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Oregon Energy Security Plan Risk Assessment Report

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Abstract

Under the Infrastructure Investment and Jobs Act, the United States Department of Energy (USDOE) directed state departments of energy to complete state energy security plans that bring together relevant energy information into a single plan to evaluate energy systems' security status and a roadmap to improve energy security over time. The Oregon Department of Energy (ODOE) in 2023 hired CNA and its subcontractor Haley and Aldrich to support development of the Oregon Energy Security Plan. This Risk Assessment Report addresses two required components of that energy security plan. The first is to address potential natural hazard and human-caused threats to the state's liquid fuels, electricity, and natural gas systems. The second is to provide a risk assessment of energy infrastructure.

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Executive Summary

This report details the findings and recommendations from a risk assessment of Oregon's energy systems, which was conducted to inform the Oregon Energy Security Plan (ESP). This body of work identifies the threats and hazards that pose the greatest risk to Oregon's liquid fuels, electric, and natural gas energy systems by Oregon Department of Emergency Management (ODEM) geographic region: Central, Eastern, Northwest, Portland Metro, Southwest, and Willamette Valley. Directed by Oregon Department of Energy (ODOE) in cooperation with the Oregon Public Utilities Commission (OPUC), the assessment draws upon geospatial data, plans, reports, literature, input from stakeholders, and interviews with energy system subject matter experts.

Findings and recommendations in this report may be leveraged to advance the resilience of Oregon's systems to an array of threats, including natural hazards, climate change, and human-caused threats. The findings and recommendations are intended for use by federal, state, and local partners to strengthen energy systems to withstand shocks and stresses and to enhance the resilience of Oregon's energy sector to serve its diverse regions and communities. This report is considered a living document that will be refined on a regular basis.

METHODS

For each of the three energy systems (liquid fuels, electricity, and natural gas), four categories of infrastructure assets were assessed: generation/production, transmission, storage, and distribution (to end user). Assets were evaluated against seven natural hazards—Cascadia Subduction Zone (CSZ) earthquake, drought, flood, lightning, wildfire, windstorms, and winter storms—and two human-caused threats—cyberattack and physical attack. Human-caused threats were defined as intentional attacks on energy systems. Four compounding hazards were embedded within the CSZ earthquake analysis: earthquake shaking, landslide, liquefaction, and tsunami. In addition, the impacts of climate change—Representative Concentration Pathway (RCP) 8.5 greenhouse gas emissions scenario—on the vulnerability of the energy systems were assessed for precipitation-induced flood risk and wildfire. Coastal hazards (sea level rise, coastal flooding and erosion), extreme heat, and volcanic activity (lahars and ashfall) were not evaluated in this analysis but are recommended for assessment in the future.

The risk assessment uses a methodology premised on best practice in hazard vulnerability assessments established by the Intergovernmental Panel on Climate Change (IPCC) for Impacts, Adaptation and Vulnerability. The framework is comprised of four dimensions of vulnerability evaluated for each system and threat, which were combined to calculate an overall vulnerability rating that denotes risk for each energy system to each hazard in each region. The four dimensions are exposure, sensitivity, impact, and adaptive capacity:

1. **Exposure** – examines the overlap of the geographic footprint of the energy system elements and hazard zones and the frequency of those hazard events.
2. **Sensitivity** – considers the conditions of the energy systems infrastructure, their physical characteristics, and interdependencies with other systems.
3. **Impact** – indicates the potential adverse consequences of the hazard, based upon system exposure to the hazard and sensitivity of system elements to the hazard.
4. **Adaptive Capacity** – considers the level of preparedness and ability to manage adverse events from the threats and hazards, such as physical mitigation measures, operational measures (including planning, training, and exercise), and policies.

Availability of data pertaining to each energy subsector varied. The liquid fuels system had robust data available. As such, geospatial analysis of the four dimensions was feasible. In contrast, data relating to the electric and natural gas systems was limited. For these subsectors, a survey was designed around the framework of exposure, sensitivity, impact, and adaptive capacity. Service providers (i.e., utilities) were encouraged to provide feedback specific to their system and regions in which they provide service or have assets. All three service providers in the natural gas subsector participated in the survey. In the electric subsector, 17 of 41 service providers participated, including the three largest service providers in the state. The Bonneville Power Administration (BPA) also provided feedback to the electric subsector survey. Because the BPA serves a distinct role relative to utilities, this feedback did not impact the overall vulnerability ratings but provides additional insight into the electric subsector.

RESULTS

Overall vulnerability ratings are summarized in **Error! Reference source not found.**,
, and**Error! Reference source not found.**. Results reveal that no threats were rated with a high level of vulnerability (greater than or equal to 9). However, winter storm often had the highest vulnerability ratings in the liquid fuels and electric systems. Specifically, winter storm was the highest rated (8) hazard in four regions (Cascades, Eastern, Portland Metro, and Willamette Valley) in the liquid fuels analysis and was the only hazard to receive a rating of 7 in the electric system, which was observed in two regions (Cascades and Willamette Valley). In addition, CSZ earthquake, windstorm, and wildfire were consistently among the highest natural hazard vulnerability ratings across the three energy systems. Lightning was rated among the highest natural hazard vulnerability ratings in the liquid fuels and natural gas systems. However, lightning had a low vulnerability rating in the electric system across all regions. Drought and flood were often rated lower relative to other threats. An exception to this trend is higher vulnerability to drought in the Portland Metro Region relative to other regions in the electric system. It is important to note that natural gas service providers did not provide feedback related to drought. Therefore, drought was not rated for that system. Cyberattack had low vulnerability scores in all regions and for all systems. Similarly, physical attack was rated low in all regions in the liquid fuels and electric systems. However, in the natural gas system it was rated moderate in three regions: Northwest, Portland Metros, and Willamette Valley. It is important to note that survey respondents in the natural gas subsector included accidental

damage (e.g., striking a buried pipeline when digging) when responding to questions related to physical attack, expanding the definition of physical attack beyond intentional attacks on the energy system.

Table 1: *Liquid fuels vulnerability ratings presented by region and hazard. Colors in the table correspond to rating categories. Green represents Low overall vulnerability (≤5), yellow and orange represent Moderate overall vulnerability (6–8), and red represents high overall vulnerability (≥9). Underlined and bolded values indicate that at least one survey response was not provided, resulting in an artificially low rating.*

	Cascades	Eastern	Northwest	Portland Metro	Southwest	Willamette Valley
CSZ	5	6	7	7	7	7
Cyberattack	5	4	5	5	5	5
Drought	6	6	4	4	6	4
Flood	4	5	4	4	4	4
Lightning	7	8	6	6	7	6
Physical Attack	**3**	**3**	**3**	5	**3**	**3**
Wildfire	7	7	6	6	6	6
Wind Storm	7	8	7	7	7	7
Winter Storm	8	8	6	8	7	8

Table 2: *Electricity vulnerability ratings presented by region and hazard. Colors in the table correspond to rating categories. Green represents Low overall vulnerability (≤5), yellow and orange represent Moderate overall vulnerability (6–8), and red represents high overall vulnerability (≥9). Underlined and bolded values indicate that at least one survey response was not provided, resulting in an artificially low rating.*

	Cascades	Eastern	Northwest	Portland Metro	Southwest	Willamette Valley
CSZ	4	5	5	5	6	4
Cyberattack	3	**2**	3	**2**	3	4
Drought	3	4	2	6	3	3
Flood	3	3	3	4	3	4
Lightning	5	4	2	4	3	3
Physical Attack	4	**2**	3	**2**	4	4
Wildfire	6	5	4	6	4	6
Wind Storm	6	6	5	6	6	6
Winter Storm	7	6	5	5	5	7

Table 3: *Natural gas vulnerability ratings presented by region and hazard. Colors in the table correspond to rating categories. Green represents Low overall vulnerability (≤5), yellow and orange represent Moderate overall vulnerability (6–8), and red represents high overall vulnerability (≥9). N/A indicates no survey responses were provided.*

	Cascades	Eastern	Northwest	Portland Metro	Southwest	Willamette Valley
CSZ	6	6	6	6	6	6
Cyberattack	2	3	2	2	3	2
Drought	N/A	N/A	N/A	N/A	N/A	N/A
Flood	4	4	4	4	4	4
Lightning	5	5	4	4	5	4
Physical Attack	4	4	7	7	4	6
Wildfire	5	5	5	5	6	5
Wind Storm	6	5	6	6	6	6
Winter Storm	4	4	4	4	4	4

DISCUSSION AND RECOMMENDATIONS

Risk assessment findings highlight opportunities to enhance resilience of Oregon's energy systems by addressing threats representing the highest vulnerability, discussed here in alphabetical order.

CSZ earthquake presents the highest potential impacts to liquid fuel storage because the majority of the state's liquid fuel storage resides in the Critical Energy Infrastructure (CEI) Hub in the Portland Metro, which sits on liquefiable soil. State efforts are already underway to improve the resilience of storage tanks in three counties and to expand storage at public facilities. Continued prioritization and expansion of the efforts is recommended. Natural gas production and storage assets are also vulnerable to the CSZ earthquake. Prioritization of hardening and containment solutions is also recommended. While the electric system owner/operators rated the CSZ earthquake as lower risk across most regions, the Southwest Region has an overall moderate rating. This rating indicates the need to strengthen electrical infrastructure and operations preparedness for the CSZ earthquake.

Lightning poses high risk to both liquid fuels and natural gas systems due to the flammability of the storage elements. A direct strike can cause ignition, can travel up the system to damage additional elements or people in proximity to system elements, and in a worst-case scenario can cause a large-scale outage if it were to strike large above-ground assets. Prioritizing opportunities to mitigate strike impacts through physical measures and operational measures is recommended. Physical measures may include weather coverings, roofs, and enclosures for critical infrastructure, while operational measures may include automatic or emergency shutdown systems, emergency action plans, and the maintenance of stores of essential supplies.

Wildfire ranks consistently among the highest vulnerabilities for all energy systems, and climate change projections for mid and late century show the risks are likely to increase. Given the identified gaps in adaptive capacities for wildfire, this is an area of importance to focus additional resources on mitigation such as defensible spaces around above-ground facilities and shut-off systems in high-risk areas for all energy systems.

Windstorm was one of the highest rated hazards across all three energy systems. Overall vulnerability ratings were primarily driven by high levels of exposure and potential impacts. For example, the majority of liquid fuels assets were located within windstorm hazards zones. High winds can dislodge poles, topple transmission and distribution lines, and turn loose vegetation and other materials into projectiles. However, shields and barriers can protect assets from the force of high winds and flying debris. Retrofitting and maintenance of equipment, as well as the construction of new buildings to minimum design specifications, may reduce the potential damage caused by windstorms. Providing debris clearing equipment at all sites subject to windstorms and implementing policy measures such as tabletop drills and incident command system training for all staff are recommended.

Winter Storms receive some of the highest vulnerability ratings for both liquid fuels and electric systems. Snow and ice buildup on transmission and distribution assets can cause damage and significant disruptions to electric service. The liquid fuel system is highly dependent upon electricity to operate pump stations and key components of the system; it experiences disruptions during winter storm events that reinforce the need to strengthen weatherization of the electric system and strengthen backup power supply for liquid fuels system assets.

Findings and recommendations emerged for the lower-rated threats and hazards, as well.

Cyberattack was rated low across all systems and regions. However, opportunities exist to improve maturity of mitigation measures. In general, measures related to Identifying and Responding to threats tend to be the most mature with regard to their implementation. Yet, measures related to Protecting from, Detecting, and Recovering from threats tend to be less mature, indicating a need to strengthen implementation. In addition, it is important to note that, although vulnerability scores were low overall, it is imperative that efforts to maintain and improve maturity continue due to the rapidly evolving threat landscape.

Drought vulnerability ratings were varied in this assessment. First, the electricity sector reflects a relatively higher rating for drought in the Portland Metro Region, which is largely driven by a lower adaptive capacity rating. Given the state's electricity generation capacity is 50.2 percent driven by hydroelectric dams, the long-term implications of drought on generation are essential for the Portland Metro, where roughly half of the State's population resides. In addition, the liquid fuels system has relatively higher drought ratings in the Southwest, Cascades, and Eastern regions driven by potential higher impacts to liquid fuel storage and, in the case of the Eastern Region, a reported relatively lower adaptive capacity rating for this hazard. The natural gas survey respondents did not provide feedback pertaining to drought; the motivation for that lack of response is unknown. However, additional research is needed regarding the vulnerability of the natural gas system to drought. In particular, given that future climate scenarios may indicate adverse impacts to electric system generation capacity, the inter-dependency impacts to natural gas would benefit from additional analysis. Finally, future drought analysis can be strengthened with climate projections to further elucidate increasing drought risk for all energy sectors.

Flood risk was rated low across all systems and regions with the exception of liquid fuels in the Eastern Region receiving a moderate rating. A full statewide assessment on flood may not be warranted in future assessments; however, more attention can be given to liquid fuel assets in the Eastern Region and opportunities to physically strengthen the system. In addition, flood risks will increase with climate change, as documented in this assessment. Therefore, continuing to monitor the climate projections for Oregon to understand increases to flood risk in coming decades is recommended.

Physical Attack was rated low across all systems and regions with the exception of the natural gas systems in the Northwest, Portland Metro, and Willamette Valley regions, where moderate ratings were observed. While it is important to remember that respondents expanded the definition of physical attack by considering accidental damage when answering questions related to physical attacks, areas for improvement can still be identified. In the Northwest, Portland Metro, and Willamette Valley Regions, no measures related to Identifying threats have been implemented. Additionally, measures related to Detecting threats tend to be among the least mature with regard to their implementation across all regions. Thus, opportunities exist to implement and improve the maturity in these areas. Further, continuing to implement and evolve mitigation measures to reflect the evolution of physical attacks is necessary for resilience.

Introduction

Under the Infrastructure Investment and Jobs Act, the United States Department of Energy (USDOE) directed state departments of energy to complete state energy security plans that bring together relevant energy information into a single plan to evaluate energy systems' security status and a roadmap to improve energy security over time. The Oregon Department of Energy (ODOE) in 2023 hired CNA and its subcontractor Haley and Aldrich to support development of the Oregon Energy Security Plan. This Risk Assessment Report addresses two required components of that energy security plan. The first is to address potential natural hazard and human-caused threats to the state's liquid fuels, electricity, and natural gas systems. The second is to provide a risk assessment of energy infrastructure. This risk assessment, along with the overall energy security plan, is a living document that will be updated regularly by ODOE as new information becomes available about threats to state energy systems. ODOE has worked closely with the CNA team, as well as with the Oregon Public Utility Commission staff, in developing this Risk Assessment Report. A companion report, the Risk Mitigation Measures Report, is a separate document that analyzes potential mitigation actions to address risks identified in this Risk Assessment report.

To account for and evaluate variations in vulnerability of energy systems and mitigation measures across the state, this assessment analyzes Oregon's energy systems at a regional scale using the six Oregon Department of Emergency Management (ODEM) regions (**Figure 1**). Public and private sector stakeholders and tribal governments were invited to provide insight for each of the region with which they are associated. **Figure 2** shows the headquarter locations of tribal governments. Note that tribes may be associated with regions in addition to that of their headquarters. Finally, the hazards and threats that were evaluated include: Cascadia Subduction Zone (CSZ) earthquake (including earthquake, landslide, liquefaction, and tsunami), drought, flood, lightning, wildfire, windstorm, winter storm, cyberattack, and physical attack. Mid- and late-century projections of precipitation and wildfire were also included for future-looking context.

Figure 1: *ODEM regions used in evaluation of regional-level hazard vulnerability for Oregon energy systems.*

Figure 2: *Tribal Governments headquarter (HQ) locations in Oregon (indicated by arrows).*

The subsequent sections of this report are structured around background information, methods, results, and recommendations. First, summaries of the components of the three energy systems are provided. This is followed by profiles of each of the ODEM regions, including region characteristics (i.e., county information, population count and density, area, social vulnerability classification) and major transportation corridors (**Figure 3**). Next, the methods section describes the approach for developing vulnerability ratings for each region. A detailed description of each hazard and threat is provided, followed by a description of the methods used to evaluate the exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for each energy system and region. Limitations and assumptions made within the analysis are explained. Findings from the assessment are presented with summary ratings for all hazards, broken out for each energy system and region. Lastly, the report concludes with several recommendations to inform the identification and prioritization of mitigation actions and future vulnerability studies, whether within future Energy Security Plans or as independently commissioned studies.

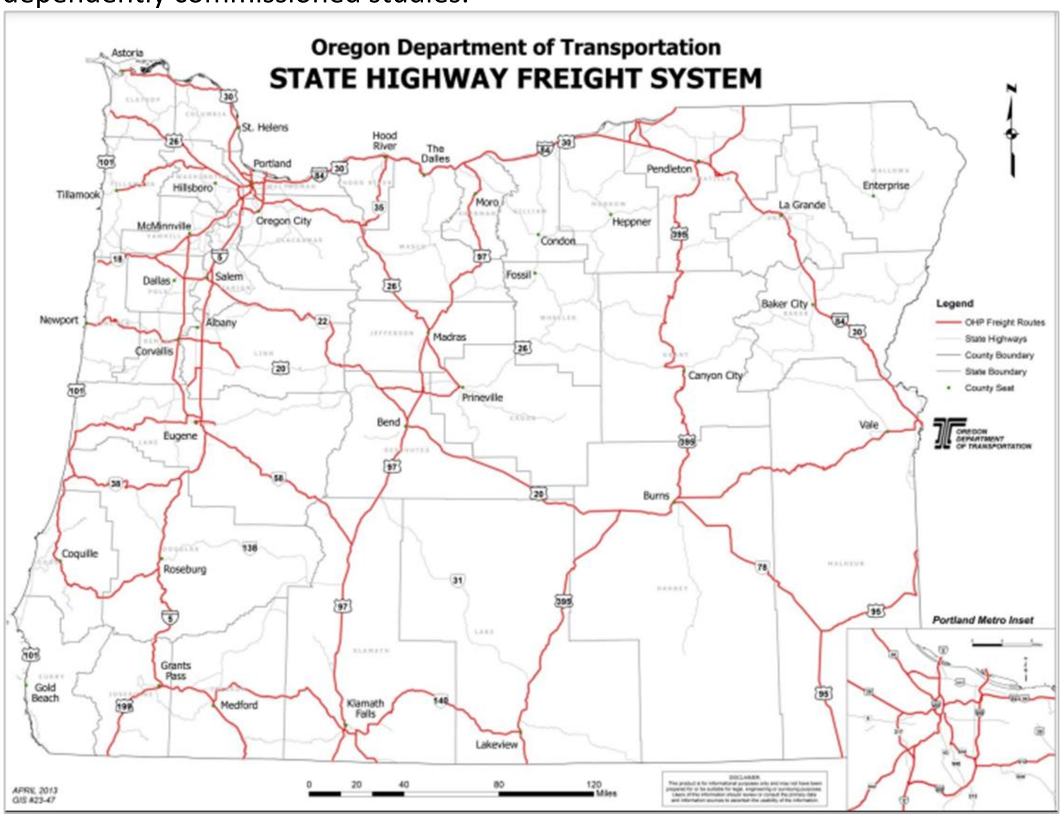

__Figure 3:__ Major transportation corridors in Oregon.[1]

Abbreviations and Definitions

Abbreviations:

- BPA – Bonneville Power Administration
- CDC – Centers for Disease Control and Prevention
- CEI Hub – Critical Energy Infrastructure Hub

- CSZ – Cascadia Subduction Zone
- DOGAMI – Oregon Department of Geology and Mineral Industries
- ESP – Energy Security Plan
- FEMA – Federal Emergency Management Agency
- GTN – Gas Transmission Northwest
- NHMP – Natural Hazard Mitigation Plan
- NRI – National Risk Index
- ODEM – Oregon Department of Emergency Management
- ODOE – Oregon Department of Energy
- OPUC – Oregon Public Utility Commission
- RCP – Representative Concentration Pathway
- SVI – Social Vulnerability Index
- USDOE – United States Department of Energy

Definitions:

- Adaptive Capacity – a measure of the level of preparedness and capability to respond to and manage impacts from a natural hazard or human caused threat.
- Climate Change – long-term shifts in temperatures and weather patterns due to human activity such as the burning of fossil fuels.
- Energy system – a system designed to supply energy services to end users; in Oregon the three systems of study include electricity, liquid fuels, and natural gas.
- Exposure – measure of the geographic footprint and frequency of a natural hazard or human caused threat.
- Potential Impact – the potential consequences or losses that may result from a natural hazard or human caused threat.
- Risk – the likelihood, possibility, and consequences of natural hazard or human-caused threat occurring.
- Sensitivity – the susceptibility of an energy system and its components to a natural hazard or human caused threat.
- Vulnerability – a combination of the exposure, sensitivity, potential impact, and adaptive capacity that gives an overall picture of the risks posed to a system by a natural hazard or human caused threat.

Oregon Energy Systems

LIQUID FUELS

The liquid fuels system in Oregon is broken down into petroleum, diesel fuel, biofuels (ethanol and biodiesel), jet fuels, and propane, with the vast majority being petroleum. For the purposes of this vulnerability analysis, the liquid fuels system was organized into five components: production, transmission, storage, distribution, and end user. For a more in-depth description of the liquid fuels system, refer to the body of the ESP.

In the production component, analysis included four ethanol plants and two biodiesel plants. Production for petroleum was not included in the analysis because there is no petroleum production in Oregon. Similarly, propane production was not included. Although there is limited propane production in Oregon, detailed data was not available for analysis.

The transmission, or transport, of liquid fuels is achieved through several modes (e.g., Inbound Flow of Diesel Fuel, **Figure 4**). A large proportion of petroleum is imported to and flows within the state via pipeline. The Olympic Pipeline transports petroleum from the Puget Sound in Washington to terminals located in Portland, Oregon. From there, the Kinder Morgan Pipeline transports liquid fuels south through the Willamette Valley to a terminal in Eugene, Oregon. Petroleum is also transported via barge on the Columbia River. Biofuels are transported via truck, rail, or barge to bulk terminals.

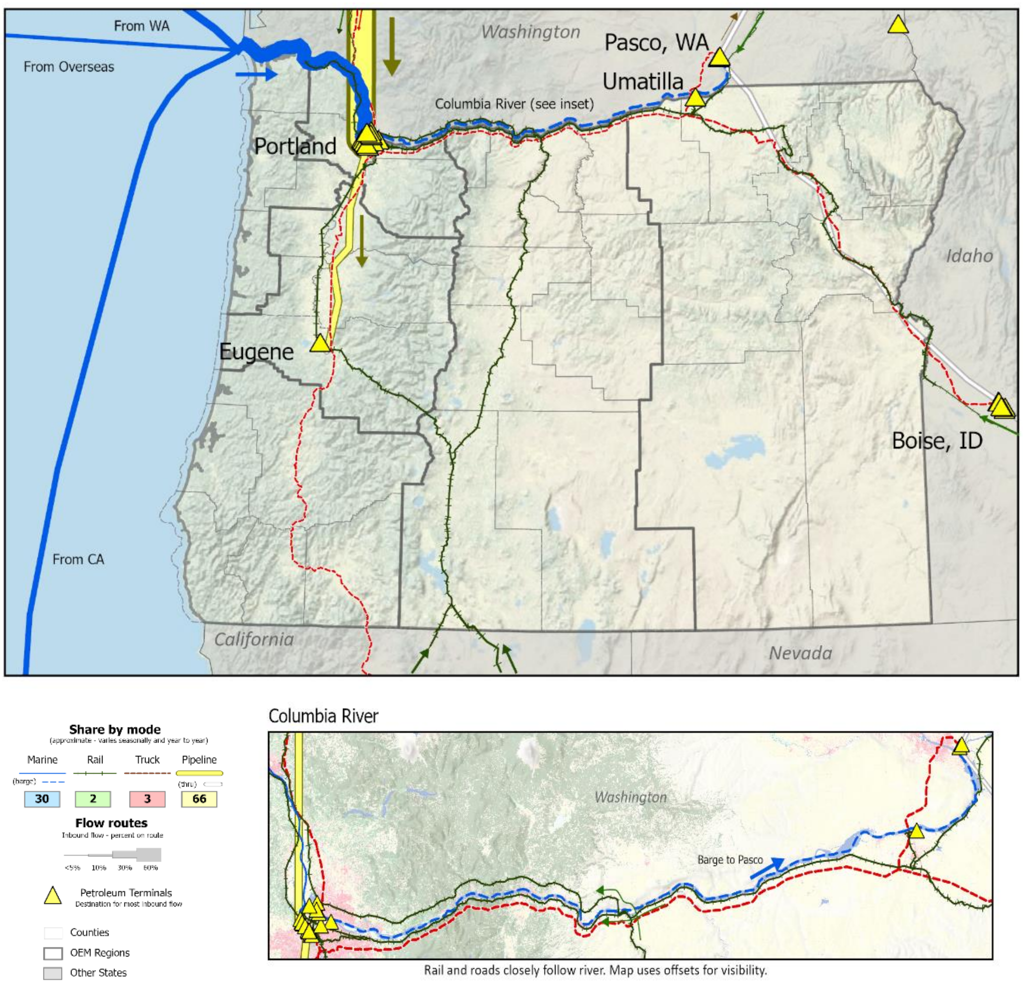

Figure 4*: Inbound flow of diesel fuel to Oregon.*[2,3]

Pre-distribution liquid fuels storage is concentrated at bulk terminals. In Oregon those terminals include the Portland Terminals at the Critical Energy Infrastructure (CEI) Hub, where the majority of Oregon fuels are stored, and the Eugene Terminal, which serves southern, central, and Eastern Oregon. Fuels are then distributed to the rest of the state via truck or pipeline to end users, with trucks responsible for the majority of distribution (e.g., Flow of Finished Diesel and Biodiesel Blends, **Figure 5**). There is also a pipeline that transports jet fuel to Portland International Airport. End users largely consist of retail stations, where fuel is used for heating, manufacturing, and/or industrial processes.

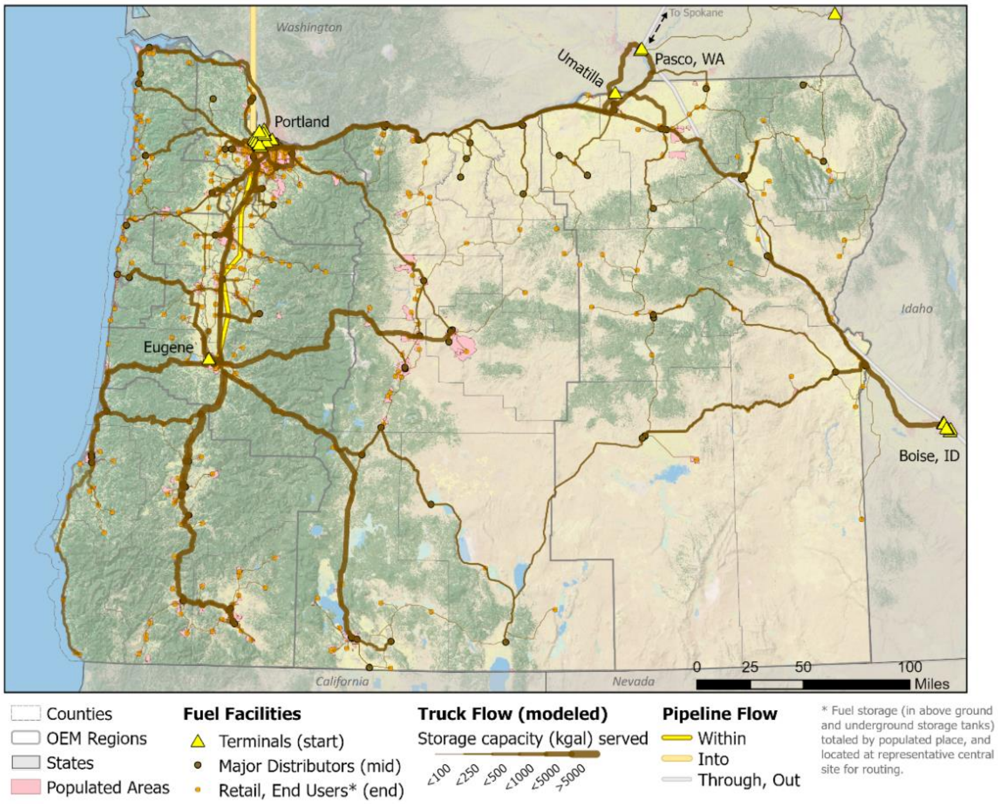

***Figure 5**: Flow of finished diesel and biodiesel blends from terminals to fuel distributors and retailers/end users.*[2,4,5,6]

ELECTRICITY

The electricity system in Oregon can be broken down into generation, transmission, distribution, and end users or consumption. Electricity is generated in Oregon using a variety of different resources (**Figure 66**). Hydropower makes up about half of the state's electricity generation, followed by natural gas power plants, wind, and small amounts of solar, coal, biomass, and geothermal. Some of the electricity generated in Oregon is also exported to other states. The electric system imports and exports power to ensure that supply and demand are balanced to maintain a safe and reliable power system (**Figure 7**). The power market in Oregon is managed by the Western Interconnection, which serves all or part of 14 states and parts of British Columbia, Alberta, and Baja, California. It is made up of 136,000 miles of transmission line and serves over 80 million people. Within the Pacific Northwest, the Bonneville Power Administration (BPA) acts as a wholesale electric power marketer that sells nearly carbon-free electricity from 31 federal hydroelectric projects, one nonfederal nuclear plant, and several small nonfederal power plants to millions of consumers and businesses via 15,000 miles of high-voltage transmission lines.[7] In Oregon, electric utilities distribute that power to end users. The state has three investor-owned utilities, 20 cooperatives, 12 municipal utilities, and six people's utility districts (PUDs) (**Figure 8 8**). Although each utility provider's service area and number of customers is highly variable across the state, a majority of end users in Oregon are served by the three investor-owned utilities. For a more in-depth description of the electric system, refer the body of the ESP.

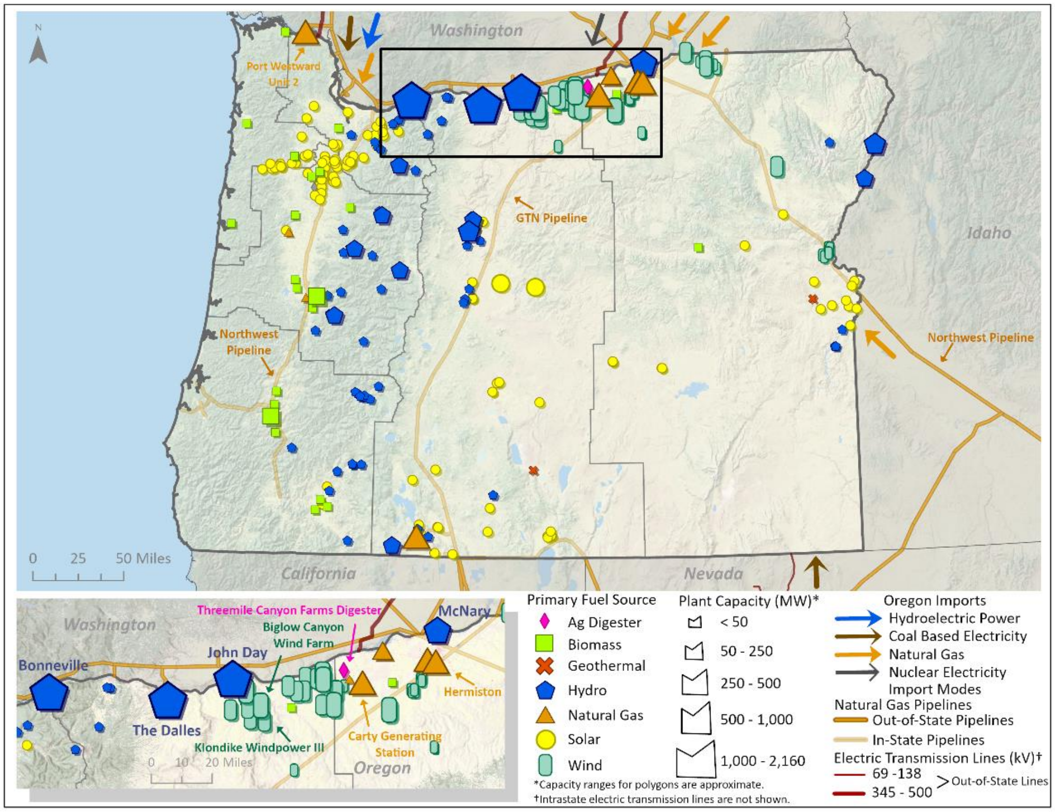

Figure 6: *Primary electric fuel sources, production, and energy imports in Oregon.*[8,9,10]

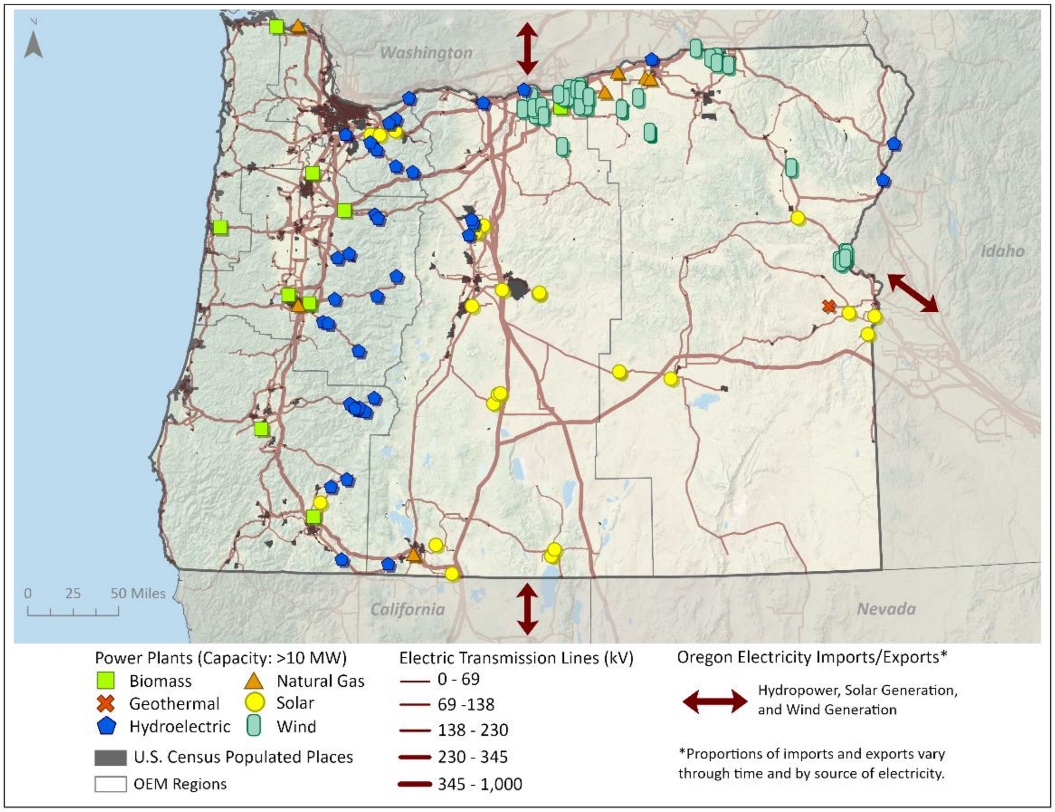

Figure 7: *Electricity transmission lines, imports, and exports.*[6,9,10]

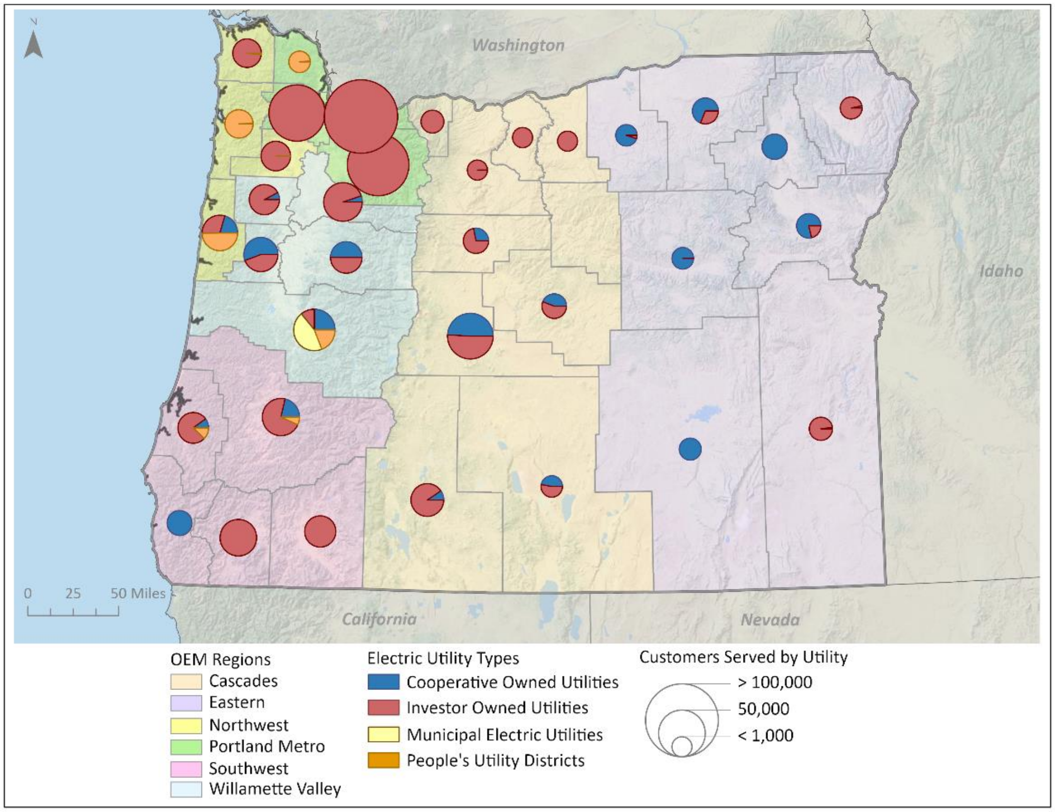

Figure 8: *Oregon's electric utility types and customers served.*[11]

NATURAL GAS

The natural gas system in Oregon consists of transmission via pipelines, storage, distribution, and consumption (**Figure 9**). Because there are no major natural gas basins in Oregon, natural gas must be brought into the state. Natural gas is transported into the Pacific Northwest, mainly from Canada, through three interstate transmission pipelines: the Enbridge BC Pipeline, the Williams Northwest Pipeline, and the Gas Transmission Northwest (GTN) Pipeline. The Williams Northwest and GTN interstate transmission pipelines directly supply gas from outside the region to the natural gas system in Oregon. There is one underground natural gas storage facility, the Mist Underground Storage Facility, that is used to balance supply and demand when interstate transmission pipelines are at capacity, either during winter heating season or hot days. That facility is located in Columbia County, 50 miles northwest of Portland. In Oregon, natural gas is used for generation of electricity as well as directly by residential, commercial, and industrial consumption. For a more in-depth description of the natural gas system, refer to the body of the ESP.

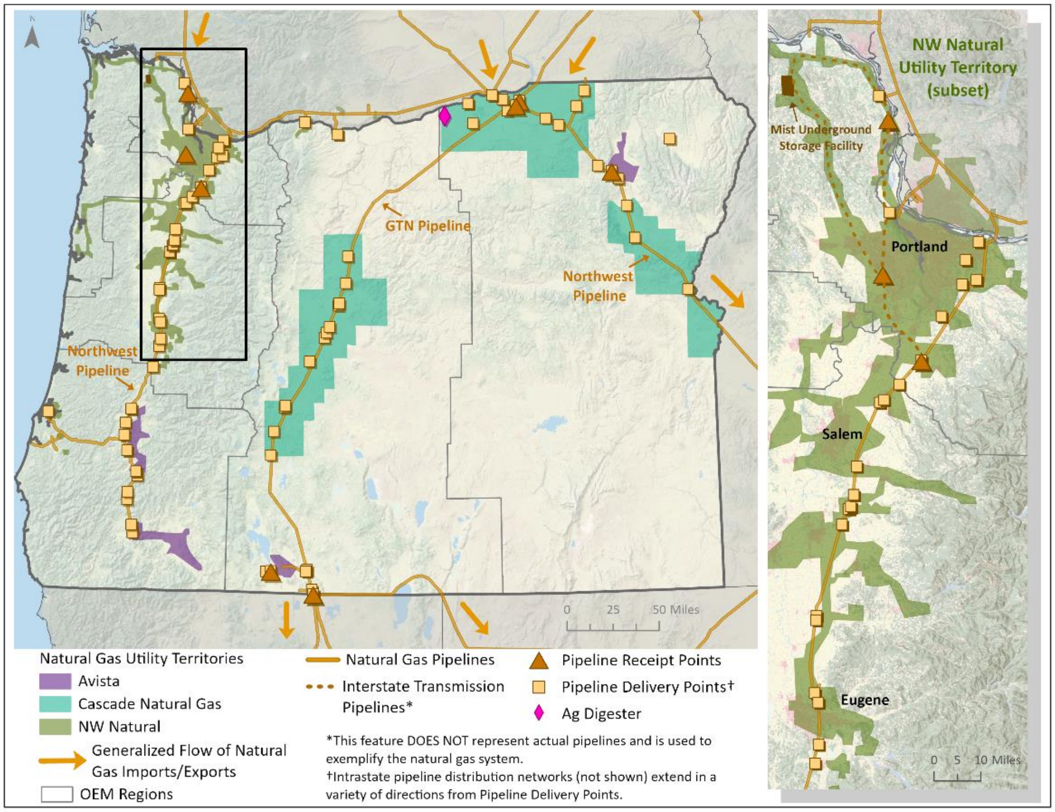

Figure 9: *Natural gas system in Oregon.*[8,12,13]

Oregon Regional Profiles

CASCADES REGION

The Cascades Region is in central Oregon (**Figure 1**) and encompasses the Oregon portion of the Cascade mountains and their surrounding areas. There are two federally recognized tribes headquartered in the Cascades region: The Confederated Tribes of Warm Springs, including the Confederated Tribes of the Warm Springs Reservation, and the Klamath Tribes, including the Klamath Indian Reservation[14] (**Figure 2**). The Cascades Region consists of 10 counties, for which descriptive statistics and characteristics are summarized in **Table 1**.

Table 1: *Descriptive statistics and characteristics of counties within the Cascades Region.*

County	County Seat[15]	County Population (2022)[16]	Area (sq mi)[17]	Population Density (pop./sq mi)	FEMA NRI Social Vulnerability[18]
Crook	Prineville	25,482	2,979	9	Relatively Moderate
Deschutes	Bend	203,390	3,018	67	Relatively Low
Gilliam	Condon	2,039	1,205	2	Relatively Low
Hood River	Hood River	23,888	522	46	Relatively High
Jefferson	Madras	244,889	1,782	137	Very High
Klamath	Klamath Falls	69,822	5,950	12	Very High
Lake	Lakeview	8,177	8,139	1	Very High
Sherman	Moro	1,908	824	2	Relatively Low
Wasco	The Dalles	26,581	2,381	11	Very High
Wheeler	Fossil	1,456	1,716	1	Relatively Low

The region encompasses an area of 28,516 square miles. Most counties in the region have very low population density, with the exceptions of Deschutes, Hood River, and Jefferson counties. Bend is the largest city in the region, with approximately 101,000 people recorded in the 2022 Census.[19, 20] The Federal Emergency Management Act (FEMA) National Risk Index (NRI) bases Social Vulnerability rankings on the Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI). SVI ranks vulnerability based on 16 factors that relate to socioeconomic status, household composition and disability, minority status and language, and housing and transportation.[21] According to the NRI, several counties in the region rank relatively high and very high for social vulnerability to the adverse impacts of natural hazards. Jefferson, Klamath, Lake, and Wasco Counties all rank very high, and Hood River County ranks relatively high.

Several transportation corridors run through the region, including US 20, which runs east-west through Deschutes and Lake Counties; US 97 that runs north-south through Sherman, Wasco, Jefferson, Deschutes, and Klamath Counties; and I-84 that runs east-west along the Columbia River through Hood River, Wasco, Sherman, and Gilliam Counties (**Figure 3**). The Central Region is also home to the Redmond Airport, which is identified as a staging area for federal support if the Portland airport is disabled due to a disaster.[22] Bend is also the location of St. Charles Medical Center, a 292-bed acute care hospital that is key for both the city itself and the larger Central and Eastern Oregon region.[23]

Storage and distribution represent the major components of the liquid fuel system in this region (**Figure 5**). Key electric facilities in the region include transmission lines from both in-state and out-of-state power sources (**Figure 7**). Two of the state's four largest electricity generating facilities—the John Day and the Dalles hydroelectric facilities—are located along the Columbia River in the northern part of the region (**Figure 6**).[24] There are also several renewable energy generating facilities in the northern portion of the region. TC Energy's GTN natural gas pipeline system runs through the region (**Figure 9**).[25]

EASTERN REGION

The Eastern Region makes up the easternmost portion of Oregon and borders Idaho to the east, Nevada to the south and Washington to the North (**Figure 1**). There are two federally recognized tribes headquartered in the region: the Burns Paiute Tribe, which is mainly comprised of descendants of the Wadatika Band of Northern Paiutes; and Confederated Tribes of the Umatilla Indian Reservation, which is made up of the Cayuse, Umatilla, and Walla Walla tribes (**Figure 2**).[26] The Eastern Region consists of eight counties, for which descriptive statistics and characteristics are summarized in **Table 2**.

Table 2: *Descriptive statistics and characteristics of counties within the Eastern Region.*

County	County Seat[27]	County Population (2022)[28]	Area (sq mi)[29]	Population Density (pop./sq mi)	FEMA NRI Social Vulnerability[30]
Baker	Baker City	16,860	3,068	5	Relatively High
Grant	Canyon City	7,226	4,528	2	Relatively Moderate
Harney	Burns	7,537	10,134	1	Relatively Moderate
Malheur	Vale	31,995	9,888	3	Very High
Morrow	Heppner	12,635	2,031	6	Relatively High
Umatilla	Pendleton	80,523	3,216	25	Very High
Union	La Grande	26,295	2,037	13	Relatively High
Wallowa	Enterprise	7,433	3,146	2	Relatively Low

Overall, the region has an area of 38,048 square miles and very low in population density with relatively small population centers around Pendleton (17,169) and Hermiston (19,969) in Umatilla County.[31] Several counties in the region rank relatively high and very high for social vulnerability to the adverse impacts of natural hazards per the FEMA NRI. Malheur and Umatilla counties rank very high, and Baker, Morrow, and Union counties rank relatively high.[32]

Several transportation corridors run through the region, including US 20, which runs east-west through Malheur County to the Idaho Border; and I-84 that runs east-west along the Columbia River through Morrow County and turns southeast through Umatilla, Union, Baker, and Malheur Counties to the Idaho border (**Figure 3**).[33, 34] Although there are no commercial airports, public and private airports are located in the region.

One major liquid fuels pipeline, the Marathon Pipeline, runs through the Eastern Region connecting out-of-state terminals located in Pasco, Washington, and Boise, Idaho (**Figure 4**). Liquid fuels are also moved via the Columbia River along the northern edge of the region.[35] One of the state's four largest electricity generating facilities, the McNary hydroelectric facility, is located along the Columbia River in the northern part of the region (**Figure 6Figure 6**).[36] The Williams Northwest natural gas pipeline runs through the northern half of the region (**Figure 9**).

NORTHWEST REGION

The Northwest Region makes up the northwestern corner of Oregon and borders Washington to the north and the Pacific Ocean to the west (**Figure 1**). There are two federally recognized tribes headquartered in the region. The Confederated Tribes of Grand Ronde includes over 30 tribes and bands; they include bands from the Kalapuya, Molalla, Chasta, Umpqua, Rogue River, Chinook, and Tillamook. The Confederated Tribes of Siletz Indians is made up of 27 bands that originate from northern California, Oregon, and Southern Washington (**Figure 2**).[37]

The Northwest Region consists of four counties, for which descriptive statistics and characteristics are summarized in **Table 3**.

***Table 3**: Descriptive statistics and characteristics of counties within the Northwest Region.*

County	County Seat[38]	County Population (2022)[39]	Area (sq mi)[40]	Population Density (pop./sq mi)	FEMA NRI Social Vulnerability[41]
Clatsop	Astoria	41,428	828	50	Relatively Moderate
Lincoln	Newport	50,903	981	52	Relatively High
Tillamook	Tillamook	27,628	1,103	25	Relatively Moderate
Yamhill	McMinnville	108,261	716	151	Relatively Moderate

Overall, the region has an area of 3,628 square miles. The largest cities in the region are McMinnville (34,251) and Newberg (25,376) in Yamhill County, with smaller population centers closer to the coast, including Newport (10,591) and Astoria (10,197) in Lincoln and Clatsop Counties, respectively. According to the FEMA NRI, Lincoln County ranks relatively high for social vulnerability to the adverse impacts of natural hazards. No counties in the region rank very high.[42]

Several transportation routes run through the region and are crucial in the event of needing to move people away from the coast (**Figure 3**). US 101 runs north-south through Clatsop, Tillamook, and Lincoln Counties along the coast. There are also the highways that connect 101 to the I-5 corridor, including US 30 in Clatsop County, US 26 in Clatsop County, and US 6 in Tillamook County.[43, 44] There are no commercial airports in the region but some public and private airports.

The electrical facilities in this region consist of electrical transmission lines, serving largely to bring power to the coast from the Willamette Valley and Portland Regions (**Figure 7**). Although there are no major liquid fuels facilities in the region, some liquid fuel is transported east along the Columbia River, which runs along the north edge of the region (**Figure 4**).

PORTLAND METRO REGION

The Portland Metro Region is located between the Northwest and Cascades Regions in northern Oregon (**Figure 1**). There are no federally recognized tribes headquartered in the region (**Figure 2**). The Portland Metro Region consists of four counties, for which descriptive statistics and characteristics are summarized in **Table 4**.

Table 4*: Descriptive statistics and characteristics of counties within the Portland Metro Region.*

County	County Seat[45]	County Population (2022)[46]	Area (square miles)[47]	Population Density (pop./sq mi)	FEMA NRI Social Vulnerability[48]
Clackamas	Oregon City	425,316	1,871	227	Relatively Low
Columbia	St. Helens	53,014	659	80	Relatively Low
Multnomah	Portland	820,672	431	1,904	Relatively Moderate
Washington	Hillsboro	605,036	724	836	Relatively Low

Overall, the region has an area of 3,685 square miles. The Portland Metro region is the most densely populated area of the state with almost 50 percent of the state's population living in four counties. According to the FEMA NRI, no counties in the region rank relatively high or very high in terms of social vulnerability to the adverse impacts of natural hazards.[49]

As the population center for the state, the Portland Metro region serves as a hub for transportation and other critical facilities. Several key corridors converge in the region, including the I-5 corridor that runs north-south; I-84 that runs east from Portland along the Columbia River, and many other major highways (**Figure 3**). Portland International Airport is the primary transportation hub for the state.[50] The region also has several public and private airports.

The Olympic Pipeline, which carries the majority of Oregon's liquid fuel, terminates at the CEI Hub along the Columbia River in the Portland Metro Region (**Figure 4**). The Kinder Morgan Pipeline, which runs down the Willamette Valley, also starts at the CEI Hub and runs through the Portland Region. Another pipeline carries Jet Fuel from the CEI Hub to Portland International Airport. One of the state's four largest electricity generating facilities, the Bonneville hydroelectric facility, is located along the Columbia River in the northern part of the region (**Figure 6**).[51] The Williams Northwest natural gas pipeline runs through the Portland region (**Figure 9**). Northwest Natural's Mist Underground Natural Gas storage facility is located in Columbia County.

SOUTHWEST REGION

The Southwest Region makes up the southwestern corner of Oregon and borders California to the south and the Pacific Ocean to the west (**Figure 1**). There are three federally recognized tribes headquartered in the region: (1) the Confederated Tribes of Coos-Lower Umpqua-Siuslaw, which is made up of three tribes: the Hanis Coos and Miluk Coos bands of the Coos Tribes, the Lower Umpqua Tribe, and the Siuslaw Tribe; (2) the Coquille Indian Tribe, which is made up of people whose ancestors lived in the Coquille River watershed and lower Coos Bay (Coos County); and (3) the Cow Creek Band of Umpqua Tribe of Indians, headquartered in Roseburg, in Douglas County (**Figure 2**).[52]

The Southwest Region consists of five counties, for which descriptive statistics and characteristics are summarized in **Table 5**.

Table 5*: Descriptive statistics and characteristics of counties within the Southwest Region.*

County	County Seat[53]	County Population (2022)[54]	Area (sq mi)[55]	Population Density (pop./sq mi)	FEMA NRI Social Vulnerability[56]
Coos	Coquille	65,154	1,596	41	Relatively High
Curry	Gold Beach	23,662	1,628	15	Relatively High
Douglas	Roseburg	111,694	5,036	22	Relatively High
Jackson	Medford	223,827	2,783	80	Relatively High
Josephine	Grants Pass	88,728	1,639	54	Relatively High

Overall, the region has an area of 12,682 square miles. Medford in Jackson County is the largest city in the region with 87,353 people, followed by Grants Pass in Josephine County with 39,475. According to the FEMA NRI, every county in the region ranks relatively high for social vulnerability to the adverse impacts of natural hazards.[57]

There are several key transportation routes that run through the region (**Figure 3**). US 101 runs north-south through Douglas, Coos, and Curry Counties along the coast. There are also the highways that connect 101 to the I-5 corridor, including US 199 that connects to 101 in Northern California and runs through Josephine County, OR 42 in Coos and Douglas Counties, and OR 38 in Douglas County.[58, 59] There are two commercial airports in the region—Southwest Oregon Regional Airport in Coos County and the Rogue Valley International-Medford Airport in Jackson County—as well as public and private airports.

There are no major liquid fuels facilities in the Southwest Region. Several electrical transmission lines run through the region (**Figure 7**). The Williams Northwest and TC Energy's GTN natural gas pipelines both run through the southwest region (**Figure 9**).

WILLAMETTE VALLEY REGION

The Willamette Valley Region makes up the portion of Oregon that lies in the Willamette Valley along the I-5 corridor, mainly between the Coast Range and the Cascade Mountains, and extends to the coast in the southern-most area of the region (**Figure 1**). There are no federally recognized tribes headquartered in this region (**Figure 2**). The Willamette Valley Region consists of five counties, for which descriptive statistics and characteristics are summarized in **Table 6**.

Table 6*: Descriptive statistics and characteristics of counties within the Willamette Valley Region.*

County	County Seat[60]	County Population (2022)[61]	Area (sq mi)[62]	Population Density (pop./sq mi)	FEMA NRI Social Vulnerability[63]
Benton	Corvallis	93,976	675	139	Relatively Moderate
Lane	Eugene	382,647	4,554	84	Relatively High
Linn	Albany	130,440	2,290	57	Relatively High
Marion	Salem	347,182	1,181	294	Very High
Polk	Dallas	88,916	741	120	Relatively Moderate

Overall, the region has an area of 9,441 square miles. Much of Oregon's population is located in the Willamette Valley Region and is largely concentrated along the I-5 corridor, including the Eugene Springfield Metro region in Lane County with populations of 175,626 and 62,353 respectively, and the state capital of Salem in Marion County with a population of 177,694. According to the FEMA NRI, several counties in the region rank relatively high and very high for social vulnerability to the adverse impacts of natural hazards. Marion County ranks very high, and Lane and Linn Counties rank relatively high.[64]

There are several key transportation routes that run through the region (**Figure 3**). I-5 runs north-south through Lane, Linn, and Marion Counties and close to Benton and Polk Counties. US 101 runs north-south through Lane County. US 20, OR-58, OR-26, and OR-22 all connect the Willamette Valley to Central Oregon through the Cascade Range.[65, 66] There is one commercial airport in the region, the Eugene Airport in Lane County, as well as several public and private airports. While the Salem Airport is owned by the city, it serves commercial flights.

The Kinder Morgan Liquid Fuel Pipeline runs through the Willamette Region between Portland (Multnomah County) and a terminal located in Eugene (Lane County), Oregon (**Figure 4**). Several electric transmission lines run through the region (**Figure 7**). There are several smaller hydroelectric facilities and renewable energy facilities in the region (**Figure 6**). The Williams Northwest Natural Gas Pipeline also runs through the region (**Figure 9**).

Methods

HAZARDS AND THREATS

Introduction

The prioritization of hazards and threats to include for assessment was the first step in the approach. To identify natural hazards that may impact Oregon energy systems, a comprehensive list was developed based upon hazards included in the most recent Oregon Natural Hazard Mitigation Plan (2020),[67] the 6th Oregon Climate Assessment (2023),[68] the State of Oregon Energy Sector Risk Profile (2021),[69] the *Drought and Infrastructure: A Planning Guide* (2021),[70] and a presentation from FEMA Region 10 (2023).[71] From these federal and state documents, a list was developed including coastal hazards (e.g., coastal flooding, erosion, sea level rise, and tsunami), drought, earthquake (predominantly CSZ), extreme heat, flood, landslide, lightning strikes (linked to thunder storms), volcanic hazards (e.g., ashfall events and lahars), wildfire, windstorms, and winter storms (e.g., ice, snow, extreme cold). In addition, climate change as a driver for increasing frequency and severity for many of these hazards was included (not listed as a stand-alone hazard).

The Representative Concentration Pathway (RCP) 8.5 greenhouse gas emissions scenario was used to generate the projected flood and wildfire data used in this report. RCP 8.5 is a high-emissions climate future that results in a global radiative forcing of 8.5 W/m^2 by the end of the 21st century and an average global temperature increase of nearly 5°C.[72] This magnitude of global temperature increase is associated with impacts on the frequency, intensity, and duration of precipitation events and increases in wildfire risk. To provide future-looking context, climate change impacts on fire weather and extreme precipitation were simulated for a mid- and late-century period. The mid- and late-century periods for the precipitation data correspond to 2040–2069 and 2070–2099, respectively. The mid- and late-century period for wildfire correspond to 2045–2054 and 2085–2094, respectively.

In addition to natural hazards, human-caused threats that could impact Oregon energy systems were considered. Threats included cyberattacks (e.g., malware, phishing, and ransomware) and physical attacks (e.g., sabotaging, shooting, and vandalizing equipment). These threats were incorporated into the comprehensive list of hazards and threats for the risk assessment based on 2015 USDOE guidance on how to protect the electricity, liquid fuels, and natural gas sectors from cyberattacks and physical attacks. In 2017, Oregon adopted this guidance into the Oregon Fuel Plan.

A subset of these natural hazards was prioritized for the full assessment with an understanding that not all hazards could be evaluated in this first Energy Security Plan (ESP) assessment. To prioritize the hazards, numerous factors were gleaned from the literature and desk research to capture details about: (1) hazard likelihood and frequency in Oregon; (2) the severity particular to energy system impacts (including notable historic occurrences in Oregon); (3) available geospatial data for the hazard in Oregon; (4) the availability of future climate scenario data for the hazard; and (5) information on historic losses. In addition, feedback from public and private sector stakeholders on the prioritization of hazards and threats was collected via surveys. For example, stakeholders were asked to rank natural hazards and human-caused threats from most to least concerning in relation to their organization's energy system(s). Together, this data informed which hazards are documented to have direct consequences on the energy systems in Oregon, which hazards are of most concern to stakeholders, and for which of the hazards reliable data exists to inform the risk assessment. Based on these inputs, a consensus was reached with the analytic team, ODOE, and Oregon Public Utility Commission (OPUC) to include the following selection of hazards and threats for analysis:

1. **Cascadia Subduction Zone (CSZ) Earthquake** – a compound hazard by combining with **tsunami** risk, **liquefaction**, and **landslide** risk that may be triggered by seismic event. CSZ Earthquake risk is defined as 9.0 (worst-case-scenario) with very strong to violent perceived shaking. Tsunami risk is defined as maximum extent of a near subduction zone triggered event (XXL scenario). Liquefaction is defined as susceptibility rated as moderate, high, and very high—indicating soft soil likely to liquefy following a seismic event. Landslide is defined as high and very high susceptibility, indicating landslide likely to be triggered by a seismic event.
2. **Cyberattacks –** intentional efforts to alter, collect, degrade, destroy, disable, expose, or steal data, applications, information system resources, or other assets through unauthorized access to a network, computer system, or digital device (e.g., ransomware).[73, 74]
3. **Droughts** (current day) – includes meteorological (driven by below average rainfall) and hydrological (impact of rainfall deficits on surface and ground water) droughts because both types can have a direct impact on energy systems. Cybersecurity and Infrastructure Security Agency reports that hydroelectric power for the Columbia Watershed is affected by drought and indicates potential impacts on liquid fuels and natural gas systems related to water availability and water quality impacts.[75] Drought forecasting and modeling are often based on multiple variables, including runoff, soil moisture, precipitation, evaporation, and snow. However, these indices do not comprehensively represent meteorological and hydrological drought. Indices such as the Standardized Precipitation-Evaporation Index more accurately account for the effect of evaporative loss and are more useful for evaluating drought severity over multiple time periods.[76] Climate change projections of this drought index were not available at the time of analysis. However, research groups and universities are actively generating this data, which may be used in future iterations of this assessment.[77, 78]
4. **Flood** hazard risk (current day) – includes climate-driven increases in precipitation for future climate scenarios. Flood risk is defined as a fluvial (riverine flood) 100-year event. There was insufficient data available for statewide analysis of the 500-year flood risks. Climate driven precipitation analyzed for RCP 8.5 mid-century and late-century scenarios.
5. **Lightning** (current day) – lighting strikes to ground (particularly to infrastructure). Although the Oregon National Hazard Mitigation Plan (NHMP) and Climate Assessment do not address lightning hazards, the USDOE reports lightning impacts as the third highest cause of damage to energy systems in Oregon.[79] The Oregon Public Utility Commission emphasized that the magnitude of strikes in Oregon can damage energy infrastructure, even though the quantity of strikes in Oregon is low relative to strike counts in other states.
6. **Physical attacks** – intentional attacks on the energy system, such as an active shooter or bomb targeting a specific energy system asset. This does *not* include accidents, such as a car accident that damages an asset.

7. **Wildfire** risk (current day) – includes climate-driven increases to wildfire risk in future climate scenarios (both mid-century and late-century scenarios). Wildfire is defined as wildfire burn probability of high to very high. Note there is an intersection of wildfire and windstorms (windstorms can create conditions that trigger and/or amplify wildfire).
8. **Windstorm** (current day) – events with wind greater than 50 knots. Wind is an exacerbating factor for other natural hazards analyzed, in particular winter storm, wildfire, and flood/heavy precipitation events. It should be noted that these hazards can be co-occurring/compounding. Analysis of co-occurring/compounding scenarios was beyond the scope of this study. Windstorm future climate data is not available (it was excluded from the NHMP due to insufficient data).
9. **Winter storm** (current day) – events with snow and ice that include geographic areas with greater than four events annually. Note that high winds can be a compounding factor in winter storms, but data does not currently exist to specifically analyze the wind impacts of winter storms.

A threshold was determined for each hazard for analysis of exposure based on their geospatial and hazard index datasets. **Table 7** describes the thresholds used to determine exposure for each hazard.

Table 7: *List of natural hazards and human-caused threats assessed, with definitions of hazard thresholds.*

Threat	Threshold Definition
CSZ Earthquake	
Earthquake	9.0 magnitude, very strong to violent shaking
Landslide	High and very high landslide susceptibility
Liquefaction	Moderate, High, and Very High liquefaction zones
Tsunami	XXL zone, maximum extent event
Cyberattack	N/A
Drought	Greater than 25 annual average drought days/census tract
Flood	100-year flood hazard
Lightning	Two or greater damaging lightning strikes annually/census tract
Physical attack	N/A
Wildfire	Burn probability of high to very high
Windstorm	Record of wind greater than 50 knots within 25-mile radius
Winter storm	Greater than 4 events annually/census tract
Precipitation Future Mid Century	25% increase or greater (100-year, 24-hour)
Precipitation Future Late Century	25% increase or greater (100-year, 24-hour)
Fire Weather Index Future Mid Century	High, very high, and extreme
Fire Weather Index Future Late Century	High, very high, and extreme

The following hazards were not selected for assessment in the current iteration of the ESP due to the following reasons:

1. **Extreme heat** (current day) and future scenarios (driven by climate change). Although this hazard was considered for inclusion and stakeholders perceived extreme heat to pose a high level of risk relative to other threat candidates, it was ultimately ruled out given the limited available information about impacts on energy systems in Oregon. In feedback from stakeholders, ODOE, and OPUC, the primary impacts (to date) have been on energy labor force (ability to perform duties in extreme heat) and economics related to demand pricing (which require further study). In contrast, there have been limited documented impacts on the physical elements of energy systems. For example, a review of the After-Action Report for the June 2021 Excessive Heat Event indicated that impacts on the energy systems were limited (few outages, short duration).[80] However, extreme heat events are projected to increase in severity and frequency in future climate

scenarios,[1] indicating that it may be advisable to include extreme heat in a future ESP update.

2. **Coastal hazards** (current day) and future scenarios (driven by climate change) including sea level rise, coastal flooding, and erosion hazards. This hazard was explored for inclusion but was ultimately ruled out due to subject matter expert input, the limited available information about impacts on energy systems in Oregon, and the limited geographic hazard risk (confined to coastal regions).

3. **Volcanic hazards** (current day). The NHMP indicates that seven counties in Oregon are at risk due to volcanic hazards, and only one reference was identified related to energy system risks in Marion, Linn, and Lane Counties. Given the limited geographic extent of the risks (predominantly focused along the Cascade Mountain range), it was decided to de-prioritize this hazard for the current study. However, it is worth noting that the US Geological Survey tracks volcanic risks for nuclear installations in the Pacific Northwest, and volcanic activity has impacted energy systems in other states (most notably in Hawaii with the Kilauea Volcanic eruption). Volcanic risks are an area that may be recommended for future energy security updates.

Cascadia Subduction Zone Earthquake and Tsunami

Earthquakes result from the release of energy caused by the buildup and sudden release of pressure of tectonic plates. Earthquakes can trigger tsunamis, landslides, and liquefy susceptible soils. Oregon is prone to crustal earthquakes in the eastern region and subduction zone seismic activity along the coast.[81]

Although Oregon experiences thousands of earthquakes of varying magnitudes every decade, there is potential for a 9.0+ magnitude earthquake along the CSZ. The damage caused by such an earthquake would be enormous, and the retrofitting required to adequately increase the resilience of buildings for such an earthquake would likely take decades.[82] In addition to the damage caused by the shaking of the ground, soft soils, liquefaction, and landslides all have the potential to cause significant damage.[83] The probability of the largest earthquake event occurring in the next 50 years ranges from 7 to 12 percent, while an 8.3–8.5 magnitude earthquake, with a return interval of 240 years, has 37 to 43 percent probability of occurring in the next 50 years.[84]

A 9.0+ magnitude earthquake would likely cause catastrophic damage to large portions of Oregon, including critical energy infrastructure and supply chains. Shaking and associated liquefaction may cause pipes to burst, piers in the CEI Hub to fail, navigation of barges on the Columbia River to halt, and oil releases into waterways, landslides, and road/railway closures.[85]

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[1] Projections show an increase of 5 degrees Fahrenheit to the annual average temperature in Oregon by 2050 and 8.2 degrees by 2080. They also show that Portland experienced 100 degrees Fahrenheit once every 10 years during the 20th century, but by 2025 this will occur once every 2 years. Oregon Climate Change Research Institute 6th Oregon Climate Assessment, 2023.

Breaks in the transportation system due to damage to infrastructure such as bridges and roadways will likely lead to disconnection and areas of isolation known as “seismic islands” or “population islands”. Landslides are one of the most potentially damaging associated effects of earthquake shaking, and the greatest concentration of landslide events occur in coastal areas and along the slopes of the Cascade Mountain range.[86] Furthermore, an offshore subduction zone earthquake will likely trigger a tsunami, which will impact much of the Oregon coast. In addition to a CSZ earthquake, Oregon has several fault zones with potential to cause crustal earthquakes. One of these, the Portland Hills Fault, is located in close proximity to the CEI Hub (located on the western bank of the Willamette River in northwest Portland). The Portland Hills Fault has the potential to generate a large-magnitude earthquake of approximately magnitude 6.8–7.2 every 1,000 years.[87] The CEI Hub is built on unstable soil with the potential for liquefaction and lateral spreading in an earthquake and even in a crustal earthquake, which will most likely be of smaller magnitude than a Cascadia earthquake, and there is potential for tanks and other infrastructure in the CEI Hub to fail.[88]

Earthquake, tsunami, landslide, and liquefaction hazard zones were delineated separately so that vulnerability ratings may be assigned to each of the four hazards. Ultimately, the overall hazard score for the CSZ hazard was determined by the highest rated among these four hazards for each region (i.e., if both shaking intensity and liquefaction tied for highest rated in a region, that top score was used for the CSZ hazard). Earthquake hazard zones were delineated using the DOGAMI Oregon Seismic Hazard Database Instrumental Intensity dataset. This data categorizes variations in perceived shaking on a range from very light to violent. For this analysis, earthquake hazard was limited to regions that experienced very strong to violent shaking, as these levels of shaking correlate to shaking damage potentials to infrastructure.[89] In addition, the XXL inundation zone from the Tsunami Inundation Scenarios for Oregon was used to delineate the tsunami hazard zone. The XXL inundation scenario was chosen to represent relevant tsunami hazard exposure because it is the maximum possible extent of inundation.[90] The analysis relied on the Statewide Landslide Information Database for Oregon dataset to assess landslide exposure at high and very high landslide susceptibilities, a threshold determined by discussions with the data owners (DOGAMI), owner/operators of energy infrastructure, and the fact that the CEI Hub is at risk from landslide.[91] The hazard zone for liquefaction susceptibility was determined using the DOGAMI Oregon Seismic Hazard Database dataset, which includes moderate, high, and very high susceptibility thresholds.[92] Geotechnical experts at DOGAMI and within the team determined that these thresholds were suitable for earthquake analysis. **Figure 10** reflects the final CSZ hazard zone. It is important to note that the impacts of a CSZ earthquake may be felt outside the identified hazard zone (the specified zone represents the highest levels of threats).

(A)

(B)

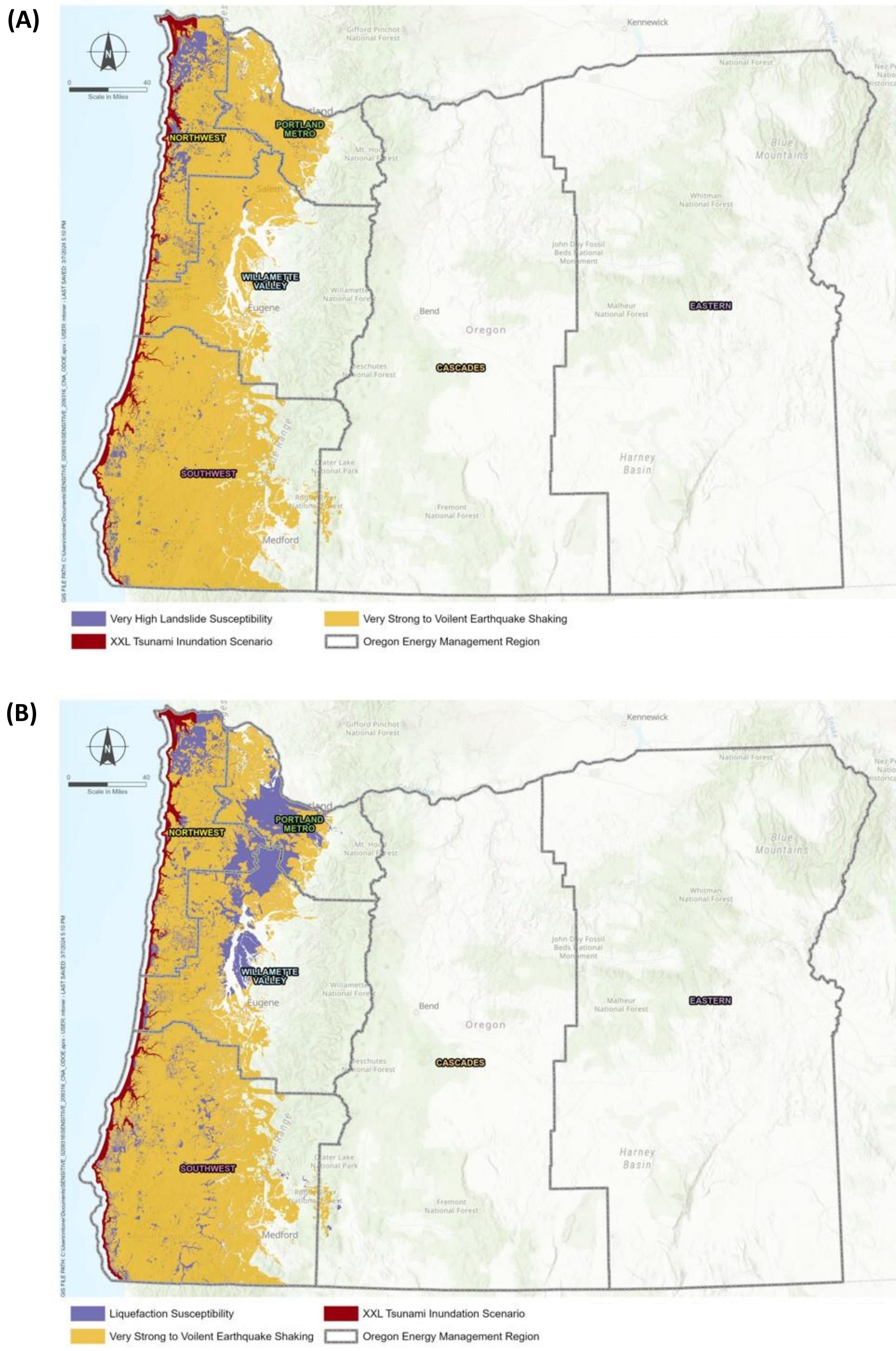

Figure 10: *CSZ hazard zones: (A) landslide susceptibility; (B) liquefaction susceptibility.*

Cyberattack

Cyberattacks generally include theft, espionage, violence, or sabotage on technological devices or through the internet. The most common forms of cyberattacks are malware, ransomware, and phishing. Malware is software used to access information technology (IT) systems. Malware includes ransomware, which holds specific information or systems hostage until ransom or payment is received. Phishing is a scam to deceive individuals into sharing private information.[93] Threats such as phishing emails, malicious content embedded into online advertisements, and rouge software expose an organization's operating system and may result in harm or stolen materials. Members of an organization may accidentally or unknowingly engage with such threats. Attacks performed by insiders, or those who work for or with the organization and intentionally steal, sell, or hold operations and information hostage,[94] are meant to interrupt normal business operations, gain protected information, identify weaknesses, or otherwise attack an IT system.

Since at least 2012, the USDOE has provided specific guidance on how to protect the electricity sector from cybersecurity risks.[95] In 2015, this guidance was widened to include liquid fuels and natural gas sectors.[96] In 2017, Oregon adopted this guidance into the Oregon Fuel Plan to develop strategies to strengthen the state's fuel lines and access.[97] Organizations within the state that manage fuel have also developed guidance for cyber protection. From 2019 to 2021, Northwest Natural, a fuel company which operates in Oregon, emphasized the importance of cybersecurity to prevent cyberattacks in their Cybersecurity overview and their Environmental, Social and Governance Report to the ODOE.[98, 99, 100] Despite the available guidance, a nationwide natural gas operator had to shut down a natural gas station in Portland, Oregon, in 2020 for 2 days following a ransomware attack. The operator's security plan was considered vulnerable as it did not focus on cyberattacks but rather physical attacks.[101] In 2022, Portland General Electric self-reported six instances of potential cybersecurity lapses. Although two of these were determined to be of minimal risk by the Western Electricity Coordinating Council, who monitors these events, the others are still under investigation.[102] In 2023, Portland General Electric produced new oversight policies increasing awareness to cyber threats and attacks.[103]

Oregon monitors cyberattacks, breaches, threats, and lapses through self-reporting through the Environmental, Social, and Governance reports that private organizations submit every other year. These reports are reviewed by the Oregon State Treasury to make investment decisions.[104]

Note that hazard zones cannot be delineated for cyberattacks. This assessment focused on publicly available and self-reported information regarding cyberattacks, noncompliance, and cybersecurity frameworks or plans.

Drought

There are four primary types of droughts: meteorological, hydrological, socioeconomic, and agricultural. Meteorological drought is related to rainfall totals over a period of time; hydrological drought is related to the quantity of water in surface and subsurface water bodies; socioeconomic drought refers to the ability of human populations to meet water demand; and agricultural drought is associated with the effects of drought on food production and agricultural productivity.[105] Oregon's average annual precipitation varies widely on an east-west gradient. As air masses are driven east over the Cascade mountains, large amounts of rain and snow fall in coastal and inland Oregon. As a result, warmer, drier air flows down the eastern slopes of the mountain range, resulting in a significantly warmer and drier climate.[106] Further, water stress can result from snow drought, a phenomenon caused by lower-than-average mountain snowpack that subsequently affects water supply.

Oregon has a long history of drought, and the period from 2000 to 2018 was the second driest 19-year span since 800 CE.[107] Furthermore, major droughts occurred in 1967–1977 in western Oregon (which contained the single driest year of the century), 2001–2002 (with over 40 counties declaring drought), and 2020, when the governor declared drought in Klamath and Curry Counties (Cascades and Southwest Regions, respectively).[108] Furthermore, on June 26, 2021, a heat dome settled over the Pacific Northwest, causing Multnomah County and the Portland Metro area to reach temperatures 30 degrees above average (to 105°F), a temperature that had only occurred three times in the past. Record temperatures were then set repeatedly on the following days, leading to a peak temperature of 117°F on June 28. Nighttime temperatures remained elevated through the duration of the event—a dangerous characteristic of this heat wave that was thought to have contributed to the deaths of 54 individuals in Multnomah County.[109] This "heat dome" was a slow-moving high-pressure system that inhibited the upward movement of air and contributed to increased soil water evaporation, prolonging the event, and increasing demand for energy throughout the Pacific Northwest.[110]

Droughts have the potential to impact all energy systems in Oregon. For example, the efficiency of hydroelectric generation may be affected by reduced water levels in reservoirs and lakes. Drought conditions can affect the liquid fuels system through low soil moisture impacts on biofuel feedstocks, and low water levels can impede traffic on waterways.[111] Furthermore, while there is no drilling and refining of natural gas in Oregon, limited water availability may inhibit these activities outside of the state, and subsequently affect Oregon's supply.

This assessment focuses on meteorological and hydrological drought and uses the Annualized Drought Index developed by FEMA to delineate drought hazard zones.[112] The Annualized Drought Index represents the number of days per year that experience drought. The threshold used to define the hazard layer (**Figure 11**) for this analysis is Greater Than 25 Annual Average Drought Days. Values above the median value were chosen because that number represents close to a month of drought days per year, which is considered a long-term drought.[113]

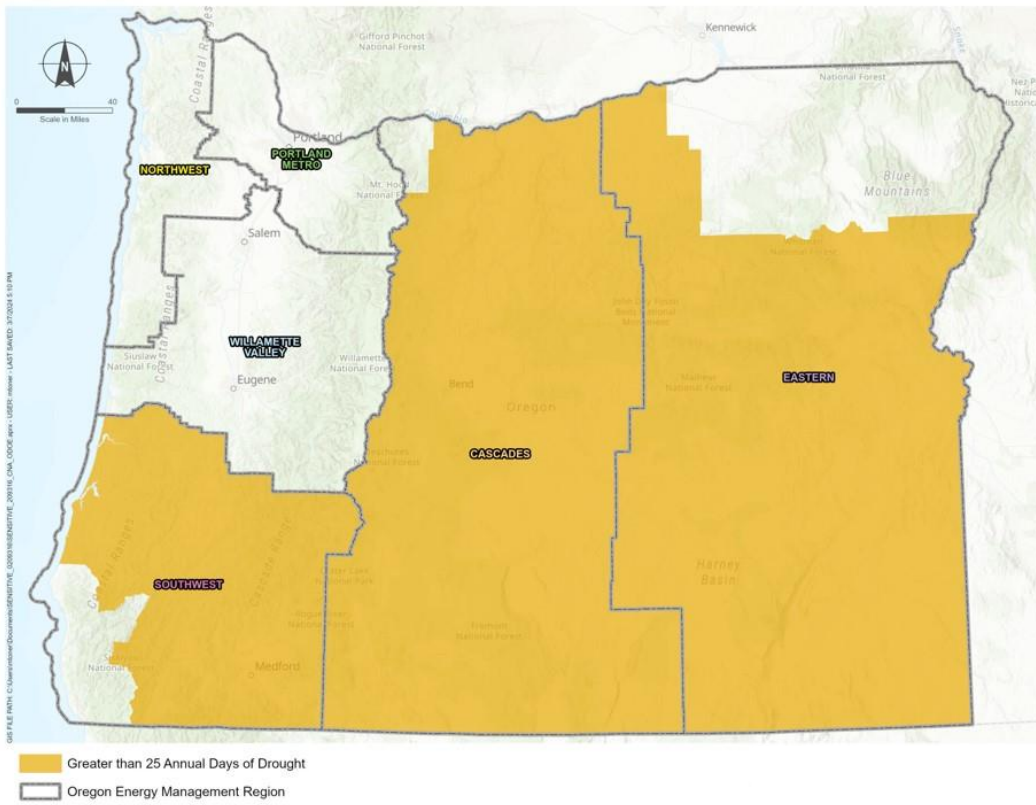

Figure 11: *Annualized drought hazard zone.*

Flood

Every county in Oregon is considered flood prone.[114] Flooding in Oregon is generally caused by extreme precipitation events that generate large amounts of runoff.[115] Oregon is affected by numerous types of flooding, including (but not limited to) riverine flooding, flash floods, alluvial fan flooding, coastal floods, and urban flooding. Extreme precipitation often occurs as a result of atmospheric rivers, which are long corridors of water vapor, approximately 250–375 miles wide, that can transport an extraordinary amount of moisture. These systems are often weak, supplying much needed water to mountainous regions along the West Coast of the United States. However, some can lead to devastating flooding, travel disruptions, and landslides.[116] Furthermore, climate change is likely to increase temperatures in Oregon, which will cause more precipitation to fall as rain rather than snow, which may increase flood risk.

Historically damaging floods have been recorded since the mid-1800s, and occur numerous times per decade, including nine events in 2019 alone.[117] In fact, a flood in April 2019 resulted from a strong atmospheric river that generated record-breaking rainfall and streamflow measurements. Large amounts of runoff into reservoirs (which were already at or near capacity) led to widespread flooding.[118] Furthermore, in February 2020, another unusually strong atmospheric river led to record runoff volumes. The probability of flooding throughout Oregon is high, and climate change is expected to increase the frequency of extreme precipitation events and riverine flows.[119] Scientists project that climate change will impact flood magnitude through more intense precipitation events, the occurrence of atmospheric rivers, and a total increase in wet season precipitation (November to April).[120] Winter precipitation is projected to increase, while summer precipitation is likely to decrease—and warmer temperatures means that more precipitation will fall as rain instead of snow, which may increase flood magnitudes.[121, 122] For example, in the Willamette Basin, in the Willamette Valley, 10-day runoff volumes are projected to increase by 11 and 43 percent by the 2030s and 2070s under the RCP 8.5 scenario, respectively.[123] However, while extreme precipitation is expected to increase in Oregon throughout the 21st century, these changes will not impact the entire state, and climate model projections of rainfall are still uncertain.[124]

The energy system is prone to flood damage wherever facilities and equipment are in the floodplain or otherwise exposed to the hydrodynamic forces of moving water and carried debris.[125] In addition, fuel lines and pump systems may be damaged from corrosion and loss of power caused by flood waters, and damaged barges may release hazardous materials, including liquid fuels and other transported chemicals.

The Risk Assessment combines the FEMA 100-year National Flood Hazard Layer with the Oregon State Digitized 100-Year Flood to create a single flood hazard layer (**Figure 12**) that incorporates all 100-year flood boundaries.[126, 127] Five-hundred-year flood zones were excluded because they are incomplete statewide. In addition, the University of Washington Climate Impact Group's rainfall projections for the 100-year 24-hour storm in the mid- and late-century were used as an indicator of the potential exacerbation of flooding impacts in the future.[128] Future precipitation values with a 25 percent or greater increase relative to the historical period of 1981–2010 (determined using standard deviations) were used as a threshold value to indicate substantial increases in precipitation intensity that may impact flooding. Hazard zones (not shown) for the mid and late century were estimated using these projected values to identify infrastructure that may be exposed to extreme precipitation, potentially exacerbating flooding, in the future.

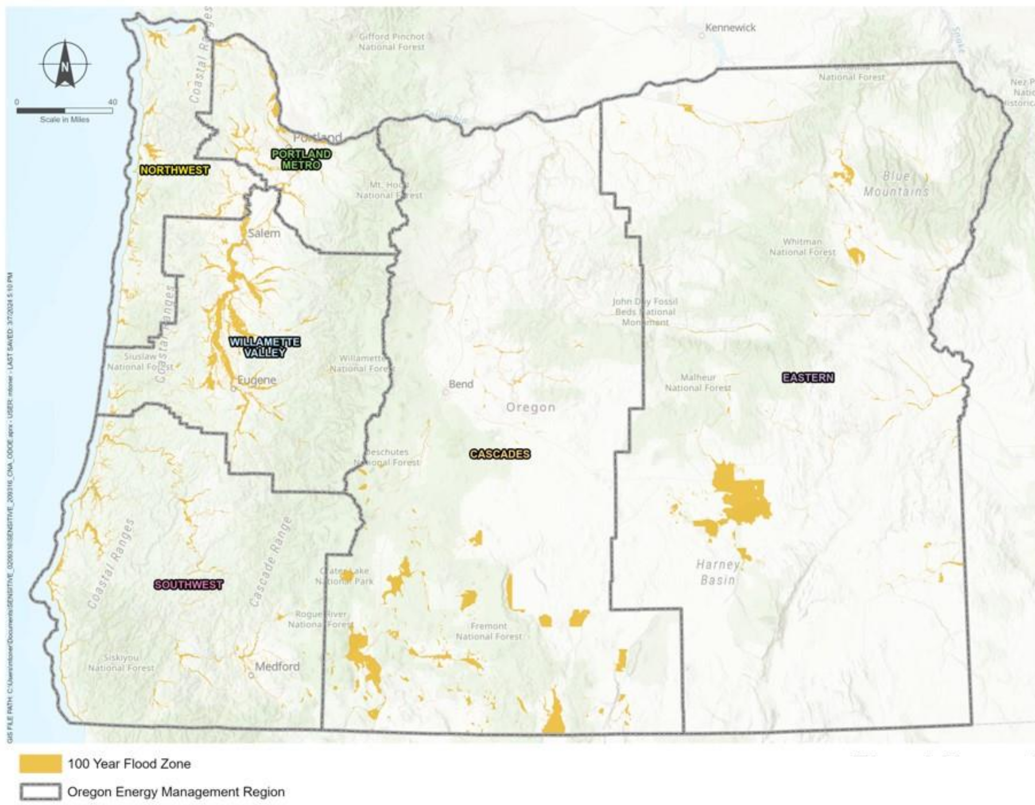

Figure 12: *Flood hazard zone.*

Lightning

Oregon experienced an average of approximately 300,000 lightning strikes per year between 2015 and 2019, with 439,082 strikes occurring in 2019 alone. As the climate changes and temperatures rise, the air can hold more moisture and the possibility of thunderstorms increases. A greater number of thunderstorms may increase the number of lightning strikes, as well as the associated potential for human injury and damage to infrastructure. In fact, there is a projected 12 percent increase in the number of lightning strikes for every 1°C rise in temperature.[129]

Lightning can pose a threat to energy infrastructure through direct strikes to pipelines, storage tanks, rail cars, transmission lines, and substations.[130] Lightning strikes to these pieces of infrastructure can result in extended power outages, wildfires, and equipment damage. Lightning hazards can also be an indirect threat, by increasing the risk of wildfire ignition and spread. For example, in August 2020, thousands of lightning strikes contributed to the ignition of over a dozen wildfires.[131] Lightning is also particularly dangerous to liquid fuel and natural gas energy infrastructure due to the flammability of these resources, which increases the risk of explosion and fire.[132]

Lightning hazard zones were delineated using the FEMA Annualized Frequency By County data source, and a threshold of two or greater damaging lightning strikes a year was used as a threshold value to characterize the hazard zone (**Figure 13**).[133] The first standard deviation marks the threshold value for annual lightning strikes.

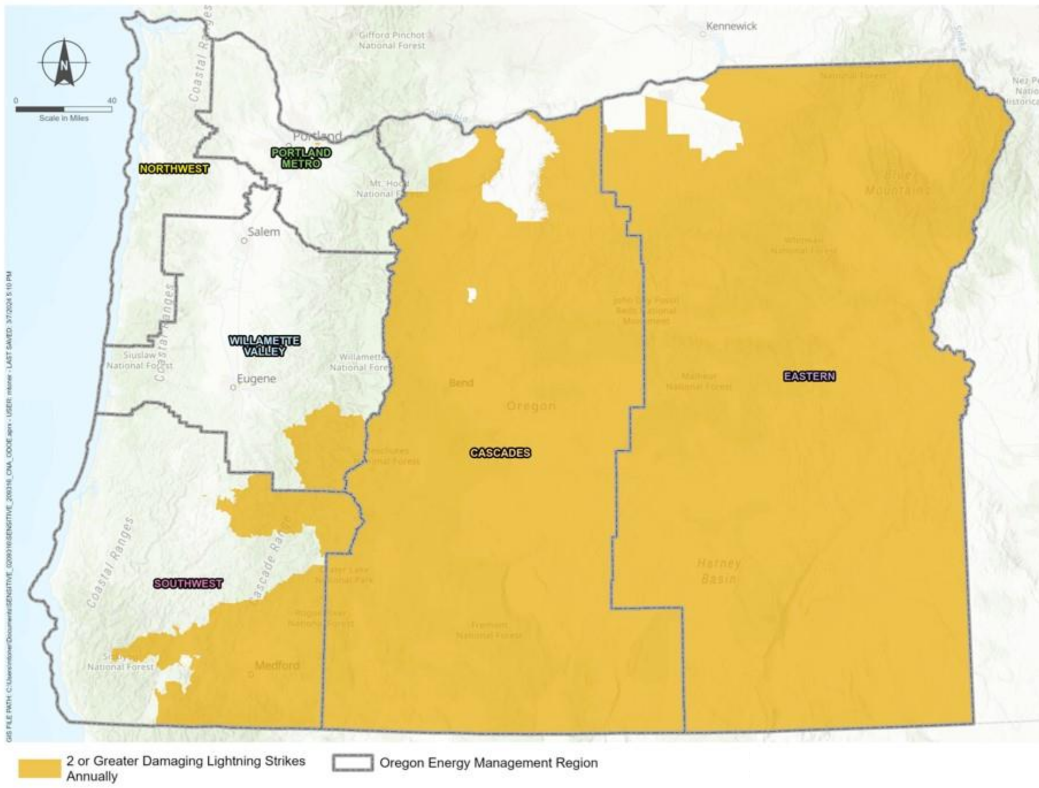

Figure 13: *Damaging lightning hazard zone.*

Physical Attack

Physical attacks threaten tangible assets, including people, property, and infrastructure. Physical attacks can be prevented, prepared for, responded to, and deterred typically by physical security. This may include infrastructure such as protective walls, fences, cameras, locks, access controls, and alarms. In addition, physical security measures may include staff such as security guards.[134]

In 2015, USDOE published a report that examines electric, natural gas, and liquid fuels resilience, reliability, and safety, which includes physical threats. The report specifically noted that physical attacks are a growing concern, and although there is some infrastructure in place, cost-saving alternatives need to be developed to increase protections. Electrical substations, above-ground distribution centers, and control centers were highlighted as vulnerable to physical attacks nationwide.[135] Each year, USDOE publishes a report that summarizes all electrical disturbance events by state across the country. From 2011 to 2023, Oregon reported 74 instances of physical attacks on electric substations. Of these, nine were specifically physical attacks, while 45 were instances of vandalism, five were suspicious activity, and one was a sabotage incident. The remaining instances included load shedding, electrical separation, and transmission interruptions.[136] In 2022, there was an additional string of six physical attacks involving firearms on the electrical grid within Oregon, resulting in some customers experiencing service disruptions.[137, 138]

Physical attacks can result in damaged equipment, infrastructure, or systems and injured staff.[139] These can range from minor infractions such as vandalism, which has minimal impact on business operations, to incidents of domestic terrorism, which may have significant impact on business operations. Physical attacks may impact the end consumer if business operations are disrupted.[140]

Instances of physical attacks on electrical infrastructure are self-reported to USDOE.[141] Reports of physical attacks may also be reported by the media, although energy representatives or substation owners may decline to comment or provide additional detail.[142]

Note that hazard zones cannot be delineated for physical attacks. This assessment focuses on publicly available and self-reported information regarding physical attacks, noncompliance, and physical security frameworks or plans.

Wildfire

Wildfire activity has increased in the western United States over the past several decades.[143] Warming temperatures and increases in atmospheric aridity are directly associated with decreasing vegetation moisture content and the extension of the fire season.[144] The potential for wildfire ignition and spread increases with temperature and wind speed. Rising temperatures increase the capacity of the air to hold moisture, which leads to higher rates of evapotranspiration, dryer vegetation, and a heightened risk of wildfire.

In fact, in 2020, hot and dry conditions, combined with high winds, drove multiple wildfires that burned nearly 1 million acres in western Oregon (more than any other year on record).[145,146] Furthermore, the number of homes built in the wildland-urban interface is increasing, with anywhere from 700,000 to 900,000 homes now located in this zone.[147] This represents an increasing risk for energy distribution assets in the wildland-urban interface; these homes are often located in areas with limited capacity for fire protection. In addition, human activity (i.e., land use/land cover change), combined with natural and human-induced climate variability, will likely contribute to a higher incidence of forest fires in the western United States.[148] For example, average annual area burned in the Clackamas Basin (Portland Metro Region) is projected to increase by 56 to 540 percent from 1992–2015 to 2040–2069, and the area subject to extreme fire weather conditions during the summer is projected to increase in the northwestern United States by up to 345 percent.[149] Climate change is increasing the likelihood of extreme heat events and extending the duration of the fire season in the western United States into the fall season.

Wildfires can impact the energy system directly by damaging powerlines, generation facilities, and transportation infrastructure.[150] In addition, indirect impacts of wildfire on energy systems include supply chain disruptions caused by reduced visibility from smoke and ash as well as road and railway closures during wildfire events.[151] Wildfires pose a particular threat to liquid fuels due to their flammability (in storage and transport).

Wildfire risk was represented by the United States Department of Agriculture Forest Service Modeling Institute Wildfire Burn Probability dataset.[152] Burn probability higher than a 1: 500 chance was used to define the wildfire hazard layer (i.e., High to Very High likelihood) (**Figure 14**). This threshold was determined by subject matter experts to reflect the level of risk of most concern to energy infrastructure and its operation. Furthermore, Argonne National Lab and the Climate Risk and Resilience Portal provides mid- and late-century projections of Fire Weather Index for the RCP 8.5 greenhouse gas emissions scenario. Fire Weather Index is a meteorological index that represents the potential for wildfires to ignite and spread, given sufficient fuel to burn. Hazard zones for the mid and late century (not shown) were delineated using projected values in order to identify infrastructure that may be at risk in the future. Therefore, these projections informed the analysis of future wildfire hazard risk in Oregon.[153]

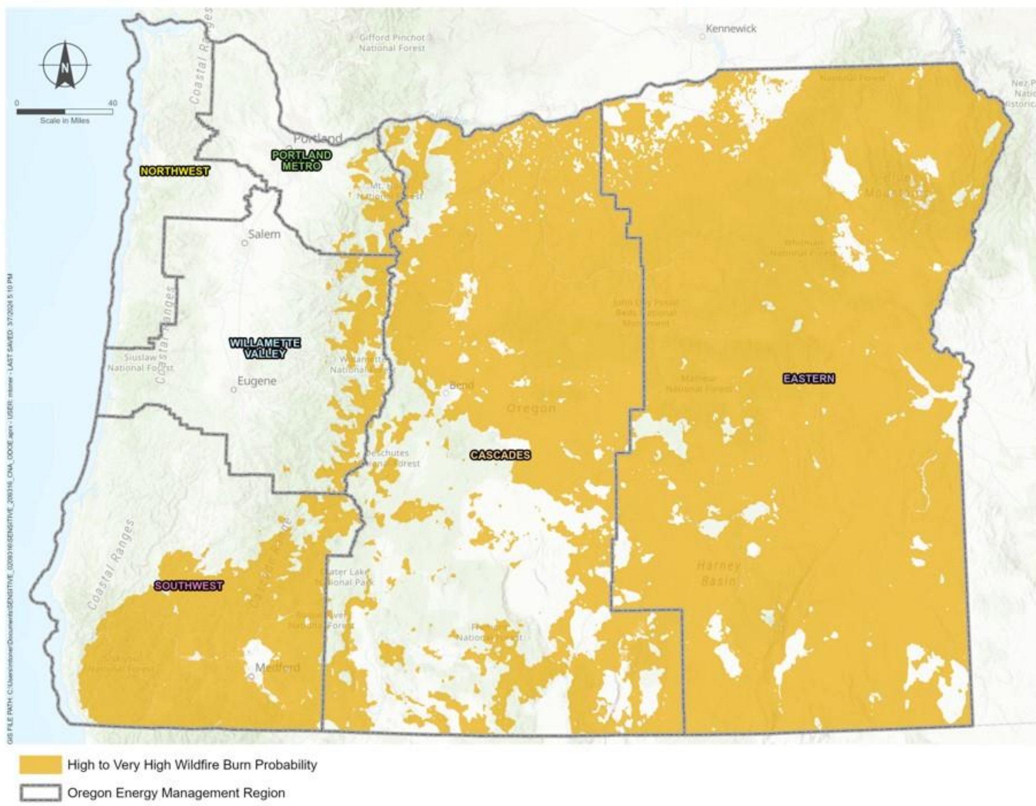

Figure 14: *Wildfire hazard zone.*

Windstorm

High winds typically occur in the coastal regions and mountains of the Coast range between October and March as large weather systems move inland from the Pacific Ocean.[154] The majority of windstorms in the Pacific Northwest are associated with lower-than-normal sea level pressure and travel out the southeast.[155] In general, Oregon experiences the highest wind speeds in areas of high elevation, particularly in the northernmost segment of the Cascade Range and the southern and northernmost portions of the Eastern Region.

In fact, wind gusts up to 100 mph occur annually in the Coast and Cascade Ranges, and gusts up to 150 mph can occur every 5 to 10 years.[156] Although most wind events occur in the winter between November and March, notable storms have occurred in October, April, and August.[157] In fact, on October 12, 1962, the Pacific Northwest experienced hurricane force winds of up to 170 miles per hour.[158] It is not clear if climate change will lead to more frequent or severe windstorms in Oregon.

High winds exert tremendous pressure on the inside and the outside of buildings. Winds can carry heavy debris, down power lines, and block roads, making travel difficult for emergency responders and commuters. Distribution lines and transmission equipment may be at increased risk of the damaging effects of wind due to direct exposure and the potential for wind-carried debris.

The National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction Storm Prediction Center's Recorded Wind Greater than 50 Knots within 25 miles of an observed point dataset was used to delineate wind hazard zones.[159] The dataset covers 1986–2022, and the 50-knot wind speed threshold was chosen because it represents the speed at which damage is expected and trees are uprooted.[160] The windstorm hazard zones can be seen in **Figure 15**.

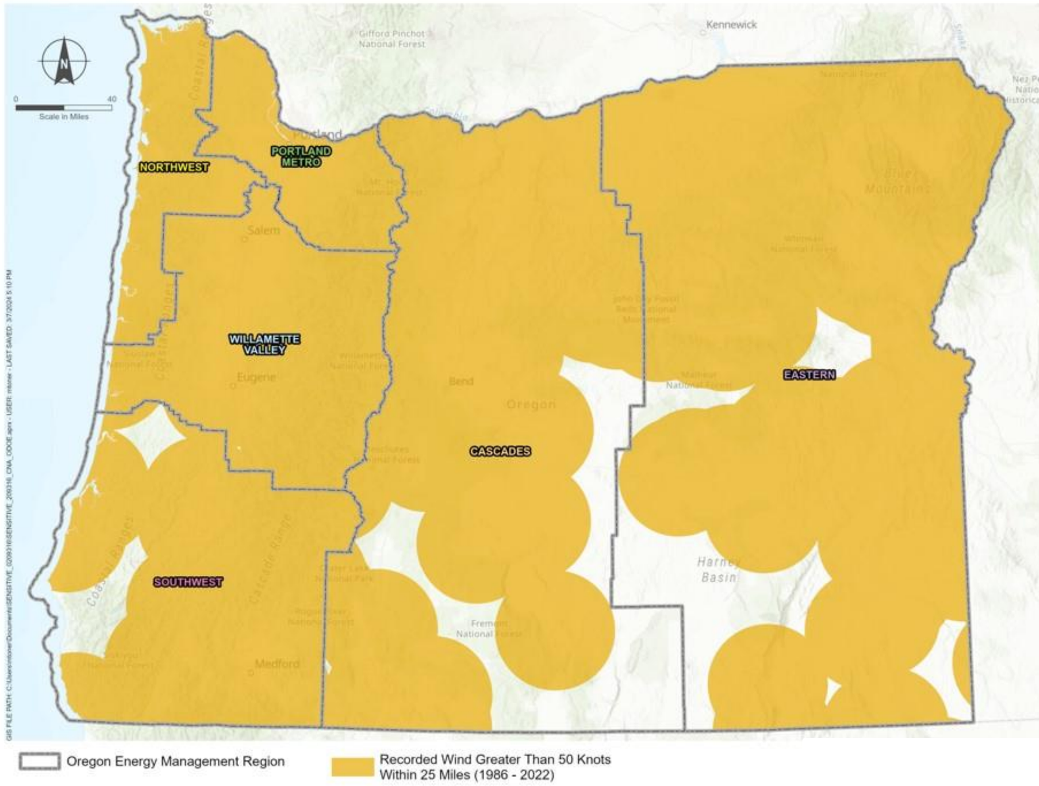

Figure 15: *Windstorm hazard zone.*

Winter Storm

Winter storms may impact energy utilities in various ways. However, this report focuses on snow and ice. Hazardous events associated with winter storms include freezing rain, sleet, heavy snow, blizzards, whiteouts, and black ice. In Oregon, winter storms are often accompanied by ice and high winds. This can lead to compounding problems when wind directly or indirectly damages electrical lines through downing of power poles or trees. Ice, snow, and wind can then slow down recovery and repairs.

For example, a winter storm in January 2024 that consisted of high winds followed by snow and ice was assessed by ODEM and found to have caused approximately $72 million in damages. Initial assessments stated that 51 percent of that damage was to public utilities, including power lines.[161, 162] However, these storms occur almost every year in Oregon. There is significant potential for winter storms to disrupt people and businesses (as people may become stuck in vehicles or their homes), disrupt supply chains and emergency services, impact transportation routes and fuels distribution, freeze infrastructure components (i.e., pipes), and halt agricultural production.[163]

Winter storms pose a threat to the transmission, distribution, and storage of energy (depending on the weatherization of infrastructure). Freezing temperatures can damage pipelines, disrupt supply chains, and cause flow control problems.[164] Furthermore, winter storms can indirectly impact the energy system through an increased demand for heating, as well as through power outages caused by falling trees or damaged infrastructure.

The FEMA NRI for winter storms was used to determine winter storm hazard zones. Winter storm hazards are defined by greater than four events annually, which represents the median value of annual storm count in the state between 2005 and 2017.[165] The winter storm hazard zones can be seen in **Figure 16.**

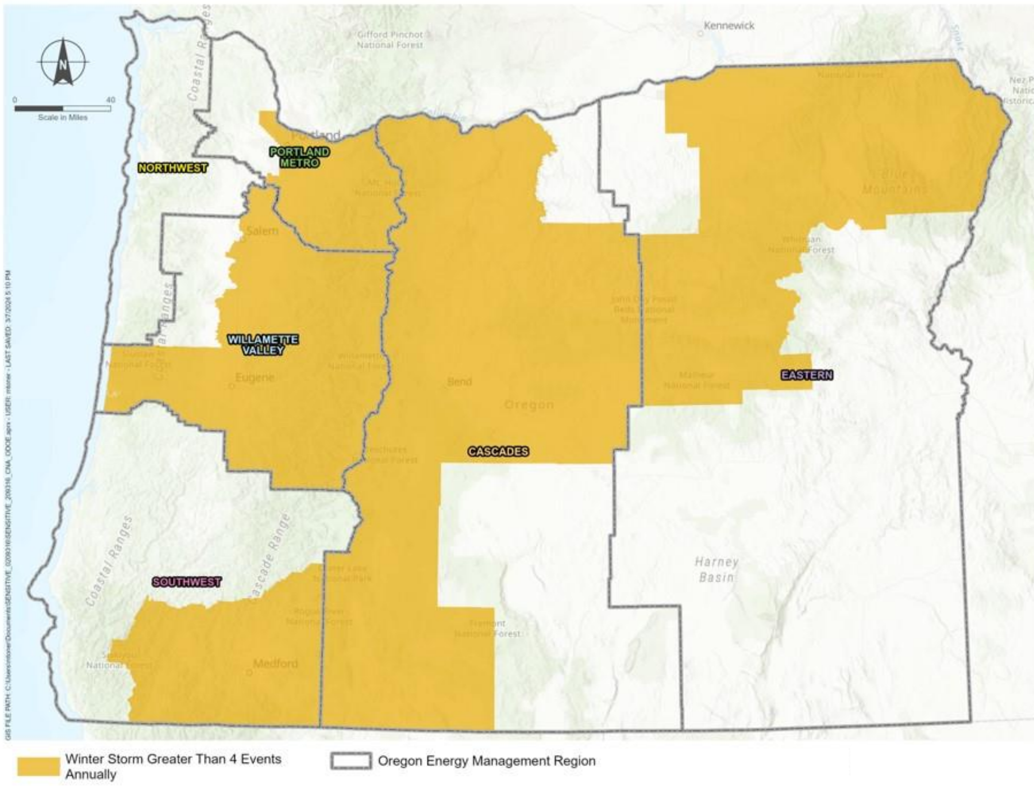

Figure 16: *Winter storm hazard zone.*

RISK ASSESSMENT APPROACH

The risk assessment methodology is based upon best practice in hazard vulnerability assessments established by the Intergovernmental Panel on Climate Change for Impacts, Adaptation and Vulnerability.[166] This best practice provides a clear framework that is effective for evaluating a variety of threats and hazards by drawing upon existing literature and research, geospatial data, planning documents, regulatory reports, and subject matter expert inputs to produce vulnerability ratings.

The risk assessment consists of four components that, when combined, produce an overall vulnerability rating. These four components include Exposure, Sensitivity, Potential Impact, and Adaptive Capacity (**Figure 17**). **Exposure** is evaluated by identifying the geographic footprint and frequency of the threat. **Sensitivity** involves identifying the susceptibility of the energy system to the threat. Sensitivity is evaluated by investigating the conditions of energy system infrastructure to understand their vulnerability to specific the threat based on physical characteristics and interdependencies with other systems, including other energy systems (i.e., liquid fuel and natural gas dependence on electricity for pump stations and transportation) and the transportation system (i.e., in the case of liquid fuels, the majority of end use distribution is dependent upon roads and bridges). **Potential impact** is evaluated by identifying potential consequences or losses that may result from the threat. **Adaptive Capacity** is evaluated for the level of preparedness and the capability to respond to and manage impacts from the threat, including mitigation measures in place or planned to be put in place, existing emergency response and recovery plans, and training and exercise programs. Publicly available data and stakeholder input are used to determine exposure, sensitivity, potential impact, and adaptive capacity, which are combined to produce an **Overall Vulnerability Rating.** The following sections provide an overview of the adaptation of this approach for the liquid fuels, electricity, and natural gas systems.

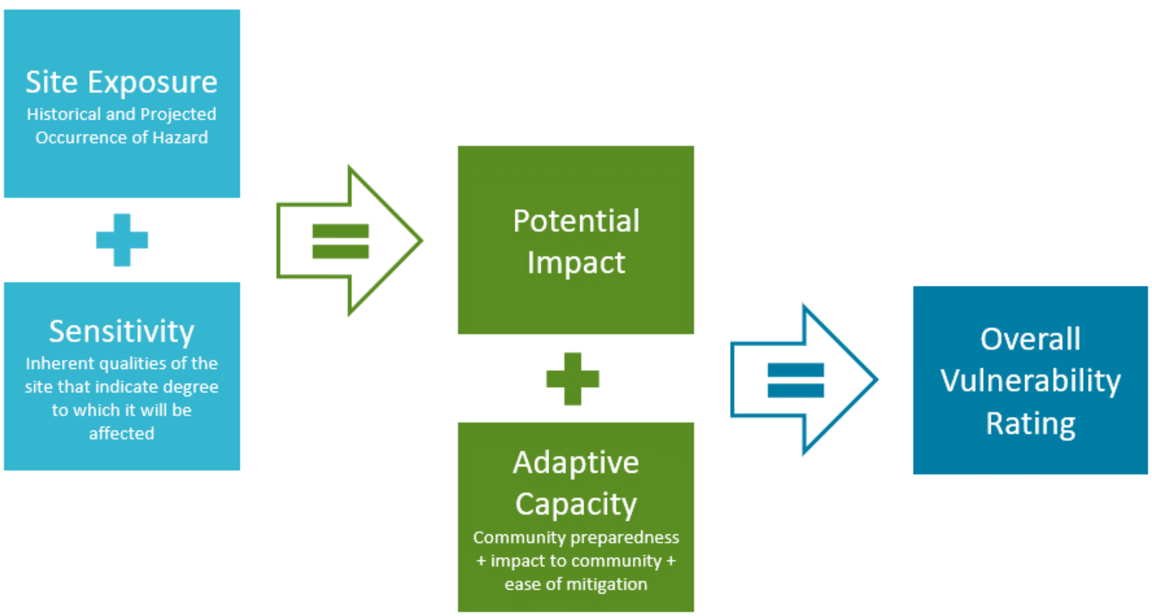

Figure 17: *Risk Assessment stepwise methodology.*[2]

LIQUID FUELS METHODOLOGY

Introduction

A data-heavy technical analysis was implemented for natural hazards and the liquid fuels system. Robust data was secured through open sources and provided by private sector stakeholders to generate a comprehensive model of the liquid fuels energy system spanning from production/generation to end-user distribution. This data collection made possible geospatial analysis of the statewide system, as described below. Note that, because hazard zones cannot be delineated for human-caused threats, a geospatial analysis is not feasible. To evaluate vulnerability to cyberattacks and physical attacks, a survey approach was used, as described in the Electricity and Natural Gas Methodology section.

Exposure

Exposure is the historical and projected occurrences of hazards. Exposure of liquid fuels assets was determined using the percentage of assets in each system that are exposed to the hazard and the historical or modeled frequency of that hazard.

The percent of assets exposed to hazards was determined using geospatial analysis. Liquid fuels assets were categorized into four component categories: production/generation, transmission, storage, and distribution. **Table 8** breaks down the types of assets that were included in each of these categories. Depending on the nature of the asset, they were shown as either a point or a line in geographic information systems (GIS).

Table 8: *Infrastructure assets that were included in the liquid fuels analysis.*

Asset Category	Asset Type
Production/Generation	Biodiesel Plant Ethanol Plant
Transmission	Highway or Alternative Route Petroleum Pipeline Petroleum Port and Port Terminal Petroleum Pump Station Petroleum Terminal Waterway
Storage	Major Distributor Bulk Plant
Distribution	Airport Alternative Fuel Station Retail End User

The liquid fuels infrastructure data was overlaid onto maps that showed the distribution of hazards across the state. The overlay yielded a count of assets that are exposed to each hazard within each region. The counts were added up cumulatively to produce a total count of assets exposed. To account for and combine point data (e.g., fuel station) and line data (e.g., transmission path), each mile of line data was counted as 1 point.

The analysis calculated the percent of total assets that are exposed to each hazard. These percentages translate to the following thresholds:

- Low (1): Less than 20 percent of energy system assets exposed to each hazard within each region
- Moderate (2): 20 to 60 percent of assets exposed to each hazard within each region

- High (3): Greater than 60 percent of assets exposed to each hazard within each region

Thresholds were determined by evaluating the frequency distribution of asset exposure to hazards. The mean and standard deviation indicated breaks for low (1), moderate (2), and high (3) thresholds.

The exposure frequency rating was determined based on literature review and subject matter expertise. Frequency ratings were determined using the following categories:

- Low (1): Approximately decadal to greater than 100 years
- Moderate (2): Approximately annually
- High (3): Approximately daily to monthly

The average was calculated of numerical ratings for exposure and frequency to determine the overall exposure rating for each hazard with 1 being low, 2 being moderate, and 3 being high. Exposure was calculated on a statewide scale. As a result, exposure ratings for each hazard are the same across regions.

Sensitivity

Sensitivity is the inherent qualities of the system and assets that indicate the degree to which a hazard will affect or damage them. Liquid fuels sensitivity was determined by evaluating whether components were directly sensitive, indirectly sensitive (e.g., supply chain disruptions due to a hazard event or disruptions to transportation), or not sensitive to hazards.

The sensitivities of high-level system components including production, transmission, storage, and end user were evaluated individually. Factors that were considered in the analysis included:

- Component materials
- System or component age
- Elevation and geographic location
- Weatherization and hardening
- Disruptions to the supply chain
- Interdependencies

System components that would be directly sensitive to damage from a hazard were given a sensitivity rating of 1. System components with indirect sensitivity or no sensitivity were given a 0. If any of the high-level system components received a score of 1, the entire system was considered sensitive and the overall sensitivity rating for the system was a 1. Otherwise, it was given a 0. Sensitivity was calculated on a statewide scale so the ratings for each hazard are the same across the regions. The amount of information about liquid fuel system sensitivity varied across hazard categories. Very little information was available for some hazards, including windstorms and drought.

Potential Impact

Potential impact for liquid fuels is measured using the percentage of total gallons of liquid fuels stored in a region that fall within hazard zones. This is different from exposure because it focuses on the actual amount of fuel rather than the number of assets to gain a better understanding of the actual impact of hazards on the fuel system.

The percent of total gallons of fuel in hazard zones was determined using geospatial analysis. The liquid fuels storage points were overlaid with the distribution of hazards across the state. The overlay yielded a count of assets that are exposed to each hazard, which then corresponded to the liquid fuel storage capacity of those assets. Liquid fuels storage, in gallons, located within hazard zones in a region was divided by the total number of gallons of storage in that region to obtain a percentage. These percentages translate to the following thresholds:

- Low (1): Less than 20 percent of total gallons of fuel in hazards zones
- Moderate (2): 20 to 60 percent of total gallons of fuel in hazards zones
- High (3): Greater than 80 percent of total gallons of fuel in hazards zones

Thresholds were determined by evaluating the frequency distribution of storage capacity potentially impacted by hazards. The mean and standard deviation indicated breaks for low (1), moderate (2), and high (3) thresholds. Unlike exposure and sensitivity, potential impacts were calculated regionally and varies by region.

Adaptive Capacity

Adaptive capacity is a measure of the operational and physical mitigation measures that have been put in place to decrease the vulnerability of a system. Liquid fuels adaptive capacity was determined using responses to the survey where seven representatives of liquid fuels service providers responded to questions relating to adaptive capacity. The survey did not distinguish hazards. As a result, responses apply to all hazards. The organizations represented by the respondents served multiple regions. As such, responses were duplicated for each region the distributors serve for a total of 34 responses.

Adaptive capacity ratings were based on representatives' responses to questions relating to the number of physical and operational measures that their organization has implemented. Ratings were calculated for each response using a count of the number of measures that representatives indicated in the survey. Those counts correspond to the following thresholds:

- Low (3): the total number of physical and operational measures is less than or equal to 2
- Moderate (2): the total number of physical and operational measures is 3–4
- High (1): the total number of physical and operational measures is greater than or equal to 5

- Very High (0): the total number of physical and operational measures is greater than or equal to 5 and at least one of those is a physical measure

Note, that because adaptive capacity negatively correlates to vulnerability, the highest adaptive capacity receives the lowest score, and the lowest adaptive capacity receives the highest score. The average was calculated for individual adaptive capacity ratings across the region for a final regional adaptive capacity rating. Ratings were not differentiated between hazards, because the survey was not structured with questions separated by hazard.

Overall Vulnerability Rating

Overall vulnerability is calculated by adding together the scores for Exposure, Sensitivity, Potential Impact, and Adaptive Capacity. Liquid fuels vulnerabilities are rated on a scale from 2 to 10. Scores of 5 and below are low vulnerability, scores between 6 and 8 are moderate vulnerability, and scores of 9 or 10 are high vulnerability.

ELECTRIC AND NATURAL GAS METHODOLOGY

Introduction

Due to limited data availability and time constraints of the project, the risk assessment of the electricity and natural gas systems relied upon surveys of owners and operators of the utilities that closely resembled the technical approach used in the liquid fuels system risk assessment. Surveys were created for each system and structured to enable the respondents to provide input on ODEM regions their organization serves and regions they don't serve but have assets in. In addition, the respondents provided feedback on hazards/threats their organization's energy system is exposed to, planning for, or generally concerned about. Both surveys included considerations for all natural hazards and human-caused threats listed in the Hazards and Threats section. Mid- and late-century models of hazards were not included. However, differences existed based on hazard/threat scenarios. For example, the frequency of energy system historic exposure and most recent exposure to CSZ earthquakes was not asked since this hazard has not occurred. Furthermore, human-caused threat questions were concentrated on collecting information related to historic incidents. Questions for human-caused threats were identical across the electricity, natural gas, and liquid fuels surveys.

Like the liquid fuels risk assessment, the electricity and natural gas risk assessments include Exposure, Sensitivity, Potential Impact, and Adaptive Capacity components that, when combined, produce an overall vulnerability rating. The electricity and natural gas survey results required processing before they could be analyzed. Therefore, responses to survey questions were converted to a numerical score of 0, 1, 2, or 3. The exact rating parameters for each of the four components are detailed below.

Exposure

Respondents were asked to estimate exposure to hazards. Specifically, the surveys included two questions related to exposure. The first question asked respondents to estimate the percentage of the organization's energy system assets that are located within the hazard zones. Maps of hazard zones (**Figures 10-16**) were provided in the survey for natural hazards. Scores were applied based on the following responses:

- Low (1): 1 to 20 percent of energy system assets are located inside the hazardous zone delineated in the maps
- Moderate (2): 20 to 50 percent of energy system assets are located inside the hazardous zone delineated in the maps
- High (3): more than 50 percent of energy system assets are located inside the hazardous zone delineated in the maps

Next, respondents were asked to estimate historic frequency of exposure. Scores were applied based on the following responses:

- Low (1): threat exposure every decade or more
- Moderate (2): threat exposure on an annual basis
- High (3): threat exposure on a daily to monthly basis

The surveys did not contain any questions pertaining to the estimated frequency of energy system historic occurrence or the most recent exposure to CSZ earthquakes as this hazard has not occurred. A score of zero was assigned for frequency of occurrence.

Average scores were then calculated for each question in each region. If a respondent did not provide an answer to a given question, they were not included in the calculation of the average for that question. The average scores of the two questions were then summed and rounded to the nearest whole number. The final score was then converted to a regional Exposure Rating of 1, 2, or 3, based on the scale in **Table 9**:

Table 9*: Conversion of exposure scores to exposure ratings.*

Score	Exposure Rating
1–2	1
3–4	2
5–6	3

Sensitivity

For natural hazard sensitivity, respondents answered a single question four times, once for each category of asset: production, transmission, storage, and end-user distribution network. Respondents were asked if their organization considered at least one asset/facility to be at risk of failure as a result of a given hazard when considering the following factors that may make a system more or less sensitive: age, materials, elevation, geographic location, weatherization/hardening, and redundancies.

If the respondent identified their energy system is sensitive to that hazard in any of the four categories of assets, they received a score of 1. Average scores across all four categories were then calculated in each region. If a respondent did not provide an answer for a given category, they were not included in the calculation of the average. The average score was rounded to the nearest whole number. The final score served as the regional Sensitivity Rating of 0 or 1 (**Table 10**).

Table 10: *Conversion of sensitivity scores to sensitivity ratings.*

Score	Sensitivity Rating
0	0
1	1

For human-caused threats, it was assumed that all energy systems were sensitive to cyberattacks and physical attacks. Private sector stakeholders affirmed this assumption. A sensitivity rating of 1 was assigned for all respondents across all three subsectors.

Potential Impact

Respondents answered two questions pertaining to the potential impacts of hazards on energy systems and those assets.

The first question asked the respondent to estimate the percentage of customers that may experience a disruption to service because of a hazard occurrence. Scores were applied based on the following responses:

- Low (1): less than 5 percent of customers may experience disruption to service
- Moderate (2): 5 to 20 percent of customers may experience disruption to service
- High (3): more than 20 percent of customers may experience disruption to service

The second question asked for an estimate of the time required to restore service after a disruption caused by a hazard. Scores were applied based on the following responses:

- Low (1): service restoration in a matter of hours to days
- Moderate (2): service restoration in a matter of weeks
- High (3): service restoration in a matter of months

Using an identical approach as in the Exposure category, average scores were then calculated for each question in each region. If a respondent did not provide an answer to a question, they were not included in the calculation of the average for that question. The average scores of the two questions were then summed and rounded to the nearest whole number. The final score was then converted to a regional Potential Impact Rating of 1, 2, or 3, based on the scale in **Table 11**.

Table 11*: Conversion of potential impact scores to potential impact ratings.*

Score	Potential Impact Rating
1–2	1
3–4	2
5–6	3

Adaptive Capacity

Survey questions for adaptive capacity focused on the implementation of mitigation measures and the level of maturity of each implemented measure. Respondents were asked to estimate their organization's level of maturity by selecting one of three maturity ratings:

1. Evolving: Essential risk management framework and documentation is in place.
2. Embedding: Risk management is integrated into business processes. The organization can demonstrate that the risk management framework is being used and benefits are being realized.
3. Optimizing: Advanced risk management practices are in place and are continuously being improved. Assessments are made to determine what is working well and where changes are appropriate. The organization could be considered a leader in risk management.

For natural hazards, respondents were presented with a series of physical and operational mitigation measures (**Table 12**) and selected evolving, embedding, or optimizing for each mitigation measure.

Table 12*: Physical and operational mitigation measures for natural hazards.*

PHYSICAL		OPERATIONAL	
Measure	**Protective Measure Example**	**Measure**	**Protective Measure Description**
Harden	Install barriers and shields (e.g., flood barriers around substations) Design structures with earthquake-resistant materials Use fire-resistant construction materials	COOP Continuity of Operations Plan	Ensures organizations are able to continue performing essential functions under distinct circumstances
Redundancy	Implement backup power systems (e.g., generators) Install multiple fuel supply lines Integrate access to alternate reservoirs	EOP Emergency Operation Plan	Assigns responsibilities to individuals and determines how actions will be coordinated internally and externally under distinct circumstances
Remove	Shift critical infrastructure outside of flood and hazard areas	ERP Emergency Response Plan	Lays out the series of steps an organization will take under distinct circumstances
Upgrade	Enhance cooling systems for higher temperatures Increase efficiency of drainage systems	ISP Integrity Safety Plan	Assesses and mitigates risks in order to reduce the likelihood and consequences of distinct incidents
Weatherize	Adopt freeze prevention measures (e.g., pipe insulation) Apply hail-resistant coatings Cover and protect outdoor machinery Install storm windows	SitAw Situational Awareness	Improves the ability to perceive, understand, and effectively respond to distinct circumstances

Average scores were calculated for each individual measure at each maturity rating in each region. If a respondent did not select a maturity rating for a given mitigation measure, they were not included in the calculation of the average for that mitigation measure. The averaged scores were rounded to the nearest whole number to determine the number of physical and operational measures implemented at each of the three levels of maturity in each region. The final score was then converted to a regional Adaptive Capacity Rating of 0, 1, 2, or 3, based on the following criteria:

- Low (3): the total number of physical measures is 0 and there is greater than or equal to 1 operational measure.
- Moderate (2): the total number of physical measures is 1 and there is greater than or equal to one operational measure.
- High (1): the total number of physical measures is greater than or equal to 2 and greater than or equal to one operational measure.
- Very High (0): the total number of physical measures is greater than or equal to 2, the total number of operational measures is greater than or equal to 2 and at least one of the measures had the response of "optimizing."

A similar approach was taken for human-caused threats. However, a single table of mitigation measures with examples was provided for cyberattacks (**Table 13**) and physical attacks (**Table 14**), respectively. Averages for each level of maturity were calculated as described above. The final score was then converted to a regional Adaptive Capacity Rating of 0, 1, 2, or 3, based on the following criteria:

- Low (3): fewer than 5 measures are implemented.
- Moderate (2): 5 or more measures are implemented; 3 or less measures are embedded or optimized.
- High (1): 5 or more measures are implemented; 3 or more measures are embedded or optimized.
- Very High (0): 5 or more measures are implemented; 5 or more measures are optimized.

Table 13: *Mitigation measures for cyberattacks.*

Category	Protective Measure Example
Identify	Develop an organizational understanding to manage risk to systems, assets, data, & capabilities
	Identify critical processes & assets
	Document information flows
	Maintain hardware & software inventory
	Establish policies for security that include roles & responsibilities
	Identify threats, vulnerabilities, & risk to assets
Protect	Develop & implement the appropriate safeguards to ensure delivery of services
	Manage access to information (e.g., unique accounts for each employee, restricted access to critical areas)
	Protect sensitive data (e.g., encryption while stored & transmitted; hard copies stored in secure areas)
	Conduct regular backups (e.g., backup frequently & store offline)
	Protect your devices (e.g., install host-based firewalls)
	Manage device vulnerabilities (e.g., update operating system & applications regularly)
	Train users (e.g., provide frequent training on policies, procedures, roles, & responsibilities)
Detect	Develop & implement appropriate activities to identify occurrence of a security event
	Test & update processes for detecting unauthorized entities & actions on networks
	Maintain & monitor logs to identify anomalies (e.g., changes to systems or accounts)
	Know expected data flows in order to identify the unexpected (e.g., information exported from internal database & exiting network)
	Understand the impact of security events
Respond	Develop & implement appropriate activities to take action regarding a detected security event
	Ensure response plans are tested
	Ensure response plans are updated
	Coordinate with internal & external stakeholders
Recover	Develop & implement appropriate activities to maintain plans for resilience & to restore any capabilities or services that were impaired due to a security event
	Communicate with internal & external stakeholders - account for what, how, & when information will be shared with various stakeholders
	Manage public relations & company reputation

Table 14: *Mitigation measures for physical attacks.*

Category	Protective Measure Example
Identify	Develop an organizational understanding to manage risk to systems, assets, data, & capabilities
	Identify critical processes & assets
	Document personnel activities
	Maintain asset inventory
	Establish policies for security that include roles & responsibilities
	Identify threats, vulnerabilities, & risk to assets
Protect	Develop & implement the appropriate safeguards to ensure delivery of services
	Manage access to assets (e.g., restricted access to critical areas)
	Protect your assets (e.g., physical barriers)
	Manage asset vulnerabilities (e.g., replace broken physical barriers)
	Train users (e.g., provide frequent training on policies, procedures, roles, & responsibilities)
Detect	Develop & implement appropriate activities to identify occurrence of a security event
	Test & update processes for detecting unauthorized entities in the physical environment
	Maintain & monitor logs to identify anomalies
	Know expected personnel activities in order to identify the unexpected
	Understand the impact of security events
Respond	Develop & implement appropriate activities to take action regarding a detected security event
	Ensure response plans are tested
	Ensure response plans are updated
	Coordinate with internal & external stakeholders
Recover	Develop & implement appropriate activities to maintain plans for resilience & to restore any capabilities or services that were impaired due to a security event
	Communicate with internal & external stakeholders - account for what, how, & when information will be shared with various stakeholders
	Manage public relations & company reputation

Overall Vulnerability Rating
Overall vulnerability was calculated by adding the hazard-specific ratings for Exposure, Sensitivity, Potential Impact, and Adaptive Capacity in each region for a final rating between 2 and 10 for each hazard within each region. The final Overall Vulnerability Rating was categorized based on the following criteria:

- Low vulnerability: 2–5
- Moderate vulnerability: 6–8
- High vulnerability: 9–10

The lowest scores (i.e., 2 or 3) are associated with energy systems that are rarely exposed to natural hazards, and potential disruptions would not impact many people or require long periods of time to restore service. These systems are likely well adapted to the hazards. The highest scores (i.e., 9 or 10) are associated with energy systems that experience substantial exposure and potential impacts, while also exhibiting distinct sensitivities with limited capacity for adaptation.

Results

INTRODUCTION
The following sections detail the results of the vulnerability analysis. Results are broken down by energy system and begin with an introductory section that includes the vulnerability rating matrix for all hazards and regions and an overview of the results. Within each energy system, results are then organized by region with a detailed discussion of hazards with the highest vulnerability ratings.

LIQUID FUELS RESULTS INTRODUCTION
The following sections detail the results of the liquid fuels vulnerability analysis, which resulted from a combination of technical analysis and surveys. The survey was distributed to private sector liquid fuel distributors in Oregon and Washington. A total of 10 survey responses by service providers were received. Responses were calculated for each region the service provider represents, and each service provider represents multiple regions. As a result, the number of responses that applied to each region ranged from 7 to 12. High-level results are provided and followed by regional results with details from the analysis for those hazards with the highest vulnerability ratings.

Findings reveal that Oregon's liquid fuels energy system is most vulnerable to CSZ earthquake (which includes earthquake, landslide, liquefaction, and tsunami hazards due to a CSZ earthquake), lightning, wildfire, windstorms, and winter storms (**Table 15**). These vulnerabilities were relatively consistent across the state. Because the liquid fuels methodology calculated exposure and sensitivity on a statewide scale for natural hazards, rather than regionally, the hazard exposure and sensitivity are the same for every region. However, the exposure rating for human-caused threats was calculated on a regional scale using the electric and natural gas

methodology. For the sensitivity rating, it was assumed the liquid fuels subsector was sensitive to cyberattacks and physical attacks and assigned a rating of 1 for both threats.
Table 16 shows the exposure and sensitivities of the liquid fuel system.

Table 15: *Liquid fuels vulnerability ratings presented by region and hazard. Underlined and bolded values indicate that at least one response was unknown. Colors in the table correspond to rating categories. Green represents low overall vulnerability (≤5), yellow and orange represent moderate overall vulnerability (6–8), and red represents high overall vulnerability (≥9).*

	Cascades	Eastern	Northwest	Portland Metro	Southwest	Willamette Valley
CSZ	5	6	7	7	7	7
Cyberattack	5	4	5	5	5	5
Drought	6	6	4	4	6	4
Flood	4	5	4	4	4	4
Lightning	7	8	6	6	7	6
Physical Attack	**3**	**3**	**3**	5	**3**	**3**
Wildfire	7	7	6	6	6	6
Wind Storm	7	8	7	7	7	7
Winter Storm	8	8	6	8	7	8

Table 16: *Liquid fuels statewide exposure and sensitivity ratings, including component hazards for the overall CSZ earthquake hazards and future climate change scenario hazards.*The liquid fuels subsector was assumed to be sensitive to human-caused threats and assigned a statewide rating of 1. For the purpose of this table, the average regional exposure rating for human-caused threats was calculated for the liquid fuels subsector.*

Hazard	Exposure	Sensitivity
CSZ		
Earthquake	2	1
Landslide	1	1
Liquefaction	2	1
Tsunami	1	1
Cyberattack	1*	1*
Drought	2	0
Flood	1	1
Lightning	3	1
Physical Attack	1*	1*
Wildfire	3	1
Windstorm	3	0
Winter Storm	3	1
Precipitation Mid Century	2	1
Precipitation Late Century	2	1
Wildfire Mid Century	3	1
Wildfire Late Century	3	1

In **Table 16**, as well as the regional vulnerability tables in the following sections, CSZ earthquake ratings are separated into their component cascading hazards (earthquake, landslide, liquefaction, and tsunami). The final CSZ vulnerability rating for each region corresponds to the highest rated of the four subhazards. Most of the hazard ratings for liquid fuels are for present day hazards. However, precipitation mid-century, precipitation late-century, wildfire mid-century, and wildfire late-century represent projected changes in these hazards due to climate change at the middle and end of the 21st century. The highest present-day hazard exposures statewide for the liquid fuel system were to lightning, wildfire, windstorms, and winter storms. The highest projected future exposures are to wildfire mid-century and wildfire late-century. The lowest exposure was to flood. The high (3) exposure rating for lightning, wildfire, windstorms, and winter storms (**Table 16**) indicates that greater than 60 percent of the components of the system are exposed to those hazards. The high (3) exposure rating for wildfire mid-century and wildfire late-century indicate that greater than 60 percent of system components have the potential to be exposed in future scenarios. The liquid fuel system is sensitive to all hazards except windstorms and drought.

Potential impact varies by region, and the regional results sections below provide potential impact scores for each hazard within each region. On average, the highest potential impacts to liquid fuel storage were from a CSZ Earthquake and winter storms. The lowest were due to windstorms and drought. Due to the survey methodology used to determine adaptive capacity, adaptive capacity ratings do not vary by hazard. They do, however, vary by region. The Eastern Region has the lowest adaptive capacity to all hazards while the Cascades region has the highest. Refer to the regional results in the following sections for further discussion of each region's adaptive capacity.

Interviews with owner/operators indicated sensitivity of the liquid fuel system to the loss of power, a critical interdependency with the electric system. Whether it is from an extreme winter storm or other hazard, the loss of power was the single-most important factor that could impact continuity of fuel distribution, including truck racks, pumping systems, and communication systems. Interviews with owner/operators also indicated that a key component of their emergency response is their Integrated Contingency Plan, which includes spill response program, and Incident Command Management System, which helps detect leaks. Although backup power exists, it is available only for safety shutdown purposes in the event of a disaster. Backup power is not adequate to maintain functionality of pump stations. Other key gaps identified are that operators do not have any plans or measures in place to address wildfires or flooding.

Despite a low overall vulnerability rating across all six regions, cyberattacks was still one of the threats most prioritized by the liquid fuels subsector. Similarly, physical attacks have low overall vulnerability ratings across all six regions, with the highest being the Portland Metro Region. However, for the other five regions, the vulnerability ratings were artificially low due to an absence of survey responses to questions pertaining to potential impact. Although neither of the two human-caused threats had moderate or high overall vulnerability ratings, both threats remain important considerations for the liquid fuels subsector, particularly given the rapid evolution of the threat landscape.

Cascades Region Liquid Fuels Results

The results of the vulnerability analysis in the Cascades region (**Table 17**) show that winter storms presents the highest (8) vulnerability followed by windstorm (7), lightning (7), and wildfire (7). Findings suggest that the liquid fuels system will become more vulnerable to wildfire in mid-century (8) and late-century (8) wildfire scenarios, revealing that wildfire vulnerability of the liquid fuel system may be on par with winter storms in the future due to the effects of climate change.

Table 17: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for all current and future hazards in the Cascades Region. This table also provides separate ratings for the components of a CSZ earthquake rating as well as ratings for projected future hazards below the primary hazards analyzed.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ					
Earthquake	2	1	1	1	5
Landslide	1	1	1	1	4
Liquefaction	2	1	1	1	5
Tsunami	1	1	1	1	4
Cyberattack	1	1	2	1	5
Drought	2	0	3	1	6
Flood	1	1	1	1	4
Lightning	3	1	2	1	7
Physical Attack	1	1	0	1	3
Wildfire	3	1	2	1	7
Windstorm	3	0	3	1	7
Winter Storm	3	1	3	1	8
Precipitation Mid Century	2	1	1	1	5
Precipitation Late Century	2	1	2	1	6
Wildfire Mid Century	3	1	3	1	8
Wildfire Late Century	3	1	3	1	8

- **Lightning** is a risk to the liquid fuel system across the Cascades region because the liquid fuels system has high (3) exposure and almost 80 percent of its storage and fuel supply capacity are exposed to the potential impact lightning strikes could have to the region's fuel supply. The sensitivities of liquid fuel system components include potential damage and flammability of stored liquid fuel at bulk distribution sites and potential equipment damage due to direct lightning strike.
- **Wildfire** presents a risk to the region's liquid fuels primarily because the liquid fuels system has a moderate (2) exposure to wildfire, and because of the high (3) historical occurrence of annual wildfires in the region. Approximately 30 percent of the region's fuel storage could potentially be impacted by wildfire. There are some key sensitivities to bulk distributors and end users, which include damage to equipment, flammability of stored fuels, and disruptions to the workforce and supply chain due to impacts to the transportation network and power system.
- **Windstorm** vulnerability is driven by high (3) exposure to wind hazard. Over 95 percent of storage could potentially be impacted by wind. Components of the liquid fuels system are indirectly affected by power outages and debris resulting in transportation disruptions.

- **Winter storms** are a risk to the liquid fuel system across the Cascades region primarily because of the large majority (over 90 percent) of the liquid fuels system components are exposed, leading to a high (3) exposure rating. Exposure is also exacerbated by the high (3) annual frequency of winter storms events (multiple times a year). In addition, over 90 percent of the liquid fuel supply storage in the region is potentially impacted by winter storm hazard risk. Key sensitivities of the system include workforce and supply chain disruptions due to snow and ice, as well as the loss of power that could disrupt fuel pumping and pipeline distribution.

Results from the adaptive capacity analysis suggest that a high adaptive capacity exists in the region. As noted in the previous methodology section, survey questions addressing adaptive capacity are not separated by hazard; therefore, owner/operator responses apply to all hazards. A total of five respondents answered questions about their capabilities to implement mitigation measures for liquid fuels. Results from the survey and stakeholder interviews show that the region's adaptive capacity encompasses physical measures, including fencing and security (80 percent of respondents), weather coverings (60 percent of respondents), and backup generators (60 percent of respondents). The adaptive capacity rating was also driven by operational measures, including staff preparedness (60 percent of respondents), winter storm equipment (60 percent of respondents), tabletop exercises (60 percent of respondents) and stores of essential supplies (60 percent of respondents). In one-on-one interviews, owner/operators shared winter storm planning activities, including shutdown plans, continuity planning, and remote dispatch capabilities.

Eastern Region Liquid Fuels Results

The results of the liquid fuels vulnerability analysis in the Eastern region, summarized in **Error! Reference source not found.**, show that lightning (8), windstorm (8), and winter storm (8) rate highest, followed by wildfire (7). Mid-century wildfire (9) and late-century wildfire (9) rate higher than any of the present-day hazards, revealing that, due to the effects of climate change, wildfire vulnerability may become the Eastern region's highest concern in the future.

Table 18: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for all current and future hazards in the Eastern Region. This table also provides separate ratings for the components of a CSZ earthquake rating as well as ratings for projected future hazards below the primary hazards analyzed.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ					
Earthquake	2	1	1	2	6
Landslide	1	1	1	2	5
Liquefaction	2	1	1	2	6
Tsunami	1	1	1	2	5
Cyberattack	1	1	1	1	4
Drought	2	0	2	2	6
Flood	1	1	1	2	5
Lightning	3	1	2	2	8
Physical Attack	1	1	0	1	3
Wildfire	3	1	1	2	7
Windstorm	3	0	3	2	8
Winter storm	3	1	2	2	8
Precipitation Mid Century	2	1	1	2	6
Precipitation Late Century	2	1	2	2	7
Wildfire Mid Century	3	1	3	2	9
Wildfire Late Century	3	1	3	2	9

- **Lightning** is a risk to the liquid fuel system across the Eastern region because of its high (3) exposure and because almost 40 percent of fuel storage capacity is potentially impacted by lightning hazard. The sensitivities of these components include potential damage and flammability of stored liquid fuel at bulk distribution sites and potential equipment damage due to direct lightning strike.
- **Wildfire** presents a risk to the region's liquid fuels primarily because of its high (3) exposure to wildfire hazard risk and because of the historical occurrence of annual wildfires in the region. This exposure poses a moderate risk to the region's fuel supply; almost 20 percent of the region's fuel storage could be impacted. Key sensitivities of bulk distributors and end users to wildfire include damage to equipment, flammability of stored fuels, and disruptions to the workforce and supply chain due to impacts to the transportation network and power system.
- **Windstorm** vulnerability is driven by high (3) exposure and almost 100 percent of storage that could potentially be impacted by wind hazard. Components of the liquid fuels system are indirectly affected by power outages and debris resulting in transportation disruptions.

- **Winter storms** are a risk to the liquid fuel system across the Eastern region primarily because of the high (3) exposure of the liquid fuels system and over 70 percent of the liquid fuel supply storage that is exposed could be lost due to winter storms. Exposure is also exacerbated by the annual frequency of winter storm events (multiple times a year). Key sensitivities of the system include workforce and supply chain disruptions due to snow and ice, as well as the loss of power that could disrupt fuel pumping and pipeline distribution.

Results from the adaptive capacity analysis suggest that a relatively low adaptive capacity exists in the region. As noted in the previous methodology section, survey questions addressing adaptive capacity are not separated by hazard; therefore, owner/operator responses apply to all hazards. A total of four respondents answered questions about their capabilities to implement mitigation measures for liquid fuels. Results from the survey show that the region's adaptive capacity encompasses physical measures, including fencing and security (75 percent of respondents), weather coverings (75 percent of respondents), and backup generators (50 percent of respondents). The adaptive capacity rating was also driven by operational measures, including staff preparedness (75 percent of respondents), winter storm equipment (75 percent of respondents), and tabletop exercises (75 percent of respondents).

Northwest Region Liquid Fuels Results

The results of the liquid fuels vulnerability analysis in the Northwest region, summarized in **Table 19**, show that CSZ earthquake (7) and windstorm (7) rate the highest followed by CSZ liquefaction (6), lightning (6), wildfire (6), and winter storm (6). Late-century precipitation also received a rating of 6 showing that, due to the effects of climate change, precipitation and flooding may become a greater concern for the Northwest region toward late century.

Table 19: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for all current and future hazards in the Northwest Region. This table also provides separate ratings for the components of a CSZ earthquake rating as well as ratings for projected future hazards below the primary hazards analyzed.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ					
Earthquake	2	1	3	1	7
Landslide	1	1	2	1	5
Liquefaction	2	1	2	1	6
Tsunami	1	1	2	1	5
Cyberattack	1	1	2	1	5
Drought	2	0	1	1	4
Flood	1	1	1	1	4
Lightning	3	1	1	1	6
Physical Attack	1	1	0	1	3
Wildfire	3	1	1	1	6
Windstorm	3	0	3	1	7
Winter Storm	3	1	1	1	6
Precipitation Mid Century	2	1	1	1	5
Precipitation Late Century	2	1	2	1	6
Wildfire Mid Century	3	1	1	1	6
Wildfire Late Century	3	1	1	1	6

- **CSZ Earthquake** vulnerability is driven by moderate (2) exposure and 100 percent of liquid fuel storage in the region that could potentially be impacted by a CSZ earthquake. The exposure rating is reduced by the low (1) frequency of CSZ earthquake. Sensitivities of the liquid fuel system to CSZ earthquake include supply chain disruptions and disruptions to the workforce as well as equipment, storage tank, and aging liquid fuel infrastructure damage due to ground shaking.
- **CSZ Liquefaction** vulnerability is driven by moderate (2) exposure and almost 80 percent of liquid fuel storage in the region that could potentially be impacted by CSZ liquefaction. Sensitivities of the liquid fuel system to CSZ liquefaction include supply chain disruptions and disruptions to the workforce as well as equipment, storage tank, and aging liquid fuel infrastructure damage due to liquefaction.
- **Lightning** is a risk to the liquid fuel system across the Northwest region because of the liquid fuel system's high (3) exposure to lightning hazard. Bulk distribution points and retail end users are exposed to lightning. The sensitivities of these components include potential damage and flammability of stored liquid fuel at bulk distribution sites and potential equipment damage due to direct lightning strike.

- **Wildfire** presents a risk to the region's liquid fuels primarily because of its high (3) exposure to wildfire hazard risk and because of the historical occurrence of annual wildfires in the region. Key sensitivities of bulk distributors and end users to wildfire include damage to equipment, flammability of stored fuels, and disruptions to the workforce and supply chain due to impacts to the transportation network and power system.
- **Windstorm** vulnerability is driven by high (3) exposure and almost 100 percent of liquid fuel storage could potentially be impacted by wind hazard. Components of the liquid fuels system are indirectly affected by power outages and debris resulting in transportation disruptions.
- **Winter storms** are a risk to the liquid fuel system across the Northwest region primarily because of the high (3) exposure of the liquid fuels system. Exposure is also exacerbated by the annual frequency of winter storm events (multiple times a year). Key sensitivities of the system include workforce and supply chain disruptions due to snow and ice, as well as the loss of power that could disrupt fuel pumping and pipeline distribution.

Results from the adaptive capacity analysis suggest that a high adaptive capacity exists in the region. As noted in the methodology section, survey questions addressing adaptive capacity are not separated by hazard; therefore, owner/operator responses apply to all hazards. A total of six respondents answered questions about their capabilities to implement mitigation measures for liquid fuels in the Northwest Region. Results from the survey show that the region's adaptive capacity encompasses physical measures, including fencing and security (67 percent of respondents), automated monitoring (50 percent) and backup generators (83 percent of respondents). The adaptive capacity rating was also driven by operational measures including staff preparedness (50 percent of respondents), tabletop exercises (50 percent of respondents), stores of essential supplies (50 percent of respondents) and secondary contracts for key suppliers (50 percent of respondents).

Portland Metro Region Liquid Fuels Results

The results of the liquid fuels vulnerability analysis in the Portland region, summarized in **Table 20**, show that winter storm (8) rates the highest followed by CSZ earthquake (7), and CSZ liquefaction (7), and windstorm (7). As seen in **Table 20**, late century precipitation also received a rating of 6 showing that, due to the effects of climate change, precipitation and flooding may become a greater concern for the Portland region over time.

Table 20: Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for all current and future hazards in the Portland Metro Region. This table also provides separate ratings for the components of a CSZ earthquake rating as well as ratings for projected future hazards below the primary hazards analyzed.

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ					
Earthquake	2	1	3	1	7
Landslide	1	1	1	1	4
Liquefaction	2	1	3	1	7
Tsunami	1	1	1	1	4
Cyberattack	1	1	2	1	5
Drought	2	0	1	1	4
Flood	1	1	1	1	4
Lightning	3	1	1	1	6
Physical Attack	1	1	2	1	5
Wildfire	3	1	1	1	6
Windstorm	3	0	3	1	7
Winter Storm	3	1	3	1	8
Precipitation Mid Century	2	1	1	1	5
Precipitation Late Century	2	1	2	1	6
Wildfire Mid Century	3	1	1	1	6
Wildfire Late Century	3	1	1	1	6

- **CSZ Earthquake** vulnerability is driven by moderate (2) exposure and over 95 percent of liquid fuel storage in the region that could potentially be impacted by a CSZ earthquake. The exposure rating is reduced by the low (1) frequency of CSZ earthquake. Sensitivities of the liquid fuel system to CSZ earthquake include supply chain disruptions and disruptions to the workforce as well as equipment, storage tank, and aging liquid fuel infrastructure damage due to ground shaking.
- **CSZ Liquefaction** vulnerability is driven by moderate (2) exposure and over 95 percent of liquid fuel storage in the region that could potentially be impacted by the CSZ liquefaction. Sensitivities of the liquid fuel system to CSZ liquefaction include supply chain disruptions and disruptions to the workforce as well as equipment, storage tank, and aging liquid fuel infrastructure damage due to liquefaction.
- **Windstorm** vulnerability is driven by high (3) exposure and 100 percent of storage that could potentially be impacted by wind hazard. Components of the liquid fuels system are indirectly affected by power outages and debris resulting in transportation disruptions.

- **Winter storms** are a risk to the liquid fuel system across the Portland Metro region primarily because of high (3) exposure. Exposure is also exacerbated by the annual frequency of winter storm events (multiple times a year). Almost 95 percent of liquid fuel storage in the region has the potential to be impacted by winter storm hazards. Key sensitivities of the system include workforce and supply chain disruptions due to snow and ice, as well as the loss of power that could disrupt fuel pumping and pipeline distribution. Interviews with owner operators validated that ice-storms can be a significant disruptor for trucks traveling to the CEI Hub.

Results from the adaptive capacity analysis suggest that a high adaptive capacity exists in the region. As noted in the methodology section, survey questions addressing adaptive capacity are not separated by hazard; therefore, owner/operator responses apply to all hazards. A total of six respondents answered questions about their capabilities to implement mitigation measures for liquid fuels in the Portland Metro Region. Results from the survey show that the region's adaptive capacity encompasses physical measures, including fencing and security (67 percent of respondents), automated monitoring (50 percent) and backup generators (83 percent of respondents). The adaptive capacity rating was also driven by operational measures including staff preparedness (50 percent of respondents), tabletop exercises (50 percent of respondents), stores of essential supplies (50 percent of respondents) and secondary contracts for key suppliers (50 percent of respondents). Interviews with operators validated that three tanks storing fuel at the CEI Hub are seismically hardened.

Southwest Region Liquid Fuels Results

The results of the liquid fuels vulnerability analysis in the Southwest region, summarized in **Table 21**, show that CSZ earthquake (7), lightning (7), windstorm (7), and winter storm (7) rate the highest.

Table 21: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for all current and future hazards in the Southwest Region. This table also provides separate ratings for the components of a CSZ earthquake rating as well as ratings for projected future hazards below the primary hazards analyzed.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ					
Earthquake	2	1	3	1	7
Landslide	1	1	2	1	5
Liquefaction	2	1	2	1	6
Tsunami	1	1	2	1	5
Cyberattack	1	1	2	1	5
Drought	2	0	3	1	6
Flood	1	1	1	1	4
Lightning	3	1	2	1	7
Physical Attack	1	1	0	1	3
Wildfire	3	1	1	1	6
Windstorm	3	0	3	1	7
Winter Storm	3	1	2	1	7
Precipitation Mid Century	2	1	1	1	5
Precipitation Late Century	2	1	2	1	6
Wildfire Mid Century	3	1	1	1	6
Wildfire Late Century	3	1	1	1	6

- **CSZ Earthquake** vulnerability is driven by moderate (2) exposure and over 90 percent of liquid fuel storage in the region that could potentially be impacted by a CSZ earthquake. The exposure rating is reduced by the low (1) frequency of CSZ earthquake. Sensitivities of the liquid fuel system to CSZ earthquake include supply chain disruptions and disruptions to the workforce as well as equipment, storage tank, and aging liquid fuel infrastructure damage due to ground shaking.
- **Lightning** is a risk to the liquid fuel system across the Southwest region because of its high (3) exposure. Bulk distribution points and retail end users are exposed to lightning. Almost 40 percent of liquid fuel storage in the region has the potential to be impacted by lightning. The sensitivities of these components include potential damage and flammability of stored liquid fuel at bulk distribution sites and potential equipment damage due to direct lightning strike.
- **Windstorm** vulnerability is driven by high (3) exposure and almost 100 percent of storage that could potentially be impacted by wind hazard. Components of the liquid fuels system are indirectly affected by power outages and debris resulting in transportation disruptions.

- **Winter storms** are a risk to the liquid fuel system across the Southwest region primarily because of high (3) exposure. Exposure is also exacerbated by the annual frequency of winter storm events (multiple times a year). Nearly 40 percent of liquid fuel storage in the region has the potential to be impacted by winter storms. Key sensitivities of the system include workforce and supply chain disruptions due to snow and ice, as well as the loss of power that could disrupt fuel pumping and pipeline distribution.

Results from the adaptive capacity analysis suggest that a high adaptive capacity exists in the region. As noted in the methodology section, survey questions addressing adaptive capacity are not separated by hazard; therefore, owner/operator responses apply to all hazards. A total of four respondents answered questions about their capabilities to implement mitigation measures for liquid fuels in the Southwest Region. Results from the survey show that the region's adaptive capacity encompasses physical measures, including fencing and security (75 percent of respondents), backup generators (75 percent of respondents), fire protection (50 percent of respondents), improved site drainage and flood protection (50 percent of respondents), minor seismic upgrades (50 percent of respondents), weather coverings (50 percent of respondents), and automated monitoring (50 percent of respondents). The adaptive capacity rating was also driven by operational measures including staff preparedness (75 percent of respondents), tabletop exercises (75 percent of respondents), and stores of essential supplies (75 percent of respondents).

Willamette Valley Region Liquid Fuels Results

The results of the liquid fuels vulnerability analysis in the Willamette Valley region, summarized in **Table 22**, show that winter storm (8) rates the highest followed by CSZ earthquake (7) and windstorm (7).

Table 22: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for all current and future hazards in the Willamette Valley Region. This table also provides separate ratings for the components of a CSZ earthquake rating as well as ratings for projected future hazards below the primary hazards analyzed.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ					
Earthquake	2	1	3	1	7
Landslide	1	1	1	1	4
Liquefaction	2	1	1	1	5
Tsunami	1	1	1	1	4
Cyberattack	1	1	2	1	5
Drought	2	0	1	1	4
Flood	1	1	1	1	4
Lightning	3	1	1	1	6
Physical Attack	1	1	0	1	3
Wildfire	3	1	1	1	6
Windstorm	3	0	3	1	7
Winter Storm	3	1	3	1	8
Precipitation Mid Century	2	1	1	1	5
Precipitation Late Century	2	1	1	1	5
Wildfire Mid Century	3	1	1	1	6
Wildfire Late Century	3	1	1	1	6

- **CSZ Earthquake** vulnerability is driven by moderate (2) exposure and over 85 percent of liquid fuel storage in the region that could potentially be impacted by a CSZ earthquake. The exposure rating is reduced by the low (1) frequency of CSZ earthquake. Sensitivities of the liquid fuel system to CSZ earthquake include supply chain disruptions and disruptions to the workforce as well as equipment, storage tank, and aging liquid fuel infrastructure damage due to ground shaking.
- **Windstorm** vulnerability is driven by high (3) exposure and 100 percent of liquid fuels storage in the region that could potentially be impacted by wind hazard. Components of the liquid fuels system are indirectly affected by power outages and debris resulting in transportation disruptions.
- **Winter storms** are a risk to the liquid fuel system across the Willamette Valley region primarily because of high (3) exposure. Exposure is also exacerbated by the annual frequency of winter storm events (multiple times a year). Over 95 percent of liquid fuel storage in the region has the potential to be impacted by winter storms. Key sensitivities of the system include workforce and supply chain disruptions due to snow and ice, as well as the loss of power that could disrupt fuel pumping and pipeline distribution.

Results from the adaptive capacity analysis suggest that a high adaptive capacity exists in the region. As noted in the methodology section, survey questions addressing adaptive capacity are not separated by hazard; therefore, owner/operator responses apply to all hazards. A total of nine respondents answered questions about their capabilities to implement mitigation measures for liquid fuels in the Willamette Valley Region. Results from the survey show that the region's adaptive capacity encompasses physical measures, including fencing and security (44 percent of respondents), backup generators (78 percent of respondents), and automated monitoring (44 percent of respondents). The adaptive capacity rating was also driven by operational measures such as staff preparedness (33 percent of respondents), tabletop exercises (33 percent of respondents), secondary contracts for key suppliers (33 percent of respondents), and stores of essential supplies (33 percent of respondents).

ELECTRIC RESULTS INTRODUCTION

The following sections detail the results of the electricity vulnerability analysis. Data for the electricity vulnerability analysis was collected via survey. The survey was distributed to all 41 electric utilities in Oregon as well as BPA. Responses were received from 17 utilities , including the three investor-owned utilities, which serve the majority of end users in the state. BPA also provided responses. Because BPA plays a distinct role in the energy system relative to the utilities, their responses provide additional context, but did not influence overall vulnerability scores. Responses from the utilities were applied to each region a utility represents, and most utilities represent multiple regions. As a result, the number of survey responses for each region ranges between four and nine. High-level results are presented followed by regional results and details from the analysis for those hazards with the highest vulnerability ratings.

Findings from the analysis reveal that Oregon's electricity energy system is most vulnerable to a CSZ earthquake, wildfire, windstorms, and winter storms (**Table 23**). These vulnerabilities were relatively consistent across the state. For example, the Northwest region was the only region that did not score a moderate rating for overall vulnerability to windstorms. Winter storms are the only hazard that scored a 7 rating (in the Cascades and Willamette Valley regions). Drought scored relatively low across the regions, with the exception of Portland Metro. In addition, overall vulnerability of assets to lightning and flood was low in all regions. In general, overall vulnerability of electric assets to CSZ earthquake was highest in the Southwest and lowest in the Cascades and the Willamette Valley. No region is considered highly vulnerable to all hazards. Results from BPA's input were generally consistent compared to results across all regions, particularly regarding CSZ earthquake, cyberattacks, drought, lightning, windstorms, and winter storms.

Table 23: Electricity vulnerability ratings presented by region and hazard. Colors in the table correspond to rating categories. Green represents low overall vulnerability (≤5), yellow and orange represent moderate overall vulnerability (6–8), and red represents high overall vulnerability (≥9).

	Cascades	Eastern	Northwest	Portland Metro	Southwest	Willamette Valley
CSZ	4	5	5	5	6	4
Cyberattack	3	2	3	2	3	4
Drought	3	4	2	6	3	3
Flood	3	3	3	4	3	4
Lightning	5	4	2	4	3	3
Physical Attack	4	2	3	2	4	4
Wildfire	6	5	4	6	4	6
Wind Storm	6	6	5	6	6	6
Winter Storm	7	6	5	5	5	7

Electric system results are specific to the electric system, however, the electric, natural gas, and liquid fuels systems are interdependent. Disruptions to the natural gas system may impact electric generation capacity in particular, and a loss of electric power could impact the continuity of liquid fuel distribution, including truck racks, pumping systems, and communication systems. While not directly queried in the survey of owner/operators, certain written responses indicated relevant interdependencies between systems.

Despite low overall vulnerability ratings and limited variability between rankings across regions for human-caused threats, cyberattacks was still one of the threats most prioritized by the electricity subsector. The Willamette Valley region had the highest vulnerability score for cyberattacks due to an exposure rating of low (1) (other regions had an exposure rating of 0). Furthermore, the Cascades, Southwest, and Willamette Valley regions have the highest vulnerability scores for physical attacks due to an exposure rating of 1 and a potential impact rating of 1. Note, the rankings for the Eastern and Portland Metro regions are artificially low due to respondents providing no feedback to questions pertaining to potential impacts. As noted for the liquid fuels subsector, neither of the two human-caused threats had moderate or high overall vulnerability ratings. However, both threats remain important considerations for the electricity subsector, particularly given the rapid evolution of the threat landscape.

Cascades Region Electric Results

The results of the electricity vulnerability analysis in the Cascades region show that windstorm (6), wildfire (6), and winter storm (7) score the highest, followed by lightning (5). Error! Reference source not found. summarizes the findings of the risk assessment in the Cascades Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the electricity system. A total of six respondents answered questions about their utility's electrical system vulnerability to winter storms, windstorms, wildfire, and lightning.

Table 24: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Cascades Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	1	1	2	0	4
Cyberattack	0	1	1	1	3
Drought	2	0	1	0	3
Flood	1	1	1	0	3
Lightning	2	1	2	0	5
Physical Attack	1	1	1	1	4
Wildfire	3	1	2	0	6
Windstorm	3	1	2	0	6
Winter Storm	3	1	2	1	7

- **Lightning** results indicate that the overall vulnerability is driven by exposure and potential impacts. Three respondents stated that 50 percent or more of their organization's energy system assets were located within lightning hazard zones. Four respondents indicated that lightning occurs at an annual frequency, and one respondent stated that lightning occurs daily or monthly. Certain energy system assets, such as substations, may be extremely sensitive to lightning depending on their location. Furthermore, distribution and transmission assets are affected on a regular basis in some areas. Most respondents considered transmission and the end-user distribution network to be most sensitive. Three respondents stated that more than 20 percent of customers may experience a disruption from the hazard, and service may be restored after a hazard occurrence in a matter of hours to days.
- **Wildfire** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. Assets that were called out as being particularly sensitive to wildfire are 69kv or 115kv transmission lines, wooden structures, and distribution lines. Four respondents stated that more than 50 percent of their energy system assets are located in the wildfire hazard zone; one respondent indicated that their energy system is exposed on a daily to monthly basis; and five respondents indicated that their energy system is exposed on an annual basis. Transmission and end-user distribution were considered the most sensitive components of the electrical

system. Five respondents stated that more than 20 percent of their customers may experience a disruption from wildfire hazards.

- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. The components of the Cascades region's electrical system most at risk from wind are transmission and distribution systems. Five respondents stated that 50 percent or more of their organization's energy system assets were located within wind hazard zones. All respondents indicated that the end-user distribution network was the most sensitive component of the electrical energy system. Four respondents stated that more than 20 percent of their customers may experience a disruption due to wind.
- **Winter storms** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. The components of the Cascades region's electrical system most exposed to winter storms are distribution and transmission. In fact, winter storm exposure may result in the buildup of ice or snow on lines, which may cause cable or pole failure (which are time-consuming and costly to repair). Four respondents specified that 50 percent or more of their organization's energy system assets were located within winter storm hazard zones. Key sensitivities of energy system to winter storms identified in the survey responses include transmission and end-user distribution assets. Ice buildup on distribution and transmission lines as well as trees falling on these assets, are specified as largely responsible for power loss. Four respondents stated that more than 20 percent of their customers may experience a disruption to service due to winter storms.

Results from the adaptive capacity analysis suggest that a high to very high adaptive capacity exists in the region. Six stakeholders provided responses to the adaptive capacity survey questions. In the results, winter storms had an adaptive capacity rating of 1, or high, due to this threat having more than two physical measures and at least one operational measure, of which none of the measures were identified as optimized. However, for the other natural hazards, they each had at least two physical and at least two operational measures, with at least one measure being optimized (i.e., very high [0] adaptive capacity rating). Furthermore, for human-caused threats, each threat had an adaptive capacity rating of 1 due to at least five measures being implemented, with at least to three measures being embedded or optimized.

Eastern Region Electric Results

The results of the electricity vulnerability analysis in the Eastern region show that windstorm (6) and winter storm (6) score the highest followed by CSZ earthquake (5) and wildfire (5). **Table 25** summarizes the findings of the risk assessment in the Eastern Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the electricity system. A total of four respondents answered questions about their utility's electrical system vulnerability to wildfire, windstorms, and winter storms.

Table 25*: Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Eastern Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	1	1	3	0	5
Cyberattack	0	1	0	1	2
Drought	2	1	1	0	4
Flood	1	1	1	0	3
Lightning	2	1	1	0	4
Physical Attack	0	1	0	1	2
Wildfire	2	1	2	0	5
Windstorm	2	1	2	1	6
Winter Storm	2	1	2	1	6

- **CSZ earthquake** results indicate that the overall vulnerability is driven by high potential impacts. Only one respondent answered the survey questions about a CSZ earthquake in the Eastern Region. The response indicated that between 1 and 20 percent of their organization's energy system is located within the earthquake hazard zone. Production, transmission, and end-user distribution network were all considered sensitive to the hazard. The respondent stated that between 5 and 20 percent of customers may experience a disruption from the hazard, and service may be restored after a hazard occurrence in a matter of months.
- **Wildfire** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. All assets, especially transmission and the distribution lines, including power lines and wood poles are sensitive to wildfire. Three respondents stated that more than 50 percent of their energy system assets are located in the wildfire hazard zone, and two responses indicate that their energy system is exposed on a daily to monthly basis. End user distribution were considered the most sensitive component of the electrical system. One respondent stated that more than 20 percent of their customers may experience a disruption from wildfire hazards.
- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and the potential impacts to power. The components of the Eastern region's electrical system most at risk from windstorms are production, transmission, and distribution systems. All respondents stated that 50 percent or more of their organization's energy system assets were located within wind hazard zones. All respondents indicated that the end-user distribution network is the most sensitive component of the electrical energy system. Two respondents stated that more than 20 percent of their customers may experience a disruption due to wind.
- **Winter storms** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. The components of the electrical system in the Eastern region most at risk from winter storms are production, transmission, and distribution

systems. One response specified that 50 percent or more of their organization's energy system assets were located within winter storm hazard zones. Key sensitivities of the energy system to winter storms identified in the survey responses include end-user distribution assets. Ice buildup on distribution and transmission lines, as well as trees falling on these assets, are specified as largely responsible for power loss. Two respondents stated that more than 20 percent of their customers may experience a disruption to service due to winter storms.

Results from the adaptive capacity analysis suggest that a high to very high adaptive capacity exists in the region. Four stakeholders provided responses to the adaptive capacity survey questions. In the results, windstorms and winter storms had an adaptive capacity rating of 1, or high, due to each threat having more than two physical measures and more than 0 operational measures, of which none of the measures were identified as optimized. However, for the other natural hazards, they each had at least two physical and at least two operational measures, with at least one measure being optimized (i.e., very high [0] adaptive capacity rating). Furthermore, for human-caused threats, each threat had an adaptive capacity rating of 1 due to at least five measures being implemented, with at least three measures being embedded or optimized.

Northwest Region Electric Results

The results of the electricity vulnerability analysis in the Northwest region show that CSZ earthquake (5), windstorm (5), and winter storm (5) score the highest, followed by wildfire (4). However, overall vulnerability through the Northwest region is low, with a score of 5 (Moderate) being the highest rating for any hazard. **Table 26** summarizes the findings of the risk assessment in the Northwest Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the electricity system. A total of five respondents answered questions about their utility's electrical system vulnerability to winter storms, windstorms, wildfire, and a CSZ earthquake.

Table 26: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Northwest Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	1	1	3	0	5
Cyberattack	0	1	1	1	3
Drought	1	0	1	0	2
Flood	1	1	1	0	3
Lightning	1	0	1	0	2
Physical Attack	0	1	1	1	3
Wildfire	2	1	1	0	4
Windstorm	2	1	2	0	5
Winter Storm	2	1	2	0	5

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by potential impacts. Transmission, distribution, and storage are all components of the Northwest Region's energy system that are sensitive to a CSZ earthquake. Three respondents stated that more than 50 percent of their energy system assets are located in the hazard zone, and one response indicated that between 1 and 20 percent of their energy system assets are located outside of the hazard zones. Transmission and end-user distribution were unanimously considered the most sensitive components of electrical system. Four respondents stated that more than 20 percent of their customers may experience a disruption from a CSZ earthquake hazard, and four respondents indicated that service could be restored after an event in a matter of months.
- **Wildfire** results indicate that the overall vulnerability is driven by exposure. One respondent indicated that more than 50 percent of their organization's energy system is located within the wildfire hazard zone, and two respondents indicated that none of their energy assets were within wildfire hazard zones. Transmission and end-user distribution network were unanimously considered sensitive to the hazard. Three respondents stated that more than 20 percent of customers may experience a disruption from the hazard.
- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. The components of the Northwest Region's electrical system most at risk from windstorms are transmission and distribution systems. Four respondents stated that 50 percent or more of their organization's energy system assets were located within wind hazard zones, and three respondents estimate that their system assets are exposed to windstorm events on a daily to monthly basis. All respondents indicate that transmission and end-user distribution network are the most sensitive components of the electrical energy system. Two respondents stated that more than 20 percent of their customers may experience a disruption due to wind, and four respondents indicated that service could be restored after a windstorm event in a matter of hours to days.
- **Winter storms** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. The components of the electrical system in the Northwest Region most at risk from winter storm hazards are transmission and distribution systems. Transmission and distribution lines and transmission equipment are prone to failure during severe events. One respondent specified that 50 percent or more of their organization's energy system assets were located within winter storm hazard zones, and two respondents stated that none of their energy system assets are in winter storm hazard areas. Key sensitivities of the energy system to winter storms identified in the survey responses include transmission and end-user distribution assets. Furthermore, four respondents stated that more than 20 percent of their customers may experience a disruption to service due to winter storms; all four individuals indicated that service could be restored after a winter storm event in a matter of hours to days.

Results from the adaptive capacity analysis suggest that a high to very high adaptive capacity exists in the region. Five stakeholders provided responses to the adaptive capacity survey questions. In the results, every natural hazard had a very high (0) adaptive capacity rating due to at least two physical and at least two operational measures, with at least one measure being optimized. However, for human-caused threats, each threat had a high (1) adaptive capacity rating due to at least five measures being implemented, with at least three measures being embedded or optimized.

Portland Metro Region Electric Results

The results of the electricity vulnerability analysis in the Portland Metro region show that drought (6), windstorm (6), and wildfire (6) all score the highest followed by CSZ earthquake (5) and winter storm (5). **Table 27** summarizes the findings of the risk assessment in the Portland Metro Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the electricity system. A total of five respondents answered questions about their utility's electrical system vulnerability to windstorms and wildfire.

Table 27: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Portland Metro Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	2	0	5
Cyberattack	0	1	0	1	2
Drought	1	1	1	3	6
Flood	1	1	2	0	4
Lightning	2	1	1	0	4
Physical Attack	0	1	0	1	2
Wildfire	2	1	2	1	6
Windstorm	3	1	2	0	6
Winter Storm	2	1	2	0	5

- **Drought** results indicate that the overall vulnerability is driven by low adaptive capacity. Exposure and potential impacts are low for drought in the Portland Metro Region. However, one respondent stated that drought would likely reduce hydropower generation capabilities, which may require a shift to other energy sources to meet demand. Two respondents stated that production is a sensitive component in the Portland Metro Region. One respondent indicated that that less than 5 percent of customers may experience a disruption from the hazard, and service may be restored after a hazard occurrence in a matter of hours to days.
- **Wildfire** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. All assets, especially transmission and the distribution lines, including power lines and wood poles, are sensitive to wildfire. One respondent stated that more than 50 percent of their energy system assets are located in the wildfire hazard zone, and one response indicated that their energy system is exposed on

a daily to monthly basis. End user distribution and transmission were considered the most sensitive components of electrical system. One respondent stated that more than 20 percent of their customers may experience a disruption from wildfire hazards.

- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. The components of the Portland Metro Region's electrical system considered most at risk from windstorms varied among the respondents; transmission and distribution systems were considered by most to be sensitive, but production and storage were also mentioned. Three respondents stated that 50 percent or more of their organization's energy system assets were located within wind hazard zones. All respondents who supplied an answer to the questions pertaining to sensitivity indicated that transmission and end-user distribution network were the most sensitive components of the electrical energy system. Two respondents stated that more than 20 percent of their customers may experience a disruption due to wind.

Results from the adaptive capacity analysis suggest that a high to very high adaptive capacity exists in the region for all threats except drought. Five stakeholders provided responses to the adaptive capacity survey questions. In the results, wildfire had an adaptive capacity rating of 1 due to this threat having more than two physical measures and more than 0 operational measures, of which none of the measures were identified as optimized (i.e., adaptive capacity rating of high, or 1). For CSZ earthquakes, floods, lightning, windstorms, and winter storms, they each had a very high (0) adaptive capacity rating due to at least two physical and at least two operational measures, with at least one measure being optimized. Furthermore, for human-caused threats, each threat had an adaptive capacity of 1 due to at least five measures being implemented, with at least three measures being embedded or optimized. However, for drought, this threat had a low adaptive capacity rating of 3 due to zero physical measures and more than one operational measure.

Southwest Region Electric Results

The results of the electricity vulnerability analysis in the Southwest Region show that CSZ earthquake (6) and windstorm (6) score the highest, followed by the wildfire (4) and winter storm (4). **Table 28** summarizes the findings of the risk assessment in the Southwest Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the electricity system. A total of five respondents answered questions about their utility's electrical system vulnerability to windstorms, CSZ earthquake, winter storms, and wildfire.

Table 28: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Southwest Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	3	0	6
Cyberattack	0	1	1	1	3
Drought	1	1	1	0	3
Flood	1	1	1	0	3
Lightning	1	1	1	0	3
Physical Attack	1	1	1	1	4
Wildfire	2	1	1	0	4
Windstorm	3	1	2	0	6
Winter Storm	2	1	2	0	5

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. The components of the Southwest Region's electrical system most at risk from windstorms are transmission and distribution; however, some respondents specified that production and storage are also sensitive. Three respondents stated that 50 percent or more of their organization's energy system assets were located within wind hazard zones. All respondents indicate that transmission and end-user distribution network are the most sensitive components of the electrical energy system. Three respondents stated that more than 20 percent of their customers may experience a disruption due to wind and that service may be restored in a matter of months.
- **Wildfire** results indicate that the overall vulnerability is driven by exposure. One response indicated that between more than 50 percent of their organization's energy system is located within the wildfire hazard zone; however, three individuals stated that none of their energy system assets are within wildfire hazard zones. Transmission and end-user distribution network components are considered sensitive to the hazard. One respondent stated that more than 20 percent of customers may experience a disruption from the hazard. Another respondent stated that service may be restored after a hazard occurrence in a matter of months.
- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. The components of the electrical system in the Southwest region most at risk from winter storm hazards are transmission and distribution systems, with power lines being particularly susceptible. Four responses stated that 50 percent or more of their organization's energy system assets were located within windstorm hazard zones and that windstorm hazards occur on a daily to monthly basis. Key sensitivities of the energy system to winter storms identified in the survey responses include transmission and end-user distribution assets. Two respondents stated that more than 20 percent of their customers may experience a disruption to service due to winter storms.

- **Winter storm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impact. According to the survey, transmission and distribution lines, including power lines, are the most sensitive assets to winter storm hazards. One respondent stated that more than 50 percent of their energy system assets are located in the wildfire hazard zone, and four responses indicate that their energy system is exposed on an annual basis. Transmission and end-user distribution were considered the most sensitive components of the electrical system. Two respondents stated that more than 20 percent of their customers may experience a disruption from wildfire hazards.

Results from the adaptive capacity analysis suggest that a high to very high adaptive capacity exists in the region. Five stakeholders provided responses to the adaptive capacity survey questions. In the results, every natural hazard had an adaptive capacity very high rating (0) due to at least two physical and at least two operational measures, with at least one measure being optimized. However, for human-caused threats, each threat had a high (1) adaptive capacity rating due to at least five measures being implemented, with at least three measures being embedded or optimized.

Willamette Valley Region Electric Results

The results of the electricity vulnerability analysis in the Willamette Valley Region show that wildfire (6), windstorm (6), and winter storm (7) score the highest followed by CSZ earthquake (4) and flood (4). **Table 29** summarizes the findings of the risk assessment in the Willamette Valley Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the electricity system. A total of eight respondents answered questions about their utility's electrical system vulnerability to winter storms, windstorms, and wildfire.

Table 29: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Willamette Valley Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	1	1	2	0	4
Cyberattack	1	1	1	1	4
Drought	1	1	1	0	3
Flood	1	1	2	0	4
Lightning	1	1	1	0	3
Physical Attack	1	1	1	1	4
Wildfire	2	1	3	0	6
Windstorm	3	1	2	0	6
Winter Storm	3	1	3	0	7

- **Wildfire** results indicate that the high vulnerability rating is primarily driven by exposure and potential impacts. All assets, especially transmission, distribution, substations, and transformers, are sensitive to wildfire. One respondent stated that more than 50 percent of their energy system assets are located in the wildfire hazard zone, and one response indicated that their energy system is exposed on a daily to monthly basis. Transmission and end-user distribution were considered the most sensitive components of the electrical system. Three respondents stated that more than 20 percent of their customers may experience a disruption from wildfire hazards.

- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Assets in the Willamette Valley region's electrical system most at risk from windstorms are transmission and distribution lines. Four respondents stated that 50 percent or more of their organization's energy system assets were located within wind hazard zones, and three respondents stated that their energy system assets are exposed to windstorm hazards on a daily to monthly basis. All respondents indicate that transmission and end-user distribution network were the most sensitive components of the electrical energy system. Two respondents stated that more than 20 percent of their customers may experience a disruption due to wind.
- **Winter storm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Assets in the Willamette Valley Region most at risk from winter storm hazards are related to transmission, distribution, and communication infrastructure, as well as poles, wires, and transformers. Three responsdents specified that 50 percent or more of their organization's energy system assets were located within winter storm hazard zones, and four respondents indicated that winter storm hazards occur on an annual basis. Key sensitivities of energy system to winter storms identified in the survey responses include transmission and end-user distribution network. Ice buildup on equipment and trees falling onto lines are specified as largely responsible for power loss. Five respondents stated that more than 20 percent of their customers may experience a disruption to service due to winter storms.

Results from the adaptive capacity analysis suggest that a high to very high adaptive capacity exists in the region. Eight stakeholders provided responses to the adaptive capacity survey questions. In the results, every natural hazard had an adaptive capacity rating of very high rating (0) due to at least two physical and at least two operational measures, with at least one measure being optimized. However, for human-caused threats, each threat had a high (1) adaptive capacity rating due to at least five measures being implemented, with at least three measures being embedded or optimized.

NATURAL GAS RESULTS

The following sections detail the results of the natural gas vulnerability analysis. Data for the natural gas vulnerability analysis was collected via survey. The survey was distributed to the three natural gas utilities in Oregon, and all three provided feedback. Responses were applied to each region a utility represents, and all utilities represent multiple regions. As a result, the number of survey responses for each region ranges between one and three. High-level results are presented followed by regional results and details from the analysis for hazards with the highest vulnerability ratings.

Findings from the analysis reveal that Oregon's natural gas energy system is most vulnerable to a CSZ earthquake, lightning, wildfire, and windstorms (**Table 30**). Vulnerability to a CSZ earthquake was consistent across all regions with a moderate rating (6). Windstorm also scored a moderate rating (6) in all regions except Eastern. Winter storms and flood scored the same low vulnerability rating (4) in all regions. The Southwest was the only region to score a moderate vulnerability rating (6) for wildfire; otherwise, vulnerability to wildfire is Low in all regions (5). None of the natural hazards scored a vulnerability rating above moderate, and no region scored a uniform moderate or high vulnerability rating for all hazards. Vulnerability to each natural hazard was consistent across all regions. For example, vulnerability ratings for each hazard varied only by +/- 1 across all regions. This may be a consequence of the limited number of service providers (three) in the state, each serving multiple regions. There were no responses for any questions pertaining to drought; thus, it received an N/A rating for each region.

Table 30: *Natural gas vulnerability ratings presented by region and hazard. Colors in the table correspond to rating categories. Green represents low overall vulnerability (≤5), yellow and orange represent moderate overall vulnerability (6–8), and red represents high overall vulnerability (≥9). N/A indicates no response.*

	Cascades	Eastern	Northwest	Portland Metro	Southwest	Willamette Valley
CSZ	6	6	6	6	6	6
Cyberattack	2	3	2	2	3	2
Drought	N/A	N/A	N/A	N/A	N/A	N/A
Flood	4	4	4	4	4	4
Lightning	5	5	4	4	5	4
Physical Attack	4	4	7	7	4	6
Wildfire	5	5	5	5	6	5
Wind Storm	6	5	6	6	6	6
Winter Storm	4	4	4	4	4	4

Natural gas system results are specific to the natural gas system; however, the natural gas system has interdependencies with the electric system. Electricity is required to keep natural gas transmission and distribution operational by powering equipment such as compressor stations and gas appliances. Conversely, Oregon has several natural gas-powered power plants and disruption of the natural gas system could affect the production of electricity.

Both cyberattacks and physical attacks were the threats most prioritized by the natural gas subsector. The higher overall vulnerability ratings for cyberattacks were largely driven by exposure. For example, the Eastern and Southwest regions have the highest vulnerability scores for cyberattacks due to a low exposure rating (1) (other regions had an exposure rating of 0). Furthermore, the Northwest and Portland Metro regions have the highest vulnerability scores for physical attacks due to a moderate exposure rating (2) as well as a low adaptive capacity rating (3). The Willamette Valley Region has the second highest vulnerability score due to a low (3) adaptive capacity rating. However, survey respondents revealed that they considered accidental damage (e.g., striking a buried pipeline when digging) when responding to questions related to physical attacks, expanding the definition of physical attack beyond intentional attacks, which may have influenced overall vulnerability ratings for physical attack.

Although neither of the two human-caused threats had moderate or high overall vulnerability ratings, both threats remain important considerations for the natural gas subsector, particularly given the rapid evolution of the threat landscape.

Cascades Region Natural Gas Results

The results of the natural gas vulnerability analysis in the Cascades Region show that CSZ earthquake (6), lightning (5), wildfire (5), and windstorm (6) had the four highest overall vulnerability scores. **Table 31** summarizes the findings of the risk assessment in the Cascades Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the natural gas system.

Table 31: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Cascades Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	3	0	6
Cyberattack	0	1	1	0	2
Drought	N/A	N/A	N/A	N/A	N/A
Flood	1	1	2	0	4
Lightning	3	1	1	0	5
Physical Attack	1	1	1	1	4
Wildfire	2	1	2	0	5
Windstorm	3	1	2	0	6
Winter Storm	2	1	1	0	4

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Natural gas assets in the Cascades Region considered most sensitive to earthquakes include production plants, transmission pipelines, above- and below-ground storage tanks, and local distribution lines and roadways. Exposure of natural gas system assets to a CSZ earthquake hazard is moderate (2) and potential impacts are high (3), implying that a large number of customers may be affected by a disruption and service may take months to be restored following an event.

- **Lightning** results indicate that the overall vulnerability is driven by high degree of exposure (3). Lightning poses a risk to above-ground facilities and could impact telemetry and travel along pipelines. Furthermore, lightning strikes of large custody transfer points could lead to large outage scenarios, which may affect transmission and distribution assets. High levels of exposure imply that more than 20 percent of customers may be disrupted and systems could experience instances of the hazard on an annual basis.
- **Wildfire** results indicate that the overall vulnerability is driven by exposure and potential impacts. Wildfires pose the greatest threat to above-ground natural gas facilities such as gate stations and meters. On average, exposure and potential impacts of natural gas systems to wildfire is moderate (2), implying that wildfires occur on an annual basis and service may be restored within weeks after an event.
- **Windstorm** results indicate that the overall vulnerability is driven by exposure and potential impacts. All assets in the Cascades Region's natural gas system are considered sensitive to the damaging effects of windstorms. Exposure of natural gas system elements to windstorms is high (3), implying that the majority of the system is exposed to hazards.

Results from the adaptive capacity analysis suggest that a very high to high adaptive capacity exists in the region. Three stakeholders provided responses to the adaptive capacity survey questions. In the results, every natural hazard had a very high (0) adaptive capacity rating due to at least two physical and at least two operational measures, with at least one measure being optimized. In addition, cyber-attacks had an adaptive capacity rating of 0 due to at least five measures being implemented, with at least five measures being optimized. However, for physical attacks, this threat had a high (1) adaptive capacity rating due to at least five measures being implemented, with at least three measures being embedded or optimized. Note, there were no responses to adaptive capacity survey questions for drought.

Eastern Region Natural Gas Results

The results of the natural gas vulnerability analysis in the Eastern Region show that CSZ earthquake (6), lightning (5), wildfire (5), and windstorm (5) score the highest. **Table 32** summarizes the findings of the risk assessment in the Eastern Region. **Table 32** is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the natural gas system.

Table 32: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Eastern Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	3	0	6
Cyberattack	1	1	1	0	3
Drought	N/A	N/A	N/A	N/A	N/A
Flood	1	1	2	0	4
Lightning	3	1	1	0	5
Physical Attack	1	1	1	1	4
Wildfire	2	1	2	0	5
Windstorm	3	1	1	0	5
Winter Storm	2	1	1	0	4

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by exposure and the potential impacts. Natural gas assets in the Eastern Region considered most sensitive to earthquake hazards include production plants, transmission pipelines, above- and below-ground storage tanks, and local distribution lines. Exposure to earthquake hazards in the Eastern Region is moderate (2) and potential impacts are high (3), implying that up to 20 percent or more of customers may be impacted by the hazard and that disruption to service following an event may last up to a month or more.
- **Lightning** results indicate that the overall vulnerability is driven by high levels of exposure. Above-ground facilities are sensitive, and lightning may strike electronics such as telemetry and travel along pipelines, potentially exposing individuals to injury. Lightning may also strike large custody transfer points and cause large outage scenarios, which, depending on the location of the strike, may affect transmission and distribution assets. Exposure to lightning in the Eastern Region is high (3), implying that anywhere from 1 to 50 percent of assets may be exposed, and lightning occurs on a monthly to annual basis.
- **Wildfire** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Wildfires may burn homes and other buildings that have natural gas service, as well as above-ground facilities. Exposure to and potential impacts of wildfire hazards in the Eastern Region is moderate (2), implying that, on average, up to 20 percent of assets may fall within the hazard zone and service may be restored in a matter of weeks.
- **Windstorm** results indicate that the overall vulnerability is driven b**y** high levels of exposure (3). All assets are considered sensitive to the effects of windstorms. Exposure to windstorms in the Eastern Region is high, implying that up to 50 percent of assets are exposed, and windstorms occur on a monthly basis.

Results from the adaptive capacity analysis suggest that a very high to high adaptive capacity exists in the region. Two stakeholders provided responses to the adaptive capacity survey questions. In the results, every natural hazard had a very high (0) adaptive capacity rating due to at least two physical and two operational measures, with at least one measure being optimized. In addition, cyber-attacks had an adaptive capacity rating of 0 due to at least five measures being implemented, with at least five measures being optimized. However, for physical attacks, this threat had a high (1) adaptive capacity rating due to at least five measures being implemented, with at least three measures being embedded or optimized. Note, there were no responses to adaptive capacity survey questions for drought.

Northwest Region Natural Gas Results

The results of the natural gas vulnerability analysis in the Northwest Region show that physical attack (7), followed by CSZ earthquake (6), wildfire (5), and windstorm (6) score the highest. **Table 33** summarizes the findings of the risk assessment in the Northwest Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the natural gas system.

Table 33: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Northwest Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	3	0	6
Cyberattack	0	1	1	0	2
Drought	N/A	N/A	N/A	N/A	N/A
Flood	1	1	2	0	4
Lightning	2	1	1	0	4
Physical Attack	2	1	1	3	7
Wildfire	2	1	2	0	5
Windstorm	3	1	2	0	6
Winter Storm	2	1	1	0	4

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Production plants, transmission pipelines, above- and below-ground storage tanks, and local distribution lines are considered sensitive to earthquake hazards. Exposure to CSZ earthquakes in the Northwest Region is moderate (2), and potential impacts are high (3), meaning more than 50 percent of energy system assets may be affected by the hazard, more than 20 percent of customers may be impacted, and service would be restored in a matter of months.
- **Physical attack** results indicate that the overall vulnerability rating is primarily driven by exposure and adaptive capacity. Exposure to physical attacks in the Northwest Region is moderate (2), and adaptive capacity is low (3), meaning that between 0 and 50 percent of energy system assets has been exposed in the past 5 years; the system has been

exposed to a physical attack on an annual to decade or more basis; and the system has a limited ability to adjust to a hazard or threat, take advantage of new opportunities, or cope with change. It is important to note that survey respondents revealed that they considered accidental damage (e.g., striking a buried pipeline when digging) when responding to questions related to physical attacks, expanding the definition of physical attack beyond intentional attacks, which may have influenced the overall vulnerability ratings.

- **Wildfire** results indicate that the overall vulnerability is driven by exposure and potential impacts. Wildfires pose a threat to above-ground storage tanks, transmission pipelines, and local distribution. Other assets that are particularly sensitive to wildfire are gate stations and meters. Exposure and potential impacts in regard to wildfire in the Northwest Region are moderate (2). Wildfire is estimated to occur on an annual basis and impact less than 5 percent of customers. Service may be restored in a matter of weeks following an event.
- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. All assets are considered sensitive to the effects of windstorms. Exposure to windstorms in the Northwest Region is high (3), and potential impacts are moderate (2), implying that more than 50 percent of energy system assets are located in the hazardous zone, windstorms occur on an annual basis, less than 20 percent of customers may be affected by an event, and service may be restored in a matter of weeks.

Results from the adaptive capacity analysis suggest that a very high adaptive capacity exists in the region for all threats except physical attacks. One stakeholder provided responses to the adaptive capacity survey questions. In the results, every natural hazard had a very high (0) adaptive capacity rating due to at least two physical and at least two operational measures, with at least one measure being optimized. In addition, cyber-attacks had a very high (0) adaptive capacity rating due to at least five measures being implemented, with at least five measures being optimized. However, for physical attacks, this threat had a low (3) adaptive capacity rating of 3 due to fewer than five measures being implemented. The majority of implemented measures that were optimized were in the categories of Protect, Respond, and Recover while less mature measures were indicated for the Detect category. Note, there were no responses to adaptive capacity survey questions for drought.

Portland Metro Region Natural Gas Results

The results of the natural gas vulnerability analysis in the Portland Metro Region show that physical attack (7), followed by CSZ earthquake (6), windstorm (6), and wildfire (5) score the highest. **Table 34** summarizes the findings of the risk assessment in the Portland Metro Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the natural gas system.

Table 34: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Portland Metro Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	3	0	6
Cyberattack	0	1	1	0	2
Drought	N/A	N/A	N/A	N/A	N/A
Flood	1	1	2	0	4
Lightning	2	1	1	0	4
Physical Attack	2	1	1	3	7
Wildfire	2	1	2	0	5
Windstorm	3	1	2	0	6
Winter Storm	2	1	1	0	4

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Production plants, transmission pipelines, above- and below-ground storage tanks, and local distribution systems are considered the most sensitive to earthquake hazards. Exposure to CSZ earthquake in the Portland Metro Region is moderate (2), and potential impacts are high (3). An estimated 50 percent or more of assets may be exposed during an event, more than 20 percent of customers may be affected, and it could take months for service to be restored.
- **Physical attack** results indicate that the overall vulnerability rating is primarily driven by exposure and adaptive capacity. Exposure to physical attacks in the Portland Metro Region is moderate (2), and adaptive capacity is low (3), meaning that between 0 and 50 percent of energy system assets has been exposed in the past 5 years; the system has been exposed to a physical attack on an annual to decade or more basis; and the system has a limited ability to adjust to a hazard or threat, take advantage of new opportunities, or cope with change. It is important to note that survey respondents revealed that they considered accidental damage (e.g., striking a buried pipeline when digging) when responding to questions related to physical attacks, expanding the definition of physical attack beyond intentional attacks, which may have influenced the overall vulnerability rating.
- **Wildfire** results indicate that the overall vulnerability is driven by exposure and potential impacts. Wildfires pose the greatest threat to above-ground natural gas facilities such as gate stations and meters. Exposure and potential impacts to wildfire in the Portland Metro Region are moderate (2). More than 50 percent of energy assets are in a hazard zone and more than 20 percent of customers may be affected by an event. Service may be restored in a matter of months.
- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. All assets are considered sensitive to the damaging effects of windstorms. Exposure to windstorms in the Portland Metro Region is high (3),

and potential impacts are moderate (2). An estimated 50 percent of the natural gas energy system is exposed to windstorms and events may occur on an annual basis. In addition, between 5 and 20 percent of customers may be impacted by a windstorm, but service may be restored in a matter of weeks.

Results from the adaptive capacity analysis suggest that a very high adaptive capacity exists in the region for all threats except physical attacks. One stakeholder provided responses to the adaptive capacity survey questions. In the results, every natural hazard had a very high (0) adaptive capacity rating due to at least two physical and at least two operational measures, with at least one measure being optimized. In addition, cyber-attacks had a very high (0) adaptive capacity rating due to at least five measures being implemented, with at least five measures being optimized. However, for physical attacks, this threat had a low (3) adaptive capacity rating due to fewer than five measures being implemented. As was observed in the Northwest Region, the majority of implemented measures that were optimized were in the categories of Protect, Respond, and Recover while less mature measures were indicated for the Detect category. Note, there were no responses to adaptive capacity survey questions for drought.

Southwest Region Natural Gas Results

The results of the natural gas vulnerability analysis in the Southwest region show that CSZ earthquake (6), wildfire (6), and windstorm (6) score the highest. **Table 35** summarizes the findings of the risk assessment in the Southwest Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the natural gas system.

Table 35: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Southwest Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	3	0	6
Cyberattack	1	1	1	0	3
Drought	N/A	N/A	N/A	N/A	N/A
Flood	1	1	2	0	4
Lightning	3	1	1	0	5
Physical Attack	1	1	1	1	4
Wildfire	2	1	3	0	6
Windstorm	3	1	2	0	6
Winter Storm	2	1	1	0	4

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Production plants, transmission pipelines, above- and below-ground storage tanks, and local distribution lines are considered particularly sensitive to earthquake hazards. Exposure to CSZ earthquake in the Southwest Region is moderate (2), and potential impacts are high (3). More than 50 percent of system assets in this region may be affected by an earthquake, more than 20 percent of customers may be impacted, and it could take months to restore service.

- **Lightning** results indicate that the overall vulnerability is driven by exposure. Above-ground facilities are considered sensitive to lightning, and lightning strikes may impact electronics such as telemetry and travel along pipelines, potentially causing injury. Exposure to lightning in the Southwest Region is high (3). Up to 50 percent of system assets may be exposed to hazards and lightning may occur on a monthly to annual basis.
- **Wildfire** results indicate that the overall vulnerability is driven by exposure and potential impacts. Wildfires pose the greatest threat to above-ground natural gas facilities such as gate stations and meters. Exposure to wildfire in the Southwest Region is moderate (2), and potential impacts are high (3). Up to 50 percent of energy system assets may be affected by wildfire and wildfire events occur on an annual basis. The end-user distribution network is considered the most sensitive component of the energy system; 20 percent or more of customers may be impacted by wildfire events and service may take weeks to months to restore.
- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Exposure to windstorms in the Southwest Region is high (3), and potential impacts are moderate (2). More than 50 percent of natural gas system assets may be exposed to windstorms and these events occur on an annual basis. Up to 20 percent of customers may be impacted by wind events and service may take days to weeks to restore.

Results from the adaptive capacity analysis suggest that a very high to high adaptive capacity exists in the region. Two stakeholders provided responses to the adaptive capacity survey questions. In the results, every natural hazard had a very high (0) adaptive capacity rating due to at least two physical and at least two operational measures, with at least one measure being optimized. In addition, cyber-attacks had an adaptive capacity rating of 0 due to at least five measures being implemented, with at least five measures being optimized. However, for physical attacks, this threat had a high (1) adaptive capacity rating due to at least five measures being implemented, with at least three measures being embedded or optimized. Note, there were no responses to adaptive capacity survey questions for drought.

Willamette Valley Region Natural Gas Results

The results of the natural gas vulnerability analysis in the Willamette Valley Region show that CSZ earthquake (6), wildfire (5), and windstorm (6) score the highest. **Table 36** summarizes the findings of the risk assessment in the Willamette Valley Region. The table is organized by hazards and the exposure, sensitivity, potential impact, and adaptive capacity of the natural gas system.

Table 36: *Exposure, sensitivity, potential impact, adaptive capacity, and overall vulnerability ratings for hazards in the Willamette Valley Region.*

Hazard	Exposure	Sensitivity	Potential Impacts	Adaptive Capacity	Overall Vulnerability Rating
CSZ	2	1	3	0	6
Cyberattack	0	1	1	0	2
Drought	N/A	N/A	N/A	N/A	N/A
Flood	1	1	2	0	4
Lightning	2	1	1	0	4
Physical Attack	1	1	1	3	6
Wildfire	2	1	2	0	5
Windstorm	3	1	2	0	6
Winter Storm	2	1	1	0	4

- **CSZ earthquake** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. Production plants, transmission pipelines, above- and below-ground storage tanks, and local distribution lines are all sensitive to CSZ earthquake hazards. Exposure to earthquake hazards in the Willamette Valley is moderate (2), and potential impacts are high (3). More than 50 percent of system elements are exposed to earthquake hazards. Production, transmission, storage, and end-user distribution networks are all sensitive components of the energy system in the Willamette Valley Region. Furthermore, more than 20 percent of customers may be impacted by an earthquake hazard and service may be restored in a matter of months.
- **Wildfire** results indicate that the overall vulnerability is driven by exposure and potential impacts. Above-ground storage tanks, transmission pipelines, and local distribution are considered particularly sensitive to wildfire hazards. Between 1 and 20 percent of system assets may be exposed and wildfires occur on an annual basis. Transmission, storage, and end-user distribution network are all sensitive components of the natural gas energy system. An estimated 5 percent or less of customers would be impacted by wildfire hazards, and service can be restored in a matter of weeks.
- **Windstorm** results indicate that the overall vulnerability rating is primarily driven by exposure and potential impacts. All assets are considered sensitive to the damaging effects of wind. Exposure to wind hazards in the Willamette Valley is high (3), and potential impacts are moderate (2). More than 50 percent of system assets are exposed to wind hazards, and windstorms occur on an annual basis. Between 5 and 20 percent of customers may be impacted by windstorms, and service can be restored in a matter of weeks.

Results from the adaptive capacity analysis suggest that a very high adaptive capacity exists in the region for all threats except physical attacks. One stakeholder provided responses to the adaptive capacity survey questions. In the results, every natural hazard had a very high (0) adaptive capacity rating due to at least two physical and at least two operational measures, with at least one measure being optimized. In addition, cyber-attacks had an adaptive capacity rating of 0 due to at least five measures being implemented, with at least five measures being optimized. However, for physical attacks, this threat had a low (3) adaptive capacity rating due to fewer than five measures being implemented. Note, there were no responses to adaptive capacity survey questions for drought.

Limitations

As with the majority of studies, the design of the current study is subject to limitations. Understanding the constraints will facilitate interpretation of findings and guide development of future assessments. In this study, time constraints and limited access to data served as two overarching constraints that impacted the risk assessment. Specifically, insufficient access to data and limited time to continue seeking necessary data for a technical analysis resulted in the need to modify the risk assessment approach for the electric and natural gas sectors. As a consequence, risk assessments between the (1) liquid fuels and (2) electric and natural gas energy subsectors represent distinct combinations of technical analysis, interviews, and surveys. Further, due to the nature of human-caused threats, the technical analysis approach for natural hazards cannot be directly translated to analysis of human-caused threats. For example, while geographic hazard layers can be developed for the natural hazards analyzed, the same cannot be generated for cyberattacks or physical attacks, as these threats can be observed at any geographic location of the energy system. Although the survey was structured to mirror the technical analysis approach and maximize consistency, results from distinct approaches cannot be directly compared. Results within a given approach can, however, be interpreted relative to each other.

Some limitations apply regardless of the approach implemented. For example, scope concentrated efforts on vulnerabilities of energy systems directly related to threats. This limited consideration of vulnerabilities of energy systems stemming from dependencies within the energy sector (e.g., liquid fuels and natural gas systems depend on electricity) and outside the energy sector (e.g., transportation plays a significant role in the liquid fuels system). Additionally, data had to be aggregated, either at the state or regional level. This limits variability and prevents identification of patterns at finer scales. Also, time constraints did not allow for validation of some of the findings. In addition, future climate change analysis for hazards was limited by the availability of data. For example, at the time of analysis, there were no spatially explicit climate change projections of drought indices for the entire state of Oregon. This constrains analysis of future-based scenarios. In public sector engagement, significant effort was dedicated to diversifying perspectives in the feedback provided, including geographically (all regions were represented), areas of interest/specialty (including environmental justice), and organizations with which the stakeholders are associated (e.g., government, nonprofit, academic, others). However, the sample group does not reflect the general population due to limited ability to gain access to the complete scope of stakeholders. This may result in sample bias.

Regarding private sector stakeholder engagement, whether via interviews or surveys, not all stakeholders provided feedback, and some feedback was incomplete, resulting in data gaps. Further, feedback was based on self-reported responses that may contain inadvertent bias and inaccuracy. Additionally, misinterpretation of concepts by respondents in stakeholder engagement efforts may result in inaccurate feedback. Finally, variability was limited by the number of respondents. This is particularly true for the natural gas subsector, which has only three service providers in the state, although all three provided responses.

Time constraints and project scope also limited data collection and analysis of social vulnerability and environmental justice issues relating to energy security. While feedback was solicited from public and private sector stakeholders and preliminary data was collected, stakeholder engagement efforts were not designed specifically around these issues, whether in the structure of the engagement or the specific outreach to stakeholder groups. Further, these issues were not variables in the analytic methods and results should be interpreted with this limitation.

For the liquid fuels subsector, the technical analysis was employed for natural hazards. This approach relied on feedback from private sector stakeholders in the liquid fuels subsector, which is subject to the same limitations outlined above for the hybrid survey and stakeholder engagement in general. In addition, the structure of interviews and surveys implemented in stakeholder engagement efforts was not directly comparable to data collected for the electric and natural gas subsector for adaptive capacity ratings. The approach may have contributed to limited variability and may not provide a comprehensive picture of adaptive capacity measures implemented in the liquid fuels subsector. Although the technical analysis was robust, bounds to the analysis were required. For example, when identifying hazard zones, thresholds were identified to estimate the highest-risk geographic regions. However, it is well-recognized that hazards may be experienced outside of those bounds. Relatedly, the Oregon state boundary was applied regarding the infrastructure evaluated. However, because liquid fuels are imported rather than produced in Oregon, infrastructure outside of the state plays a significant role in the resilience of the liquid fuels system. Finally, evaluation of potential impact was limited to fuel storage. As in the case of imports, other aspects of the system (e.g., pipelines for transmission) contribute to resilience.

It is important to highlight that the information provided represents a snapshot in time. The data provided in the report may not be accurate or complete at the time of a disaster or hazard event. In addition, this work is intended for planning purposes only and updates are recommended as information changes.

Discussion and Recommendations

The approaches employed in this risk assessment enable decisionmakers to evaluate threats relative to each other within a given approach. Further, the dimensions of the analysis include exposure, sensitivity, potential impact, and adaptive capacity, and balance acute threats—those with potential relative high risk but very infrequent occurrence (or in the case of a CSZ earthquake, no occurrence in recent history)—and chronic threats—those with potential relative low risk but very frequent occurrence. For example, while CSZ earthquake overall vulnerability ratings fall in the moderate category for the liquid fuels subsector, the Northwest, Portland Metro, Southwest, and Willamette Valley Regions received an overall vulnerability rating of 7, which is the second-highest score of all natural hazards across all regions, indicating the significance of a CSZ earthquake threat to the liquid fuels system. These attributes of the design inform interpretation of results and underlay the discussion and recommendations that follow. The following sections discuss vulnerabilities identified as high-priority and future considerations. All priorities and recommendations reflect the opinions of the analytic team – CNA and Haley and Aldrich – and may not represent the position of ODOE or the State of Oregon.

PRIORITY VULNERABILITIES

Several high-priority vulnerabilities for Oregon energy systems to address have been identified through the risk assessment by the analytic team (CNA and Haley and Alrdrich) First, all three energy systems are vulnerable to a CSZ earthquake, windstorms, and wildfire. CSZ earthquake represents one of the highest potential impacts to liquid fuels storage. Efforts are underway to improve the seismic resilience of liquid fuel storage in Lane, Multnomah, and Columbia Counties,[167] and ODOE is actively working to identify opportunities to expand liquid fuel storage at public facilities to mitigate the impacts of a seismic event. Electric system assets, including transmission and distribution, and storage facilities are vulnerable to a CSZ earthquake hazard. Hardening of substations and implementation of early warning systems with seismometers and sensors may decrease these vulnerabilities. Natural gas assets are vulnerable to a CSZ earthquake, transmission pipelines, above- and below-ground storage tanks, and local distribution lines. These assets need to be protected from seismic risks through hardening, retrofitting, and containment.

Windstorms indirectly impact the liquid fuels system via impacts to interdependencies, including roads and electricity. Therefore, the best efforts to manage this vulnerability will focus on backup power and alternate access/routes. Electric system assets that are vulnerable to windstorms include transmission and distribution, production, and storage. Upgrades to transmission and distribution lines and equipment, undergrounding transmission lines, and breakaway disconnect systems may help to reduce failure. In the natural gas system, wind had the highest exposure rating, and survey respondents indicated that assets that are vulnerable to windstorms may include transmission, distribution, storage, and end user networks, though specifics behind this sensitivity are not known. Anchoring equipment, building new structures to meet design specifications, and providing incident command system training for all staff may help to reduce vulnerabilities. Given the statewide sensitivity to wind, additional efforts to physically harden elements, improve design specifications, and contingency systems for shutoffs have multi-hazard benefits.

Wildfire threatens liquid fuels system assets, including bulk distributors and end users by damaging equipment or igniting stored fuels. Liquid fuels are also vulnerable to impacts to interdependencies, including roads that are used for the majority of liquid fuel distribution and the electric system. Electric system assets, including transmission lines and substations, are particularly vulnerable to the effects of wildfire. Natural gas system assets, including above-ground facilities such as gates and stations, are vulnerable to wildfire. Remote-operated valves, subdivided pipeline networks, defensible spaces for above-ground facilities, and the development of shutoff systems for end users in high-risk areas may be implemented to increase resilience. With the expectation that extreme fire weather will increase, robust planning and mitigation investments across all energy systems will be required.

Second, the liquid fuels and electric systems are vulnerable to winter storms. The highest potential impacts to liquid fuel storage are also from winter storms, and freezing temperatures can cause equipment failure and damage to pipes due to material expansion and contraction relating to temperature change. In addition, roadways and trucking are a key component of the liquid fuels distribution system. Road disruptions due to snow, ice, and debris can impact the functionality of the liquid fuels system. The electric system is particularly vulnerable to snow and ice buildup on transmission and distribution assets, and four owner/operators indicated that more than 20 percent of their customers may experience disruptions. Because the liquid fuels subsector is dependent on the electricity subsector, efforts to increase electric system resilience to winter storms benefits both subsectors.

Third, the liquid fuels and natural gas systems are vulnerable to lightning strikes. Liquid fuel has higher vulnerability to lightning in the Eastern, Cascades, and Southwest regions, but all regions have moderate vulnerability. Lightning has the most potential to cause ignition of liquid fuels by direct strike to pipelines or storage, and above-ground assets are more vulnerable than below-ground assets. Lightning poses the most risk to above-ground natural gas assets as well. Depending on the location of the strike, it could lead to large-scale outage scenarios that could affect transmission and distribution assets.

Finally, there are some regions with unique vulnerabilities. For example, owner/operators of the electric system in the Portland Metro region reported higher vulnerability to drought than other regions in the state. Since there are 105 hydropower facilities and four federal hydroelectric dams with roughly 50 percent of the state's electric power reliant upon those facilities, this finding is important to flag for future analysis and to better articulate the risks. In addition, flood risk was rated low across all systems and regions, with the exception of liquid fuels in the Eastern Region, which had moderate vulnerability. Given the likelihood for increased flooding due to climate change, flood risk may increase vulnerabilities statewide in the coming decades. Also, some regions report being particularly low in their adaptive capacity to respond to threats and hazards. For example, the Eastern Region has lower adaptive capacity in the liquid fuels subsector relative to other regions. Prioritization of operational and physical mitigation measures for liquid fuel resilience in this region is recommended.

The overall vulnerability of physical attacks was rated moderate in the Northwest, Portland Metro, and Willamette Valley regions for the natural gas subsector. While it is important to remember that the natural gas subsector survey respondents considered accidental damage (e.g., striking a buried pipeline while digging) when responding to physical attack survey questions, areas for improvement can still be identified. For example, higher vulnerability ratings were largely driven by low (3) adaptive capacity ratings. Specifically, each of these regions possessed zero protective measures in the Identify category, which highlights an opportunity to strengthen adaptive capacity. For the liquid fuels subsector, physical attacks in the Portland Metro region had a higher overall vulnerability compared to the other regions due to a moderate (2) potential impact rating. To date, cyberattack vulnerability is low across all regions and subsectors. However, continued refinement of protective measures across all subsectors is needed as the threat of cyberattacks increases and becomes more sophisticated.

FUTURE CONSIDERATIONS

Because the ESP is a living document, ODOE will continue work to inform advancement of resilience efforts. The following are recommendations were identified by the analytic team (CNA and Haley and Aldrich) for consideration in future ESP iterations.

Social Vulnerability and Environmental Justice: Concerns around social vulnerability and environmental justice vary across and within regions. Although the scope of analysis in this first iteration of the ESP did not include analysis of social vulnerability and environmental justice related to energy security, it did include stakeholder engagement activities to improve understanding of these issues throughout the state. It would be beneficial build off of the information provided by stakeholders and conduct targeted analysis of specific topics including but not limited to: the disproportionate impact of energy outages on vulnerable groups; the increasing access burden (cost-driven) for energy security on low-income households as the energy markets continue to face mounting costs related to hazard mitigation and response and recovery; and opportunities for environmental justice concerns related to energy infrastructure risks and impacts to communities to be addressed via future energy system upgrades.

Energy Transition: As Oregon is making efforts to support the transition to renewable energy, a more in-depth analysis of how increases in solar, wind and micro-grids can support enhanced resilience of the energy systems to specific vulnerabilities (for example via more redundancy) and how they may introduce unique vulnerabilities (for example to winter storms or wind conditions). As is currently taking place, continued collaboration is recommended between the ODOE ESP team and the Oregon Energy Strategy team, which is actively working to identify pathways to achieving the state's energy policy objectives. This collaboration will inform analysis and identification of emerging vulnerabilities.

Methodology: Although robust data was secured for the liquid fuels subsector, constraints of this project resulted in limited access to data in the electric and natural gas subsectors. As a result, two approaches to the risk assessment were adopted: (1) a technical, geospatial analysis, and (2) a self-assessment in the form of a survey completed by private sector stakeholders in the electric and natural gas subsectors. Even with the survey being structured to parallel the technical analysis, these mixed methods present challenges for the interpretation of findings and comparison of results across energy systems. Continued efforts are recommended to secure robust and detailed data on the electric and natural gas systems to support future technical analyses. If securing the required data is not possible, considering use of a consistent method across all energy subsectors would facilitate interpretation.

Should the survey approach be implemented in future iterations of the ESP, prioritizing efforts to maximize robust and complete responses from private sector stakeholders is recommended. For example, stakeholders in the electric and liquid fuels subsectors provided no information related to potential impacts from physical attacks, yielding artificially low vulnerability ratings. Similarly, natural gas respondents provided no feedback pertaining to drought. Efforts are also recommended to improve understanding of the motives behind the lack of responses so that future efforts can capture these areas of vulnerability. In addition, a process to validate results and interpretation of findings would strengthen future iterations.

Should the technical analysis approach be implemented, exposure and sensitivity is recommended to be evaluated on a regional scale rather than statewide to identify variability more thoroughly across the state. If the technical analysis is employed for liquid fuels, gaining access to data about propane generation will support assessment of those system elements.

Region Delineation: Exploration of the impact(s) of how the ODEM-delineated regions influence findings is recommended. For example, stakeholders in regions that include a coastal area expressed concern that coastal risks are under-appreciated. If necessary, adjusting regional delineations may be considered.

Dependencies: Because dependencies exist within the energy sector (e.g., liquid fuels and natural gas systems depend on electricity) and outside the energy sector (e.g., transportation plays a significant role in the liquid fuels system), continuing work to identify and evaluate the highest-priority dependencies and their impact(s) as additional data is available in future analyses is recommended.

Hazards: For future USDOE Energy Security Plan updates or other ODOE studies in support of energy security, there are additional hazards that may be considered:

1. Extreme heat: Centered on the increasing frequency and severity of days exceeding 95 Fahrenheit each year and “heat dome” events, with attention paid to potential peak demand models (if those can be obtained), increased outage risks, and economic analysis of potential impacts on end users.
2. Volcanic activity: Centered on potential lahars and ashfalls that could occur along the Cascade Mountain range and impact the system elements and surrounding communities.

3. Coastal hazards: If more comprehensive data or new research becomes accessible concerning the transmission and distribution infrastructure that supports coastal communities, along with the specific vulnerabilities and effects of coastal hazards such as sea level rise, flooding, and erosion, this information can inform future mitigation strategies for coastal regions.
4. Climate change: Research on the impacts of climate change in Oregon continue to evolve year-upon-year. As updated data is available to support more in-depth analysis of climate-driven increases in frequency and severity of extreme heat and drought, it is highly recommended this new data inform future analysis of these two hazards. For example, The River Management Joint Operating Committee 2018 study on climate-driven changes in temperature and rainfall impacts to the Columbia River Basin can be leveraged for future drought analysis (though it does not cover the full State of Oregon), in addition to a recent study by Oregon State University using projections of future drought based on downscaled climate model simulations for which data is not yet publicly available.[168, 169] These can provide insight on climate-driven potential for increased severity and frequency of drought conditions that may impact management of electric supply to the state, which may be of particular importance for the densely populated Portland Metro Region. Relatedly, additional research is needed regarding the vulnerability of the natural gas system to drought. In particular, given that future climate scenarios may indicate adverse impacts to electric system generation capacity, the interdependency impacts to natural gas would benefit from additional analysis.

As a final note, when prioritizing mitigation measures for implementation, an important consideration is cost-effectiveness. The cost-effectiveness for resilience investments for energy systems is understudied and generally poorly understood.[170] However, available research indicates that operational measures, efficiency improvements, and policy interventions offer relatively lower cost-effectiveness. Physical solutions such as backup power supply, hardening upgrades and undergrounding or upgrading system components tend to be more cost-effective.[171, 172] A resilience investment, such as replacing a pole or instituting vegetation management, compared to their monetized benefits in terms of avoided power disruption, loss of service or load, and recovery time can be modeled using various economic tools (cost-benefit analysis; regional economic models, input-output models). Life cycle cost analysis can be used to assess the cost of acquiring, owning, and operating a resilient measure over the life of that system. These analyses can support owner/operators and regulators with justification for higher-cost physical measures where necessary and can support the decision to make relatively lower-cost interventions that shore up operational and policy enablers for enhanced resilience. Details of prioritized mitigation measures for each energy system to address the vulnerabilities identified in each region are discussed in the Risk Mitigation Measures Report.

References

[1] Oregon Department of Transportation. (2023). *State Highway Freight System. https://edcoinfo.com/wp-content/uploads/2017/04/FreightSystem-Map.pdf*

[2] U.S. Energy Information Administration. (2024). *Petroleum Product Terminals*. https://atlas.eia.gov/datasets/c3c2e337bee54706a3564b8889b8848d_36/explore?location=5.348422%2C-15.983711%2C1.35.

[3] Oregon Department of Environmental Quality. (2024). *Oregon Fuels Reporting System*. https://cfprt.deq.state.or.us/Login.aspx?ReturnUrl=%2f.

[4] U.S. Energy Information Administration. (2023). *Petroleum Product Pipelines*. https://atlas.eia.gov/datasets/b93f85a642b14dc6a46fe041c5dc2929_0/explore?location=33.634166%2C-95.221420%2C3.85.

[5] U.S. Department of Energy. (2024). *Alternative Fuels Data Center*. https://afdc.energy.gov/.

[6] U.S. Census Bureau. (2020). *USA Census Populated Place Areas*. https://hub.arcgis.com/content/4e75a4f7daaa4dfa8b9399ea74641895/about.

[7] Bonneville Power Administration. (2014). *Quadrennial Energy Review Transmission*. United States Department of Energy. www.energy.gov/sites/prod/files/2014/07/f17/portland_mainzerelliot_presentation_qer_0.pdf

[8] U.S. Energy Information Administration. (2023). *Natural Gas Interstate and Intrastate Pipelines*. https://atlas.eia.gov/datasets/eia::natural-gas-interstate-and-intrastate-pipelines/about.

[9] U.S. Environmental Protection Agency. (2022). *Emissions & Generation Resource Integrated Database (eGRID)*. https://www.epa.gov/egrid.

[10] Homeland Infrastructure Foundation Level Data. (2023). *Transmission Lines*. https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::transmission-lines/about.

[11] PowerOutage.us. (2024). *Oregon*. https://poweroutage.us/area/state/oregon (Accessed on April 24, 2024).

[12] Homeland Infrastructure Foundation Level Data. (2023). *Natural Gas Receipt Delivery Points.* https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::natural-gas-receipt-delivery-points/about.

[13] Oregon Public Utility Commission. n.d. *Oregon Public Utility Commission Regulated Gas Utility Territories*. https://www.oregon.gov/puc/utilities/Documents/MAP-GasCompany.pdf.

[14] State of Oregon. (2024). *Overview of the Nine Tribes.* Oregon Department of Human Services. www.oregon.gov/odhs/tribal-affairs/pages/tribes.aspx

[15] State of Oregon. (2024). *Oregon Counties.* Oregon.gov. www.oregon.gov/pages/counties.aspx

[16] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/county-population.aspx

[17] US Census Bureau. (2022). *State Profiles – Oregon.* Census Data. https://data.census.gov/profile?q=Oregon+population

[18] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map

[19] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/city-population.aspx

[20] CH2M Hill. (2022). *Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification*. Oregon Department of Transportation.

[21] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map

[22] CH2M Hill. (2022). *Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification*. Oregon Department of Transportation.

[23] State of Oregon. (2024). *Hospital Reporting Information.* Oregon Health Authority Office of Health Analytics. www.oregon.gov/oha/HPA/ANALYTICS/Pages/index.aspx

[24] US Energy Information Administration. (2024). *Oregon State Profile and Energy Estimates: Profile Analysis.* www.eia.gov/state/analysis.php?sid=OR

[25] TC Energy. (2024). *Gas Transmission Northwest.* www.tcenergy.com/operations/natural-gas/gas-transmission-northwest/
[26] State of Oregon. (2024). *Overview of the Nine Tribes.* Oregon Department of Human Services. www.oregon.gov/odhs/tribal-affairs/pages/tribes.aspx
[27] State of Oregon. (2024). *Oregon Counties.* Oregon.gov. www.oregon.gov/pages/counties.aspx
[28] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/county-population.aspx
[29] US Census Bureau. (2022). *State Profiles – Oregon.* Census Data. https://data.census.gov/profile?q=Oregon+population
[30] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[31] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/city-population.aspx
[32] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[33] Oregon Department of Transportation (ODOT). (2023). *Oregon Official State Map*. www.oregon.gov/odot/Data/Documents/Map_Official_State_Front.pdf
[34] CH2M Hill. (2022). *Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification*. Oregon Department of Transportation.
[35] US Department of Energy. (2023, July). *Pacific Northwest Critical Energy Infrastructure Study*.
[36] US Energy Information Administration. (2024). *Oregon State Profile and Energy Estimates: Profile Analysis.* www.eia.gov/state/analysis.php?sid=OR
[37] State of Oregon. (2024). *Overview of the Nine Tribes.* Oregon Department of Human Services. www.oregon.gov/odhs/tribal-affairs/pages/tribes.aspx
[38] State of Oregon. (2024). *Oregon Counties.* www.oregon.gov/pages/counties.aspx
[39] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/county-population.aspx
[40] US Census Bureau. (2022). *State Profiles – Oregon.* Census Data. https://data.census.gov/profile?q=Oregon+population
[41] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[42] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[43] Oregon Department of Transportation (ODOT). (2023). *Oregon Official State Map*. www.oregon.gov/odot/Data/Documents/Map_Official_State_Front.pdf
[44] CH2M Hill. (2022). *Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification*. Oregon Department of Transportation.
[45] State of Oregon. (2024). *Oregon Counties.* Oregon.gov. www.oregon.gov/pages/counties.aspx
[46] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/county-population.aspx
[47] US Census Bureau. (2022). *State Profiles – Oregon.* Census Data. https://data.census.gov/profile?q=Oregon+population
[48] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[49] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[50] Department of Land Conservation and Development (DLCD). (2020). *Oregon Natural Hazards Mitigation Plan*. www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[51] US Energy Information Administration. (2024). *Oregon State Profile and Energy Estimates: Profile Analysis.* www.eia.gov/state/analysis.php?sid=OR
[52] State of Oregon. (2024). *Overview of the Nine Tribes.* Oregon Department of Human Services. www.oregon.gov/odhs/tribal-affairs/pages/tribes.aspx
[53] State of Oregon. (2024). *Oregon Counties.* Oregon.gov. www.oregon.gov/pages/counties.aspx
[54] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/county-population.aspx

[55] US Census Bureau. (2022). *State Profiles – Oregon.* Census Data. https://data.census.gov/profile?q=Oregon+population
[56] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[57] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[58] Oregon Department of Transportation (ODOT). (2023). *Oregon Official State Map*. [map]. Salem, OR: ODOT. www.oregon.gov/odot/Data/Documents/Map_Official_State_Front.pdf
[59] CH2M Hill. (2022). *Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification*. Oregon Department of Transportation.
[60] State of Oregon. (2024). *Oregon Counties.* www.oregon.gov/pages/counties.aspx
[61] State of Oregon. (2024). *Oregon Blue Book – Almanac & Fact Book.* Oregon Secretary of State. https://sos.oregon.gov/blue-book/Pages/local/county-population.aspx
[62] US Census Bureau. (2022). *State Profiles – Oregon.* Census Data. https://data.census.gov/profile?q=Oregon+population
[63] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[64] FEMA. (2024). *National Risk Index.* FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[65] Oregon Department of Transportation (ODOT). (2023). *Oregon Official State Map*. [map]. Salem, OR: ODOT. www.oregon.gov/odot/Data/Documents/Map_Official_State_Front.pdf
[66] CH2M Hill. (2022). *Seismic Lifelines Evaluation, Vulnerability Synthesis, and Identification*. Oregon Department of Transportation.
[67] Oregon Department of Land Conservation and Development (DLCD). (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[68] Fleishman, E., editor. (2023). *Sixth Oregon Climate Assessment*. Oregon Climate Change Research Institute, Oregon State University, Corvallis. https://blogs.oregonstate.edu/occri/oregon-climate-assessments.
[69] US Department of Energy: Cybersecurity, Energy Security and Emergency Response. (2021). *State of Oregon Energy Sector Risk Profile*.
[70] Cybersecurity and Infrastructure Security Agency (CISA) with the National Drought Resilience Partnership. (2021). *Drought and Infrastructure, A Planning Guide*.
[71] Restricted information (2023).
[72] Riahi, K., Rao, S., Krey, V., Cho, C., Chirkov, V., Fischer, G., Kindermann, G., Nakicenovic, N., & Rafaj, P. (2011). *RCP 8.5: A Scenario of Comparatively High Greenhouse Gas Emissions*. https://doi.org/10.1007/s10584-011-0149-y
[73] IBM. *What Is a cyberattack*. www.ibm.com/topics/cyber-attack
[74] NIST. *Cyber Attack*. https://csrc.nist.gov/glossary/term/cyber_attack
[75] Cybersecurity and Infrastructure Security Agency (CISA) with the National Drought Resilience Partnership. (2021). *Drought and Infrastructure, A Planning Guide*.
[76] O'Neill, L., Koszuta, M., Siler, N., & Fleishman, E. (2023). *Historical and Projected Future Drought in Oregon*. www.oregon.gov/owrd/Documents/OWRD_drought_summary_Dec_2023%20(Siler%20Comment).pdf
[77] Pytlak, E., Frans, C., Duffy, K., Johnson, J., Nijssen, B. and Chegwidden, O., & Rupp, D. (2018). *Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies: Second Edition (RMJOC-II). Part 1: Hydroclimate Projections and Analysis*. https:// rmjoc-ll-report-part-l.pdf
[78] O'Neill, L., Koszuta, M., Siler, N., & Fleishman, E. (2023). *Historical and Projected Future Drought in Oregon*. www.oregon.gov/owrd/Documents/OWRD_drought_summary_Dec_2023%20(Siler%20Comment).pdf
[79] US Department of Energy: Cybersecurity, Energy Security and Emergency Response. (2021). *State of Oregon Energy Sector Risk Profile.*
[80] Oregon Office of Emergency Management (2021). *State of Oregon Initial After-Action Review of the June 2021 Excessive Heat Event.*
[81] Oregon Department of Land Conservation and Development (DLCD). (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[82] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf

[83] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[84] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[85] Oregon Department of Energy. (2023). *Draft Oregon Energy Security Plan*. www.oregon.gov/energy/safety-resiliency/Documents/2023-Draft-Oregon-Energy-Security-Plan.pdf
[86] Oregon Department of Land Conservation and Development (DLCD). (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[87] Washington County. (2024). *Local Earthquakes*. Washington County Oregon. www.washingtoncountyor.gov/emergency/local-earthquakes
[88] EcoNorthwest. (2022). *Impacts of Fuel Releases from CEI Hub Due to a Cascadia Subduction Zone Earthquake*.
[89] Madin, I. P., Franczyk, J. J., Bauer, J. M., & Azzopardi, C. J. M. (2021). *Oregon Seismic Hazard Database (OSHD), release 1.0 (OSHD-1).* https://pubs.oregon.gov/dogami/dds/p-OSHD-1.htm
[90] Priest, G. R., Witter, R. C., Zhang, Y. J., Wang, K., Goldfinger, C., Stimely, L. L., English, J. T., Pickner, S. G., Hughes, K. L. B., Willie, T. E., & Smith, R. L. (2013). *Tsunami Inundation Scenarios for Oregon*. https://pubs.oregon.gov/dogami/ofr/p-O-13-19.htm
[91] Burns, W. J., Mickelson, K., & Madin, I. P. (2021). *Statewide Landslide Information Database for Oregon (SLIDO).* www.oregon.gov/dogami/slido/Pages/data.aspx
[92] Madin, I. P., Franczyk, J. J., Bauer, J. M., & Azzopardi, C. J. M. (2021). *Oregon Seismic Hazard Database (OSHD), Release 1.0 (OSHD-1)*. https://pubs.oregon.gov/dogami/dds/p-OSHD-1.htm
[93] Cybersecurity and Infrastructure Security Agency. *Malware, Phishing, and Ransomware*. www.cisa.gov/topics/cyber-threats-and-advisories/malware-phishing-and-ransomware
[94] Cybersecurity and Infrastructure Security Agency. *Defining Insider Threats.* www.cisa.gov/topics/physical-security/insider-threat-mitigation/defining-insider-threats#:~:text=Cyber%20%2D%20Cyber%20threat%20includes%20theft,%2C%20devices%2C%20or%20the%20internet
[95] United States Department of Energy. (2012). *Electricity Subsector Cybersecurity Risk Management Process*. www.energy.gov/sites/prod/files/Cybersecurity%20Risk%20Management%20Process%20Guideline%20-%20Final%20-%20May%202012.pdf
[96] United States Department of Energy. (2015). *Increasing the Resilience, Reliability, Safety, and Asset Security Of TS&D Infrastructure*. www.energy.gov/sites/prod/files/2015/04/f22/QER%20ch2%20final_1.pdf
[97] Oregon Department of Energy. (2017). *Fuel Action Plan*. www.oregon.gov/energy/safety-resiliency/Documents/Oregon-Fuel-Action-Plan.pdf
[98] Northwest Natural. (2019). *NW Natural Cybersecurity Overview*. https://oregonpuc.granicus.com/MetaViewer.php?view_id=2&clip_id=428&meta_id=22259
[99] Northwest Natural. (2020). *Environmental, Social and Governance (ESG) Report*.
[100] Northwest Natural. (2021). *Environmental, Social and Governance (ESG) Report*.
[101] Goodin, D. (2020). US Natural Gas Operator Shuts Down for 2 Days after Being Infected by Ransomware. *Ars Technical*. https://arstechnica.com/information-technology/2020/02/ransomware-infection-shuts-down-us-natural-gas-operator-for-2-days/
[102] Portland General Electric. (2022). *2022 Environmental, Social & Governance (ESG) Report*. https://assets.ctfassets.net/416ywc1laqmd/6DyinUJ9dQKg7ZnpXEbMel/5d9c2cf8013e5d9c8f84a6a555498f7a/103122_PGE_2022ESG_R23b.pdf
[103] Portland General Electric (2023). *2023 Proxy Statement: Advancing Toward a Clean Energy Future*. https://investors.portlandgeneral.com/static-files/0a7e1267-ea72-4e91-ac58-1effcf711680
[104] Oregon State Treasury. *Sustainable Investing*. www.oregon.gov/treasury/invested-for-oregon/pages/sustainable-investing-governance.aspx
[105] Fleishman, E., editor. (2023). *Sixth Oregon Climate Assessment*. Oregon Climate Change Research Institute, Oregon State University, Corvallis. https://blogs.oregonstate.edu/occri/oregon-climate-assessments.

[106] Oregon Department of Land Conservation and Development (DLCD). (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[107] Williams, A. P., Cook, E. R., Smerdon, J. E., Cook, B. I., Abatzoglou, J. T., Bolles, K., Baek, S. H., Badger, A. M., & Livneh, B. (2020). *Large Contribution from Anthropogenic Warming to an Emerging North American Megadrought*. doi: 10.1126/science.aaz9600
[108] Oregon Department of Land Conservation and Development (DLCD). (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[109] Multnomah County. (2021). *Preliminary Review on Excessive Heat Deaths*.
[110] Simon, M. (2020). How a "Heat Dome" Forms – and Why this One Is So Perilous. *Wired.* www.wired.com/story/how-a-heat-dome-forms/
[111] Oregon Department of Energy. (2023). *Draft Oregon Energy Security Plan.* www.oregon.gov/energy/safety-resiliency/Documents/2023-Draft-Oregon-Energy-Security-Plan.pdf
[112] FEMA National Risk Index. (2023). *Drought Risk Index*. https://hazards.fema.gov/nri/drought
[113] US Drought Monitor. (2024). https://droughtmonitor.unl.edu/
[114] Oregon Department of Land Conservation and Development (DLCD). (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[115] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[116] NOAA. (2024). *What Are Atmospheric Rivers?* www.noaa.gov/stories/what-are-atmospheric-rivers
[117] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[118] Dalton, M., & Fleishman., E., editors. (2021). *Fifth Oregon Climate Assessment*. Oregon Climate Change Research Institute, Oregon State University, Corvallis. https://blogs.oregonstate.edu/occri/oregon-climate-assessments/.
[119] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[120] Dalton, M., & Fleishman., E., editors. (2021). *Fifth Oregon Climate Assessment*. Oregon Climate Change Research Institute, Oregon State University, Corvallis. https://blogs.oregonstate.edu/occri/oregon-climate-assessments/.
[121] Frankson, R., Kunkel, K. E., Champion, S. M., Stevens, L. E., Easterling, D. R., Dello, K., Dalton, M., Sharp, D., & O'Neil, L. (2022). *Oregon State Climate Summary 2022*. NOAA Technical Report NESDIS 150-OR.
[122] Chegwidden, O. S., Rupp, D. E., & Nijssen, B. (2020). *Climate Change Alters Flood Magnitudes and Mechanisms in Climatically-Diverse Headwaters across the Northwestern United States*. Environmental Research Letters. https://doi.org/10.1088/1748-9326/ab986f
[123] Queen, L. E., Mote, P. W., Rupp, D. E., Chegwidden, O., & Nijssen, B. (2021). Ubiquitous Increases in Flood Magnitude in the Columbia River Basin under Climate Change. *Hydrology and Earth System Sciences.* https://doi.org/10.5194/hess-25-257-2021
[124] Dalton, M., & Fleishman., E., editors. (2021). *Fifth Oregon Climate Assessment*. Oregon Climate Change Research Institute, Oregon State University, Corvallis. https://blogs.oregonstate.edu/occri/oregon-climate-assessments/.
[125] Oregon Department of Energy. (2023). *Draft Oregon Energy Security Plan.* www.oregon.gov/energy/safety-resiliency/Documents/2023-Draft-Oregon-Energy-Security-Plan.pdf
[126] Oregon DLCD. (2015). *State Digitized Flood Layer*. www.oregon.gov/dogami/hazvu/Pages/hazards-assets.aspx
[127] FEMA. (2024). *National Risk Index*. FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[128] Salathé, E. P., Hamlet, A. F., Mass, C. F., Lee, S.-Y., Stumbaugh, M., & Steed, R. (2014). Estimates of Twenty-First-Century Flood Risk in the Pacific Northwest Based on Regional Climate Model Simulations. *Journal of Hydrometeorology.* https://doi.org/10.1175/jhm-d-13-0137.1
[129] Romps, D. M., Seeley, J. T., Vollaro, D., & Molinari, J. (2014). Projected Increase in Lightning Strikes in the United States Due to Global Warming. *Science.* https://doi.org/10.1126/science.1259100

[130] Cruz, A. M., & Krausmann, E. (2013). Vulnerability of the Oil and Gas Sector to Climate Change and Extreme Weather Events. *Climatic Change.* https://doi.org/10.1007/s10584-013-0891-4
[131] Folden-Vencil, Kristian. (2020). Lightning Sparks Dozens of Large Oregon Wildfires. *OPB.* www.opb.org/article/2020/08/24/oregon-wildfires-lightning-strikes/#:~:text=Over%20the%20past%20week%2C%20thousands%20of%20lightning%20strikes,burned%20about%204%2C400%20acres%20and%20is%2030%25%20contained
[132] Cruz, A. M., & Krausmann, E. (2013). Vulnerability of the Oil and Gas Sector to Climate Change and Extreme Weather Events. *Climatic Change.* https://doi.org/10.1007/s10584-013-0891-4
[133] FEMA. (2024). *National Risk Index*. FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map
[134] Bharti Mehta, G. (2023). Physical Security vs Cybersecurity: Differences in Strategy and Their Execution at Your Workplace. *OLOID.* www.oloid.ai/blog/physical-security-vs-cyber-security/#:~:text=Physical%20security%20is%20focused%20on,that%20threats%20are%20typically%20addressed
[135] United States Department of Energy. (2015). *Increasing the Resilience, Reliability, Safety, and Asset Security of TS&D Infrastructure.* www.energy.gov/sites/prod/files/2015/04/f22/QER%20ch2%20final_1.pdf
[136] United States Department of Energy. Office of Cybersecurity, Energy Security, & Emergency Response. www.oe.netl.doe.gov/OE417_annual_summary.aspx
[137] Ryan, J., & Wilson, C. (2022). String of Electrical Grid Attacks in Pacific Northwest Is Unsolved. *OPB.* www.opb.org/article/2022/12/08/string-of-electrical-grid-attacks-in-pacific-northwest-are-unsolved/
[138] Iboshi, K. (2022). FBI Investigating 'Deliberate Physical Attack' on PGE Substation in Clackamas Area. *BizJournals.* www.bizjournals.com/portland/news/2022/12/08/substation-attack.html
[139] Bharti Mehta, G. (2023). Physical Security vs Cybersecurity: Differences in Strategy and Their Execution at Your Workplace. *OLOID*. www.oloid.ai/blog/physical-security-vs-cyber-security/#:~:text=Physical%20security%20is%20focused%20on,that%20threats%20are%20typically%20addressed
[140] United States Department of Energy. Office of Cybersecurity, Energy Security, & Emergency Response. www.oe.netl.doe.gov/OE417_annual_summary.aspx
[141] United States Department of Energy. Office of Cybersecurity, Energy Security, & Emergency Response. www.oe.netl.doe.gov/OE417_annual_summary.aspx
[142] Ryan, J., & Wilson, C. (2022). String of Electrical Grid Attacks in Pacific Northwest Is Unsolved. *BizJournals.* www.opb.org/article/2022/12/08/string-of-electrical-grid-attacks-in-pacific-northwest-are-unsolved/
[143] Westerling, A. L., Hidalgo, H. G., Cayan, D. R., & Swetnam, T. W. (2006). Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. *Science.* https://doi.org/10.1126/science.1128834
[144] Jones, M. W., Abatzoglou, J. T., Veraverbeke, S., Andela, N., Lasslop, G., Forkel, M., Smith, A. J., Burton, C., Betts, R. A., van der Werf, G. R., Sitch, S., Canadell, J. G., Santín, C., Kolden, C., Doerr, S. H., & Le Quéré, C. (2022). Global and Regional Trends and Drivers of Fire under Climate Change. *Reviews of Geophysics.* https://doi.org/10.1029/2020rg000726
[145] Abatzoglou, J. T., Battisti, D. S., Williams, A. P., Hansen, W. D., Harvey, B. J., & Kolden, C. A. (2021). Projected Increases in Western US Forest Fire Despite Growing Fuel Constraints. *Communications Earth & Environment.* https://doi.org/10.1038/s43247-021-00299-0
[146] Abatzoglou, J. T., Rupp, D. E., O'Neill, L. W., & Sadegh, M. (2021). Compound Extremes Drive the Western Oregon Wildfires of September 2020. *Geophysical Research Letters.* https://doi. org/10.1029/2021GL092520
[147] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf
[148] Zhuang, Y., Fu, R., Santer, B. D., Dickinson, R. E., & Hall, A. (2021). Quantifying Contributions of Natural Variability and Anthropogenic Forcings on Increased Fire Weather Risk over the Western United States. *Proceedings National Academy of Sciences (PNAS) USA.* https://doi.org/10.1073/pnas.2111875118.
[149] Fleishman, E., editor. (2023). *Sixth Oregon Climate Assessment*. Oregon Climate Change Research Institute, Oregon State University, Corvallis. https://blogs.oregonstate.edu/occri/oregon-climate-assessments.
[150] Oregon Department of Energy. (2023). *Draft Oregon Energy Security Plan.* www.oregon.gov/energy/safety-resiliency/Documents/2023-Draft-Oregon-Energy-Security-Plan.pdf

[151] Oregon Department of Energy. (2023). *Draft Oregon Energy Security Plan.* www.oregon.gov/energy/safety-resiliency/Documents/2023-Draft-Oregon-Energy-Security-Plan.pdf

[152] Scott, J. H., Dillon, G. K., Jaffe, M. R., Vogler, K. C., Olszewski, J. H., Callahan, M. N., Karau, E. C., Lazarz, M. T., Short, K. C., Riley, K. L., Finney, M. A., & Grenfell, I. C. (2024). *Wildfire Risk to Communities: Spatial datasets of landscape-wide wildfire risk components for the United States. 2nd Edition.* Forest Service Research Data Archive. doi: 10.2737/RDS-2020-0016-2

[153] Argonne National Laboratory. (2023). *Climate Risk and Resilience Portal (ClimRR)*. https://disgeoportal.egs.anl.gov/ClimRR/

[154] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf

[155] Dames, J. (2019). What You Need to Know About Our Windstorms in the Pacific Northwest. *KOIN.* www.koin.com/weather/what-you-need-to-know-about-our-windstorms-in-the-pacific-northwest/

[156] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf

[157] Dames, J. (2019). What You Need to Know About Our Windstorms in the Pacific Northwest. *KOIN.* www.koin.com/weather/what-you-need-to-know-about-our-windstorms-in-the-pacific-northwest/

[158] Horton, K. (2022). It's Been 60 Years Since the Northwest's Record-Breaking Columbus Day Storm. *OPB*. www.opb.org/article/2022/10/12/oregon-experience-remembering-record-breaking-columbus-day-storm-of-1962/

[159] NOAA. (2022). *Storm Prediction Center, Severe Weather Maps, Graphics and Data Page*. www.spc.noaa.gov/wcm/#data%20AND%20Field%20descriptions:%20

[160] National Weather Service. (2024). *Wind Threat Defined*. www.weather.gov/mlb/wind_threat

[161] Bourgeois, M. (2024). Initial Report Finds $72 Million in Damage from Oregon's Arctic Blast. *KOIN.* www.koin.com/weather/initial-report-finds-72-million-in-damage-from-oregons-arctic-blast/

[162] Portland Bureau of Emergency Management. (2015). *2014-2015 Winter Weather Portland NET Deployments After Action Report.*

[163] Oregon DLCD. (2020). *Oregon Natural Hazard Mitigation Plan.* www.oregon.gov/lcd/NH/Documents/Approved_2020ORNHMP_00_Complete.pdf

[164] Oregon Department of Energy. (2023). *Draft Oregon Energy Security Plan.* www.oregon.gov/energy/safety-resiliency/Documents/2023-Draft-Oregon-Energy-Security-Plan.pdf

[165] FEMA. (2024). *National Risk Index*. FEMA Mapping Information Platform. https://hazards.fema.gov/nri/map

[166] Intergovernmental Panel on Climate Change (IPCC). (2015). *IPCC Fourth Assessment Report (AR4), Working Group II Report: Climate Change 2007: Impacts, Adaptation and Vulnerability*. www.ipcc.ch/report/ar4/wg2/

[167] Oregon Senate Bill 1567. (2022). https://olis.oregonlegislature.gov/liz/2022R1/Measures/Overview/SB1567

[168] Pytlak, E., Frans, C., Duffy, K., Johnson, J.,Nijssen, B., Chegwidden, O., & Rupp, D. (2018*). Climate and Hydrology Datasets for RMJOC Long-Term Planning Studies: Second Edition (RMJOC-II). Part 1: Hydroclimate Projections and Analysis*. Bonneville Power Administration. https:// rmjoc-ll-report-part-l.pdf

[169] O'Neill, L., Koszuta, M., Siler, N., & Fleishman, E. (2023). *Historical and Projected Future Drought in Oregon*. www.oregon.gov/owrd/Documents/OWRD_drought_summary_Dec_2023%20(Siler%20Comment).pdf

[170] Sanstad, A. H., Leibowicz, B. D., Zhu, Q., Larsen, P. H., & Eto, J. H. (2022). Electric Utility Valuations of Investments to Reduce the Risks of Long-Duration, Widespread Power Interruptions, Part I: Background. *Sustainable and Resilient Infrastructure.* https://doi.org/10.1080/23789689.2022.2148450

[171] Leddy, L., Jenket, D., Thomas, D., Ericson, S., Cox, J., Grue, N., & Hotchkiss, E. (2023). *Measuring and Valuing Resilience: A Literature Review for the Power Sector*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5R00-87053. www.nrel.gov/docs/fy23osti/87053.pdf

[172] Zamuda, C. D., Larsen, P. H., Collins, M. T., Beiler, S., Schellenberg, J., & Hees, S. (2019). Monetization Methods for Evaluating Investments in Electricity System Resilience to Extreme Weather and Climate Change. *The Electricity Journal*. https://doi.org/10.1016/j.tej.2019.106641

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