COASTAL RESILIENCE FOR THE ELECTRIC POWER SYSTEM: A NATIONAL OVERVIEW AND THE OREGON EXAMPLE

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I. INTRODUCTION

Resilience is an emerging and evolving concept for the U.S. electric system.[3] The electric sector is highly prepared to deal with disruptions to electric service. It is a normal business practice for utilities, transmission operators, and certain industries to harden infrastructure and operating systems to protect from external influences – substations and power plants have fences; lines are often routed underground; operations centers have extensive procedures in the event of an outage. Due to the interdependence of the power system, utilities and operators are also subject to regulatory standards, strict financial penalties, and compliance

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[3] The variety of interpretations for the concept of resilience can be demonstrated by the nationally active debate at the Federal Energy Regulatory Commission, first under docket RM18-1, initiated in October 2017, regarding whether the anticipated retirement of thermal generating plants would cause unacceptable vulnerability in the electric system. Grid Resiliency Pricing Rule*,* 82 Fed. Reg. 46940 (Oct. 10, 2017). The subsequent docket AD18-7, established in January 2018 "to holistically examine the resilience of the bulk power system," asked organized electric markets to evaluate whether their operations are sufficiently resilient. Grid Resilience in Regional Transmission Organizations and Independent System Operators, 162 F.E.R.C. P61, 012 (Jan. 8, 2018).

practices to ensure system reliability. But resilience investments – those intended to prevent, adapt, or recover from dynamic and unusual "off-design" disruptions – remain largely ad hoc, determined by the system manager and common practices.

Such fracturing creates gaps and makes enhancing resilience to new or multi-dimensional threats challenging and slow to develop. For example, there is no standard metric for measuring and comparing the relative resilience of systems, making progress, regression, or peer comparison difficult to evaluate. Today, with greater awareness of important but complex threats such as cyber-attacks and climate change, the U.S. electric sector has only recently developed a greater body of research, policy, and programs around resilience of the electric system. These efforts will bring coherence to the industry's understanding of the challenges and ensure that the U.S. power system remains robust and better prepared. Part II of this article highlights technology, policy and research in these areas, while Part III considers recent developments in Oregon focused particularly on enhancing the resiliency of the electric system in that state's coastal communities.

II. TECHNOLOGY, POLICY AND RESEARCH OVERVIEW

A. Reliability and Resilience in the Electric Power System

A defining feature of the electric system is its reliability. A variety of regulatory standards and compliance practices assure that the power grid operates within a tight band of frequency around 60 hertz. That voltage is sufficient to meet electric demand at homes and businesses, and that an adequate amount and character of power plants are available to meet a reasonably estimated forecast of electric load. These reliability principles for the U.S. power system assure that the lights come on immediately when we flip a switch. Electricity is a just-in-time service: it cannot presently be stored in any substantial amount, and therefore all electricity must be produced when it is needed. As a result, the power system is a vastly complicated machine that simultaneously combines economic forces, regulatory oversight, and the laws of physics to deliver electricity only and exactly when we need it.

Resilience in the electric power system is slightly different than reliability, generally defined in the federal government by policy directive 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."[4] Resiliency describes the system's robustness to external circumstances that are difficult to anticipate, occur with varying magnitudes, and force idiosyncratic effects. Events may be human-caused, such as cyber-attacks, or natural, such as wildfire.

The effort to define resilience has led to questions about overlaps with reliability and a need to bring more formality to each domain. Foundational policy documents differentiate between the ability of the system to withstand disruptions (reliability) from its ability to adapt and recover from disruptions.[5] Although definitions have not been unanimously adopted, there is agreement that traditional reliability frameworks do not effectively address the suite of anticipated challenges to the power system.[6]

B. The National Outlook and Research Prospectus

The U.S. Department of Energy (U.S. DOE) is responsible for two approaches for addressing resiliency in the electric power system. The first, the Quadrennial Energy Review, or QER, lays the foundation for recommendations and research by compreheisvely reviewing the nation's energy systems, challenges, and interdependencies every four years. The second, the Grid Modernization Initiative, is the responsive research effort that attempts to address many of the challenges described in the QER.

In support of its QER, a process directed by a Presidential memorandum, the U.S. DOE initially commissioned two significant resiliency studies. One of

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[4] The White House Office of the Press Secretary, *Presidential Policy Directive – Critical Infrastructure Security and Resilience*, THE WHITE HOUSE PRESIDENT BARACK OBAMA, https://obamawhitehouse.archives.gov/the-press-office/2013/02/12/presidential-policy-directive-critical-infrastructure-security-and-resil (last visited June 6, 2018).

[5] U.S. DEP'T OF ENERGY OFFICE OF POLICY, QUADRENNIAL ENERGY REVIEW: SECOND INSTALLMENT – RELIABILITY, RESILIANCE, AND SECURITY: GRID MANAGEMENT AND TRASNFORMATION, at. 4-4 (2017), https://www.energy.gov/epsa/downloads/quadrennial-energy-review-second-installment (last visited June 6, 2018) ("Reliability is the ability of the system or its components to withstand instability, uncontrolled events, cascading failures, or unanticipated loss of system components. Resilience is the ability of a system or its components to adapt to changing conditions and withstand and rapidly recover from disruptions.")

[6] NAT'L ACAD. OF SCI., ENG'G, AND MED., ENHANCING THE RESILIENCE OF THE NATION'S ELECTRICITY SYSTEM (The National Academies Press 2017), https://www.nap.edu/catalog/24836/enhancing-the-resilience-of-the-nations-electricity-system (last visited June 6, 2018).

these studies investigated valuation of essential properties of the power system.[7] The study identified six properties: affordability, reliability, security, flexibility, sustainability, and resiliency. In its review of these properties, the study found that there are few quantitative methods to measure the relative resiliency of a given system, due to the unusual and infrequent nature of disruptive events.

A second study catalogued the variety of threats facing the power system, the state of knowledge and practice regarding effects, and response actions.[8] This study provides a comprehensive overview of resiliency in the power system today and where there are important gaps to address in the near future. A critical identified risk is that high impact low frequency events (HILF) – rare but potentially devastating disruptions – present unique challenges for the electric sector because the collective experience is a small data pool of very serious effects, from which it is difficult to draw conclusions. The report recommends scenario planning, such as table-top exercises, as one method to evaluate the resiliency of affected systems and gain a sense of the costs and benefits of management strategies.[9]

The U.S. DOE published its Second Installment of the QER in January 2017, focused on the electric system. Regarding resilience, the report found that grid disruptions disproportionately affect low-income and minority communities, extreme weather events are the primary cause of disruptions, and many such events are likely to increase due to climate change.[10] Recommended actions include establishing a national data archive on events and effects and developing a coordinated governance strategy between the intelligence and energy sectors to deal with the exponential threat of cyber-attacks.[11]

The Grid Modernization Initiative (GMI) is a multi-year U.S. DOE research effort intended to develop tools and technologies to meet future

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[7] PAC. NW NAT'L LAB & U.S. DEP'T OF ENERGY, VALUATION OF ELECTRIC POWER SYSTEM SERVICES AND TECHNOLOGIES (2016) http://www.brattle.com/system/publications/pdfs/000/005/389/original/Valuation_of_Electric_Power_System_Services_and_Technologies.pdf?1484183040 (last visited June 6, 2017).
[8] BENJAMIN L. PRESTON ET AL., RESILIENCE OF THE U.S. ELECTRIC SYSTEM: A MULTI-HAZARD PERSPECTIVE (2016), https://www.energy.gov/sites/prod/files/2017/01/f34/Resilience%20of%20the%20U.S.%20Electricity%20System%20A%20Multi-Hazard%20Perspective.pdf (last visited June 6, 2017).
[9] *Id*. at 49-50.
[10] U.S. DEP'T OF ENERGY OFFICE OF POLICY, *supra* note 5, at 4-2 and 4-3.
[11] *Id*. at 7-24.

requirements and expectations of the electric grid.[12] Under this initiative, research projects range from developing a methodological framework for evaluating value streams that can be provided by grid-related technologies and services, including methods for deriving resiliency's economic value, to improving preparation, planning, and response to extreme events, such as hurricanes and electromagnetic pulses, by developing faster and better modeling of cascading events.[13] Establishing universal metrics for measuring resiliency and other emerging system attributes is one objective of a current foundational GMI project.[14]

C. Technologies that Enable Resilience in the Electric Power System

Technologies are available today that offer significant resiliency benefits to electric power systems. A microgrid, for example, is a grouping of electric generation, loads, circuitry, and controllers that are designed to be operated independently from the rest of the system, both grid connected and isolated from the bulk system. Advanced inverters, which allow the control of system elements like batteries and solar panels, along with microgrid designs allow continuous electric service to homes and businesses even when separated – or "islanded" – from the remainder of the grid.[15] This paradigm shift toward distribution system technologies could provide significant resiliency if properly supported.

In addition to public and private utilities, many technological advancements can be adopted by electric power customers concerned about resiliency by making their own investments "behind the meter." Technologies are already deployed where commercial and industrial customers have a significant business or public interest in maintaining power quality and avoiding downtime, such as data centers or hospitals, or a national security interest in interdependent operations, such as military bases.[16] Increasingly, communities want to be sure

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[12] *Grid Modernization Initiative: What We Do*, ENERGY.GOV, https://www.energy.gov/grid-modernization-initiative-0 (last visited June 4, 2018).
[13] U.S. DEP'T OF ENERGY, GRID MODERNIZATION MULTI-YEAR PROGRAM PLAN (2015), https://energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf (last visited June 6, 2018).
[14] *DOE Grid Modernization Labratory Consortium (GMLC) – Awards*, ENERGY.GOV, https://www.energy.gov/grid-modernization-initiative-0/doe-grid-modernization-laboratory-consortium-gmlc-awards (last visited June 4, 2018).
[15] U.S. DEP'T OF ENERGY OFFICE OF POLICY, *supra* note 5, at 1-24.
[16] ARGONNE NAT'L LAB., ONSITE AND ELECTRIC POWER BACKUP CAPABILITIES AT CRITICAL INFRASTRUCTURE FACILITIES IN THE UNITED STATES (2016) https://emp.lbl.gov/sites/all/files/onsite-and-electric-power-backup.pdf (last visited June 6, 2018).

that essential services such as water treatment, fire stations, police, and shelters will have the same guaranteed electrical supply in the event of a long-duration outage. In response, state and federal programs are beginning to offer grants expressly to support resiliency objectives. For example, the state of Connecticut legislatively established a Microgrid Program in the wake of Superstorm Sandy to help municipalities install microgrids.[17]

The combination of distributed power generation technologies and battery storage could offer a strong resiliency benefit. In Oregon, Eugene Water and Electric Board is combining solar power and storage in a microgrids to serve critical public infrastructure in the event of a grid disruption.[18] This system will assure emergency functions for customers while providing services to the electric utility during normal operations. As battery storage becomes more available for "behind the meter" applications, residential and small commercial electric customers can access this option.[19] There is an emerging utility incentive model that encourages customer investment in storage. This model provides utilities with a tool to manage the system for reliability as needed while the user is grid connected, and also maintain the customer's interest in a resiliency benefit in the event of an outage that isolates that user.[20]

Other technologies offer vast new operator visibility into system conditions. In the past, our awareness of system conditions was observational, managed by correcting for excursions and deviations. With new real-time data acquisition tools, the system is managed with increasing speed, insight, and responsiveness. For example, the North American SynchroPhaser Initiative (NASPI) is a broad partnership that takes advantage of technologies that precisely monitor power flows and system conditions on the bulk transmission system to

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[17] *Microgrid Program*, STATE OF CONNECTICUT, http://www.ct.gov/deep/cwp/view.asp?a=4405&Q=508780&deepNav_GID=2121 (last visited June 6, 2018).

[18] *See Energy Storage Brings Resiliency to Eugene OR*, CLEAN ENERGY GROUP, http://www.cleanegroup.org/energy-storage-brings-resiliency-to-eugene-or/ (last visited June 6, 2018).

[19] *Energy Storage*, CA.GOV, http://www.cpuc.ca.gov/General.aspx?id=3462 (last visited June 4, 2018). In California, there is a statewide requirement for "behind-the-meter" storage and an incentive program, which has driven successful business models to install solar and storage.

[20] *Green Mountain Power, Overview*, GREEN MOUNTAIN POWER, http://products.greenmountainpower.com/product/tesla-powerwall/ (last visited June 4, 2018) (Green Mountain Power's incentive for customer installation of a Tesla Powerwall 2.0).

conduct real-time operational controls and response.[21] Yet even these breakthroughs that improve system reliability can create new vulnerabilities and implications for resiliency. Here, the increase in data processing which enables higher performance and more opportunities for clean energy also creates new needs for cyber-security protections and high performance computing.

D. Electric Power System Resilience on the Coast

Providing electric service to coastal areas presents unique physical challenges. Systems and components will experience more moisture with higher mineral content, faster and more volatile wind with no natural shielding, saturated soils, and unusually sandy or fine soil substrates. Coastal systems, structures, and power lines must be built to withstand these challenges in order to maintain routine operating conditions. Nationally, weather is by far the greatest cause of outages in the power system, but usually its effects remain confined to the distribution system – the network of wires, poles, and equipment that assure electric delivery in our neighborhoods and business districts. For coastal utilities facing more volatile weather conditions than other utility service territories, these outages may be experienced more frequently and for greater durations.

Coastal electric delivery systems are also spatially constrained by the presence of an ocean and, particularly on the U.S. Pacific Coast, coastal mountain ranges. Often electric generation sources are located at a great distance from these coastal areas, which means more equipment is needed to assure reliable electric delivery over long distances.[22] Transmission services – carrying the bulk of electric power over large distances at higher voltages – can be volumetrically constrained on the coasts. As a result, providing more electricity during peak demand or to new industries may present a challenge, and siting new high voltage

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[21] North American SynchroPhasor Initiative, *About NASPI*, U.S. DEP'T OF ENERGY, PAC. NW NAT'L LAB., AND ELEC. POWER RESEARCH INST., https://www.naspi.org/ (last visited June 4, 2018).
[22] *Offshore Wind: New York State Offshore Wind Master Plan*, NEW YORK STATE ENERGY RESEARCH AND DEV. AUTH., https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/New-York-Offshore-Wind-Master-Plan (last visited June 4, 2018). "Offshore wind can also diversify the State's energy system by providing abundant clean energy where New York's energy system is most strained—New York City and Long Island—thereby aiding the State's interconnected energy system and spreading the environmental benefits of this home-grown, renewable, and low-carbon source of energy." *New York State Offshore Wind Master Plan: Charting a Course to 2,400 MW of Offshore Wind Energy.*, NEW YORK STATE ENERGY RESEARCH AND DEV. AUTH., https://www.nyserda.ny.gov/All-Programs/Programs/Offshore-Wind/New-York-Offshore-Wind-Master-Plan (last visited June 4, 2018).

transmission services is a very difficult enterprise, whether along densely-populated or rural coastlines. Coastal transmission and distribution lines may be "single-contingency," meaning there is no redundancy for electric service if a line is suddenly unavailable. These conditions present unique challenges for coastal electric service providers to assure a reliable and resilient system.

Many of the natural threat vectors affecting U.S. coastal infrastructure have historically been well-characterized. Coastal flooding, for example, may impact substations. Under typical siting conditions, substations are built above grade and the high voltage components are situated high above the ground. Where areas are known to be flood prone, utilities can construct substations using submersible equipment or elevated components. Typically, if a substation is inundated by four feet of floodwater, the substation will be damaged and out of service.[23]

While utilities already consider the potential for flooding under planning and siting processes, climate change is challenging the usefulness of past conditions to predict future events. With climate change, sea-level rise, storm surge, and flooding frequency and intensity may become increasingly severe.[24] Modeled predictions suggest that by 2050, extreme flooding events described today as occurring once every 100 years will be decadal and possibly annual events, even when sea-level rise is relatively modest.[25] After Superstorm Sandy, one New Jersey utility indicated that a primary reason for outages in its territory were storm-surge flooded substations. These substations – which had never previously flooded – experienced inundation levels of four to eight feet that easily incapacitated the substation.[26]

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[23] PRESTON ET AL., *supra* note 8, at 17.
[24] CLIMATE CHANGE IMPACTS IN THE UNITED STATES: THE THIRD NATIONAL CLIMATE ASSESSMENT, U.S. GLOBAL CHANGE RESEARCH PROGRAM (May 2014), http://s3.amazonaws.com/nca2014/low/NCA3_Climate_Change_Impacts_in_the_United%20States_LowRes.pdf (last visited June 6, 2018).
[25] Claudia Tebaldi, Benhamin H. Strauss & Chris E. Zervas, *Modelling Sea Level Rise Impacts on Storm Surges Along US Coasts*, ENVIRONMENTAL RESEARCH LETTERS, Mar. 2012, http://stacks.iop.org/ERL/7/014032 (last visited June 6, 2018).
[26] *Learning From Superstorm Sandy: PSE&G Improves Infrastructure, Communications and Logistics*, PUBLIC SERVICE ENTERPRISE GROUP, INC., https://www.pseg.com/info/media/newsreleases/2014/2014-10-28.jsp (last visited June 6, 2018).

III. THE OREGON EXAMPLE

As described above, HILF events pose unique challenges to the electric sector, and the state of Oregon is no exception. The state's electric sector is expected to face significant future disruptions from HILF events like catastrophic wildfires, major wind and ice storms, and earthquakes. In response to these and other potential threats, a team led by the Oregon Department of Energy (ODOE) is developing a Guidebook to Enhance Local Energy Resiliency (Guidebook).[27] The Guidebook will be focused primarily on providing guidance to the state's consumer-owned utility sector to identify incremental actions that individual consumer-owned utilities can take to enhance local energy resiliency. In addition, the Guidebook will provide assistance for those utilities in their engagement with local communities to prioritize the need for local energy resiliency investments given the unique threats from HILF events across different regions of the state.

A. Energy Resiliency Planning in Oregon Today

The effort led by ODOE to develop the Guidebook is intended to supplement existing statewide energy resiliency planning efforts in Oregon. The two primary existing planning efforts in the state that address energy resiliency are the Oregon State Energy Assurance Plan[28] and the Oregon Resilience Plan.[29]

The Oregon State Energy Assurance Plan is designed to address the state's responsibilities with regards to response and recovery efforts consistent with Emergency Support Function 12. At a high-level, ODOE develops and maintains plans related to emergency response efforts related to petroleum fuels, while the Oregon Public Utility Commission develops and maintains plans related to recovery and restoration of electric and natural gas infrastructure. Collectively, these plans comprise the Oregon State Energy Assurance Plan, which is intended to supplement local efforts.

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[27] Led by the Oregon Department of Energy, in collaboration with the Office of Oregon Governor Kate Brown, Central Lincoln People's Utility District, and the National Governors Association's Center for Best Practices.

[28] OREGON DEP'T OF ENERGY AND OREGON PUBLIC UTILITY COMM'N, OREGON STATE ENERGY ASSURANCE PLAN (2012), https://www.oregon.gov/energy/facilities-safety/safety/Documents/2012%20Oregon%20State%20Energy%20Assurance%20Plan.pdf (last visited June 6, 2018).

[29] OREGON SEISMIC SAFETY POLICY ADVISORY COMM'N, THE OREGON RESILIENCE PLAN: REDUCING RISK AND IMPROVING RECOVERY FOR THE NEXT CASCADIA EARTHQUAKE AND TSUNAMI (2013), http://www.oregon.gov/oem/Documents/Oregon_Resilience_Plan_Final.pdf (last visited June 6, 2018).

Meanwhile, the Oregon Resilience Plan was published in 2013 specifically to evaluate the expected impacts to different economic sectors and geographic regions of the state from a major rupture of the Cascadia Subduction Zone[30] (Cascadia) fault system. In particular, Chapter 6 of the plan evaluated expected impacts to the energy sector. It found that it could take several weeks to restore electric, gas, and liquid fuel service to most areas of the Willamette Valley, the most densely populated part of the state. Further, Chapter 6 found that it could take anywhere from several months to a year to restore electric, gas, and liquid fuel service to coastal areas of the state.

It is within this policy context that ODOE sought and received facilitation and policy support from the National Governors Association (NGA) to develop the Guidebook in Oregon. ODOE identified an opportunity to provide assistance to the state's public power sector that could enhance local energy resiliency in a manner complementary to the existing statewide planning efforts described above.

As will be discussed in greater detail below, most consumer-owned utilities (also referred to as public utilities) in Oregon are customers of the Bonneville Power Administration (BPA) and rely exclusively on BPA's transmission system and its access to federally operated hydropower resources to meet local electricity needs. In many instances, these consumer-owned utilities are located in more remote, less densely populated areas of the state that could face long duration interruptions of service following a HILF event, such as a major wildfire, severe wind or ice storm, or Cascadia earthquake. In particular, as a result of the state's geography combined with the location of the region's hydropower resources and the resulting network of electric transmission infrastructure emanating therefrom, consumer-owned utilities located along Oregon's coastline are likely to be without power for the longest period of time following a catastrophic event.

For this reason, ODOE partnered with Central Lincoln People's Utility District (Central Lincoln PUD) to develop a first of its kind Guidebook for use by consumer-owned utilities across the state. This effort will build upon the existing statewide resiliency efforts described above by facilitating engagement among the

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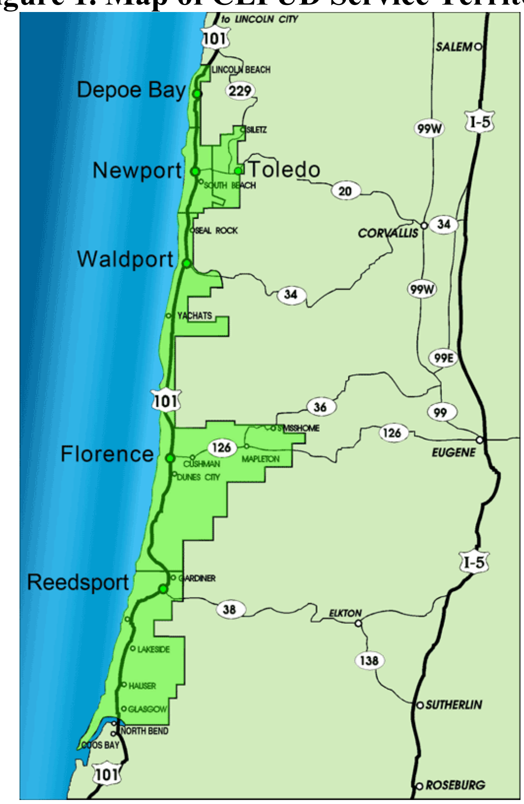
[30] *Id*. at 5. The Cascadia Subduction Zone parallels the coastline of the Pacific Northwest for approximately 600 miles. Only in recent decades have geologists come to understand the potential that a rupture along this fault could produce a catastrophic subduction zone earthquake capable of registering above 9.0 on the Richter scale that generates a significant tsunami. Geologists believe there is a 10 to 40% chance of a major rupture of the fault by 2050.

thirty-seven different consumer-owned utilities in the state to develop a guidebook that identifies incremental actions that those utilities can take to enhance local energy resiliency.

B. Particular Vulnerabilities of the Electric Sector in Oregon's Coastal Communities

As part of the development of the Guidebook, ODOE is working first to identify the particular challenges of the electric sector in Oregon's coastal communities. Project partner Central Lincoln PUD is a consumer-owned utility with a service territory that stretches 112 miles from north-to-south along the central Oregon coastline. As shown in Figure 1, the territory is only a few miles wide on average and is as narrow as one mile, with a total service area of approximately 700 square miles.[31]

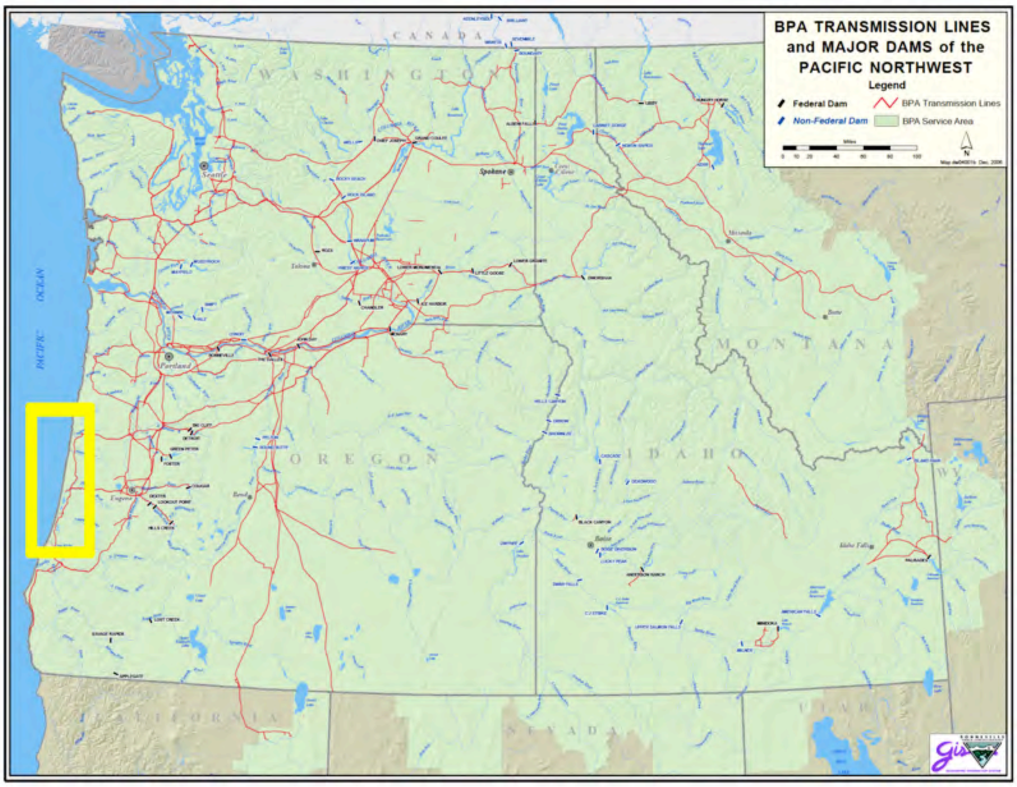
Figure 1. Map of CLPUD Service Territory



[31] *District Map/Service Area*, CENTRAL LINCOLN PEOPLE'S UTIL. DIST., http://clpud.org/district-mapservice-area/ (last visited June 6, 2018).

Central Lincoln PUD owns, maintains, and operates approximately 110 miles of transmission lines, 2,000 miles of distribution lines, 31 substations, and more than 20,000 poles.[32] The utility uses this infrastructure to deliver power to its more than 38,000 residential, commercial, and industrial customer accounts.[33] Central Lincoln PUD buys all of its power from BPA and, like most other electric utilities in the state, relies on BPA's extensive transmission system to deliver that power to its service territory.[34] Figure 2 illustrates the approximate location of Central Lincoln PUD's service territory within BPA's extensive transmission system that stretches across the Pacific Northwest.[35]

Figure 2. BPA Transmission Lines and Major Dams of the Pacific Northwest



[32] Email from Gail Malcolm to Adam Schultz (May 22, 2017, 4:24 PST) (on file with author).
[33] CENTRAL LINCOLN PEOPLE'S UTIL. DIST., *supra* note 31.
[34] KENNETH KUHNS & CO., CENTRAL LINCOLN PEOPLE'S UTILITY DISTRICT AUDIT REPORT: YEARS ENDED JUNE 30, 2016, AND 2015 (2016), http://clpud.org/wp-content/uploads/2016/12/2016-CLPUD-Audit-Report.pdf (last visited June 6, 2018).
[35] Map of BPA Transmission Lines and Major Dams of the Pacific Northwest, available at https://www.bpa.gov/news/pubs/maps/Tlines_Dams_SAB.pdf (last visited June 6, 2018).

As shown in Figure 2, BPA's transmission network is concentrated in the following areas:

(1) In proximity to the hydropower dams along the Columbia River;

(2) In the more densely populated Willamette Valley and greater Seattle metropolitan area; and

(3) North-to-south along the eastern front of Oregon's Cascade Range to provide a transmission connection to California.

Not surprisingly, these areas are likely to see transmission service restored the fastest following a catastrophic event. According to the Oregon Resilience Plan, it is expected to take one to three months to restore transmission service to 90% of normal operations for coastal regions of Oregon that are outside of the tsunami zone compared to less than one month in the Willamette Valley.[36] The target of the Oregon Resilience Plan is to improve these restoration times by the middle of this century, but with the expectation that it would still take three to four weeks to restore transmission service to 90% of normal operations for coastal regions of Oregon that are outside of the tsunami zone.[37]

For those coastal regions of Oregon that are within the tsunami zone, the Oregon Resilience Plan concludes that it is "not practical" to establish recovery timelines for areas directly impacted by the tsunami.[38] According to the Oregon Resilience Plan, it would take an even longer time to restore roads and bridges in coastal areas outside of the tsunami zone: as much as one to three years to restore roads and bridges to 60% of current operations and three-plus years to restore roads and bridges to 90% of current operations.[39]

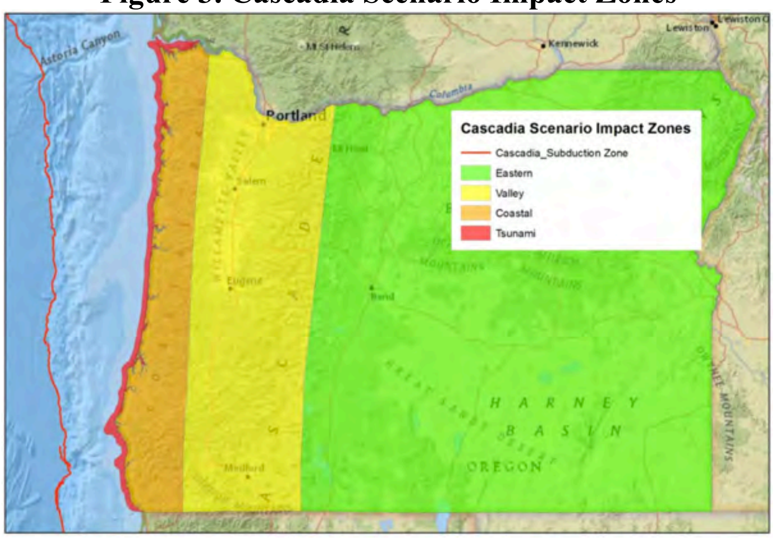
Given these realities, and the necessary focus of BPA and other entities on prioritizing the resiliency of centralized energy assets and infrastructure (including liquid fuel facilities, large electric generators, and the core components of the electric transmission network), it is likely that Central Lincoln PUD and other utilities similarly situated along Oregon's coast could be without electricity

[36] OREGON SEISMIC SAFETY POLICY ADVISORY COMM'N, *supra* note 29, at 176.
[37] *Id*.
[38] *Id*. at 175.
[39] *Id*. at 142.

for a prolonged period of time, for as long as several months, following a Cascadia earthquake or other catastrophic HILF event.

The electric transmission and road network connections from the Oregon coast to the interior of Oregon will be disrupted for a significant period of time following a catastrophic HILF event. In the case of a Cascadia event, these challenges will be compounded by the expectation of significant localized damage on the coast to buildings, critical infrastructure, and the electric distribution system resulting from structural failures, landslides, and potential tsunami inundation. As seen in Figure 3 below, damage from a 9.0 earthquake along the Cascadia subduction zone is expected to be "extreme" in the tsunami zone and "heavy" in the remaining coastal zones.[40] These factors must be considered when developing the Guidebook.

Figure 3. Cascadia Scenario Impact Zones



The Guidebook identifies proactive strategies with regards to incremental actions that Oregon's consumer-owned utilities can take to enhance energy resiliency in their communities. These actions have been identified by ODOE through consultation with Central Lincoln PUD and through outreach to many of the state's other thirty-six consumer-owned utilities. Additionally, ODOE has also incorporated best practices from the electric sector around the United States through its collaboration with the NGA. The Guidebook identifies incremental

[40] *Id*. at xiii.

actions to enhance local energy resiliency in the following categories: (1) Preparedness; (2) Mitigation; (3) Response and Recovery; and (4) Deploying Distributed Energy Resources.

The following are examples of the types of actions explored in the Guidebook:

> **Preparedness:** Creating a culture of preparedness; training employees to under their role during and following a major event; training employees to communicate with emergency responders from different government organizations; digitizing utility financial and customer records; deploying smart grid technologies to enable increased remote functioning; equipping fleet vehicles with Global Positioning System transponders, etc.
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> **Mitigation:** Conducting all hazards mitigation mapping; assessing hazards risk to all utility facilities and key infrastructure; retrofitting or otherwise reinforcing key facilities and assets; bolting substation transformers to their foundation; replacing porcelain components of substations with flexible polymers; relocating facilities and assets out of high risk locations; etc.
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> **Response and Recovery:** Implementing mutual aid agreements, standing up redundant communications systems, etc.[41]

C. Distributed Energy Resources

The deployment of distributed energy resources[42] (DERs) can supplement the efforts described above and has the potential to add significant new energy resiliency capabilities to the communities in which they are deployed. While the other actions highlighted above are focused on protecting existing utility assets and preparing utility staff, the deployment of DERs is of a fundamentally different nature in that doing so can actually increase and improve the local availability of energy during and following a major event.

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[41] On file with the authors.

[42] The term "distributed energy resources" is used here to include advanced metering infrastructure that enables utilities to remotely communicate and control end-use customer meters; small-scale solar energy systems interconnected on the utility distribution system; energy storage systems; electric vehicles; other types of distributed generation, including small-scale wind, fuel cells, diesel generators, bioenergy resources, or other types of generation interconnected on the utility distribution system.

In Oregon, few if any DER projects have been deployed by utilities to enhance local energy resiliency. For this reason, planning efforts will consider a framework for prioritizing investment in DERs that achieve this purpose. That framework will include the following core elements:

(1) Identification of localized threats and risks to the electric system;

(2) Identification of critical public infrastructure;

(3) Identification of other location-specific energy considerations;

(4) Prioritization of the need for local energy resiliency investments; and

(5) Identification of mechanisms to enable the deployment of local energy resiliency measures.

Due to the location-specific nature of many of these elements and the importance of developing community consensus, ODOE is facilitating stakeholder and community engagement to inform this planning effort. On May 5, 2017, the project team organized and hosted a retreat that attracted representatives from local utilities, municipal and county governments, and multiple state agencies, as well as energy experts from around the state and nation.[43] On December 8, 2017, ODOE held another public engagement workshop focused specifically on cross-sector coordination of energy resiliency investments, attracting attendees from local governments, healthcare providers, transportation agencies, the water sector, and the electric utility sector. It is anticipated that ODOE will engage in additional outreach meetings in the future to continue these discussions across the state.

i. Identification of Localized Threats and Risks to the Electric System

The unique threats to Oregon's coastal communities were described in detail above and provide the context for the project team's work with Central Lincoln PUD. While a major Cascadia earthquake poses the greatest risk on the

[43] *Oregon Retreat on Prioritizing and Valuing Local Energy Resilience*, NAT'L GOVERNORS ASS'N, https://www.nga.org/cms/center/meetings/eet/oregon-retreat (last visited June 6, 2018).

coast, the area is still susceptible to other HILF events and other areas of the state also face significant threats. For example, energy infrastructure in other parts of the state could be threatened by cyber or terrorist attacks, wildfires, wind and ice storms, extreme flooding events, or eruptions from one of the several active volcanoes in the Pacific Northwest, including Oregon's Mount Hood.

The expected localized impacts from these types of HILF events are likely to vary considerably. As a result, ODOE recognizes the importance of engaging local communities and emergency planners to better understand potential impacts and the location-specific risks to the electric system in different parts of the state. In 2011 and 2012, the cities of Salem and Portland respectively published Local Energy Assurance Plans to describe community critical infrastructure, priority risks to energy services, and management responses.[44] The localized threats and risks to the electric system identified by these efforts and others will be incorporated into the work being led by ODOE.

ii. Identification of Critical Public Infrastructure

Multiple federal, state, and local entities have identified critical public infrastructure assets within Oregon and an effort is underway in the state to catalog these assets in a single database.[45]

The collection of information about these assets will be a critical pre-requisite to prioritizing local energy resiliency investments. The project team intends to cross-reference this database of critical public infrastructure assets with publicly available data related to the threats and risks identified in the previous element of this process. For example, it will be important for local communities to understand the following with regard to those critical public infrastructure assets: the seismic readiness of each asset; the relationship of the site of the asset to other pieces of energy infrastructure (e.g., proximity to one of BPA's transmission

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[44] PORTLAND BUREAU OF ENERGY MANAGEMENT AND PORTLAND BUREAU OF PLANNING AND SUSTAINABILITY, PORTLAND LOCAL ENERGY ASSURANCE PLAN (2012), https://www.portlandoregon.gov/pbem/article/389162; CITY OF SALEM, SALEM LOCAL ENERGY ASSURANCE PLAN (2011), https://scholarsbank.uoregon.edu/xmlui/bitstream/handle/1794/12201/LEAP_Final.pdf;sequence=1 (last visited June 6, 2018).

[45] Mike Harryman, Oregon State Resilience Officer, Threats to Oregon's Local Energy Systems and Existing Statewide Resilience Preparation Efforts, Presentation at the Oregon Retreat on Prioritizing and Valuing Local Energy Resilience (May 5, 2017), https://www.nga.org/files/live/sites/NGA/files/pdf/2017/1705OregonRetreat-HarrymanWang.pdf (last visited June 6, 2018).

substations or an airport which may receive emergency fuel deliveries sooner than other locations); whether the asset already has any type of on-site energy generation capabilities (e.g., a diesel generator or distributed solar); whether the asset is located in a tsunami or flood zone; whether the asset is likely to be islanded following an emergency due to the failure of other nearby assets (e.g., if the road to access that asset is likely to collapse); and whether the asset is located on soils with a high risk of liquefaction or landslide, among other factors.

iii. Identification of Other Location-Specific Energy Considerations

The actual need for a specific output of local energy will likely vary considerably by location. The amount of local energy needed, and the duration for which it will be needed, are key factors in the community's prioritization discussion. For example, many police, fire, and critical medical facilities may already have on-site diesel generators that can provide some amount of emergency back-up power. Following a catastrophic HILF event such as a Cascadia earthquake, however, a key consideration will be how long it will take to re-supply liquid fuels to on-site diesel generators, which typically have no more than forty-eight to seventy-two hours of fuel available on-site.

Another example would include an evaluation of whether critical public infrastructure assets are well suited for the installation of on-site solar capacity. Factors such as solar irradiance potential and the presence of rooftops, parking lots, or other open space for the placement of solar must be considered. These factors must be evaluated for each asset and will depend on the type, location, and orientation of each asset.

Beyond on-site diesel generators and solar, local communities may also have access to other distributed sources of electric generation, such as: anaerobic digesters at local wastewater treatment plants; biomass; small-scale hydropower; wind; geothermal; and wave energy, among other technologies. The ability to utilize any of these distributed generation resources to enhance local energy resiliency is likely to be highly location specific.

This discussion must also be informed by how specific locations interact with the existing energy resiliency efforts underway in Oregon. For example, when can a specific location or asset expect to receive emergency fuel deliveries pursuant to the state's Fuel Allocation Plan? The answer to this question will be critical to understanding the need for on-site capabilities and how local energy resiliency investments should be prioritized.

iv. Prioritization of the Need for Local Energy Resiliency Investments

This element of the framework is heavily dependent on input from local community stakeholders, as it will require a hierarchical prioritization of which critical public infrastructure assets should receive local energy resiliency investments. ODOE intends for this framework to provide guidelines to assist local communities in making more informed decisions about local energy resiliency investments.

As an example, a community might identify a community center or a school as an emergency shelter during and following a catastrophic event. The framework process is intended to guide communities in thinking through how to prioritize local energy resiliency investments at one particular site compared to other sites. The threshold question will always be whether the location needs energy to function as intended (e.g., for lighting, heating and cooling, refrigeration, or other needs) during and following a catastrophic event. Assuming that the answer is yes, the community will then need to consider key attributes of the asset based on its specific location, whether the structure itself can be expected to survive the impact of the event, its proximity to other infrastructure assets, and other factors, as described above.

v. Identification of Mechanisms to Enable the Deployment of Local Energy Resiliency Measures

The final component of the framework will be to identify key challenges and the potential for innovative solutions to enable the deployment of DERs as a local energy resiliency measure. The financial investment required to deploy DERs for this purpose will vary significantly depending on the type of technology deployed and the desired performance. The cost for a 5 kW diesel generator with an on-site fuel storage tank that can supply the generator for one week, for instance, would be quite different from a 10 kW rooftop solar installation paired with a 5 kW / 25 kWh battery. The performance of these types of systems would also be very different.

A range of mechanisms could be utilized to enable the deployment of DERs as a local energy resiliency measure. The first, perhaps most obvious, option would be for the local electric utility to include these types of investments in its capital improvement plans to be recovered through electric rates charged to its ratepayers. In the public power sector, this type of decision would need to be made by the utility's governing board. In the investor-owned utility sector, this type of decision would likely require authorization by the Public Utility Commission. In both cases, the question distills to whether utility investments in DERs to enhance local energy resiliency would be in the "common good."[46] For example, it is common industry practice for utilities to make investments in enhancing the reliability of their systems under routine conditions. These investments in reliability are in the common good and thus the associated costs are socialized and recovered through rates. Similarly, utilities frequently extend electric infrastructure to new developments and those associated costs are also recovered through rates because such investments are in the common good.

In the case of investments in DERs to enhance local energy resiliency, communities must consider the potential for benefits (e.g., enhanced resiliency) to be distributed unevenly. When a utility and local community prioritize investments in DERs to enhance local energy resiliency, some areas of a utility service territory would become more resilient than others and equity concerns must be acknowledged. These investments are a value added for the communities in which they are deployed, and a service would be provided in the form of enhanced local energy resiliency that previously did not exist. Provided that this service, over an extended timeline, could be deployed to a wide range of locations within a utility service territory, it is likely that this concern about equity could be sufficiently addressed. Yet the seriousness of this issue reinforces the importance of engagement with local community stakeholders to inform the process.

A combination of taxpayer and ratepayer monies would be another potential mechanism to fund investments in local energy resiliency. Whether in the form of state tax credits or grants, or match funding from local or county governments, a possible mechanism could include legislatively appropriated public money invested alongside utility ratepayer funds.

A third mechanism could be a voluntary opt-in resiliency surcharge offered by the local utility to create a local energy resiliency fund. A fourth mechanism would be to pursue one-time grant funding opportunities from the

[46] Munn v. Illinois, 94 U.S. 113, 124-40 (1876) (establishing the concept that the public regulation of rates charged by private utilities is justified when utility investment is for the "common good," often referred to as the regulatory compact).

federal government, non-governmental organizations, or other sources to deploy individual local energy resiliency projects; however, this approach is unlikely to sustain long-term resiliency investments across a utility service area.

Underlying each approach suggested above, and indeed others not suggested, is the need to develop a way to monetize the non-resiliency benefits that these investments in DERs could provide during routine operation. For example, distributed solar paired with a storage system might reduce demand charges or provide valuable grid services, such as frequency support, voltage regulation, reactive power. These services could provide separate revenue streams for the investment beyond enhancing resiliency.

IV. CONCLUSION

In 2010, nearly 40% of the U.S. population lived in U.S. coastal counties. Population density in these counties is over four times greater than the national average, and trends project increasing density in the decades ahead.[47] Delivering and maintaining essential electric services for these growing demands presents a unique challenge. Coastal power systems are spatially limited in the solutions that can be deployed to enhance electric system resiliency. Rarely are large generating resources located nearby and these coastal areas are instead often dependent on electric delivery over long distance transmission lines to provide electric service. This condition narrows the field of options for planning resiliency measures. Coastal electric utilities in Oregon in particular are located at great distance from generating resources and dependent on single contingency transmission lines for delivery. Along the approximately 300 miles of Oregon coastline, there are five different electric utility service areas – including portions of PacifiCorp's service territory, two people's utility districts (including Central Lincoln PUD), one rural electric cooperative, and a municipal utility.[48]

Coastal electric utilities and their delivery systems are also more vulnerable to weather conditions, which are the greatest cause of outages on the power system today. When it comes to enhancing the resiliency of the electric system, researchers and power system planners are most concerned about preparing for HILF events. Key recommendations to improve electric system

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[47] NAT'L OCEANIC AND ATMOSPHERIC ADMIN., NATIONAL COASTAL POPULATION REPORT: POPULATION TRENDS FROM 1970 TO 2020 (2013), http://oceanservice.noaa.gov/facts/coastal-population-report.pdf.
[48] *BPA Public, Tribal, and IOU Customers Oregon State*, BONNEVILLE POWER ADMIN., https://www.bpa.gov/news/pubs/maps/OregonUtils.pdf (last visited June 6, 2018).

resilience include information sharing, scenario exercises, and coordinated governance to address interdependencies and fragmented experience in the electric sector.

Given the localized nature of threats, resources, characteristics of the electric system, and other factors, the prioritization of investments in DERs to enhance local energy resiliency must necessarily be informed at the community level. The primary goal of the work ongoing in Oregon outlined in this article is the development of a framework for involving community stakeholders in discussions to prioritize and focus efforts on the threats of greatest significance, to ensure equity in decision making, to satisfy "common good" standards, and to address other unique location specific contextual issues. To support those investments, the research community is working to expand the pool of knowledge about effects from these disruptions and develop technologies that prevent and restore systems. Still, there are technologies already available to customers and system operators that improve system resiliency today. Policy mechanisms are evolving but under rapid development, driven largely by customer interest.