2018 BIENNIAL ENERGY REPORT

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About the Report

In 2017, the Oregon Legislature charged the Oregon Department of Energy with developing a comprehensive energy report to inform local, state, regional, and federal energy policy development and energy planning and investments, and to identify opportunities to further energy policies in our state. Our goal is to summarize and analyze Oregon's current energy resources while exploring energy topics important to people across the state. As we see in the news every day, energy is a fast-moving topic. This inaugural Biennial Energy Report is intended to help Oregonians keep up with trends, impacts, and changes in the energy sector and—more importantly—understand what those changes mean for our state.

About the Oregon Department of Energy

Our mission: leading Oregon to a safe, clean, and sustainable energy future

At the Oregon Department of Energy, we're dedicated to keeping our state on the leading edge of energy efficiency, renewable energy, and energy resilience. Our focus is on reliable, accessible energy for every Oregonian, and on safe, secure energy systems with diverse resources that can withstand change, including emergencies. As we support efforts to meet our most pressing challenges, including climate change, we're committed to meaningful, effective energy systems and policy that reflect Oregonians' needs and values.

CHAPTER 5: RESILIENCE

The prospect of a major earthquake and tsunami may seem so overwhelming that preparation – by individual Oregonians or their state government – is too big of a task.

But we can do this and we will do it together.

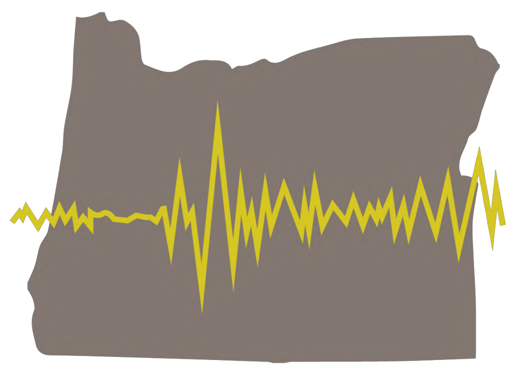
We must build a better prepared and more resilient Oregon, one step at a time.

— Governor Kate Brown, 2016[1]

KEY TAKEAWAYS

- An increased awareness of the threats (e.g., Cascadia Subduction Zone earthquake, climate change, cyber and physical attacks) to Oregon's energy systems, combined with advances in distributed energy resources (e.g., distributed solar and batteries), is creating new interest in **community energy resilience solutions**.
- Entities across Oregon — from state government, to local communities, and individual energy providers — have been taking steps to improve the resilience of the energy sector.
- Oregon can take advantage of technology advancements to make systematic improvements to community energy resilience threats like the Cascadia earthquake and climate change. For example, the state can support the development of community microgrids that can provide emergency back-up power to **support critical public services** following a major disruption to the state's energy systems.
- The state has the opportunity to engage communities to identify mechanisms for funding and deploying community energy resilience and **climate adaptation solutions** that deliver the maximum benefit to those communities.

Introduction



In 1700, an earthquake struck off the coast of the Pacific Northwest and unleashed a massive tsunami. Geologists have since concluded that the earthquake and tsunami resulted from a major rupture of the Cascadia Subduction Zone (CSZ) fault, and that the region is due for another. When — not if —that occurs, Oregonians are likely to be faced with devastating impacts resulting from a 9.0 earthquake and subsequent tsunami. In addition, the state will experience power outages and disruptions in liquid fuel supply across much of the state that will likely be measured in weeks and months rather than in hours. These energy disruptions have the potential to cripple the response of public agencies and communities to this disaster.

The first part of this chapter explores what activities are currently underway in Oregon to improve the resilience of Oregon's energy sector when facing extreme events, while also considering what more can be done to prepare, with a particular focus on improving community energy resilience. The second part of the chapter focuses on how energy resilience factors into climate change policy discussions. As Americans' understanding of and attention to climate risks has evolved from indistinct future threat to present reality, public and private sector entities around the U.S. and the world are considering how to adapt and build resilience to address long-term, slower changes like sea level rise and changing average temperature and hydrologic conditions, as well as changes to the frequency, duration, and intensity of extreme events like drought, flooding, storms, and wildfires. The chapter summarizes some of the key climate risks and vulnerabilities for Oregon's energy sector and the status of climate adaptation planning efforts.

Defining Energy Resilience

Improving the resilience of the state's energy systems has emerged as a topic of significant interest within Oregon's energy industry in recent years. This interest stems from several independent factors, including an increased awareness of threats to Oregon's energy systems and rapid advancements in distributed energy resources with the potential to improve community energy resilience.

While resilience has become a commonly used term, there is no widely agreed upon definition within the energy sector. Most definitions, however, include similar themes. For the purposes of this report, resilience is defined as: "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents."[2]

The lack of clarity around what energy resilience means specifically is further complicated by the frequent conflation of the term with another that has a longer history in the electric sector: reliability. Resilience and reliability are not interchangeable. In the electric sector, reliability is a well-defined technical attribute for which there is significant government oversight to ensure compliance with established metrics and standards.[3]

These metrics and standards ensure that utilities provide reliable electric service — e.g., avoiding outages or significant disruptions to power quality — to end-use customers under conditions reasonably expected to occur within the grid. These conditions can range from infrequent but predictable events, such as geomagnetic storms that can damage electrical equipment, to routine seasonal weather-related extremes or storms that may affect electricity load or transmission and distribution.

To track service reliability, Oregon's investor-owned electric utilities, for example, file annual reliability reports with the Oregon Public Utility Commission. Portland General Electric, PacifiCorp, and Idaho Power measure and track the overall reliability of their systems using industry standard metrics focused on measuring the frequency and duration of outages and causes.* Resilience has no similar

RESILIENCE IN THE ENERGY SECTOR

Resilience: the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions, including the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents. (Presidential Policy Directive 21.[2])

Energy Resilience: the ability of energy systems — from production through delivery to end-users — to withstand and restore energy delivery rapidly following non-routine disruptions of severe impact or duration. (ODOE.)

Community Energy Resilience: The ability of a specific community to maintain the availability of energy necessary to support the provision of energy-dependent critical public services to the community following non-routine disruptions of severe impact or duration to the state's broader energy systems. (ODOE.)

*PGE uses the following indices that are based upon methodologies established by the Institute of Electrical and Electronics Engineers (IEEE) Standard 1366: System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), and Momentary Average Interruption Frequency Index (MAIFI).

oversight mechanisms, nor does it have metrics or standards against which a system can be evaluated for compliance.

As this chapter will explore in greater detail, lack of definitions and regulatory oversight notwithstanding, entities across Oregon have been starting to take steps to enhance the resilience of the energy sector. For example, state government has called attention to the need to improve the resilience of the Critical Energy Infrastructure Hub in the Portland metro area. Meanwhile, both investor-owned and consumer-owned electric utilities have been taking proactive steps to reinforce and move infrastructure to make it more resilient to anticipated threats. And lastly, local governments are increasingly thinking about the concept of community energy resilience and the interdependencies of many of their communities' critical public services on the continued delivery of energy following a major disruption to the state's broader energy systems. These efforts will be detailed below in addition to identifying a need to build upon these efforts through a collaborative process to define a community energy resilience vision for the state.

Identifying Resilience Threats to Oregon's Energy Systems

While reliability standards are focused on how energy systems operate under reasonably expected conditions, energy resilience concerns the ability of energy systems to maintain operation during and recover following an acute non-routine event, typically one of severe impact and/or duration. This section identifies three resilience threats — a Cascadia Subduction Zone earthquake, cyber and physical attacks, and climate change — to consider as the state continues working toward building more resilient energy systems in Oregon.

Cascadia Subduction Zone

Federal Emergency Management Agency

In recent decades, geologists have learned more about the risk to the Pacific Northwest from the Cascadia Subduction Zone (CSZ) — an active seismic fault that parallels the coast of the Northwest approximately 100 miles offshore.[5] By investigating the geologic record, scientists have found that a rupture of the CSZ occurs approximately every 300 to 400 years, with the last rupture occurring on January 26, 1700 — or 318 years ago as of the publication of this report.[5] The chance of a significant rupture of the CSZ occurring within the next 50 years is expected to be between 15 and 20 percent.[6,7,8] The CSZ is capable of producing a megathrust earthquake registering a magnitude of 9.0+ on the Richter Scale with a devastating tsunami to follow.[5] This type of an event has the potential to be similar to the Tohoku earthquake and resulting tsunami that devastated the Sendai region, including the Fukushima nuclear plant, off coastal Japan in March 2011.[5]

The Oregon Resilience Plan (ORP), published in 2013, evaluated the expected effects to different sectors of the economy from a 9.0 earthquake along the CSZ. Chapter 6 of that plan evaluated the expected impacts to the energy sector. The plan identified significant vulnerabilities to the state's Critical Energy Infrastructure

(CEI) Hub, a six-mile stretch of the lower Willamette River northwest of downtown Portland where key liquid fuel and natural gas storage and transmission facilities are located, along with a significant concentration of electric transmission facilities, on soils prone to liquefaction.[5] Given the severe impacts expected to the CEI Hub, there will likely be severe disruptions to liquid fuel deliveries across the state. The plan also found that it could take one to three months to restore electric service in the Willamette Valley, and upwards of six months in coastal areas of the state.[5]

Climate Change: Redefining Normal

Climate change poses a unique threat to Oregon's energy systems because it has implications for both resilience and reliability. Climate change will affect the frequency and intensity of short-term extreme events like wildfires, floods, and storm surges in certain parts of the state in addition to average weather and hydrologic conditions over longer time horizons.[9,10] Reliability efforts are built around expectations of "routine" disturbances to energy systems that fall within a range of expected conditions based on historical data and experience. Resilience efforts are also typically based on historic data and experience to prepare for extreme, infrequent, or severe impacts.[4] But climate change is projected to alter future conditions to an extent where historical trends are no longer reliable, and a "new normal" for what constitutes expected average and extreme conditions will need to be integrated into decision-making.[11,12]

For example, Oregon is projected to experience higher average temperatures and more frequent and longer-lasting extreme heat events in summer, which could affect reliability if utilities are unprepared for higher electricity loads and reduced transmission capacity of power lines. The metrics and standards that measure reliability may need to evolve accordingly to account for these changes.[20] Climate scientists also expect that climate change is likely to increase wildfire frequency and the area burned in Oregon, which could adversely impact the operation of the electric transmission system. This will heighten the need for enhanced resilience of our energy systems to withstand these still non-routine, though increasingly common, events. Reliability and resilience are concepts that exist on a continuum. If once uncommon events begin occurring with sufficient frequency, they might become reliability issues.[20] A more in-depth consideration of climate vulnerabilities and adaptation in Oregon's energy sector is discussed later in this chapter.

Cyber and Physical Attacks

The U.S. Department of Homeland Security developed the *National Infrastructure Protection Plan 2013: Partnering for Critical Infrastructure Security and Resilience.*[13] As part of that plan, the U.S. Department of Energy developed a plan for the energy sector in which it identified cybersecurity and physical attacks as a significant threat.[14] In a widely publicized example from 2013, an unknown attacker used a high-powered rifle to destroy several transformers at a substation in California, knocking the substation offline for nearly a month.[14] While that isolated incident did not cause a significant disruption of service, it showed how vulnerable energy systems can be to physical attacks.

Cyberattacks have the potential to cause significant disruptions, particularly given the increasing digital interconnectedness of people's lives. This digital connectivity enables new innovations and savings — such as the deployment of smart meters that allow utilities to remotely monitor energy demand at a particular meter without having to manually check the meter, or the ability of customers to set their home thermostat to respond to specific price signals from the grid, or for electric vehicle chargers to only charge during certain times of day when electricity prices are low. While these new technologies create new opportunities and conveniences, they also create new pathways for cyberattacks. New interconnected entry points into the electric system create an increased risk of cyberattacks that could result in widespread disruptions. These attacks have the potential to target not only the computer software systems that control the energy sector, but also to overload critical infrastructure components beyond their designed operating limits in a manner that results in physical damage.

Understanding Current Actions

Currently, there is no single state or federal agency charged with evaluating or planning comprehensive improvements to the overall resilience of Oregon's energy systems, inclusive of the production and delivery systems for liquid fuels, electricity, and natural gas. Given this reality and the absence of widely accepted standards or metrics to measure energy resilience, it is difficult to evaluate the current level of resilience of energy systems in the state today. Regardless, as noted above, entities across the state have begun taking actions to address concerns about energy resilience. This chapter provides a snapshot of some of the specific actions currently underway in Oregon at the state level and within individual communities and utilities to improve the resilience of the energy sector and plan for an organized response to a major event.

State Level Actions

Energy Assurance Plan

Supported by federal stimulus funding in 2009, the Oregon Department of Energy, in collaboration with the Oregon Public Utility Commission, developed an Energy Assurance Plan.[15] The plan provides an overview of the state's energy infrastructure and overall energy profile; at a high level, evaluates the role of renewables and smart grid technologies in energy assurance planning; describes different types of energy emergencies that could occur in Oregon; and explains how the state would respond to energy emergencies.

Substation in Canby, Oregon.

ODOE and OPUC are the designated primary state agencies for planning, preparedness, response, and recovery to energy emergencies with potential impacts to Oregonians. OPUC is responsible for developing and maintaining emergency response plans for electricity and natural gas emergencies, while ODOE is responsible for developing and maintaining a fuel sector emergency response plan.

In 2017, ODOE released the Oregon Fuel Action Plan, which details how the state will respond to an event that causes severe shortages of liquid fuels.[16] ODOE developed the Plan pursuant to ORS 175.750-785 to ensure that adequate fuel supplies will be provided to the state's emergency and essential service providers in the event of a severe or long-term fuel disruption or shortage. The Plan, the first of its kind in the nation, identifies nine priority actions ODOE would take to arrange acquisition and delivery of fuel in support of the state's response and recovery efforts in times of crisis. The Plan is a working document and will be updated as needed to ensure that all response strategies remain current and sync with those of our federal, tribal, military, state, local, and industry partners.

OREGON FUEL ACTION PLAN… IN ACTION

While the Oregon Fuel Action Plan is designed to address even the region's worst-case disaster — a 9.0 Cascadia Subduction Zone earthquake and tsunami, which would devastate the region's fuel infrastructure — all strategies in the plan are flexible and can be scaled down in response to a wide range of events:

- **August 21, 2017 Solar Eclipse:** ODOE activated the Fuel Action Plan in preparation for an influx of visitors to Oregon to view the first total solar eclipse in the United States in 38 years. ODOE worked with the petroleum industry leading up to the August event to maximize fuel volumes to meet the anticipated increase in demand. The agency worked with the industry to add fuel deliveries, and to schedule them at strategic times to avoid heavy traffic congestion. ODOE also successfully secured a temporary waiver from the Oregon Department of Transportation to lift "Hours of Service" restrictions, which ensured fuel haulers would not be fined if they exceeded the 11.5 hour limit to complete deliveries.
- **2017 Wildfire Season:** Oregon battled as many as 17 fires simultaneously during summer 2017, wreaking havoc on fuel deliveries and stressing the supply of aviation fuel, unleaded gasoline, and diesel. In particular, the Eagle Creek Fire closed vehicle traffic on Interstate 84 and barge traffic on the Columbia River in September. ODOE implemented the Fuel Action Plan and worked with the petroleum industry and ODOT to ensure fuel haulers had viable alternate routes to complete deliveries. ODOE also worked with the U.S. Coast Guard to ensure fuel barges were vetted and given priority passage despite USCG's Shutdown Order of the Columbia River. As a result, three fuel barges were cleared for passage, delivering 420,000 gallons of ethanol, 900,000 gallons of aviation fuel, and 1,596,000 gallons of diesel with only minimal delay.
- **December 2016 Winter Storms:** Snow and icy conditions caused wide-spread power outages, including some operations at the CEI Hub. Without power, Kinder Morgan was unable to transport jet fuel by pipeline to the Portland International Airport, which had less than two days' supply of jet fuel. ODOE implemented strategies from the Fuel Action Plan and worked with Portland General Electric to ensure the utility prioritized restoring power to the Hub. Despite treacherous conditions, PGE crews navigated safely through black ice and downed power lines to get power restored, and Kinder Morgan was able to deliver jet fuel to PDX before the airport ran out.

Emergency Preparedness Manager Deanna Henry discusses Oregon's Fuel Action Plan on ODOE's *Grounded* podcast:

https://go.usa.gov/xPQVc

There is no single State of Oregon agency with regulatory authority over the petroleum terminals located within the Critical Energy Infrastructure (CEI) Hub northwest of Portland. These terminals are expected to be severely damaged by a CSZ earthquake,[5] yet no single state agency can require these facilities to invest in seismic upgrades to their aging tanks, pipeline systems, and other facilities. The Oregon Department of Environmental Quality, meanwhile, is responsible for working with industry to develop and maintain the Oil Spill Prevention Program to reduce the risk of spills and minimize damage to human health and the environment when responding to spills.[17] DEQ's authority for developing this program is based on legislation adopted in 1991 that did not address seismic resilience, and its authority is limited to marine oil transfer facilities, which is a subset of the facilities located within the CEI Hub.

Oregon Resilience Plan

The Oregon Resilience Plan was developed in 2013 by the Oregon Seismic Safety Policy Advisory Commission at the direction of the Oregon Legislature.[5] The ORP evaluates the expected effects of a CSZ earthquake and tsunami to different sectors and regions of Oregon, with recommendations to reduce risk and improve recovery. These recommendations were formulated with the intention that, if implemented over the next 50 years, the state could achieve resilience targets as identified by the ORP with regards to reducing timelines for the restoration of certain services following a CSZ earthquake. Chapter 6 of the ORP is focused on the state's energy sector, and identifies ten recommendations for the state to improve its resiliency.

The ORP also recommended that the state Legislature create a new position in state government—a State Resilience Officer—to "provide leadership, resources, advocacy, and expertise in implementing a statewide resilience plan." The Legislature followed this recommendation, creating the position with the passage of House Bill 2270 in 2015.[18] With the subsequent appointment and confirmation of the state's first Resilience Officer in 2016, Oregon became one of the first states in the nation with a cabinet-level position in state government charged with coordinating resilience efforts.[19]

CRITICAL ENERGY INFRASTRUCTURE HUB

The CEI Hub is located along a six-mile stretch of the Willamette River in northwest Portland. The Hub includes all of Oregon's major liquid fuel port terminals, liquid fuel transmission pipelines and transfer stations, natural gas transmission pipelines, a liquefied natural gas storage facility, high voltage electric substations and transmission lines, and electric substations for local distribution.

Nearly all of Oregon's refined petroleum products are imported by pipeline or marine vessels through the CEI Hub before being distributed throughout the state to end-use customers. A portion of the state's natural gas fuel supply also passes through the CEI Hub. The Hub is vulnerable to a CSZ earthquake, according to the Oregon Resilience Plan:[5]

- The Hub is constructed on soils susceptible to major movement after an earthquake, including liquefaction — where solid earth behaves like liquid or quicksand
- The 1960s-designed pipeline was not built to withstand ground movements from earthquakes
- Fuel spills could affect the navigable waterway, impeding marine traffic and emergency response
- Substations, transmission lines, and other infrastructure are vulnerable; severe damage could result in an electricity blackout

The ORP recommends a number of actions to strengthen the CEI Hub, including working with energy sector companies to improve the resilience of their infrastructure located at the Hub.[5]

Community and Utility Level Actions

Consistent with state-level planning, many local governments and utilities are making investments designed to improve energy resilience at the local level. These actions vary, from evaluating whether buildings and energy infrastructure are seismically sound, to relocating key assets, to deploying advanced energy technologies. This section highlights several of these community level activities.

Assessing and Hardening Infrastructure

Central Lincoln PUD's Northern Operations Center, completed in 2017.

Particularly with regard to the threat of a CSZ earthquake, many utilities across Oregon have taken steps to assess and address the vulnerabilities of their buildings and infrastructure.* Central Lincoln People's Utility District is one of the state's 36 consumer-owned utilities; its service territory stretches over 100 miles of central Oregon coastline. Given risks to its service territory, in 2017 the utility completed construction of a new Northern Operations Center in Newport. The previous operations center was in an area of Newport at lower elevation and within the tsunami zone (i.e., the area expected by geologists to be affected by a tsunami following a major rupture of the CSZ fault). The new Operations Center has been built at higher elevation, outside of the tsunami zone, and constructed to seismic standards designed to withstand the ground forces from a CSZ earthquake.

Blachly-Lane Electric Cooperative, a consumer-owned utility located northwest of Eugene in the southern end of the Willamette Valley, is seismically retrofitting its headquarters to withstand a CSZ earthquake. The Eugene Water and Electric Board, meanwhile, is working with a team of engineers at Oregon State University to evaluate how its concrete electric transmission towers — utilized in some locations on its system — will hold up to a CSZ earthquake. PGE has also been working to reinforce or replace unreinforced masonry buildings, particularly those associated with older hydroelectric facilities.

In addition, the Bonneville Power Administration has been working for decades to improve the resilience of its transmission network to a major seismic event. For example, BPA has bolted the transformers at all of its transmission substations to their foundations. This helps to prevent these large pieces of equipment from sliding off of their foundations during a seismic event. BPA and many of the state's distribution utilities have replaced inflexible substation components, often made of porcelain, with more flexible components made of polymers. BPA is also currently in the process of seismically retrofitting the control house buildings at each of its transmission substations. BPA and other federal agencies have also evaluated seismic risks to the federal hydroelectric dams themselves, finding those risks to be minimal.

*The examples cited in this subsection are based on statements made by representatives of Central Lincoln PUD, Blachly-Lane Electric Cooperative, Eugene Water and Electric Board, Portland General Electric and the Bonneville Power Administration either at public events, or in meetings with ODOE staff, in 2017-18.

ENERGY RESILIENCE GUIDEBOOK

In 2019, the Oregon Department of Energy plans to publish a *Guidebook to Enhance Local Energy Resilience in the Consumer-Owned Utility Sector*. The Guidebook is the culmination of two years of work by ODOE staff in collaboration with the Governor's Office and Central Lincoln People's Utility District. The work was made possible by the support of the National Governors Association Center for Best Practices, through its Policy Academy on Grid Modernization.

More information about ODOE's resiliency work is available on its website:

www.oregon.gov/energy/safety-resiliency

The Guidebook is designed specifically for staff working at the state's consumer-owned utilities who have been tasked with developing plans to enhance the resilience of their utility. With that audience in mind, the Guidebook:

- Identifies the role of local electric utilities within the context of the field of emergency management at the county, state, and federal level;
- Identifies incremental actions that local utilities can take to enhance resilience based on the examples of other utilities in Oregon and across the nation; and
- Proposes a framework for local utilities to utilize to prioritize investments in distributed energy resources to enhance resilience.

Deploying Distributed Energy Resources

Several Oregon utilities are also deploying distributed energy resources (DERs) as part of projects that enhance energy resilience at the local level. To the extent that these projects have the ability to operate independently from the rest of the grid, they can provide some improvement to community energy resilience in the event of a wider disruption to the state's larger energy systems.

For example, the Eugene Water and Electric Board, which serves about 93,000 electric customers and 53,000 water customers in the Eugene area, has partnered with the two Eugene-area school districts to install back-up power capability and install or upgrade water well equipment at district-owned facilities.[21] Many Eugene-area schools have existing rooftop solar that could provide on-site power for pumping water in addition to the back-up power sources. EWEB is investigating several possible back-up power sources, and is installing a microgrid back-up battery power source at Howard Elementary school in 2018 and a new water

EWEB contractor installs back-up battery power system.

well and pump station in the spring of 2019. This microgrid is sized to run the water well pump at the site for up to three weeks, while the existing solar array will be configured to allow for charging of the battery bank. EWEB's project, which is designed to increase resiliency and support research and design, was funded through a grant with ODOE, Sandia National Laboratories, Advanced Grid Research and Clean Energy States Alliance.[22] EWEB's goal is that five schools will be water resource-ready within five years. Within 5-10 years, microgrids may become more cost effective, which may result in penetration of these power sources to the electrical grid, due to an increase in customer-owned battery storage systems. Research from this first project and the following efforts will inform future policies, and will be used for planning purposes to better understand how integration with these systems will benefit the grid and the customer.

WHAT'S A DER?

Distributed Energy Resource is an umbrella term used to refer to any resource interconnected to the distribution grid of a local utility. While definitions vary on the range of resources included, the Oregon Department of Energy considers DERs to be inclusive of the following:

- Generation sources (e.g., rooftop solar or diesel generators)
- Technologies that modify demand on the distribution system (e.g., energy efficiency and demand response)
- Electric vehicles and associated charging infrastructure; energy storage technologies (e.g., distributed batteries)
- Hardware or software control systems utilized to communicate with the grid and/or to optimize the usage of other DERs

Meanwhile, Portland General Electric is involved in several energy projects around the Portland metro area with resilience benefits. First, PGE manages a Dispatchable Standby Generation (DSG) program that partners with large customers, many of them hospitals, that already have on-site diesel generators.[23] Through the DSG program, PGE upgrades the customers' control and communications equipment, assumes most routine maintenance and fuel costs, expands on-site fuel storage capabilities, and regularly tests the generator. In exchange, the customer agrees to allow PGE to rely on the customer's generator to supply extra capacity to meet system needs if there is ever an emergency need for capacity. PGE benefits by having an additional emergency capacity resource, while the customer benefits through a more robust on-site energy resilience solution.

City of Portland Fire Station 1.

PGE is also involved in the deployment of microgrid projects that combine solar and storage to enhance resilience. In 2017, the utility partnered with the City of Portland's Fire Station 1 through its Renewable Development Fund grant program to deploy a solar and storage project that can provide resilient back-up power for the fire station following a grid disruption.[24] PGE is also seeking authorization from the Oregon Public Utility Commission to develop a customer and community microgrid pilot that would deploy up to 12.5 MW of energy storage across two to five customer sites.[25]

MICROGRIDS

A microgrid is "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode."[26]

- **Size and Location.** A microgrid can range in size from a single home or building to an entire campus or even a city. The larger the size, the more complicated and expensive it is to design, build, and control.
- **Energy Efficiency.** The first step in designing a microgrid is to evaluate ways to reduce energy demand for the microgrid by improving energy efficiency.
- **Isolate Critical Loads.** All system loads should be evaluated to identify and isolate only those that are critical. For example, providing power from a microgrid to a building's heating system may be considered critical, while powering the cooling system may not be.
- **Technology Selection.** A microgrid can include virtually any type of energy technology. Additional efficiencies can be achieved through combining technologies. This might include, for example, supplementing an existing diesel generator with a solar plus storage system that can enable the microgrid to utilize its on-site liquid fuel supplies for a longer period of time, and to operate during some hours without the generator at all.
- **Control Equipment.** The key distinguishing characteristic of any microgrid involves its ability to disconnect or "island" itself from the larger electric grid. Advanced control equipment can automatically island the system from the grid and optimize the use of DERs within the microgrid.

Climate Adaptation for Oregon's Energy Systems

This section takes a closer look at some of the reliability and resilience implications of climate change, both from the effects that Oregon is already experiencing and projected future changes. This includes long-term, slower onset changes, such as average temperature and hydrologic conditions, and changes to patterns of extreme events including drought, floods, storms, and wildfires. Organizations use such climate information as the foundation to assess and create plans to reduce risks and vulnerabilities in energy and other sectors. Such actions are commonly referred to under the umbrella terms climate adaptation or climate resilience. The goal of adaptation or resilience in this context is "to prepare for and adjust to new conditions, thereby reducing harm or taking advantage of new opportunities."[27] Adaptation efforts can reduce the potential for climate change to adversely affect U.S. energy infrastructure and operations.[28,29]

One of the main inputs into and first steps in a climate adaptation planning process is to conduct a vulnerability assessment for the sector or area of interest. Oregon does not currently have a climate vulnerability assessment or adaptation plan that is specific to its energy sector. The subsections below first introduce likely areas of climate vulnerabilities for Oregon's energy systems, and then discuss the current status of state efforts to assess climate vulnerability and create a statewide plan.

Climate Vulnerabilities

Electricity Generation

As described in Chapter 1, Oregon's electricity needs are supplied by a variety of in-state and imported sources from throughout the West. Many of these generation technologies are highly dependent on water, and many studies consistently identify temperature and hydrologic changes as key drivers of risks, focusing on vulnerabilities within this "energy-water nexus" under a changing climate.[30]

Hydroelectric power generation capacity — both from the Federal Columbia River Power System and from non-federal dams that provide electricity to Oregon customers — is vulnerable to warming temperatures, reduced snowpack, earlier snow melting and peak runoff, and reduced summer flows.[31,32,33,34] For example, U.S. DOE estimates that the Bonneville Power Administration lost $164 million in fiscal year 2010 due to insufficient hydropower generation to fulfill load obligations resulting primarily from low water volumes in the Columbia River basin.[43]

In addition, salmon and steelhead habitat and populations in the Columbia River Basin are projected to be adversely affected by increasing water temperatures and seasonal streamflow changes,[35] which may have implications for hydropower operations.[9] The River Management Joint Operating Committee for the Federal Columbia River Power System updated its initial climate change study from 2009-2011, focusing on changes to temperature, precipitation, snowpack, and streamflow through the 21st century. The RMJOC's next report will assess the following six categories of system vulnerabilities to warming and streamflow changes in the Columbia River Basin: "hydroelectricity generation, temperature-driven energy demand, flood risk management, water supply, ecosystem/habitat, recreation, biological reservoir operations (e.g., operations targeting reservoir storage and releases favorable to fish), and fixed timing-based reservoir operations (e.g., refill operations derived from historical flow seasonality)."[34]

HIGHLIGHTING TRIBAL ENERGY VULNERABILITIES

Pelton Round Butte Hydroelectric Dam
Photo by U.S. Forest Service

Fisheries management and hydropower generation are inextricably linked as both depend on the region's rivers and streams. Two Oregon tribes — the Confederated Tribes of Warm Springs and the Confederated Tribes of Umatilla Reservation — are founding members of the Columbia River Inter-Tribal Fish Commission, the mission of which is to "ensure a unified voice in the overall management of the fishery resources, and as managers, to protect reserved treaty rights through the exercise of the inherent sovereign powers of the tribes."[36] Climate change is a priority area for the Commission, with a focus on efforts "to prepare for the coming changes, including helping salmon in an altered climate with habitat projects designed to cool down tributaries and exploring alternative hydrosystem operations."[36] As described more in Chapter 2, tribes are uniquely vulnerable to climate change effects on water and fisheries resources that have religious, spiritual, and cultural significance and sustain tribal subsistence and commercial economies.[37]

Some Oregon tribes will also be affected by climate impacts to federal and non-federal hydropower.[32] For example, the Confederated Tribes of Warm Springs has joint ownership with Portland General Electric of the Pelton Round Butte hydroelectric project.[38] The Umpqua Indian Utility Cooperative is the first utility in the Northwest both owned and operated by a tribe, the Cow Creek Band of Umpqua Indians; it distributes solely BPA power to its customers. Climate change vulnerabilities facing the Federal Columbia River Power System will also affect UIUC and any other Oregon utilities that rely on BPA power to serve tribal customers. Additional research in partnership with tribes would be needed to comprehensively identify and evaluate energy system vulnerabilities of relevance to Oregon's tribes.

Thermal power plants depend on water for system cooling and process use (i.e., to run steam turbines). Types of thermal power include natural gas, coal, petroleum (fuel oil), nuclear, geothermal, solar thermal electric, waste incineration, and biomass plants. Each employs various types of cooling technologies that differ in their water usage. In 2015, U.S. thermoelectric power generation drew 133 million gallons of water a day primarily from surface freshwater bodies (rivers, lakes, reservoirs, etc.), which was nearly half of all national surface freshwater withdrawals that year.[39] The Columbia Generating Station in Richland, Washington, which supplies about 3 percent of Oregon's electricity, uses an estimated 24 million gallons of water per day for cooling, then returns about 1.9 million gallons each day to the Columbia River.[40] All thermal power plants must follow applicable state and federal water quality regulations regarding the temperature of their discharge back into water bodies. Thermal power plant operations are expected to be adversely affected by higher ambient temperatures and reduced summer water availability.[28,32,33] U.S. DOE described national examples of these types of impacts.[43] For example, in August 2012, Dominion Resources' Millstone Nuclear Power Station in Connecticut shut down one reactor because the temperature of the intake cooling water, withdrawn from the Long Island Sound, was too high and exceeded technical specifications of the reactor. Water temperatures were the warmest since operations began in 1970.

Electricity Demand

The Northwest Power and Conservation Council's Seventh Power Plan analyzed the balance of available electric generation with the region's changing electricity needs in scenarios with and without climate change. Through 2026, the Northwest is projected to maintain an adequate supply of electricity to meet expected demand even if climate change is factored in. By 2035, climate-induced shifts in hydrology affecting hydropower supply and increases in electricity demand are expected to strain the already tight summer market for electricity, resulting in a 15 percent likelihood of a shortfall and exceeding the Council's adequacy standard of five percent.[41]

In the Northwest, demand for electricity is projected to increase over the next century due to population growth, increased cooling degree days (a standard measure of need for cooling defined as the number of degrees that a day's average temperature is above 65°F), and increased use of air conditioners as people cope with higher temperatures.[28,29,33] Hotter and longer summers are projected for the Northwest, with an 89 percent increase in cooling degree days per year by mid-century (2041–2070, compared to 1971–2000).[29] Nationally, demand for electricity to pump water for irrigation is also expected to rise as the agricultural sector adapts to increasing frequency and intensity of drought and changing seasonality of water availability.[29] The Power Council similarly found that projected increases in summer electricity demand will be primarily driven by air conditioning and irrigation loads.[41]

Temperature increases by mid-century will likely result in a modest reduction in the region's energy demand for space heating even accounting for population growth, though the increase in cooling needs is expected to be greater than the decrease in heating needs.[28,29,33] This has led some to describe an ongoing shift in the Northwest from being a traditionally "winter peaking" region, with our largest electricity/energy needs in winter, to a "dual peaking" region, with large loads in both winter and summer. The Seventh Power Plan states that regional demand for summer peaking services is increasing faster than winter peaking need.[41]

Energy Supply Chains and Infrastructure

The changing climate and more frequent or intense extreme events pose risks to the national or regional supply chains that Oregon currently depends on for some types of energy, as well as the energy infrastructure located within the state. Electricity and fuel suppliers' dependence on capital-intensive infrastructure investments for resource extraction, generation/production, and transmission/distribution increases their vulnerability because it is more expensive and time-consuming to bounce back from damages to or loss of high-value assets.[42] Most infrastructure is designed for a historical climate, so present-day examples of infrastructure damage and disruptions caused by extreme events demonstrate existing vulnerabilities that are likely to increase in a changing climate.[29]

As described in Chapter 1, Oregon imports nearly all of the liquid fuels and natural gas used in the state. The infrastructure required to get those fuels to Oregon includes pipelines, barges, roads, bridges, railways, and storage tanks or terminals — all of which are vulnerable to a variety of extreme events that can interrupt supply and/or drive up transport costs.[28,32] For example, in summer 2012, drought and low river water depths grounded barge transportation along the Mississippi River, which is a major route for moving commodities like petroleum and coal.[43] As Oregon progresses towards transitioning its economy away from fossil fuels in line with state climate and energy goals, these types of climate vulnerabilities related to fossil fuel supply chains are expected to be reduced.

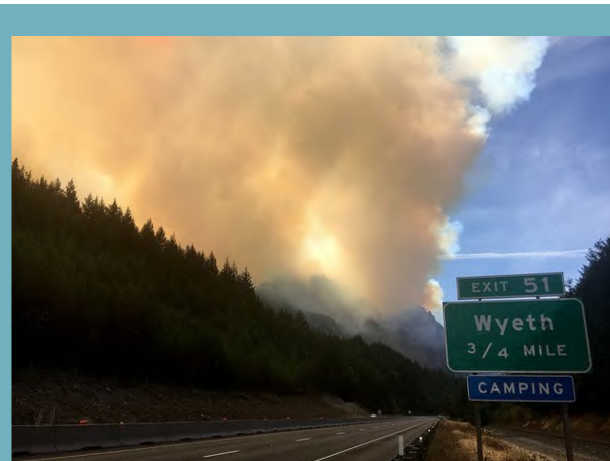
Electricity infrastructure is vulnerable to a variety of climate impacts including drought, extreme heat, flooding, wildfire, wind and winter storms, and coastal storm surges.[28,32,33] For example, increasing average and extreme temperatures reduce the efficiency and capacity of substations, transformers, and power lines, which increases line losses and reduces overall grid capacity during periods of greatest demand for electricity.[32,33] Warmer temperatures can also cause power lines to sag when conductors expand, and although the National Electrical Code[47] requires utility poles and line clearances to account for sag, climate change projections are not currently factored into design criteria. Power line sag increases the risk of tree strikes that can cause brush fires and power outages if sufficient redundancy is not available to reroute power.[32] Grid operators must reduce transformer loading on very hot days or risk causing damage or failures.[29,32] Increased ambient temperatures and heat waves also accelerate aging of insulating materials within power transformers, which can dramatically decrease initial designed lifetimes of one of the more expensive pieces of electrical distribution equipment.[32,44]

Wildfire knocked out BPA's Hot Springs-Rattlesnake 230-kV line in Montana in August 2015[46]
Photo: Mike Stolfus, BPA

Both the frequency and severity of wildfires are projected to increase in Oregon and the western U.S.[10,29,45] Wildfire disruptions and damage to electricity transmission have been seen in a number of recent events in California, Montana, Washington, and Oregon.[46] BPA has begun work to develop a proactive plan for wildfires throughout its transmission network.[46]

EAGLE CREEK FIRE

The September 2017 Eagle Creek wildfire in the Columbia River Gorge burned approximately 49,000 acres[48] through areas that house critical components of the Northwest's transmission system, resulting in power outages and emergency maintenance and repair activities to address direct threats to the reliability of the power grid.[49] BPA removed thousands of burned and damaged trees near transmission lines. Access roads, degraded by the fire where culverts melted or collapsed, were vulnerable to washing out from post-fire surface water flows. Access road repairs were required to maintain power to the city of Cascade Locks and ensure access to the structures during inclement weather. In addition, BPA helped to provide fire crews with safe access to fight the wildfire by taking its transmission lines and facilities in and out of service (de-energizing and re-energizing) as needed.[49]



Eagle Creek Fire, 2017
Photo: Oregon Department of Transportation

Statewide Climate Vulnerability Assessment and Adaptation Planning

The sections above identified some of the likely areas of vulnerability for Oregon's energy sector, but a comprehensive state-specific analysis has not yet been conducted. This is generally the first step in a climate adaptation planning process.[50] One of the advantages of starting with a vulnerability assessment is that it provides information about the magnitude and timing of climate threats at the geographic scale and level of detail that planners and policymakers need to identify and prioritize adaptation strategies for high risk areas.

UNPREPARED

Oregon Public Broadcasting's "Unprepared" series asks if Oregon will be ready for a megaquake:

https://www.opb.org/news/series/unprepared/

Oregon state government released a statewide climate adaptation framework in 2010 that provided a high-level summary of climate vulnerabilities from both long-term, slower onset changes and changes in patterns of extreme events, but only touched briefly on energy sector issues. The Oregon Department of Land Conservation and Development is initiating an interagency effort in late 2018 to revise and update the framework. Oregon state government now has an opportunity to conduct a more comprehensive and systematic assessment of vulnerabilities specific to the energy sector, either as part of that interagency effort or as a standalone product used to inform that effort. The following section provides more detail about suggested actions to pursue as first steps.

A climate vulnerability assessment for Oregon's energy sector will help inform the interagency process to identify and prioritize climate adaptation strategies. Other sources include existing federal government analysis and guidance, such as U.S. DOE's climate resilience guidebook for the electricity sector,[51] as well as relevant state government planning documents that recently have begun including climate change considerations, such as the Oregon Natural Hazards Mitigation Plan[52] and the Oregon Integrated Water Resources Strategy.[31] The IWRS includes recommendations to address drought, including increased water conservation and efficiency efforts, expanded natural and built storage, and strengthened resilience of riparian areas, forest lands, wetlands, and floodplains.[31]

Adapting to fundamental, slower onset climatic shifts like rising temperatures and declining water availability could include deployment of technologies that increase water efficiency, use of non-traditional water sources, or alternative electricity generation sources that inherently require less or no water.[32] Expanded deployment of renewable technologies such as wind and solar could reduce water demand for energy.[32] For example, water withdrawals and water consumption are projected to be reduced nationally by 97 percent and 85 percent, respectively, under a future 2050 scenario with very high levels of energy efficiency and renewable electricity generation (wind, solar, geothermal, biomass, and hydropower) across the U.S.[53]

Strategies for adapting to changing patterns of extreme events typically fall into one of two general categories. First is physical change, often called hardening, to make particular pieces of infrastructure less susceptible to extreme event-related damage. For example, this could include elevating energy equipment or structures deemed at risk for coastal flooding exacerbated by sea level rise and storm surge.[32,33] The second general category is actions that increase the ability to recover quickly from damage to components or systems. This could include, for example, creating energy storage and redundant systems as back-ups, or having real-time operational contingencies where, if conditions merit, grid operators will preemptively power down system components to minimize damage.[32,33]

Next Steps

While actions have been taken to improve the resilience of and prepare for climate change effects on Oregon's energy systems, significantly more can be done. No single entity is responsible for, or has the authority to implement, a comprehensive approach to make the energy systems of a single state more resilient to a range of threats.[33] That said, as described above, Oregon state government has taken significant steps to identify risks and vulnerabilities to some of the key components of the state's bulk energy systems. In addition, electric and gas utilities have made important investments that improve the resilience of other elements of the state's energy systems.

ODOE has identified two key gaps in current efforts:

1. **Comprehensive Vulnerability and Risk Assessment of Oregon's Energy Infrastructure**

   To date, there has never been a comprehensive evaluation of the vulnerabilities of and risks to Oregon's energy infrastructure. Key components, such as the CEI Hub near Portland, have received significant attention from the state, and utilities have taken steps to reinforce, upgrade, or rebuild some of their assets to better protect against threats. What is missing, however, is a comprehensive analysis of all of the state's energy infrastructure — inclusive of electric, natural gas, and liquid fuels production and delivery systems. Such an analysis should include an evaluation of the risks and vulnerabilities to that infrastructure from all potential threats and should include an analysis of critical interdependencies between different segments of the energy sector (e.g., the need for electricity to power liquid fuel pumping stations, or the need for liquid fuels to operate electric utility trucks, etc.) and between the energy sector and other critical public services (e.g., the dependence of first responders, healthcare providers, and others on energy).

   This type of an analysis would give the state and key stakeholders better context when evaluating specific actions that they might take to improve the resilience of and prepare for climate change impacts to the state's energy systems. For example, a local government may make different decisions with respect to community energy resilience investments depending on the findings of this type of a statewide assessment and what it might portend for their specific community. At the same time, this type of a statewide analysis could provide better guidance to the Legislature and state agencies when prioritizing investments.

2. **Developing a Vision for Community Energy Resilience**

   Within Oregon, multiple entities and jurisdictions will need to work collaboratively to identify location-appropriate solutions to improve community energy resilience. Building upon the findings of the type of comprehensive assessment of the state's energy infrastructure described above, local governments will need to collaborate with utilities and other energy providers to maximize the impact of their efforts at the community level. There is also significant work to be done to explore mechanisms to finance investments in community energy resilience and climate adaptation solutions and to prioritize those investments while considering important trade-offs.

Technology Advancements Creating Opportunities for Community Energy Resilience Solutions

On-site diesel or propane generators have been the primary source of back-up power at the customer level for decades. Hospitals, first responders, and many other large commercial and industrial customers have long utilized on-site diesel generators to ride through grid disruptions. In addition to the negative impact of emissions from these types of generators, they also depend on liquid fuel re-supply. Many diesel generators, for instance, only have sufficient on-site fuel to run for 48 to 72 hours while the Oregon Resilience Plan found that liquid fuel deliveries could be disrupted for a period of weeks or months (depending on one's location in the state) following a CSZ earthquake.[5] Exclusive reliance on on-site diesel generators for resilient back-up power comes with significant limitations when considering a long duration event.

Ice Storm, 2016
Photo: Eugene Water & Electric Board

Technology advancements are creating new opportunities to enhance local energy resilience in a manner that can complement in some cases, or replace in others, the utilization of diesel or propane generators for on-site resilient energy needs. For example, distributed solar and battery storage systems could be more cost-effective options for back-up power capabilities. The increasing availability of electric vehicles creates new opportunities to deploy a more resilient transportation fleet that can be fueled with electricity produced on-site. Advanced software and control systems are also creating new opportunities to incorporate a portfolio of technologies with different capabilities that can be optimized for maximum resilience to extend the amount of back-up power available.

Any utility, community, or customer considering investments in energy resilience technologies should also consider the capabilities of those technologies to provide resilience benefits irrespective of the type of event that might occur. For example, while a solar plus storage microgrid might be particularly effective in providing on-site resilient power during a long duration disruption like a CSZ earthquake, the same installation will also be able to provide resilient power following more routine, shorter duration disruptions, which may become more common due to climate change (for example, extreme heat events, drought, wildfires, severe winter storms). It is also important, of course, to consider whether these energy resilience solutions will physically survive anticipated threats and remain operable.

Financing Community Energy Resilience and Climate Adaptation Investments

While costs have fallen for technologies that can enhance community energy resilience, there are still barriers to investment. One major financing barrier relates to a common issue in public policy: short- versus long-term time horizons and differing viewpoints on valuing benefits and costs. It is unknown, for instance, whether the next CSZ earthquake will happen in 2019 or in 2099. Should local jurisdictions invest today in community energy resilience solutions that might not be needed for their intended purpose for many decades? On the other hand, climate scientists have modeled some future changes with a great degree of certainty in their magnitude and timing of projected impacts; for example, the latest U.S. National Climate Assessment concluded that increasing U.S. temperature trends are understood with very high confidence (meaning there is strong evidence, including well documented and accepted methods and results, and high consensus) and that impacts are extremely likely (indicating a 95 to 100 percent probability of occurrence).[12] Investment timing considerations may therefore be different for well-understood risks for which society has some long-term predictive ability.

As noted above, one key attribute of energy resilience solutions is that they also have the potential to provide value under a variety of different scenarios. A microgrid system intended to provide long duration back-up power following a major disruption can also provide back-up power during more routine power outages. Importantly, these systems also have the potential to provide value during "blue sky" conditions. For example, distributed microgrid systems can help contribute to a utility's peak capacity needs or provide ancillary services that can help maintain grid stability.

One of the challenges for these systems is identifying ways to monetize these types of values. PGE's DSG program (see page 11) is a local example where the electric utility splits costs with a customer by compensating them for the capacity their on-site diesel generator can provide to the utility under certain conditions. This helps those customers offset the costs of owning and maintaining the diesel generator for its primary intended purpose: resilient back-up power. In other parts of the country, organized wholesale markets exist that allow projects to develop revenue streams by selling these types of services into active markets. And at least one state, Hawaii, has recently initiated a process that will require its electric utilities to develop a tariff that compensates these types of microgrid projects for the benefits that they can deliver to the grid. These types of mechanisms can create sufficient revenue streams that allow communities to finance the deployment of resilient microgrid projects for which the resilience benefit that the project confers becomes an added value.

Other funding mechanisms that have been identified as potential climate adaptation tools at the state or federal level include:

- **Government bonds, loan guarantees, or revolving loan funds.**
- **State, federal, and private philanthropic grants.**
- **Transfer of development rights programs: a voluntary and market-based tool used to incentivize development away from areas of relatively higher climate vulnerability and into areas of relatively lower climate vulnerability that also have desire and capacity for more development.**
- **Insurance and insurance pooling: insurance services can help with absorbing part of the losses due to (weather related) natural disasters, thereby lessening the need for disaster relief. Second, these services can help in reducing vulnerability by setting standards related to buildings and land use planning, such as for the National Flood Insurance Program.**
- **Integrating eligible climate change adaptation considerations into existing infrastructure funding or rebuilding mechanisms — for example, FEMA Disaster Relief Fund and Hazard Mitigation Grant Program, U.S. EPA's Drinking Water State Revolving Fund, etc.**

FUNDING RESILIENT MICROGRIDS

If Oregon wants to deploy resilient microgrids in a systematic way to enhance energy resilience at the community level, the state will need to identify mechanisms to fund their deployment.

The following highlights several examples of state-level support for resilient microgrid deployments around the country:

Connecticut's Wesleyan University installed solar arrays to support its larger microgrid project.[63] *Photo: John Wareham, Wesleyan*

Connecticut: In 2013, Connecticut created a microgrid program to help support the deployment of local distributed energy generation for critical facilities. To date, the program has held four open calls for applications and has disbursed more than $30 million in grant funding.[54]

Hawaii: Recognizing a need to standardize the valuation of the services that a microgrid can provide, Hawaii's legislature enacted a law in July 2018 to require its Public Utility Commission to develop a tariff for customers who deploy microgrids and supply services back to the grid.[55,56]

Washington: Washington's state legislature established the Clean Energy Fund in 2013 to support the development, demonstration, and deployment of clean energy projects.[57] The CEF has been reauthorized twice and has been funded with a total of $136 million in funds.[58] Microgrid projects are an important focus of this fund, as evidenced by the $7 million awarded to two separate microgrid projects in 2017.[59]

New Jersey: Established the New Jersey Energy Resilience Bank to finance investments in microgrids at critical facilities that were directly or indirectly impacted by Superstorm Sandy or other eligible natural disasters. The bank was established with $200 million in funding through New Jersey's second Community Development Block Grant-Disaster Recovery from the U.S. Department of Housing and Urban Development.[60]

California: The California Public Utilities Commission established the Electric Program Investment Charge (EPIC) in 2011 to support investments in clean energy research, demonstration, and deployment.[61] Funds (totaling approximately $162 million annually from 2012-2020) for the program come from the rates charged to customers of the state's investor-owned utilities. According to the 2017 EPIC Annual Report, California has invested more than $37 million in EPIC funds into microgrid projects since 2012.[62]

Prioritizing Community Energy Resilience and Climate Adaptation Investments

As discussed earlier in this chapter, uniform reliability standards (i.e. every customer has the same level of reliable service) in the electric sector is one key characteristic that distinguishes reliability from resilience. By definition, resilience to various types of disruptive events will be non-uniform. This is true even at the stage of assessing vulnerabilities and risks — coastal areas of the state, for example, have greater vulnerabilities to a CSZ earthquake than do areas of eastern Oregon. By virtue of that geographic difference alone, energy infrastructure in eastern Oregon is likely to be less vulnerable to a CSZ earthquake than similar infrastructure located in coastal regions.

How, then, should the state and local governments think about prioritizing investments in community energy resilience and climate adaptation solutions for the energy sector? The following are key elements and related potential tradeoffs that could be evaluated to help inform the prioritization of such investments:

Vulnerability and Risk Assessment

As described above, a comprehensive analysis of the vulnerabilities and risks to energy infrastructure across the state would provide a strong foundation for identifying gaps and opportunities to make investments that maximize community energy resilience.

Critical Facilities or Infrastructure

Several of the states highlighted above that are investing in the deployment of resilient microgrids have targeted those investments specifically at critical facilities. By targeting such investments, a state can help to maximize the benefit to community energy resilience. For example, there is likely a greater community benefit if first responders and medical providers in a neighborhood have more resilient back-up power than if a non-critical private business were to have the same. Oregon could benefit from the development of a database of all critical facilities in the state plus relevant energy resilience considerations for the same, such as: an assessment of the building's energy efficiency, the size of the building's electrical load, and whether there currently exists any on-site energy generation or storage.

Potential Considerations on Safety and Security

Both of the above elements would require the collection of sensitive information in databases. The safety, security, and storage of that information would need to be ensured to avoid information being inappropriately shared or accessed.

Potential Considerations with Redundant Infrastructure

The energy industry has developed clear metrics and standards to justify significant capital investment by electric and gas utilities in technologies designed to improve and maintain a proscribed level of reliable service. For example, a certain level of redundancy (e.g., two distribution lines serving a single neighborhood) is already built into our electric grid, which helps to mitigate against routine disruptions and to allow grid operators to reroute power flows across a secondary route in the event that the primary route goes offline. Utilities and their regulatory commissions are accustomed to evaluating the prudency of these types of redundancy investments. Most investments that are made to enhance community energy resilience — such as deploying on-site diesel generators or solar and battery systems — are likely to be providing a level of redundant power service to a particular location, of course, with an added benefit of having more resilient power during times of disruption to the wider energy system. This benefit comes at a cost and the issue becomes how much redundancy is too much?

Identification of High-Value Resilience Nodes

Upon completion of a vulnerability and risk assessment of the state's energy infrastructure and the development of a database identifying critical facilities or infrastructure, the state would be in a position to assist local governments to identify clusters of critical facilities and energy infrastructure in areas with the least vulnerability or risk (e.g., areas within communities less prone to landslides or liquefaction from an earthquake). Particularly in these areas, it may be valuable then to identify the technical potential to deploy distributed energy resources to improve community energy resilience. For example, this might include an evaluation of the potential to develop biodigesters at landfills, wastewater plants, or farms. This might also include an evaluation of the potential to develop distributed solar, or small hydro projects, or distributed locations for storing liquid fuels. Of course, the ability of particular distributed energy resources to survive whatever threat(s) a community is planning for must also be considered.

Potential Considerations Regarding Timing of Investments

Given the rapid decline in costs for many distributed energy systems, another trade-off concerns the issue of when to make investments in community energy resilience. For example, according to the National Renewable Energy Laboratory, the cost for a 5.7 kW rooftop solar PV system fell more than 60 percent, from $7.24/watt (DC) in 2010 to $2.80/watt (DC) in 2017.[64] Understanding the value of the resilience benefits that these systems can provide will help entities seeking to make these investments better understand when they become cost effective.

Equity and Environmental Justice

Separate from an evaluation of the location-specific vulnerabilities and risks that might exist to energy infrastructure across the state, there should also be a recognition that some communities and populations will be less able to respond to and recover from a major disruption than others. For example, people with limited economic resources living in areas with deteriorating infrastructure are more likely to experience disproportionate impacts from extreme events such as a hurricane or flood.[65] Adaptive capacity and ability to respond to climate change and disasters are affected by factors including socioeconomic status, certain demographic characteristics, human and social capital (the skills, knowledge, experience, and social cohesion of a community), the condition and accessibility of critical infrastructure, and the availability of institutional resources like emergency response and disaster recover funding.[65] For these reasons, community energy resilience and climate adaptation solutions could be evaluated to determine if and how their benefits flow to vulnerable communities and specific populations with greater vulnerability, and how project designs could be modified to increase social and environmental equity.

Potential Tradeoffs

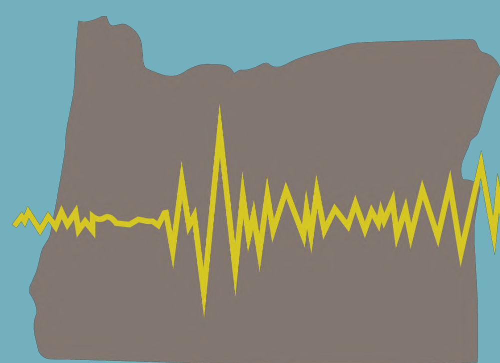
Again, it is helpful to contrast resilience with reliability with regards to equity concerns. In the electric sector, the reliability of the services provided is expected to be uniform to all customers. Investments that improve community energy resilience, however, will enable certain customers or communities to benefit from more resilient energy supply following a major disruption. This will likely create a scenario where some customers and communities have more resilient energy supplies than others. These types of equity considerations should be evaluated when designing public policies to encourage, or incentivize, investments in community energy resilience.

Community Engagement

One common denominator is that engagement with individual communities across the state in the near-term, before the worst impacts of climate change are realized or a major disruptive event occurs, is important. The work led by ODOE to develop the Fuel Action Plan through outreach with counties across the state serves as a example of this type of engagement. These discussions must necessarily consider location-specific risks, vulnerabilities, assets, and opportunities that communities themselves are best able to address. Solutions that make sense in one part of the state will not necessarily make sense somewhere else.

CONCLUSIONS

An increased awareness of threats to the state's energy infrastructure combined with advancements in technology have created an opportunity to **enhance community energy resilience** and to better prepare energy systems for the impacts of climate change. While entities across Oregon have begun taking action, the state is well-positioned to build upon these efforts to **lead a collaborative effort** to define a vision for an energy sector that is better prepared for future threats.



To inform this vision, it would be beneficial to develop a comprehensive assessment of the risks and vulnerabilities to energy infrastructure across the state. Additionally, it will also be critical to engage local communities in this effort to better understand unique circumstances across Oregon — including an evaluation of location-specific risks, vulnerabilities, and resources, and an identification of the interdependencies of the provision of **critical public services** in those communities on the energy sector.

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