will be necessary.** Operators will need further education due to the increasingly high level of sophistication at the distribution level, which will require a different set of core competencies. The workforce is also in transition, with a significant portion expected to retire in the next 5–10 years.

Business Models and Pricing

- **The price transparency that currently exists in the wholesale markets will be needed at the customer level in the retail markets.** Customers must know what they are buying and why.
- **Utilities of the future must be allowed to accommodate sustainable services with various energy commodities.** There will be greater integration of gas, electric, thermal, and water energy, as appropriate, to support sustainable cities (in a holistic utility-city environment).
- **A pricing methodology that is acceptable to the customer; encourages the needed infrastructure investment; and supports investments in distributed energy resources by customers, third parties, and utilities will be needed.**
- **The utility revenue model must be changed to incentivize cities and customers to invest in innovation now.** Utilities as a group tend to delegate innovation to third parties. Utilities need to (and be approved to) invest in research for innovative products and services. Utilities must be

incentivized to invest properly—the investment thesis must be changed. There should be a shift to revenue streams based on system optimization. Different incentives will drive new asset planning approaches.

- **Smart grid implementation includes information, automation, and action.** A plan is needed to synchronize these three elements.
- **Common standards to support interoperability across all of the various entities in this complex ecosystem must be developed.**

Policy

- **Utility R&D will be needed for a horizontal market.** R&D has to be a component of the future grid. Funds have to be devoted to what is next: when moving from a situation where utilities are paid for their infrastructure/capital assets to one in which they are paid for an idea or service, money will need to be dedicated to R&D to develop the next idea or service. This represents a competitive perspective to the landscape rather than the traditional R&D landscape.

> **What are Horizontal Markets?**
>
> Horizontal markets encompass the grids and grid services. These markets are multifaceted and include operations, services, devices, and product offerings. Players in this market are grid utilities, energy service providers, and other third parties.

- **There must be a change in how utilities operate and how regulators regulate.** There must be changes in how investments are approved, how regulators interact with utilities, how rate cases are handled, and how utilities operate day to day. Decision making and approvals will need to be faster. Clarity will need to be provided regarding how investments will be evaluated and recovered.
- **Policies must be easy to implement, consistent, and supported through pricing of services.** Policies must allow for the integration of existing and emerging technologies, including state-of-the-art forecasting tools. They must also be smart; i.e., based on a collection of information. Pricing (for the service, not the asset) should support policy.

Opening Remarks

Tom Standish, Executive Vice President of Energy Resources for CenterPoint Energy, presented the opening remarks. Mr. Standish first reviewed a presentation he gave in 2003 predicting the future of the smart grid, while also assessing the accuracy of his 2003 predictions. He then reviewed and evaluated the obstacles to smart grid advancement that he predicted in 2003, noting which obstacles still exist today.

Mr. Standish also offered his current predictions for two time frames: the near term (next 10 years), and the long term (the subsequent 15 years). Looking ahead over the next 10 years, Mr. Standish predicts that the digitization of the grid will remain primarily utility-centric. He also predicts more smart meter deployment, incremental gains in distributed generation, fewer gains in efficiencies, and large investments in peaking generation and electric grid stabilization. One area where he has changed his perspective is how customers will engage. He predicts that there will be improvements in the customer experience, but also little customer interest and therefore minimal investment in home automation.

Over the subsequent 15 years, Mr. Standish predicts achievement of the "holy grail"—a low-cost, high-density storage method. He believes that this will lead to the elimination of new peaking generation, a reduction in baseload generation, and proliferation of distributed solar/wind units with rapid switching storage. He predicts that homes connected to the grid will be able to have a storage unit with a very fast switch, and that the homes will automatically decide, based on price, whether to use electricity from the grid or from the battery, without the customer even knowing. He also forecasts the decline of fossil fuel use in transportation and energy.

Mr. Standish predicts that these changes will lead to the rapid transformation of the grid into an energy network, and the fulfillment of the goal of a long-term supply of highly reliable, low-cost energy, perhaps by 2035. He believes that regulated utilities will be reduced to playing a transportation role – moving the power back and forth to optimize the grid. He predicts that automation will free customers from making decisions. He encourages the continuation of the movement toward automation, so that when the technology is ready, the components can be connected to create the new grid.

Vision: Capabilities and Functions of the Future Grid

Becky Harrison, CEO of GridWise Alliance, introduced the large group Visioning Exercise, asking participants to consider the capabilities and functions of the future grid starting with a "blank sheet of paper." This brief exercise was not intended to produce a consensus; instead, it provided participants with an opportunity to brainstorm in order to expand their thinking and envision the grid without the constraints imposed by the legacy infrastructure and business models. The exercise informed and stimulated conversation in the breakout group discussions that followed.

Elements of the Future Grid
Brainstorming Ideas from Workshop Participants

- The grid will be an energy and information highway, with both energy and information flowing bi-directionally.
- All pieces of the grid will interconnect. The grid will meet the delivery requirements established by the customer/marketplace. Users will define what it is and where it is.
- The grid will integrate 40%–50% from wind or other renewables that will be linked with intercontinental connections.
- Disturbances will be localized.
- The grid will be secure and resilient.
- Transport will be electrified—there will be a greatly reduced need for liquid fuels.
- Electricity will be integrated with other utility services. Critical infrastructure will be built together and protected underground (e.g., in ductwork or tunnels).
- Interoperable infrastructures.
- Grid operators will have supervisory control. Control will exist at multiple layers: low-level control at distribution substations, coordination control at the mid-level, and executive function (grid operator) at the top level.
- Grid operations will be fully automated and models will be correct. They will have the ability to see ahead (predict) and act, rather than reacting (as they do today). Uncertainty will decline, supported by seasonal forecasting and overall better probabilistic understanding.
- Grid operators will be compensated based on performance, not assets.
- Grid operators will utilize cognitive computing. The grid will monitor and self-heal; automatically switching, without human intervention.
- Grid operators will be IT-centric, rather than electrical engineers.
- The local or large utility grid operator will be more of a transactive manager of information and energy, similar to a stock exchange. Two exchanges will be needed: one for retail distribution with smaller local transactions, and one for the bulk transmission system.
- New entrant expectations:
    - Impartiality—it will not matter who owns the asset or who is making the connection.
    - Indifference to voltage—it will not matter if the asset is added to the transmission system or the distribution system.
    - Transparency and efficiency.
    - Defined by functionality rather than device type—it will not matter if an organization is a generator, provides storage, or provides a load.
    - Price mechanisms will be clear. There will be clear access to pricing, transparency in pricing, and open access across the grid.
- The grid's fundamental purpose—to provide reliable power to customers—will be unchanged.
- The regulatory system will guarantee ease of entry; there will be no barriers to entry.

- Customers will be able to define their desired level of reliability individually.
- Pricing for services will be unbundled. The grid operator will provide pricing for various types of services. Pricing will no longer be just a commodity price (per unit of electricity consumed).
- Electricity will be affordable for consumers.
- Retail and wholesale prices will be coupled.
- An information platform will provide accurate information to customers that they want/need.

Other Thoughts Presented by Participants

- The laws of physics are foundational. Electricity and markets must follow these laws.
- If designing the grid today, expectations might be different: would the system cover 100% of critical loads all the time, or 100% of all loads all the time?
- If starting fresh, it might be hard to get someone to put in a 30-year asset; many individuals might want to put in local generation.

Scenario 1: Balancing Supply and Demand as Grid Complexity Grows

Description of the Scenario

This scenario is characterized by:

- On the customer side: increased distributed generation and storage at the residential level as well as larger distribution-size renewables; for example, microgrids, community renewable projects, smarter home energy management systems, smart appliances, and electric vehicle (EV) charging.
- On the transmission side: increasing penetration of non-dispatchable generation sources ("large wind"), more utility-scale renewables, and utility-scale energy storage.
- Increased use of customer devices or generation to balance the system or provide ancillary services.
- Increased dependence on smaller generation versus large baseload generation or peaking plants to manage the system.

Together, these characteristics suggest a need for:

- Managing two-way power flows for the distribution grid, not only the transmission grid.
- Enhanced balancing capabilities to balance more complex supply and demand options. Greater dependence on "edge-of-the-grid devices."
- Greater interaction between the distribution and transmission grids and grid operators to optimize the balancing of supply and demand.
- Enhanced weather forecasting methods.

Path Forward: Articulating the Vision

The following summarizes the Scenario 1 breakout session discussions. This content was generated entirely by participants and reflects their vision for the end state of the future electricity grid under the Scenario 1 assumptions. The participants also recognized that there will be a transition period before the end state is reached.

<u>Description of the Group's Future Grid, Based on the Scenario</u>

- **Horizontal integration platform—transactive and communicative (plug and play).** The grid will be the enabling platform to which other devices "plug in." The interaction will be transactive in nature. All elements will have to communicate together to operate as a virtual single "machine." Connectivity will be equal in this single communications platform, representing a functionally based approach. A common language will be used. Industry has always talked about vertically integrated utilities; the grid of the future will be more plug and play. Participation in a horizontal field will be multifaceted. All entities that are connected to the grid will participate. Decisions need to be geared toward giving customers the ability to plug and play with outwardly projected standards and someone providing price signals, and the infrastructure will come.
- **Function-based—not limited by technology, device, or entity type.** Standards should be more functionally based and more device agnostic rather than current North American Electric Reliability Corporation (NERC)-based characteristics. There will be a shift toward energy

providers facilitating "energy on your own terms"—allowing customers to make their own decisions based on price signals. Some customers will want a mechanism in place to allow them to make pricing decisions. Accommodations must be made to meet the needs of all customers, from very interested buyers to customers who do not want to worry about tracking their electricity usage. This will represent a more functional model, as opposed to an asset model. Revenue will be based on what is sold, not on assets. Simplicity will be essential for this new model. The model will involve buying and selling services, not buying and selling a commodity. Outwardly projected standards will need to be imposed—function-based models.

- **Internally sophisticated, yet outwardly simple to use.** The grid must be simple for customers to use, but it will be complex behind the scenes—like a phone app. Out of sight of the customers, the grid will feature balancing at different voltage classes, information exchange, and rapid communication. A future system with increasing customer generation will increase complexity. For example, a customer's distributed generation might affect his neighbor. The current paradigm is limited to utility-initiated one-way controls (demand response). The future paradigm will require mechanisms for two-way communications in a new marketplace.

<u>New Capabilities and Functions</u>

- **Communications platform.** Rapid and complex communication between distribution and transmission, and among the whole value chain. The future paradigm will require mechanisms for two-way communications in a new marketplace.
- **Tighter predictive collaboration between transmission and distribution operation centers.** Communications will be more predictive, rather than reactive, so that the distribution system is operated more like the transmission system. Integrating transmission and distribution will be very complex because they are very different. The distribution side will transform from a responsive-based system to being more predictive-based, similar to the transmission side now. There will need to be more active information exchange between transmission and distribution.
- **Responsive controls in distribution operations.** More predictive metrics will be needed and shared by both transmission and distribution operators.
- **Proactive supply and demand balancing.** There will be distributed and coordinated supply and demand balancing. Balancing at the distribution level will be a natural overflow as it becomes more proactive. Consumers will have to be more involved, whether they hire someone or do the work themselves. To maintain grid stability, a mechanism will need to be in place to produce the behavior required by consumers or other entities participating in the grid. There will be issues with balancing supply and demand. From a distribution perspective, this will include issues related to reactive power flow and voltage control. There will be rapid changes in the direction and volume of power flow on the grid. The dependability of sources will be key to balancing supply and demand.
- **New grid ancillary services (e.g., frequency response and microgrid services).** There will be less central generation and more distributed generation. There will be a new set of services that are more defined and used across markets.

<u>Differences for the Operations Centers</u>

Transmission and Distribution:

- **Closer coordination of transmission and distribution operating centers.** The lines between transmission and distribution will blur, so that there will no longer be a logical separation between the two. There will be more transparency and the two sides will merge into one operating center—perhaps not physically, but in terms of connectivity. Distribution will become more like transmission; operations for both will be more similar, but there will still be different metrics. Relevant metrics will need to be defined. Their relationship will become a function of voltage and equipment rating realities created by market infrastructure. The mechanisms will allow everyone to participate. There will be rapid and complex communication/interaction between distribution and transmission, and throughout the whole value chain. The need for balancing at the distribution level will be much more complex. As complexity grows, more mechanisms will be needed to seamlessly integrate the transmission and distribution systems together. The group noted that questions remain regarding inventory of this equipment—where it is going to reside, who will get paid to keep it, and how it will be allocated.

- **Security extending to the end user.** Security currently stays at the bulk electric system apex. In the grid of the future, it will extend down to the device level. Standards will have to change to support cybersecurity at the operations centers. Next-generation operating centers will be required to have infrastructure to do cybersecure transactions that will be inherent to the communications function and will ripple into the operations center. Improved communication will allow data to be quarantined and security breaches to be addressed. The communications will be happening in real-time. All players participating in the system will need to take steps to ensure security.
- **Market clearing—facilitate end price for customers and enable their participation in the wholesale market.** The operations center could serve as a market clearinghouse to facilitate buying and selling. Both the physical elements and the buying/selling capacity will have to be optimized.
- **New clearance requirements in distribution—outage planning.** Currently, on the transmission side, clearances to perform maintenance and construction work that will limit system capacity must be scheduled in advance. If distribution grid operations approach this level of sophistication, clearances on the distribution side will have to be more structured. In the future, performing maintenance or construction on the distribution system may require the same type of advanced planning to minimize the impacts of planned outages as on the transmission system.
- **Responsive controls in distribution operations.** This will involve a look-ahead environment.
- **Proactive supply and demand balancing.** More predictive metrics will be needed. Current data can be used to do predictive analytics—this will be shared by both transmission and distribution operators.

Business Models and Investments

Financial/Business Model Changes:

- **Utilities will be able to offer a portfolio of selectable services and reliability.** Reliability will be a product; customers will have a choice of what level of reliability they want. Utilities should be able to offer options; for example, they could offer the option of minimal backup (i.e., 10% of demand). The pricing for this minimal backup option would vary—if the customer only wants to use that backup power during outages, when everyone else also wants power, the price would be higher than if the customer only wants to use it at night. Or customers could choose basic electric service, and then pay extra for more reliability. Other possible services could involve availability or power quality. To do this, a new definition of system reliability will be needed. If individuals are responsible for producing power, they will have more responsibility regarding reliability. Utilities will need to think about where redundancy matters and what levels of critical circuits are important. The new portfolio of services will also require education for customers and regulators. With this new portfolio of services, the cost allocation of the wires will need to be considered. New indexes will need to be developed to determine the new reliability service.

- **Free market will drive products and services.** Customers will need to pay for additional services. As the grid evolves, there will be a chicken/egg issue with generating business models and making required regulatory changes. Today's integrated system is very reliable. Technology advances will enable new approaches and will likely be implemented prior to the new regulatory frameworks being developed to effectively support and manage these additional services.
- **Revenue will be generated by demand of new service offerings for generation and conservation.** Utilities will be facilitators of the market, not controllers of the market. They will have to be more entrepreneurial and look to achieve their current rate of return in multiple ways. They will need to be more adaptive, rather than rely on the old model. Wires companies will be paid on who/what they can integrate into the system; they will have to be an enabler of the platform.
- **Service-based rate filing to allow fixed fee in revenue stream.** Service-based rate filing would be a better model than asset-investment-based rate filing. The entire costing will not have to come from rate-based filing—there can still be a performance-based portion. Utilities will want customers to use the grid to power more devices, and for every transaction, utilities will want to get paid. Enabling transactions on the system would allow utilities to get paid. Value-added services would be an additional cost over the basic service offering for all customers. Innovation could be rewarded. If utilities offer customers the choice of services, customers will decide how to use their devices. Regarding new rate structures, there is the question of why the utility would want to suddenly invest in something to which other entities could add devices.
    - One participant noted the need to make the discussion more generic in terms of how grid owners/operators will remain financially viable, noting that business models must be different and that one size does not fit all.

New Investment/Funding Requirements:

- **Price transparency to the individual customer level.** With value-based pricing, the positive or negative pricing level must be transparent at the customer level. Regulators must make sure the price is transparent, exactly like with buying gasoline. Therefore, the role of regulators will have to evolve and include considerations for jurisdictional issues involving numerous political borders. The role of the Federal Energy Regulatory Commission (FERC) and state authorities, as well as considerations for the cost/benefit of policy decisions of different states, such as who bears the cost, and whether it should be socialized, will need to be addressed.
- **Business plan for services.** To accommodate the buying or selling of power by anybody anywhere on the grid, new business models will be needed. If energy storage is available, there will be an adverse impact on the traditional transmission and distribution utility. There will be questions about how transmission and distribution utilities will embrace this transition, what the incentive will be if they could save money on both capital costs and operations, and if there will be a business model to reward efficiencies or savings. System-level basic

Other Ideas for Possible Business Models

Other ideas for business models include the following:

- Receiving payment based on who or what is integrated into the system
- An exchange commodity transaction with services that provide additional revenue on top of the base
- Service- and construction-based rate filing

services will be needed, which will require investment in basic infrastructure. An energy information highway will require investment. The business model will involve recovering this investment. Ambiguity can create difficulty in raising funds for capital investments—investors will need to know how energy providers will make money. Someone will need to provide risk insurance.

- **Market-based model instead of asset-based model.** The grid of the future will be a service-based model, not a commodity- and infrastructure-based model. Utilities need the ability to project a price longer than the short term. Currently, when utilities build a power plant, they have a return on equity based on regulatory certainty and the faith of the state. In the new model, there might not be this certainty. Considerations need to be made regarding what needs to change so that infrastructure investment is possible.

Message to Policy Makers

Participants determined that the following technical limitation(s) or operational constraint(s) should be considered by policy makers when developing future policies so electricity delivery is not adversely impacted:

- **The value to the customer must accompany the cost.**
  - **Optionality will not be free.** Any services above basic electric service will have a cost, allowing for a more customer-focused model. The necessary pricing structure will be much more sophisticated than today. There is question as to whether regulators will want to write in this increase in sophistication. The system should be developed with a focus on services, not infrastructure. Regulators should be ready to step in and support the infrastructure development. Value orientation for energy as a commodity does not currently exist. The value of the service must be in concert with the cost in the future world.
  - **Services should be unbundled.** Rates and services should not be bundled with basic electricity delivery cost—they should be separate and understandable to customers.
  - **Safeguards should be built into services.** Solutions will be found in many forms. Regulators and generators should be open minded to all forms of solutions, rather than compartmentalize them by technology type, etc.
- **Utilities should be allowed—but not required—to operate in a competitive market.** Utilities—or anyone who is able to provide services—should have the option to operate, but they should not be mandated to do so. Considerations will have to be made for how to prevent handicapping regulated entities versus their unregulated competitors. Considerations will also need to be made regarding how regulators can facilitate the transition for customers who want to leave the grid, rather than hinder those customers. Policies should consider the need for wire infrastructure investment.

Turning the Question Around

The group also discussed what guidance regulators would give to utilities. The group determined that the advice would be to no longer build infrastructure and expect to get a fixed rate of return; value must go hand-in-hand with costs. Cost without value will be a nonstarter in the future world.

Necessary Actions

Participants identified the following actions that should be undertaken in order to evolve to a cost-effective, reliable, and resilient grid of the future:

- **Education of many entities will be critical.** Education of and communication with stakeholders will be an important challenge. Education—of policy makers, regulators, businesses, and customers—will be needed throughout the transition to increase the understanding of all parties. As the grid becomes more complex, customers will have more choice, and the explanation to customers will need to be very simple and include a value proposition. The industry will need to determine how to explain complex concepts such as average interruption index to customers in a simple, easy-to-understand manner. Getting customers to change their behavior will be a big challenge and education will be a key component in facilitating this shift. Operators will also need further education due to the increasingly high level of sophistication at the distribution level, which will require a different set of core competencies.
- **Utility R&D will be needed for a horizontal market.** R&D has to be a component of the future grid. Funds have to be devoted to what is next; when moving from a situation where utilities are paid for their infrastructure/capital assets to one in which they are paid for an idea or service, money will need to be dedicated to R&D to develop the next idea or service. This represents a competitive perspective to the landscape rather than the traditional R&D landscape. Utilities currently are dependent on suppliers/vendors instead of doing their own R&D. In-house R&D will be very important. Currently, R&D is often one of the areas cut in a rate case, but it will be an important aspect in the development of the future grid. R&D efforts will need to better demonstrate the commercial use of the technology in the marketplace; R&D will not just be research into the basic chemistry or next device.
- **Price transparency will be important.** Price transparency that currently exists at the transmission level will be needed at the customer level. Customers must know what they are buying and why. This will allow customers to make decisions based on advanced knowledge of the price.

Scenario 2: Involving Customers and Their Loads in Grid Operations

Description of the Scenario

This scenario is characterized by:

- Retail availability of smart devices and customer expectations that devices will "plug and play" with grid operations.
- Greater customer control over, and ability to react to, the price of energy. A greater number of available service options.
- Increased availability and prevalence of smart devices, along with EVs that can respond to signals from the grid operator. Devices are capable of two-way communication with the grid.
- A significant increase in local (edge-of-grid) clean generation (such as rooftop solar), electrified transportation, and storage to meet individual customer (residential, commercial, and industrial) needs and expectations. Ancillary services being met through the control of these devices. An imbalance between reduced/falling overall demand and higher peak demand.

Together, these characteristics suggest a need for:

- The ability to incorporate complex economics with complex physical integration.
- An architecture and design that can optimize the loads and their response in a way that maximizes efficiency and minimizes costs.
- Ways to synchronize the operation of potentially millions of devices at the edge of the grid.
- Ways for the grid to adapt when edge-of-grid devices are scaled from hundreds to tens of thousands. Customers are unaware how their own choices impact larger grid operations; when these individual decisions are scaled to hundreds or thousands of devices, the impact to grid operations will be tremendous.
- A "transactive energy" concept, representing the complex interaction between physics and economics at the edge of the grid.

Path Forward: Articulating the Vision

The following summarizes the Scenario 2 breakout session discussions. This content was generated entirely by participants and reflects their vision for the end state of the future electricity grid under the Scenario 2 assumptions. The participants also recognized that there will be a transition period before the end state is reached.

Description of the Group's Future Grid, Based on the Scenario

- **Software to aggregate all data and convert it into action will be involved.** Automated controls will be needed. Utilities already have a lot of data and the future grid will involve even more; utilities will need more tools to turn the data into action. Open architecture and standardization will help address the challenges related to data sharing.
- **Communication will be ubiquitous.** Communications will be stronger than today so that all elements work in a common way and the transmission and distribution systems are communicating with each other. For communication of devices behind the meter, the more standardization and consistency, without proprietary systems, the better. Cybersecurity issues will need to be considered.

- **Power attributes will be standardized.**
- **Wholesale and retail markets will be seamlessly integrated.** There will be the same level of opportunity among various marketplaces.
- **May include islanded customers.** Some customers may want to disconnect from the grid in a permanent way.

New Capabilities and Functions

- **Cognitive computing.** The future grid will involve computers that can learn and be more predictive of conditions on the system, and then react to those conditions.
- **Tighter integration of the Distribution Management System (DMS) and the Distributed Energy Resource Management System (DERMS).** DMS and DERMS will be integrated to manage and operate the distribution system, connecting price with power output. Currently, the DMS software does not factor in cost. DMS requires DERMS to provide power regardless of price. In the future there will be a step when DMS and DERMS will operate together to look for the cheapest power source.
- **Tighter integration of transmission and distribution operations.** Transmission and distribution operators will need to coordinate. If there will be a seamless market for devices to play in, then the distribution system will need to look like the transmission system. The same amount of control and information will be needed. The transmission and distribution systems will need to communicate better.
- **A higher-bandwidth, lower-latency, and cost-effective communication system will overlay the grid.** The communication system will have to process more data and will involve getting information on a real-time basis, allowing energy providers to act on it in near real time.
- **Robust energy dispatch system.**
- **Near-real-time data.**

Differences for the Operations Centers

Transmission

- **Greater uniformity across an ISO for transmission and distribution operators.** There will be more uniformity between the transmission and distribution systems. There will have to be an understanding and a flow of information between them. Transmission and distribution operations will need to coordinate.

Distribution:

- **[None identified]**

Business Models and Investments

Financial/Business Model Changes:

- **Rate flexibility.** The main issue across the board is the way rates are designed—they currently include everything and do not articulate the different aspects included in the rate. In the future there will be a utility-customer partnership; utilities will need to recognize the different types of customers and develop rates that fit customers' needs. Utilities will need to have the capability to articulate costs. Customers need to understand what they are paying for and pricing should be transparent. Without transparency, customers are making investments without complete knowledge. The level of customer engagement with the utility will have to change so utilities know what is on the system. Considerations must also be made to prevent double billing.

- **Potential user's fee.** As customers take less power, there must be a way for electricity providers to change their rate structure to make sure they recover their investments. A user's fee is one option. All customers will be using the distribution system, even if they do so only rarely for backup, so investments must be made to keep the infrastructure strong and these investments will need to be recovered. When customers install distributed generation, they do not understand that they must pay to have standby power. If price incentives are given and customers decide to engage, there could be impacts to the grid—such as voltage issues—that must be accommodated. Additionally, when customers install photovoltaics (PV), they do not necessarily contact the utility. Utilities find out because they see strange things on the feeder such as zero power.
- **Volumetric capture may no longer be viable.** Pricing based on the amount of energy sold may not be sustainable into the future. Pricing may shift from customers paying for how much they use to paying for a service.

Customer Partnerships with Utilities

As customers become more engaged and rate structure, visibility, and classes potentially change, utilities and customers will need to partner. More sophisticated users will maximize their value by installing distributed generation or responding to price signals. There will still be a small number of customers who do not want to engage. There will need to be more opportunities for utilities to partner with customers.

New Investment/Funding Requirements:

- **IT infrastructure.** To modernize the grid and meet customers' changing needs, investments in IT infrastructure will be needed. However, utilities are currently concerned about spending money on IT, because if people leave the grid, their investments in IT could become stranded investments that are not recoverable.
- **Communication infrastructure.**
- **Other market participants assisting in funding.** Nationally, not all investments may be done by utilities—other participants may help with the funding.

Message to Policy Makers

Participants determined that the following technical limitation(s) or operational constraint(s) should be considered by policy makers when developing future policies so electricity delivery is not adversely impacted:

- **From a regulated utility perspective, the utility profit model needs to change so that it is based on efficiencies, not investment.**
- **Co-ops must be creative with rate policies. More distributed generation is coming; the co-ops need to think about the future and be flexible.** There must be creativity in rate making and in determining who gets rewarded and who does not.
- **Politics must be set aside.**
- **The future grid will require investment.** Utilities need assurances that these investments will be recoverable.

Necessary Actions

Participants identified the following actions that should be undertaken in order to evolve to a cost-effective, reliable, and resilient grid of the future:

- **Closer integration of the ISO, transmission, and distribution will be needed.** With all of the devices coming onto the system, it will be necessary to have the same level of visibility at the distribution level as there is at the transmission level.
- **IT and communication investment will be a very important part of the grid of the future.** Methods will have to be developed to deliver, aggregate, understand, and return information to customers. Grid operators will have to incorporate the tools and technology needed for the younger generation, which will have different expectations.
- **A cost recovery methodology that is acceptable to the customer and that encourages investment will be needed.**

Scenario 3. Higher Local Reliability through Multi-Customer Microgrids

Description of the Scenario

This scenario is characterized by:

- Microgrids that are widely deployed to meet a variety of customer needs: increased reliability, greener generation, higher power quality, etc.
- Increased sophistication of these microgrids, with a mature market by 2020.
- Microgrids becoming a dominant force in grid operations in 2030 and beyond.
- Microgrids serving a single customer or multiple customers.
- Microgrids that utilize larger grid infrastructure but are also able to operate independently when necessary.
- A possible disruptive or destabilizing impact of microgrids on the traditional grid (shrinking number of ratepayers to support grid infrastructure, rising costs per ratepayer).

Together, these characteristics suggest a need for:

- Appropriate grid interface standards to allow for optimal operation of the grid, the microgrid(s), and both together.
- Consideration for how these microgrids will impact infrastructure investment for the larger grid.

Path Forward: Articulating the Vision

The following summarizes the Scenario 3 breakout session discussions. This content was generated entirely by participants and reflects their vision for the end state of the future electricity grid under the Scenario 3 assumptions. The participants also recognized that there will be a transition period before the end state is reached.

Description of the Group's Future Grid, Based on the Scenario

- **There will be both physical and virtual microgrids (i.e., franchised entities encapsulating their own "grids" with the potential to share a utilities infrastructure).** For example, organizations with multiple properties (e.g., a chain of fast food restaurants or a university campus) could have specific service needs or challenges that make them more interested in proactively participating in the grid than a typical consumer. These groups could develop physical microgrids to serve their collection of properties. They could also consider creating a "virtual microgrid," which is the aggregation of loads to provide customer, utility, or community services (local optimization). Virtual microgrids are analogous to a cloud computing model, for electricity. Organizations with multiple properties could manage and operate their own virtual microgrids, or they could turn over the management to a third party. As another example, groups of consumers (such as neighborhoods or even all customers in a small city) could form a virtual microgrid, managed by a utility. NRG Energy is already doing this—serving groups of customers that together form a virtual microgrid. The virtual microgrid concept challenges DOE's definition of a microgrid, which dictates that microgrids must be able to island. For some customers and utilities, a physical microgrid, which provides power generation and can island, will be the preferred choice. The requirements of each physical microgrid will dictate the generation options and storage options required, which will in turn dictate cost (e.g., high-reliability, high-capacity systems will be more expensive). The utility system was built on a large scale and may need to be rebuilt at the customer level. A move from a radial system to a networked system may be required. Microgrids will require a notable investment; adding capacity to a microgrid incrementally may be a way to manage costs.

- **Private microgrids may be nested within a utility microgrid.** Microgrids could be managed and operated by private companies on behalf of communities, neighborhoods, multi-property organizations, and other entities. Utilities are also well-positioned to provide utility-based microgrids; utilities have staff with the kinds of expertise required for microgrid management. Utility microgrids could offer utilities new options and opportunities to expand services in a way that supports microgrids. For example, distribution companies could provide thermal distribution, enabling them to offer backup power for hedging peak prices, or firms could offer volt/volt-ampere reactive (VAR)/frequency support. Critical facilities (such as hospitals) could be targeted first and offered incentives such as reduced interconnection and standby charges.
- **The grid will be more complex.** Information and energy will flow bidirectionally. There will be a mixture of local generation assets at the edge of the grid and large-scale renewable generation that may be remotely located. The grid will evolve to provide more than electricity (e.g., energy storage, natural gas, and combined heat and power). With distributed energy storage, aggregation of local loads/generation will become possible, ranging from very small localized aggregation to larger (community-based) aggregation. The grid may also need to move from a radial system to a more opportunistic, networked system (for some locations), which will require significant investment. There will be a very large, complex group of stakeholders involved in the grid, including homeowner associations, state utility commissions, city governments, and others. **System planning needs to be considered on a long-term time scale**, within the context (needs/requirements) of particular communities.
- **Business as usual for rural communities.** There is a central question as to whether utilities will continue providing service to rural communities. Microgrids at the neighborhood level are not realistic in rural communities because of the often long distances between residences. The cost to provide this service (and to maintain the distribution system for these customers) is very high. Generation may move closer to large population centers because utilities may not be able to afford the costs of serving rural and remote customers. In addition, there will be a growing number of prosumers (customers who generate their own on-site electricity and sell it back to the grid). Many rural customers already have their own generation as backup. If, in the future, utilities are required to continue providing service to rural customers, rates could be decoupled in a way that passes the cost of that delivery to them. However, cost recovery is a complex issue. Utility service to these customers may depend on the utility's territory, customer base, and system type (e.g., radial, networked, looped). Business as usual could persist, or in the future, rural customers could perhaps be moved off the distribution system, using some sort of local microgrid that combines on-site generation with storage.
- **Where large-scale distribution remains, utilities will move distribution underground to minimize disruptions from very severe weather events.** To boost resilience, ducting and other techniques could help ensure reliable operations. However, in some areas, moving distribution underground could be more problematic (repairs take longer and underground distribution could be subject to flooding). Long-term reliability, especially within particular communities—for example, with the transition to "smart cities"—could involve moving distribution underground.

New Capabilities and Functions

- **Price control driven by transactive price.** Both transmission and distribution will be involved in sending these signals. A local pricing system will be possible. Price mechanisms will be clear.
- **Utilities will offer more electric and thermal commodities.** Utilities will integrate electrical and thermal services. Utilities may provide frequency management and volt/VAR support, or district energy solutions to support more sustainable solutions, such as smart city services.
- **Utilities will control multiple microgrids, and microgrids will be capable of controlling other microgrids.**

Differences for the Operations Centers

Transmission:

- **Cross-functional transmission and distribution visibility and communication.** Transmission and distribution roles will fundamentally change and become more alike. Overall, an integrated view and perspective on operations system-wide (transmission and distribution) will be needed. Greater visibility into the distribution system and better two-way communications between transmission and distribution (for example, across ISOs) will be required to support cross-system/cross-functional decision making. With this wide-scale visibility, operators will be able to tap local resources to meet system needs. Utilities will be integrators and service providers, as long as the grid supports these abilities (to tap into remote renewables, support two-way power flow, and more). Utilities will also be master communicators—they will need to communicate with assets across the entire system.
- **Responsible for sending transactive signals.** Both transmission and distribution will be involved in sending transactive pricing signals. Grid operators will become information providers; for example, they could inform customers of price changes that, if necessary, encourage home generation.
- **Security on the whole system across transmission and distribution; must provide secure end-point communication.** Reliable and trustworthy information is essential. Communication will flow from various points throughout the system (e.g., customer to utility, vendor to vendor, and utility to microgrid) rather than from a single point (i.e., the utility "command center"). Security will be needed for all levels of communication to ensure reliable, secure information exchange. This could present a considerable challenge; utilities have their own communications systems, and communications coverage will need to cover a wide geographical area (much like cell phone service providers strive to provide coverage anywhere in the United States, but still have not reached 100% coverage). In addition, with multiple players on the system, methods of determining responsibility will have to be resolved; currently, when a breach occurs, the utility is responsible.

Distribution:

- **Responsible for sending transactive signals.** Both transmission and distribution will be involved in sending pricing signals. There will be a need to develop appropriate pricing mechanisms and control systems to enable transactive signals in a more complex grid, including data management and two-way communications. Locational pricing will also be needed.
- **Utilities will have the opportunity to become a secondary market maker.** The blurring of the transmission and distribution systems will not just be physical—the markets will converge as well. There will be a market mechanism within the distribution system.

- **Security on the whole system across transmission and distribution; must provide secure end-point communication.** Operations centers must include a security center. Securing the transmission and distribution systems may require different approaches. As was also noted for the transmission system, security will be needed for communications between all players in the electric grid (e.g., between utilities and their customers, vendor to vendor, and utility to microgrid). Currently, when a breach occurs, the utility is responsible.

Business Models and Investments

Financial/Business Model Changes:

- **Rate cases are too cumbersome and too far out in relation to a reasonable timeline.** Private industry makes decisions about pricing much more quickly. Utilities need to be able to respond quickly to adapt to changing customer desires/expectations. It currently takes 3–5 years to gain approval and move forward on any investment. The system needs to be more agile, and decisions need to be made on rate structures/pricing models today to support changes tomorrow. In addition**,** regulations should change to allow utilities to recover operational efficiencies over longer periods of time.
- **Energy providers should have the ability to provide different levels of reliability.** Reliability could be a service of microgrids, or a service provided by the utility. Customers that need lower levels of reliability could have the option to use a less expensive service, and customers that need higher levels of reliability could pay a premium for that service. Some customers will also pay for excess capacity. A highly reliable grid may have redundancies and inefficiencies to prepare for "worst case" scenarios—as well as a one-size-fits-all approach—which lead to higher costs for those who do not want or need the increased reliability.
- **Customers may make their own investments in energy-related technologies.** As the cost of solar (such as rooftop PV) and other generation technologies comes down, these options will become very competitive with grid-provided electricity. Customers may also transition from purchasing PV systems to leasing them. Regarding this point, the group raised the question of whether customers should make their own investment decisions in energy technology or whether all consumers should be given the same level of service.
- **There will be a need for accountability of infrastructure/technology reliability and maintenance.** Utilities provide an essential reliability service to consumers who generate some or all of their own electricity. When their generation asset fails, consumers can use electricity provided by the utility. In a microgrid model, the microgrid provider would need to ensure safety for consumers and for workers performing tasks further down the system (e.g., ensuring that local systems do not back-feed while linemen are maintaining lines). Reliability targets will have to be loosened to enable microgrids; it may not be possible to deliver 99.99% reliability to every customer. Decoupling of rates will require new metrics to ensure accountability (to demonstrate that services are being provided, rather than a unit of energy). Accountability should be based on performance, rather than utilities being held responsible for any failures that occur on the system (such as failures caused by manufacturer defects or issues). For example, some utilities currently do not get cost recovery for repairs made after storms. One question to be resolved with independent microgrid implementation is that if an enterprise develops and installs a microgrid, but then decides to leave (because of bankruptcy or other reasons) the marketplace, it is unclear who is responsible for providing the service.
- **Less regulatory burden and more cooperation among states are needed.** There needs to be more cooperation among state jurisdictions, rather than an expansion of FERC. Most investor-owned utilities are located in multiple states and must deal with conflicting requirements from

state to state (as well as varying rate recovery models from different public utility commissions). Utilities have to report to many different entities. Microgrid development is hampered by state rules about where generation can be located, how electricity can be transmitted, and similar issues. In addition, the framework is quite different between regulated states and restructured states. Large property owners are currently the only groups that have the level of control over their property that is required to make microgrids work within state regulations. Decision making and approvals need to be faster and clearer. Certainty is required on issues of timing and costs to support investment and decision making. Decisions, once made, are sometimes overturned, which adds to uncertainty. Regulators are currently rejecting smart grid plans from utilities in some locations, which is leading utilities to make smart grid investments that are biased toward particular locations. It is also difficult to engage utilities in a public-private partnership, due to regulatory constraints.

- **Transparency regarding requirements for participating markets and timeliness.** Today's markets exist at the FERC level, not the state level. To create a secondary market, requirements for participation must be clearly defined. If secondary markets do not develop, aggregation must be supported. Cost recovery is a key consideration to spur innovation; utilities need a way to recover investments over shorter time frames and get faster payback on their investments. Capital costs versus operations and maintenance costs impact the payback horizon for utilities; how these are handled must be reevaluated.
- **Utilities should move to dynamic rates and away from volumetric pricing.** Utilities should move away from a model in which they charge only for the quantity of electricity used. Rate decoupling (unbundling of rates) is needed to allow utilities to charge consumers both for transmission/distribution costs and for energy services used. This decoupling can allow utilities to charge high-use customers more appropriately. Ultimately, utilities will be paid for services rather than units of energy, and utilities will be able to pay prosumers for services provided as well. Unbundling will support more sustainable markets and enable choices to be made regarding technologies such as solar PV, fuel cells, and others.

New Investment/Funding Requirements:

- **Ability of utilities to provide behind-the-meter services. Utilities need the ability to charge for value-added services** such as storage, distributed generation, microgrids, etc. There will be a market mechanism within distribution.
- **Municipalities and private investors should be allowed to contribute to a microgrid environment.** Attracting private investment into microgrid development will help drive microgrid adoption. Therefore, the industry must be able to show the profitability (and payback periods) for microgrid systems. A few successful test cases are needed to show that private investment in microgrids can really pay off. Utilities should provide only a portion of the capital required to invest in the future grid. Attracting private investment in microgrid build-out will be key, as will utilities' ability to expand into new services. There also needs to be a financial incentive for private investment in non-utility-owned assets. For example, the private sector could be invited to invest in a neighborhood storage system on behalf of the utility, with the promise of recouping that investment via a percentage of revenues made off of the system (transactive model). Regulation currently limits this type of arrangement; utilities may be limited to a maximum percentage of profit (such as 7%) and be required to invest the rest into system maintenance or other services. With this model, and with so little income, it is difficult to incentivize investors. In addition, small operators need the opportunity to enter the market and

participate; currently small operators are unable to participate because the interconnection cost is prohibitive.

- **Targeted, smart incentives should be provided to start-up microgrid environments/communities.** Investment is needed now, not 10–15 years from now, to encourage investment and adoption of microgrids. The incentive can trade real value for services the microgrid provides back to the grid.
- **Create standards around emerging energy technologies to include microgrids.** Standards around microgrids, storage, and interconnection need to be established that support utilities' engagement with microgrid companies, cogeneration companies, and others. Even acceptance of standards that exist today would go a long way toward microgrid development. Currently, standards can be different from state to state, which makes it difficult for companies providing microgrid services in a variety of locations.

Message to Policy Makers

Participants determined that the following technical limitation(s) or operational constraint(s) should be considered by policy makers when developing future policies so electricity delivery is not adversely impacted:

- **There is a manpower shortage, insufficient knowledge, and a lack of resources among policy makers.** State regulators are responsible for a number of areas but are often short-staffed. State legislatures have added new requirements that utilities must meet—such as regarding the use of solar, energy efficiency, etc.—that can add complexity and cost and have required regulatory bodies to become more specialized so that they can understand the complexity. Electricity is just part of many public utility commissions' work. In the grid of the future, one possible option to consider is having a regulatory agency or similar entity that is dedicated to only electricity—the staff would need to be well educated in electricity and the nuances of operations.
- **Cross-jurisdictional issues create confusion.** For utilities, FERC versus state jurisdiction is a big issue that creates barriers. There are many cross-jurisdictional issues, and these issues need clarity. Questions often arise about which groups have responsibilities for which part.
- **There is little coordination across jurisdictions (city, states, etc.).** There are multiple layers of regulation (federal, state, local, air pollution control districts, etc.) and no consistency between them. Even from city to city, requirements can be different. This makes it difficult to do business.
- **Transparent, unbundled rates are needed to support value discovery.** Transparent, unbundled rates can provide appropriate signals that demonstrate the value of storage, reliability, and other services. Value discovery is needed.
- **Utilities should be given the authority to create their own service model as well as perform their own "prototyping."** Utilities need the authority—but should not be required—to come up with new service offerings as they start to see competition in certain areas (e.g., microgrids). Utilities need to be able to do more prototyping and issue requests for proposals for innovative pilots or the development of new technologies. Utilities are generally risk-averse because there is no upside for taking on this risk, but innovation requires risk. Utilities must be rewarded for taking on the risk of innovation.
- **Managing the grid is becoming more complex.** Multidirectional communication, aggregation of loads, third-party service providers, and complex and overlapping stakeholder groups are just some of the factors that will come into play.

- **Decisions must be made regarding appropriate levels of reliability.** If reliability is offered at multiple levels for the future grid, it will be important to consider which levels are adequate. New metrics will be needed to ensure accountability.
- **Clarity will be needed regarding who is responsible for customers' choices.** If a customer contracts a third party but that company's system fails or a manufacturer's system has issues and the customer is without electricity, it is unclear who would be held accountable. If the utility must rectify the issue, it is unclear how it would be compensated.
- **Regulatory certainty will increasingly become a key point.** Transparency regarding requirements and clarification on who is able to participate in markets will be needed. Regulations are often short-term and reactionary, which creates many unintended consequences, such as forgetting to open opportunities (such as distributed generation) to utilities.
- **Policy makers should focus on the desired outcome, rather than the specific technology.** Technology needs to serve the desired outcome (e.g., diversification of supply, emissions reduction), rather than policy dictating a specific technology.

Necessary Actions

Participants identified the following actions that should be undertaken in order to evolve to a cost-effective, reliable, and resilient grid of the future:

- **There must be a change in how utilities operate and how regulators regulate.** There must be changes in how investments are approved, how regulators interact with utilities, how rate cases are handled, and how utilities operate day to day. Decision making and approvals will need to be faster. Clarity will need to be provided regarding how investments will be evaluated and recovered.
- **Utilities of the future must be allowed to accommodate sustainable services with various energy commodities.** There will be greater integration of gas, electric, thermal, and water energy, as appropriate, in particular to support sustainable cities (in a holistic utility-city environment).
- **Technology systems must be able to accommodate an increasingly complex grid,** including data management and two-way communication.
- **The utility revenue model must be changed to incentivize cities and customers to invest in innovation now.** Utilities as a group tend to delegate innovation to third parties (such as the Electric Power Research Institute). In addition, the investments should extend beyond electricity alone. Utilities need to (and be approved to) invest in research for innovative products and services. Currently, R&D is an item that typically gets cut during a rate case to reduce costs, but for utilities to compete and meet the needs of customers, they will need to fund these types of activities.
- **The lines between transmission and distribution operations will blur.**

Scenario 4: Transitioning Central Generation to Clean Energy Sources—Large Wind, Large Solar, and Large Gas

Description of the Scenario

This scenario is characterized by:

- Increasingly affordable natural gas; rising use of natural gas.
- Lower costs for wind, solar, and other renewable generation technologies (as a result of incentives and increasing market demand).
- A majority of new generating capacity being supplied by renewables.
- New policies and regulations that are driving up the price of coal, oil, and nuclear.
- New participants in the market; impacts of changing wholesale prices on the profit margins of traditional and renewable power generators.
- New operating characteristics for the generation fleet.
- Possible strain from ramping and cycling.

Together, these characteristics suggest a need for:

- Increased infrastructure to transmit electricity from sites where it is produced to where it is used.
- Increased flexibility of the power system to manage the variability and uncertainty of generation from intermittent renewables.
- Strategies for addressing increasing penetration of non-dispatchable resources; curtailment.
- New alternatives to traditional planning processes to avoid overbuilding some asset capacity and underbuilding others.

Path Forward: Articulating the Vision

The following summarizes the Scenario 4 breakout session discussions. This content was generated entirely by participants and reflects their vision for the end state of the future electricity grid under the Scenario 4 assumptions. The participants also recognized that there will be a transition period before the end state is reached.

Description of the Group's Future Grid, Based on the Scenario

- **The grid will be multiregional and will operate with a higher capacity and connect more regions simultaneously.** The multiregional system will comprise both intraregional and interregional elements. This will enable more interconnection between regions, as well as the need for fewer balancing authorities and RTOs. Greater multiregional coordination will be necessary. There will be a larger role for centralized communication and cross-region control. Stakeholders will not be able to just think locally. More capacity will be needed for a multiregional space. Interconnected regions will be larger to help ensure reliability.
- **The grid will be operated with real-time knowledge of operational capacity.** Technology will be needed to have real-time knowledge of grid capacity and for energy providers to be able to leverage this capacity and dispatch generation. Real-time capacity value of the grid will also be needed. Big Wind/Solar is built in areas that require transmission. The generation mix will

impact transmission system optimization. As evolution occurs, transmission development turns to system reconfiguration.

- **With the integration of distributed generation and storage, the distribution grid will more closely resemble the current transmission system.** The transmission system will not be eliminated. The distribution system will be managed similar to how the transmission system is currently managed.

New Capabilities and Functions

- **Tools and processes to automate and utilize data at the sub-second level.** Methods to use and analyze this data will have to be developed.
- **Technology to leverage grid capacity awareness in management of resources and market optimization.** Additional development is needed to leverage real-time data from sensors to expand dynamic line ratings capabilities to optimize and enhance the ability to maximize capacity on existing lines. Technology will enable greater visibility into the distribution system and provide knowledge about the actual capacity on lines to manage congestion.
- **Smarter protection systems and schemes on the distribution side will allow for scalable integration of distributed generation and storage.** Protection schemes on the distribution side will need to be redesigned as new distributed generation assets are added. Customer generation storage will drastically impact distribution systems. More reliability/loop situations will be needed.

Differences for the Operations Centers

Transmission:

- **Wide-area grid operation and coordination will allow for more integration of renewable resources.** A single entity will be responsible for grid operations and will have the ability to facilitate different market structures based on generation mix and other factors. This wide control will enable the scalable integration of renewable and distributed generation assets. Existing standards and operating procedures will be revised to allow for this shift. Two-way power flow protection schemes and infrastructure upgrades will also enable this shift. Communication from transmission down to the customer meter will be needed.
- **More sophisticated models that reflect both load and generation resources on the distribution system will need to be developed.**
- **Transmission networks must be retooled to meet future needs through optimization of existing assets.** A shift will occur to adjust to new markets. For the evolution that enables simultaneous multiregional interconnection to occur, there will be a need for upfront system optimization in order to avoid stranded transmission assets. The changing generation mix will impact transmission system optimization. Retiring the assets the system was originally built for (coal plants) will require system adjustments. Natural gas facilities will be located in different places than coal plants and will operate differently. Natural gas will be effective during shoulder periods when there is a high penetration of renewable penetration. A flexible transmission system can inject power where it is needed. Substations will change substantially.

Distribution:

- **Revised existing standards and operational procedures will make the distribution system smarter and better able to accommodate widespread distributed generation.** Existing standards and operating procedures will need to be revised to allow for the shift from one-way power flow that is fully controlled by the utility to two-way power flow with new entities putting power on the grid.

- **Grid design should be allowed to be flexible regarding the location of storage at the distribution level.**
- **Infrastructure upgrade at the distribution level (smarter protection schemes, voltage/frequency control) will be needed.**

Business Models and Investments

Financial/Business Model Changes:

- **A shift to a service-based model.** The pricing model could potentially include hybrid structures that include capacity or connection charges. There will be a shift to revenue streams based on system optimization.
- **Clear, transparent pricing signals.** There will need to be a strong emphasis on price signals.
- **Clarity of regulation and rules.** Policies need to be smart (based on collection of information), consistent, and clear.
- **More sophisticated ancillary services markets will be needed.** This will enable a shift to business models based on services provided as well as services provided by customers/prosumers.
- **Clarity is necessary around federal/state jurisdictional oversight.** Clarity is needed between federal and state jurisdictions. Regulators with a strong understanding of the rules can bring clarity. Consistency across jurisdictions is needed.
- **Competitive solicitation of project builds.** Project builds will not just be limited to traditional utilities.

New Investment/Funding Requirements:

- **Allow master limited partnership for transmission and distribution assets.**
- **Performance-based incentives and cost recovery structure.** Those who can offer services to the system will be able to get in—the marketplace will be fair and competitive, and not limited to just traditional utilities. The right cost structures to support this will be needed. Services and reliability must be balanced. Grid costs will move to socialization. Cost-based structures will attract financing. Financial constructs will be ever-evolving.
- **Cost allocation structure must change.** Wholesale and retail prices must be coupled. Benefits need to be associated directly with their costs.

Message to Policy Makers

Participants determined that the following technical limitation(s) or operational constraint(s) should be considered by policy makers when developing future policies so electricity delivery is not adversely impacted:

- **Wide range of benefits.** The transmission system has a wide range of benefits that will facilitate grid modernization, but these benefits are not always easy to quantify. Benefits need to be associated directly with their costs.
- **The federal/state jurisdictional quagmire is costly.** There are many entities to deal with. Investors need to work down both paths.
- **Investment risks and benefits need to be aligned.** Investments and the benefits realized from investments need to be better aligned. Achieving this alignment would help define a better path

toward investments. There is the question of whether investments will be driven by reliability requirements or by new paradigms.

Necessary Actions

Participants identified the following actions that should be undertaken in order to evolve to a cost-effective, reliable, and resilient grid of the future:

- **Policies must be easy to implement, consistent, and supported through incentives.** Policies must also allow for the integration of existing and emerging technologies, including state-of-the-art forecasting tools. They must also be smart; i.e., based on a collection of information. Incentives (for the service, not the asset) should support policy.
- **The utility revenue model must be changed to incentivize the deployment of new technology.** Utilities must be incentivized to invest properly—the investment thesis must be changed. There should be a shift to revenue streams based on system optimization. Different incentives will drive new asset planning approaches.
- **Smart grid implementation includes information, automation, and action.** A plan is needed to synchronize these three elements.

Scenario 5: Planning for Empowered Customers

Description of the Scenario

This scenario is characterized by:

- Technological innovations, new market structures, changing customer expectations, and policies that foster customer empowerment.
- Customers being more informed about their options, in part due to social media.
- Rising electricity prices and falling distributed generation costs, which lead customers to more closely consider their options.
- Increased interest in energy efficiency.
- Customer behavior changes as a result of education, resulting in lower electricity demand.

Together, these characteristics suggest a need for:

- Recognition that customers now have choices for meeting their specific electric power needs.
- A better understanding of customers' needs, desires, and choices.
- A better understanding of how increasing customer expectations and choices impact the distribution grid and the transmission grid.
- Consideration that by 2030, customers will have a profound impact on how the energy value chain is built and operated.

Path Forward: Articulating the Vision

The following summarizes the Scenario 5 breakout session discussions. This content was generated entirely by participants and reflects their vision for the end state of the future electricity grid under the Scenario 5 assumptions. The participants also recognized that there will be a transition period before the end state is reached.

Description of the Group's Future Grid, Based on the Scenario

- **Smarter connectivity—home area networks (HANs), solar, consumer storage, and electric vehicles (EVs).**
- **"Set it and forget it."** Empowered customers will need to know what the price is and have the choice of whether to use the information or not. Many customers might not want to be actively involved. They will want to automatically obtain their electricity for the lowest cost without any additional action required by them. They will not want data and graphs; they will want to preset devices in case events happen—for example, shutting off appliances at certain times or putting off a wash cycle if prices are high—and then forget about it. The end data or results of these settings are what they will want to see. They will want

Customer Characteristics

Participants identified the following characteristics of future grid customers:

- Aging
- Segments will worry about sustainability
- More tech-savvy
- Sensitive to price
- Interested in the top level of fair and transparent pricing
- Most will not be interested in the pricing details

to know whether their bill was reduced and what it would have been if they had not participated.

- **Flexibility—plug and play—opt-in/opt-out.** Utilities will need to know what devices and generation are on the grid, down to the customer level. They will need system and auto-detection capabilities. Utilities will also need to plan for customers who do not self-generate (non-adopters)—a mixed model will be prevalent for the foreseeable future.
- **The grid will be technologically advanced and connective.** The whole concept must be more technologically advanced. Through the transition period, utilities will have to manage both old and new IT systems. This could prove to be cost prohibitive for some utilities and could keep them from adopting new systems as a result.
- **Consumer engagement in selecting services and commodity pricing will lead to market-based solutions with fair and transparent prices.** Whoever will engage the customer will have to have a menu of options. Ancillary services will have to operate in the background or under agreed upon standards at the technology and market level so it is clear when to send price signals. It is assumed that there will be a market for ancillary services and that the market will have fair and clear pricing. Currently, pricing is thought of in volumetric units, but future developments (e.g., EV owners buying more home chargers) might require service and commodity pricing. Customers will need to know the price and have access to their electricity usage data. It will then be their choice whether to use that information or not. There might be a better way to engage low-income customers—to provide them with access to services (such as distributed generation and clean power) at a lower cost than they could achieve by pursuing those services themselves. One option is possibly through aggregators. Supporting the growth of additional services—such as data analytics and data systems—is necessary for customer engagement.
- **There will be more sub-segmentation—beyond commercial, residential, and industrial.** There will be sub-segmentation of these groups. To effectively segment, utilities will need a whole new level of understanding of their customers and their needs/wants.

New Capabilities and Functions

- **Ability to scale and aggregate with flexibility and adaptability.** Distribution will need to be adaptable and handled locally.
- **Agreed upon standards at the technology and market level.**
- **Control/manage output parameters.** For distributed generation inflows, utilities must control and manage the parameters of the output ramp rates, VAR support, and curtailing.
- **More intercommunication will be needed between transmission, distribution, and the ISO.** More of a communication marriage between transmission, distribution, and the ISO will be needed. Most outages start at the distribution level where there are pinch points—perhaps multiple paths to the customers will be needed. ISOs will be involved because central generation will have a role, but they will be closer to the distribution grid than previously. Many different types of controls will be needed to have better oversight of the reliability of the grid, not just at the high transmission side. Some entity will need to play a role in order to keep the voltage and power factor at the right levels for a given feed line. There will still be a grid operator mentality in the services world. There will need to be increased communication, integration, and end-to-end system planning. Plans need to be made from the source of fuel to the customer.
- **Auto-device detection.** For plug and play to work, there will need to be auto-device detection. For example, a customer buys a smart dishwasher, brings it home, and installs it, and then his smartphone recognizes the appliance and informs him that he can choose the option he prefers (e.g., to delay the start time based on the cost of electricity).

- **Big Data – analytics; security and privacy are guaranteed.**
- **Ability to price differently at the micro/service level – "price to the device."** A question was raised as to whether targeted pricing of ancillary services will need to be provided at the local level, where the aggregators can be helpful. This is largely currently determined at the higher level.
- **All must be simple and seamless to the customer.** All of the capabilities and functions will have to appear simple to the customer.
- **Enhanced understanding of the customer.** In order for utilities to get to the level of engagement they want and/or need from their customers, utilities will need to increase their understanding of customers' wants, needs, trends, etc.—this will be a new capability for utilities.

Differences for the Operations Centers

Transmission:

- **Increased communication and planning between transmission and distribution and the ISO.** Increased integration will also be needed.
- **Real-time monitoring capabilities of distribution systems for transmission and the ISO.**

Distribution:

- **Real-time control and adaptability to contend with fluctuations in distributed generation and loads.** Loads that are variable and stochastic (EV, solar) are a real challenge. Solar, without smart inverters, does not produce reactive power, so there will be questions about who will provide it and how the injection into the grid will be managed.
- **Systems will need caching capabilities for data that is collected remotely.**
- **Increased knowledge of and coordination with operations at the transmission and ISO level will be needed.** There will have to be increased and tighter communications with the transmission side; in the future, distribution operators will have to consider the ongoing transmission activities and coordinate better with the transmission and ISO levels.

Business Models and Investments

Financial/Business Model Changes:

- **Move toward performance-based model—(pay for levels of reliability, etc.) while still maintaining recovery of investment.** Utilities must be able to recover their investments while maintaining reliability. Considerations will have to be made for customers who do not want to pay for performance. Policy is needed that supports transmission upgrades and system modernization. One idea that was proposed was a national infrastructure bank to fund the modernization. Currently, the way costs are recovered is somewhat socialized in that the price to all customers is the same, but in the future, customers may pay for various levels of reliability and different levels of services. For transmission, if multistate planning is needed, the utility needs to go to six regulatory commissions, which often makes the idea of an investment a nonstarter. Private equity is looking at grid investments. Railroads and pipelines are created across jurisdictions, so the grid should be able to follow suit. Highways are privatized with 25 years to operate and recoup investment. In Europe, services are a lower return on equity business. The grid is a macro-system that is not as conducive to progress and modernization as it could be.

- **Changes in the grid utilization pricing model (commodity versus how it is utilized).** There will be a move away from the throughput model. The grid may not be able to be priced based on the commodity that flows across it, but on how it performs. If utilities have an obligation to serve, it will need to be determined how they will remain financially whole and continue to get the capital dollars needed to make necessary improvements or upgrades. Currently, every good effort utilities make to get customers to be more efficient impacts their revenue.
- **A roadmap needs to be developed that integrates policy pathways conducive to new business model formation.** A strategic vision that aligns tactical moves is needed; however, the whole structure is so segmented that it is hard to build one vision and boil it down to tactical moves. The roadmap should not be only a technology roadmap, but one that considers policy and societal implications as well. Policy is connected to business models and market structure, so it needs to be in place when discussing changes to business models. The roadmap should not be top-down (e.g., from federal to states and cities). It needs to be detailed enough to be meaningful—perhaps at the regional, state, or company level. The roadmap should be developed by an organization that is unbiased and has no hidden agenda. The roadmap should feature input from all of the different stakeholders that will be impacted.
- **Accurate cost of service calculations and cost of service recovery for energy delivery, backup capacity, etc.** Distribution and ancillary services must be priced correctly.

New Investment/Funding Requirements:

- **Expansion of transmission nationwide to accommodate added wind.**
- **Investment incentive will follow new business model formation.** Utilities will also need to recover investment for R&D.
- **Regulators must approve faster depreciation.**

Message to Policy Makers

Participants determined that the following technical limitation(s) or operational constraint(s) should be considered by policy makers when developing future policies so electricity delivery is not adversely impacted:

- **Policy makers, both state and federal, must be more informed about technology and aware of the costs, consequences, and benefits to the consumer and the grid. They should seek input from all impacted stakeholders and welcome innovation from outside parties.** Sometimes policy makers think technology is further along than it is and drive industry to pursue large-scale deployment when the technology is not ready. However, sometimes industry is hesitant to make changes without urging from regulators. Policy makers could help change the collective mindset and foster innovation from outside parties. There needs to be a balance between pushing technology that is not ready and pushing industry.

Necessary Actions

Participants identified the following actions that should be undertaken in order to evolve to a cost-effective, reliable, and resilient grid of the future:

- **Common standards must be developed.**
- **Education of shareholders, regulators, and customers will be needed.** Industry should proactively provide information to policy makers, consumers, and other stakeholders to help them remain informed. Stakeholder education might be extensive and continuing—it is not a

one-time activity. Policy makers need to understand the technology and its limitations, as well as the consequences of installing it and of doing nothing.

- **A "roadmap" must be developed.** This roadmap should be stakeholder-driven but facilitated by a trustworthy, unbiased entity with no hidden agenda.

Conclusion and Next Steps

The Central Region workshop provided an interactive forum for participants to identify a vision of the future grid based on their given scenario from a Central Region perspective. Stakeholders participated in productive discussions, and the output from this workshop represents an excellent step in gathering viewpoints from stakeholders nationwide. Participants reported the usefulness of the frank and thoughtful discussions that allowed them to hear various stakeholder perspectives in an open, constructive format.

Output from this workshop, as well as from the previous and subsequent regional workshops and the Executive Summit in Washington, DC, will feed into a final report, which will be published after the Executive Summit.

Appendix A. Setting the Stage: Factors to Consider

In order to frame the workshop discussions, participants received pre-read materials describing the scenarios and highlighting a number of key factors to consider that are shaping the electrical grid today and will likely emerge as dominant forces by 2030:

The shift to renewable generation. Rapid growth in wind capacity will continue, boosted by lower-cost, larger-sized turbines; larger production volumes; tax credits; consumer interest; and improved capacity factors. Solar photovoltaics (PVs) will also grow rapidly, driven by higher demand, consumer interest, lower PV module costs, and support from tax credits and other incentives. Although both wind and solar represent a small portion of the total electricity market, in regions where these resources are abundant, they can be disruptive and pose challenges to the grid. Biopower, geothermal, and hydropower will also grow rapidly. Some coal-fired plants may be retired.

The rise of cheap natural gas. Low natural gas prices and tightened emissions requirements will create more demand for natural gas from the power sector. Natural gas generation will grow through 2050, as low costs make existing natural gas plants more competitive with coal, and lower capital costs make natural-gas-fired plants a viable choice for new generation capacity.

Growing building energy efficiency. Growing federal adoption of Leadership in Energy & Environmental Design (LEED) standards for new building construction and state programs such as California's Zero Net Energy Building initiative will drive a broader growth of high-efficiency residential, commercial, and industrial building efforts that also feature on-site renewable energy generation or the purchase of renewable energy from utilities. The renewable requirements and possibility of on-site generation will greatly affect the performance of the grid, both locally and holistically, with implications for grid operation and stability.

The maturing of demand response. There will be increased availability of demand-side management to reduce peak demands, which in turn may help defer new generating capacity or improve operator flexibility in day-ahead or real-time operations. Dynamic pricing, time-of-use pricing, incentive payments, and other strategies will encourage users to change their energy consumption patterns. State policies and federal technical assistance, research, and development, will help drive adoption of demand response.

The smart grid. In response to aging infrastructure and a desire to increase electricity transmission and distribution efficiency, there will be an increased push for technology that utilizes remote controls and automation to better monitor and operate the grid. Increasingly over the past decade, Congress has taken a serious interest in electrical grid issues by passing various laws to address them. Title XIII of the 2007 Energy Independence and Security Act includes language specific to the smart grid. Congress continues to consider new legislation to address cybersecurity concerns, privacy and data access for consumers, and other policies to accelerate investments in the future grid.

Growth in energy storage. Maturing energy storage technologies will provide flexible solutions throughout the electricity value chain, helping grid operators address energy management, the intermittency of renewable power sources, and power quality issues.

Increase in microgrids. North America is the leading microgrid market in 2013, and it will remain so in the future, with major growth expected in the United States and worldwide. With the U.S. Department of Defense as an early adopter, and public investment in microgrids from a variety of other state, federal, and university entities, microgrid integration will be a crucial element in addressing grid reliability and resilience issues associated with energy generation from distributed renewables, power outages from natural disasters, and the increasing impacts to national security.

Smart cities and smart appliances. The amount of data being created and collected by municipalities and utilities is growing rapidly; by some estimates, it is expected to double every two years until 2020. Understanding and leveraging this data will be critical for municipalities. To maximize participation in smart cities, stakeholders will need to plan grid development in conjunction with planning authorities. Residential "smart appliances" are expected to become increasingly mainstream in 2015 and could reach up to $35 million in sales by 2020.

The rise of electric vehicles (EVs). EV sales account for less than 1% of total new light-duty vehicle sales, but federal support, state support, purchasing incentives, and fueling costs are aimed at boosting their adoption. The ways in which charging will impact the grid remain to be seen. The U.S. Department of Energy is encouraging more workplace charging. Technology advances could make quick chargers, wireless charging, or other methods more common at home. Utilities will need to evaluate their distribution system against these possible demand scenarios.

Overall growth in energy demand, with higher industrial demand and lower residential demand. Overall energy use is expected to increase by 2040. The U.S. Energy Information Administration (EIA) projects industrial-sector energy use to grow by 5.1 quadrillion British thermal units by 2040, primarily due to the increased use of low-priced natural gas and an increase in industrial shipments. However, EIA projects average electricity demand per household to decline by 6% by 2040.

A rising frequency of extreme weather events. Weather-related issues are the cause of nearly half of U.S. outages and are on the rise, meaning that grid resiliency will need to be addressed. In light of Superstorm Sandy, local leaders are considering options for local generation to address the most critical loads. Investments are being made in distributed power systems.

Policy and regulation. The grid will need to accommodate, forecast, and communicate with renewable generation resources spurred by renewable portfolio standards. The continuation of existing demand response policies would lead to a 4% reduction in U.S. peak demand by 2019. Renewable requirements for buildings and the possibility of on-site generation greatly affect the performance characteristics of the grid. Some states have launched emissions goals and cap-and-trade programs that may affect electric power producers and industry and shift production toward renewables.

Aging infrastructure and limited addition of new transmission capacity. Much of the U.S. power infrastructure is outdated and needs to be refurbished, replaced, or upgraded. Updating the existing infrastructure will present many challenges. These updates will become more and more necessary as the age of the infrastructure begins to show. Utilizing smart grid technology will increase grid resilience, efficiency, and reliability. The federal government has allocated billions of dollars to replace, expand, and refine grid infrastructure.

Appendix B. Workshop Agenda

GRIDWISE ALLIANCE

THE FUTURE OF THE GRID
Evolving to Meet America's Needs

Tuesday, February 4, 2014 • 8:00 am – 4:00 pm
Oncor
1616 Woodall Rodgers Parkway, Dallas, TX 75202

7:30 am **Registration and Continental Breakfast**

8:00 am **Welcome**
Becky Harrison, CEO, GridWise Alliance
Eric Lightner, Director, Federal Smart Grid Task Force, US Department of Energy Office of Electricity Delivery and Energy Reliability

8:10 am **Welcome and Opening Remarks from Host**
Jim Greer, Chief Operating Officer, Oncor Corporation

8:25 am **Stage Setting: External Factors and Variables Impacting Future Electricity Delivery**
Tom Standish, Executive Vice President, Energy Resources, CenterPoint Energy

8:50 am **Visioning Exercise: A Future Grid – Capabilities and Functions**
Facilitated discussion with the entire group
If you were starting with a "blank sheet of paper" and did not have any constraints that are imposed by the legacy infrastructure and business models:
- How would you define the future role of the grid?
- What would the future grid look like?
- What capabilities and functions would be necessary to meet society's needs?
- What does grid operations look like?

9:25 am **Break**

9:35 am **Breakout Sessions**
Participants will be assigned to one of the following breakout sessions. A description of the scenarios will be provided in the pre-read materials. Breakout group assignments will be given to participants during registration.

Scenarios
- The Challenge of Balancing Supply and Demand as Grid Complexity Grows (Orange)
- The Challenge of Involving Customer and Their Electrical Loads in Grid Operations (Yellow)
- The Challenge of Higher Local Reliability Through Multi-Customer Microgrids (Red)
- The Challenge of Transitioning Central Generation to Clean Energy Sources – Big Wind, Big Solar and Big Gas (Green)
- The Challenge of Planning for Empowered Customers (Blue)

Scope and Task
In the afternoon session, each breakout groups will be reporting out on their Grid of the Future, which is based on their scenario, and will provide answers to the following questions:
- What capabilities or functionality will the grid need to have?
- How will the operations center function?

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- What is the one technical limitation or operational constraint that a policy maker would need to know when developing future policies so as not to adversely impact electricity delivery?
- What three actions must be undertaken in order to evolve to your cost effective, reliable, and resilient grid of the future?

9:35 am **Breakout Group Discussion: *Defining Grid Operations***

For both the transmission and distribution systems:

- How does the grid have to evolve to get from where we are today to the future vision?
- What capabilities and functions will it need to have?
- How will the operations centers function (distribution, transmission and ISO)?
- How will the interaction between transmission, distribution and the independent system operator change?
- What are the technical capabilities that will be needed that don't exist today?

11:05 am **Breakout Group Discussion: Business Models and Investments**

- What market structure changes, if any, will be necessary to ensure future viability of utilities and to move from a commodity to services model?
- How will grid owners/operators make money (rate based versus performance based)?
- What will be the new investment and funding requirements?
- How will both capital and O&M costs be covered?

12:00 pm **Lunch**

12:45 pm **Breakout Group Discussion: Regulatory and Policy Barriers and Opportunities**

- What are the policy and regulatory barriers at the state and federal levels?
- Do regulatory bodies have the authority they need to make the necessary business model changes?
- Are there opportunities that must be embraced now?

1:40 pm **The Path Forward: Articulating Your Vision for Report Out**

- Provide answers to the questions posed in the Scope and Task section above.
- Select a spokesperson for group to present your vision
- Select 4 "panelists" who represent the different stakeholder groups to participate with the spokesperson for the Q&A session

2:10 pm **Break**

2:20 pm **Report Outs**

Breakout groups will report the results of their discussions back to the larger group. Breakout groups will have 5-7 minutes to present their vision followed by a 10 minute Q&A session.

3:45 pm **Summary and Final Thoughts**

4:00 pm **Adjourn**

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Appendix C. Attendees

Sandy Aivaliotis
Nexans

Massoud Amin
Technological Leadership Institute, University of Minnesota, Texas RE, MRO, and IEEE Smart Grid

Angela Beehler
Walmart

Tom Bialek
San Diego Gas & Electric

Eileen Brannon
ONCOR

Tanya Burns
Energetics Incorporated

Jeff Burton
TXU Energy

Ward Camp
Landis+Gyr

Jay Caspary
Southwest Power Pool

Don Clevenger
Oncor Electric Delivery

Lee Coogan
GridWise Alliance

Valentine Emesih
CenterPoint Energy Houston Electric LLC

Jimmy Glotfelty
Clean Line Energy Partners

Becky Harrison
GridWise Alliance

Darrell Hayslip
Narrow Gate Energy

William Hetherington
Bandera Electric Cooperative

Milton Holloway
Center for the Commercialization of Electric Technologies

Frank Hoss
HP Enterprise Services, LLC

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