

Initial Draft WECC Scenarios for 2018-2038

Scenario Development Subcommittee

DRAFT – Version 5.0

Submitted by Quantum Planning Group

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155 North 400 West, Suite 200
Salt Lake City, Utah 84103-1114

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Introduction

This report contains the initial draft of a set of long-term scenarios covering the period from 2018 to 2038 based on input from members of the Western Electricity Coordinating Council's (WECC) Scenario Development Subcommittee (SDS). That input emerged from a scenario development workshop held March 27-28, 2018 at WECC's headquarters offices in Salt Lake City, Utah. The purpose of that workshop was to gather ideas, facts, and suggestions for new long-term scenarios from a diverse group of SDS members and stakeholders. The meeting was attended by 25 people from a wide range of WECC member organizations and WECC staff members, and was facilitated by a team of consultants hired by WECC from the Quantum Planning Group, Inc. The purpose of this report is to share initial draft scenario narratives based on the input from the members so that these scenarios and ideas in their narratives can be further refined.

At its core, using scenarios as an analytical tool for planning involves sharing, learning, and some "art" in the use of imagination, facts, and analysis of key trends impacting the energy industry. Readers of this report should anticipate revisions and additions to the initial narratives before they are final.

Once these scenario narratives are finalized, they will serve as the qualitative basis from which quantitative inputs will be developed to support various ten and twenty-year modeling efforts by WECC committees and staff that will assess questions about how electric reliability assurance will be sustained within the Western Interconnection within each scenario. Various WECC subcommittees and SDS teams will be involved in determining key metrics and their use in various models, which may answer a range of questions related to how electric reliability assurance will be met in the Western Interconnection.

Scenario Background

Scenario-based planning is a technique for managing uncertainty in decision making. It is especially useful when long-term investments must be evaluated despite the human inability to accurately predict the distant future. Scenarios offer a tool for imagining plausible and well-researched futures thereby enabling planning across a wider range of potential futures. When used well, this approach can spur learning and help in identifying emerging risks and opportunities.

Scenarios cannot take into account all aspects of the complexity of interrelationships and interdependencies of the real world. However, scenarios are a powerful tool for sensitizing decision makers to emergent key factors which can influence the outcome of their decisions. When used as a tool for guiding long-term capital decisions, scenarios can help managers to more effectively assess both the timing and scale of investments. They can also provide the time needed to create alternative financing and risk management options. It is in that manner that these scenarios are being prepared and used by WECC and its stakeholders in the reliability assessment and transmission planning processes.

The scenarios are based on the following key structural elements: (1) An anchoring "focus question" for all of the scenarios; (2) A set of "key drivers" representing trends and factors that must be reflected

in all of the scenarios; and (3) An organizing matrix structure based on two highly uncertain and very important key drivers. Each of these is described in this report.

Focus Question for the Scenarios

Scenario planning, as a tool for managing future uncertainty, enables stakeholders to create and test strategic responses given a diverse range of plausible future conditions. Good scenarios are based on a clear enunciation of the decisions and uncertainties at play: the “focus question” that ensures scenarios are developed with a clear sense of the issues at hand. Leading up to and during the scenario development workshop, the SDS agreed on the focus question detailed below.

Figure 1: The Focus Question Over the Next 20 Years

*How might **customer** demand for electric **services** in the Western Interconnection evolve as new **technologies** and policies create more **market options**, and with that, what risks and opportunities may emerge for the power **industry** in sustaining electric **reliability**?*

<i>How might customer demand</i>	How do we define customers, in what segments or categories? With DER? Grid connected?
<i>for electric services</i>	What services beyond commodity supply of electricity? What kinds of enhanced services?
<i>in the Western Interconnection evolve as new technologies</i>	Technology innovation that impacts distributed energy as well as utility scale power supply and delivery systems
<i>and policies</i>	Policies at all levels
<i>create more market options, and with that,</i>	Markets: regulated and unregulated Options: Power supplies
<i>what risks and opportunities may emerge for the power industry</i>	Who and what players will be in it?
<i>in sustaining electric reliability?</i>	What risks to the reliability of the Bulk Power System in the Western Interconnection? What standards and requirements will apply?

A Consistent Set of Key Drivers of Change

While scenario analysis does not allow accurate *predictions* of the future, it does provide a tool for rigorously imagining alternative *plausible futures* in which important decisions may play out. The most useful scenarios derive these imagined futures from a studied consideration of factors and trends (“key drivers”) that will most likely and powerfully influence future conditions.

For the following scenario narratives, the SDS agreed on the following initial set of key drivers shown below. This is still the initial stage of scenario development, and it is possible that other key drivers *might* be added, however, we think this list is adequate and covers the significant ground:

1. Changes in State and Provincial electric energy market policies
2. Changes in Federal electric energy market policies
3. Evolution of customer-side energy supply technology and service options

4. Changes in the character and shape of customer demand for electric power
5. Changes in utility-scale power supply options
6. Changes in State, Provincial, and Federal electric system regulations for reliability
7. Evolution of climate change and environmental issues on electric power service
8. Evolution of fuel markets in the electric power sector
9. Shifts in the cost of capital and financial markets
10. Economic growth within the Western Interconnection
11. Worldwide developments in the electric power industry

Key Drivers Summaries

1. Changes in State & Provincial Electric Energy Market Policies

Fourteen Western states, two Canadian provinces, and Northern Baja California¹ make up the geographical footprint of the Western Interconnection supported by WECC. They set policies and rate which directly impact how electricity markets function within their areas of jurisdiction and influence regional patterns as well. How electricity supply and demand are met is governed in large part by the policies set by individual states and provinces. This includes rules that govern markets - in conjunction with federal regulations - in places like California and Alberta where formal markets are in place to procure services such as imbalance energy and ancillary services. This also includes policies on cost recovery for plant investment in utility rates, renewable portfolio standards, climate change policies, rules governing the use of local distribution systems, and much more. Specific areas covered in this driver may include:

- Rules and policies that impact states and provinces abilities to expand their energy products and energy services markets.
- The emergence of new regional transmission organizations (RTOs) that can manage system reliability.
- Renewable portfolio standards and climate change mitigation policies established by states or provinces.
- Cost recovery regulations related to power sales from distributed energy resources (DER)².
- Rules or regulations that impact the price of power in wholesale energy markets.
- Rules and regulations that change as technological innovations allow for new energy products and services options.

2. Changes in Federal Electric Energy Market Policies

The US, Canadian, and Mexican national governments set policies that have national impacts on electric energy markets. In terms of assuring electric service reliability, the very foundation of WECC itself (in conjunction with FERC and NERC) is an example of this. Entities such as the FERC, NERC, the DOE, and other federal agencies that oversee nuclear power, oil and gas development, coal

¹ [Western Electricity Coordinating Council website](#)

² Distributed energy resources (“DER”) are those resources on the distribution system on either the utility side or the customer side of the end-use customer meter, including rooftop solar, energy storage, plug-in electric vehicles, demand response, and small gas generation.

development, and environmental standards are among those which can have great influence on the evolution of electricity markets and on the ways in which electricity services are delivered aside from market rules. Federal laws on consumer protection, taxes, and other areas can also have an influence on the evolution and nature of electric customer demand. Specific areas covered in this driver may include:

- Federal rules and regulations that affect cost recovery and electric rates for all power related generation, transmission or other power industry plant assets.
- Federal policies and regulations which impact fuels such as coal, natural gas, or nuclear fuels used in the power industry.
- Federal regulations or policies on environmental issues (air, water, land use) which can have effects on power industry activities of any kind (investment, operations, etc.).

3. Evolution of Customer-side Energy Technology and Supply Options

Distributed and smaller scale energy supply options are evolving and expanding rapidly, especially solar power (both rooftop and ground-based), energy storage, fuel cells, demand response, energy efficiency, and small-scale natural gas-fired generators. Commercial and industrial customers have distributed energy resource options as well as residential consumers. Technological innovation appears to be expanding those options by making them less costly, easier to install, and by adding more features for customer management and engagement. As electric distribution systems evolve, more of those distributed energy supply options may become a part of the electric power infrastructure and change how assuring electric power reliability is managed. Specific areas covered in this driver might include the emergence and evolution of:

- Devices or machines which can allow customers to generate power that can be used onsite or sold into wholesale or retail power markets.
- Devices or machines which allow the customer to store power that can be used onsite or sold into wholesale or retail power markets.
- Penetration of electric vehicles which allow new distributed power supply and demand-side management options within electric distribution systems, and which may affect wholesale or retail power markets.
- Systems that allow consumers to participate as buyers or sellers of power into wholesale or retail power markets, including the purchase and sale of customer demand.
- The emergence of technology in the electric distribution system that allows two-way power flows.
- The emergence of corporate (e.g., Google, Apple, Anheuser Busch, and industrial companies), municipal, and community-based activities (e.g., Community Choice Aggregation) to procure clean energy supplies and options.
- The emergence of power flow control technology that allows the Bulk-Power System (BPS) to respond quickly and effectively to meet rapid changes in customer energy use or energy supply.
- The emergence of information management systems that allow power sales and purchase options for customers with distributed energy resources (i.e., blockchain and other related

innovations).

4. Changes in the Character of Customer Demand for Electric Power

Customer demand for electric power can shift for a wide range of reasons, including costs and need for new features and benefits (like carbon reduction). The many segments of customers include large and small industrials, large and small commercial, large and small agriculture, and high income to low-income residential consumers. Customers within all of the segments may change the features they desire for electric power service as market conditions change. Economic factors may influence costs and features offered. Social values may shift and change how customers value different aspects of their electric power consumption, e.g., how clean or how exposed to cyber-security risk.

The basis upon which customers are segmented or put into categories may shift as customers adopt new service options (especially those customers who have some level of onsite self-generation or use new information services). Customers' adjustments will affect how power is supplied and thus have implications for sustaining electric reliability. Specific areas covered in this driver might include:

- Any social or economic issue which emerges that persuades electricity consumers to shift the values on which they make electricity purchasing decisions from any source.
- The emergence of any capability or technology that allows consumers to act on values (new or previously not actionable) related to electricity consumption.

5. Changes in Utility Scale Power Supply Options

Technological innovation, improved sales and marketing programs, and improvements in customer services will continue to occur at the wholesale and traditional utility-scale level of the electric business. Some customers may even prefer to maintain the historically traditional utility service and its levels of reliability. Some states and provinces may also prefer this form of service for regulatory reasons or for local economic and social factors. Additionally, technological innovation may continue to lower the cost of utility-scale clean energy supply options such as wind energy, solar power, and new forms of energy storage, as well as innovation and cost reductions in conventional technologies such as carbon capture and sequestration (CCS) and modular nuclear power generation, allowing them to compete effectively with distributed energy resource options. Technological innovation is also likely to enable utility-scale renewable resources to provide greater essential reliability service capabilities, and therefore additional flexible resource adequacy.

6. Changes in State and Federal Electric System Reliability Standards and Regulations

Federal, State and Provincial agencies directly set rules and standards that the power industry must follow to meet electric system reliability. Issues like climate change, cyber-security risks, and improved system resilience (in response to damaging climate events or physical attacks) are becoming increasingly important as they impact electric system reliability, and will likely lead to increased costs for electric power infrastructure. A clear understanding of these developments and how they may play out in the longer term is important for understanding the evolution of electric reliability. Additionally, as increasing amounts of variable generation resources are integrated into the system and relied upon in maintaining and assuring bulk electric system reliability, the dynamics of assuring system reliability

may change in comparison to what is required in traditional utility systems. Specific areas covered in this driver might include:

- Evolution of regulatory bodies in the Western Interconnection (ISO, EIM, regional planning organizations, etc.).
- Changes in statutory requirements from Federal or State agencies that load-serving entities have to meet to uphold reliability standards.
- The development of Regional Transmission Operators (RTO)³ beyond the current status in the Western Interconnection to take advantage of opportunities for broadened reserve sharing footprints, resulting in lower reserve margin requirements and other cost savings.

7. Evolution of the Impacts of Climate Change and Environmental Issues on Electric Power Service

Addressing climate change is a central issue in the evolution of the electric power supply systems in the US, Canada, and the world. Other environmental issues like air and water quality and land use are also important. Policies set by governmental agencies will influence electric supply and demand choices for all customers, and the cost of power will be impacted by those policies. How customers see and value climate and environmental issues will impact future legislation placed on the power industry. Specific areas covered in this driver might include developments in:

- Climate change that leads to new policies or regulations in the power industry.
- Monitoring and knowledge development about the impact of energy-related activities on the natural environment.
- State, provincial, and local leadership in climate policy that may outpace federal actions.

8. Evolution of Fuel Markets in the Electric Power Sector

All electric power generation requires a fuel source. Historically coal, natural gas, oil, and nuclear fuel have been dominant (sunlight, wind and water are not traditionally thought of as “fuel” though they serve similar purposes). It is therefore critical to understand the role of fuels in the power sector, particularly natural gas, including the transportation infrastructure (including pipelines and storage). How and at what levels these fuels will be used as the power system evolves will be central to how electric reliability will be met. Specific areas covered in this driver might include:

- Factors that influence prices or the supply of any fuels used to generate electric power.
- Regional, national or global developments which influence the price or supply of fuels used to generate electric power.
- Developments which might create a new source of fuel for power generation.
- Developments which might influence how fuels are used in power generation.
- Changes to the natural gas transmission infrastructure.
- Potential events that heighten awareness of the risks of methane leakage (fracking, the Aliso Canyon reservoir leaks, etc.)

³ See Appendix page 63 for the full text of a suggested additional driver on this topic

9. Shifts in the Cost of Capital and Financial Markets

Power industry assets are capital intensive investments and cost a lot of money, and often necessitate long-term borrowing and debt. Thus, the cost of capital is an essential component in the cost of the electric power supply generation, transmission, and distribution, and can influence the choice and use of supply options.

Tax incentives and financial structuring of securities can also have significant influences on option choices. As supply options are determined based on costs, there will be implications for meeting electric reliability standards based on the energy supply assets financed and built.

10. Economic Growth in the Western Interconnection

Economic growth is a prime driver in electricity demand growth and thus the need for additional power supplies. Economic growth is determined by a wide range of local, regional and national factors that play out differently in the states and provinces in the Western Interconnection. The different forms and levels of economic growth which vary across the Western Interconnection contribute to varied energy policy responses (prime examples being varied policies in support of renewable energy portfolio standards and addressing climate change). In this way, variations in economic growth can impact what actions and investments are made to assure and sustain electric reliability in the Western Interconnection.

11. Worldwide Developments in the Electric Power Industry

There are tremendous forces of change impacting the electric power industry worldwide, and we are seeing an acceleration of these changes driven by technology, policy choices, (e.g., addressing climate change), economics, and public demand. Many of those changes may influence or directly impact choices and changes in the US and, specifically, in the Western Interconnection power systems.

Examples of these changes may include:

- Technology innovations and applications in supply, distribution, and consumer power management devices.
- Technology innovations in distribution grid modernization.
- New utility business models and innovative power market structures.
- Changes in the amount and costs of financial capital needed (in particular levels of debt financing) to build energy-related assets which can lead to preferences for those with short-term financial advantages (i.e., faster revenue generation).
- Changes in regulatory structures and energy supplier business models which can be replicated widely across the power industry.
- Lessons learned from policy choices and implementation that can be replicated widely across the power industry.
- Global developments that impact supply and cost factors in the power supply.

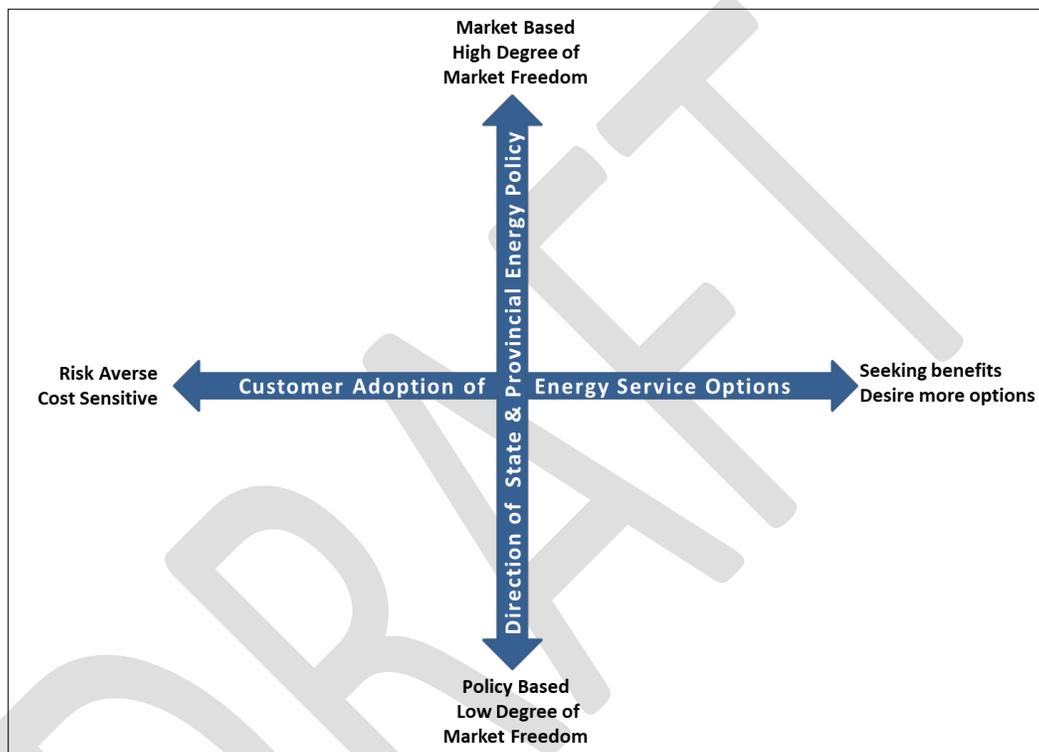
The Organizing Scenario Matrix

A “scenario matrix” is a tool for organizing and distinguishing ideas when creating scenarios. To create a matrix, the key drivers are first prioritized using the consensus or majority vote of a team to select

the two drivers that are simultaneously the most uncertain and the most important. Additionally, the top two drivers should be independent of one another.

These two drivers are then given a range of uncertainty, represented as an arrow with ends pointing in opposite directions to indicate polar extremes. Crossing these arrows represent two vectors (axes), and creates four quadrants that function as “scaffolding” for developing distinctive scenarios. This process was used during the SDS workshop to create the scenario matrix shown below.⁴

Figure 2: The Scenario Matrix



The organizing scenario matrix is a conceptual device in which the future can be explored within distinct quadrants as well as by moving among the quadrants over time. The matrix serves as a map or tool for distinguishing, at a glance, the major differences and starting assumptions in the imagined worlds. Movement among the quadrants to represent a plausible evolution of future conditions is discussed later in this report in the section on Early Indicators.

As seen above, the members selected “Customer Adoption of Energy Service Options” and “Changes in State and Provincial Energy Policy”⁵ as the two central vectors. These two vectors are sufficiently distinct because even though government policies may influence consumer choices, those policies do

⁴ During the workshop, the highest vote totals were for Drivers 1, 3, 4 and 7. Drivers 3 & 4 were combined to create the Evolution of Customer Supply & Demand. Drivers 1 and 7 were combined for the Changes in State & Provincial Policy.

⁵ The driver name was changed to “Direction of State and Provincial Energy Policy” in the matrix chart to allow for an understandable graduation of movement from low to high market freedom along this axis as opposed to just “change”.

not completely control or determine customer choice. This is clear when looking at other industries such as: the automotive industry (consumers do not always choose the cleanest and most fuel-efficient autos and are willing to pay “gas guzzler” taxes); cigarette smoking (many people choose to smoke, despite government policy that requires a statement on packages announcing the product will kill the user); and healthy food choices (over 40% of adult Americans are overweight).

In this light, we believe that consumers can and may make energy service choices that vary widely from any government policy directives. As technological developments provide new energy service options and as consumer values shift, we see significant future uncertainty in this area.

Each axis is discussed in more detail below, starting with the Horizontal Axis.

The Horizontal Axis: Customer Adoption of Energy Service Options

A factor that we think will contribute to consumers making a diverse set of choices about how they use electric energy services is the fact that electricity is not directly consumed, but is an input into getting other valuable services and products. Among those associated services are air conditioning and heating, lighting, the energizing of a wide assortment of tools and equipment, refrigeration, fueling all modes of transportation such as cars, trucks, rail, people movers, and many others.

Decisions about those associated services will in many cases override decisions about the efficient or most productive use of electricity. These decisions are so numerous, varied and diverse that we do not see how one or even a few government policies could completely determine consumer decisions.

Parsing Customer Segments

During the discussion of electric power customers, members also gave further thought as to how electricity customers might be put into distinct and useful categories. We anticipate further analysis of this issue as the scenario analysis process proceeds. As shown in Table 1 below, members saw customers in different segments which might have very different responses to developments within the scenario such as technology development, regulatory changes and shifts in customer values.

Within each segment a customer could have a demand-side interaction with its electric service provider or not, and the customer might have distributed energy resources in which it might use or share with the electric service provider.

Depending on the customer conditions, members thought consumers might vary widely in response to the different conditions in the scenarios. Customer responses could include high, moderate, low or no use of new product and service developments in the industry, and usage may be qualified by determining factors.

A version of the following Table specific to the scenario narrative will be in each of the scenarios to lend clarity and allow comparisons across the scenarios. The chart will describe how each Customer Segment responds to or uses the services listed across the top row of the Table.

Table A: Customer Segments and Choice

----- Electric Power Services or Products Offered to End Use Customers -----							
Customer Segment	Wholesale	Demand Side Management	Distributed Energy Resources	Local Micro-Grids	Self-Generation	Retail Choice	CCAs
Large commercial & industrial	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined	To Be Determined
Small-medium C&I							
Residential Rural*							
Residential Urban							
Agricultural							

*Based on a comment during the session, residential customers were split into the rural and urban categories.

When considering customer adoption of new energy product and service options, a model of the social and psychological factors that drive adoption of new technology-based products and services among different customers can be used as discussed below.

The differing volumes of *technology adoption* of new electric energy services within the electric power market sector, at the supplier, operator, or consumer levels which are incorporating emerging and innovative technologies is a key factor in differentiating the left and right sides of the organizing scenario matrix. In general, we would expect to see a smaller volume of adoption of new technologies in the left quadrants, and a higher volume of adoption in the right quadrants. It is critical to note that we are not speaking of the speed of technology *innovation* here, but rather, the volume of new innovations, once developed, coming into the marketplace, and accepted by consumers.

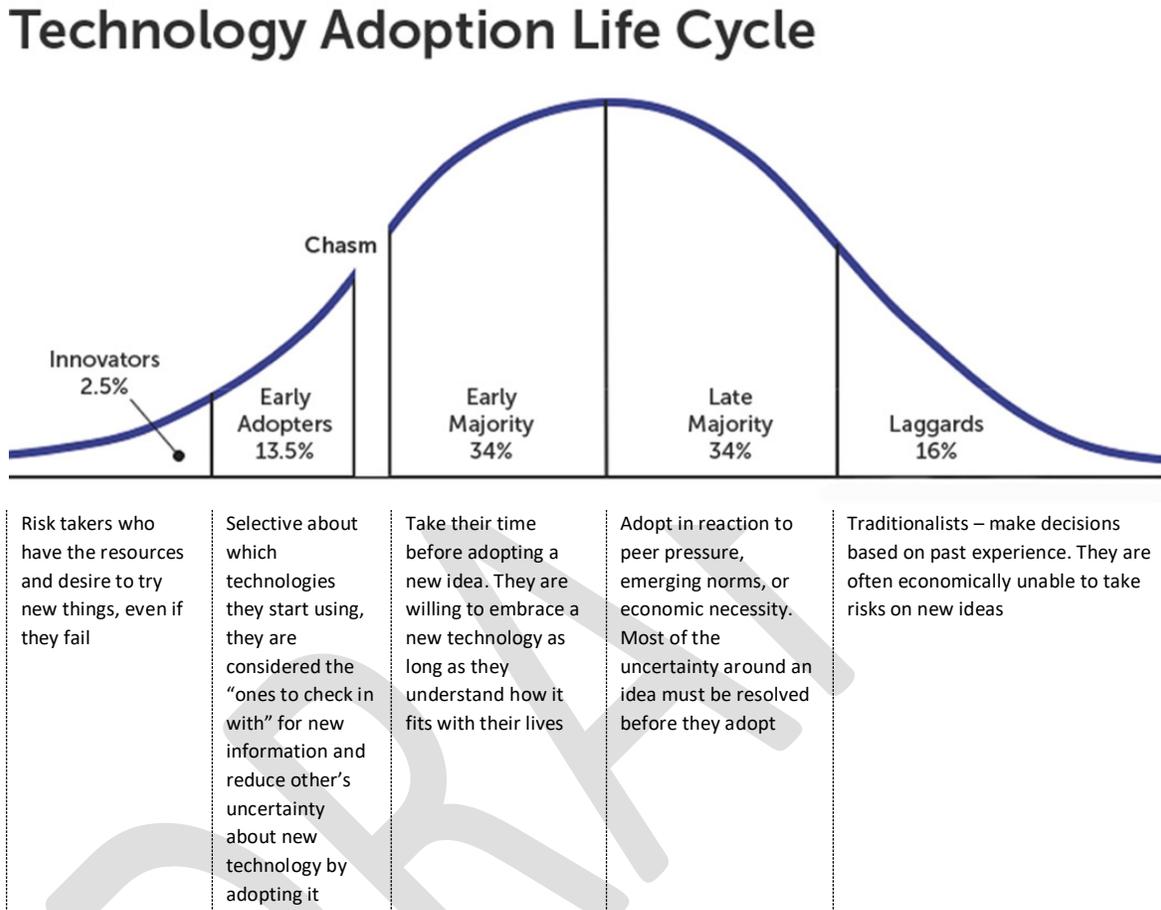
The Technology Adoption Lifecycle⁶ is a sociological model that describes the adoption or acceptance of a new product or innovation, according to the demographic and psychological characteristics of defined adopter groups. The process of adoption over time is typically illustrated as a classical normal distribution or "bell curve" shown in Figure 3 below.

The model indicates that the first group of people to use a new product is called **Innovators** (or **Visionaries**), followed by **Early Adopters**. Next come the **Early Majority** and **Late Majority**, and the last group to eventually adopt a product is called **Laggards**. It is important to remember that many products and services get stuck at the innovator & early adopter stages, and never progress to the early majority stage – effectively failing to penetrate the mainstream markets.

⁶ [Technology Adoption Lifecycle](#), Wikipedia, edited April 5 2018

In the figure below, the area between Innovators and the Early Majority is the Chasm, separating the mainstream market from the Early Adopter market.⁷

Figure 3: Technology Adoption Lifecycle



One way that we might use this model in the scenarios is to imagine different paces of adoption of technology-based products and services by customers within the different customer segments in each scenario (see Table: Customer Choice above). For example, on the right side of the scenario matrix (scenarios 2 and 4 - see Figure 2 above) we might imagine that the volume of adoption and movement from the innovators through to the laggards progresses through a larger number of electric energy services than on the left side (scenarios 1 and 3). As the scenario process proceeds, this model can be used to assess how consumers may adopt energy services and products, and thus influence how energy resources are used to meet reliability.

⁷ NOTE: For additional discussion on this model and how it is used, see *The Technology Adoption Hype Cycle – Crossing the Chasm* Appendix 6, on page 68

The Vertical Axis: Direction of State and Provincial Energy Policy

During the scenario development workshop, there was significant discussion about the factors that might lead to changes in state and local energy services regulation and policies. Ideas included:

- A desire to meet environmental and air quality objectives;
- Policies to allow consumer and market forces to determine energy service choices;
- Policies that would support more local control;
- Policies that would support the introduction of innovative energy service options; and
- Policies to protect the interest of the larger community in a connected power grid.

Parsing Energy Policy and Regulation

Shown below is a high-level set of categories for suggesting how state, provincial and local regulations might be active in the current and evolving electric power sector. This is a suggested “work in progress” to show how policies and regulations may affect each scenario.

Each scenario will have a version of this table with some explanation of how policies and regulations are playing out in support of the narrative. Readers will note that there is a consistent view in all of the scenarios that Federal regulatory policies are seen as supporting leadership by State and Provincial regulations.

Table B: Category & Forms of Oversight

Policy Area	Statewide Oversight	Local (County/City) Oversight	Scenario
Electric Rates, Prices and Revenue	State/Provincial PUCs	For municipal utilities and community aggregation	
Renewable Portfolio Standards & Climate	State/Provincial Laws and PUCs	For municipal utilities and community aggregation	
Air Quality, Water and Land Use	State/Provincial Laws, Commissions & Agencies	City & County Departments and Agencies	
Capital/Resource Investment Planning Approval	State/Provincial Laws, ISOs, Commissions & Agencies	For municipal utilities and community aggregation	
Operating standards, equipment & Safety	State/Provincial approved Industry Assoc.	State & local oversight in areas like fire codes, building codes, etc.	
Consumer protection and product quality	State/Provincial Laws and Approved Industry Associations	Generally not applicable	

Areas of State and Federal Regulation and Policy Interface

Environmental Protection: Air quality, Emissions and Endangered Species	Regional Planning: Rates and Costs Sharing	Siting: Renewable Energy Zones and Protected Lands
Scenario Activity		

In the scenarios below these ideas are used to create, what we trust will be plausible and diverse future worlds, which will present diverse conditions in which to assess long-term electric service reliability in the Western Interconnection.

Point of View of the Scenarios

The scenarios are written from the point of view of a neutral observer (similar to a newspaper reporter) explaining the future as it is unfolding. In addition to the events and trends playing out in relation to the key drivers, the observer identifies the actions of key stakeholder groups:

1. Regulators, legislators and government entities;
2. Companies in the electricity industry (investor-owned utilities, power plant and transmission system owners, operators, developers and new entrants);
3. Activists and advocates for various causes, especially the environment; and
4. Electric energy consumers (residential, commercial, industrial and agricultural).

Since this is an exercise in storytelling, different stakeholders may be active or dormant in particular timeframes in each of the scenarios.

Overview of the Scenario Narratives

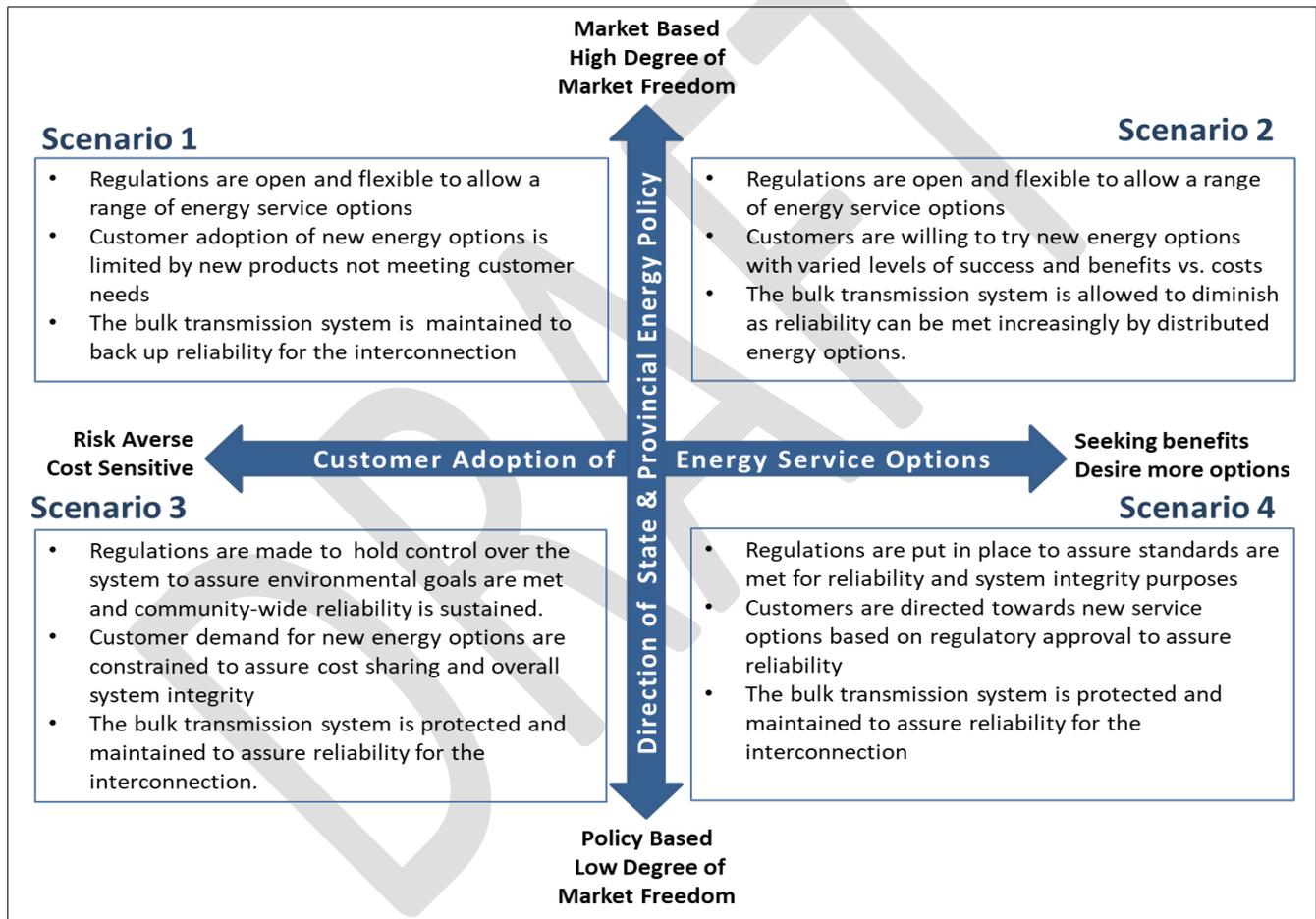
The scenario narratives are a best effort at creating plausible, understandable and diverse stories about how the future of electric services used by customers in the Western Interconnection may evolve, and with those developments, what might be implications for how reliable electric services are attained. The scenarios are not an attempt to accurately predict the future, as this is not humanly possible, especially about such a complex environment as electric power. This new set of scenarios have the benefit of the 2012 WECC scenarios (the Legacy Scenarios) which were “top-down” in the sense that they looked at broad industry level supply and demand conditions to determine the need for new supply and transmission resources. Key questions have shed light on the Legacy Scenarios from this earlier top-down view including: the impact of levels of economic growth, variations in fuel prices, variations in the price of carbon, and variations in the cost of many types of electric supply resources (solar power, wind energy, etc.).

The new 2018 Scenarios take a “bottom-up” and distributed view of electric energy markets, and attempt to start with the end-use customer and how his or her decisions will impact the evolution of the power industry. Those bottom-up decisions are impacted by the full range of key drivers set forth above. The scenarios below are thus an attempt at imagining various futures for how the key drivers may interact to create potential electric energy business environments. To be of most value for WECC reliability planning, the scenarios need to be diverse and offer different challenges, risks, and opportunities. By thinking through and analyzing diverse futures, WECC can identify a range of those risks and opportunities related to the uncertainties surrounding electric reliability. In particular, WECC will use these scenarios to assess the risks to and uses of the bulk transmission system in the Western Interconnection. In this light, we have intentionally created narratives that suggest very different futures. The narratives will be presented in the following format:

- A high-level summary of the essential ideas of the story.
- A space for showing key quantitative variables relevant to the scenario so they can be compared against those of the other scenarios.
- A three-stage narrative that covers the first five years, the middle eight years and the final seven years of a 20 year period.
- Potential reliability risks that could emerge if the scenario comes to pass.

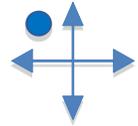
Based on the key drivers and the focus on electric reliability assurance, Figure 4 below describes the essential relative points of the scenarios, which are expanded on in the narratives.

Figure 4: Scenario Matrix with Description⁸



The full scenario narratives follow.

⁸ NOTE: For a Comparison of the four scenarios by Key Driving Forces across the four scenarios, please see Appendix 1 on page 58



Scenario 1: *Open market approach to State & Provincial Policy with Restricted choices in the Evolution of Customer Supply and Demand*

Scenario Overview

- During the next 20 years, this is a world that experiences intermittent chaos due to social and political conflicts, and as a result, regulators in different states and provinces in the Western Interconnection pursue uncoordinated energy policies. On the whole, the policies across the region do lean toward allowing more choices for energy services for consumers, but in many cases, the products and services meet only some consumer expectations and value, and in other cases, the benefits do not exceed the costs.
- State and local regulators, though embracing innovation and change in general, are watchful in overseeing the net benefits of proposed new options, and go about it in a variety of ways.
- In light of variation in energy policies, both energy service providers and consumers in all segments are hesitant to take on what may be innovative new options. The benefits of these new offerings must prove worthwhile and meet customer values.
- Residential customers with different values, incomes, appetites for risk, and living circumstances will try new electric service options based on wide variations in their personal criteria.
- Utility-scale electric power operations and regional coordination evolve in the Western Interconnections to assure and sustain reliability so that actions to meet environmental goals – but only at reasonable costs. Utility-scale investments in the power supply are a competitive check on distributed power options.
- Large Commercial & Industrial customers work within regulated options to integrate the lowest cost and most useful electric service options that meet their operating needs.
- New fossil-fuel powered generation investments are limited to those situations where it is the least cost alternative to support system reliability.
- Economic growth is sufficient over the long term to drive growth in demand for power, but there are periods of instability in demand growth.
- Capital markets are deep and resilient enough to fund new electric energy service innovations provided they have market demand.
- Worldwide developments in the power sector have only marginal effects on what is going on in the Western Interconnection because there is such wide variation of adoption of new technologies within each State and Province.
- By 2038, there are disparate electric service markets within the Western Interconnection with some looking very much like traditional regulated services, and others supporting experiments, pilots, and emerging markets for innovative services.

Key Scenario 1 Metrics⁹

Key Variable	Metrics for Scenario 1
To be determined	To be determined

The Early Years 2018-2023: *Space to Try a Little of Everything*

This world begins in 2018 with state and provincial regulators overseeing the electric industry in the Western Interconnection making their best efforts to interpret the widely varying signals from power customers about what rights, options, and opportunities they want. In high-income urban areas, there is an appetite to take risks and pay premiums for more control, independence, and choice. In rural areas where incomes are lower and lives are lived at a slower pace, many customers are focused on lowest cost above all other values, and have little interest in buying equipment or services which may lead to increased financial and electric service risks. This split among customers is echoed in the political sphere where social, cultural and economic choices are subject to polarizing debates.¹⁰

As time unfolds there is movement in many directions in each state and province to make policy adjustments focused on the electric power sector that influences how electric services are provided that fit with the moment. A coordinated set of policies of what new services are allowed, how their prices are regulated or not, or if prices are included in rates or not, across the Western Interconnection do not arise. In light of this, regulatory policies tend to lean toward more choice for customers as the safest option, but regulators are careful to retain their power to oversee and allocate utility and service costs incurred by customers.

Electricity customers in all segments—large and small, industrial and commercial, residential urban and rural—are offered a wide range of new service options. This includes getting commodity power from a provider other than the local distribution utility, as well as opportunities to participate in customer aggregation plays and new micro-grid developments. There are products that promise new information-intensive services and all manner of behind-the-meter (BTM) equipment including battery storage and devices that promise increased energy efficiency and an ability to follow price signals.

At the same time, traditional power companies that produce power and buy it at the wholesale level, and who manage power systems at the bulk transmission and distribution level are also taking advantage of technological and market developments that allow them to offer competitively priced power with rate and service options for customers. Utility-scale renewable power costs are falling, and the use of utility-scale storage systems allows new ways to manage reliability with reduced grid

⁹ NOTE: Metrics for scoping and studying the scenarios will be developed by the SDS later in 2018

¹⁰ [California customer choice advocates, IOUs face off on departing load charge.](#) Utility Dive, April 23, 2018

investments.¹¹ Some states and provinces in the Western Interconnection give support to regional cooperation to assure reliability and to take advantage of lower cost seasonal power. Wind and solar power in particular are traded between California and other states with bulk transmission connections. Within distribution systems, some load-serving entities utilize distributed generation resources as they find ways to use them flexibly to lower costs and create options for meeting reliability standards.

Depending on the needs and wants of a particular customer, multiple choices do exist. For some customers price matters most. For others, a balance between costs and benefits, with benefits varying widely from personal control, mobility, information intensity, environmental values, and other factors only they can measure drive their decisions. As many of the services are new and based on emerging technology, many of the services marketed to consumers in terms of lower costs or more engagement fail to deliver the promised value or the final features are not as promised. As time unfolds both customers and regulators are in learning mode. Regulators are careful not to allow too many “experiments or pilots” in rate structures for innovations that are being heavily promoted, but with no operating history. However, when new power system innovations work well and allow more flexibility in operations, regulators push for more.

Activity and shifts in electric markets are occurring in an economic environment subject to disruption based on several factors that are not well coordinated. These include national trade and tariff policies that are impacting export markets for Western-based companies, fiscal deficits at the Federal level that are causing increases in interest rates, and contested immigration policies that are disrupting labor markets in manufacturing and agriculture.

There is widespread concern among voters that policies in the social, cultural and economic spheres are moving too far in conflicting directions. This leads some residential power customers to feel they should disconnect from the power grid for their own independence and desire for security and control. Other customers are demanding that regulators put a priority on the needs of the community and its institutions (hospitals, schools, government offices, etc.), and not forget that electricity is a public good that benefits their nation as a whole.

Looking toward international development in the power industry during these years provides little direction, because almost any approach to service can be found somewhere else in the world and with non-conclusive results, or results that apply only to that narrow environment. What is commonly seen, however, is steady experimentation, testing of new options, and continuous investment in potential innovations that might reduce costs. Increasing problems with lithium and cobalt supplies in the global market provide new encouragement for more research on different chemical bases and new advanced materials for new battery technologies.

The Middle Years 2024-2031: *Fracturing the Grid*

During these years, the lack of coordination and cooperation between the states and provinces in the

¹¹ Grid Update Costs: [Is the third pillar of electricity delivery preventing the building of the first two?](#) Utility Dive, February

Western Interconnection starts the ball rolling toward the longer-term fracturing of the bulk power system in the West.¹² Some states and provinces decide to continue to support the bulk system while others effectively opt out by not being willing to participate in any costs related to the expansion of the grid. Some agree to pay the absolute minimum in other costs to assure access in emergencies or in the event of catastrophic events. In the longer term, the operations of the bulk power system will have to be restructured.

Underneath the fracturing of the system are significant policy disagreements about how to handle the costs associated with providing electric power services, and who should incur them based on what received benefits. In some states and provinces there is a strong concern for high-income customers who can afford distributed generation options pushing costs on customers who remain tied to the traditional system. In others, there are concerns about paying for reserve capacity to assure reliability when wind and solar power sources are not delivering. Other states are trying to avoid costly the “duck curve” phenomena when there is steep daily ramping up and down of energy needs with impacts on energy prices. On the most fundamental policy level, some state regulatory rulings are aimed at assuring the notion that power is a public good that does not exist in a vacuum from other issues of economic and community development. With such variations in concern and actions, it is not surprising that an un-coordinated field of energy policies emerge in the Western Interconnection.

Table 1.1: Category & Forms of Oversight

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 1
Electric Rates, Prices and Revenue	State/Provincial PUCs	For municipal utilities and community aggregation	Wide variations across the region with little or no commonality
Renewable Portfolio Standards & Climate	State/Provincial Laws and PUCs	For municipal utilities and community aggregation	RPS are maintained where they exist, and climate issues are addressed with widely varying laws and actions
Air Quality, Water and Land Use	State/Provincial Laws, Commissions & Agencies	City & County Departments and Agencies	Concerns about environment quality are common throughout the region, actions may vary widely

¹² Reader Note: Scenario 1 presumes changes in how the electric grid is regulated that would allow for the events in this section to unfold. As of this writing, July 31 2018, there are already current early stage discussions about revising FERC Order 1000 within the power industry. However, it is too early to know just what changes might occur. At the same time, recent FERC rulings would seem to be allowing for greater flexibility for states to manage their portions of the grid. Ongoing trends research will watch these developments as they unfold.

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 1
Capital/Resource Investment Planning Approval	State/Provincial Laws, ISOs, Commissions & Agencies	For municipal utilities and community aggregation	Investments and approvals are considered from a cost-benefit view of tested and proven technology and infrastructure
Operating standards, equipment & Safety	State/Provincial approved Industry Assoc.	State & local oversight in areas like fire codes, building codes, etc.	Wide standards across the region
Consumer protection and product quality	State/Provincial Laws and Approved Industry Associations	Generally not applicable	High focus on consumer protection and quality of products

Areas of State and Federal Regulation and Policy Interface

Environmental Protection: Air quality, Emissions and Endangered Species	Regional Planning: Rates and Costs Sharing	Siting: Renewable Energy Zones and Protected Lands
The Federal government is basically not involved or supportive as states and provinces take the lead		

Technological innovation does not help to bring order to the electric energy services market because the fractured market creates fractured opportunities for sales and revenue. Investment in start-ups and new services decline during these years for lack of a stable open market environment¹³ with supportive regulatory policies.

During an economic downturn in these years, the price of energy falls and drives out a lot of competition in the market. The Federal government pulls back on spending including reductions in entitlement payments that hurt many rural communities.

Economic pressures within the large integrated utility segment of the electric industry force structural rationalization, and drives some consolidation as companies merge, are taken over, or drop out, and with that comes reductions or limits in choice for some customers. Wholesale power supply markets are also pushed to rationalize as margins are squeezed during this downturn.

Solar panels lose efficiency over time and usually become uneconomic after 20 years, and some customers who self-generate with early adopted solar facilities solar are finding them increasingly obsolete and uneconomic, and make arrangements to reconnect to the grid as price risks for long-term replacement equipment emerge. Wind, solar, and storage technologies continue to see incremental improvements in materials, production and operating costs, and see consistent price and cost declines leading to a steady greening of the power system. Clean energy is still politically supported as climate events in the forms of extreme storms and droughts continue worldwide and particularly in the western US. Fossil-fueled generation continues on its long-term decline with coal plants

¹³ [Xcel pulls out of Mountain West in blow to SPP market expansion](#), Utility Dive, April 23, 2018

decommissioned and replaced by renewable energy sources.

To resolve the cost and market issues in the electricity sector, some states move to performance-based rates providing incentives for local power companies to take on innovative options that open up alternative power supply options for customers. Some states and provinces approve varying levels of residential demand charges to assure reliability and shared costs. In a major shift in the Western Interconnection, several states enter into regional transmission organizations to manage costs and improve reliable access to power.

All states and provinces in the West increase communication and notifications with customers about new rules and regulations so that they can become more sophisticated and wiser consumers. Customers with electric vehicles and other behind the meter devices are interested in more empowerment to match their lifestyles. Other customers simply want to know what choices to make to keep their bills as low as possible while avoiding information overload.

Table 1.2: Customer Segments and Choice

----- Electric Power Services or Products Offered to End Use Customers -----							
Customer Segment	Wholesale	Demand Side Management	Distributed Energy Resources	Local Micro-Grids	Self-Generation	Retail Choice	CCAs
Large commercial & industrial	At current levels unless increased by new technology	High adoption and use	High adoption and use based on cost benefits	Limited availability and use	High use by high power users	High use where offered – cost and values-driven	Not applicable
Small-medium C&I	At current levels unless increased by new technology	High adoption and use	High use if available	Low usage	Moderate to low use: usually rooftop solar	Moderate to high use if offered, cost or values-driven	At current levels unless increased by customer demand, technology or policy
Residential Rural*	Not applicable	Limited to High use with wide regional variation	Limited to offering by incumbent utility	Little or no usage	Moderate rooftop solar, region dependent	Moderate to high use if offered, cost or values-driven	At current levels unless increased by customer demand, technology or policy

----- Electric Power Services or Products Offered to End Use Customers -----							
Customer Segment	Wholesale	Demand Side Management	Distributed Energy Resources	Local Micro-Grids	Self-Generation	Retail Choice	CCAs
Residential Urban	Not applicable	High to Limited use and adoption with wide regional variations	Moderate to high usage where available	Moderate to high usage where available	Moderate to high rooftop solar, wide regional variations	High to moderate use if clear cost and values benefits	At current levels unless increased by customer demand, technology or policy
Agricultural	At current levels for large agricultural companies	High use and adoption	Left to local Co-ops	Limited to Co-op actions	Moderate solar and wind where climate allows	Limited to Co-op offerings	Not applicable

The End Years 2032-2038: *The Puzzle of the Western Interconnection*

Just as a puzzle can have oddly shaped pieces but still fit together, the Western Interconnection is now a mixed picture that somehow holds together so that power across the Interconnection is reliable, but on a base of varying costs, rules and operating conditions. There are some areas that are “doing their own thing,” and only loosely connected to the bulk power system. Micro-grids are common. Consumer choice aggregation is in place throughout the West, especially in highly populated areas. However, traditional integrated power companies are also serving many customers the old-fashioned way at low costs while meeting all of their renewable portfolio requirements. Those same integrated power companies have various customer choice structures¹⁴ operating within their distribution networks. There are individual consumers who are totally independent of the grid as well.

This energy system in the West is reflective of the shifts which have occurred in society and in how people live. In some urban and rural high-income pockets, the distribution grid is very high tech and interactive with faster adoption of smart technologies. Some people can and choose to live very isolated lifestyles. In other areas, there is a deep sense of community and shared interests where local power companies have developed customer relationships with demand-side options that support low cost and very reliable power. A common feature in the way energy markets work and society is organized is the lack of Federal government involvement.

The Federal government is largely viewed as ineffective, incapable of offering resources due to its deficits, and out of touch with local priorities. Regional cooperation in energy markets, when it occurs, is negotiated by the states and provinces, and is mostly around joint efforts to address climate issues and keep energy costs low.

¹⁴ [PG&E Proposes Reforms to Support the State’s Clean Energy Future. Business Wire, April 3, 2018](#)

With moderate economic growth returning during these years state leaders look to stabilize conditions and allow people the freedom to choose how they want to live. Proactive people are allowed to pursue activities they want, while people happy with the status quo can be left to live within the bounds they choose. Electric power options and services are available for both kinds of customers.

The Western Interconnection is compared to many countries in Europe who have similar wide variations driven by culture, history, and tolerance for incurring costs to meet environmental standards or to integrate promising technology - Just as Germany and Italy may differ, so may California and Idaho. Each place has chosen different mixes of technology, standards, policies, and rules to create a power system that best fits local concerns. There is no “right” or “wrong.” There are just differences.

Table 1.3 – Reliability Assurance and Bulk System Implications

Implications for Electric Reliability and Use of the Bulk Electric System	
Resource Adequacy	Throughout the years even as the system begins to fracture, states and provinces ensure resource adequacy within their boundaries, and interconnection-wide resource adequacy through just enough cooperation
Operational Integrity Risks	High risk in the early and middle years as the system balkanizes, mitigated in the ending years as the region comes to grips with how to manage and plan within a system made up of so many disparate pieces and configurations
Infrastructure Integrity Risks	Regional entities are able to maintain their infrastructure well enough to manage and mitigate degradation – some regions are more effective and proactive than others, while others delay as long as possible to take corrective actions
System Stability Risks	The system is managed as separate stable parts with just enough connections and cooperation to maintain overall stability

Scenario 1 Potential Key Questions for Analysis

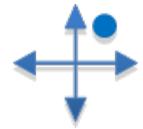
1. How might customer and other behind the meter energy products and services be captured for planning purposes?
 - a. What key categories of energy services and products might be selected for scale?
2. What potential reliability risks should we be thinking about if the world of Scenario 1 comes to pass?

Scenario 1 Early Indicators and Complete Scenario Metrics

Early Indicators for Scenario 1 ¹⁵	
Indicator	Definition/Rationale
Change in State/Provincial Energy Policies	Designed to provide open markets for products, services, and customer choice options
Customer Adoption of Energy Service Options	Wide differences in and moderate speed of adoption of new energy product and service options across the Western Interconnection
Limited success of pilot projects in new energy services and products that enable more customer choice options	Delays the proliferation and availability of customer choice options
Fracturing of electric energy markets across the Western Interconnection away from current patterns	Customer choice driven, and supported through state and provincial regulations and policies

Key Variable	Metrics for Scenario 1
To be determined	To be determined

¹⁵ See also the General Early Indicators in Appendix 7 on page 70



Scenario 2: *An Open Market Approach to State & Provincial Policy with High Levels of Choice in the Evolution of Customer Supply and Demand*

Scenario Overview

- This is a world in which attempts are made over 20 years by innovative companies to shift electric power services to a more distributed supply structure in which resources are distributed closer around the end consumer and varied new reliability service options are available.
- The magnitude of the effort and challenges in making a quick transition to a more distributed structure, even with innovation, prove to be difficult. While traditional and embedded patterns of customer activity are slow to change and constrain the pace of market acceptance in some areas, in some states and provinces in the Western Interconnection the transition to a distributed structure is moving forward.
- State, provincial and local regulations largely support and facilitate the introduction of new electric energy services into the market, but do so carefully to assure that customers incur reliable power at fair costs. Federal energy policies play a secondary role to states and provinces provided that power supplies are reliable.
- All customer segments are willing to try new innovative offerings, but are careful to fully weigh the costs versus the benefits before wide adoption can occur. Large Commercial and Industrial customers and local organized communities and micro-grids find the most beneficial and useful applications due to their scale.
- Consumers in all segments are concerned, along with regulators, about climate change issues and are interested in energy services which address those concerns provided that costs are reasonable and power is reliable.
- Exposure to cyber-security and privacy issues also greatly concern regulatory bodies, utilities and customers.
- Utility-scale power options play a role in meeting customer and environmental concerns and compete with distributed electric service options. Some distribution-only companies emerge.
- Economic growth in the Western Interconnection is sufficient throughout the period to allow the adoption of new electric service options in an open market.
- Capital markets are vibrant and seek to fund new electric energy service options provided they find sufficient long-term market demand.
- Coal and natural gas based generation are allowed to languish as they cannot compete with new market options which meet environmental requirements, consumer demands and allow for continued reliable system operations.
- Worldwide developments in the power industry move toward more distributed innovative choices with varied applications depending on local conditions.
- By the end of the scenario, the vision of a fully distributed electric power market structure is becoming more visible, but not yet fully achieved as not all new technology and benefits are

proven throughout the market. However, in early adopter states and provinces, distributed energy structures are proving both reliable and economic. Some decentralized power generation and transmission are still needed to ensure grid reliability, and the bulk electric system still provides economic benefits by facilitating regional energy markets.

Key Scenario 2 Metrics¹⁶

Key Variable	Metrics for Scenario 2
To be determined	To be determined

The Early Years 2018-2023: Pushing Customer Choice Through Innovation

This world begins in 2018 with electricity customers in several states in the Western Interconnection (especially California, Washington, Colorado, and Oregon) expressing interests in more innovative electric energy services and choices of supply, driven in large part by social values and cost savings. Regulators in these states are beginning to support policies that open up options and signal support to entrepreneurs and innovative businesses who want to expand a market of new energy products and services which they feel will give customers more choice, with whole new areas of information-based services, alternative supply options and cleaner energy mixes.

Customers throughout the wider Western Interconnection are aware of these new options as new products and services enter the marketplace, yet in many cases they are happy to wait until they are tested, proven, and economical. Customers have interests in improving electricity services (costs & rate options, demand-side management, ability to sell excess self-generated power into the grid, and others), lowering costs and having the ability to choose suppliers, but have concerns about the entry cost versus the promised benefits.

Adding to the initial inertia in the marketplace are those customers who are quite happy with the status quo – they already have cheap and

What Electricity Customers Might Drive a Push Towards Higher Levels of Energy Services?

Smart Grid Collaborative conducted a survey in 2017 to examine how customers interact with electricity providers and utility programs, and how they view a broad suite of “smart grid” technologies and programs. The 2017 survey obtained responses submitted online from 1,652 individuals sampled from each of the nine U.S. census divisions.

Based on the survey answers, the respondents were then categorized in three broad groups: Always Engaged, Rarely Engaged and Selectively Engaged.

Within those segments, the report identified five sub-groups: Green Champions, Movers and Shakers, Technology Cautious, Savings Seekers, and Status Quo. The study result summary is in Appendix 2 on page 61.

¹⁶ NOTE: Metrics for scoping and studying the scenarios will be developed by the SDS later in 2018

reliable electricity, and feel their current supplier, usually a utility, is doing a good job.

New entrepreneurial companies anxious to compete in the electric energy service space emerge with creative new options: they feel the power industry is an outdated model that is ripe for disruption and innovation. They believe that emerging digital-based technologies, advanced materials, information processing, sensor-based metering, and communications technologies, along with distributed generation, can be applied to the power industry shifting the whole system from a centralized monolith toward a more distributed structure where customer needs are met closer to the end-user, and more in line with their values and needs.

These companies see cost reductions in providing smaller scale distributed and on-site power supply using solar energy, battery technology, and energy efficiency as the future, especially when combined with local micro-grids. The challenge is to make all of this come true by offering customers new retail choices, products and services that deliver on their promises at competitive costs, and provide real additions to value over the traditional reliable and safe power system, while meeting customer lifestyle choices.¹⁷

With a still growing economy and low unemployment in the early years of this world, there is a positive business environment for risk-taking in energy and other industries, so the ideas about disrupting the power industry are not extraordinary. State and Provincial regulation in the power sector have been on a trend to address clean power and climate issues for well over a decade as evidenced by renewable portfolio standards and renewable electricity programs, coupled with tax breaks and other incentives to support wind, solar and battery storage technologies. California, Washington, Oregon, and Colorado lead this effort in the Western Interconnection, but other states that are dealing with slower economic growth and higher unemployment continue to support existing fossil generation, as maintaining jobs is top of mind. Power costs from wind, solar and storage technologies have been on long-term declines increasing their competitiveness. New options are being tested in grid modernization, especially in areas where more situational awareness can contribute to safer and more reliable operations and reduce costs. It is in this environment that a vision of a transformed electric power sector finds substantial support.

However, a complete look at market conditions in the power sector in the West points to some other important considerations. Electric power demand is not growing rapidly when compared to other products, 1% to 1.5% growth is considered normal and the long-term range of expected demand growth is flat as electricity demand continues to decouple further from economic growth. Excess generation in some states and provinces that have built large bases of renewable power continues to result in power curtailment and very low wholesale power purchase prices periodically through the year.¹⁸ Incumbent utilities and traditional electric service companies continue to serve customers well with highly reliable, safe, and reasonably priced power.

¹⁷ [Retail Choice in Electricity: What Have We Learned in 20 Years?](#) Christiansen Associates, February 2016

¹⁸ LBNL Study: As Renewables Added, [Lower Wholesale Prices, Lots of Price Volatility](#). Lawrence Berkeley National Laboratory, May 16, 2017

The regulation and rules put in place over many decades have generally served power customers well and provided a vital service to the health and wealth of communities as a whole. Increases in utility rates have been moderate and regulation provides oversight to protect consumers, and new electric service options must compete with this existing reality.

Issues seen in the recent past in the implementation of electric service innovations, including concerns about cost shifting (net metering); retail choice options with alternative supplier that have not always delivered lower cost and reliable power; and some products sitting on the customer's side of the meter have been of poor quality leading to operational failures, cyber-security and privacy risks, and provide a sense of caution in most markets. While those experiences have taught consumers and regulators to not relax their oversight of the industry, there is a willingness to support new ideas and innovation, and some markets are allowed to willingly push the envelope by betting on technology to provide solutions.

Early on, due to vibrant national economies there is plenty of investment capital to support new energy options, so there is a steady stream of announcements of new ventures and technological advancements that portend potential new ideas and disruption from old patterns. Companies in China, Europe and across the US are sharing ideas and information globally with expectations of global market potential. The long-term future of natural gas is standing on solid ground with supply supported by continuing improvements in production and cost, with concerns about carbon emissions in some but not all parts of the world.

Companies looking to be innovators in the power industry counter the talk about low fossil fuel costs with reports on the growth in electric vehicles, expanding cap & trade markets, micro-grid investments by commercial and industrial companies and local communities, and progress in customer aggregation in many areas of the Western Interconnection. They predict that in the long-term, as clean energy supply technology costs continue to decline, fossil fuel generation will be pushed to the margins. Incumbent utilities see and understand these changes, and feeling the pressure on the traditional business model forward-thinking companies begin looking at ways to maintain their market share. As new services and retail choices enter the market, initial costs and benefits provide savings to customers and early reports of customer satisfaction with new features points toward continued investment.

Short-term issues related to power curtailment and low wholesale power purchase prices are seen as resolvable with better information and load forecasting systems. Federal energy policies also are showing favor for innovation with tax breaks, market opening directives, and increased R&D funding, however, FERC and Canadian regulators continue to monitor local, state, and provincial policies to assure reliability and overall power system integrity. A more ominous signal is seen as cracks in the system are beginning to show at the distribution level, as more and more distributed generation is added and must be integrated into the system.

The Middle Years 2024-2031: *The Power System in Turmoil*

As state and provincial regulators pursue electric power industry innovation during this period, they are also circumspect in retaining their oversight responsibilities to assure customer costs are fair and reasonable and that electric power is reliable.

After 15 years of economic recovery from the 2008 recession, the US economy has finally begun to slow. As the downturn deepens more and more customers, residential and small business especially, take advantage of any means at their disposal to reduce their cost of living and operating costs. Reducing their power bills seem like a good option as electric service companies begin to compete more aggressively for customers with claims of costs savings and service benefits (some of which are highly questionable). At the same time, utilities have begun offering many of the same power management services and power choices as they attempt to maintain market share as more customers begin to flee traditional providers.

Sure signs that some regulations and policies need changing are the rise in residential and small commercial customer complaints, and increasing turmoil in financial markets related to the investment performance of companies in the power sector. Customers are complaining about broken promises for lower cost power supplies within customer aggregation areas. Customers are unhappy with cyber-security¹⁹ and privacy breaches related to customer's energy use and personal and financial data as providers push to market poorly tested services and retail choice option programs. Customers are finding it difficult to contact real people for customer service complaints as more and more companies put too much faith in automated processes to try and hold down operating costs.

Compounding these emerging problems is the difficulty in understanding new rate and tariff structures that can cause unexpected increases in customer bills. Customers who are able to switch retail service providers are unclear on the details of their contracts and their options to switch back to previous providers. Some of the companies who entered the electric energy services market did so with very little capital as they were in "start-up" mode. Many burned through their initial capital before generating significant revenues, much less real profits. With investment capital retreating in the slower economy, some of these companies declare bankruptcy, and leave customers with no alternative options and lost payments for services never delivered.

Industrial and large-scale commercial customers who have long used demand-side management and distributed and self-generation technologies leveraged to manage energy costs have an easier time. Almost all of their services, technology, and systems providers have focused on these customers for decades, are usually large global companies, and are considered leaders in this transition period. While these providers do have divisions that serve smaller industrial and commercial customer, most choose not to move into the residential customer markets, leaving the door open for new disruptive players.

¹⁹ [DOE Unveils 'Integrated Strategy' to Reduce Utility Cyber-threats](#). Utility Dive, May 15, 2018

Table 2.1: Customer Segments and Choice

----- Electric Power Services or Products Offered to End Use Customers -----							
Customer Segment	Wholesale	Demand Side Management	Distributed Energy Resources	Local Micro-Grids	Self-Generation	Retail Choice	CCAs
Large commercial & industrial	Increase based on new or improved technology	High adoption and use	High adoption and use	Low	Moderate: High Use of Information Services	Moderate to Low	Not applicable
Small-medium C&I	Increase based on new or improved technology	High use and adoption	Moderate	Limited to local micro-grids	Low: Limited to Rooftop Solar	Limited	At current levels unless increased by customer demand, technology or policy
Residential Rural*	Not applicable	Limited as provided by the incumbent utility	Low: most served by the incumbent utility	Limited to low, may be served by local cooperatives	Limited to Rooftop Solar	Limited as provided by the incumbent utility	At current levels unless increased by customer demand, technology or policy
Residential Urban	Possible selling to local utility based on policy	High use and adoption	Low	High within CCA's and local micro-grids	Limited to rooftop solar	Moderate: Based on costs benefit analysis	At current levels unless increased by customer demand, technology or policy
Agricultural	Selling or buying to local utility or Co-op by large agricultural companies	High use and adoption	Left to local Co-ops	Limited to Co-ops	Wind and rooftop solar	Left to local Co-ops	Not applicable

Underneath this turmoil in electricity markets is a hard-to-solve problem: how to assure reliable supplies of power and services in a more distributed system when there could be large daily and seasonal swings in the demand for electric energy.²⁰ This presented well understood operational challenges for the incumbent and traditional power companies, but it is not fully understood by many (or even considered by some) of the new entrants to the industry. In the traditional power industry, utilities built and customers paid for standby capacity and power.

A reliable power system is not possible without such resources and paying for them often requires

²⁰ Consumer and Retail Choice, the Role of the Utility. [CA PUC White Paper](#), May 2017

fixed payments for long periods of time to assure such resources can secure financing. Spreading these costs over a long period of time usually kept customer rates and monthly bills at moderate levels in the traditional regulated power industry. How to address this issue within the emerging distributed energy and customer choice regimes coupled with local self-generation in high population and usage dense areas are the primary challenges facing regulators throughout the Western Interconnection.

A challenge facing operators and planners at all levels across the region is integrating, coordinating, and managing increasing amounts of distributed resources. These resources are beginning to serve major load areas and can create significant excess power that flows back into the bulk system or to other inter-linked distribution systems. Planners must now co-optimize distributed systems with the bulk system – they can no longer consider them as simply reductions in load. Long-overdue distribution infrastructure improvements cause distribution system operators to struggle to keep up. Improvements are further delayed as utilities, distribution companies, and micro-grid operators argue over who will approve upgrade plans, who will build upgrades, who will pay for them and how, who will operate and coordinate the integrated system, and how and at what levels they will do so.

Due to the rapid expansion of investments in distributed resources, energy storage, and customers with flexible loads and self-generation, daily and seasonal power demand is hard to forecast. Weather, especially extreme events, causes havoc with energy management systems due to its impact on daily and short-term energy market prices. The instability in energy supply markets and their sensitivity to sudden price swings are contributing to larger economic instability across the entire Western Interconnection. Grid operators are becoming more and more distanced from sources of power for balancing and information about hour-to-hour loads. Reliability impacts from changes at the local distribution level and beyond into micro-grids are increasing challenges in maintaining the reliability of the bulk power system. For the first time, reliability crises are seen as a result of the proliferation of technologies dependent on software-only management systems that ultimately prove incapable of interfacing with the bulk system in high demand stress periods.²¹ This causes isolated local system brownouts and system crashes and over time, these events become more frequent during extreme weather events.

These years are a time of turmoil and change, and some traditional utilities that owned distribution systems are driven to restructure into transmission and distribution only wires companies, as they completely exit the power supply business. Other utilities take a different approach, and become full-service providers to their customers offering well-thought-out power management tools, retail choice options, and time of use programs as they fight for market share. Regulations for open access distribution system operators are put in place in several states and provinces, especially where regulated micro-grids are expanding. In these states and provinces there are also growing markets for products that serve needs for ancillary power and power quality. These rule changes and market corrections contribute to some companies leaving the electric energy services market, as their offerings no longer fit. The period of uneven economic growth during these years takes a mounting

²¹ [Utilities, Grid Operators Tell FERC They Need Real-Time Data to Better Manage DER](#). GreenTech Media, April 12, 2018

toll on under-funded companies.

Other parts of the power industry are also changing. In particular, in the natural gas sector pipeline expansion has ground to a halt as overall gas demand in the power industry is declining. Hedge funds and other financial players are securitizing under-utilized thermal plants to secure low-cost wholesale power. Natural gas prices are rising in the US due mostly to international demand and other factors related to trading and managing inventories. Global events in the power sector point away from a standard model for energy services as innovations in many areas such as battery storage, use of IT in the grid, micro-grid models, and community choice aggregation continue to outpace the ability of state, provincial, and local governments to set standards. New entrants in energy services can point to pilots and market developments that support their visions, but they are still largely immature and unproven. In general, there is evidence of cleaner power supplies, more flexible options and smarter use of distribution level resources.

Table 2.2: Category & Forms of Oversight

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 2
Electric Rates, Prices and Revenue	State/Provincial PUCs	For municipal utilities and community aggregation	State/Provincial struggle with old regulations protecting traditional utilities but eventually allow for cost recovery of the bulk system <i>and</i> DER investment
Renewable Portfolio Standards & Climate	State/Provincial Laws and PUCs	For municipal utilities and community aggregation	Initially states/provinces maintain existing RPS and other environmental regulations, by the end years, most allow regulations to fall away as the grid is over 90% clean powered.
Air Quality, Water and Land Use	State/Provincial Laws, Commissions & Agencies	City & County Departments and Agencies	Water pollution and other environmental regulations continue and are tightened. Land use regulations are modified to encourage and allow for local distribution needs and micro-grids

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 2
Capital/Resource Investment Planning Approval	State/Provincial Laws, ISOs, Commissions & Agencies	For municipal utilities and community aggregation	Laws and approval systems are modified to encourage investment in DER, self-generation, micro-grids, etc. Cities and community groups create financing instruments for CCA's
Operating standards, equipment & Safety	State/Provincial approved Industry Assoc.	State & local oversight in areas like fire codes, building codes, etc.	Rules continue to encourage energy efficiency, and demand-side management, and in some areas even mandate it.
Consumer protection and product quality	State/Provincial Laws and State/Provincial Approved Industry Associations	Generally not applicable	States/Provinces and local entities slow to realize the extent of consumer protection required under this new paradigm. In later years problems are addressed

Areas of State and Federal Regulation and Policy Interface

Environmental Protection: Air quality, Emissions and Endangered Species	Regional Planning: Rates and Costs Sharing	Siting: Renewable Energy Zones and Protected Lands
Federal departments and agencies are content to allow states and provinces to manage these areas while providing oversight		

As these years progress, federal, state, provincial, and local regulators are beginning to feel the pressure to address the instability from customers and legislators. Responses vary within the Western Interconnection with some states and provinces imposing restrictions on customer aggregation and micro-grid operations which effectively put them under PUC-level regulation. The focus of many regulators is to assure that distribution level operations are well managed and secure, and that transmission systems provide needed assurance of reliability.

The End Years 2031-2038: *The Fully Distributed Vision Yet to Come*

During these years, there is a shakeout in the electric services market: small players claiming but not delivering innovation collapse for lack of customers. In places where new services catch on, there is continuing market consolidation, and only stable and trusted competitive and profitable providers offering a wide range of services and products survive. A rebounding economy provides the impetus and means for long-needed system-wide infrastructure to be upgraded in both the bulk system and distribution systems, and begins to drive new levels of innovation across the system for suppliers and

customers. Companies offering grid-modernization technology are focused on a few high value-added capabilities related to energy management where AI and blockchain capabilities (which provides faster and more secure transaction processing) can be economically applied. Smart controllers are well integrated into the distribution grids.

Wind and solar energy costs are very low, and innovation in battery storage has greatly reduced costs and increased efficiencies as well. The bulk transmission system is also evolving in how it is being used. Transactions driven by economic trades and communications with direct service providers are commonplace. The more extensive use of two-way communication systems, more real-time communications, data analytics, and information management are leading to smarter and trusted grid operations. Driven by customer choice and costs, the power sector overall is providing power from a much cleaner supply base to the point that most states and provinces have eliminated renewable portfolio standards as they are no longer needed.

Electricity customers, large and small, are moving up the learning curve in how to select and use electric services. In some areas, customers have adjusted to buying electricity as a commodity which may be priced differently at different times. Some customers in some areas in the Western Interconnection are willing to pay for different levels of reliability assurance and resilience, as they manage the risks with their own resources and within local micro-grids. Customer choices for commodity power and energy services are available throughout the Western Interconnection, but not evenly used as regions move at many different speeds in acceptance and adoption. Uneven levels of cyber-security and privacy still concern some customers even though actual breaches are few. Larger commercial and industrial customers are active in using new options tailored specifically for their high usage. Some customers in rural areas want and require traditional electric services, as do older urban customers whose limited incomes depend on a stable and continuing supply of cheap electricity – for them, the bulk system utility is the obvious choice.

Traditional utilities have either shrunk with a focus on distribution or “wires only” systems or consolidated into larger companies. Large independent producers and IOUs offering wholesale power have consolidated into large players who have enough market power and relationships with state regulators to assure reliable production and thereby earn sufficient capacity payments. The generation base is approaching 90% renewable across the Western Interconnection with some residual natural gas generation for balancing purposes.²²

Managing and regulating this emerging hybrid utility system is not easy, as it has lots of distributed resources. There are variations in how customers are buying and selling electricity within the distribution grid, widely varying expectation of reliability at the end-user level, price volatility in wholesale power markets, and many sources of real-time daily and seasonal information flow.

The overall picture across the Western Interconnection cannot yet be characterized as a fully

²² Reader Note: This is a critical issue in this scenario, and just how it would play out and resolve itself suggests a topic of further discussion by the SD before these scenarios are finalized.

distributed power system where distribution, rather than transmission providers are the primary guarantors of reliability. Regional organizations still manage the bulk power flow and are still responsible for ultimate reliability assurance and resilience of the system, especially in extraordinary situations like storms and national or region-wide cyber-security attacks. Electricity system planning across the region has changed as distributed resources, micro-grids, and self-generated power now must be co-optimized with the bulk system to ensure reliability, and at the same time provide resilience in the face of continuing extreme weather events

Given the geographic diversity and regional needs within the west, a complete transition of the Western Interconnection into a fully distributed and end-user led power system is likely never to be fully realized. However, in 2038, the transition is in full swing, and the reach of distribution-level service providers has expanded in breadth and depth across the Western Interconnection.

Table 2.3 – Reliability Assurance and Bulk System Implications

Implications for Electric Reliability and Use of the Bulk Electric System	
Resource Adequacy	High Risk and Impacts with struggles in middle years as increasing amounts of distributed resources are added, and must be integrated and coordinated with the bulk system. By 2038 operating and planning issues are largely resolved and distributed resources are fully integrated and co-optimized across the system
Operational Integrity Risks	High during the middle years into the final years as operators struggle with integrating and coordinating increasing amounts of distributed resources
Infrastructure Integrity Risks	High in the middle years as increasing distributed resources puts tremendous pressures on distribution systems. 2038 sees most of these issues resolved but there are still problem areas as infrastructure upgrades try and keep pace
System Stability Risks	High going into the final years as there are constant pressures on the system for stable and reliable operations and as more reliability assurance responsibilities are pushed to the distribution and micro-grid level. New planning techniques and operating systems are required in the latter years to mitigate and offset the pressure

Scenario 2 Potential Key Questions for Analysis

1. As distributed resources, both in front of and behind the meter become significant and integrated load serving resources:
 - a. What infrastructure changes and upgrades in both the BPS and distribution systems might be needed for system integration, co-optimization, and coordinated operations?
 - b. Where are these changes and upgrades needed; what would they cost, who would pay for them, and how would their costs be allocated among customers?
 - c. What unique changes would be needed to integrate behind-the-meter (BTM) residential and small business self-generation?
 - d. What timeline would the changes and upgrades play out over, and how would states and provinces differ in their timing?

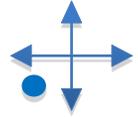
2. How might customer and other BTM energy products and services be captured for planning purposes? What key categories might be selected because they can be aggregated to support system capacity?
3. How might the value of reliability services from the bulk transmission system change as more distributed resources are used to meet reliability standards within utility distribution systems? On what basis would that value be determined?
4. If cost recovery in utility rates is allowed to cover the costs of prematurely retired generation, should those costs be allocated to the new supply resources coming on stream? If not, where should those costs go and how should they be included in planning analyses?
5. Is there one “crisis conditions” study case request that the SDS might make which incorporates a sudden return of demand in the Western Interconnection when for some reason a lot of self-generating customers (how much capacity?) needed to return to receiving services from the incumbent power suppliers?

Scenario 2 Early Indicators and Complete Scenario Metrics

Early Indicators for Scenario 2 ²³	
Indicator	Definition/Rationale
Change in State/Provincial Energy Policies	Designed to provide freedom for markets, with many products, services, and customer choice options
Customer Adoption of Energy Service Options	High levels of and fast adoption of new energy products and services across the Western Interconnection
Developments in public concern addressing climate change that drives customer values in energy markets	Increasing concern to lower carbon emissions and other environmental actions even when it increases energy costs
Customer choice technology innovations	Technology innovations which enable wider customer choice while meeting costs and benefits demands of consumers
Restructuring of the traditional utilities and emergence of distributed energy resource companies	Technology and customer choice acts as a major force in how energy markets function
Increased grid modernization that supports the use of DER across the Western Interconnection	Increasing DER requires faster enhancements to both the bulk and distribution level system

Key Variable	Metrics for Scenario 2
To be determined	To be determined

²³ See also the General Early Indicators in Appendix 7 on page 70



Scenario 3: Mandates and Standards for State & Provincial Policy with Restricted Choices in the Evolution of Customer Supply and Demand

Scenario Overview

- This is a world in which movement toward a more distributed electric power system is forestalled for 20 years due to concerns about assuring reliability, resilience, and control over the power system to manage risks and costs.
- Higher penetrations of rooftop solar PV will increase the risk to reliability and will make reliability assurance more difficult, especially regarding disruptive events.
- Utility-scale investments in power supplies are seen as an effective way to reliably address climate change concerns in the electric power industry
- Consumers in all segments and regulators turn toward incumbent and largely proven systems for electric energy services, especially as those providers are able to address environmental concerns and meet customer demands for service options within regulated rate structures.
- The Western Interconnection moves toward more regional cooperation to assure and sustain reliability and to efficiently use supply resources to manage costs and meet environmental goals. Cost savings from more regional cooperation and trading drive the regulatory policies.
- Variations in economic growth during the period stay within the normal range in terms of their impact on electricity demand growth.
- Capital markets are deep enough to provide capital as needed to the power industry.
- Coal and natural gas power supplies continue to decline based on costs, age, and environmental factors; however, the value of the interconnection benefits may support new transmission investments.
- Worldwide development in electric services support incumbent electric service providers by continuous investment in utility-scale power systems and adopting models for regional cooperation.
- Due to advances in renewables with better energy management systems, only limited natural gas-powered generation in the role of supporting reliability at competitive costs will remain in the Western Interconnection.
- At the end of this scenario, some consumers are seeking more distributed electric service options to compete with the incumbent suppliers to the extent that they are reliable, safe, and cost competitive with the regulated system.

Key Scenario 3 Metrics²⁴

Key Variable	Metrics for Scenario 3
To be determined	To be determined

The Early Years 2018-2023: How is This Supposed to Work?

This is a world where the adage of “building a car while we drive it” applies to policy setting that leads to more customer choice²⁵ in the electric power industry; and in the Western Interconnection, several states decide to “put their foot on the brakes.” The central concerns are costs to consumers and sustaining reliable power so that economic growth and the role power plays in managing everyday life are maintained. Policymakers are reluctant to move swiftly ahead on increasing customer choices for electric services when they see the difficult problems emerging in other states. Among the bigger problems they see is the so-called “duck curve” in California where managing the daily ramp in power demand does not match well with the excessive renewable energy supply resources (both those connected to the transmission grid as well as distributed renewables) that are available during the day but quickly fall to zero commensurate with the loss of solar energy.²⁶ This is leading to curtailments of gas power supplies as renewables peak and a steady increase as renewable energy dwindles towards the end of the day. This has created a very different paradigm for gas resources where they were once needed for base load supply but are now, under high renewable scenarios, needed to fill in the energy “gaps” that are an outcome of the intermittency of renewable resources. The result has been a much less stable market for gas resources where low wholesale prices result from renewable “oversupply” and even bankruptcies for some independent power gas-fired power plants due to a market failure to provide the revenue needed to sustain these resources. Inconsistent policy on supporting intermittent resources with capacity payments is sending signals to independent power providers to not invest in needed balancing resources.

The issues that policymakers are concerned about do not all originate in California. In recent years, there have been concerns about net metering benefits for solar rooftop owners, which some have argued shift system costs from solar panel owners to those who choose not to invest in them. Unfair cost shifting between customer classes is a growing concern for regulators as they seek to balance policies that support growth in renewable energy. Regulators are also listening with concern about the costs projections submitted by investor-owned utilities for modernizing their local distribution grids with promising new technology. The technologies promise benefits, but regulators are not sure the

²⁴ NOTE: Metrics for scoping and studying the scenarios will be developed by the SDS later in 2018

²⁵ As California Energy Markets Modernize, Regulators Worry About Repeating the Past. [Sacramento Bee](#), [Utility Dive](#), [CAPUC](#), May 3, 2018

²⁶ [Customer Empowerment Upheaval Forces Hold on Renewables](#), Utility Dive, February 22, 2018

benefits justify the costs and exactly what real saving for customers might result.

Regulators are seeing requests to allow aggregating customers into pools, but are not sure how the lower costs for power and long-term new power sources promised by developers of these pools will increase or sustain reliability. Leaders from traditional vertically integrated utilities that have invested in power supplies to serve customers are also wondering how those resources fit in a world where they are losing sales to alternative energy suppliers and customer side generation. More rooftop solar panels and distributed power resources mean less dependence on large generating plants tied to transmission grids for electric power. Traditional power companies are investing in clean energy sources like wind and utility-scale solar plants to sell power to utilities that need to meet their renewable portfolio standard requirements and need to sell that power to recover their costs. The power industry seems to have many ways to supply power at a time when growth in power demand is in the 1% range as the general economy is growing less energy intensive and more energy efficient.

Policy makers in the Western Interconnection seeing these complex issues move to focus on the needs of their state or province to protect their customers and economies. Some policymakers see the leading edge of change as the bleeding edge of change in terms of risks to reliability and higher costs for power. This is particularly true for the states in the Western Interconnection with smaller populations and low existing costs for power from historical investment in their power infrastructure. Those states are comfortable working with their vertically integrated traditional power companies who they feel can move toward clean energy and other policy objectives within existing regulation. Policymakers in those states decide to take a go-slow approach in expanding customer choice and subsidizing small-scale distributed generation resources that allow customers to self-generate or disconnect from the power grid.

Policymakers find support for their actions from customers who are afraid of unpredictable rate increases, unfair charges, and threats to reliable power in a time when extreme weather and other disruptive events like cyber-attacks have demonstrated the need for strong and well-capitalized utilities in restoring electric service. Customers in states with reasonable rates and relatively low-cost electricity are risk averse and are not anxious to “fix what isn’t broken.” Reliable power has been and continues to be available from incumbent power companies, and renewable portfolio standards and clean energy goals are being met.

Regulators see that progress and decide to continue coordinating policy with their in-state vertically integrated utilities. As power companies request permission to build or contract for a limited amount of gas-fired generation to balance intermittent resources, policymakers accommodate their needs.

The tendency for more conservative energy policies in the West is not completely dampening innovation or evolution in energy markets. Electric vehicle sales are growing as new offerings from many suppliers enter the market. The cost of solar panels continues to fall. Utility-scale wind energy continues to grow as a cost-competitive source of power. Innovation is occurring in information systems and power system control technologies that can enhance and add flexibility to distribution grid management. At the bulk transmission level, large utilities are seeing opportunities for regional

coordination that can lower costs and improve reliability. The energy imbalance market is functioning well and is allowing access to low-cost power across the region. In general, the US economy is moving toward more electrification, it's just doing so very efficiently.

The Middle Years 2023-2031: *Put the Genie Back in the Bottle for a While*

A reliability crisis occurs in energy markets in the Western Interconnection during these years which precipitates a need to increase the efficiency of how power is economically generated and used. Electricity market prices across the Western Interconnection swing wildly during months where energy production from solar resources is more prevalent. “Duck curve-like” conditions ((e.g., extreme ramps in demand; periods of low net load), arising from higher levels of solar energy production, results in large wholesale market electricity price swings, and spread to several states. Policymakers agree that existing rules and regulations cannot continue for resources that create too much power at the wrong time and lead to ramping issues, wildly fluctuating wholesale power prices, and risks to reliability. States like California have to change their policies so that regional cooperation and transmission expansion can proceed and in the process allow economic power trading across the Western Interconnection. As part of this shift, incumbent utilities are given protections against loss of sales through customer choice options and rights to procure power to assure reliable resources to address intermittent power issues. Federal governments approve of those new arrangements and make changes to national policy that gives states and provinces more powers if they move toward regional cooperation. States and provinces alike are allowed to unwind some historical transmission rights. Some under-utilized transmission is reinvigorated, and expansion is allowed to address changes in demand patterns throughout the Interconnection. Negotiations to form regional transmission organizations are pursued. Growing wind resources are in a particularly good position to take advantage of those changes in how the bulk power system will be used.

Table 3.1: Regulatory Categories and Forms of Oversight

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 3
Electric Rates, Prices and Revenue	State/Provincial PUCs	For municipal utilities and community aggregation	State/Provincial PUCs active in setting policy that supports reliability through empowering incumbent utilities.
Renewable Portfolio Standards & Climate	State/Provincial Laws and PUCs	For municipal utilities and community aggregation	RPS standards are maintained and met with no reduction in state authority.
Air Quality, Water and Land Use	State/Provincial Laws, Commissions & Agencies	City & County Departments and Agencies	States/Provinces do not pull back in these areas and are successful in getting incumbent power companies to meet their requirements

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 3
Capital/Resource Investment Planning Approval	State/Provincial Laws, ISOs, Commissions & Agencies	For municipal utilities and community aggregation	States/Provinces use their powers here to direct investment in the power industry to assure reliability and contain costs.
Operating standards, equipment & Safety	State/Provincial approved Industry Assoc.	State & local oversight in areas like fire codes, building codes, etc.	Existing policies in this area prove sufficient to meet needs
Consumer protection and product quality	State/Provincial Laws and Approved Industry Associations	Generally not applicable	States/Provinces focus primarily on maintaining reliability. Existing policies on safety are sufficient

Areas of State and Federal Regulation and Policy Interface

Environmental Protection: Air quality, Emissions and Endangered Species	Regional Planning: Rates and Costs Sharing	Siting: Renewable Energy Zones and Protected Lands
Federal policy supports the leadership at state and regional levels. No need for change.	Federal policy changes to accommodate more state leadership in adopting policies and rules that facilitate regional cooperation, especially to allow power trading that lowers costs and increases reliability.	Federal policy supports and accommodates more state-level leadership and makes it easier for bulk electric system expansion.

During these years the idea that the power system should be reorganized to allow individuals to pursue their own ends with a wide arrange of choices is seen as risky by customers and regulators. How a customer who does this can secure long-term reliable power is questionable. Allowing customers who fail in this pursuit to return to the integrated power system is seen as “allowing them to have their cake and eat it too,” with their costs pushed onto customers who did not make that choice. Innovations that promise this kind of customer choice are seen as suspect in their ability to deliver long-term reliable power. Incumbent power companies are delivering cleaner and reasonably priced power with larger and proven system investments that assure reliability.

Incumbent power companies find ways to integrate more technology into their existing systems that improve situational awareness and communications. These systems are improving operations, reliability, and providing better cost management. Quick recoveries from a series of cyber-attacks²⁷ that attempt to disrupt power delivery to large geographic areas provide a demonstration of the resilience in modernizing large-scale grid operations. Recoveries from several damaging storms demonstrate the community-wide value of maintaining the power grid with well-capitalized

²⁷ Russia Cyber-attacks on US Power Grid. [The New York Times](#), [Bloomberg News](#), March 15, 2018

companies. Technology innovations and increased consumer sophistication will drive the adoption of distributed energy service alternatives to the extent that they are reliable, safe, and cost competitive. Incumbent power companies are forced to offer new service options to their customers and to deploy distributed energy resources (DER) like energy storage to meet peak demands in their systems which will reduce the dependence on the bulk transmission system for electrical service. Usage of smart inverter technologies will become more prevalent as will the procurement of contracted ancillary services from independent power producers who also use distributed power resources. With this technology, incumbents are offering forms of customer choice to large commercial and industrial customers, especially when those resources can be integrated to enhance overall system reliability.

Table 3.2: Customer Segments and Choice

----- Electric Power Services or Products Offered to End Use Customers -----							
Customer Segment	Wholesale	Demand Side Management	Distributed Energy Resources	Local Micro-Grids	Self-Generation	Retail Choice	CCAs
Large commercial & industrial	Current levels unless restricted by regulation	Used with the incumbent power company	Very limited, allowed if grid connected for reliability assurance	Reduced by regulation and policy			
Small-medium C&I	Current levels unless restricted by regulation	Used in cooperation with the local incumbent power company	Used in cooperation with the local incumbent power company	Used in cooperation with the local incumbent power company	Used in cooperation with the local incumbent power company	Limited to a few states, curtailed over time	Reduced by regulation and policy
Residential Rural*	Not applicable	Limited	Limited	Limited	Limited	None	Reduced by regulation and policy
Residential Urban	Not applicable	In cooperation with local utility	Limited to a few states and in some states not allowed	Limited to a few states and in some states not allowed	Limited to a few states and in some states not allowed	Limited to a few states, curtailed over time	Reduced by regulation and policy
Agricultural	Current levels for large agricultural companies unless restricted by regulation	In cooperation with local utility or Co-op	Limited to a few states and in some states not allowed	Limited to a few states and in some states not allowed	Limited to a few states and in some states not allowed	Limited to a few states and curtailed over time	Reduced by regulation and policy

Electricity demand continues to grow slowly during these years due to increased energy efficiency. What little boost in growth that does occur, is largely driven by the growing use of EVs and their need

for periodic charging. Customers and policymakers continue to desire clean energy, so older coal-fired power plants continue to be retired and replaced with clean energy alternatives.

The End Years 2031-2038: *Integrating Continuing Innovation*

The issue of scale—how big should the most efficient operating power company be—is the question confronting policymakers during these years. How big should interstate electricity transmission companies be allowed to grow through consolidation? If, through better technology, companies can effectively manage larger operations, why should they not be allowed to do so? Through a sequence of mergers, a mega-utility is forming in the Western Interconnection²⁸ which strides across several states. How should such an entity be federally regulated when its operations within one state are so well integrated with operations in another that they are actually one seamless whole?

Incumbent utility managers don't see a problem because they argue they are meeting all of their regulated requirements, meeting all renewable portfolio standards, and delivering reliable power at fair prices. Their companies are successfully integrating clean energy resources with a limited amount of gas-fired generation so that reliable power is available at the lowest cost. Natural gas markets have stabilized in the US as excess supplies are being exported.

The large utility companies suggest that a natural next step in the evolution of the US power system is toward some form of nationalization²⁹ of the grid to enhance reliability. Federal support will be needed for investments to connect a nationalized grid.³⁰ FERC is satisfied with assuring openness in the market for emerging technologies, and that big companies don't exert too much market power.

During these years economic conditions in the Western Interconnection are stable and in line with the national economy. Global economic trends are still affected by trade flows, swings in capital markets, and demographics. Companies in the West remain strong players in international trade. The power industry in the Western Interconnection is benefitting from global trends that improve technology and lower power costs. The business models and energy policies in place in the West are not unusual when compared to international patterns as several other countries have taken similar conservative paths.

A small segment of power customers has not entirely given up on the promise of more choice. Even though they are most comfortable with the embrace of vertically integrated power companies that have allowed some options allowing flexibility to meet some of their needs, they have a sense that there might be more. These customers wonder whether it is possible to totally disconnect from the power grid and through a combination of self-generation, energy efficiency, energy storage, and achieve their desired personal independence.

Some regulators are open to listening since some local situations may not be best met by big company

²⁸ [The Innovations Just Keep Coming in the Corporate-Utility Deal Space](#). Utility Dive, April 26, 2018

²⁹ Reader note: As described by the Scenario 3 Team, this term requires explanation as it can have different meanings. Exactly how this would unfold in this scenario is a topic for further discussion by the SDS, and should be resolved before these scenarios are finalized.

³⁰ [New Study Looks at Energy System Transformation](#). MIT Technology Review, March 14, 2018

solutions. Changes in policy to crack open room for more choices will be considered over time.

Table 3.3: Reliability Assurance and Bulk System Implications

Implications for Electric Reliability and Use of the Bulk Electric System	
Resource Adequacy	Met through the leadership of incumbent companies under the direction of state and appropriate federal regulators
Operational Integrity Risks	Met through the leadership of incumbent companies under the direction of state and appropriate federal regulators
Infrastructure Integrity Risks	Met through the leadership of incumbent companies under the direction of state and appropriate federal regulators
System Stability Risks	Met through the leadership of incumbent companies under the direction of state and appropriate federal regulators

Scenario 3 Potential Key Questions for Analysis

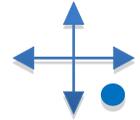
1. As more utility-scale wind and solar (also intermittent) resources are brought into the Western Interconnection, what kind and at what level will fossil, storage or other non-intermittent resources be needed to assure reliability in the Western Interconnection?
 - a. What policies should govern the addition of those utility scale reliability related resources so that they are optimized across the Western Interconnection (thus taking advantage of the bulk transmission system to allow the sharing of resources and thus lower overall region-wide costs)?
 - b. What would be the basis of economic analyses to determine the appropriate addition of those utility scale reliability resources on a regional basis?
2. Is there an optimal sub-regional structure (sub-dividing the Western Interconnection) for the addition of utility-scale resources (new capacity) that will support and assure reliability as more intermittent resources are added by load-serving entities?

Scenario 3 Early Indicators and Complete Scenario Metrics

Early Indicators for Scenario 3 ³¹	
Indicator	Definition/Rationale
Change in State/Provincial Energy Policies	Constrained markets restricting customer choice
Customer Adoption of Energy Service Options	Limited and managed choices by policies with low rates of adoption across the Western Interconnection
Increased regional grid planning across the Western Interconnection where it lowers power costs and enhances reliability	Policy choices in this scenario emphasize high levels of reliability
DER growth focused on utility-scale investment with an emphasis on reducing power costs	Traditional utilities are seen as the primary generation sources to ensure reliability and low prices
Consolidation of utilities across the Western Interconnection (especially if costs and utility rates can be lowered)	Providing economies of scale and simpler planning

Key Variable	Metrics for Scenario 3
To be determined	To be determined

³¹ See also the General Early Indicators in Appendix 7 on page 70



Scenario 4: *Mandates and Standards for State & Provincial Policy with High Levels of Choices in the Evolution of Customer Supply and Demand*

Scenario Overview

- This is a world in which for 20 years regulatory policy, especially those policies meant to meet environmental concerns, exerts significant influence in shaping customer energy service choices. Regulatory policies throughout the Western Interconnection create mandates and set standards that support choice options that prove technologically feasible and deliver on promised costs and environmental benefits.
- New energy services providers accept the regulatory oversight because it assures cost recovery and financial security for their investments.
- Residential customers adopt energy service options, such as community choice aggregation, as supportive regulatory policies make those options safe, reliable and cost competitive.
- Large commercial and industrial customers adopt new electric supply options and services as those choices fit with the operational goals of the companies, and are facilitated by supportive government policies.
- Distributed energy resources increasingly become a part of how the overall electric system is operated driven based on costs and consumer choice, but with appropriate regulatory oversight and controls to sustain reliability.
- Economic growth within the Western Interconnection drives electric power demand within historical bounds and is sufficient to allow investment in emerging technological options.
- Capital markets are strong enough to provide all capital needed throughout the power industry.
- Coal-fired power generation is largely retired, and natural gas-fired power is used sparingly to support and assure reliability when it is the best option.
- Costs continue to decline for both utility-scale and distributed clean energy options and regulatory policies balance how both are used to cost-effectively provide energy services.
- Worldwide electric industry developments support investment, technological innovation and market development for new electric service options.
- As this scenario ends, a more distributed and clean electric power system is emerging guided by the hand of regulation and government policy, which has largely shaped which new innovations gained a place in the market.

Key Scenario 4 Metrics³²

Key Variable	Metrics for Scenario 4
To be determined	To be determined

The Early Years 2018-2023: No “Uber-ization” of the Power System

Beginning in 2018, this is a world for the electric power industry in which the idea of uncontrolled disruption in the name of innovation is thoroughly rejected because the cost of such undisciplined actions places large, measurable, and visible costs on the power system on which communities and the broader economy depend on. Constituents, who are hurt or have costs forced on them without their agreement, have recourse in regulatory proceedings and also as voters. Policymakers understand that a lack of oversight in managing costs and assessing benefits in an industry as important as the power industry is simply not acceptable to anyone. In this light new services and innovations are introduced and allowed to play in the power industry with clear rules and processes to assure accountability.

A policy framework with such oversight is not a killer for innovation in the power industry, rather, it allows it to proceed in an orderly fashion while sustaining the reliability and quality the industry has traditionally provided. For companies creating and offering new services, this framework provides a level playing field and secure revenues based on clear operating standards and even more importantly approved and standardized contracts. For electric service customers, this style of control of the industry assures safe, well-tested products and services at costs they feel are fair and reasonable. Competition for electric services encourages new ideas, but it is also quick to identify and extinguish weak and poorly grounded offerings early on.

Customers, who are also voters, support a more controlled and secure power industry because they have experiences that are costly and disruptive when power is interrupted. Power outages from weather-related events, operating glitches, fires, cyber-attacks,³³ and other problematic events make customers demand accountability in the power industry. Investors in the power sector, who are often risking hundreds of millions dollars building assets which will likely last for decades, also desire a stable industry structure with clear standards and policies. Around the world, the most stable nations with the strongest economies have this same structure.

Historically, innovation in the power industry has lowered costs, added flexibility, improved reliability, and assured safety. These same goals are sought during these years, and are increasingly being found with renewable energy, distributed energy resources and with the use of smart information and communications based technologies.

³² NOTE: Metrics for scoping and studying the scenarios will be developed by the SDS later in 2018

³³ [Energy Companies Aren't Doing Much to Defend Against Soaring Cyber Attacks](#). Bloomberg News, April 27, 2018

As distributed generation grows, its operations become better understood, and reliable coordination with distribution utilities increases.

Policies are put in place which encourages distribution utilities to use and rely on those distributed generation sources to enhance system reliability. This drives a variety of valued ancillary services provided by these distributed power owners and managers. Cooperation and coordination between customers and distribution utilities emerge as a general best practice in the evolution of the power industry.

Starting first in states like California, Oregon and Washington, new energy service options such as customer aggregation, customer energy supply choice, micro-grids, and variations in time-of-use rate structures are allowed by regulators. As bugs are worked out in these pilots, states and provinces in the rest of the Western Interconnection adopt them as well. Through supportive legislation, policies are put in place to encourage more electrification of the economy. Subsidies and set-asides are included with an eye toward achieving climate and clean energy goals. Falling prices and expanded availability of electric vehicles is a big part of this electrification shift as EVs grow in their share of new car purchases. Policies that encourage energy efficiency and carbon reduction are supported by customers across the West.

Policymakers, working with companies and customer feedback, are active in assessing new electric service options.³⁴ New developments in roof-top solar systems, battery technology, and demand-side information systems are tested and validated before they enter the market. In particular, customers want new options that help them reduce their carbon footprint.

Companies and regulators are keeping an eye on the larger system investments which underlie long-term reliability, including evaluating options for displacing generation whose reliability is tied to gas storage facilities, assuring adequate gas generation for reliability and balancing, monitoring wholesale market activities and prices, and integrating utility-scale wind, solar and transmission expansion. Managing the power system net load ramps and load-shedding within system operations is a challenge with some high-stress events occurring when weather conditions shift in unanticipated ways.

The Middle Years 2024-2031: *Institutional Upgrades*

Incremental changes in the power industry over the previous five years precipitate thinking by policymakers about whether the institutions managing the changes need upgrading themselves. Some

Retail Choice Impacts Over 20 Years

The Electric Markets Research Foundation asked Christian Energy Associates to study 20 years of retail choice in electric markets and the impacts on those markets.

The study provides findings that can be a guide to areas that need to be considered by rules makers and regulators in opening markets allowing higher levels of consumer choice.

The study results summary is in Appendix 3 on page 63.

³⁴ [What Electricity Customers Really Want](#). GreenTech Media, June 2017

of the ways the institutions work are based on old assumptions about the industry that no longer apply. An emerging change is that a growing customer base is willing to respond to short-term price signals in real time. Some customers are also willing to accept lower levels of reliability (demand response?) for a lower price, as they have resources on the home side of the meter.

Large commercial and industrial customers have self-generation options that are fundamentally changing their relationships with local distribution companies, and managing those resources are part of how reliability is met within the distribution company’s system. Some states are piloting independent distribution services providers to see how they might work. In light of this, several states start proceedings to determine what new regulatory authorities or “tools” policymakers need for the future.

Managing extreme ramps in demand and periods of low net load, as illustrated by the so-called “Duck Curve,” are common issues that are growing throughout the Western Interconnection as distributed resources increase. Customer service options, especially time-of-use rates, are being adopted throughout the Western Interconnection. Policies encourage widespread adoption and use of energy saving technology by customers. On the other hand, some customers are finding that distributed energy resources like older generation rooftop solar panels are failing due to age, and are no longer economic. Some of those customers want to return to the reliable local distribution company at no costs.

Table 4.1: Customer Segments and Choice

----- Electric Power Services or Products Offered to End Use Customers -----							
Customer Segment	Wholesale	Demand Side Management	Distributed Energy Resources	Local Micro-Grids	Self-Generation	Retail Choice	CCAs
Large commercial & industrial	Increase or decrease based on state/provincial policy	High Use	High Use	Limited	High Use	Used if cost benefits are worthwhile	Not applicable
Small-medium C&I	Change based on policy	High use	High use as available	Moderate use as available	Moderate use, business specific	Used if cost benefits are worthwhile	At current levels unless increased by policy
Residential Rural*	Not applicable	High use as available	High use as available	Moderate use as available	High use	Used if cost benefits are worthwhile	At current levels unless increased by policy
Residential Urban	Possible selling to local utility based on policy	High use	High use as available	High use as available	High Use	Used if cost benefits are worthwhile	At current levels unless increased by policy

----- Electric Power Services or Products Offered to End Use Customers -----							
Customer Segment	Wholesale	Demand Side Management	Distributed Energy Resources	Local Micro-Grids	Self-Generation	Retail Choice	CCAs
Agricultural	Selling or buying to local utility or Co-op by large agricultural companies based on policy	High use	High use as available	Dependent on local Co-op	High use	Used if offered by local Co-op	Not applicable

Policymakers are not sure in all cases how to react to some of these changes, but in general, they lean toward asking for and are granted increased regulatory authority to set new rules.³⁵ Policies that govern how distributed resources can be used to support overall system reliability are an area of debate. Distribution companies are ordered to procure reliability services from distributed resources and to assure the bulk power system reliability performance through long-term contracts for services.

Policy makers begin to approve large investments by distribution system owners for system upgrades, and allow recovery of those costs through revised utility rates. In a few states, experiments with adding two-way power flow capability are approved, and oversight for safety and quality of power is strengthened with new standards.

The Federal government is not sitting idly by and watching these changes. FERC steps in to assure states are holding up reliability standards. Increased standards in some areas lead to increased costs in utility rates. FERC is particularly watching customer choice aggregation and micro-grids which might not have access to secure long-term supplies of power. At the same time, FERC keeps an eye on how large industrial and commercial customers are using micro-grids to assure they have adequate capacity without subsidies from local power companies in the event of a disruption.

Table 4.2: Category & Forms of Oversight

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 4
Electric Rates, Prices and Revenue	State/Provincial PUCs	For municipal utilities and community aggregation	Highly activist with focused and directed actions
Renewable Portfolio Standards & Climate	State/Provincial Laws and PUCs	For municipal utilities and community aggregation	Maintained and extended until no longer needed
Air Quality, Water and Land Use	State/Provincial Laws, Commissions & Agencies	City & County Departments and Agencies	Highly activist with focused and directed actions

³⁵ [Different Options for Different States](#). Utility Dive, April 11, 2018

Policy Area	Statewide Oversight	Local: County/City Oversight	Scenario 4
Capital/Resource Investment Planning Approval	State/Provincial Laws, ISOs, Commissions & Agencies	For municipal utilities and community aggregation	Focus on tested and proven technology and systems
Operating standards, equipment & Safety	State/Provincial approved Industry Assoc.	State & local oversight in areas like fire codes, building codes, etc.	Highly activist with focused and directed actions
Consumer protection and product quality	State/Provincial Laws and Approved Industry Associations	Generally not applicable	Highly activist with focused and directed actions

Areas of State and Federal Regulation and Policy Interface

Environmental Protection: Air quality, Emissions and Endangered Species	Regional Planning: Rates and Costs Sharing	Siting: Renewable Energy Zones and Protected Lands
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High focus and actions in these areas with coordinated state, provincial and federal policies

Disruptive events from weather and other natural causes (earthquakes, wildfires, droughts, volcanic eruptions, etc.) are common throughout the US and the world in general, and governments, policy makers, and customers are seeing the impact, especially on key infrastructure like the power system. Multi-year droughts occurring in the Western US are occurring regularly, and are still costly. Water availability issues arise to the level that legislators approve tax incentives for desalinization facilities - Water consumption is a major consideration in siting new power facilities in the West.

Maintaining conditions that support economic growth and contribute to social stability are a key guide to policy setting and regulatory changes during these years. In the Western Interconnection, this results in policies that encourage more integration and communications between all organizations playing a role in the power system. From transmission owners and operators through to the more distributed parts of the power system, the direction of policy and standards is to assure reliability, and the bulk transmission system is still viewed as an important part of the solution.

The End Years 2031-2038: *The Shaping of Customer Choice and Innovation*

During these years, concerns turn to costs and benefits, performance, and long-term reliability assurance govern development in the power industry in the Western Interconnection. Energy infrastructure must be reliable and in many cases last for several decades or more, and because of this, costs are a key concern, including investment costs, operating costs, and long-term maintenance costs.³⁶ These costs are inescapable, cannot be hidden, and are hard to pass on people who are not benefitting from the underlying assets. Those realities guide regulators and policymakers as they attempt to integrate emerging service options in the power industry. Customers are wary of any unpredictable and hard-to-explain increases in rates and costs, or declines in reliability, and if decisions

³⁶ EPS: [SCE and SDG&E in California seek \\$4 billion for grid modernization](#). Utility Dive, October 16, 2017

are made that rely on traditional power companies and structures, then they're happy to accept them. The wider use of distributed energy infrastructure contributes to new kinds of reliability challenges associated with managing the maintenance, forced outages, and other disruptive events which need to be planned for.³⁷ Prices for new energy capacity are higher than regulators think are needed to encourage new supplies. It is not always clear who, between vertically integrated utilities, state-level system operators or distribution companies, should be responsible for this kind of planning.

Due to the significant increase in EV use and clean energy resources in the power industry, carbon emissions throughout the US have been greatly reduced from earlier levels. The fossil fuel industry is smaller and is now much more dependent on export sales rather than on domestic power generation. Natural gas is still used for power generation, but efforts continue to reduce its use to a minimum. Small-scale clean generation resources (e.g., solar, wind, and storage) are now so economical that they are the first choice in adding resources to local distribution systems. Despite this, the bulk power system is maintained as a valued resource. Growth in overall electricity demand and policy in some of the less populated states keeps power flowing on the bulk system, providing the power needed to manage seasonal exchanges, and to ensure reliability. Expansion of the bulk transmission system however, is limited due to significant use of distributed energy resources.

Growing use of inverter-based technologies combined with software and other advanced system controls has allowed some forms of synchronous generation. Any technique or process that allows power costs to be better managed is welcome as high capital costs and often high prices for new power supplies are common in the West. Economic growth is not hindered by disruptions in electricity markets, even though short-term weather-related events or natural disasters present short-term challenges. Economic growth in the Western US is in line with the rest of the country.

Electric service options are much more varied than in the past, and the power industry infrastructure in the Western US has evolved toward a more distributed, smarter, cleaner, and end-user engaged system. Guided to this end by policies and standards that largely shaped what energy services options were available to customers, that guidance and oversight continue as a backstop for reliability assurance. The result is a power industry that still contains large investor-owned regulated utilities, but also a wide range of small and medium-sized organizations that provide a wide range of services and products allowing most consumers choices in their sources of electricity, flexible prices and rates, and options for services they choose on the other side of the meter.

³⁷ [A Regional Grid Helps, Not Hurts Distributed Renewable Energy](#). GreenTech Media, April 25, 2018

Table 4.3: Reliability Assurance and Bulk System Implications

Implications for Electric Reliability and Use of the Bulk Electric System	
Resource Adequacy	System planning and investment is designed and implemented to provide continued system assurance – highly coordinated across the region
Operational Integrity Risks	The system is managed with proactive actions for minimal risks
Infrastructure Integrity Risks	Proactive upgrades to infrastructure needs across the region
System Stability Risks	The system is managed with proactive actions for minimal risks

Scenario 4 Potential Key Questions for Analysis

1. If micro-grids and customer choice aggregation reduce load-serving entities' requirements to add resources to meet reliability in their service areas, how should this be reflected in (or taken out of) resource planning for the Western Interconnection?
 - a. Or should it be included, and if so, how? If there are different answers for different states, how can this be incorporated in planning analyses?

Scenario 4 Early Indicators and Complete Scenario Metrics

Early Indicators for Scenario 4 ³⁸	
Indicator	Definition/Rationale
Change in State/Provincial Energy Policies	Policies designed for a low degree of free market-based activity in electric power, with emphasis on customer choice options that meet policy directives
Customer Adoption of Energy Service Options	Limited choices from traditional regulated options, with a policy focus on assuring reasonable costs and proven benefits (including reliability) for any new service or product options
Assertive rulemaking and standards by regulators that direct and limit customer choice options to fit with state and provincial policy.	Policy makers want to assure the benefits of customer choice options sufficient for cost incurred
Growth in utility-owned DER across the Western Interconnection with emphasis on lowering power cost and enhancing reliability	Policy makers want to ensure benefits of DER investment are sufficient for costs incurred
Increased grid modernization across the Western Interconnection with focus on bulk system reliability	Supports regulatory focus on ensuring reliability
Developments in public concern addressing climate change that drives customer values in energy markets	Customers support strong regulatory actions that push industry change toward cleaner and more reliable power system

³⁸ See also the General Early Indicators in Appendix 7 on page 70

Key Variable	Metrics for Scenario 4
To be determined	To be determined

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Appendices

The following appendices are included:

1. Driving Forces Comparison
2. What Customers Might Drive a Push Towards Higher Levels of Energy Services?
3. Lessons Learned from Retail Choice Impacts Over 20 Years
4. Developments in Nuclear Power
5. Development in Carbon Capture Utilization and Sequestration
6. The Technology Adoption Hype Cycle – Crossing the Chasm
7. General Early Indicators

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1. Scenario Driving Forces Comparison

Scenario Driving Forces Comparison				
Key Driver	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Changes in State and Provincial electric energy market policies	Each State and Province pursues its own course appropriate for its citizens; little coordination across the Western Interconnection	States and Provinces support policies that enable more consumer choice and market-based solutions to meeting power demand and electric reliability	States and Provinces based on concerns about costs and reliability limit consumer choice options in favor of more traditional utility solutions	States and Provinces direct consumer choice options and regulated power developments to fit with their politically determined policy directives
Changes in Federal electric energy market policies	Leans toward empowering and supporting States and Provinces leading energy policies. Stays within current institutional frameworks, with support for market-based energy solutions	Leans toward empowering and supporting States and Provinces leading energy policies. Stays within current institutional frameworks, with support for market-based energy solutions	Lean towards empowering and supporting States and Provinces leading energy policies. Stays within current institutional, with a strong emphasis on reliability.	Lean towards empowering and supporting States and Provinces leading energy policies. Stays within current institutional, with a strong emphasis on reliability
Evolution of customer-side energy supply technology and service	Free market product and service options developed and tried as enabled by new technology and consumer interest; however costs/benefit trade-off limits large-scale adoption.	Free market product and service options developed and tried as enabled by new technology and consumer interest; costs/benefit trade-off sufficient to encourage significant adoption.	The pace of development of free-market product and service options slows due to lack of policy support and lower consumer interest; cost/benefit trade-offs are weak especially for electric reliability	The direction of development of free-market product and service options is focused on areas of policy support; costs/benefit trade-offs determined by regulation and policy
Changes in the character and shape of customer demand for electric power	Overall electricity demand is growing at 1 – 1.5% Consumer values around clean energy, environmental protection, higher levels of engagement, and interest in new technology influence new power options; with some willingness to compromise of costs	Larger seasonal swings than in previous years common, and harder to forecast. Consumer values around clean energy, environmental protection, higher levels of engagement, and interest in new technology influence new power options, with some willingness to compromise on costs	Power demand in the 1% growth range, extreme ramps in demand; periods of low net load. Consumer values primarily focus on power costs and reliability; large C&I segment has high interests in more engaged services and new technology; environmental protection remains important with reasonable costs	Consumer values primarily focus on power costs and reliability; large C&I segment has high interests in more engaged services and new technology; environmental protection remains important in policy support from consumers
Changes in utility-scale power supply options	Innovation and declining costs continue for clean energy options; Utility-scale investments in the power supply are a competitive check on distributed power options, DER options expand as enabled by technology; Grid modernization uneven across the region,	Innovation and declining costs continue for clean energy options; Utility-scale power options play a role in meeting customer and environmental concerns and compete with distributed electric service options. Some distribution-only companies emerge, DER options expand as driven by customer demand and as enabled by technology; Grid modernization increases and enhanced as enabled by technology	Innovation and declining costs continue for clean energy options; Utility-scale investments in power supplies are seen as an effective way to reliably address climate change concerns in the electric power industry. DER options expand as enabled by technology; Grid modernization enhanced as enabled by technology	Innovation and declining costs continue for clean energy options; Utility-scale DER expands as DER enabled by technology; Grid modernization increases as enhanced and enabled by technology

Scenario Driving Forces Comparison

Key Driver	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Changes in State and Federal electric system regulations for reliability	Reliability standards remain at current levels; open to supporting new options if they maintain adequate levels of reliability; Throughout the years even as the system begins to fracture, states and provinces ensure resource adequacy within their boundaries, and interconnection-wide resource adequacy though just enough cooperation	Reliability standards remain at current levels; open to supporting new options if they maintain adequate levels of reliability; FERC and Canadian regulators continue to monitor local, state, and provincial policies to assure reliability and overall power system integrity as there is a widely varying expectation of reliability at the end-user level	Reliability standards strengthened; open to supporting new options at utility level of incumbents if they maintain adequate or improved levels of reliability	Reliability standards strengthened; open to supporting new options if they maintain adequate or improved levels of reliability, system planning and investment areas designed and implemented to provide continued system assurance – highly coordinated across the region
Evolution of climate change and environmental issues on electric power	Current patterns remain in which needed investment in the power sector to reverse climate impacts is inadequate; clean energy investment may increase with consumer options, concerns about environmental quality are common throughout the region, actions may vary widely	Current patterns remain in which needed investment in the power sector to reverse climate impacts is inadequate; environmental regulations are strengthened and tighten, clean energy investment increase with consumer options, land use regulations are modified to encourage and allow for local distribution needs and micro-grids	Current patterns remain in which needed investment in the power sector to reverse climate impacts is inadequate; clean energy investment increase with utility-scale investment; States/Provinces do not pull back in these areas and are successful in getting incumbent power companies to meet their requirements	Current patterns remain in which needed investment in the power sector to reverse climate impacts is inadequate; clean energy investment increases with utility-scale investment by policy and due to public support encouraging regulated solutions.
Evolution of fuel markets in the electric power	Supply and prices continue to be influenced by the market factors; no major policy shift in fuel markets to affect supply, demand or prices	Supply and prices continue to be influenced by the market factors; no major policy shift in fuel markets to affect supply, demand or prices: natural gas prices are rising in the US due mostly to international demand and other factors related to trading and managing inventories.	Supply and prices continue to be influenced by the market factors; no major policy shift in fuel markets to affect supply, demand or prices; policy responses may occur for price spikes: natural gas prices are stable in the Ending Years, the excess is exported	Supply and prices continue to be influenced by the market factors; no major policy shift in fuel markets to affect supply, demand or prices; policy responses may occur for price spikes
Shifts in the cost of capital and financial markets	Current factors that influence capital costs and financial flows remain: Capital markets are deep and resilient enough to fund new electric energy service innovations provided they have market demand.	Current factors that influence capital costs and financial flows remain: Capital markets are vibrant and seek to fund new electric energy service options provided they find sufficient long-term market demand.	Current factors that influence capital costs and financial flows remain: Capital markets are deep enough to provide capital as needed to the power industry.	Current factors that influence capital costs and financial flows remain: capital markets are strong enough to provide all capital needed throughout the power industry.
Economic growth within the Western Interconnection	Current factors that influence growth remain; economic growth is sufficient over the long term to drive growth in demand for power, but there are periods of instability in demand growth	Current factors that influence growth remain; economic growth in the Western Interconnection is uneven with instability in the Middle Years, but overall sufficient throughout the 20 years to allow the adoption of new electric service options in an open market.	Current factors that influence growth remain; variations in economic growth during the period stay within the normal range in terms of their impact on electricity demand growth	Current factors that influence growth remain; economic growth within the Western Interconnection drives electric power demand within historical bounds and is sufficient to allow investment in emerging technological options.

Scenario Driving Forces Comparison

Key Driver	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<p>Worldwide developments in the electric power industry</p>	<p>Worldwide developments in the power sector have only marginal effects on what is going on in the Western Interconnection because there is such wide variation of adoption of new technologies within each State and Province: Integration of new and innovative technologies continue as they offer improvements in costs, operational integrity and consumer engagement; industry structures evolve to include some non-utility DER as new options are integrated</p>	<p>Worldwide developments in the power industry move toward more distributed innovative choices with varied applications depending on local conditions: Integration of new and innovative technologies continue as they offer improvements in costs, operational integrity and consumer engagement; industry structures evolve to include some non-utility DER as new options are integrated</p>	<p>Worldwide development in electric services support incumbent electric service providers by continuous investment in utility-scale power systems and adopting models for regional cooperation: Integration of new and innovative technologies continue as they offer improvements in costs, operational integrity and consumer engagement; industry structures evolve as mostly utility owned DER options are integrated</p>	<p>Worldwide electric industry developments support investment, technological innovation and market development for new electric service options: Integration of new and innovative technologies continue as they offer improvements in costs, operational integrity and consumer engagement; industry structures evolve as mostly utility owned DER options are integrated</p>



2. What Customers Might Drive a Push Towards Higher Levels of Energy Services?³⁹

Three Main Groups and Five Sub-Groups:

The “Always Engaged” Consumers - These mostly Green Champion consumers demonstrate the highest levels of interest in utility programs and Smart Grid-enabled products, and members of this segment are the most willing to pay for Smart Grid benefits and the expansion of their utility’s use of clean energy resources.

Demographically, these consumers are younger, urban and college educated with higher incomes. They are more connected with their utility via digital channels.

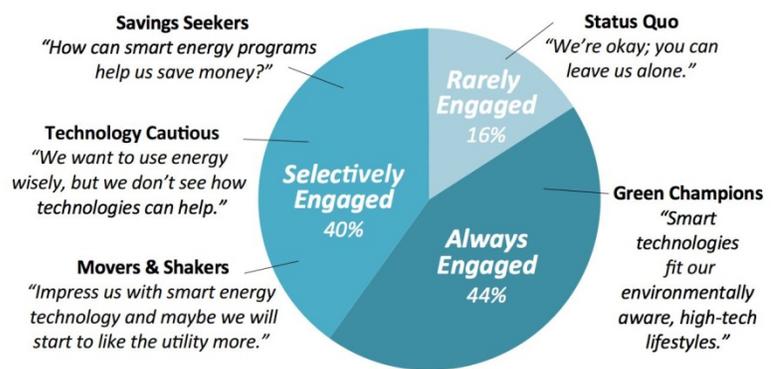
The “Selectively Engaged” Middle - This middle group of “Selectively Engaged” consumers exhibits a variety of attitudes, behaviors and demographics. It is this diversity that presents challenges and opportunities for industry stakeholders.

While they place high importance on energy efficiency, the Savings Seekers consumers in this group consistently lag in their knowledge and awareness of Smart Grid technologies, and they are the least likely to have participated in any energy efficiency programs. Demographically, these consumers are likely to be Generation Xers, have lower incomes and be unemployed. Interestingly, they also tend to live in larger homes.

The “Rarely Engaged” Consumers - These Status Quo consumers are least likely to report being aware of the term Smart Grid or smart meters. Members of this group are also least likely to report being knowledgeable about how to make their home energy efficient and have the lowest interest in and willingness to pay for utility programs and Smart Grid-enabled products. Demographically, these consumers tend to be older, are more likely to be retired and have lower incomes.

Conclusion #1: There is a strong overlap in demographic characteristics among those who embrace a digital lifestyle and those who have an affinity for a clean energy lifestyle -These consumers tend to be younger, urban and college educated — and they are strongly associated with the “Always Engaged” group. They also demonstrate an interest in and willingness to try smart energy products and services, and they actively engage in digital communications.

Conclusion 2: Despite having a stronger affinity for a clean energy lifestyle, younger people— especially Millennials — generally perceive more barriers in taking energy-saving actions - Millennials have lower rates of homeownership than other generations. This is one reason why



³⁹ [What Electricity Customers Really Want](#). GreenTech Media, June 2017

they are more likely to perceive more barriers. Millennial renters, in particular, feel disadvantaged due to split incentives, and they are reluctant to cost-share with their landlords.

Conclusion 3: For Suppliers: The real opportunity when creating programs and working to increase engagement is reaching the “Selectively Engaged” middle group of consumers - The largest consumer group, the “Always Engaged”, is the most aware, knowledgeable and engaged in energy efficiency. They are interested, and they are the most likely to take action. They are already on board.

The “Rarely Engaged” consumers (the smallest engagement group) are the least aware, knowledgeable and engaged. They show very little interest, and they tune out most offers and educational messages.

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3. Lessons Learned from Retail Choice Impacts Over 20 Years⁴⁰

On Innovative Service Offerings:

- Retail choice extends market penetration of dynamic pricing programs that reflect power system conditions. All other things equal, this improves the efficiency of use of power system resources, lowers the average costs of producing power, and tends to improve resource adequacy.
- Retail choice promotes renewable resources. To the extent that this raises the market penetration of intermittent resources such as wind and solar, it may raise resource adequacy issues because of the non-dispatchability of such resources.

Retail choice has a mixed record in promoting demand response.

- Retail choice has not generally promoted smart metering.

On Consumer Prices:

- Retail choice states, from the beginning of retail choice up to the present, have had retail prices persistently higher than those in other states, with the price gap varying over time with changes in fuel prices and other factors. The overall trend has been toward a lower price gap, though that is at least partly due to the happenstance of natural gas prices being low at the present time.
- Retail electricity prices in retail choice states vary more immediately with current fuel prices and other market factors than do retail prices in other states, and are therefore less stable than retail prices in other states.
- Retail electricity prices in retail choice states vary by location in a manner that mimics locational variations in wholesale electricity market prices.
- Neither price regulation nor the opening of retail markets seems to have had a significant impact on average residential prices in the EU.
- The numerous statistical studies of the relationship of electricity prices to restructuring have reached contradictory conclusions about the price impacts of retail choice.

On Costs:

- Retail choice exacerbates the resource adequacy problem by materially adding to the financial uncertainties faced by investors in generating resources because it adds to uncertainties in the revenues that a generator will receive for its services and requires higher returns on new investment capital. This increase in required returns must ultimately be paid by consumers in the form of higher prices.
- The risk of retail supplier bankruptcies under retail choice is greater than under traditional regulation, which may increase the costs borne by consumers.
- Retail choice requires that billing procedures be adapted so that appropriate shares of customer payments go to the utility (for non-competitive services) and to third-party retail suppliers (for competitive services).

⁴⁰ [Retail Choice in Electricity: What Have We Learned in 20 Years?](#) Christiansen Associates, February 2016

- Retail choice requires metering that is compatible with new retail service offerings.
- Under retail choice, retail suppliers incur marketing costs that must be recovered from customers.
- To facilitate the competition in generation services that is necessary for retail choice, there must be functional unbundling of utilities' generation function from its distribution and transmission functions. In most retail choice states, government encouraged or required utilities to divest generation assets or move them to separate affiliates, which, due to bad timing, ultimately cost customers tens of billions of dollars.

Other Impacts:

- Some retail energy suppliers cherry pick customers. Some of the most attractive customers, namely industrial and large commercial customers, take advantage of lower prices in either the retail choice market or the regulated market, which may result in other customers bearing disproportionate shares of utilities' generation costs.
- There does not seem to be a clear relationship between retail choice and customer satisfaction.
- Retail choice decisions require business savvy that many consumers lack. Less educated or low-income consumers are more likely than other consumers to make poor retail supplier choices.

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4. Developments in Nuclear Power

Nuclear power was mentioned during the scenario workshop teams' work, but it was difficult to see the development of additional nuclear power in any of the scenario narratives in a way that built on the current state of the industry.

At this writing, there are three traditional nuclear power plants⁴¹ in the currently in the Western Interconnection:

1. Columbia Generating Station in Washington
2. Palo Verde Generating Stations 1, 2 & 3 in Arizona
3. Diablo Canyon Generation Stations 1 and 2, in California (scheduled for closure)

No new traditional plants or additions to existing traditional plants are currently scheduled in the region, and it was the consensus view of SDS members at the SDS meeting during June 25-26 2018 that none would be built during the 20 year span of these scenarios – the capital costs are simply too high, the build time is decades and most recent construction have had huge costs overruns, operating costs are high, and the power produced cannot compete with natural gas-fired power. NERC notes that a total of seven nuclear plants in the US are scheduled for closure by 2020.⁴²

There are a number of small, modular reactors (SMRs) under design and development, such as the NuScale⁴³ reactor, which is considered to be the furthest along of the SMRs under design and development.

The NuScale phase 1 reactor design approval has just been received, and final design approval is expected in 2020. Utah Associated Municipal Power Systems (UAMPS)⁴⁴ will own the first NuScale plant, a 12-module pilot unit, placed at the Idaho National Laboratory. It will be operated by Energy Northwest; however, there is no announced date of anticipated operations startup.

However, the view of the SDS members attending the June 25-26 meeting was that SMRs would not be available to provide a significant level of power generation, if at all, during the 2018-2038 year period of these scenarios. It was also voiced that on a \$ per kWh basis, the current NuScale design would not be cost effective and unable to compete with gas or renewable generation.

In light of these views, a decision was made not to have increased nuclear power generation in the Western Interconnection, by traditional plants or SMRs, in the 2018-2038 scenarios

Going forward, the on-going trend analysis work by the SDS, WECC staff, and Quantum Planning will provide continual monitoring of developments in the nuclear power sector.

⁴¹ The US Nuclear Regulatory Agency: [Operating Nuclear Power Plants in the US](#)

⁴² EPS: [New Report: 75 Coal and Nuclear Plants to Close by 2020](#), Governor's Wind Energy Coalition, et al, November 13, 2017

⁴³ [NuScale SMR Technology](#)

⁴⁴ [Utah Associated Municipal Power Systems \(UAMPS\) SMR](#)

5. Development in Carbon Capture Utilization and Sequestration

Among the new and developing technologies on the horizon, as described elsewhere in this document, is the concept of capturing carbon from the effluent stream of fossil-fueled power plants for later use or storage, known as Carbon Capture Utilization and Sequestration (CCUS). Although there are currently no federal laws or rules that limit the emission of CO₂, several states, including some western states, have adopted state policies limiting CO₂ emissions and/or taxing those emissions. Other states and private interests, particularly states which currently produce large amounts of coal (i.e. Ohio, Pennsylvania, West Virginia, Wyoming), have an interest in developing and commercializing technologies that can ostensibly put fossil fuel generation on a more even footing with cleaner but intermittent forms of renewable generation, including wind and solar generation.

Although capturing CO₂ from the slipstream of a coal or gas-fired electric generation plant is not new, per se, developments regarding the disposition of the captured CO₂ have evolved rather quickly over the last decade. Ten years ago, it was thought that the only practical way to dispose of captured carbon was to bury it deep underground in suitable geological formations capable of containing the captured carbon in perpetuity. Capturing and sequestering carbon underground, essentially for eternity, is an extraordinarily risky and costly endeavor.

An alternative method for disposing of carbon involves its use in the tertiary recovery of oil, also known as enhanced oil recovery, or EOR. It is estimated that only about 25% of technically recoverable oil reserves in a given location can be recovered using traditional drilling and reservoir management practices. The remaining 75% is either unrecoverable or recoverable only by stimulating the production of the reservoir. Captured CO₂ from power plants (or other sources) can be used for reservoir stimulation, vastly increasing the amount of oil recoverable from existing reservoirs. In this scenario, CO₂ becomes an asset to the plant owner producing the CO₂, rather than a liability. Instead of funding the permanent sequestration of a waste product produced in the combustion of fossil fuel, the plant owner can sell the CO₂ to a third party field operator who will then use it to recover additional quantities of hydrocarbons from existing fields.

One drawback associated with EOR is that its viability depends to a large extent on the value of the captured CO₂ to the oil field operator, which in turn depends heavily on the price per barrel of oil. The cost of capturing the CO₂ is largely fixed (and sunk); such that recovering the investment associated with carbon capture based on the volatile price of CO₂ is highly risky. Additionally, beyond the sizable upfront capital cost associated with the capture equipment itself, the equipment imposes a substantial power penalty on the host plant in the form of parasitic loads required to run the capture equipment. One way to mitigate this risk is to minimize the cost of capturing the carbon in the first place. This is where most research has focused in recent years; this research has shown decidedly mixed results at utility scale.

In 2013, SaskPower undertook the Boundary Dam carbon capture project located in southern Saskatchewan. The project was retrofitted to the existing unit number 3 (there are five units total located at the site) which was repowered at the same time to a gross nameplate capacity of 160 MW.

The initial capital cost of the project was estimated at {C} \$1.3 billion and the final capital cost was {C} \$1.5 billion. Of the original capital cost {C} \$800 million, or approximately 61% was devoted to carbon capture with the remainder directed to retrofit costs. Additionally, the plant generation for sale to ultimate consumers is 110 MW net of power required for the capture equipment; parasitic load penalties of one quarter to one-third of nameplate capacity are not uncommon in the current generation of carbon capture technology.

Moreover, the Boundary Dam unit has been beset by equipment failures and other forced outages that have prevented it from fulfilling its contractual obligations to supply CO₂ to the neighboring Weyburn oil field to use in EOR, resulting in penalties which further increase the cost of the project. One study found that the project reduces CO₂ at a cost of \$100/tonne and claims it is in effect "a very high carbon tax" levied on Saskatchewan households and other energy consumers.⁴⁵ The Boundary Dam project is arguably the most successful CCS project undertaken to date, anywhere in the world.

Still, efforts continue to commercialize carbon capture technology at utility scale. For example, in May of 2018, the state of Wyoming and its public and private partners celebrated the completion of the Wyoming Integrated Test Center (ITC). The ITC is a real-world carbon capture and utilization laboratory connected directly to Basin Electric's Dry Fork coal-fired power plant located near Gillette, Wyoming. The purpose of the ITC is to allow teams to compete for a \$20 million XPrize sponsored by the Carbon XPRIZE foundation and others, in developing viable and cost-effective uses for captured carbon. Several teams are ready to develop useful products from the Dry Fork CO₂, from additives to make cement stronger and more durable, to mediums for 3-D printing. There is also some research on the use of calcite and some forms of volcanic rocks to use as carbon capture technology.⁴⁶

WECC will continue to assess the levelized costs (LCOE) of new power generation options, including those using carbon capture and sequestration. Trend analyses will continue to monitor development in this area and determine whether developments warrant further assessments.

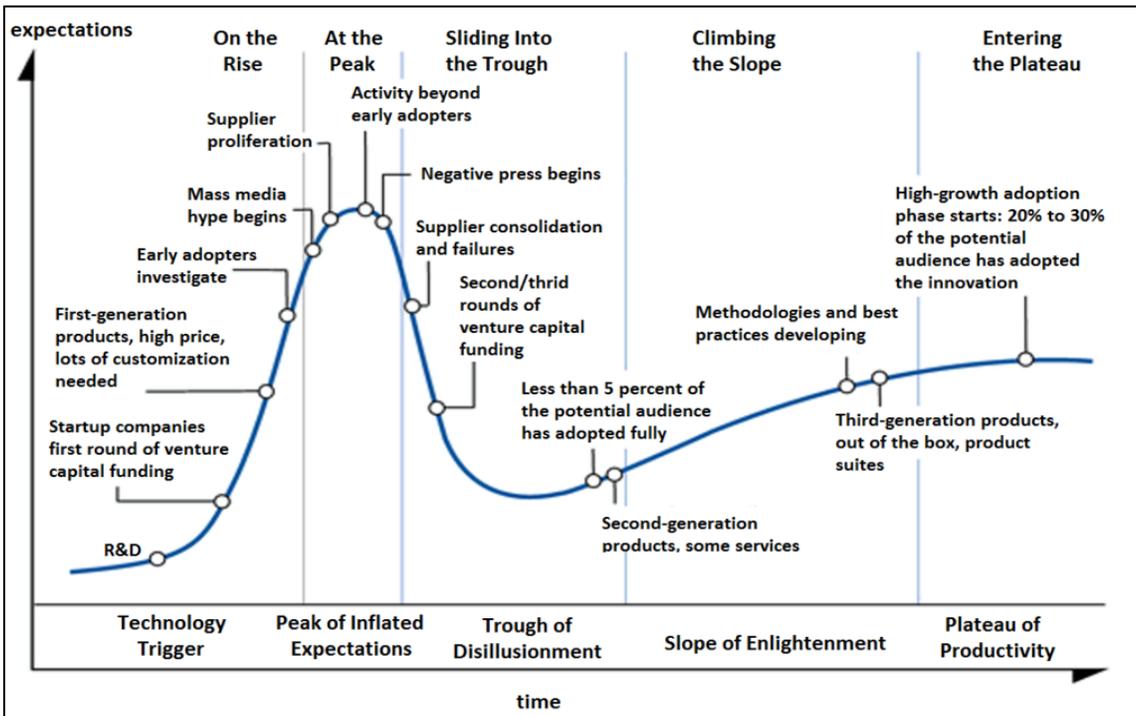
⁴⁵ <https://www.saskwind.ca/boundary-ccs>

⁴⁶ [Iceland Carbon Dioxide Storage Project Locks Away Gas, and Fast](#), The New York Times, June 9, 2016

6. The Technology Adoption Hype Cycle – Crossing the Chasm

The Gartner Hype Cycle⁴⁷ provides insight into the expectations of new technology over the entry and adoption of the technology or product

Figure 5: The Hype Cycle



Source: Wikipedia

The hype cycle is a branded graphical presentation developed and used by the American research, advisory and information technology firm Gartner, for representing the maturity, adoption and social application of specific technologies. The hype cycle provides a graphical and conceptual presentation of the maturity of emerging technologies through five phases, and is broadly used in the marketing of new technologies.

A condensed statement of a hype cycle is found in Amara's law⁴⁸ coined by Roy Amara, which states that "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run." The five phases of the Hype Cycle are:

1. The Technology Trigger - A potential technology innovation or breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.
2. Peak of Inflated Expectations - Early publicity produces a number of success stories -often

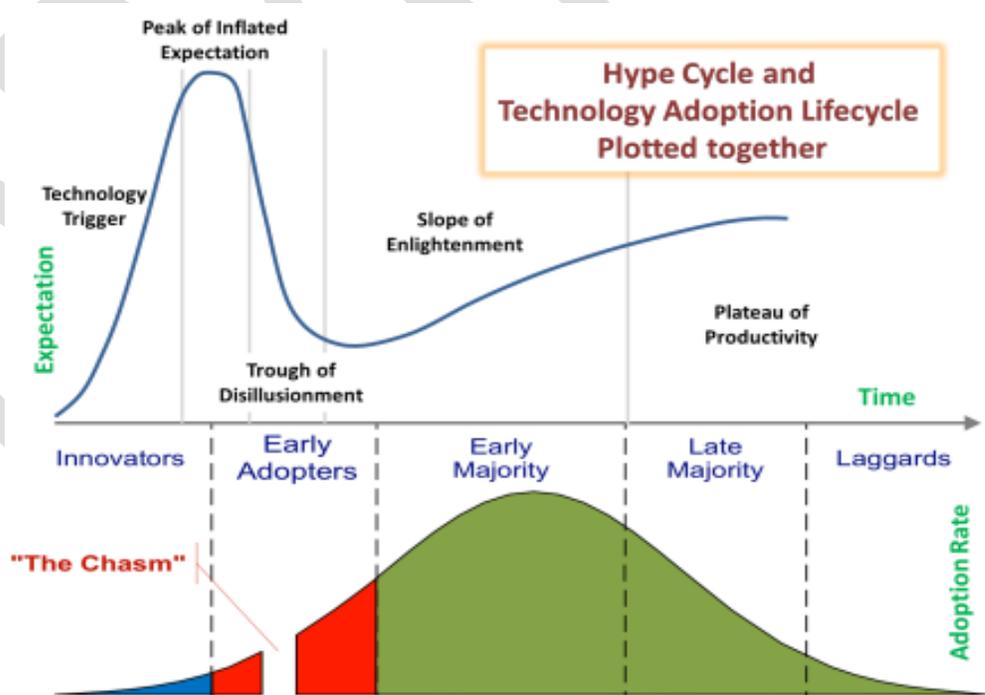
⁴⁷ [Hype Cycle](#), Wikipedia, edited April 10 2018

⁴⁸ [Amara's Law](#)", Spotless Data, 2017

- accompanied by scores of failures. Some companies take action; most don't.
3. Trough of Disillusionment - Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investment continues only if the surviving providers improve their products to the satisfaction of early adopters.
 4. Slope of Enlightenment - More instances of how the technology can benefit the individual or enterprise start to crystallize, and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
 5. Plateau of Productivity - Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off. If the technology has more than a niche market then it will continue to grow.⁴⁹

Geoffrey Moore considered technology adoption in the context of discontinuous innovations where there may be gaps between the five groups noted above, in particular between the early adopters and the early majority. New technology-based products (or services) cannot be successful in the mainstream until they “cross the chasm”.⁵⁰ Companies cannot sustain themselves selling just to the innovators or early adopters as the number of either category in any single marketplace is small, and there are other competing products. One way to consider the Hype Cycle and the Technology Adoption curves is to map them together.

Figure 6: The Hype Cycle and Technology Adoption Curves



⁴⁹ Chaffey, Dave, (2016). *Digital Marketing*. Ellis-Chadwick, Fiona, (Sixth edition). Harlow: Pearson. pp. 140–141.

⁵⁰ Geoffrey Moore, *Crossing the Chasm*, 3rd edition, Collins Business Essentials, January 28 2014

7. General Early Indicators

While there are scenario-specific Early Indicators (EIs), there is also a class of indicators which may affect any or all of the scenarios at any point in time, in different ways. These EIs are very important for trends analysis, and will be followed along with developments in Key Drivers and the EIs for each scenario. A beginning list of the General EIs includes:

1. Developments in the U.S. national and global economy that might influence growth in power demand (this should include economic growth across the Western Interconnection).
2. Significant technological breakthroughs that can influence the industry by lowering key costs (especially of power generation), enable new service or product offerings, or ease the entry of new forms of competition.
3. The emergence of a new standard or criteria that influences energy policy directions at the Federal, State or Provincial level.
4. How innovative DER, like battery storage technologies and other distributed generation options, evolve and are used to meet reliability. In particular, what is the balance in DER investment between utility scale and owned investments versus DER investment by independent non-utility players and consumers?
5. Cyber-security risks in the electric power infrastructure of the nation.

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