The WECC 2018-2038 Scenarios:
Trends Analysis and Early Indicators Report

Fourth Quarter of 2019

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CONTENTS

INTRODUCTION

This report by the Quantum Planning Group (QPG) to WECC and the Scenario Development Subcommittee (SDS) covers significant Event-Pattern-Structure (EPS) events and developments in the electric industry and energy markets in the Fourth Quarter of 2019 (October, November, and December). The report also serves as a year-end report for 2019 by looking at the long-term trends for each Key Driver from 2018 through 2019. This report focuses on:

1. Significant Uncertainties, Major Long-Term Trends, and Wild Cards
2. Significant Key Driver Events for the 2018-2038 WECC Scenarios and their implications,
3. Trend developments and Early Indicators (EIs) for each Scenario, and
4. Movement and progress indicated by the trends towards one or more of the WECC Scenarios.

This report also includes coverage of Scenario 5: Energy, Water, and Climate Change since EPSs can be related to this Scenario, even though there are no specific Early Indicators for this Scenario other than a 3-degree F temperature rise by 2034.

Our analysis in this report considers and builds on learnings from the Trends Reports since the beginning of the 2018-2038 WECC Scenarios, about two years ago. We refer the reader to the previous *WECC Scenarios: Early Indicator, Trends, and Scenario Movement Analysis reports (Trends Reports)* for additional background information found here.

Keeping a focus on reliability, we include summary remarks about possible implications for electric reliability after each of the Key Driver sections below.

In the Fourth Quarter of 2019, there were 98 EPS submitted to the WECC EPS system with 94 EPS with EIs flagged (96%), for a total of 208 EIs. For the year 2019, there were 461 EPS submitted to the WECC EPS system, with 432 EPS with EIs flagged (94 %), for a total of 998 EIs. All EPS can be viewed and searched, and SDS members and WECC Staff can submit their EPS here.

The links to the EPS referenced in this report are "hot" and, when clicked, will take the reader directly to the referenced EPS. If the reader finds a problem with a link in this report, you can contact QPG directly for help.

Many times, a single EPS may affect more than one Scenario or multiple Key Drivers, and we may cite them multiple times in the report, so the full impact of the EPS is clear.

We think direct reporting of the source article is essential for the reader's learning, and therefore, the EPS items referenced may include excerpts taken directly from the referenced article text as well as Quantum Planning commentary. Because of the wide diversity and interests of the readership, and how the reader elects to read the report—printed or screen viewed—we have erred on the side of more detail rather than less in the excerpted text.

EXECUTIVE SUMMARY

This report of Key Driver Trends and Scenario Early Indicators (EIs)—the Trends Report—by the Quantum Planning Group (QPG) is produced for WECC and the Scenario Development Subcommittee (SDS). The 2018-2038 WECC Scenarios are now almost two years old, and we think it is time to consider the long-term trends in each Key Driver seen over the past two years. This review will also provide an opportunity for WECC Staff and SDS Members to revisit the focus of the scenarios as described in the Key Focus Question of the scenarios:

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?

Key long-term trends for each Key Driver use the EPS submitted by WECC Staff, QPG consultants, and SDS Members since July 2018. Significant EPS for the Fourth Quarter will be noted in the Scenario Trends and Early Indicators section starting on page 21. Wild Cards and Outliers are reported as in previous reports.

Wild Cards and Outliers

Cyber-Security: We continue to track developments around cyber-security as a Wild Card. In the fourth quarter, we saw two significant events and a new analysis of grid cyberattack entry points. Small regional utilities located near critical infrastructure are being targeted in cyberattacks as attackers try to find alternate routes to attack targets. The first cyberattack on solar and wind assets revealed widespread grid weaknesses, and an analysis shows that the proliferation of DER into distribution systems and the Bulk Power System (BPS)is providing an increasing number of access points for cyber attackers—in many cases these assets have little or no cybersecurity, allowing attackers easier access than through hardened BPS assets.

The US 2020 Election: The general election in November 2020, and the events leading up to it, will have broad and unforeseen effects for the US and the Western Interconnection, not to mention worldwide, as the most likely candidates in the election have widely differing views and policies related to energy. The primary season will kick off with the US president impeached and facing a trial in the US Senate. What happens after the election is anyone's guess at this point, whether President Trump wins or loses the election. We are adding the election to our Wild Cards for 2020.

BREXIT: As of this writing, Great Britain is facing an exit from the European Union (EU) by January 31, 2020. UK Prime Minister Boris Johnson won the most recent general election, and his BREXIT deal passed Parliament with an overwhelming majority. The withdrawal agreement bill must clear the House of Lords. The UK and European parliaments must formally ratify the BREXIT deal. If approved, the UK will leave the EU on January 31, 2020, and a transition period begins.

Reports of Technological Advances: We have captured in several EPS various technological advances or increases in understanding of some fundamental physical properties. However, none of these reports suggest the creation or production of a significant new product or service that can be offered in the near term to the electric power industry or customers. Historically the course of this kind of innovation takes years, if not decades, before a truly useful and competitive product or service is introduced into the market. Even with the introduction of an innovative product to the marketplace, competitive and market forces related to consumer values make the success or industry impact of a breakthrough largely unpredictable.

Details on these Wild Cards start on page 7.

Key Driver Trends

There are significant long-term trends for each of the Key Drivers chosen by the SDS for the 2018-2038 Scenarios:

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 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 Driver Summary

Changes in State and Provincial Electric Energy Market Policies: Across the Western Interconnection, we see a continuation of policies at the State and Provincial levels which support the continued and expanded use of cleaner and more renewable power supplies. Distributed energy options, including batteries and storage, are being encouraged at both the customer and utility levels. Due to the wide variations in state and provincial policies related to managing and investing in local distribution systems, no dominant new trend appears visible.

Evolution of Customer-side Energy Supply Technology and Service Options: At the most fundamental level, we see nothing that persuades us that electricity customers do not still want quality, safe, and reliable electric power at a reasonable cost. They also want to use electricity for the primary purposes that have been dominant for decades, including operating an almost infinite range of equipment and appliances, providing light, supporting living space heating and air conditioning, pumping water, and, more recently, powering transportation (EVs). In addition to EVs, it is feasible that electricity demand may grow to take advantage of the cost-effective use of power to provide services related to health and environmental concerns.

Changes in the Character and Shape of Customer Demand for Electric Power: A fully functional prototype that points clearly to the next evolution of customer side electric power supply innovation (think moving from the wall phone to the cell phone) has not been demonstrated in the marketplace. The exact nature of the possible underlying devices and services remains unclear as do the needs they will meet (lower costs, more reliable, new capabilities, flexibility of use, etc.). There is no standard industry-wide, peer-reviewed, and accepted economic analysis that shows how a more distributed customer-centered power system will have benefits that make the costs—now unclear— justify the benefits. However, the nature of any such benefit may be based on uncertain consumer values that will not be subject to strict economic value criteria.

Changes in Federal Electric Energy Market Policies: Federal policies that have taken place to support investment in the power industry, such as tax breaks, accelerated depreciation, subsidies of various sorts, and R&D related grants appear to remain within recent historical patterns. The current US administration continues to move against climate change-related policies at both the international and national levels. However, due to challenging lawsuits and the slow pace of change built into regulatory and legal systems, the direct impact of many of the changes attempted by the Administration have yet to have any dramatic effects.

Changes in Utility-scale Power Supply Options: We fully expect the now long-standing trend of declining costs for clean energy production from wind and solar power to continue at a level where those technologies are highly competitive options and used widely in the power industry. Due to competitive costs of the fuel and long term expectations of abundant domestic supplies, natural gas-fired electric generation continues to be built across the Western Interconnection. Abundant long-term supplies suggest long-term competitive prices for natural gas and, thus, a continued role in the U.S. power system.

Changes in State and Federal Electric System Regulations for Reliability: The thrust and intent of developments in Federal, State, and Provincial regulations of system reliability continue to focus on improving conditions in which reliability risks can be addressed and reduced. The big change we see over the past two years is a growing local trend of requiring and enabling through regulation more battery storage to be included in the mix of reliability resources as more renewable generation is added to both the bulk power system (BPS) and at the distribution level. Cybersecurity continues to be of critical importance to long-term power system reliability and system resilience.

Evolution of Climate Change and Environmental Issues on Electric Power Service: In the past two years, many new studies have added to our knowledge of the rate of increase in global warming, extreme weather events, the understanding of local temperature rises versus the global average and the projected impacts and costs of a warming climate. All signs point to this trend of accelerating warming and increasing GHG emissions continuing, with little or no effective efforts to slow or halt the trend on WECC's planning horizons.

Evolution of Fuel Markets in the Electric Power Sector: Recent and short-term developments in fuel markets in the power sector—mainly natural gas and coal— do not present any new emerging risks for any of the categories of electric reliability. However, we are seeing a potential trend of over-production straining the storage and transportation infrastructure in two major natural gas fields that may cause a correction in the long-term market dynamics and prices.

Shifts in the Cost of Capital and Financial Markets: The global economy has been in turmoil and is slowing, exacerbated by the trade wars between the US and China and the European Union (EU), the continued uncertainty of BREXIT, and the normal cycle of slow down after recovery from recession. Even in this environment, continued low cost and abundant sources of capital will exist for the power industry for development both in the short and long-term.

Economic Growth within the Western Interconnection: North American (NA) economies are stressed, continuing the slowdown noted in past Trends Reports. The current US trade deficit continues to widen—not in favor of the US— and as the global economy slows, US manufacturing continues to contract and is experiencing significant job losses. There is no unanimous agreement among analysts, economists, or pundits as to the trajectory of either the global economies or those of North America—uncertainty is the rule, rather than the exception.

Worldwide Developments in the Electric Power Industry: In the short and medium-term, we see a continued decline in the costs of renewable energy technologies and a corresponding increase of use. Innovations and cost reduction in storage paired with clean energy will be cost-competitive and enhance approaches to meeting reliability. Information, communications, monitoring, and software management systems have been and continue to be used in the provision of electric power services. However, the use of artificial intelligence systems to provide enhanced customer engagement and new services, using customers and other sources of data, is just emerging. However, we remained concerned that the power industry—on a global basis—will not move far enough toward renewable and low carbon emission generation to address the scientific community's recommendations on replacing greenhouse gas emissions needed to reduce climate change risks.

Implications for Reliability: At this time, we see no extraordinary challenges emerging that would lead to a decline in the ability of the industry to meet historical levels of reliability, with two exceptions.

1. Developments related to the evolution of climate change and environmental issues that could impact the power sector: Actions by humans and policy developments to address climate change nationally and globally are not now sufficient to slow the forecasted increasing destructive effects (e.g., drought, wildfires, flooding, extreme storm events, etc.).
2. Cyber-security: Will the power industry successfully adopt the necessary tools and operating processes that can prevent or mitigate large-scale or cascading power system failures due to cyberattacks?

We are also concerned about a potential economic disruption due to recent events impacting the US and global economy (e.g., tariffs, high debt levels). In the past, these kinds of events have slowed energy demand growth but have not directly reduced reliability.

On a more positive note, we see enhanced opportunities to improve reliability driven by the falling cost of storage based technologies and their growing use in utility-scale applications. Also, we think the eventual emergence of expanded purchases of electric vehicles could offer demand-side energy management options in the power industry if combined with distribution system upgrades.

Scenario Trends

Past Trends Reports, based on the WECC Legacy Scenarios, focused on an analysis of the movement from one scenario to another scenario of the Western Interconnection as a whole. As we noted in past SDS meetings, we believe that in the 2038 Scenarios, given the choices by the SDS for the Primary Scenario Drivers and other Key Drivers, states, and provinces within the region will not move in lockstep towards any particular scenario. Considering the new Scenario Matrix, this would imply that there would not be a region-wide "movement" that could be plotted against the new scenario matrix as in the Legacy Scenarios until later in the life of the scenarios, as trends develop over time and converge into a recognizable trajectory.

However, our review of the 2018-2019 Key Driver long-term trends tends *to support movement in the Western Interconnection as a whole towards both Scenario 1 and Scenario 4*. We can also see developments that argue for Scenario 3 in many states in the Western Interconnection. A key element of this assessment is the lack of any significant technological developments or other market-related issues that would lead to a quickened uptake of the kinds of energy-related services and products advocated most strongly in Scenario 2. We also consider the Western Interconnection in Scenario 5 as many regions within the Western Interconnection have already met or exceeded the 3 degrees Fahrenheit temperature rise threshold for the scenario. Many other areas are just reaching that tipping point, and others may soon follow.

Our detailed look at Wild Cards, Key Driver Trends, and Scenario Trends and Movement follow.

WILD CARDS AND OUTLIERS

Cyber-Security: In the fourth quarter, we saw two significant events and a new analysis of grid cyberattack entry points. Small regional utilities located near critical infrastructure are being targeted in cyberattacks as attackers try and find alternate routes to attack targets. Security firm Proofpoint in September concluded more than a dozen utilities were targeted. The attacks were not successful, and some utilities were unaware of the attempt. Smaller electric utilities may pose an oversized threat to the electric grid, as they often lack the robust cybersecurity infrastructure of larger investor-owned utilities. The list of targeted utilities included at least two in the Western Interconnection: *Klickitat Public Utility District in Washington,* and *Flathead Electric Cooperative,* which serves members on the Montana-Wyoming border. Some of the utilities were unaware of the attacks until the Federal Bureau of Investigation told them they had been targeted.

- EPS: Small, regional utilities located near critical infrastructure targeted in cyberattack: WSJ

A March 5 cyberattack of U.S. wind and solar assets (see EPS A "cyber event" disrupted operations in California, Wyoming, and Utah in March) is back in the news, with new documents helping shed light not just on the extent, but also the simplicity of the first-of-its-kind intrusion. Cybersecurity experts say it reveals a utility sector not sufficiently vigilant and failing to employ the most simple fixes. Though there was no loss of generation, the March cyberattack impacted the company's visibility into about 500 MW of wind and PV across California, Utah, and Wyoming. The company is the first-ever US provider of solar and wind renewable energy to have been the victim of a cyber-attack, and the company is the first US power grid operator that is known to have lost connection with its power generation installations as a result of a cyberattack. "The simplicity of this attack should make generators sit up and take notice," an analyst said. *"This was a 'simple' IT attack on an unpatched firewall, which was still vulnerable, in spite of the patch being available."*

- EPS: First cyberattack on solar, wind assets revealed widespread grid weaknesses

As the United States' electric system becomes more distributed, security experts say the growing array of internet-connected sensors and industrial control systems presents a potential vulnerability that is not clearly understood and could be exploited to cause blackouts. A new assessment from the U.S. Government Accountability Office, notes that industrial control systems and the rise of distributed resources are now playing major roles in the growing risk. The report recommends the Federal Energy Regulatory Commission (FERC) analyze the threat of a "coordinated cyberattack on geographically distributed targets" and consider beefing up its security requirements and compliance thresholds. Security by obscurity was historically an important way of protecting ICS infrastructure. The GAO report notes that early ICS "operated in isolation, running proprietary control protocols using specialized hardware and software." These systems were also often in physically secured areas, unconnected to broader networks—this is no longer the case.

- EPS: US power grid attack points surge with proliferating DERs
- EPS: US electric grid more vulnerable to cyberattacks as DERs increase potential targets

The US 2020 General Election: The US will have a general election in November 2020, and events leading up to the election will have unforeseen effects on both the NA and global economies, especially in light of the recent impeachment of the US president and a Senate trial, which will linger into the New Year. The primary season will kick off with the US president impeached and facing a trial in the US Senate. Election interference by foreign state actors and others in a variety of forms will quite probably occur, leveraging learning from their 2016 efforts. What happens after the election is anyone's guess at this point, whether President Trump wins or loses the election. We are adding the election to our Wild Cards for 2020.

BREXIT Update: As of this writing, Great Britain is facing an exit from the European Union (EU) by January 31, 2020. UK Prime Minister Boris Johnson won the most recent general election, and his BREXIT deal passed Parliament with an overwhelming majority. The withdrawal agreement bill must clear the House of Lords, and the UK and European parliaments must formally ratify the BREXIT deal. If approved, the UK will leave the EU on January 31, 2020, and a transition period begins. As this process will continue well into the next five years, we will continue to watch developments.

Why BREXIT Matters - We noted in past reports that BREXIT could have significant economic implications not just for Britain, but also for the global economy and the US. At this point, indicators point to a so-called "hard" exit, which means that Britain will leave not only the EU but also the single market and the customs union. In this scenario, the UK would instead aim to secure free-trade deals with the EU, ideally covering both goods and services. Direr would be a "no-deal" exit, where Britain would no longer be a member of the EU, and it would have no trade agreement. It would have all of the disadvantages of a hard Brexit, and there would be no trade agreement.

The US would not be immune from the global economic impacts[1], and more directly, many US businesses use Britain as their doorway into the EU, and under a hard BREXIT, that entry point goes away. That's going to cause a lot of complications for US businesses, as companies will find it harder and more expensive to move goods between the U.K. and the rest of Europe, with delays, tariffs, and more paperwork. The net result could easily be a push accelerating the already slowing US economy and slowing electricity demand.

Reports of Technological Advances: We have captured in several EPS various technological advances or increases in understanding of some fundamental physical properties. However, none of these reports suggest the creation or production of a significant new product or service that can be offered in the near term to the electric power industry or customers. Historically the course of this kind of innovation takes years, if not decades, before a truly useful and competitive product or service is introduced into the market. Even with market introduction of innovative products, competitive and market forces related to consumer values make

[1] EPS: Storm Clouds Are Brewing for the Global Economy, The World Bank, Global Economic Prospects, January 8 2019

the success, or industry impact, of a breakthrough largely unpredictable. We suggest the reader review the following EPS for more detail on recent technology advances and a piece on innovation adoption timing:

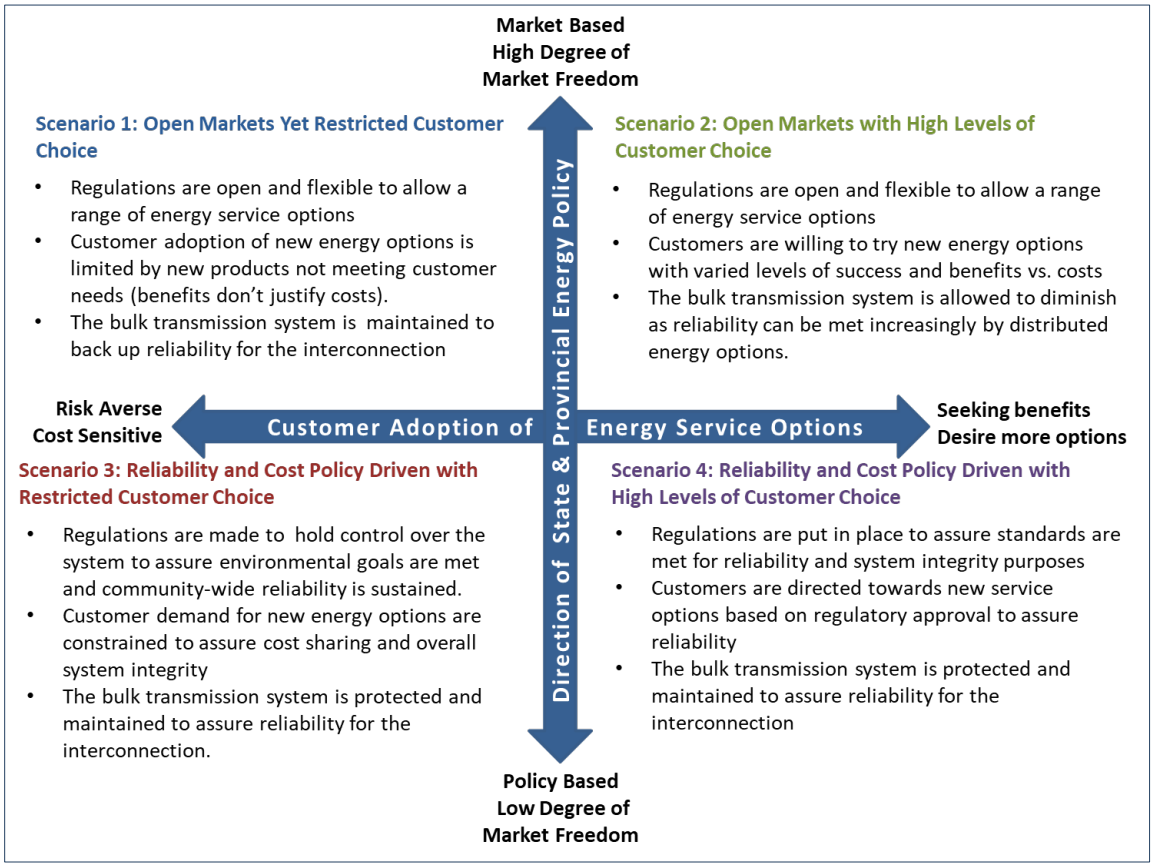
- Energy startup backed by Bill Gates achieves solar breakthrough
- Researchers announce breakthrough in carbon fibers allowing for superconductivity
- Scientist create a permanent liquid form magnet
- How 5G high-speed America jolts grid security
- Study released on the slow uptake of energy technologies

KEY DRIVER LONG-TERM TRENDS

The WECC Scenario Matrix

Each of the four WECC 2018-2038 Scenarios fits into one of four quadrants within a 2 x 2 matrix, using the two primary scenario drivers chosen by the SDS of 1), Direction of State and Provincial Energy Policy, and 2), Customer Adoption of Energy Service Options. Each Scenario can thus be described – *at a high level* – by the combination of the matrix axes.

Figure 2, WECC Scenario Matrix



The matrix provides both a quick visual model for the Scenarios and a reference for the discussions that follow. However, for a complete understanding of the Scenarios, we encourage readers to read the WECC 2018-2038 Scenarios Narratives.[2]

Our review of Key Driver trends follow, and in this report, it is provided to generate discussion among SDS members and WECC Staff to assess how the Key Drivers on which the Scenarios were built are trending. The

[2] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

2018-2038 WECC Scenarios are now almost two years old, and we think it is time to consider the long-term trends in each Key Driver as they have evolved over the past two years. This review will also provide an opportunity for WECC Staff and SDS Members to revisit the focus of the scenarios, and a starting point for that discussion begins on page 21.

The observations below are provided by QPG as starting points, and should not be considered as "comprehensive" given the underlying uncertainties faced by the electric power industry, and the wide-ranging developments within the Western Interconnection's states and provinces. Based on our review of the past two years, we find no reason to change the fundamental starting point definitions of the Key Drivers, and we include them as a reminder for the reader.

At the end of each Key Driver review, we provide a starting set of keywords for the reader to search the EPS system for events related to that driver through a link to the EPS system. The reader can also look for any other EPS on topics of interest by using keywords typed in the search box on the webpage. For those readers who may want to read the report on paper, here is the full URL for the EPS system page you can copy and paste into your web browser:
https://www.wecc.org/SystemAdequacyPlanning/Pages/Scenario-Planning.aspx

Changes in State and Provincial Energy Market Policy

From the 2038 Scenario Report: "Fourteen Western states, two Canadian provinces, and Northern Baja California make up the geographical footprint of the Western Interconnection supported by WECC. They set policies and rates which directly impact how electricity markets function within their areas of jurisdiction and influence regional patterns as well. How electricity supply and demand is met is governed in large part by the policies set by individual states and provinces, including 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. States and Provinces also set 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."[3] Long-term trends in the evolution of this driver over the last two years include:

- Across the Western Interconnection, we see a continuation of policies at the State and Provincial levels, which support the continued and expanded use of cleaner and more renewable power supplies. Distributed energy options, including batteries and storage, are being encouraged at both the customer level and at utility-scale.
- While there are variations in the intensity of State and Provincial policy support explicitly directed at addressing climate change and reducing carbon emissions, we see broad policy support in making efforts to address climate risks.
- In several cases within the Western Interconnection—California and Colorado in particular—state regulatory authorities are making efforts to assure electric reliability by requiring alternative energy services entities, e.g., customer choice aggregators, to assure long term supply capacity. As these regulations are just taking form and debated, they will require continued monitoring.
- Due to the wide variations in state and provincial policies related to managing and investing in local distribution systems, no dominant new trend is visible. States and provinces remain concerned about the costs and benefits of investments such as advanced meter technology and energy system management technologies. There is a wide range of those technologies and their applications, so this area should continue to be monitored for the emergence of a standard that has broad industry-wide applications and clear benefits.

[3] WECC 2018-2019 Draft Scenarios for Horizon Year 2038, July 24 2018

Implications for Reliability: We see no challenges to electric reliability in the Western Interconnection from these long-term trends in State and Provincial energy market policies. Policies continue to support capacity expansion and thus enhance long term reliability.

Reader Note: By using keywords such as: the proper name of a state or province, e.g., **Alberta, Utah, California, etc., CAISO, EIM, Regulators, PUC,** and **Markets**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

Changes in Federal Electric Energy Market Policies

From The 2038 Scenario Report: "The US, Canadian, and Mexican national governments set policies that have national impacts on electric energy markets. In terms of electric service reliability, the very foundation of WECC itself 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 development, and environmental standards are among those which can have a great influence on the evolution of electricity markets and on how electricity services are delivered aside from market rules. Federal laws on consumer protection, taxes, and other areas can also influence the evolution and nature of electric customer demand."[4] Long-term trends in the evolution of this driver over the last two years include:

- The current US administration continues to move against climate change-related policies at both the international and national levels. However, due to challenging lawsuits and the slow pace of change built into regulatory and legal systems, the direct impact of many of the changes attempted by the Administration have yet to have any dramatic effects. This may not be true over time.
- Federal policies that support investment in the power industry, such as tax breaks, accelerated depreciation, subsidies of various sorts, and R&D related grants appear to remain within recent historical patterns. A tax break to support carbon capture and sequestration is in the 2017 tax reform law; however, it has not been effective in slowing coal plant retirements, which are mostly occurring due to broader economic issues such as plant retro-fitting, or life extension costs, and low-cost natural gas.
- Federal policy supporting the expanded use of battery storage technology is complementary with the cost reductions from improved technology and is an additional factor in the growing use of battery storage at utility-scale.
- In Canada, there seems to be a commitment to addressing climate change issues at the federal level and in some provinces. Economic growth and job concerns in other provinces dependent on oil and gas as their primary economic drivers continue to fight the federal carbon tax even though they have lost all court challenges to date

Implications for Reliability: We see no challenges to electric reliability in the Western Interconnection from these long-term trends in Federal energy market policies. Policies continue to support capacity expansion and thus enhance long term reliability.

Reader Note: By using keywords such as: **federal government, FERC, DOE, IEA, PURPA,** and **capacity market**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

Evolution of Customer-side Energy Technology and Supply Options

From The 2038 Scenario Report: "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

[4] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

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 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."[5] Long-term trends in the evolution of this driver over the last two years include:

- A fully functional prototype that points clearly to the next evolution of customer side electric power supply innovation (think moving from the wall phone to the cell phone) has not been demonstrated in the market place. The exact nature of the underlying devices and services remains unclear as do the needs they will meet (lower costs, more reliable, new capabilities, flexibility of use, etc.).
- Within the US, the rate of electric vehicle sales has barely moved above 2% of total car and light-duty vehicle sales in recent years. However, the global automotive industry is moving toward more production of EVs and offering consumers a wide range of options. Billions of dollars of investment are being made in this effort. In the near term, some auto manufacturers are concerned that more EVs will be offered to the market than there will be demand. If this occurs and how this shakes out has to be monitored. Even with growth in EV sales, it is not anticipated that meeting the growth in demand from charging those vehicles represents a significant challenge to the Western Interconnection as the power industry can easily add capacity.
- There is no standard industry-wide peer-reviewed and accepted economic analysis to show that a more distributed customer-centered power system will have benefits that make the costs—now unclear— justify the benefits.
- Some of the information and communications technologies suggested for use in the power grid (in particular at the distribution level to enable more "customer engagement") have their origins and most accepted applications in product markets not related to electric power. Historically most of the technology upon which the electrical power industry is built was targeted and optimized for the electric power sector. Transferring new information and communications technology to the power system thus represents adoption and adaptation challenges that could lead to errors, false starts, and unpredictable costs as well as opportunities for breakthroughs—although what might emerge or in what combinations is unclear.
- Within the Western Interconnection, state and provincial jurisdiction over local and in-state electric services markets can provide a wide range of approaches to creating—or transitioning toward— a new, more distributed customer-centric power system. We do not see signs of emergent Federal policy leadership in this area that will provide guidance and direction toward a common model or process for industry transformation.

Implications for Reliability: In considering these long-term trends, we cannot suggest that electric system reliability is being harmed or helped. In particular, the use of the BPS may change, with emerging trends in more distributed customer-centric electrical energy services. However, it is simply too early to say what those changes will be or their effect on bulk system expansion. We do find it interesting that some consultants, analysts and equipment providers in the field are using conditional language ("could, may, has the potential to, if and in the future") to suggest that such benefits for improved reliability, sustainability and environmental quality are likely to emerge.

Reader Note: By using keywords such as: **DER, solar, lithium ion, batteries, tesla, bitcoin,** and **blockchain**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

[5] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

Changes in the Character and Shape of Customer Demand for Electric Power

From The 2038 Scenario Report: "Customer demand for electric power can shift for a wide range of reasons, including economic growth, response to cost changes, customer desires for new features and benefits (like carbon reduction). The many segments of customers include large and small industrials, large and small commercial, both large and small agriculture, high income to low-income residential consumers, and other marketing defined segments. Customers within all of the segments may change the features they desire for electric power service as market conditions change. Economic factors may influence the costs and the 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."[6] Long-term trends in the evolution of this driver over the last two years include:

- At the most fundamental level, we have seen nothing that persuades us that electricity customers do not still want quality, safe, and reliable electric power at a reasonable cost. They also want to use electricity for the primary uses that have been dominant for decades, including operating an almost infinite range of equipment and appliances, providing light, supporting living space heating and air conditioning, pumping water, and more recently powering transportation (EVs). In addition to EVs, it is feasible that electricity demand may grow to take advantage of the cost-effective use of power to provide services related to health and environmental concerns.
- The Duck Curve phenomenon, in which peak supply and hourly demand diverge, most visibly in California, will continue and may emerge in other areas of the Western Interconnection as more intermittent power sources are added. We expect that the companies and regulatory authorities involved will manage this issue within local conditions and future resource plans. How power may be traded within the Western Interconnection as the growth in energy supplies continue will warrant continued observation. In the short-term, this continuing growth is encouraging expanded participation in electric power imbalance markets.
- Cost management issues and participation in demand-side energy management program customers where energy is a significant portion of their operating costs, e.g., industrial, commercial, and agricultural customers, continue to use more information about their energy use. Detailed information on energy use by residential customers already exists and can be further developed, especially with additional smart meter installations. And, there are some instances where power companies can manage their distribution systems more effectively using those customer information system capabilities. How this expands and with what new benefits for residential customers and distribution utilities remains a question in light of new applications emerging and offered. We have yet to see reported large-scale benefits for residential energy management at levels where the operation of the bulk transmission system has been impacted through changes in needs for power capacity.

Implications for Reliability: We see no significant challenges or risks to electric reliability emerging from these long-term trends in the character or shape of customer demand for electric power.

Reader Note: By using keywords such as: **electric vehicles, EV, energy efficiency, behind the meter, advanced meters,** and **appliances**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

[6] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

Changes in Utility-Scale Power Supply Options

From The 2038 Scenario Report: "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 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 more capabilities in meeting reliability services, and therefore, additional flexible resource adequacy."[7] Long-term trends in the evolution of this driver over the last two years include:

- We fully expect the long-standing trend of declining costs for clean energy production from wind and solar power to continue at a level where those technologies will be highly competitive options and used widely in the power industry.
- Battery-based storage options at utility-scale are continuing to improve in terms of costs and usefulness in power system management. While we expect this growing trend to continue for at least a decade, in the longer-term, some new non-lithium-ion based technology will be needed to sustain large-scale cost reductions.
- Small-scale nuclear power remains in the pilot and demonstration phases of development, and we expect that to be the case for many years before a widely reliable and cost-competitive power supply option will emerge for wide use at utility or distribution scale.
- Due to competitive costs of the fuel and long term expectations of abundant domestic supplies, natural gas-fired electric generation continues to be built across the Western Interconnection. Abundant long term supplies suggest long term competitive prices for natural gas and thus a continued role in the U.S. power system. However, some industry analysts are concerned about locking in the carbon emissions from continued use of natural gas and argue that if carbon taxes emerge, investment in natural gas-fired power will be regretted as some units may be stranded based on continued declines in renewable cost, eventual carbon taxes, and emissions restrictions.

Implications for Reliability: We see no significant challenges or risks to electric reliability emerging from long-term trends and changes in utility-scale power options.

Reader Note: By using such keywords as: **natural gas, solar power, wind energy, hybrid, nuclear, capacity,** and **reliability**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

Changes in State and Federal Electric System Reliability Standards and Regulations

From The 2038 Scenario Report: "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

[7] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

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."[8] Long-term trends in the evolution of this driver over the last two years include:

- The thrust and intent of developments in Federal and State/Provincial regulations of electric systems' reliability continue to focus on improving conditions in which reliability risks can be addressed and reduced. The federal regulatory departments and agencies, e.g., FERC and the EPA, have generally supported the status quo. For states and provinces within the Western Interconnection, natural gas plants continue to be the primary reliability reserve generation choice by state regulators—primarily driven by continued low fuel costs—even to the point of adding capacity over traditional reserve margins. However, as battery storage and renewable costs continue to drop, the mix of tools in the regulator tool kit has evolved.

- The big change we saw over the past two years is a growing local trend of requiring and enabling through regulation more battery storage to be included in the mix of reliability resources as more renewable generation is added to both the bulk power system (BPS) and at the distribution level. Storage is added as a standalone resource or added to natural gas plants, renewable installations, or with hybrid installations of storage + gas + solar/wind. In some cases, new storage installations have served to replace new distribution lines. As the cost of battery storage continues to fall (almost 50% in the past three years), we expect this new trend to continue.

- Cybersecurity continues to be of critical importance to long-term power system reliability and system resilience. Although not all attacks are made public, hacker attacks on localized grid nodes seem to be accelerating in number and effectiveness, exposing widespread grid weaknesses. And, as more DER is added to systems, attack points grow in number, making the grid more vulnerable. NERC did recently strengthen cyber "event" reporting requirements, but there is no national, state, or provincial regulations focused on hardening the national grid to cyberattacks. Cybersecurity remains one of the most significant threats to grid reliability in both the short and long term.

Implications for Reliability: While the long-term trend of Federal, State, and Provincial regulations of electric systems are intended to maintain reliability and improve conditions in which reliability risks can be addressed and reduced, cybersecurity remains a distinct and significant short and long-term threat to reliability across the Western Interconnection.

Reader Note: By using keywords such as: **reliability, regulations, rules, reserve, hybrid, capacity, cybersecurity, cyber**, and **hacker**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

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

From The 2038 Scenario Report: "Addressing climate change is a central issue in the evolution of 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 those policies will impact the cost of power. How customers see, and value climate and environmental issues will impact future legislation placed on the power industry."[9] Long-term trends in the evolution of this driver over the last two years include:

[8] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018
[9] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

- In the past two years, many new studies have added to our knowledge of the rate of increase in global warming, extreme weather events, the understanding of local temperature rises versus the global average, and the projected impacts and costs of a warming climate. We have reported extensively on these studies in past Trends Reports. The most significant change we have seen in these studies and reports is the fast-developing trend of global warming increasing at a faster rate than anticipated, even in 2018. Also, the effects of continued warming are more extreme and happening much sooner than expected. Indeed, there are already areas in the Western Interconnection that have met or exceeded the 3 degrees Fahrenheit temperature rise threshold for WECC's Energy, Water, and Climate Change scenario (Scenario 5), and many other areas just reaching that tipping point.
- All signs point to this trend of accelerating warming and increasing GHG emissions continuing, with little or no effective efforts to slow or halt the trend on WECC's planning horizons.

Implications for Reliability: Due to the widespread and varied impacts of global warming and potential climate change events, we continue to see recent and long-term developments in this area presenting significant risks to electric reliability in all four of the areas of concern. Climate-related events can stress, disable, and destroy power systems so that resource adequacy, operational, infrastructure, and system stability risks emerge.

Reader Note: By using keywords such as: **climate change, warming, extreme, weather, GHG, greenhouse gas, emissions, tipping, environment, EPA, DOE,** and **UN**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

Evolution of Fuel Markets in the Electric Power Sector

From The 2038 Scenario Report: "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."[10] Long-term trends in the evolution of this driver over the last two years include:

- Recent and short-term developments in fuel markets in the power sector—mainly natural gas and coal— do not present any new emerging risks for any of the categories of electric reliability. In particular, domestic natural gas resources serving the power sector continue to be abundant, thus enhancing the ability to add resources to address reliability concerns.
- Longer-term natural gas pricing is hard to forecast, however. We are seeing a potential trend of over-production straining the storage and transportation infrastructure in two major fields. There has been a significant increase in venting and flaring of excess natural gas in the Permian Basin and the Bakken Shale field during the past year. At this writing, we do not know if this is a short-term occurrence that supply and demand will correct, or if it is an early warning signal of future price increases as companies move to curtail production in the face of continued low gas prices.

Implications for Reliability: In general, fuel markets present little short-term risk to the reliability of the power sector. As the continued building of natural gas generation plants adds to demand, so far, there is no shortage of resources to fuel these plants, and prices remain low. However, longer-term gas market dynamics and prices are difficult at best to predict. Natural gas prices have a considerable impact on choices of power generation, especially for reliability reserves, and any emerging signals of changes in the market should be monitored.

[10] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

Reader Note: By using such keywords as: **natural gas, coal, fuel prices, EIA, pipeline, transportation**, and **fuel markets**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

Shifts in the Cost of Capital and Financial Markets

From The 2038 Scenario Report: "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."[11] Long-term trends in the evolution of this driver over the last two years include:

- The global economy has been in turmoil and is slowing, exacerbated by the trade wars between the US and China and the European Union (EU), the continued uncertainty of BREXIT, and the normal cycle of slow down after recovery from recession. North American economies have also slowed. As a result, interest rates remain relatively low, and some countries' central banks have established negative rates in attempts to kick start their economies. In the US, after raising rates, the Federal Reserve lowered rates in 2019, and along with Canada, decided to hold rates steady in December. Sovereign and corporate debt is at record levels, and China is experiencing record levels of bond defaults. Economies worldwide seem to be slipping into a period of "synchronized stagnation."
- We are well past the historic timing (~7 years) of a slowdown following economic recovery, and in the long-term, we will see another recession sooner rather than later within WECC's planning horizons. Even with that, it is likely that capital will be available for deserving power system projects at reasonable rates. And, the primary effect of a recession would be on power demand and loss of revenues for power suppliers. As in the past, we would expect no impact on or risks for reliability during such a period.

Implications for Reliability: We see no new emerging issue in capital markets that raises significant risks to electric reliability in any of the key categories. Continued low cost and abundant sources of capital will exist for the power industry for development with sound credit quality both in the short and long-term.

Reader Note: By using such keywords as: **interest rates, capital, capex, financial markets, debt, bond, economy, money supply,** and **recession**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

Economic Growth within the Western Interconnection

From The 2038 Scenario Report: "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 different 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."[12] Long-term trends in the evolution of this driver over the last two years include:

[11] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018
[12] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

- North American (NA) economies are stable but are increasingly stressed, and the slowdown noted in past Trends Reports continues. There is widespread uncertainty in the long-term economic outlook as the trade wars between the US and China and the EU continue, although there seems to be an end of the year back down from both President Trump and China's president for Life Xi. Whether the deal will be signed and what it means for the US economy is unknown at this writing—so far it is not seen as progress, but merely a step back to an earlier state of trade agreement—and a return to new tariffs could happen after the US 2020 election. What the next year holds for US trade relations with its NA partners remains unclear until the new USMCA trade agreement (replacing NAFTA) is approved and goes into effect. In the meantime, the current US trade deficit continues to widen, and not in favor of the US, and as the global economy slows, US manufacturing continues to contract and is experiencing significant job losses.
- There is no unanimous agreement among analysts, economists, or pundits as to the trajectory of either the global economy or those of North America—uncertainty is the rule, rather than the exception. And amid this uncertainty, a new Wild Card is on the near horizon. The US will have a general election in November 2020, and events leading up to the election will have unforeseen effects on both the NA and global economies, especially in light of the recent impeachment of the US president and a Senate trial, which will linger into the New Year. What happens after the election is anyone's guess at this point, whether President Trump wins or loses the election.

Implications for Reliability: At this time, economic indicators in the Western Interconnection are showing a slowing economy with increasing levels of uncertainty, and yet do not indicate an emerging threat to power system reliability *in the short-term*. Likewise, global economic indicators indicate a slowing of the worldwide economy with as much or more uncertainty as the North American economies are experiencing. For the long-term, given the increasing levels of economic uncertainty, it is simply not clear at this time whether a long-term risk to reliability in the Western Interconnection exists. In the past, economic risks to reliability have been associated with high capital costs, which can impact resource additions.

Reader Note: By using such keywords as: **economy, global growth, global economy, debt, bond, recession, trade war, tariff, uncertainty, GDP,** and **unemployment**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

Worldwide Developments in the Electric Power Industry

From The 2038 Scenario Report: "There are tremendous forces of change impacting the electric power industry worldwide, and we see 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."[13] Long-term trends in the evolution of this driver over the last two years include:

- Looking globally, we are beginning to see some signs of the downsides of the expanding use of solar power panels and lithium-ion batteries. In short, the waste streams and need to recycle the material flow as the end of the useful economic lives of these technologies present challenges. Toxic materials, including heavy metals, can end up on water systems and cause health effects. Addressing those issues is likely to push some costs back onto users of those resources.
- Information, communications, monitoring, and software management systems have been and continue to be used in the provision of electric power services. However, the use of artificial intelligence systems to provide enhanced customer engagement and new services, using customers and other sources of data, is just emerging. There are much promise (new innovative services,

[13] *WECC 2018-2019 Draft Scenarios for Horizon Year 2038 V 0.1*, July 25 2018

Blockchain management systems) and risks (high costs, cybersecurity risks, software performance glitches, etc.) possible in the future use of these technologies. We think it is too early to make any general assessment.

- In the short and medium-term, we see a continued decline in the costs of renewable energy technologies and a corresponding increase in their use. Innovations and cost reduction in storage paired with clean energy will be cost-competitive and enhance approaches to meeting reliability. Only in the far later years do we expect storage cost reductions to flatten and require further fundamental materials based innovation to continue widespread use.
- Despite a period of growth and contraction in national or global economic trends, we see no significant threat to the electric power industry in accessing capital markets to fund resource development.
- China continues to export its technology to build coal-fired generation plants worldwide, especially now that internal curbs on emissions have taken effect. China is involved in 102 GW out of a total of 399 GW under construction worldwide, with a total investment amount of $35.9 billion. The top destinations are Bangladesh, Vietnam, South Africa, and Pakistan, and about a quarter of the proposed capacity would use technology no longer allowed in China.

Implications for Reliability: Worldwide developments in the power sector continue to suggest that the wide range of options for meeting electric reliability will continue to expand. Resource options are abundant. Continued technological innovation suggests that operational, infrastructure, and system stability risks will be manageable at current or improved levels. However, we believe that cyber-security risks have expanded to become a more significant risk to electric systems operations worldwide, we expect intensive scrutiny of those risks and investment to address them will likely be a central issue in the power industry. We also remain concerned that the power industry—on a global basis—will not move far enough toward renewable and low carbon emission generation to address the scientific community's recommendations on replacing greenhouse gas emissions needed to reduce climate change risks.

Reader Note: By using such keywords as: **recycling, waste, blockchain, information, data, customer enjoyment, cost reduction, fossil, coal,** and **capital markets**, the reader can search the EPS system here for EPS related to this Key Driver. We encourage readers to explore further the EPS system for items that may be helpful on this driver and other topics that may be of interest.

REVISITING THE FOCUS QUESTION

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?

Considering the time that has passed since the Scenario Workshop in July 2018, and the learning and insights from thinking through all of the key drivers, we believe the focus question remains a valid point of inquiry. However, we think perceptions about how customer demand for electric services may "evolve" might be different from how they were thought of two years ago. We believe the following considerations can serve as starting points for discussion by the SDS:

- The traditional power industry, especially at the utility-scale, has a history of economic analyses in which costs, performance, and benefits are looked at rigorously, often under review by regulators, to determine the least-cost delivery of services in balance with benefits such as power quality, safety, and reliability. In most consumer product markets, this rigorous and regulated approach does not exist, and only market-level responses determine which products and services are sold. Safety, reliability can be seen as similar features above a certain base-level for many consumer products.
- Consumers will often pay more for some benefits that far exceed the costs of providing them, leading to very high levels of profits for producers. Consumer value propositions are often challenging to determine, and similar products with similar features can sell for radically different prices. For example, a Nissan Leaf electric vehicle sells for roughly one third the cost of the high-end Tesla EV even though both provide emission-free personal transportation. If a prototype of a mass-market, behind the meter (BTM), independent power supply that meets the full daily needs of consumers, emerges in the market, it may be subject to the same market dynamics of other consumer products and thus be disconnected from any form of utility engineering economics.
- The scenario focus question anticipates the emergence of such a power source that could expand into the market without any connection to traditional utility-scale resource planning processes. Such a market disruption could lead to difficulty in utility-scale resource planning as forecasting the impacts and growth of consumer-level BTM power supplies may be difficult, and subject to sudden swings based on new consumer values. We have no idea of the long-term market response to this opportunity would be, or what new consumer values related to behind the meter power sources and services would be. It is possible to envision a time when utility-scale resource planning is unable to respond to consumer-level market dynamics.
- In light of the points raised above, we are not primarily concerned about electric reliability risk to the bulk power system. What conceivably might emerge would be a situation of a glut of power supply options for consumers where the bulk power system is maintained but with unpredictable power flows we cannot predict, e.g., when, how much, used by whom? In such a glutted market, we are unclear on how regulators might respond, what actions suppliers may take to command market share, which assets may be stranded, or what externalities may arise.

This EPS provides a review of current behind the meter power supply options for customers:

- Haas UC. Berkeley Energy Analyst Assess Behind the Meter Options for Consumers

SCENARIO TRENDS AND EARLY INDICATORS

As noted at the beginning of this report, WECC has a fully functioning EPS system related to the current 2018-2038 Scenarios. With that, the purpose of this section is to give SDS members a sense of how recent developments might reflect on the key potential developments in each scenario. Members should hold in mind that the scenarios are intended to be different possible future states and not "good or bad" or "opposites," just different plausible futures that can be considered for learning and analysis.

Complexity in the WECC Scenarios: The WECC Scenarios anticipate a transformation in scenarios 1 and 2, or an evolution in the case of Scenario 4, in the electric power system (the system), driven by customer choices enabled by evolving technologies and policies. Scenario 3 could be considered the "control" scenario, as it anticipates a steady-state system. In looking at Key Driver events, we have to consider the types of and differences between the enabling technologies that work together in the scenarios, especially those that impact customer choice, which can include the following choice options: [14]

- Electric service provider,
- Rate plan,
- Type of generation procured by the provider to serve load,
- Behind the meter assets to self-generate,
- Participation in programs offering benefits to the customer for reducing and shifting load, and
- Other accommodations supporting grid reliability, greenhouse gas (GHG) reduction, and operation of the electric system.
- In our consideration, customer choice would not include the choice of poles and wires distributing electricity.

There is a natural tension when faster-moving technologies and systems, e.g., digital, computer, and AI, begin to merge and impact slower-moving systems, e.g., the grid, which being infrastructure-based, changes much slower.[15] The technologies intersecting and combining to allow these customer choices, and the ability of the system and operators to effectively integrate them range from slower evolving generation type evolution to faster-moving and more transformative digital information, data gathering, and analytics, and communications technologies.[16] The later technology types are already used at varying degrees of adoption within the system at the generation, transmission, and distribution levels, but are just being thought of and developed at the customer-side.

When taking customer choice out of the equation, the trajectory and timing of a transformation of the system could be more easily anticipated. By adding the additional layer of complexity of customer choice and the attendant technology complexities that come with customer choice, the trajectory and timing of the system are harder to anticipate, especially in the early life of each scenario. In many cases, events seen in the early years of the scenarios can point to more than a single scenario depending on how the events resolve themselves over the future. Then you add the fact that each state and province in the Western Interconnection is independently making its way toward its future electric power system, and not moving in lockstep towards a single, well-defined future, and another layer of complexity is added. Some are moving faster than others towards something that looks somewhat like one—or more—of the scenarios, while others are moving much slower, and their trajectory is unclear.

When these three layers of complexity are in play, and even when there are 998 events to consider, in the early years of the WECC scenarios a single event or combination of events can point to more than a single scenario, or in many cases, their impact on any scenario is vaguely discernible—but clarity depends on how the events resolve themselves in the future. Based on our review of Key Driver trends over the past two years relative to

[14] From California CPUC Customer Choice Project Green Book, May 17 2018
[15] Based on the concept of Pace Layering, where the relationships between components in a system that have different change rates and different scales of size, as detailed in *The Clock of the Long Now*, by Stewart Brand, pp 34-37. Basic Books, 1999
[16] EPS: Study released on the slow uptake of energy technologies, Resilience.org, February 27 2019

the scenarios, and the 998 events reported in the EPS system, we have seen no events that would indicate a definitive trajectory or movement toward one of the WECC scenario over all the others. At this point, each of the scenarios is equally plausible as possible futures, especially when applied to individual states, provinces, or regions of the Western Interconnection. We also anticipate that during 2020 key learnings and assessments will emerge from the modeling analysis of the WECC Scenarios and provide further insight for monitoring of key trends.

Therefore, the following is a high-level review of developments we have captured in the EPS system, and how they might resonate with the core ideas contained in each scenario, with associated EPS listed for the reader to explore. We encourage readers to explore further the EPS system for items that may be helpful on other topics that may be of interest.

Scenario 1: Open Markets Yet Restricted Customer Choice

The key elements of Scenario 1, as described in the WECC 2018-2038 Scenario Report are:

- During the next 20 years, Scenario 1 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.

We see this as a very relevant scenario in light of recent developments that put an accent on State and Provincial regulatory power and control over the electric power industries within its boundaries.

Key events in the Fourth Quarter that impact Scenario 1 include:

- Federal government signs off on Alberta's industrial carbon price: The federal government is letting Alberta Premier Jason Kenney proceed with his version of an industrial carbon tax instead of applying Ottawa's carbon pricing on heavy emitters in Alberta.
- The Downside of Solar Energy: As renewable energy expands, used photovoltaic panels are creating a growing waste problem—but recycling could be the answer.
- CAISO issues policy analysis paper on market and infrastructure policy: CAISO issued the paper the last week of November to put forth its ideas on the policies that should govern energy market evolution and investment in energy infrastructure in CA
- Participation in electricity customer choice programs has remained unchanged since 2013: After more than a decade of steady growth, the share of U.S. electricity sales served by non-utility retail power marketers has grown only slightly since 2013 (about a 1% increase over the period)
- BLOCKCHAIN: Not Ready for Energy Transactions?: Blockchain relies on massive duplication of data storage and processing (owing to its consensus process), which could prove prohibitive given the volume of data and computation required for energy market processes and transactions.

Scenario 2: Open Markets with High Levels of Customer Choice

The key elements of Scenario 2, as described in the WECC 2018-2038 Scenario Report, are:

- Scenario 2 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 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 widespread adoption can occur. Large Commercial and Industrial customers, locally organized communities, and micro-grids find the most beneficial and useful applications due to their scale.

Since we are in the very early years of this scenario, we still think it is relevant and useful for WECC analysis; however, this scenario may need more time to come to pass than any of the others.

Key events in the Fourth Quarter that impact Scenario 2 include:

- Montana Rejects Changes to Net Metering: In a vote of 5-0, the Montana Public Service Commission rejected NorthWestern Energy's proposal to end net metering, implement a separate rate class, and impose punitive demand charge rates for rooftop solar customers.
- California proposes energy efficiency market overhaul with single administrator: California regulators are mulling a proposed decision to allow local governments to continue collaborating on Regional Energy Networks (REN) aimed at rolling out energy efficiency efforts more flexibly, along with other changes designed to help consumers use less energy.
- As CCAs take over utility customers, local renewable generation emerges as the next big growth driver: A renewed national expansion of community choice aggregation (CCA) is raising ambitions for transforming the U.S. power system. On the heels of an explosion of customer choice in California over the last three years, the slowly growing aggregation market in Massachusetts is accelerating.
- Battery prices fall nearly 50% in 3 years: Average market prices for battery packs have plunged from $1,100/kWh in 2010 to $156/kWh in 2019, an 87% fall in real terms, according to a report released Tuesday by Bloomberg New Energy Finance (BNEF).

Scenario 3: Reliability and Cost Policy-Driven with Restricted Customer Choice

The key elements of Scenario 3, as described in the WECC 2018-2038 Scenario Report, are:

- Scenario 3 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 can address environmental concerns and meet customer demands for service options within regulated rate structures.

This scenario, in assuming a "steady state" of more stagnant evolution that the other three scenarios, as well as the WECC Year 10 Case, is still relevant and useful as a base for comparison.

Key events in the Fourth Quarter that impact Scenario 3 include:

- Ernst & Young Report on Future of U.S. Power industry pinpoints continued uncertainty: Once varying levels of digital-grid maturity and differing state regulatory regimes are considered, it becomes difficult to ascertain the current state and predict the future trajectory of the US distribution system.
- A not-so-good milestone for natural gas: A record amount of U.S. natural gas was released or burned at oil-and-gas well sites last year, EIA data shows.
- Preventative Blackouts Put California's Renewable Generators at Risk: This year's fire-prevention outages have introduced a "new form of curtailment risk for the state's independent power producers," according to a recent report from credit rating firm S&P Global. The concern stems from the possibility that PG&E will effectively shut down projects during PSPS events, and then not pay the developer for the lost production.
- First cyberattack on solar, wind assets revealed widespread grid weaknesses: A March 5 cyberattack of U.S. wind and solar assets is back in the news, with new documents helping shed light not just on the extent, but also the simplicity of the first-of-its-kind intrusion. Cybersecurity experts say it reveals a utility sector not sufficiently vigilant and failing to employ the most simple fixes.
- BLOCKCHAIN: Not Ready for Energy Transactions?: Blockchain relies on massive duplication of data storage and processing (owing to its consensus process), which could prove prohibitive given the volume of data and computation required for energy market processes and transactions.

Scenario 4: Reliability and Cost Policy-Driven with High Levels of Customer Choice

The key elements of Scenario 4, as described in the WECC 2018-2038 Scenario Report, are:

- Scenario 4 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.

We see this as a very relevant scenario in light of continued developments that put an accent on State and Provincial regulatory power and control to enable customer choice within the context of ensuring costs and benefits for the customer.

Key events in the Fourth Quarter that impact Scenario 4 include:

- Salt River Project to install Arizona's largest battery system: Arizona's Salt River Project (SRP) on Thursday announced plans for two solar + storage projects that will push the utility more than 60% toward its goal of adding 1 GW of new utility-scale renewables by the end of the fiscal year 2025.
- Haas UC. Berkeley Energy Analyst Assess Behind the Meter Options for Consumers: Analysts showed that in light of consumer demand for power to essential appliances such as air conditioning, refrigeration, and charging mobile devices, current power options are insufficient and costly, especially for outages extending over several days.
- NV Energy Gets Green Light for Massive Solar-Battery Projects: Nevada regulators have given the green light to utility NV Energy's plan to add nearly 1.2 gigawatts of solar and 590 megawatts of batteries, underscoring a broader push toward renewable energy and storage by other Western utilities also owned by Warren Buffett's Berkshire Hathaway.
- Details emerge about the Department of Energy's 'super grid' renewable study:"… additional analysis probably will not change the basic thrust of our conclusions: High-capacity interregional transmission lines, particularly lines connecting the eastern and western grid compounds, have significant benefits."
- PacifiCorp releases Integrated Resource Plan indicating shift to clean power and less coal power: PacifiCorp plans to add nearly 7,000 MW of renewable generation and storage capacity by 2025 and will shut down 20 of its 24 coal-fired units by 2038, the company announced when it unveiled a draft of its 20-year Integrated Resource Plan (IRP).
- CAISO gains rights to support must run plants regionally to assure reliability: The Federal Energy Regulatory Commission (FERC), on September 27th, approved a California ISO tariff proposal granting its wider authority to contract for out-of-market resources through the use of Reliability Must Run (RMR) designations.

Scenario 5: Energy-Water-Climate Change

The key elements of Scenario 5, as described in the introductory pages of the WECC Energy, Water, and Climate Change[17], are:

Climate change is generally acknowledged to be occurring with effects across the world and throughout the global economy. A majority of climate scientists expect average global temperatures to increase by 2° F to 11.5° F by 2100 depending on the level of future greenhouse gas emissions, and the outcomes from various climate models. Research is ongoing about climate change impacts in many fields besides the electric energy industry, including agriculture, water resources, land use, and fishing. Listed below are the key areas in which climate change is likely to have the most significant impact on the electric power sector and, thus, electric reliability, not only within WECC but nationwide.

- Rising ambient temperatures are expected to impact the operations of electric generating plants and transmission lines.
- Rising temperatures may contribute to more frequent firestorms, raising the risk of damage to transmission lines in both traditional and new areas of the Western US.
- Changing patterns of precipitation, droughts, and floods may have impacts on the operating conditions of electric generation facilities and, in particular, the energy production of hydroelectric generation. Water availability for cooling thermal power plants and other generation plant operations may come under pressure from shortages.
- Rising temperatures may impact patterns of consumer energy demand and cause shifts in seasonal electric demand peaks that vary from the historical patterns used to build electric power infrastructure, which may require new investment to meet reliability.

As we noted above, the significant change we have seen in the past two years is the fast-developing trend of global warming increasing at a faster rate than anticipated, even in 2018. Also, the effects of continued warming are more extreme and happening much sooner than expected. Indeed, there are already areas in the Western Interconnection that have met or exceeded the 3 degrees Fahrenheit temperature rise threshold for WECC's Scenario 5, and many other regions are just reaching that tipping point. All signs point to this trend of accelerating warming and increasing GHG emissions continuing, with little or no effective efforts to slow or halt the trend on WECC's planning horizons.

The continuing impacts of climate change on the electric power system and reliability make Scenario 5 a critical part of WECC planning in both Year 10 and Year 20 studies.

Key events in the Fourth Quarter that impact Scenario 5 include:

- Climate change: Oceans running out of oxygen as temperatures rise: Climate change and nutrient pollution are driving the oxygen from our oceans, and threatening many species of fish.
- The Arctic may have crossed a key threshold: The Arctic is undergoing a profound, rapid, and unmitigated shift into a new climate state, one that is greener, features far less ice, and emits greenhouse gas emissions from melting permafrost.
- Carbon Dioxide Emissions Hit a Record in 2019, Even as Coal Fades: Emissions of planet-warming carbon dioxide from fossil fuels hit a record high in 2019.
- Carbon dioxide levels reach the highest recorded levels in human history: Greenhouse gas concentrations continued to rise in 2018, with carbon dioxide levels hitting an all-time high of 407.8 parts per million.
- UN report: Climate change causes and impacts are increasing: Climate change causes and effects are increasing rather than slowing down. Sea level rise has accelerated, and we are concerned that an abrupt decline in the Antarctic and Greenland ice sheets, which will exacerbate future rise - sea level rise and intense tropical storms will lead to more humanitarian and economic catastrophes

[17] *WECC Energy, Water, and Climate Change Scenario Report*, May 5 2015

SCENARIO MOVEMENT

As we noted in previous Trends Reports and our presentations in past SDS meetings, we believe that in the 2038 Scenarios, given the choices by the SDS for the Primary Scenario Drivers and other Key Drivers, states, and provinces within the region will not move in lockstep towards any particular scenario. Considering the new Scenario Matrix, this would imply that there would not be a region-wide "movement" that could be plotted against the new scenario matrix as in the Legacy Scenarios until later in the life of the scenarios, as trends develop over time and converge into a recognizable trajectory.

However, we can say that, based on the Key Driver events we have seen in the past three months with differing state and provincial policy actions, from a high level, these events *tend to support movement in the Western Interconnection as a whole towards both Scenario 1 and Scenario 4*. We can also see developments that argue for Scenario 3 in many states in the Western Interconnection. A key element of this assessment is the lack of any significant technological developments or other market-related issues that would lead to a quickened uptake of the kinds of energy-related services and products advocated most strongly in Scenario 2.

As noted above, many regions within the Western Interconnection have already met or exceeded the 3 degrees Fahrenheit temperature rise threshold for WECC's Scenario 5. Many other areas are just reaching that tipping point, and others may soon follow. Western North America is already in Scenario 5, and continued understanding of warming and its effects across the region is prudent.