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Oregon Energy Security Plan Risk Mitigation Measures 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 report contributes to the Oregon Energy Security Plan by improving understanding of potential measures that may help mitigate threats across Oregon's energy systems (liquid fuels, electricity, natural gas). Specifically, this report identifies and prioritizes mitigation measures that may improve energy security and presents an action plan to work toward increased resilience.

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SAS works to help improve decision-making during crisis operations and foster innovative solutions to challenges in the areas of public safety, emergency management, public health preparedness, homeland security, risk management, and national security.

Contents

Executive Summary

Objectives

This report contributes to the Oregon Energy Security Plan (ESP) by improving understanding of potential measures that would help mitigate threats across Oregon's energy systems (liquid fuels, electricity, natural gas). This body of work builds off the Risk Assessment Report to identify risk mitigation measures (RMMs) for an array of threats, including human-caused threats and natural hazards. While no report could analyze every possible mitigation measure, this report includes a broad suite of options that can be considered by Oregon's elected officials, government agencies, utilities and energy providers. This RMM Report was prepared by CNA and its subcontractor, Haley and Aldrich, on contract and in coordination with the Oregon Department of Energy. The team also worked closely with the Oregon Public Utility Commission staff.

The RMM Report presents the findings and results of prioritized mitigation strategies that may reduce risk, enhance recovery, and improve energy resilience to Oregon's energy systems by geographic region. Specifically, the Report:

1. Identifies mitigation measures that may reduce exposure or consequence of vulnerabilities to respective hazards by geographic region in Oregon;
2. Prioritizes mitigation measures that may reduce the exposure or consequence of vulnerabilities to respective hazards by geographic region in Oregon;
3. Presents an action plan and measures of success of prioritized mitigation measures and respective goals that may improve resilience.

Methods

Selection of RMMs was dependent on results obtained from the risk assessment across the four dimensions of analysis (exposure, sensitivity, potential impact, and adaptive capacity) and stakeholder feedback. A matrix was leveraged (not shown) to evaluate threats, system components, and RMMs, which were assigned to one of four categories, including physical, operational, policy, and training. The mitigation matrix was reviewed to identify measures that apply generally to all hazards and all systems. To address variation in hazard vulnerability by region for each energy system, an additional customized set of recommended measures was identified for each system in each region. Wherever the highest priority hazards or threats in a given region differed from the highest hazards statewide, additional measures were added to recommendations that were specific to those hazards.

Identified RMMs and preliminary results of the risk assessment were presented at a total of seven meetings (herein referred to as the meeting series), one in each of the six Oregon Department of Emergency Management regions and one with Tribal governments. For ease of interpretation in stakeholder engagement efforts, operational measures were broadly defined to include any RMM that did not qualify as a physical measure (i.e., operational measures encompassed policy and training measures). Surveys specific to each meeting solicited feedback on preliminary findings, including stakeholder prioritization of recommended RMMs.

To develop the action plan, recommended RMMs were first assigned to themes and goals (**Table 1**). Once assigned, dominant themes and goals were identified based on either stakeholder feedback or analytic results. In regions where more than three stakeholders participated in the survey – Cascades, Portland Metro, and Willamette Valley (n = 4, 8, and 5, respectively), mean prioritization scores of RMMs

by stakeholders at the meeting series were leveraged. In these regions, the three most prioritized themes and, within each theme, the two most prioritized goals and top five respective RMMs were included. In regions where stakeholder participation was limited – Eastern, Northwest, and Southwest (*n* = 2, 0, and 1, respectively), the number of RMMs recommended in each theme and goal was utilized. In this case, the three themes with the highest number of RMMs and the goal within each theme with the most recommended RMMs were included along with the respective RMMs.

***Table 1**: Themes and goals to which RMMs were assigned for development of the action plan.*

Theme	Goal
All (human-caused threats)	• Improve RMM Maturity
Rapid Detection/Recovery	• Improve Distribution Management • Secure Equipment/Supplies • Improve Impact Response • Increase Intersectoral Collaboration • Improve Situational Awareness
Redundancy	• Establish Backup Communications • Establish Backup Energy Sources • Establish Backup Facilities
Research, Planning, and Training	• Expand Planning • Expand Research • Expand Training
Robustness	• Implement Demand Response Programs • Harden, Upgrade, Weatherize Assets • Remove Assets • Segment Systems

Results

Results include a statewide, all-systems perspective as well as findings specific to each energy subsector and region. At the statewide level, RMMs related to Redundancy, Hardening, Upgrading, and Weatherizing were among the most frequent physical measures recommended while numerous RMMs related to studies, plans, and procedures were included for operational measures. The top three physical measures ranked by stakeholders included developing drone inspection capabilities and procedures, removing assets out of hazard zones, and improving maturity of measures related to the Protect category of mitigation measures for human-caused threats. The top three operational statewide measures included integrating artificial intelligence into operational plans/monitoring, generating incident after-action reviews, and conducting studies on lifeline service delivery systems and disaster resilience. At the regional scale, the threats that recommended RMMs were most frequently associated with included the Cascadia subduction zone earthquake, human-caused threats, and windstorms. This was observed for all three subsectors. In addition, wildfire was a dominant threat for which RMMs were recommended in the electric and natural gas subsectors, while winter storm was included in the top threats for liquid fuels. Prioritization of RMMs for each energy subsector varied region to region.

Action Plan

The action plan is intended to inform officials in local, county, state, and federal governments of future potential investments to reduce risk, enhance recovery, and improve resilience. RMMs are not intended to provide specific recommendations for any individual facility or system element. However, Oregon officials can use the RMMs in combination with the dominant themes and goals to guide investment and programming decisions to advance energy system resilience to the assessed hazards and threats. The priorities and recommendations in the Action Plan 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.

Action-oriented plans and measures of success are presented at a statewide, all-systems scale and region-specific scale. At the statewide, all-systems scale, stakeholder feedback identified Human-caused Threats as the highest priority theme, which had one goal associated with it – Improve RMM Maturity. This was followed by the Robustness theme, with the goals of Remove Assets, Segment Systems, and Implement Demand Response Programs. Finally, Rapid Detection/Recovery was the third most prioritized theme and included Improve Situational Awareness and Secure Equipment/Supplies goals. While prioritization varied across regions, the cumulative, regional-scale results of stakeholder feedback reveal that the most consistently prioritized theme was Robustness, followed by Rapid Detection/Recovery and then Human-caused Threats. Within the theme of Robustness, Harden, Upgrade, Weatherize Assets and Remove Assets were the most prioritized goals. For Rapid Detection/Recovery, most emphasis was placed on Improve Situational Awareness.

It is important to note the cost-effectiveness correlation of RMMs. In general, physical RMMs, particularly those emphasized in the Robustness theme, tend to be the most effective, yet most expensive to implement. In contrast, operational measures tend to have a lower cost associated with them but lower effectiveness relative to physical RMMs. Feasibility studies are necessary to execute the action plan in the most effective manner possible. Analysis of cost-effectiveness of RMMs via cost-benefit analysis, regional economic models, input-output models, and/or life cycle analysis is recommended. Further, continuation and expansion of additional studies including After Action Reports, regular review of resilience plans, risk maps and system models is recommended.

Finally, data-sharing agreements between Oregon State Government and utilities/energy companies are of highest priority for improved understanding of vulnerabilities in the energy system, particularly relating to human-caused threats, where access to granular, detailed data is very limited. Most importantly, agreements between Oregon State Government and utilities/energy companies that secure access to data in the natural gas and electric subsectors would allow Oregon government to work with energy companies and third-party consultants to conduct a technical, geospatial analysis of vulnerability, which will serve to refine the action plan.

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 Risk Mitigation Measures (RMM) Report contributes to the Oregon Energy Security Plan (ESP) by improving understanding of priority measures to support threat mitigation across energy systems in the state of Oregon. Further, this report outlines a potential path forward to improved resilience for use by Oregon officials as investment decisions are made aimed at reducing risk to energy security. This report and associated analysis were prepared by CNA and its subcontractor, Haley and Aldrich, under contract and in coordination with the Oregon Department of Energy. The team also worked closely with the Oregon Public Utility Commission staff.

The RMM Report is tied closely to the Risk Assessment Report, building off findings through literature review, technical assessment, and stakeholder engagement that identify vulnerabilities to distinct threats and RMMs with potential to mitigate said vulnerabilities. Three energy systems – liquid fuels, electricity, and natural gas – are evaluated for opportunities to reduce risk to energy security. Risk stemming from nine threats were included. Six of the threats are natural hazards: Cascadia Subduction Zone (CSZ) earthquake and tsunami, drought, flood, lightning, wildfire, windstorm, and winter storm. The remaining two threats are human caused: cyberattack and physical attack, defined as intentional attacks on energy systems. The geographic scope of the work includes two scales – statewide and regional (**Figure 1**). The regions of Oregon as defined by the Oregon Department of Emergency Management (ODEM) were used for this assessment, for consistency between government agencies.

The overarching objective of the RMM Report is to present the findings and results of prioritized mitigation strategies that may reduce risk, enhance recovery, and improve energy resilience to Oregon's energy systems by geographic region. Specifically, this body of work builds off the risk assessment to:

4. Identify mitigation measures that may reduce exposure or consequence of vulnerabilities to respective hazards by geographic region in Oregon;
5. Prioritize mitigation measures that may reduce the exposure or consequence of vulnerabilities to respective hazards by geographic region in Oregon;
6. Present an action plan and measures of success of prioritized mitigation measures and respective goals that may improve resilience.

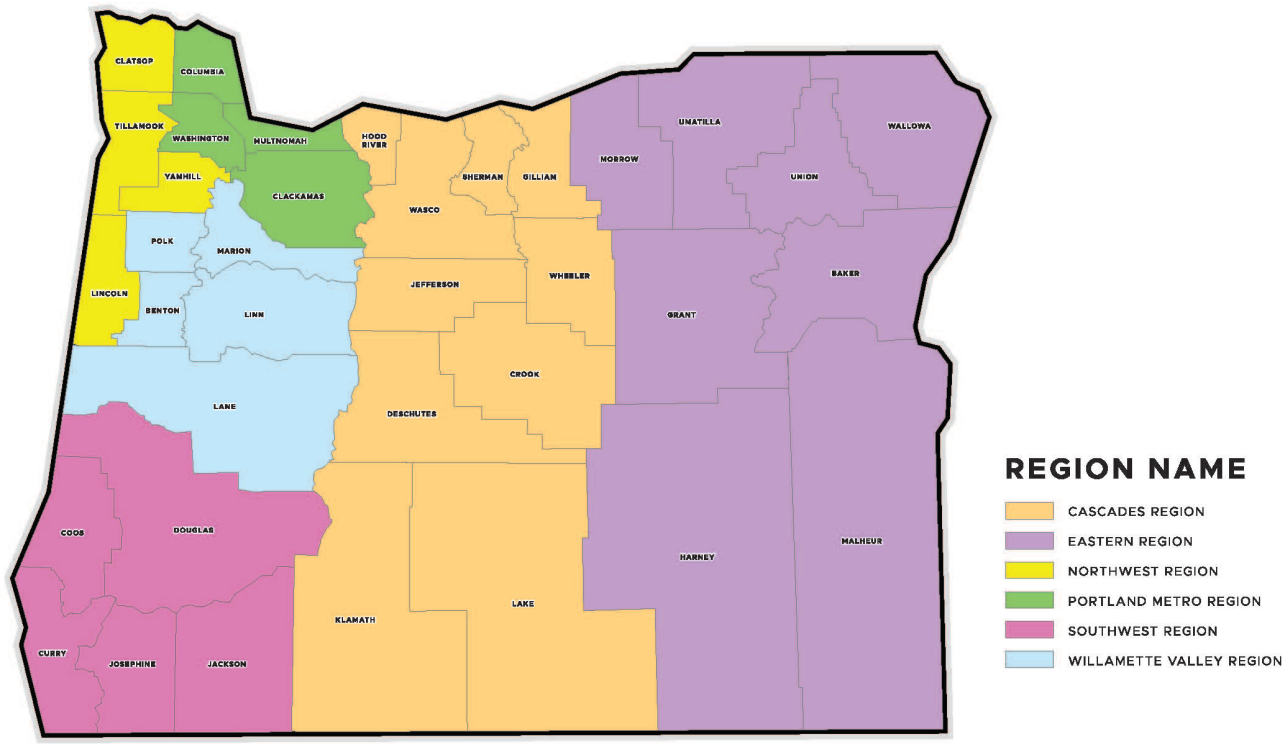


***Figure 1**: ODEM regions used in evaluation of regional level hazard vulnerability for Oregon energy system.*

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.

Methods

Identification of Risk Mitigation Measures

Selection of RMMs was dependent on stakeholder feedback and results obtained from the risk assessment (see the Risk Assessment Report) including the overall vulnerability rating and details of the four dimensions of analysis that informed the vulnerability ratings:

1. **Exposure** – evaluated by identifying the geographic footprint and frequency of the threat.
2. **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.
3. **Potential impact –** evaluated by identifying potential consequences or losses that may result from the threat.
4. **Adaptive Capacity –** evaluated for the level of preparedness and the capability to respond to and manage impacts from the threat.

For example, analyzing a system's exposure, sensitivity, and potential impact revealed how distinct hazards pose particular threats to infrastructure and operations while evaluating the status of mitigation measures implemented served to highlight adaptive capacity gaps that RMMs could address.

To improve understanding of adaptive capacity, stakeholders were asked to provide feedback on the types of mitigation measures that were implemented at the time of the stakeholder engagement effort. **Table 1** provides a summary of physical and operational mitigation measure categories related to natural hazards. **Tables 2 and 3** provide summaries of mitigation measure categories related to cyberattack and physical attack, respectively. Stakeholder engagement efforts differed for the liquid fuels subsector relative to the natural gas and electric subsectors. Stakeholders in the liquid fuels subsector were asked which physical and operational measures were implemented for natural hazards. For the electric and natural gas subsectors, stakeholders were not only asked which mitigation measure categories for natural hazards were implemented, but also the maturity of said implementation. Stakeholders were asked to provide an estimate of the maturity of each measure that is in place referencing three levels of maturity: 1.) evolve – lowest level of maturity, embed – mid-level maturity, and optimize – highest level of maturity. Additionally, all three subsectors were asked to estimate the maturity of mitigation measure categories for human-caused threats.

***Table 1**: 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

Table 2: *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 3: *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

Mitigation measures are often applicable to multiple systems and multiple hazards. Further, many mitigation measures reflect best practices in risk management and emergency management for public utilities. The following process was used to identify appropriate RMM recommendations for all energy systems and regions in Oregon.

First, stakeholder feedback was considered throughout the identification process. The primary methods of engagement included a hybrid Stakeholder Kickoff Meeting (53 attendees) and 12 surveys which included a(n) Stakeholder Kickoff Meeting Survey (*n* = 17), Energy System Threats Public Sector Survey (*n* = 48), Electricity Risk Assessment (*n* = 22), Natural Gas Risk Assessment (*n* = 3), and a Liquid Fuels Hazards and Threats Survey (*n* = 10), where n is the number of survey responses received. Comprehensive reporting on stakeholder feedback is outside the scope of this report but can be found in the Stakeholder Engagement Report.

A literature review was conducted to determine and inventory best practices for mitigation measures that have been documented and/or recommended in previous research and planning for all energy systems and hazards included in the study. The objective of the literature review was to identify relevant mitigation and risk reduction strategies that are specific to each system and hazard. See references 1-19 for a collection of sources informing the literature review.

As a tool to organize findings from the literature review, a mitigation matrix (not shown) was developed to detail measures for each energy system. The matrix organized the hazard, the mitigation action type (i.e., physical, operational, policy, or training), which system component the measure addresses (i.e., systemwide, generation, storage, transmission, or distribution), and the specific mitigation action identified. The types of mitigation measures included 1.) Physical – strategies and actions to protect against and/or reduce damage and disruption related to physical assets and structures of energy systems; 2.) Operational – strategies and actions to protect energy system business operations, core functions for business continuity, as well as system personnel from disruption in service delivery; 3.) Policy – includes legal, institutional and policy instruments (e.g., guidelines, rules, codes, and laws) that can be put in place to minimize the potential impacts to energy systems; and 4.) Training – includes formal and on-the-job training and exercise programs related to natural hazard preparedness and emergency management, cybersecurity, and physical security.

The mitigation matrix was reviewed to identify measures that apply generally to all-hazards and all-systems. These measures are general best practices for natural hazard resilience of energy systems, or for emergency management. The top hazard vulnerability ratings for each system (at a statewide level) were identified to address each energy system's unique sensitivities for specific hazards and threats. These were used to identify specific mitigation measures that address the sensitivities of each energy system to their highest vulnerability hazards.

To address variation in hazard vulnerability by region, an additional customized set of recommended measures was identified for each system in each region to support stakeholder engagement efforts across all regions and with Tribal governments. Wherever the highest rated hazards or threats differed from the highest hazards statewide, additional measures were added to recommendations that were specific to those hazards.

Prioritization of Risk Mitigation Measures

Preliminary results of the risk assessment and identified RMMs were presented to stakeholders at a total of seven meetings (herein referred to as the meeting series), one in each of the six ODEM regions (**Figure**

1) and one with Tribal governments. All content was region-specific except for the Tribal Government meeting, which included statewide data for Tribes across all regions. During the meeting series, surveys created in Slido were distributed to participants to solicit feedback on the preliminary results of the liquid fuels, electricity, and natural gas risk assessments as well as the RMMs identified. Recommended RMMs were shared with stakeholders for all energy systems in Oregon as well as RMMs specific to each region's energy subsectors. RMMs were divided into physical and operational categories. For ease of interpretation in stakeholder engagement efforts, operational measures were broadly defined as any RMM that did not qualify as a physical measure. In other words, operational measures encompassed policy and training measures. Stakeholders were asked to rank RMMs in order of priority and given the opportunity to recommend additional RMMs. Additional feedback collected from participants included input on prior stakeholder engagement activities during the project; EJ concerns; and aspects of the analysis that stakeholders resonated with or disagreed with.

Action Plan Development

A combination of analytic results and stakeholder feedback was used in the development of the action plan to identify dominant themes of RMMs across energy subsectors. For regions in which more than three stakeholders provided feedback – Cascades, Portland Metro, and Willamette Valley (n = 4, 8, and 5, respectively) – the action plan relied on stakeholder feedback. All RMMs presented to stakeholders for prioritization were assigned to a theme and goal (**Table 4**). At the statewide level and for each region, the mean prioritization score of all RMMs within each theme was calculated. This was repeated for each goal. Statewide, only RMMs that apply to all systems were included in the calculation. Regionally, all RMMs were included in the calculation, regardless of which system(s) they apply to. The three most prioritized themes were selected. Within those themes, the two most prioritized goals were selected. Of all RMMs that were associated with each selected goal, up to five of the most prioritized RMMs were included in the action plan (some had less than five RMMs). If, at any step, a tie was observed, both were included.

***Table 4**: Themes and goals to which RMMs were assigned for development of the action plan.*

Theme	Goal
All (human-caused threats)	• Improve RMM Maturity
Rapid Detection/Recovery	• Improve Distribution Management • Secure Equipment/Supplies • Improve Impact Response • Increase Intersectoral Collaboration • Improve Situational Awareness
Redundancy	• Establish Backup Communications • Establish Backup Energy Sources • Establish Backup Facilities
Research, Planning, and Training	• Expand Planning • Expand Research • Expand Training
Robustness	• Implement Demand Response Programs • Harden, Upgrade, Weatherize Assets • Remove Assets • Segment Systems

In regions where stakeholder participation was limited – Eastern, Northwest, and Southwest (*n* = 2, 0, and 1, respectively) – the action plan relied on analytic results. The RMMs selected for inclusion in the action plan were determined by first identifying the three most recommended themes and the most recommended goal within each theme (i.e., the themes and goals with the highest number of RMMs). All RMMs in each of the most recommended goals were included. As above, if a tie was observed, both were included. Though the sample size was exceedingly small, the approach based for stakeholder feedback was also applied to the Eastern and Southwest Regions and these results are included for awareness. They do not inform the action plan. No action plan specific to Tribal Governments was calculated. This is because no feedback was provided by stakeholders in Tribal Governments and the data presented to Tribal Governments was statewide. The nine federally-recognized Native American Tribal reservations are located across a diverse geographic region in the state, and energy is provided by the same regional energy providers that serve non-reservation communities.

Results

Risk Assessment Results Summary

A detailed discussion of the results from the risk assessment is available in the Risk Assessment Report. Here, a summary of key takeaways across the four dimensions of analysis (exposure, sensitivity, potential impact, and adaptive capacity) is presented. Adaptive capacity results significantly influenced recommendations of RMMs. Important insights from stakeholder maturity ratings of mitigation measures are provided in the regional results below to highlight opportunities for improvement.

Exposure

Liquid Fuels: 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 cyberattacks, flood, and physical attacks. The high (3) exposure rating for lightning, wildfire, windstorms, and winter storms indicates that greater than 60 percent of the system components 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.

Electric: The natural hazards with the highest exposure ratings across all regions for the electric system are windstorms, winter storms, and wildfire. Windstorms received an exposure rating of 3 in four of the regions, indicating that a majority of the system assets are exposed, and that windstorms occur on a daily, monthly, or annual basis, on average. Winter storms is the natural hazard with the second-highest exposure ratings, with a high (3) exposure score in two of the six regions. The percentage of system assets exposed to winter storms ranges from 0 percent in some regions to over 50 percent in other regions. Historical occurrence of winter storms ranges from a daily or monthly, to an annual basis. Wildfire received the third highest exposure ratings on average, with one high exposure rating out of the six regions. The percentage of system assets exposed to wildfire ranges from 0 percent in some regions to more than 50 percent in others, and historical occurrences of the hazard ranges from on a daily basis to once every decade.

Natural Gas: The natural hazards with the highest exposure ratings across all regions for the natural gas system are CSZ earthquake, lightning, wildfire, windstorms, and winter storms. Windstorms received a high (3) exposure rating in all six regions, indicating that a majority of system assets are exposed on an

annual basis. Lightning received the second-highest exposure scores with three high (3) exposure ratings out of the six regions. The percentage of system assets exposed to lighting hazards ranges from 1 percent to more than 50 percent and the historical frequency of occurrence ranges from a daily basis to once a year. CSZ earthquake, wildfire, and winter storms all received moderate exposure scores across all regions, while physical attacks received moderate exposure scores in two of the regions, indicating that, on average, the percentage of energy system assets located within a hazard zone ranges from 1 percent to more than 50 percent, and the historical frequency of occurrence ranges from once a year to once a decade.

Sensitivity

Liquid Fuels: The most sensitive elements of the liquid fuels system include pipelines and bulk distribution locations where large amounts of fuel are stored and the road network, which is used for distribution. Sensitivity analysis of the liquid fuels system found the following:

- Key sensitivities of the system to winter storms 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.
- The sensitivities of liquid fuel system components to lightning include potential damage and flammability of stored liquid fuel at bulk distribution sites and potential equipment damage due to direct lightning strikes.
- 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.
- Indirect wind sensitivities of components of the liquid fuels system are power outages and transportation system disruption due to debris and trees blocking transportation routes.
- 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.
- 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.

Electric: The most sensitive electric elements across all hazards are transmission and distribution assets. Owner/operator respondents to the survey reported the following sensitivities:

- System elements such as high voltage transmission lines can be destroyed by wildfire. This may cut off systems from the BPA grid and the lines are difficult to repair because reserve components and equipment may be limited or not available. Even with aggressive vegetation management in place, high voltage lines can be sensitive to wildfire if they rely on wooden structures. Distribution lines are sensitive for the same reason. Substations are also sensitive to wildfire.
- Power lines (transmission, distribution) are sensitive to buildup of snow, ice, and frost due to winter storms. This buildup can lead to cable and pole failures. Substations, transformers, and communications infrastructure are also sensitive to winter storms.
- Fuses are impacted by lightning strikes, which can disable distribution and transmission assets. Power transformers, distribution transformers, and other electrical equipment are also sensitive

to lightning. There is at least one substation in a rural high-lightning strike area that is highly sensitive if struck directly. Downtime could last several days due to the remote location and lack of redundancy, because no spare transformer or backup supply system is in place.
- Power generation is particularly sensitive to low water levels due to drought, which would force utilities to rely on market purchases.

Natural Gas: The most sensitive natural gas elements across all hazards are above-ground facilities that serve transmission and distribution functions. Owner/operator respondents to the survey reported the following:

- Above-ground facilities such as gate stations and meters are sensitive to wildfire. There are also concerns about the ability to shut off gas service in impacted areas, particularly in residential areas and buildings where end-user distribution elements are sensitive to damage.
    - Above-ground facilities can be impacted by snow, ice, and freezing temperatures from winter storms. These storms also cause a peak in consumer demand, particularly if there are extended periods with low temperatures. System pressure can drop, and areas can experience low pressure due to extended peak demand. Access to facilities for personnel to conduct service and repair is also limited during winter storms.
    - Above-ground facilities are sensitive to lightning strikes. Transmission and distribution assets could be damaged, as could electronics such as telemetry. A strike to a telemetry facility could cause an uncontrolled release or loss of communication. A strike could travel along pipelines, exposing workers to injury. A strike at a large custody transfer point could cause a large outage.

All systems were assumed to be sensitive to cyberattack and physical attack, which stakeholders validated across the liquid fuels, electricity, and natural gas subsectors.

Potential Impact

Liquid Fuels: Potential impact varies by region. On average, the highest potential impacts statewide to liquid fuel storage are due to CSZ earthquake and winter storms. The lowest were due to windstorms and drought. CSZ earthquake received a high (3) potential impact rating for four of the six regions—Northwest, Portland Metro, Southwest, and Willamette Valley—meaning that greater than 80 percent of the liquid fuel storage in those regions has the potential to be impacted by the hazard. Winter storms received a high (3) rating for three of the six regions—Cascades, Portland Metro, and Willamette Valley. Cyberattacks received a moderate (2) potential impact rating for all regions except Eastern, while physical attacks received a moderate rating for only the Portland Metro region. A moderate rating indicates that more than 20 percent of customers may experience a disruption and service could be restored in a matter of weeks.

Electric: The CSZ earthquake hazard received the highest potential impact ratings out of all the hazards, scoring high (3) potential impacts in three of the six regions. A high level of impact was defined as more than 20 percent of customers affected, which is the estimated impact for the CSZ earthquake, and service may take weeks to months to be restored following an event. Winter storms received a moderate rating and the second-highest average potential impact ratings across the state. The percentage of customers that may be affected by winter storms following a disruption range from 5 percent to more than 20 percent, and the time required to restore service following an event range from hours to weeks.

Windstorms were the third most highly rated hazard across the state, averaging moderate potential impacts. The percentage of customers that may be affected by windstorms following a disruption range from 5 percent to more than 20 percent, and the time required to restore service ranges from hours to weeks.

Natural Gas: The CSZ earthquake hazard received the highest potential impact ratings of all hazards with a high potential impacts score (3) in every region. According to the survey, more than 20 percent of customers may experience a disruption to service due to the CSZ earthquake and service will be restored in a matter of months. No other hazards received a high (3) rating, but several others had overall moderate scores. Wildfire's potential impact scores were moderate across the state on average. Based on the average potential impact score, the percentage of customers impacted by a disruption of service ranges from 5 to 20 percent, and the approximate amount of time required to restore service varies from hours to days in some regions to a matter of months in others. Potential impact ratings for windstorms were also moderate across the state, meaning the percentage of customers that may be affected by a disruption caused by wind ranges from 5 to 20 percent, while the time required to restore service ranges from hours to weeks.

Adaptive Capacity

Liquid Fuels: The adaptive capacity measures that were chosen in the survey as measures that have been implemented the most by liquid fuel operators were generators, fencing and security, automated monitoring, weather coverings, staff preparedness, tabletop exercises, stores of essential supplies, and secondary contracts with key suppliers. Many of these measures are multi-hazard measures or serve purposes in addition to hazard mitigation. Many of the operators who said they had backup generators stipulated that generators would not bring facilities back to full operating capacity. The majority of generators use diesel fuel. Fifty percent or less of respondents indicated that they have implemented fire protection, improved site drainage and flood protection, minor seismic upgrades, physical IT security, vegetation management, backup communication, debris clearing, deployable flood protection, security personnel on site, or winter storm equipment. Without further inquiry, it is unknown if any safeguards that were not identified were due to the fact that they were not applicable or another motive. Finally, for human-caused threats, many of the adaptive capacity protective measures have opportunities for optimization. Although the Identify measure for cyberattacks is optimized and the Respond measure for cyberattacks and physical attacks is close to being optimized, the Protect, Detect, and Recover measures for cyberattacks as well as the Identify, Protect, Detect, and Recover measures for physical attacks are primarily embedding.

Electric: Adaptive capacity ratings were high-very high in all regions for the CSZ earthquake, cyberattacks, flood, lightning, physical attacks, wildfire, windstorms, and winter storms. Nevertheless, there are still opportunities to further optimize mitigation measures for these threats. For example, the Protect measure for cyberattacks, the Upgrading physical measure for flood, all physical measures for lightning, the Situational Awareness operational measure for wildfire, and the Redundant physical measures for the CSZ earthquake, windstorms, and winter storms are optimized. However, the remaining physical and operational measures are either evolving or embedding. Therefore, more attention to most of the measures may be beneficial in the future. Additional opportunities for optimization also exist for hazards or threats in specific regions. With no physical measures implemented, drought in the Portland Metro region had the lowest adaptive capacity rating across all hazards/threats and regions. Thus, prioritizing physical measure optimization would be beneficial for the region.

Natural Gas: Adaptive capacity ratings were very high in all regions for the CSZ earthquake, cyberattacks, flood, lightning, wildfire, windstorms, and winter storms. For instance, the majority of physical and operational measures are optimized across these threats. However, the Situational Awareness operational measures for the CSZ earthquake and flood as well as the Integrity Safety Plans operational measure for lightning have room for optimization as these measures were primarily embedding. Additional opportunities for optimization also exist for lightning, wildfire, and windstorms as there were no physical measures implemented related to Remove Assets out of hazard zones. Furthermore, physical attacks in the Cascades, Eastern, and Southwest regions had high adaptive capacity ratings. Optimized measures included Respond and Recover protective measures while embedded measures included Identify, Protect, and Detect. Nevertheless, due to having no Identify protective measures implemented, the Northwest, Portland Metro, and Willamette Valley regions had low adaptive capacity ratings. For these regions, the Protect, Respond, and Recover protective measures implemented for physical attacks were optimized.

Stakeholder Engagement

The project team engaged with a total of 210 stakeholders within the state of Oregon, the Pacific Northwest region, and Washington, D.C. throughout the project. During the meeting series, a total of 90 stakeholders were engaged, which included 31 in-person and 59 virtual meeting participants. Most of the participants were from the Portland Metro (25), Cascades (17), and Willamette Valley regions (16) (**Figure 2**). However, there was limited attendance at the Eastern (11), Southwest (10), and Northwest (5) region meetings. Of the 90 participants, 57% represented government entities, such as federal and state agencies, and local jurisdictions (**Figure 3**). Stakeholders from private sector, utilities, non-profit organizations, and Tribal Governments represented 17%, 8%, 6%, and 6%, respectively. Furthermore, 36% of the participants at the roadshow meetings have an interest in EJ issues and topics. A total of 20 survey responses were received from participants that attended the Cascades, Eastern, Portland Metro, Southwest, and Willamette Valley meetings. No survey responses were received from the Northwest Region or Tribal Governments meeting participants, where meeting attendance was limited. **Table 5** provides an overview of meeting series attendance, the number of survey responses, and the survey response rate for each of the seven meetings. Details can be found in the Stakeholder Engagement Report.

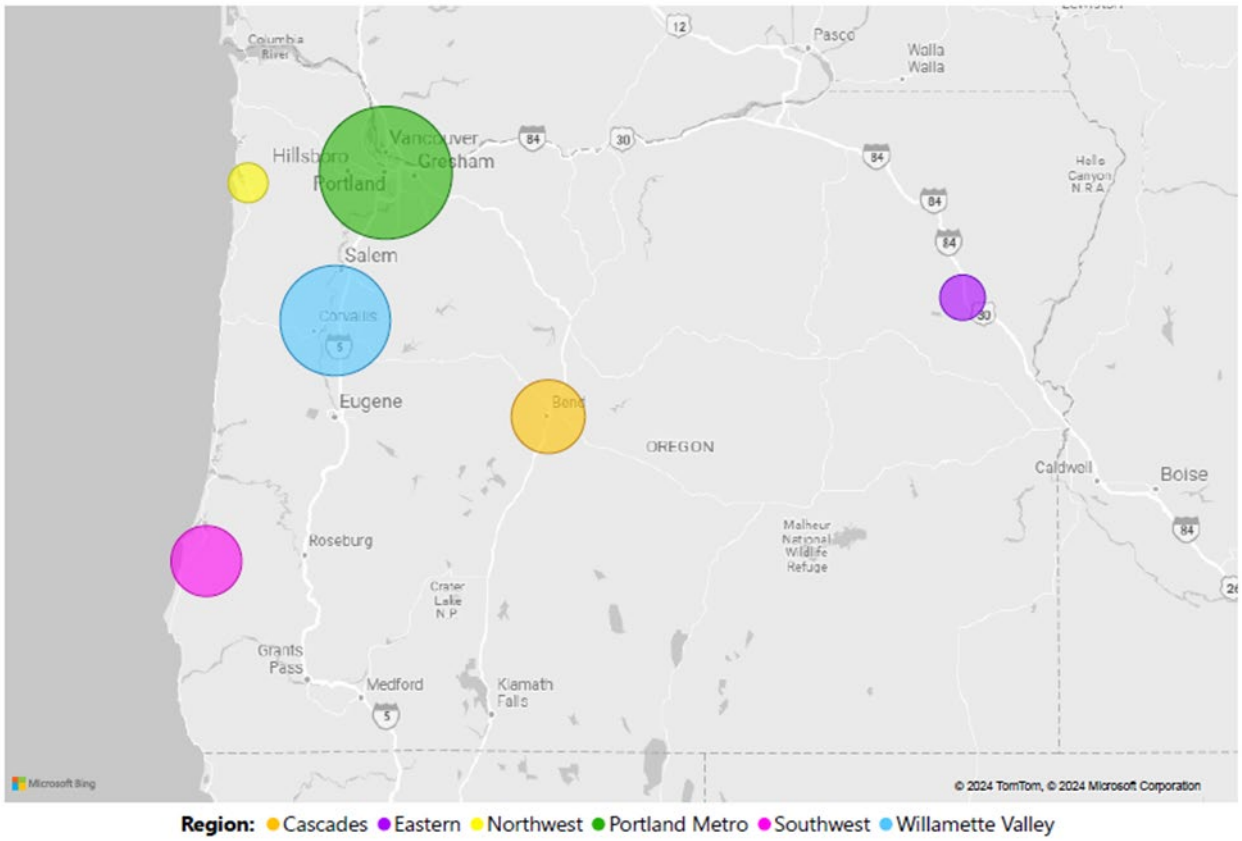


***Figure 2**: Spatial distribution of stakeholders by region.*

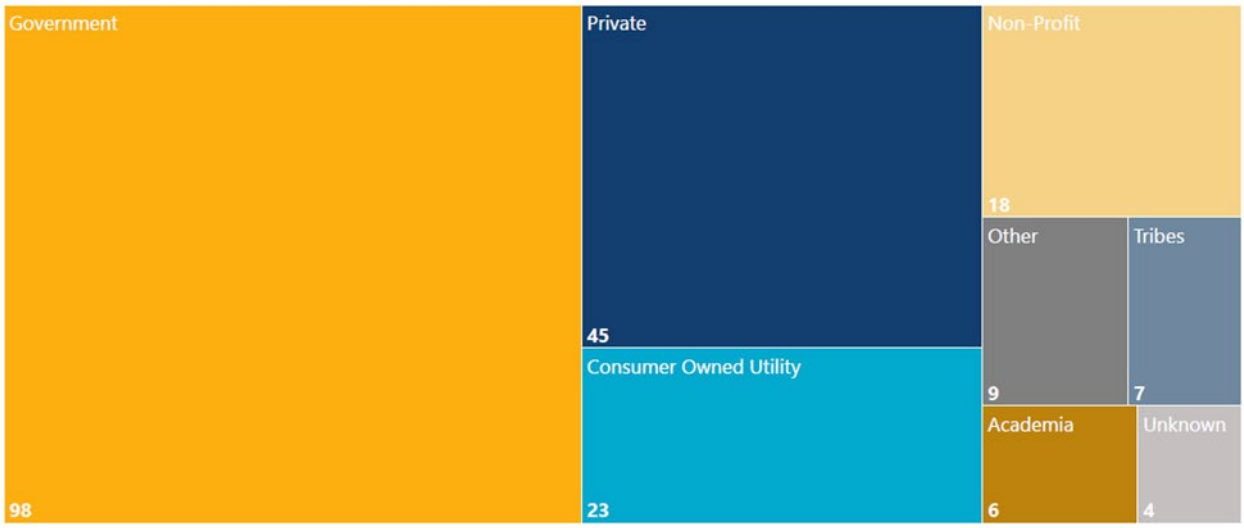


***Figure 3**: Stakeholders by employment category.*

***Table 5**: Meeting series attendance, survey participation, and survey response rate.*

Meeting	Meeting Attendance	Survey Responses	Survey Response Rate
Cascades	17	4	24%
Eastern	11	2	18%
Northwest	5	0	0%
Portland Metro	25	8	32%
Southwest	10	1	10%
Willamette Valley	16	5	31%
Tribal Governments	6	0	0%
Total	**90**	**20**	**22%**

All Systems Risk Mitigation Measures

The final selection of 'all systems' RMMs were presented to each region and the Tribal governments throughout the meeting series. These included 12 physical measures (**Table 6**) and 15 operational measures (**Table 7**).

***Table 6**: Physical measures for all energy systems.*

RMMs	Descriptions
Drones	Develop drone inspection capabilities (and procedures).
Hardening	Harden and upgrade components.
Monitoring	Establish automated and remote monitoring systems.
Protect	Improve maturity of measures related to the Protect category for human-caused threats.
Redundancy	Identify alternate facility sites (i.e., backup operations centers).
Redundancy	Increase fixed and/or portable backup generator capacity to provide backup power to critical facilities when grid-supplied power is interrupted.
Redundancy	Reduce isolation of critical facilities (i.e., backup access routes, backup communication systems).
Removal	Remove assets out of hazard zone.
System Segmentation	Subdivide energy systems to more efficiently isolate damaged areas, allowing undamaged segments to continue serving customers.
Undergrounding	Replace overhead with underground cables.
Vegetation Management	Manage vegetation to minimize impacts of natural hazards.
Weatherization	Weatherize energy system assets.

***Table 7**: Operational measures for all energy systems.*

RMMs	Descriptions
AARs	Generate incident After Action Reviews.
AI	Integrate artificial intelligence into operational plans/monitoring (AI analysis can augment the abilities of subject matter experts to prioritize transmission line operations, identify defects, and update asset management systems).
Audits	Audit resilience strategies and recommend improvement plans.
Inventories	Maintain inventories of equipment and inter-operability/mutual aid.
Maturity	Improve maturity of measures across all categories for human-caused threats.
MOUs	Develop Memorandums of Understanding with government.
Planning	Develop scenario-driven emergency response plans including back-up communications and employee preparedness.
Projections	Improve forecasting and situational awareness abilities.
Reduce Demand	Develop peak Demand Reduction Programs.
Redundancy	Have secondary key suppliers in place.
Risk Maps	Maintain baseline risk maps to inform long term investments and programs.
Studies	Comprehensive, site-specific risks to inform Capital Improvement Plans (CIPs) and Asset Management Plans (AMPs).
Studies	Lifeline service delivery systems and disaster resilience.
Studies	Assess current supply chain resilience for continuity planning.
Training	Conduct regular training and exercises.

Stakeholders (*n* = 20) ranked Drones, Removal, and Protect as the top three physical measures to prioritize, and AI, AARs, and Studies (i.e., conduct studies on lifeline service delivery systems and disaster resilience) as the top three operational measures to prioritize (**Table 8)**. For context, AI references how AI analysis could augment the abilities of subject matter experts to prioritize transmission line operations, identify defects, update asset management systems, etc., during an event. Furthermore, lifeline service delivery systems refer to critical infrastructure related to electric supply, natural gas supply, telecommunications, water/wastewater systems, hydraulic structures (e.g., dikes, levees, dams), transportation corridors, pipelines, and petroleum fuels storage facilities.

***Table 8**: Mean RMM rankings by meeting series participants for all energy systems: (A) physical measure rankings; (B) operational measure rankings. (1 = highest ranking)*

(A)

Physical RMMs	Physical RMM Rankings
Drones – develop drone inspection capabilities (and procedures)	3.83
Removal - remove assets out of hazard zone	5.39
Protect – improve maturity of measures related to the Protect category for human-caused threats	5.53
System Segmentation – subdivide energy systems to more efficiently isolate damaged areas	5.89
Monitoring – establish automated and remote monitoring systems	6.50
Vegetation management – manage vegetation to minimize impacts of natural hazards	6.56
Undergrounding – replace overhead with underground cables	6.68
Weatherization – weatherize energy system assets	6.89
Redundancy – Identify alternate facility sites (i.e., backup operations centers)	6.89
Redundancy – Increase backup generator capacity	7.16
Redundancy – Reduce isolation of critical facilities (i.e., backup access routes, backup communication systems)	7.28
Hardening – harden and upgrade components	8.44

Table 8 *(continued).*

(B)

Operational RMMs	Operational RMM Rankings
AI – integrate artificial intelligence into operational plans/monitoring	3.69
AARs – generate incident After Action Reviews	5.33
Studies – Lifeline service delivery systems disaster resilience	5.56
Reduce demand – develop peak Demand Reduction Programs	5.93
Maturity – improve maturity of measures across all categories for human-caused threats	6.33
Studies – Supply chain resilience for continuity planning	6.40
Studies – Comprehensive, site-specific risks to inform Capital Improvement Plans (CIPs) and Asset Management Plans (AMPs)	7.35
Projections – Improve forecasting and situational awareness abilities	7.63
Training – conduct regular training and exercises	7.80
Audits - audit resilience strategies and recommend improvement plans	7.94
Redundancy – have secondary key suppliers in place	9.00
MOUs – develop Memorandums of Understanding with government	9.47
Inventories – maintain inventories of equipment and inter-operability/mutual aid	9.88
Planning – develop scenario-driven emergency response plans including back-up communications and employee preparedness	10.59
Risk Maps - maintain baseline risk maps to inform long term investments and programs	11.00

Regional Results Introduction

The successive sections detail results for each energy subsector at a regional scale. These sections begin with an overview of maturity ratings for mitigation measures already implemented to highlight opportunities for RMMs to improve resilience. In the liquid fuels subsector, stakeholder feedback was collected in a distinct manner for natural hazards compared to human-caused threats. As such, only takeaways for human-caused threats are provided. Further, because there are only three natural gas service providers in the state, maturity ratings are presented on a statewide scale for the natural gas subsector to protect anonymity of respondents. Following maturity ratings, RMM development and gaps identified by stakeholders (refer to the Risk Assessment Report for more information on RMM gaps and recommendations), RMM measures shared with participants for each region and subsector, meeting

attendance, survey participation, and survey results with the mean physical and operational RMM rankings by region and subsector are described.

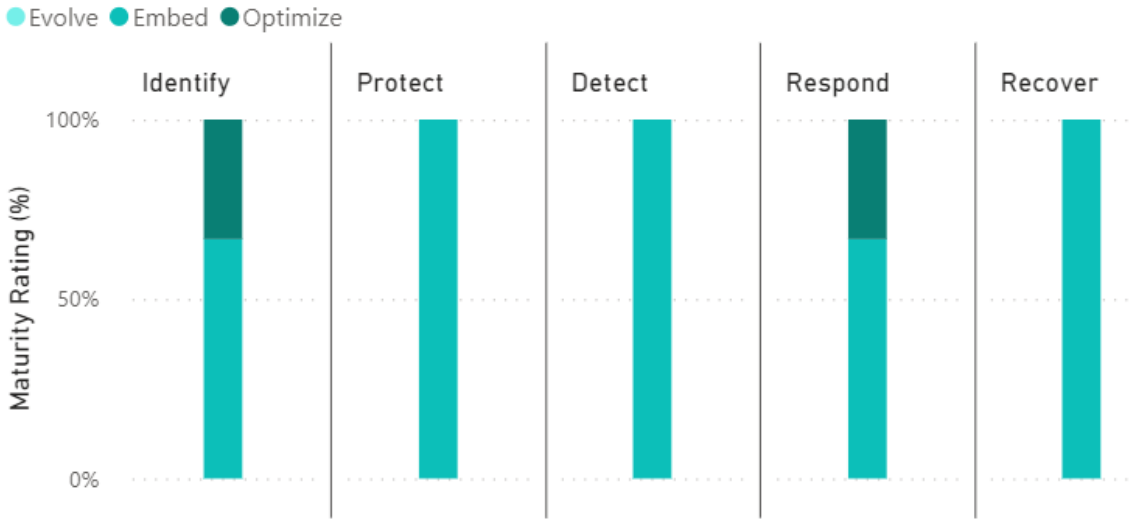
It is important to note that, in the Natural Gas Risk Assessment survey, respondents included accidental damage (e.g., striking a buried pipeline when digging) when responding to questions related to physical attacks. This expanded the definition of physical attacks, which were defined as being limited to intentional attacks on energy systems. This interpretation may have impacted the vulnerability ratings of physical attack threats across regions and, therefore, may influence recommendation and prioritization of RMMs related to physical attacks. Also, note that redundancies exist on a region-by-region basis for RMM gaps due to limited variation between survey responses.

Liquid Fuels Results

Cascades Region Liquid Fuels Results

Figure 4 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Interestingly, distribution of maturity ratings were identical for both human-caused threats. The mitigation measure categories of Protect, Detect, and Recover are rated as embed and represent the areas with the greatest potential for improvement.

(A)



(B)

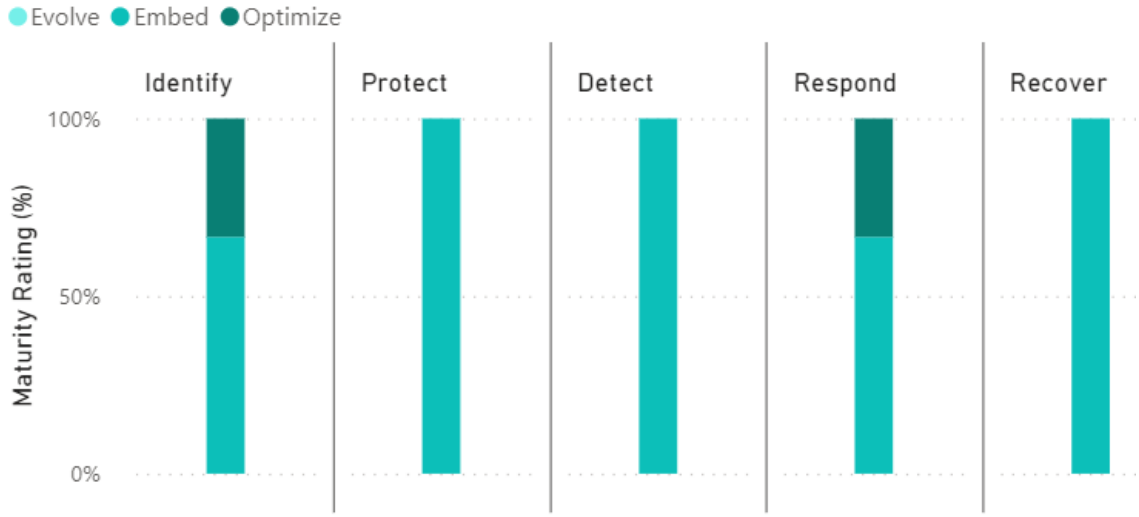


***Figure 4**: Distribution of mean maturity ratings of mitigation measures in the liquid fuels subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Additional stakeholder feedback on the preliminary results of the liquid fuels risk assessment included identified gaps specific to resiliency strategies and practices as well as infrastructure improvement and operational resilience practices adaptive capacity measures. For example, stakeholders suggested

engaging with external consultants to audit and recommend improvements to resiliency strategies as well as utilizing feedback from exercises (e.g., drills, tabletop, or functional exercises) and real incident responses to adjust and improve operational resiliency practices. Improvements in resiliency strategies and practices are largely guided by local, state, and federal regulations. Furthermore, gaps exist for infrastructure improvement adaptive capacity measures related to automated monitoring, fire protection, improved site drainage and flood protection, physical IT security, and seismic upgrades. Additional gaps are also present for operational resilience practices adaptive capacity measures as it pertains to backup communication, debris clearing, deployable flood protection, secondary contacts for key suppliers, and vegetation management.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Cascades Region Meeting (**Table 9**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 9*: RMMs presented at the Cascades Region Meeting for the liquid fuels subsector and mean RMM rankings by participants (n = 4): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
Human-Caused Threats	Optimize implementation of measures in the Protect categories	1.50
Lightning	Install weather coverings, roofs, and enclosures for critical infrastructure	2.25
Wildfire	Improve detection capabilities and install automated monitoring systems	3.50
	Improve fire protection measures (active or passive, including vegetation management and defensible space)	4.75
Winter Storms	Improve site drainage and flood protection in preparation for storms (e.g., levees, berms, storage areas)	3.00

Table 9 *(continued).*

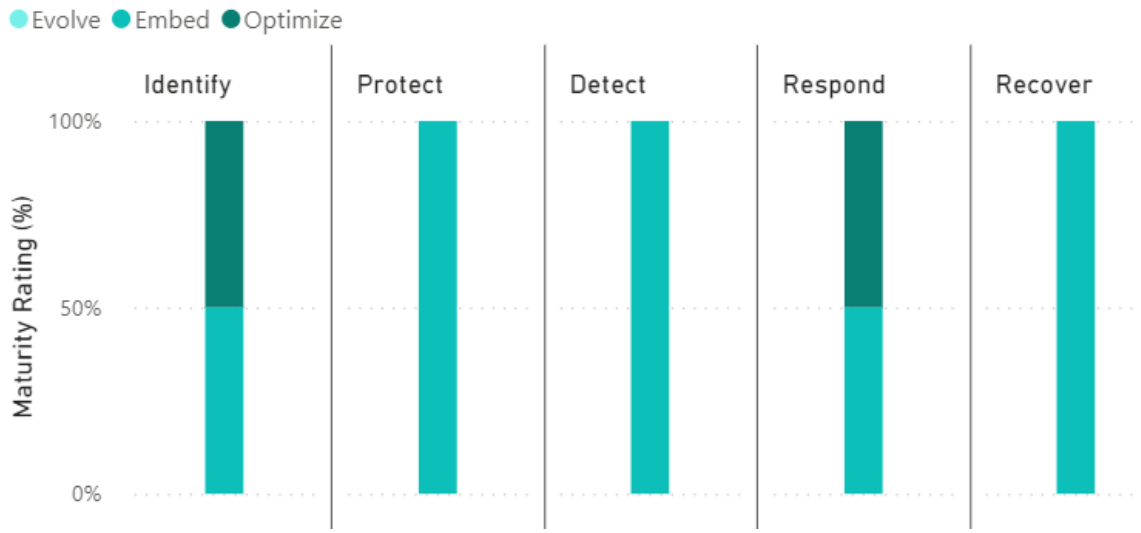
(B)

Threats	Operational RMMs	Operational RMM Rankings
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	6.75
	Ensure stores of essential supplies (e.g., vehicle fluid, tires)	8.75
	Implement an emergency action plan	9.50
Lightning	Integrate automatic or emergency shutdown systems	6.25
	Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices	2.25
Wildfire	Develop vulnerability assessment of system assets	6.25
	Engage external consultants or partners to audit and recommend improvements to resiliency strategies	11.25
	Improve capacity of back-up generators to accommodate at least moderate operations (25%-75%)	9.25
	Maintain risk maps and system modeling	6.25
	Supply back-up communication devices (e.g., satellite phones, two-way radios)	6.00
Winter Storms	Provide debris clearing equipment staging and maintenance	5.00
	Provide winter weather equipment and supplies (e.g., shovels, plows, ice melt)	3.75
	Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices.	3.00

Eastern Region Liquid Fuels Results

Figure 5 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Interestingly, distribution of maturity ratings were identical for both human-caused threats. The mitigation measure categories of Protect, Detect, and Recover are rated as embed and represent the areas with the greatest potential for improvement.

(A)



(B)

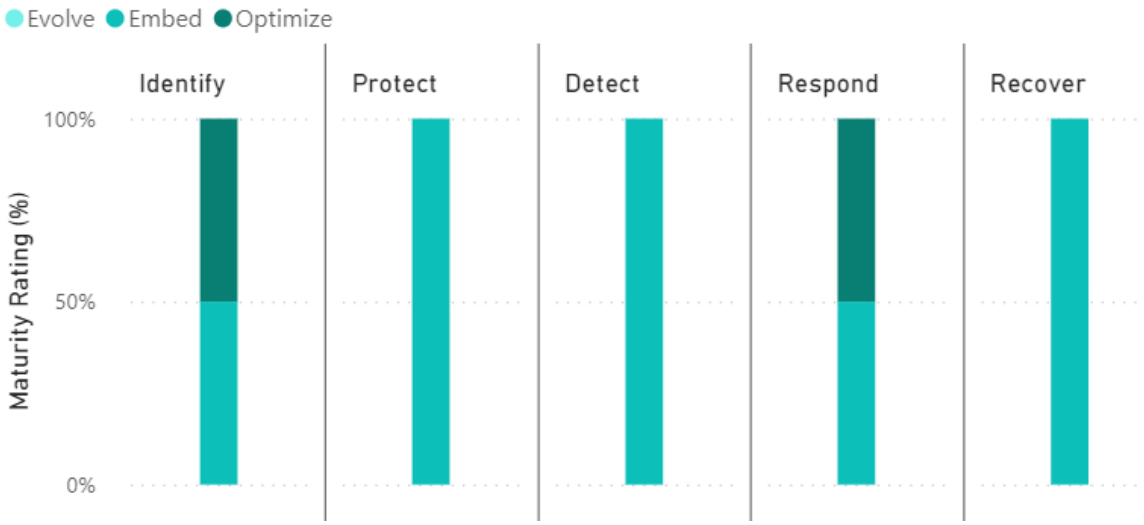


Figure 5*: Distribution of mean maturity ratings of mitigation measures in the liquid fuels subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Additional stakeholder feedback on the preliminary results of the liquid fuels risk assessment included identified gaps specific to resiliency plans/evaluations, strategies, and practices as well as infrastructure improvement and operational resilience practices adaptive capacity measures. For example,

stakeholders suggested conducting regular reviews and updating resiliency plans based on incidents and/or annual threat evaluations, engaging with external consultants to audit and recommend improvements to resiliency strategies, as well as utilizing feedback from exercises (e.g., drills, tabletop, or functional exercises) and real incident responses to adjust and improve operational resiliency practices. Improvements in resiliency strategies and practices are largely guided by local, state, and federal regulations. Furthermore, liquid fuel subsector owner/operators noted gaps in adaptive capacity measures for all hazards in the Eastern region. One such gap includes infrastructure improvement adaptive capacity measures related to automated monitoring, fire protection, improved site drainage and flood protection, physical IT security, and seismic upgrades. Additional gaps are also present for operational resilience practices adaptive capacity measures as it pertains to backup communication, deployable flood protection, secondary contracts for key suppliers, and security personnel on site.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Eastern Region Meeting (**Table 10**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 10*: RMMs presented at the Eastern Region Meeting for the liquid fuels subsector and mean RMM rankings by participants (n = 2): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
Human-Caused Threats	Optimize implementation of measures in the Protect categories	3.50
Lightning	Install weather coverings, roofs, and enclosures for critical infrastructure	1.00
Wildfire	Improve detection capabilities and install automated monitoring systems	3.50
	Improve fire protection measures (active or passive, including vegetation management and defensible space)	4.00
Wind and Winter Storms	Improve site drainage and flood protection in preparation for storms (e.g., levees, berms, storage areas)	3.00

Table 10 *(continued).*

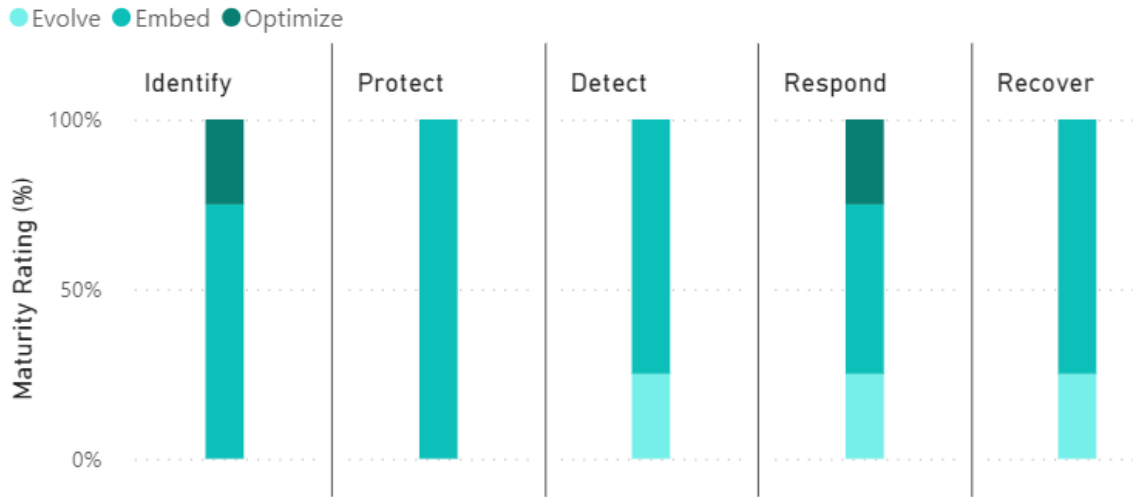
(B)

Threats	Operational RMMs	Operational RMM Rankings
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	3.50
Lightning	Conduct regular reviews and updates of resiliency plans based on specific incidents or annual evaluations	8.00
	Emergency action plan	9.00
	Improve capacity of back-up generators to accommodate at least moderate operations (25%-75%)	9.00
	Integrate automatic or emergency shutdown systems	9.00
	Supply back-up communication devices (e.g., satellite phones, two-way radios)	5.50
Wildfire	Develop vulnerability assessment of system assets	7.00
	Engage external consultants or partners to audit and recommend improvements to resiliency strategies	5.00
	Improve capacity of back-up generators to accommodate at least moderate operations (25%-75%)	10.00
	Maintain risk maps and system modeling	7.00
	Supply back-up communication devices (e.g., satellite phones, two-way radios)	5.50
Wind and Winter Storms	Ensure stores of essential supplies (e.g., vehicle fluid, tires)	7.00
	Provide debris clearing equipment staging and maintenance	6.50
	Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices	3.00

Northwest Region Liquid Fuels Results

Figure 6 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Interestingly, distribution of maturity ratings were identical for both human-caused threats. The mitigation measure categories of Detect and Recover include ratings of embed and evolve and represent the areas with the greatest potential for improvement.

(A)



(B)

***Figure 6**: Distribution of mean maturity ratings of mitigation measures in the liquid fuels subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Additional stakeholder feedback on the preliminary results of the liquid fuels risk assessment included identified gaps specific to resiliency strategies as well as infrastructure improvement and operational resilience practices adaptive capacity measures. For example, stakeholders suggested engaging with external consultants to audit and recommend improvements to resiliency strategies. Improvements in resiliency strategies and practices are largely guided by local, state, and federal regulations. Furthermore, gaps exist for infrastructure improvement adaptive capacity measures related to fire protection, improved site drainage and flood protection, physical IT security, seismic upgrades, and weather coverings. Additional gaps are also present for operational resilience practices adaptive capacity measures as it pertains to back up communication, debris clearing, flood protection, MOUs, security personnel on site, vegetation management, and winter weather equipment.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Northwest Region Meeting (**Table 11**). During the meeting, five surveys were distributed to participants which gave them the opportunity to rank the updated physical and operational RMMs for the liquid fuels subsector. However, we received zero responses, and as a result, we were unable to collect participant feedback on the physical and operational RMMs.

***Table 11**: RMMs presented at the Northwest Region Meeting for the liquid fuels subsector.*

Threats	Physical RMMs	Operational RMMs
CSZ Earthquake/ Liquefaction	Apply seismic upgrades to critical infrastructure (structural intervention) Utilize flexible connections, control valves Increase fuel storage capacity, diversity, and foundation strength	Perform seismic vulnerability studies of critical infrastructure Protect critical facilities from landslide by identifying high risk slopes Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices
Human-Caused Threats	Optimize implementation of measures in the Protect categories	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover
Windstorms and Winter Storms	Improve site drainage and flood protection in preparation for storms (e.g., levees, berms, storage areas) Install weather coverings, roofs, and enclosures for critical infrastructure	Provide debris clearing equipment staging and maintenance Provide winter weather equipment and supplies (e.g., shovels, plows, ice melt) Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices.

Portland Metro Region Liquid Fuels Results

Figure 7 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. For both human-caused threats, mitigation measure categories of Detect, Respond, and Recover include ratings of embed and evolve and represent the areas with the greatest potential for improvement.

(A)

(B)

Figure 7*: Distribution of mean maturity ratings of mitigation measures in the liquid fuels subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Additional stakeholder feedback on the preliminary results of the liquid fuels risk assessment included identified gaps specific to CEI Hub vulnerability and earthquake preparedness, resiliency strategies, as

well as infrastructure improvement and operational resilience practices adaptive capacity measures. For example, stakeholders identified there is a unique opportunity in the Portland Metro region to advance early warning system for CSZ earthquake (e.g., Shake Alert pilot project) and evaluate fuel storage tank vulnerability to earthquakes in the CEI Hub. Furthermore, stakeholders suggested engaging with external consultants to audit and recommend improvements to resiliency strategies. Improvements in resiliency strategies and practices are largely guided by local, state, and federal regulations. Lastly, gaps exist for infrastructure improvement adaptive capacity measures related to fire protection, improved site drainage and flood protection, physical IT security, seismic upgrades, and weather coverings. Additional gaps are also present for operational resilience practices adaptive capacity measures as it pertains to back up communication, debris clearing, deployable flood protection, MOUs, security personnel on site, vegetation management, and winter weather equipment.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Portland Metro Region Meeting (**Table 12**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 12*: RMMs presented at the Portland Metro Region Meeting for the liquid fuels subsector and mean RMM rankings by participants (n = 8): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake/ Liquefaction	Flexible connections, control valves	4.00
	Increase fuel storage capacity, diversity, and foundation strength	4.83
	Implement seismic upgrades to biodiesel plants, port terminals, pump stations, distributor bulk plants and pipelines (structural interventions	5.17
Human-Caused Threats	Optimize implementation of measures in the Protect categories	3.17
Wildfire	Improve fire protection measures (active or passive, including vegetation management and defensible space)	3.60
Windstorms and Winter Storms	Improve site drainage and flood protection in preparation for storms (e.g., levees, berms, storage areas)	3.00
	Install weather coverings, roofs, and enclosures for critical infrastructure	3.33

Table 12 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake/ Liquefaction	Protect critical facilities from landslide by identifying high risk slopes	4.00
	Perform seismic vulnerability studies of major bulk distribution plants, terminals, and pump stations	6.50
	Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices	4.00
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	6.00
Wildfire	Develop vulnerability assessment of system assets	9.20
	Engage external consultants or partners to audit and recommend improvements to resiliency strategies	6.20
	Improve capacity of back-up generators to accommodate at least moderate operations (25%-75%)	8.00
	Maintain risk maps and system modeling	7.00
Windstorms and Winter Storms	Provide debris clearing, equipment staging and maintenance	4.83
	Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices	4.67
	Supply back-up communication devices (e.g., satellite phones, two-way radios)	4.60

Southwest Region Liquid Fuels Results

Figure 8 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Distribution of maturity ratings were similar for both human-caused threats. The mitigation measure categories of Protect, Detect, and Recover are rated as embed and represent the areas with the greatest potential for improvement.

(A)

(B)

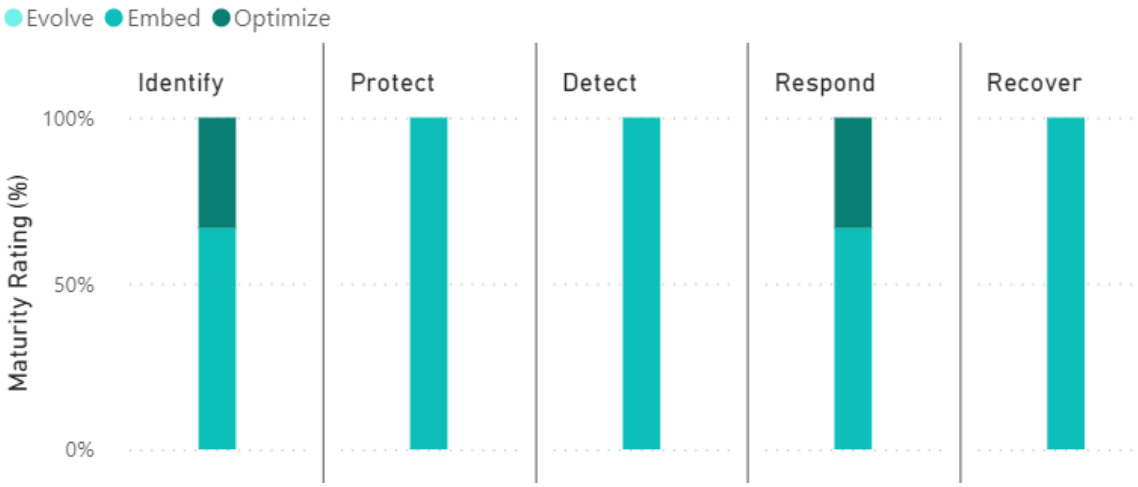


***Figure 8**: Distribution of mean maturity ratings of mitigation measures in the liquid fuels subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Additional stakeholder feedback on the preliminary results of the liquid fuels risk assessment included identified gaps specific to resiliency strategies and practices as well as infrastructure improvement and operational resilience practices adaptive capacity measures. For example, stakeholders suggested engaging with external consultants to audit and recommend improvements to resiliency strategies as well as utilizing feedback from exercises (e.g., drills, tabletop, or functional exercises) and real incident

responses to adjust and improve operational resiliency practices. Improvements in resiliency strategies and practices are largely guided by local, state, and federal regulations. Furthermore, gaps exist for infrastructure improvement adaptive capacity measures related to automated monitoring, fire protection, improved site drainage and flood protection, physical IT security, seismic upgrades, and weather coverings. Additional gaps are also present for operational resilience practices adaptive capacity measures as it pertains to debris clearing, deployable flood protection, MOUs, secondary contacts for key suppliers, and security personnel onsite.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Southwest Region Meeting (**Table 13**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 13*: RMMs presented at the Southwest Region Meeting for the liquid fuels subsector and mean RMM rankings by participants (n = 1): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake/ Liquefaction	Apply seismic upgrades to critical infrastructure (structural interventions, flexible connections, control valves)	6.00
	Increase fuel storage capacity, diversity, and foundation strength	5.00
Human-Caused Threats	Optimize implementation of measures in the Protect categories	1.00
Lightning	Install weather coverings, roofs, and enclosures for critical infrastructure	3.00
Windstorms and Winter Storms	Improve site drainage and flood protection in preparation for storms (e.g., levees, berms, storage areas)	2.00
	Install weather coverings, roofs, and enclosures for critical infrastructure	4.00

Table 13 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake/ Liquefaction	Perform seismic vulnerability studies of critical infrastructure	7.00
	Protect critical facilities from landslide by identifying high risk slopes	8.00
	Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices.	3.00
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	1.00
Lightning	Engage external consultants or partners to audit and recommend improvements to resiliency strategies	2.00
	Integrate automatic or emergency shutdown systems	9.00
	Supply back-up communication devices (e.g., satellite phones, two-way radios)	4.00
Windstorms and Winter Storms	Improve capacity of back-up generators to accommodate at least moderate operations (25%-75%)	10.00
	Provide debris clearing equipment staging and maintenance	6.00
	Provide winter weather equipment and supplies (e.g., shovels, plows, ice melt)	5.00
	Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices	11.00

Willamette Valley Region Liquid Fuels Results

Figure 9 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Interestingly, distribution of maturity ratings were identical for both human-caused threats. The mitigation measure categories of Detect and Recover include ratings of embed and evolve and represent the areas with the greatest potential for improvement.

(A)

(B)

Figure 9*: Distribution of mean maturity ratings of mitigation measures in the liquid fuels subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Additional stakeholder feedback on the preliminary results of the liquid fuels risk assessment included identified gaps specific to fuel storage tank vulnerability to earthquakes, resiliency strategies, as well as

infrastructure improvement and operational resilience practices adaptive capacity measures. For example, stakeholders identified there is an opportunity in the Willamette Valley region to evaluate fuel storage tank vulnerability to earthquakes in the CEI Hub. Furthermore, stakeholders suggested engaging with external consultants to audit and recommend improvements to resiliency strategies as well as utilizing feedback from exercises (e.g., drills, tabletop, or functional exercises) and real incident responses to adjust and improve operational resiliency practices. Improvements in resiliency strategies and practices are largely guided by local, state, and federal regulations. Lastly, liquid fuel subsector owner/operators noted gaps in adaptive capacity measures for all hazards in the Willamette Valley region. One such gap includes infrastructure improvement adaptive capacity measures related to improved site drainage and flood protection, physical IT security, seismic upgrades, and weather coverings. Additional gaps are also present for operational resilience practices adaptive capacity measures as it pertains to back up communication, debris clearing, flood protection, MOUs, security personnel on site, vegetation management, and winter weather equipment.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Willamette Valley Region Meeting (**Table 14**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 14*: RMMs presented at the Willamette Valley Region Meeting for the liquid fuels subsector and mean RMM rankings by participants (n = 5): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake/ Liquefaction	Apply seismic upgrades to critical infrastructure (structural interventions, flexible connections, control valves)	4.00
	Increase fuel storage capacity, diversity, and foundation strength	4.00
Human-Caused Threats	Optimize implementation of measures in the Protect category	4.00
Windstorms and Winter Storms	Improve site drainage and flood protection in preparation for storms (e.g., levees, berms, storage areas)	1.75
	Install weather coverings, roofs, and enclosures for critical infrastructure	2.50

Table 14 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake/ Liquefaction	Perform seismic vulnerability studies of critical infrastructure	7.00
	Protect critical facilities from landslide by identifying high risk slopes	6.00
	Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices	1.00
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	2.00
Windstorms and Winter Storms	Provide debris clearing equipment staging and maintenance	4.50
	Provide winter weather equipment and supplies (e.g., shovels, plows, ice melt)	3.50
	Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices	4.00

Electricity Results

Cascades Region Electricity Results

Figure 10 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. For cyberattacks, the categories of Detect, Respond, and Recover include the largest percentage of evolve maturity ratings and represent the most opportunity for improvement. For physical attacks, Identify is the only category with optimize ratings, leaving all other categories with the most opportunity for improvement.

(A)

(B)

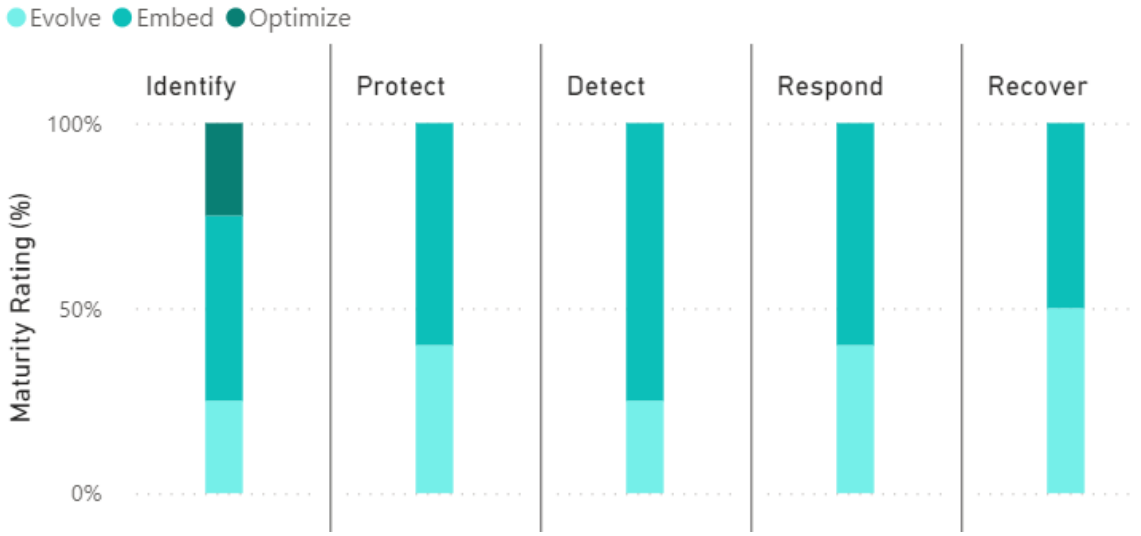
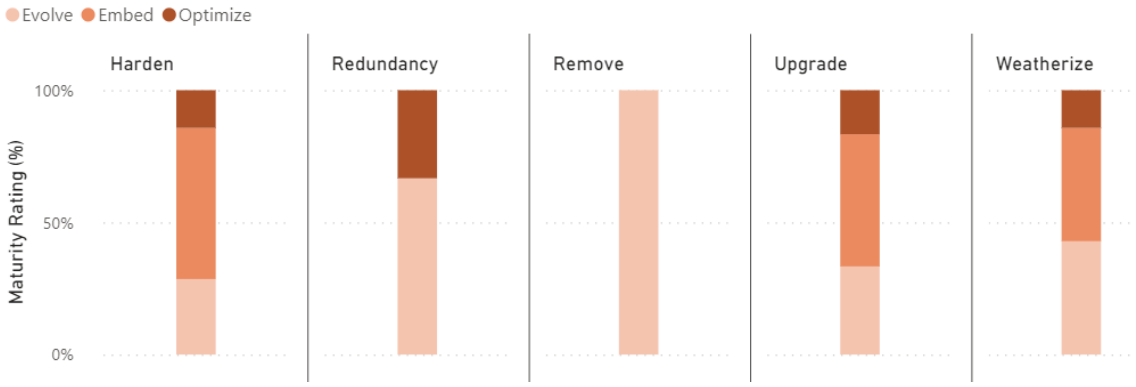


***Figure 10**: Distribution of mean maturity ratings of mitigation measures in the electricity subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Figure 11 summarizes mean maturity ratings of physical mitigation measures for (A) wildfire and (B) winter storms, respectively. The greatest opportunities for improvement include the Remove category

rated as evolve for wildfire and the categories of Harden, Upgrade, and Weatherize, which include ratings of embed and evolve for winter storms. The distribution of mean maturity ratings of operational measures for (A) lightning and (B) winter storms in **Figure 12** shows that all measures for winter storms and Integrity Safety Plans for lightning include ratings of evolve and embed and represent the greatest opportunity for improvement.

(A)



(B)

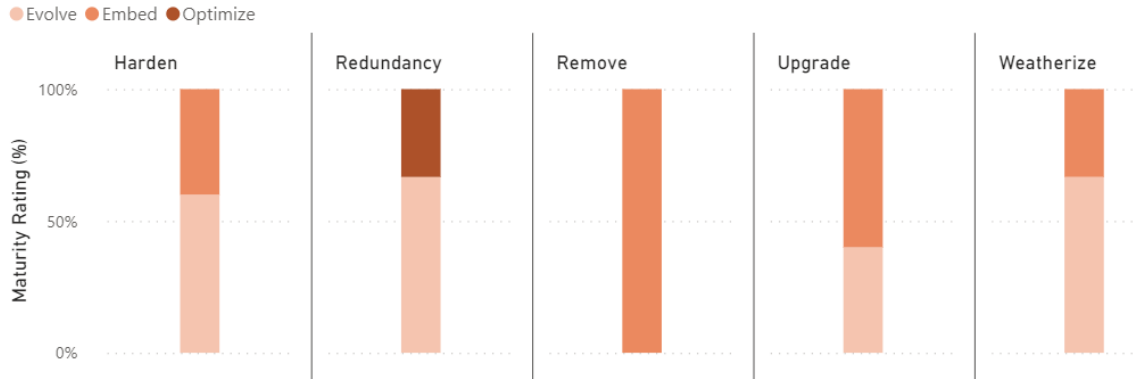
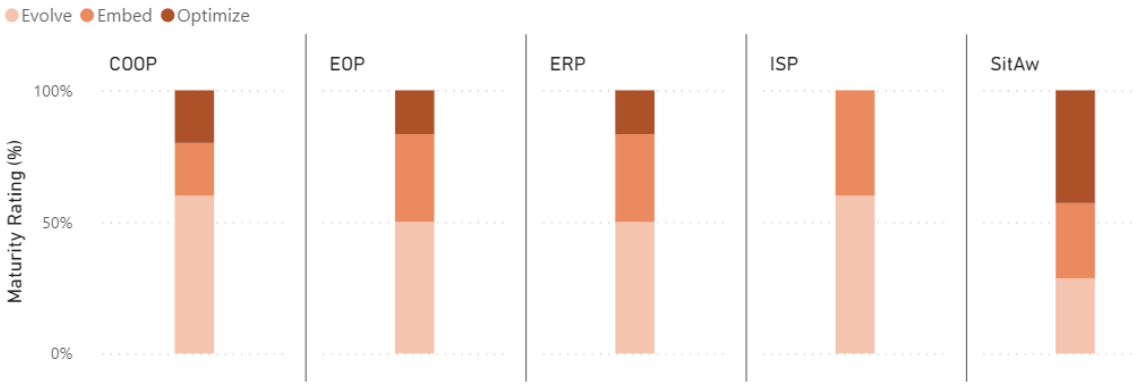


***Figure 11**: Distribution of mean maturity ratings of physical mitigation measures in the electricity subsector for (A) wildfire and (B) winter storms across five categories of mitigation measures: 1.) Harden; 2.) Redundancy; 3.) Remove; 4.) Upgrade; and 5.) Weatherize. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

(A)



(B)

***Figure 12**: Distribution of mean maturity ratings of operational mitigation measures in the electricity subsector for (A) lightning and (B) winter storms across five categories of mitigation measures 1.) COOP – Continuity of Operations Plan; 2.) EOP – Emergency Operation Plan; 3.) ERP – Emergency Response Plan; 4.) ISP – Integrity Safety Plan; and 5.) SitAw – Situational Awareness. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

Additional stakeholder feedback on the preliminary results of the electricity risk assessment included identified gaps specific to physical mitigation measures for a CSZ earthquake, drought, and lightning as well as infrastructure sensitivity to wildfire and winter storms. For example, stakeholders identified that physical mitigation measures are lacking for the majority of electric utility providers. Specifically, for a CSZ earthquake, the Cascades region is in need of backup power systems in addition to protective measures for all other assets from shaking damage, landslides, and liquefaction. Furthermore, owner/operators reported that electric assets, such as high voltage transmission lines and wooden structures are sensitive to both wildfires and winter storms. These threats cause widespread electric outages across the region.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Cascades Region Meeting (**Table 15**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

***Table 15**: RMMs presented at the Cascades Region Meeting for the electricity subsector and mean RMM rankings by participants (n = 4): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Harden sub-stations	5.75
	Implement geotechnical and foundation interventions and ground improvements	4.25
	Improve backup power systems (generators, batteries, redundancies)	6.50
Human-Caused Threats	Optimize implementation of measures in the Protect category, particularly for physical threats	5.00
Lightning (Small Provider)	Implement stroke shielding for substations	5.25
	Increase insulation strength and implement surge arresters for transmission lines	3.00
	Spare transformer	6.00
Wildfire	Manage vegetation	8.00
	Utilize fire resistant materials and retrofits: covered conductors, resistant poles, and transmission lines	9.00
Wind and Winter Storms	Underground transmission lines	4.50
	Upgrade transmission and distribution lines and equipment	8.75

Table 15 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Implement advanced early warning systems with seismometers and sensors	3.50
	Regularly utilize exercises and drills to identify improvement actions	5.00
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	N/A
Lightning (Small Provider)	Back-up mobile substation	5.50
	Implement workforce response	5.25
	Regularly utilize thunderstorm warning system	3.25
Wildfire	Develop protocols for de-energization during firefighting response	9.00
	Implement weather monitoring combined with public-safety shut-off programs	8.50
	Implement workforce preparedness training	6.00
Wind and Winter Storms	Develop mutual aid agreements for repair support	9.25
	Implement automated distribution	4.75
	Implement industry best practices through Oregon Public Utilities Commission (OPUC) safety programs	9.25
	Implement remote grid monitoring	8.75

Eastern Region Electricity Results

Figure 13 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. For cyberattack, the categories of Detect, Respond, and Recover include ratings of embed and evolve while the Identify category of physical attack is rated as evolve. These represent the greatest opportunities for improvement.

(A)

(B)

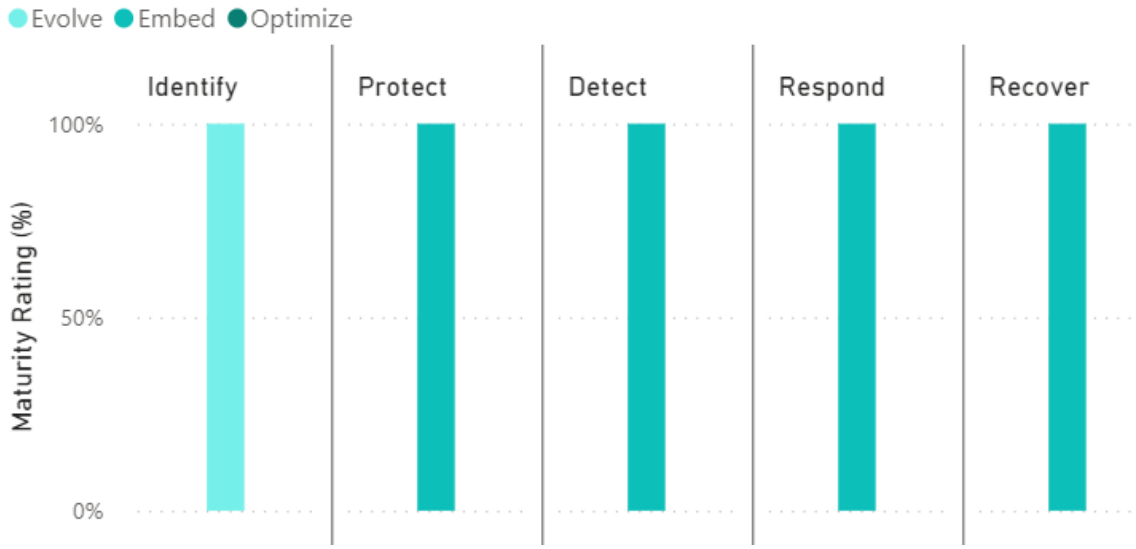
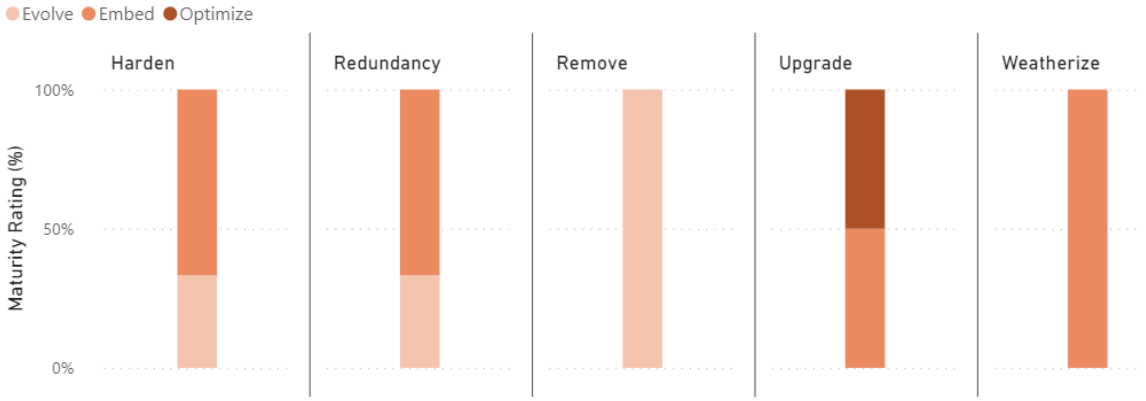


***Figure 13**: Distribution of mean maturity ratings of mitigation measures in the electricity subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

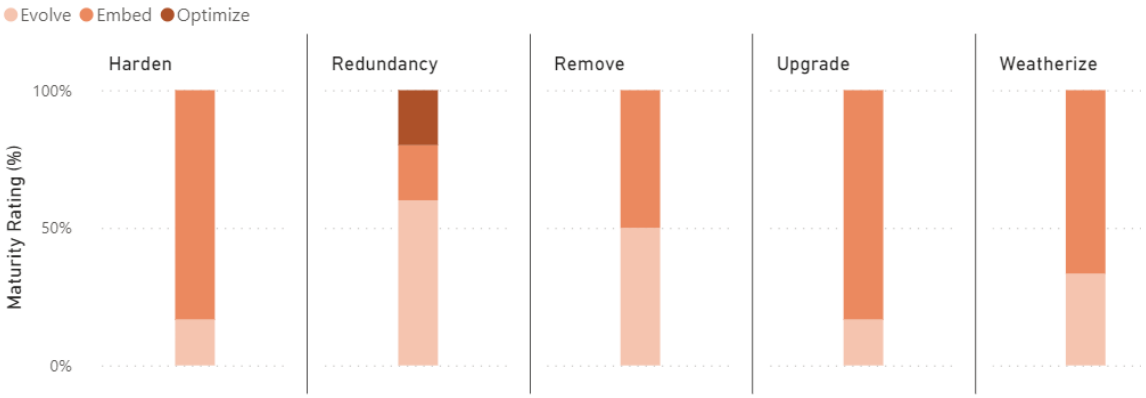
Figure 14 summarizes mean maturity ratings of physical mitigation measures for (A) drought, (B) wildfire, and (C) windstorms. The greatest opportunities for improvement are represented by the evolve rating

for drought in the Remove category and all categories other than Redundancy for wildfire and windstorms, which include combinations of evolve and embed ratings. The distribution of mean maturity ratings of operational measures for (A) CSZ earthquake, (B) drought, and (C) windstorms in **Figure 15**. Emergency Operation Plan is rated as evolve for CSZ earthquake. All categories other than Continuity of Operations Plan and Situational Awareness for drought and all categories other than Situational Awareness for windstorms consist of evolve and embed ratings. These represent the most opportunity for improvement.

(A)



(B)



(C)

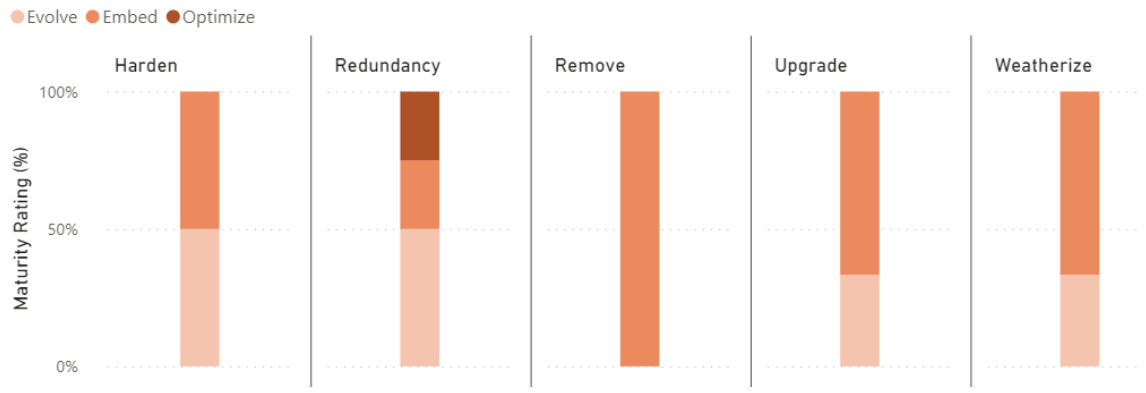
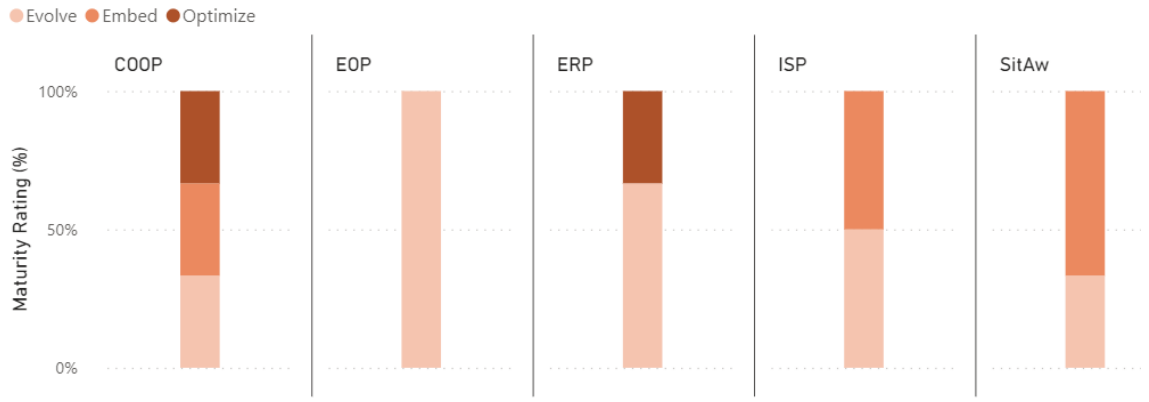


***Figure 14**: Distribution of mean maturity ratings of physical mitigation measures in the electricity subsector for (A) drought, (B) wildfire, and (C) windstorms across five categories of mitigation measures: 1.) Harden; 2.) Redundancy; 3.) Remove; 4.) Upgrade; and 5.) Weatherize. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

(A)



(B)

(C)

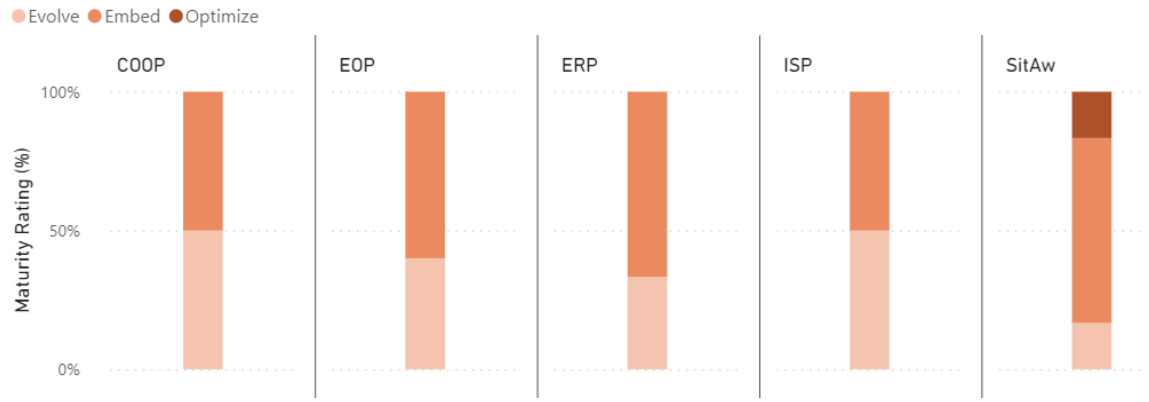


***Figure 15**: Distribution of mean maturity ratings of operational mitigation measures in the electricity subsector for (A) CSZ earthquake, (B) drought, and (C) windstorms across five categories of mitigation measures 1.) COOP – Continuity of Operations Plan; 2.) EOP – Emergency Operation Plan; 3.) ERP – Emergency Response Plan; 4.) ISP – Integrity Safety Plan; and 5.) SitAw – Situational Awareness. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

Additional stakeholder feedback on the preliminary results of the electricityrisk assessment included identified gaps specific to physical mitigation measures. For example, stakeholders identified that physical mitigation measures for drought and lightning are lacking for the majority of electric utility providers in the region.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Eastern Region Meeting (**Table 16**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 16*: RMMs presented at the Eastern Region Meeting for the electricity subsector and mean RMM rankings by participants (n = 2): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake (Large Provider)	Harden sub-stations	5.50
	Implement geotechnical and foundation interventions and ground improvements	N/A
	Improve backup power systems (generators, batteries, redundancies)	3.50
Drought (Small Provider)	Increase reservoir storage capacity and hydroelectric turbine efficiency at power plants	2.50
Human-Caused Threats	Optimize implementation of measures in the Protect categories	5.00
Wildfire	Manage vegetation	3.50
	Utilize fire resistant materials and retrofits: covered conductors, resistant poles, and transmission lines	6.00
Windstorms	Underground transmission lines	4.50
	Upgrade transmission and distribution lines and equipment	5.50

Table 16 *(continued).*

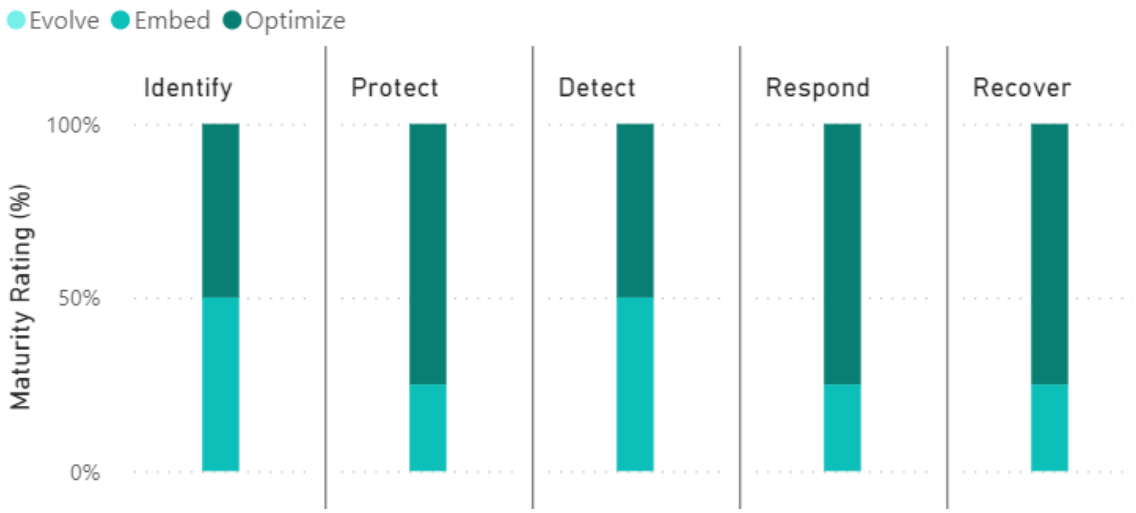
(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake (Large Provider)	Implement advanced early warning systems with seismometers and sensors	7.00
	Regularly utilize exercises and drills to identify improvement actions	2.00
Drought (Small Provider)	Adopt dry-cooling technologies to reduce water use	2.50
	Study projected climate change impacts to hydropower	2.50
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	5.50
Wildfire	Develop protocols for coordination with fire agencies	9.00
	Develop protocols to de-energize during firefighting response	11.00
	Implement weather monitoring combined with public-safety shut-off programs	8.50
	Implement workforce preparedness training	5.00
Windstorms	Implement automated distribution	7.00
	Implement industry best practices through Oregon Public Utilities Commission (OPUC) safety programs	9.50
	Implement remote grid monitoring	8.50

Northwest Region Electricity Results

Figure 16 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Ratings for both human-caused threats are fairly consistent across all five categories of mitigation measures. However, physical attack includes evolve ratings and represents greater opportunity for improvement relative to cyberattack.

(A)



(B)

***Figure 16**: Distribution of mean maturity ratings of mitigation measures in the electricity subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Figure 17 summarizes mean maturity ratings of physical mitigation measures for wildfire. The categories of Remove and Weatherize include embed and evolve ratings and represent the most opportunity for improvement. The distribution of mean maturity ratings of operational measures for (A) CSZ earthquake, (B) wildfire, and (C) winter storms are in **Figure 18**. The evolve and embed ratings for Integrity Safety

Plans and Situation Awareness for CSZ earthquake and Continuity of Operations Plan and Emergency Response Plans for wildfire represent the most opportunity for improvement. Ratings for all five categories are fairly consistent for winter storms. However, no categories include optimize ratings, suggesting opportunities for improvement in general for winter storms.

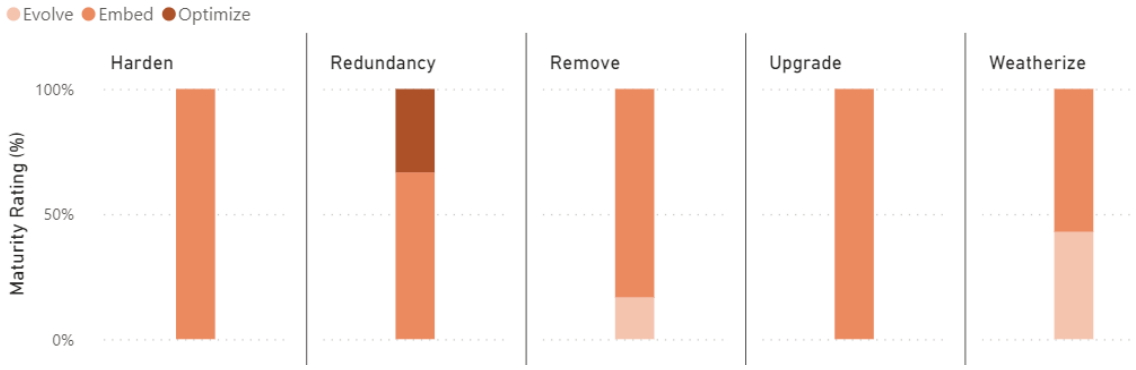


***Figure 17**: Distribution of mean maturity ratings of physical mitigation measures in the electricity subsector for wildfire across five categories of mitigation measures: 1.) Harden; 2.) Redundancy; 3.) Remove; 4.) Upgrade; and 5.) Weatherize. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

(A)

(B)

(C)

***Figure 18**: Distribution of mean maturity ratings of operational mitigation measures in the electricity subsector for (A) CSZ earthquake, (B) wildfire, and (C) winter storms across five categories of mitigation measures 1.) COOP – Continuity of Operations Plan; 2.) EOP – Emergency Operation Plan; 3.) ERP – Emergency Response Plan; 4.) ISP – Integrity Safety Plan; and 5.) SitAw – Situational Awareness. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

Additional stakeholder feedback on the preliminary results of the electricity risk assessment included identified gaps specific to infrastructure sensitivity. For instance, stakeholders indicated that transmission and distribution assets are the most sensitive to a CSZ earthquake, wildfires, windstorms, and winter

storms. Note, for wildfires, de-energization capabilities are required to facilitate firefighting response, and winter storms requires specific workforce Standard Operating Procedures (SOPs) to be in place.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Northwest Region Meeting (**Table 17**). During the meeting, five surveys were distributed to participants which gave them the opportunity to rank the updated physical and operational RMMs for the liquid fuels subsector. However, we received zero responses, and as a result, we were unable to collect participant feedback on the physical and operational RMMs.

Table 17*: RMMs presented at the Northwest Region Meeting for the electricity subsector.*

Threats	Physical RMMs	Operational RMMs
CSZ Earthquake	Harden sub-stations	Implement advanced early warning systems with seismometers and sensors
	Implement geotechnical and foundation interventions and ground improvements	Regularly utilize exercises and drills to identify improvement actions
	Improve backup power systems and redundancy (e.g., generators, redundant coastal power supply)	
Human-Caused Threats	Optimize implementation of measures in the Protect categories	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover
Wildfire	Manage vegetation	Develop protocols for de-energization for firefighting response
	Utilize fire resistant materials and retrofits (e.g., covered conductors, resistant poles, and transmission lines)	Implement weather monitoring combined with public-safety shut-off programs
		Implement workforce preparedness training
Wind and Winter Storms	Underground transmission lines	Develop SOPs for winter storm workforce response
	Upgrade transmission and distribution lines and equipment	Implement automated distribution
		Implement grid monitoring
		Implement industry best practices through safety programs of Oregon Public Utilities Commission (OPUC)

Portland Metro Region Electricity Results

Figure 19 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Embed ratings for the Identify and Detect categories for cyberattack indicate the greatest opportunity for improvement. However, physical attack has evolve ratings for each of the five categories, indicating more opportunity for improvement overall relative to cyberattack.

***Figure 19**: Distribution of mean maturity ratings of mitigation measures in the electricity subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

(A)


Evolve
Embed
Optimize
Identify
Protect
Detect
Respond
Recover
100%
50%
0%
Maturity Rating (%)

(B)

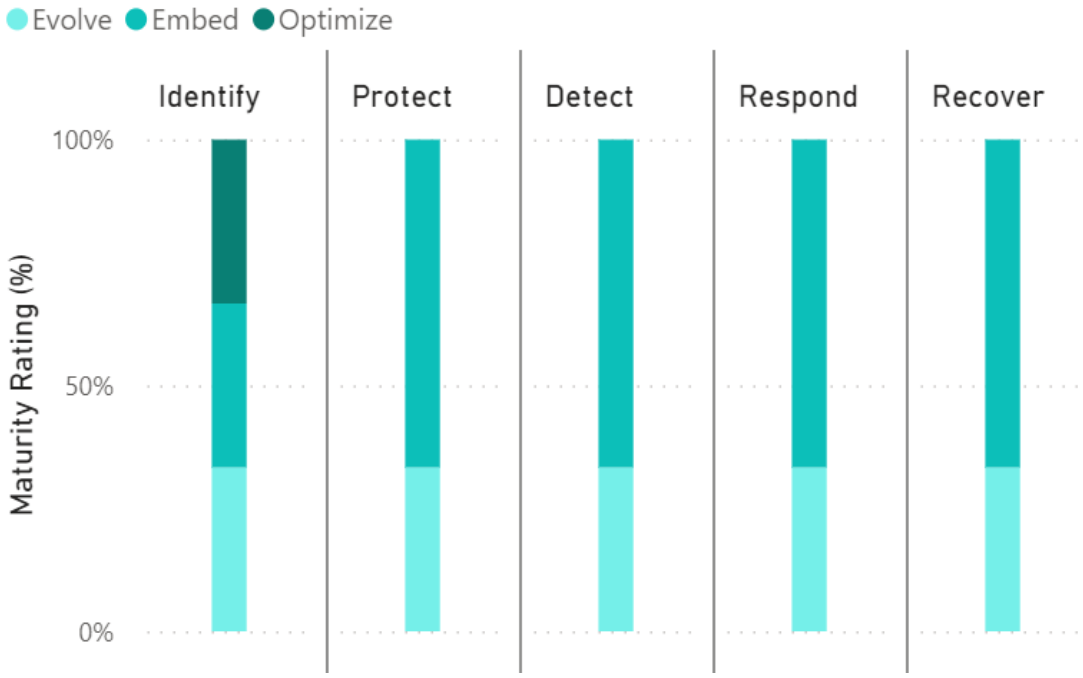

Evolve
Embed
Optimize
Identify
Protect
Detect
Respond
Recover
100%
50%
0%
Maturity Rating (%)

Figure 20 summarizes mean maturity ratings of physical mitigation measures for wildfire. The Remove and Weatherize categories include embed and evolve ratings and represent the most opportunity for improvement. The distribution of mean maturity ratings of operational measures for (A) CSZ earthquake, (B) wildfire, (C) windstorms, and (D) winter storms are in **Figure 21**. The most opportunity for improvement for CSZ earthquake is in the Integrity Safety Plan category, which consist of evolve and embed ratings. The same is true for the Continuity of Operations Plan, Emergency Operation Plan, and Emergency Response Plan categories for wildfire. For windstorms and winter storms, all give categories including optimize ratings. The categories with the most opportunity for improvement are those that also have evolve ratings and includes Continuity of Operations Plan and Emergency Operation Plans for both hazards in addition to Emergency Response Plans for windstorms.

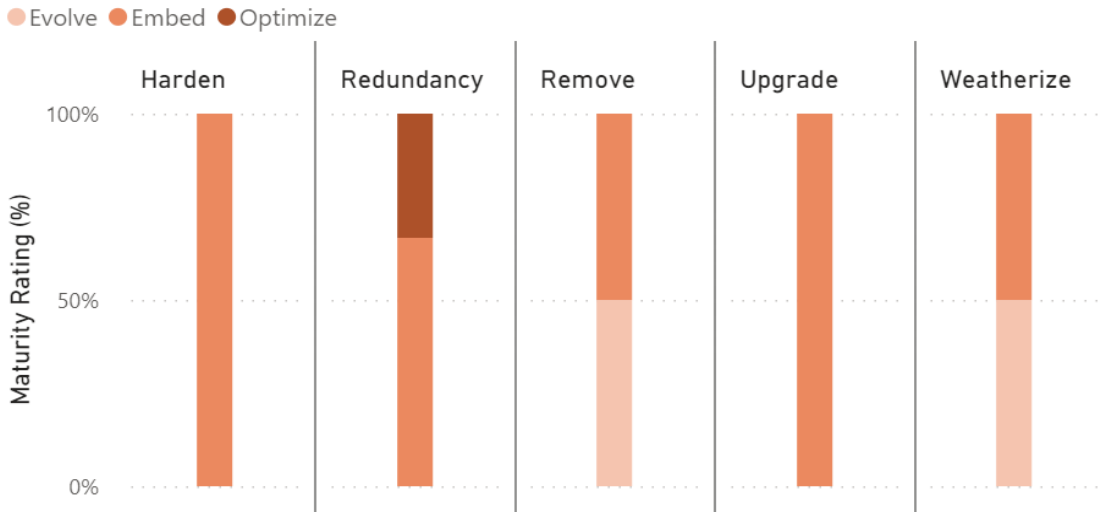
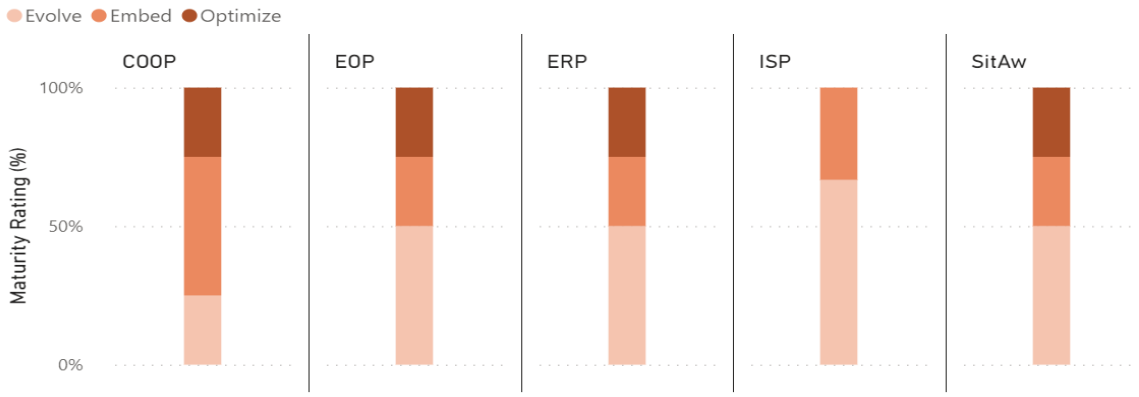


***Figure 20**: Distribution of mean maturity ratings of physical mitigation measures in the electricity subsector for wildfire across five categories of mitigation measures: 1.) Harden; 2.) Redundancy; 3.) Remove; 4.) Upgrade; and 5.) Weatherize. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

***Figure 21**: Distribution of mean maturity ratings of operational mitigation measures in the electricity subsector for (A) CSZ earthquake, (B) wildfire, (C) windstorms, and (D) winter storms across five categories of mitigation measures 1.) COOP – Continuity of Operations Plan; 2.) EOP – Emergency Operation Plan; 3.) ERP – Emergency Response Plan; 4.) ISP – Integrity Safety Plan; and 5.) SitAw – Situational Awareness. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

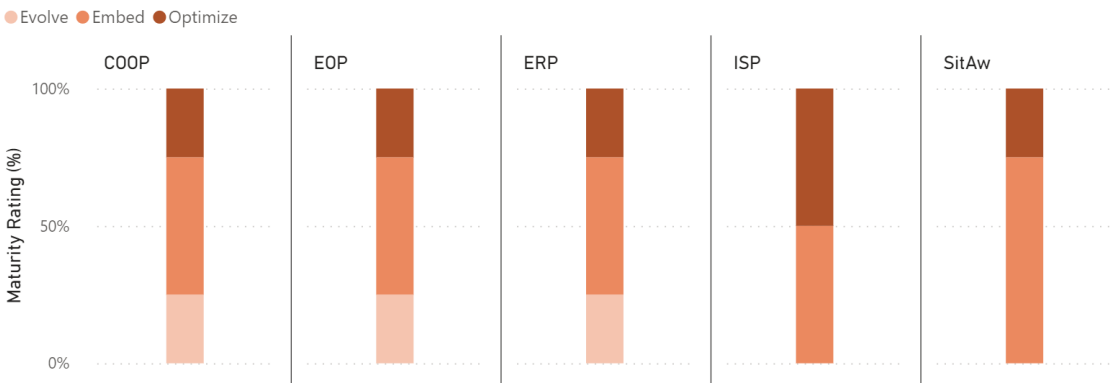
(A)


Evolve
Embed
Optimize
COOP
EOP
ERP
ISP
SitAw
100%
50%
0%
Maturity Rating (%)

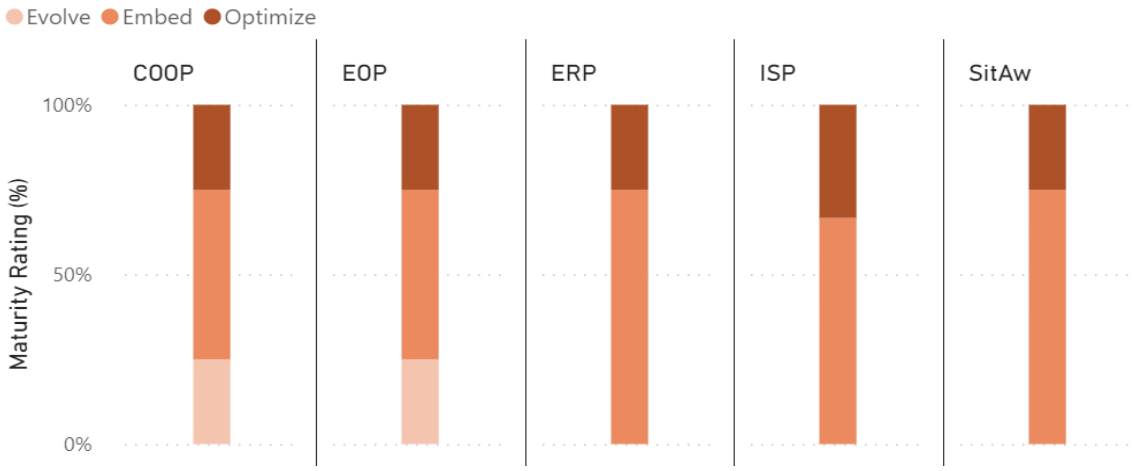
(B)


Evolve
Embed
Optimize
COOP
EOP
ERP
ISP
SitAw
100%
50%
0%
Maturity Rating (%)

(C)


Evolve
Embed
Optimize
COOP
EOP
ERP
ISP
SitAw
100%
50%
0%
Maturity Rating (%)

(D)


Evolve
Embed
Optimize
COOP
EOP
ERP
ISP
SitAw
Maturity Rating (%)
100%
50%
0%

Additional stakeholder feedback on the preliminary results of the electricity risk assessment included identified gaps specific to infrastructure sensitivity. For example, stakeholders identified that transmission and distribution assets are the most at risk in the region, specifically to wildfires, windstorms, and winter storms. In particular, wildfire mitigation capacity is more pronounced among small electric providers. Production and storage assets were also indicated as being sensitive to windstorms.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Portland Metro Region Meeting (**Table 18**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 18*: RMMs presented at the Portland Metro Region Meeting for the electricity subsector and mean RMM rankings by participants (n = 8): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Harden sub-stations	5.50
	Implement geotechnical and foundation interventions and ground improvements	4.00
	Improve backup power systems (generators, batteries, redundancies)	5.50
Human-Caused Threats	Optimize implementation of measures in the Protect category, particularly for physical threats	N/A
Wildfire (Large Provider)	Manage vegetation	4.43
	Utilize fire resistant materials and retrofits: covered conductors, resistant poles, and transmission lines	3.14
Wind and Winter Storms	Install breakaway disconnect systems to preserve poles	3.50
	Underground transmission lines	4.50
	Upgrade transmission and distribution lines and equipment to reduce failure	4.43

Table 18 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Implement early warning system with seismometers and sensors	8.25
	Regularly utilize exercises and drills to identify improvement actions	4.50
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	N/A
Wildfire (Large Provider)	Develop mutual aid agreements for workforce augmentation	7.75
	Enhance policies and trainings to use prescribed fire and fuel treatments	3.25
	Implement weather monitoring combined with public-safety shut-off programs	5.00
	Implement workforce preparedness training	1.74
Wind and Winter Storms	Implement automated distribution	6.25
	Implement industry best practices through Oregon Public Utilities Commission (OPUC) safety programs	7.25
	Implement remote grid monitoring	5.75

Southwest Region Electricity Results

Figure 22 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks, respectively. Distribution was very similar for both threats with half of the rating across all five categories being optimize. However, the other half of ratings for physical attack were evolve while for cyberattack they were embed. Thus, more opportunity for improvement is present for physical attack relative to cyberattack.

(A)

(B)

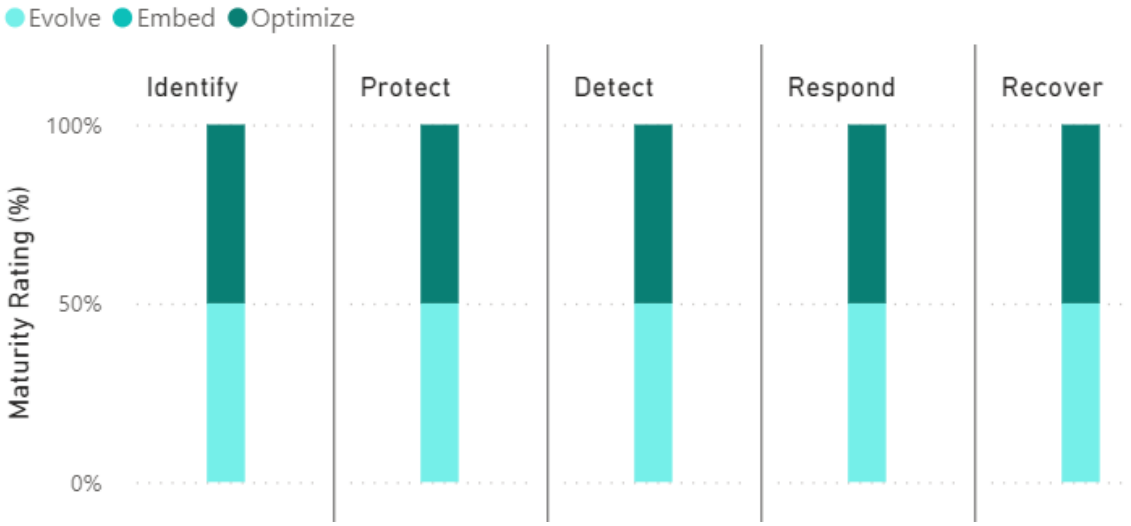
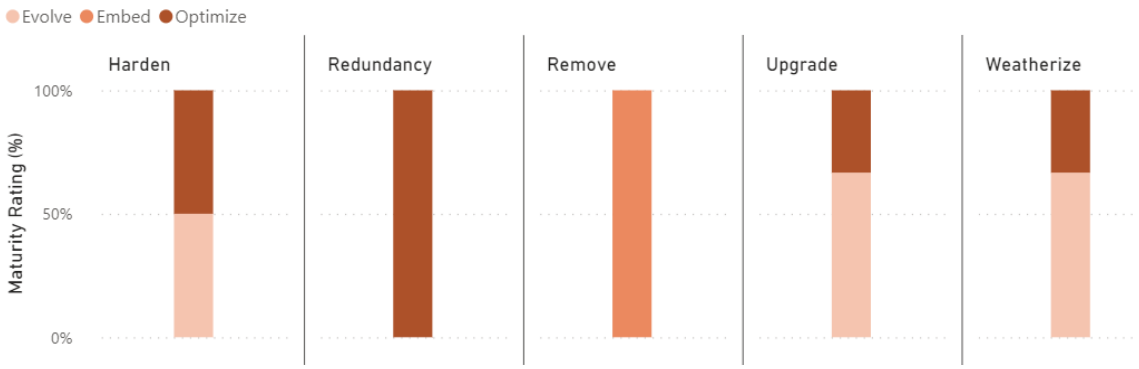


***Figure 22**: Distribution of mean maturity ratings of mitigation measures in the electricity subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

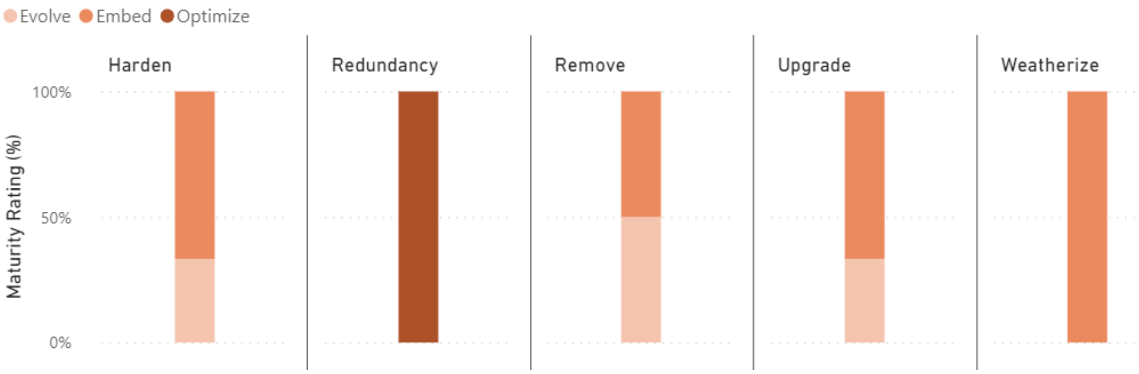
Figure 23 summarizes mean maturity ratings of physical mitigation measures for (A) CSZ earthquake, (B) wildfire, and (C) winter storms. For CSZ earthquake, the categories of Upgrade and Weatherize include the highest percentage of evolve ratings. For wildfire, the categories of Harden, Remove, and Upgrade consist of combinations of evolve and embed ratings. Harden and Upgrade categories include evolve

ratings for winter storms. This collection represents the greatest opportunities for improvements across each hazard. The distribution of mean maturity ratings of operational measures for (A) CSZ earthquake, (B) wildfire, and (C) winter storms in **Figure 24** reveal that winter storms has the most frequent evolve rating, present in all five categories of measures, and represents more opportunity for improvement relative to CSZ earthquake and wildfire. However, for CSZ earthquake, the Emergency Operation Plan and Emergency Response Plan categories consist of evolve and embed ratings. The same is true for the Continuity of Operations Plan, Emergency Response Plan, and Integrity Safety Plan categories for wildfire. These represent the greatest opportunities for improvement for each respective hazard.

(A)



(B)



(C)

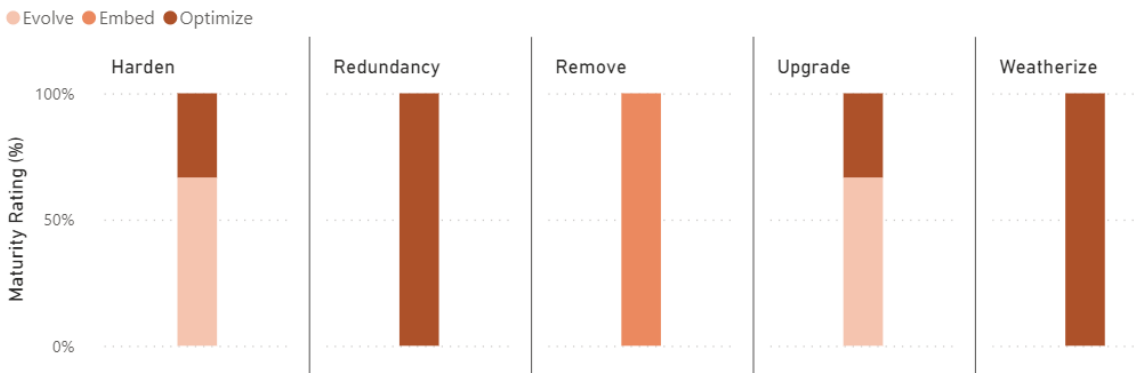
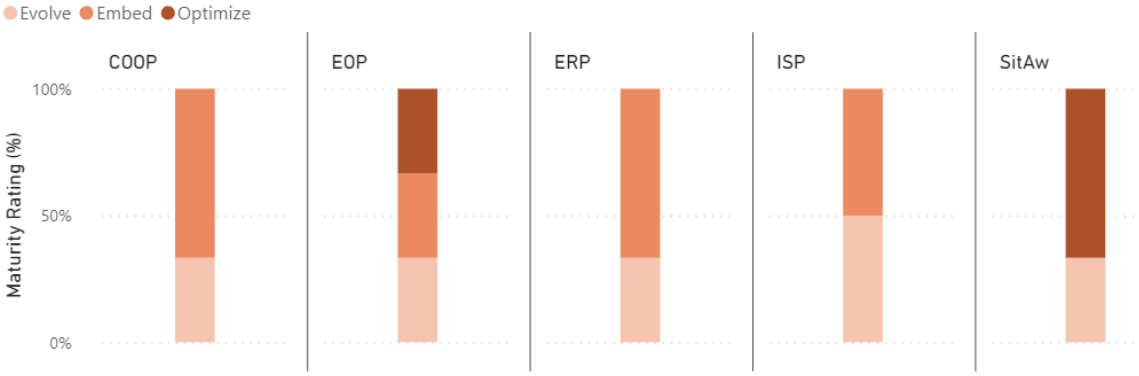


***Figure 23**: Distribution of mean maturity ratings of physical mitigation measures in the electricity subsector for (A) CSZ earthquake, (B) wildfire, and (C) winter storms across five categories of mitigation measures: 1.) Harden; 2.) Redundancy; 3.) Remove; 4.) Upgrade; and 5.) Weatherize. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

(A)

(B)



(C)

***Figure 24**: Distribution of mean maturity ratings of operational mitigation measures in the electricity subsector for (A) CSZ earthquake, (B) wildfire, and (C) winter storms across five categories of mitigation measures 1.) COOP – Continuity of Operations Plan; 2.) EOP – Emergency Operation Plan; 3.) ERP – Emergency Response Plan; 4.) ISP – Integrity Safety Plan; and 5.) SitAw – Situational Awareness. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

Additional stakeholder feedback on the preliminary results of the electricity risk assessment included identified gaps specific to electric system resilience and infrastructure sensitivity. For example, considering CSZ earthquake risk, stakeholders identified a need to improve back-up power supply;

harden transmission, distribution, production, and storage assets in the region; as well as increase awareness on the location of assets along the coast that are currently outside of the tsunami zone. Furthermore, transmission and distribution assets in the region are most sensitive to windstorms and winter storms. Stakeholders noted that BPA distribution power lines are also at risk to wildfires in the region.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Southwest Region Meeting (**Table 19**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 19*: RMMs presented at the Southwest Region Meeting for the electricity subsector and mean RMM rankings by participants (n = 1): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Harden sub-stations	6.00
	Implement geotechnical and foundation interventions and ground improvements	5.00
	Improve backup power systems and redundancy (generators, redundant coastal power supply)	4.00
Human-Caused Threats	Optimize implementation of measures in the Protect categories	1.00
Wildfire	Manage vegetation	8.00
	Utilize fire resistant materials and retrofits: covered conductors, resistant poles, and transmission lines	7.00
Wind and Winter Storms	Underground transmission lines	2.00
	Upgrade transmission and distribution lines and equipment	3.00

Table 19 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Implement advanced early warning systems with seismometers and sensors	5.00
	Regularly utilize exercises and drills to identify improvement actions	3.00
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	1.00
Wildfire	Implement weather monitoring combined with public-safety shut-off programs	9.00
	Implement workforce preparedness training	8.00
Wind and Winter Storms	Develop mutual aid agreements for repair support	6.00
	Implement automated distribution	2.00
	Implement grid monitoring	7.00
	Implement industry best practices through Oregon Public Utilities Commission (OPUC) safety programs	4.00

Willamette Valley Region Electricity Results

Figure 25 summarizes mean maturity ratings of mitigation measures for (A) cyberattacks and (B) physical attacks. The Identify, Detect, and Respond categories for cyberattack include evolve ratings and represent the greatest opportunity for improvement. Ratings are fairly consistent across all categories for physical attack and, relative to cyberattack, are more mature overall, indicating more opportunity for improvement for cyberattack relative to physical attack.

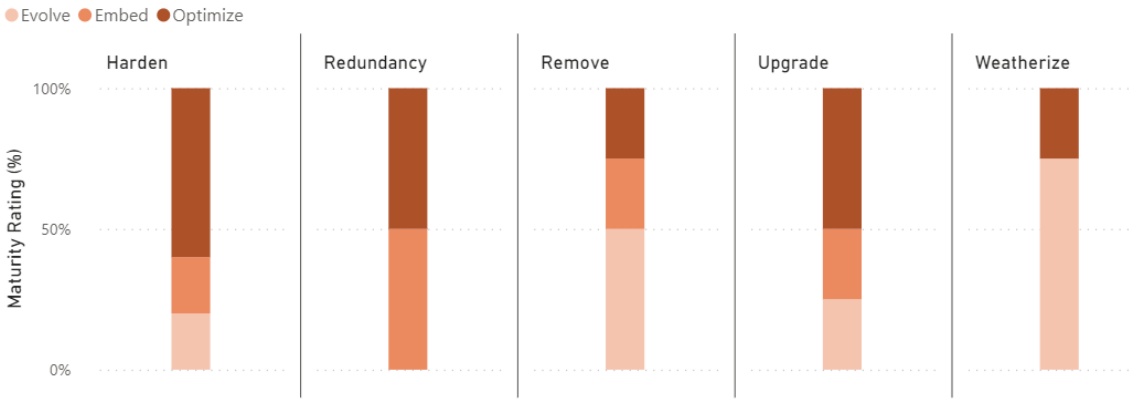
(A)

(B)

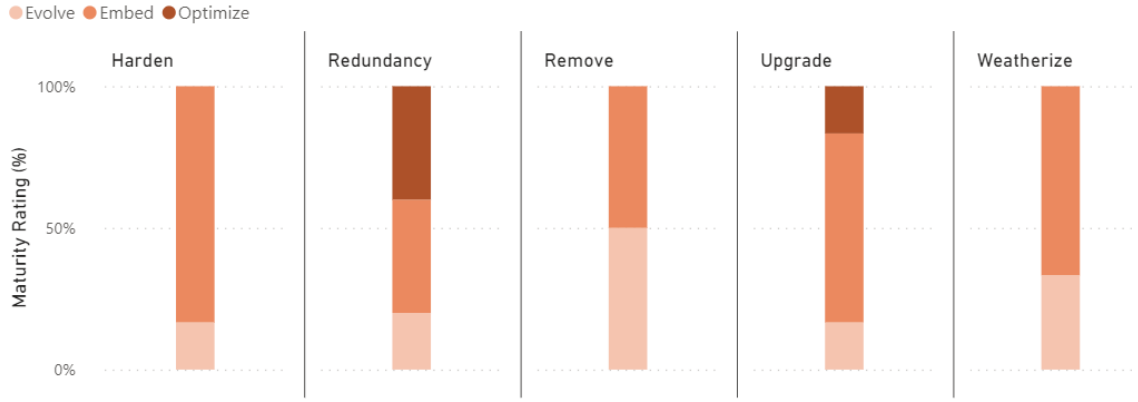
Figure 25*: Distribution of mean maturity ratings of mitigation measures in the electricity subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Figure 26 summarizes mean maturity ratings of physical mitigation measures for (A) CSZ earthquake, (B) wildfire, and (C) windstorms. The categories of Remove and Weatherize for CSZ earthquake and Harden and Upgrade for windstorms have the highest percentage of evolve ratings, indicating those categories represent the greatest opportunities for improvement for the respective hazards. For wildfire, all five categories include evolve ratings, indicating opportunity for improvement in general for this hazard with relatively more opportunity in the Remove category, which has the highest percentage of evolve ratings and no optimize ratings. The distribution of mean maturity ratings of operational measures for (A) CSZ earthquake, (B) wildfire, and (C) windstorms in **Figure 27** reveal consistent evolve ratings. With the exception of Continuity of Operations Plan for CSZ earthquake, all categories for all three hazards include both evolve and embed ratings, indicating consistent opportunities for improvement.

(A)



(B)



(C)

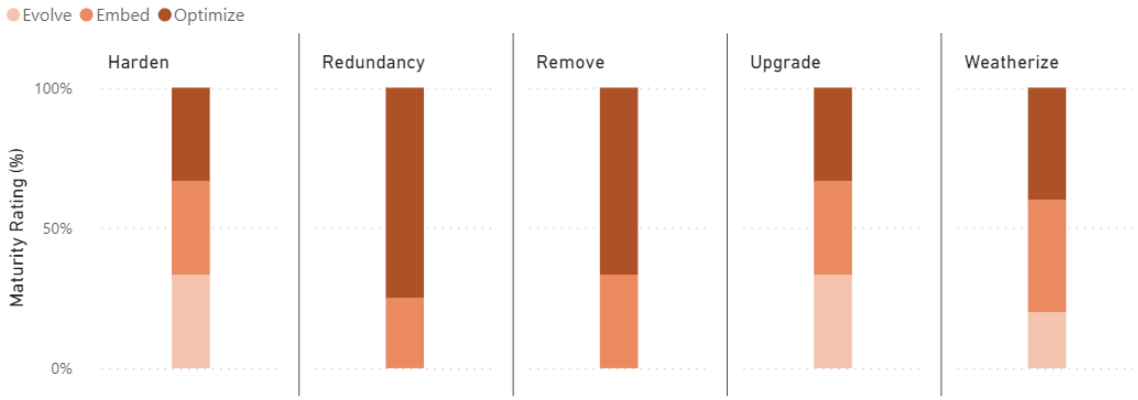
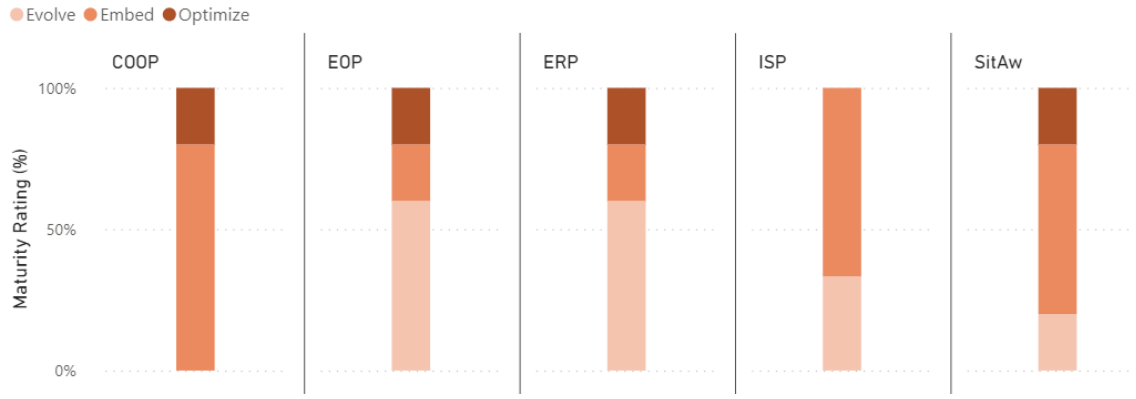
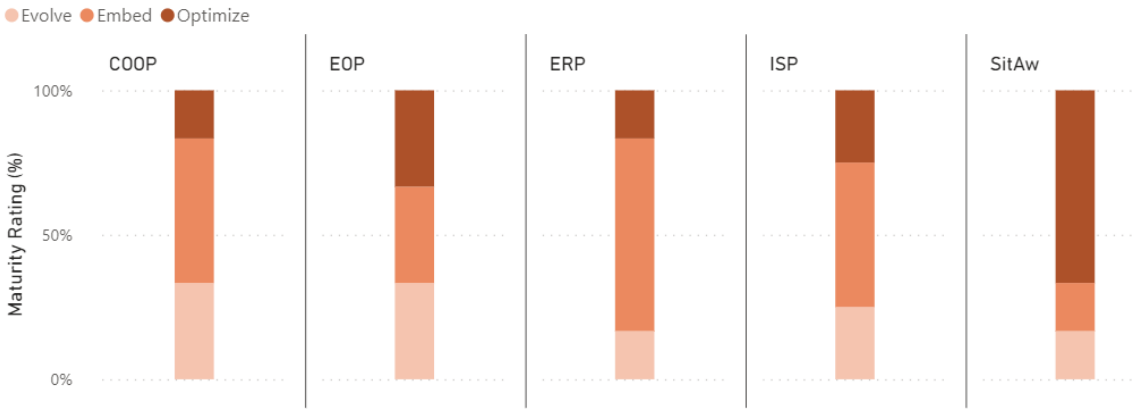


***Figure 26**: Distribution of mean maturity ratings of physical mitigation measures in the electricity subsector for (A) CSZ earthquake, (B) wildfire, and (C) windstorms across five categories of mitigation measures: 1.) Harden; 2.) Redundancy; 3.) Remove; 4.) Upgrade; and 5.) Weatherize. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

(A)



(B)



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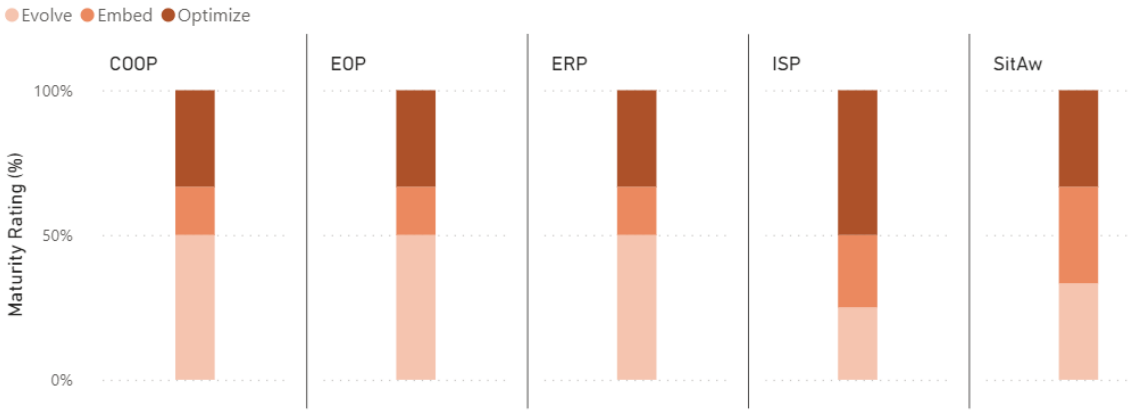


***Figure 27**: Distribution of mean maturity ratings of operational mitigation measures in the electricity subsector for (A) CSZ earthquake, (B) wildfire, and (C) windstorms across five categories of mitigation measures 1.) COOP – Continuity of Operations Plan; 2.) EOP – Emergency Operation Plan; 3.) ERP – Emergency Response Plan; 4.) ISP – Integrity Safety Plan; and 5.) SitAw – Situational Awareness. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

Additional stakeholder feedback on the preliminary results of the electricity risk assessment included identified gaps specific to infrastructure sensitivity. For instance, stakeholders identified that transmission and distribution assets are the most at risk in the region, specifically to a CSZ earthquake and winter storms. Storage and production assets are also sensitive to these threats. Furthermore, winter storms cause significant outages across the region due to ice buildup on equipment, collapsed trees on power lines, load shedding, and workforce limitations. Stakeholders noted that BPA distribution power lines, substations, and transformers are also at risk to wildfires in the region.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Willamette Valley Region Meeting (**Table 20**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 20*: RMMs presented at the Willamette Valley Region Meeting for the electricity subsector and mean RMM rankings by participants (n = 5): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Harden sub-stations	7.00
	Implement geotechnical and foundation interventions and ground improvements	6.75
	Improve backup power systems (generators, batteries, redundancies)	5.25
Human-Caused Threats	Optimize implementation of measures in the Protect categories	3.50
Wildfire	Manage vegetation	5.00
	Utilize fire resistant materials and retrofits: covered conductors, resistant poles, and transmission lines	2.80
Wind and Winter Storms	Underground transmission lines	3.60
	Upgrade transmission and distribution lines and equipment	3.40

***Table 20** (continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Implement advanced early warning systems with seismometers and sensors	11.00
	Regularly utilize exercises and drills to identify improvement actions	6.00
Human-Caused Threats	Optimize implementation across all categories – Identify, Protect, Detect, Respond, Recover	1.50
Wildfire	Develop protocols to de-energize for firefighting response	8.25
	Enhance policies and trainings to use prescribed fire and fuel treatments	10.00
	Implement weather monitoring combined with public-safety shut-off programs	6.00
	Implement workforce preparedness training	5.00
Wind and Winter Storms	Develop mutual aid agreements for emergency support	6.75
	Implement automated distribution	4.00
	Improve emergency communications	N/A
	Implement grid monitoring	5.67
	Implement industry best practices through Oregon Public Utility Commission safety programs	2.75

Natural Gas Results

Maturity ratings for the natural gas sector are presented on a statewide scale to protect anonymity of respondents. Stakeholders largely rated maturity as optimized across the state. Ratings for both human-caused threats are included for consistency. Ratings for select natural hazards are highlighted to include ratings that were not optimized.

As seen in **Figure 28A**, statewide maturity ratings of mitigation measures for cyberattacks across the five categories of mitigation measures were 100 percent optimized. However, for physical attacks, the categories of Identify and Detect included ratings of embed and evolve (**Figure 28B**) and represent the greatest opportunities for improvement.

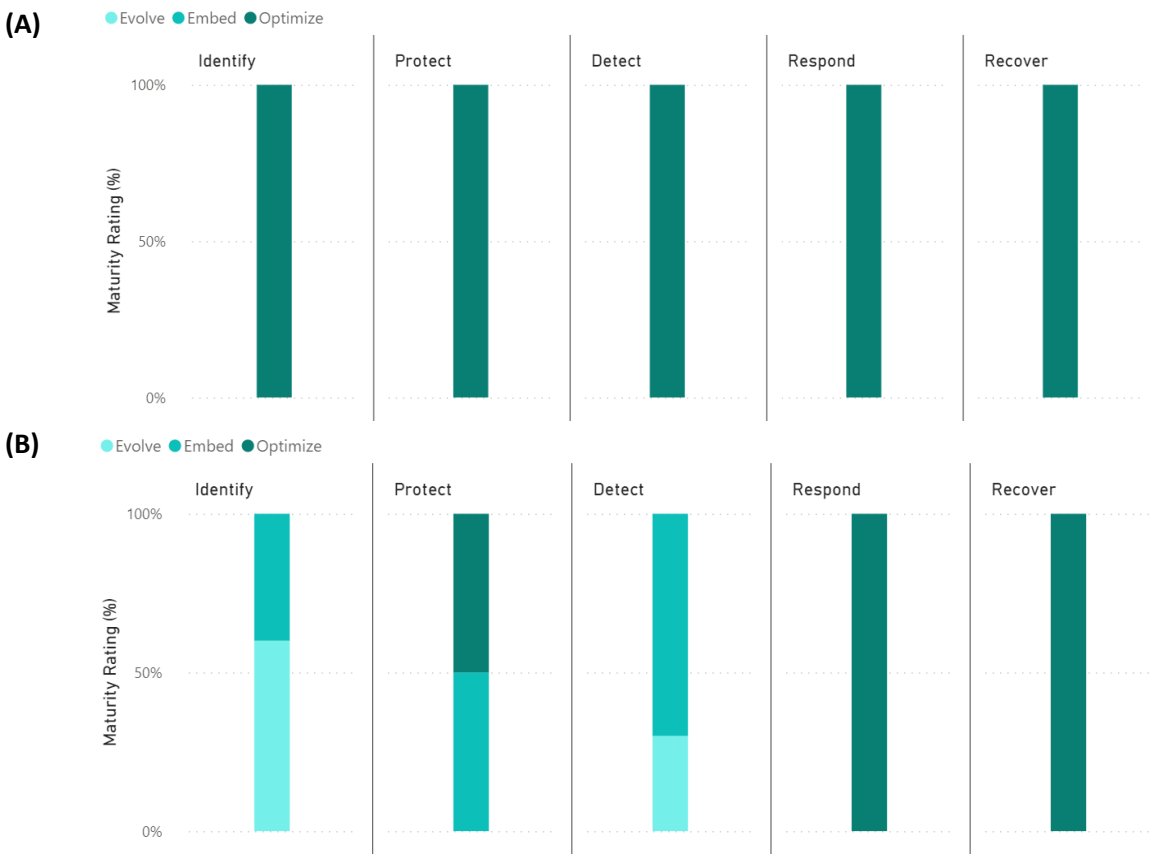
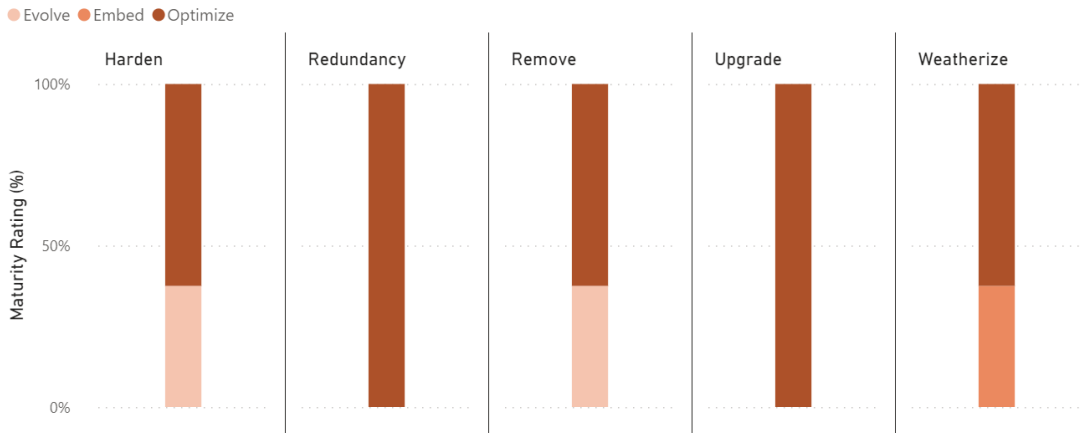


***Figure 28**: Distribution of mean maturity ratings of mitigation measures in the natural gas subsector for (A) cyberattacks and (B) physical attacks across five categories of mitigation measures: 1.) Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities; 2.) Protect – develop and implement appropriate safeguards to ensure delivery of services; 3.) Detect – develop and implement appropriate activities to identify occurrence of a security event; 4.) Respond – develop and implement appropriate activities to take action regarding a detected security event; 5.) Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event. Ratings of maturity increase from least mature, evolve (light teal), mid-level maturity, embed (medium teal), and highest maturity, optimize (dark teal).*

Figure 29 summarizes statewide mean maturity ratings of physical mitigation measures for (A) CSZ earthquake, (B) flood, (C) lightning, (D) wildfire, and (E) windstorms, respectively. While four of the five categories of physical mitigation measures are largely rated as optimized for (C) lightning, (D) wildfire, and (E) windstorms, no measures are implemented in the category of Remove for any of the three hazards. For (A) CSZ earthquake, the Harden and Remove categories include evolve ratings. Similarly, evolve ratings are included for (B) flood in the categories of Harden, Redundancy, and Remove. These represent the most opportunity for improvement. The distribution of mean statewide maturity ratings of operational measures for (A) CSZ earthquake, (B) flood, and (C) lightning in **Figure 30** shows that Situational Awareness includes ratings of evolve and embed and represents the greatest opportunity for improvement.

***Figure 29**: Distribution of statewide mean maturity ratings of physical mitigation measures in the natural gas subsector for (A) CSZ earthquake, (B) flood, (C) lightning, (D) wildfire, and (E) windstorms across five categories of mitigation measures: 1.) Harden; 2.) Redundancy; 3.) Remove; 4.) Upgrade; and 5.) Weatherize. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

(A)


Evolve
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Harden
Redundancy
Remove
Upgrade
Weatherize
100%
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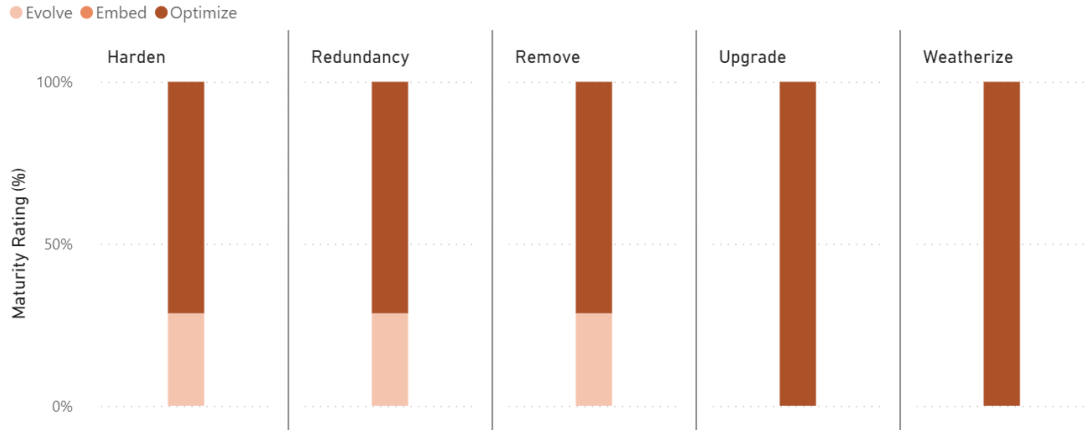
Maturity Rating (%)

(B)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Redundancy
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Upgrade
Weatherize
100%
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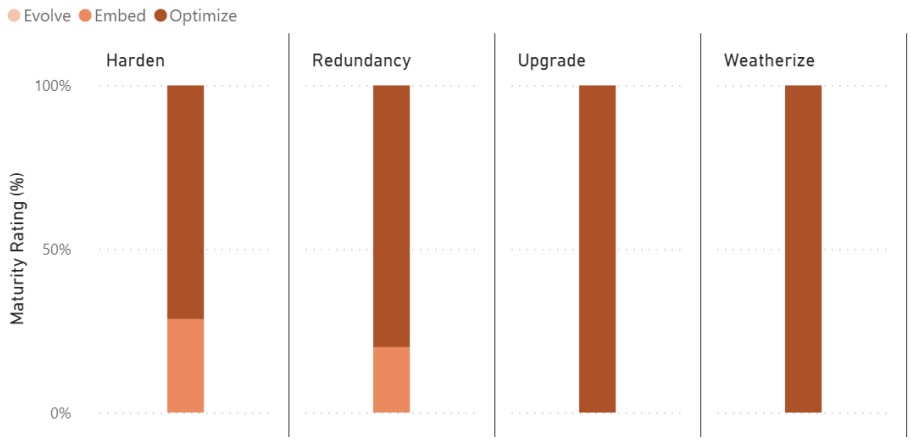
0%
Maturity Rating (%)

(C)


Evolve
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Redundancy
Upgrade
Weatherize
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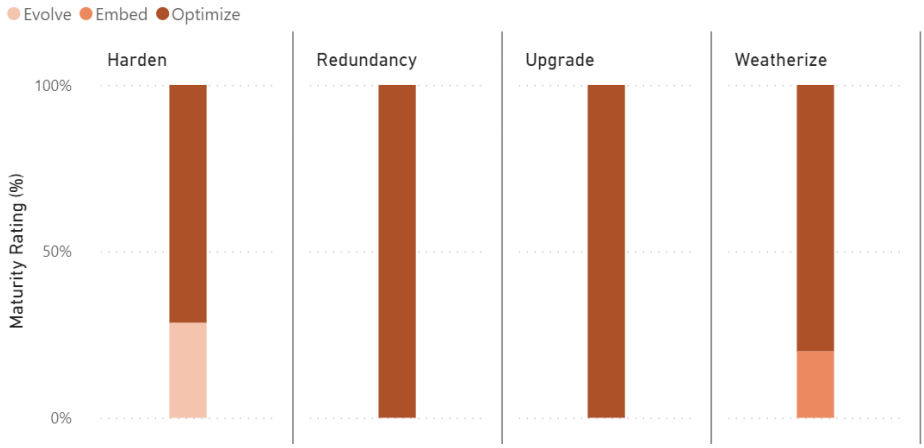
Maturity Rating (%)

(D)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Upgrade
Weatherize
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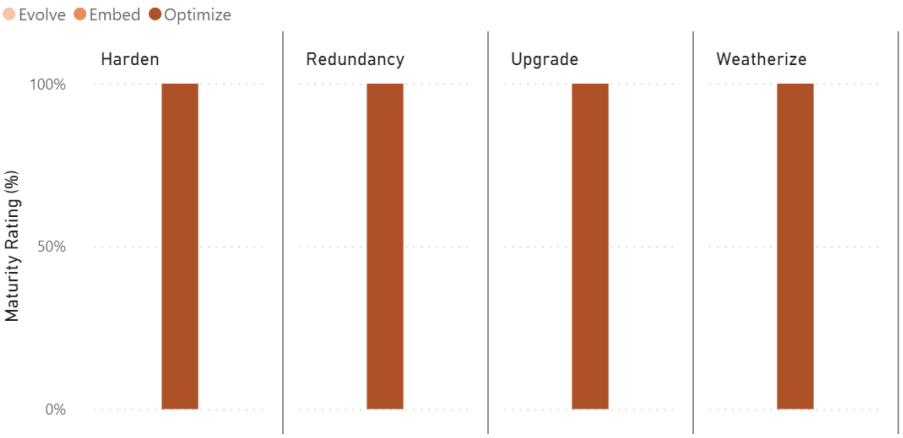
Maturity Rating (%)

(E)


Evolve
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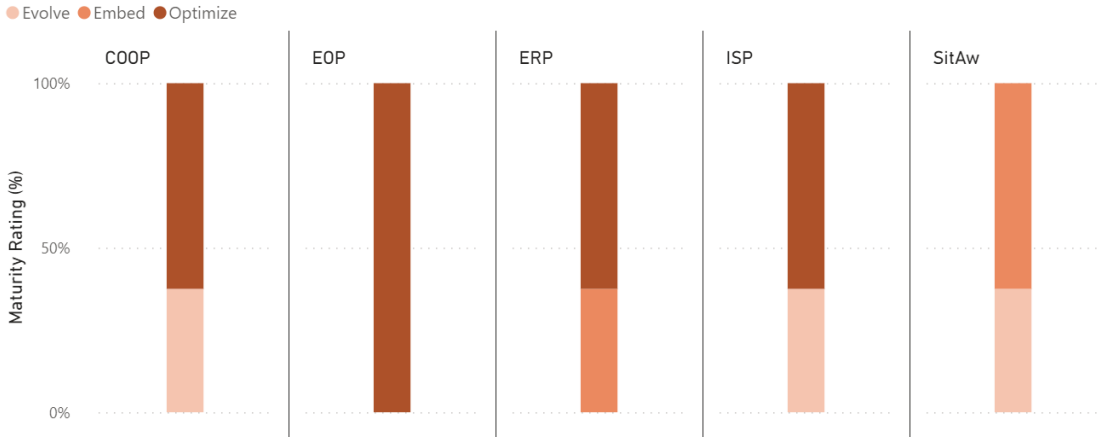
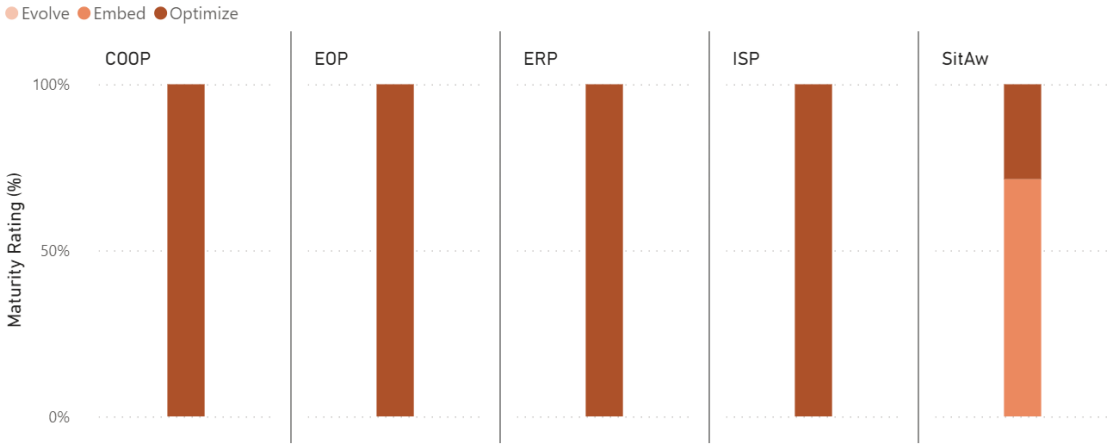
Optimize
Harden
Redundancy
Upgrade
Weatherize
100%
50%
0%
Maturity Rating (%)

***Figure 30**: Distribution of statewide mean maturity ratings of operational mitigation measures in the natural gas subsector for (A) CSZ earthquake, (B) flood, and (C) lightning across five categories of mitigation measures 1.) COOP – Continuity of Operations Plan, 2.) EOP – Emergency Operation Plan, 3.) ERP – Emergency Response Plan, 4.) ISP – Integrity Safety Plan, and 5.) SitAw – Situational Awareness. Ratings of maturity increase from least mature, evolve (light orange), mid-level maturity, embed (medium orange), and highest maturity, optimize (dark orange).*

(A)


Evolve
Embed
Optimize
COOP
EOP
ERP
ISP
SitAw
100%
50%
0%
Maturity Rating (%)

(B)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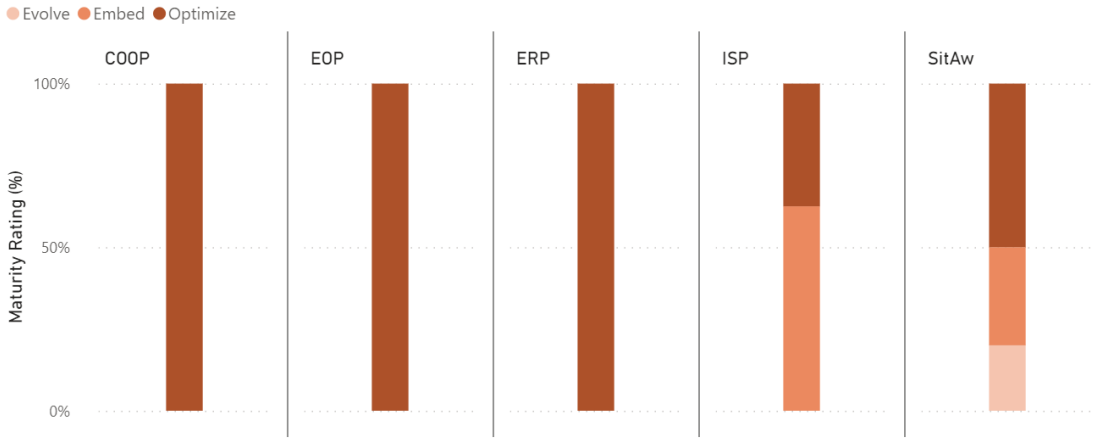
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Cascades Region Natural Gas Results

Stakeholder feedback on the preliminary results of the natural gas risk assessment supported the development of RMMs for the Cascades region. Feedback included identified gaps specific to above ground facility/asset risk, infrastructure sensitivity to earthquakes, and situational awareness. For example, stakeholders noted that wildfire and windstorms threaten all above ground natural gas infrastructure in the Cascades region. Furthermore, production plants, transmission pipelines, above and below ground storage tanks, and distribution lines are examples of assets that are also sensitive to a CSZ earthquake. Lastly, for all hazards and threats in the region, stakeholders highlighted gaps related to the situational awareness adaptive capacity measure.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Cascades Region Meeting (**Table 21**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 21*: RMMs presented at the Cascades Region Meeting for the natural gas subsector and mean RMM rankings by participants (n = 4): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	6.75
	Implement containment measures for spills	6.00
	Implement tank foundation seismic retrofits	5.75
	Improve backup power systems	7.75
	Harden pipelines (ties, flexible joints, etc.)	8.25
Flood	Protect critical facilities: gas regulator vents	2.75
	Protect facilities in flood zone or move out of flood zone	1.75
Human-Caused Threats	Optimize implementation of measures in the Protect category, particularly for physical threats	4.25
Windstorms	Anchor equipment securely to prevent displacement or overturning during high winds	6.50
	Install barriers/shields	5.25

Table 21 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Coordinate with Oregon Department of Energy (ODOE) and Oregon Department of Emergency Management (ODEM)	11.25
	Develop detailed vulnerability assessment of system assets	9.75
	Develop Integrity Safety Plans and Supply chain continuity plans	9.25
	Engage in local and state emergency transportation route planning	10.00
	Strengthen Oregon Public Utilities Commission's seismic oversight authority	4.50
Flood	Develop detailed vulnerability assessment of system assets	7.50
	Maintain baseline risk maps and a framework for identifying areas of high risk	4.50
	Provide stormwater pumps to remove flood water and prevent submersion	1.50
Human-Caused Threats	Optimize implementation of measures in the Identify, Protect, and Detect categories, particularly for physical threats	7.00
Windstorms	Develop detailed vulnerability assessment of system assets	8.00
	Implement emergency shutdown systems	8.25
	Provide incident command system training for all staff	4.75
	Provide minimum design specifications	4.75

Eastern Region Natural Gas Results

Stakeholder feedback on the preliminary results of the natural gas risk assessment supported the development of RMMs for the Eastern region. Feedback included identified gaps specific to above ground and below ground facility/asset risk and situational awareness. For example, stakeholders detailed above ground facilities are the most sensitive to windstorms, and above/below ground storage tanks and regulating stations are at risk due to floods and liquefaction. In addition, for all hazards and

threats in the region, stakeholders highlighted existing gaps related to the situational awareness adaptive capacity measure.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Eastern Region Meeting (**Table 22**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

***Table 22**: RMMs presented at the Eastern Region Meeting for the natural gas subsector and mean RMM rankings by participants (n = 2): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	4.50
	Harden pipelines (ties, flexible joints, etc.)	6.50
	Implement containment measures for spills	5.50
	Improve backup power systems	8.50
Flood	Protect critical facilities: gas regulator vents	3.00
	Protect facilities in flood zone or move out of flood zone	1.50
Human-Caused Threats	Optimize implementation of measures in the Protect category, particularly for physical threats	6.50
Windstorms	Anchor equipment securely to prevent displacement or overturning during high winds	5.00
	Install barriers/shields	4.00

Table 22 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Coordinate with Oregon Department of Energy (ODOE) and Oregon Department of Emergency Management (ODEM)	6.00
	Develop detailed vulnerability assessment of system assets	6.00
	Develop Integrity Safety Plans and Supply chain continuity plans	4.00
	Engage in local and state emergency transportation route planning	5.50
	Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	2.50
Flood	Develop detailed vulnerability assessment of system assets	12.00
	Maintain baseline risk maps and a framework for identifying areas of high risk	7.00
	Provide stormwater pumps to remove flood water and prevent submersion	8.00
Human-Caused Threats	Optimize implementation of measures in the Identify, Protect, and Detect categories, particularly for physical threats	11.50
Windstorms	Develop detailed vulnerability assessment of system assets	12.00
	Implement emergency shutdown systems	6.50
	Provide incident command system training for all staff	5.50
	Provide minimum design specifications for new construction and retrofitting	4.50

Northwest Region Natural Gas Results

Stakeholder feedback on the preliminary results of the natural gas risk assessment supported the development of RMMs for the Northwest region. Feedback included identified gaps specific to physical hardening of natural gas system elements, wildfire adaptive capacity, and situational awareness. For

example, stakeholders indicated that a CSZ earthquake and tsunami poses a risk to the natural gas system in the region. Therefore, there is a need for physical hardening of system elements, particularly storage facilities/tanks and pipelines. Stakeholders also noted that spill containment and transportation networks are critical considerations. In addition, wildfire adaptive capacity gaps also exist for protecting above ground storage tanks, ensuring capabilities to isolate areas of the system, and ensuring defensible spaces around key assets. Lastly, for all hazards and threats in the region, stakeholders highlighted gaps related to the situational awareness adaptive capacity measure.

Referencing the feedback collected from stakeholders, a region specific list of physical and operational RMMs was created and presented to participants at the Northwest Region Meeting (**Table 23**). During the meeting, five surveys were distributed to participants which gave them the opportunity to rank the updated physical and operational RMMs for the liquid fuels subsector. However, we received zero responses, and as a result, we were unable to collect participant feedback on the physical and operational RMMs.

***Table 23**: RMMs presented at the Northwest Region Meeting for the natural gas subsector.*

Threats	Physical RMMs	Operational RMMs
CSZ Earthquake	Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil Harden pipelines (ties, flexible joints, etc.) Implement containment measures for spills Implement tank foundation seismic retrofits Improve backup power systems	Coordinate with Oregon Department of Energy (ODOE) and Oregon Department of Emergency Management (ODEM) Develop detailed vulnerability assessment of system assets Develop Integrity Safety Plans and supply chain continuity plans Engage in local and state emergency transportation route planning Strengthen Oregon Public Utilities Commission's seismic oversight authority
Physical Threats	*All measures are optimized*	Optimize implementation of measures in the Identify and Detect categories
Wildfire	Implement fire protection measures (e.g., remote-operated valves, subdivided pipeline networks that isolate damage) Maintain defensible space around assets such as storage tanks Utilize backup generators	Backup communications Develop detailed vulnerability assessment of system assets Develop scenario-driven wildfire and wildland urban interface (WUI) emergency response exercises and planning Maintain risk maps and system modeling
Windstorms	Anchor equipment securely to prevent displacement or overturning during high winds Install barriers/shields	Develop detailed vulnerability assessment of system assets Implement emergency shutdown systems Provide incident command system training for all staff Provide minimum design specifications for new construction and retrofitting

Portland Metro Region Natural Gas Results

Stakeholder feedback on the preliminary results of the natural gas risk assessment supported the development of RMMs for the Portland Metro region. Feedback included identified gaps specific to physical hardening of natural gas system elements, wildfire adaptive capacity, and situational awareness. For example, stakeholders indicated that a CSZ earthquake and tsunami poses a risk to the natural gas system in the region. Therefore, there is a need for physical hardening of system elements, particularly storage facilities/tanks and pipelines. Stakeholders also noted that spill containment and transportation networks are critical considerations. In addition, wildfire adaptive capacity gaps also exist for protecting above ground storage tanks, ensuring capabilities to isolate areas of the system, and ensuring defensible spaces around key assets. Lastly, for all hazards and threats in the region, stakeholders highlighted gaps related to the situational awareness adaptive capacity measure.

Referencing the feedback collected from stakeholders, a region-specific list of physical and operational RMMs was created and presented to participants at the Portland Metro Region Meeting (**Table 24**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

***Table 24**: RMMs presented at the Portland Metro Region Meeting for the natural gas subsector and mean RMM rankings by participants (n = 8): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	8.00
	Harden pipelines (ties, flexible joints, etc.)	6.60
	Implement tank foundation seismic retrofits	7.80
	Implement containment measures for spills	5.20
	Improve backup power systems	5.40
Physical Attacks	Optimize implementation of measures in the Protect category	N/A
Wildfire	Implement fire protection measures: remote operated valves, subdivide pipeline networks to isolate damage	5.40
	Maintain defensible space around assets such as storage tanks	6.20
	Provide backup generators	5.40
Windstorms	Anchor equipment securely to prevent displacement or overturning during high winds	5.40
	Install barriers/shields	1.60

Table 24 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Coordinate with Oregon Department of Energy (ODOE) and Oregon Department of Emergency Management (ODEM)	9.00
	Develop detailed vulnerability assessment of system assets	11.00
	Develop Integrity Safety Plans and Supply chain continuity plans	9.20
	Engage in local and state emergency transportation route planning (i.e., Regional Disaster Preparedness Organization)	10.00
	Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	9.00
Physical Attacks	Optimize implementation of measures in the Identify and Detect categories	N/A
Wildfire	Backup communications	6.20
	Develop detailed vulnerability assessment of system assets	8.60
	Develop scenario-driven wildfire and WUI emergency response exercises and planning	5.00
	Maintain risk maps and system modeling	6.00
Windstorms	Develop detailed vulnerability assessment of system assets	6.00
	Implement emergency shutdown systems	3.60
	Provide incident command system training for all staff	3.20
	Provide minimum design specifications for new construction and retrofitting	4.20

Southwest Region Natural Gas Results

Stakeholder feedback on the preliminary results of the natural gas risk assessment supported the development of RMMs for the Southwest region. Feedback included identified gaps specific to physical hardening of natural gas system elements, wildfire adaptive capacity, and situational awareness. For example, stakeholders indicated that a CSZ earthquake and tsunami poses a risk to the natural gas system along the coastal area of this region. Therefore, there is a need for physical hardening of system elements, particularly storage facilities/tanks and pipelines. Stakeholders also noted that spill containment and transportation networks are critical considerations. In addition, wildfire adaptive capacity gaps also exist for protecting above ground storage tanks, ensuring capabilities to isolate areas of the system, and ensuring defensible spaces around key assets. Lastly, for all hazards and threats in the region, stakeholders highlighted gaps related to the situational awareness adaptive capacity measure.

Referencing the feedback collected from stakeholders, a region-specific list of physical and operational RMMs was created and presented to participants at the Southwest Region Meeting (**Table 25**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

Table 25*: RMMs presented at the Southwest Region Meeting for the natural gas subsector and mean RMM rankings by participants (n = 1): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	7.00
	Harden pipelines (ties, flexible joints, etc.)	5.00
	Improve backup power systems	9.00
	Implement containment measures for spills	3.00
Flood	Protect critical facilities: gas regulator vents	2.00
	Protect facilities in flood zone or move out of flood zone	4.00
Human-Caused Threats	Optimize implementation of measures in the Protect category, particularly for physical threats	1.00
Wildfire	Implement fire protection measures: remote operated valves, subdivide pipeline networks to isolate damage	6.00
	Maintain defensible space around assets, esp. above ground gas facilities	10.00
	Provide backup generators	8.00

Table 25 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Coordinate with Oregon Department of Energy (ODOE) and Oregon Department of Emergency Management (ODEM)	9.00
	Develop detailed vulnerability assessment of system assets	13.00
	Develop Integrity Safety Plans and Supply chain continuity plans	3.00
	Engage in local and state emergency transportation route planning	8.00
	Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	2.00
Flood	Develop detailed vulnerability assessment of system assets	6.00
	Maintain baseline risk maps and a framework for identifying areas of high risk	5.00
	Provide stormwater pumps to remove flood water and prevent submersion	4.00
Human-Caused Threats	Optimize implementation of measures in the Identify, Protect, and Detect categories, particularly for physical threats	1.00
Wildfire	Backup communications	11.00
	Consult with weather & fire experts	7.00
	Develop detailed vulnerability assessment of system assets	14.00
	Develop scenario-driven wildfire and wildland urban interface (WUI) emergency response exercises and planning	10.00
	Maintain risk maps and system modeling	12.00

Willamette Valley Region Natural Gas Results

Stakeholder feedback on the preliminary results of the natural gas risk assessment supported the development of RMMs for the Willamette Valley region. Feedback included identified gaps specific to physical hardening of natural gas system elements, flood, and wildfire adaptive capacity, as well as situational awareness. For example, stakeholders indicated that a CSZ earthquake and tsunami poses a risk to the natural gas system in the region. Therefore, there is a need for physical hardening of system elements, particularly storage facilities/tanks and pipelines. Stakeholders also noted that spill containment and transportation networks are critical considerations. In addition, flood and wildfire adaptive capacity gaps also exist for relocating facilities/assets away from hazard zones, protecting pressure regulating stations and above ground storage tanks, ensuring capabilities to isolate areas of the system, and ensuring defensible spaces around key assets. Lastly, for all hazards and threats in the region, stakeholders highlighted gaps related to the situational awareness adaptive capacity measure.

Referencing the feedback collected from stakeholders, a region-specific list of physical and operational RMMs was created and presented to participants at the Willamette Valley Region Meeting (**Table 26**). Within the table, the physical and operational RMM prioritization results are detailed by mean measure ranking (1 = highest ranking).

***Table 26**: RMMs presented at the Willamette Valley Region Meeting for the natural gas subsector and mean RMM rankings by participants (n = 5): (A) physical RMMs and rankings; (B) operational RMM and rankings. (1 = highest ranking)*

(A)

Threats	Physical RMMs	Physical RMM Rankings
CSZ Earthquake	Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	7.33
	Harden pipelines (ties, flexible joints, etc.)	6.33
	Improve backup power systems	6.33
	Implement containment measures for spills	6.33
	Implement tank foundation seismic retrofits	4.33
Human-Caused Threats	*All measures are optimized*	4.00
Wildfire	Implement fire protection measures: remote operated valves, subdivide pipeline networks to isolate damage	7.50
	Maintain defensible space around assets such as storage tanks	8.50
	Provide backup generators	1.50
Windstorms	Anchor equipment securely to prevent displacement or overturning during high winds	7.33
	Install barriers/shields	3.00

Table 26 *(continued).*

(B)

Threats	Operational RMMs	Operational RMM Rankings
CSZ Earthquake	Coordinate with Oregon Department of Energy (ODOE) and Oregon Department of Emergency Management (ODEM)	9.67
	Develop detailed vulnerability assessment of system assets	8.33
	Develop Integrity Safety Plans and Supply chain continuity plans	8.00
	Engage in local and state emergency transportation route planning	6.67
	Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	6.50
Human-Caused Threats	Optimize implementation of measures in the Identify, Protect, and Detect categories, particularly for physical threats	5.00
Wildfire	Backup communications	5.50
	Develop detailed vulnerability assessment of system assets	9.00
	Develop scenario-driven wildfire and Wildlife Urban Interface (WUI) emergency response exercises and planning	9.00
	Maintain risk maps and system modeling	6.00
Windstorms	Develop detailed vulnerability assessment of system assets	7.00
	Implement emergency shutdown systems	3.67
	Provide incident command system training for all staff	6.50
	Provide minimum design specifications	1.50

Assumptions and Limitations

A number of limitations should be borne in mind when interpreting findings of this body of work. First, information pertaining to adaptive capacity was self-reported, not all responses were comprehensive or

detailed, and in some instances sample sizes were small. As a result, the RMMs provide helpful guidance but should not be interpreted as a comprehensive picture of all hazard vulnerability capacity needs. Relatedly, feedback from stakeholders at the meeting series to prioritize RMMs reflect individual perceptions and sample sizes were exceedingly small in several regions. Further, document review and stakeholder feedback reveal that, in general, existing and ongoing best practices put in place by providers is widespread. However, data access limitations, limitations in stakeholder feedback, and data aggregation result in limited understanding at a granular level – which RMMs are implemented by specific providers in specific locations, at a granular geospatial scale. As such, the action plan is presented with the assumption that many of the goals may actively be considered and/or implemented by providers. Therefore, the recommendations in the action plan represent a combination of strengthening existing RMMs that are currently implemented and future actions for RMMs being considered. The action plan does not pretend to differentiate these options for each RMM in each energy subsector. Rather, it serves to highlight themes and goals which may be highest priority. Additionally, the threats and subsectors emphasized for individual RMMs in the action plan are assumed not restrictive. While results and feedback suggest the most direct benefit of the included RMMs may be associated with the emphasized subsector and/or threat, benefits may extend to other subsectors and in the context of other threats.

In summary, RMMs are not intended to provide specific recommendations for any individual facility or system element. However, Oregon officials can use the RMMs in combination with the dominant themes and goals to guide investment and programming decisions to advance energy system resilience to the assessed hazards and threats.

Action Plan

The action plan is intended to inform officials in local, county, state, and federal governments of future potential investments to reduce risk, enhance recovery, and improve resilience. It consolidates the findings and results of the mitigation measures identified, analyzed, and prioritized through the risk assessment (see the Risk Assessment Report) to work toward reduced risk, enhanced recovery, and improved resilience. Action-oriented plans are presented at a high-level, statewide, all-systems scale (**Table 28**) and region-specific scale (**Tables 29-34**). Analytic results and RMM prioritization by stakeholders (when possible) were leveraged to identify dominant themes of RMMs. The themes are further broken down into goals (the desired outcomes) and strategies (the collection of prioritized RMMs that support reaching goals). See the Methods section for details on the procedure. Additionally, the subsector(s) and/or threats that were emphasized in the results and/or stakeholder feedback are indicated for regional-scale strategies, where applicable. Finally, measures of success are outlined (**Table 27**) for each of the goals included in the action plan.

Cumulative, regional-scale results based on stakeholder feedback reveal that the most consistently prioritized theme was Robustness, followed by Rapid Detection/Recovery and then Human-caused Threats. Within the theme of Robustness, Harden, Upgrade, Weatherize and Remove Assets were most prioritized. For Rapid Detection/Recovery, most emphasis was placed on Situational Awareness. Human-caused threats had only one goal associated with it – Improve RMM Maturity. The emphasis on Human-caused Threats is interesting as vulnerability scores for cyberattack and physical attack were consistently low across all subsectors and regions, with the exception of moderate ratings for physical attack in a

handful of regions for the natural gas subsector. It is important to remember, however, that Natural Gas Risk Assessment survey respondents considered accidental damage (e.g., striking a buried pipeline when digging) when responding to questions related to physical attack. This may have influenced vulnerability ratings. The low vulnerability scores are often driven by strong adaptive capacity. These findings may point to human-caused threats being considered a high priority in general and considered well-managed thus far while, importantly, highlighting the significance of continuing to implement mature RMMs to adapt to the rapidly evolving threat landscape.

Important to note is how the emphasized themes highlight the cost-effectiveness correlation, modeled in **Figure 31**. In general, physical RMMs, particularly those emphasized in the Robustness theme, tend to be the most effective, yet most expensive to implement. In contrast, operational measures tend to have a lower cost associated with them but lower effectiveness relative to physical RMMs. The cost-effectiveness of resilience investments for energy systems is understudied and generally poorly understood[15]. A resilience investment measure such as replacing a pole or instituting vegetation management compared to their monetized benefits or effectiveness in terms of avoided power disruption, loss of service or lost load, and/or recovery time can be modeled using various economic tools or models (e.g., 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.

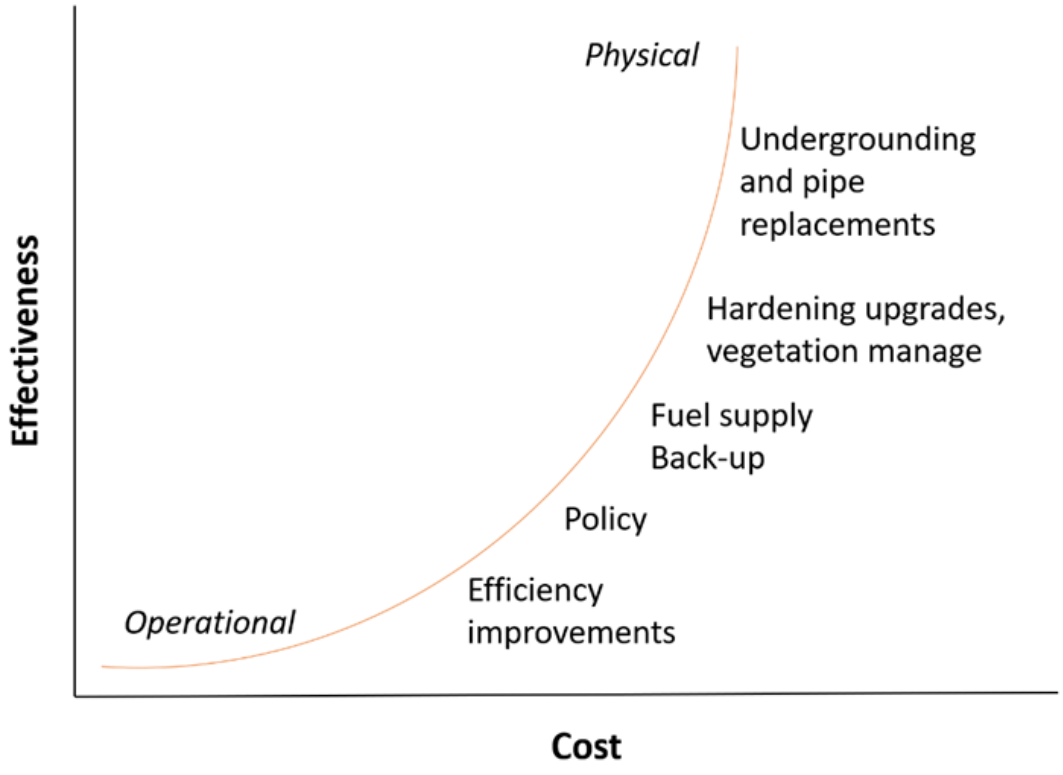

***Figure 31**: Conceptual model of the cost-effectiveness correlation of risk mitigation measures.*

In electric power systems, lower-cost operational and short-term investments such as pre-positioning inventories of stockpiles or line workers in strategic locations for rapid response can be put in place while

longer term investments are planned[5]. A general axiom is to begin with efficiency improvements, since they typically incur the least cost with the best payback[5]. Targeting efficiency first also improves other capital projects. Back-up batteries can provide power for up to approximately four to six hours for critical facilities[17]. Line hardening is understood as one of the most effective methods for improving power system resilience at a relatively low cost[5]. Pole replacements cost approximately $1,500-$3,000 to replace with steel or concrete poles that are fire resistant[17]. Using a breakaway system to preserve poles reduces cost and restoration time when a line is impacted with an estimated cost of $1,000 per breakaway kit[17]. Grid hardening on transmission and distribution systems is key to reducing the most consequential outages[5]. Hardening system components include reconductoring with heavier/thicker wire to improve performance against ice-storms & vegetation, and costs approximately $5,000-$10,000 per mile on the distribution system[17]. Vegetation management improves performance against strong winds, winter storms/snow/ice, and wildfires[17]. Clearing vegetation from power lines and critical infrastructure as often as possible is time intensive and costly, roughly $50-$5,000 per item (e.g., mowers, tree, climbers, saws, etc..) plus additional training and other overhead contracting costs[17]. Undergrounding is one of the costliest measures, ranging from $150K to up to $1M per mile for standard underground lines or larger feeder cables[17].

In natural gas systems, providers seeking to replace older infrastructure can face high costs. Factors that contribute to higher replacement costs include congestion, multiple (sometimes poorly documented) underground utilities, limited construction seasons due to weather, and high labor costs. Finally, in the liquid fuels system, increased fuel supply may extend a community's ability to endure extreme weather events. A 500-gallon residential propane storage tank costs roughly $1,000-$2,000[17]. Diesel fuel requires replacement or polishing every two years which will impact how cost-effective it is to store in large volumes[17].

Next Steps

The subsequent recommended actions are presented with the assumption that many of the goals may actively be considered and/or implemented. Therefore, the recommendations represent a combination of strengthening existing RMMs that are currently implemented and future actions for RMMs being considered. 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.

A number of initiatives that may be implemented by utilities, ODOE, and other government entities are recommended for continued strengthening of resilience. These include development of legislation, policies, and procedures, such as developing and/or continuing peak Demand Reduction Programs, remote grid monitoring, forecasting and situational awareness, de-energizing for firefighting response, Standard Operating Procedures for workforce response, weather monitoring combined with public-safety shut-off programs, Integrity Safety Plans and Supply Chain Continuity plans, and integrating artificial intelligence into operational plans and monitoring efforts. Also recommended is extension of training via drills, tabletop exercises, etc. with a focus on real incident responses to provide feedback and improve procedures. Outreach to subject matter experts to audit and recommend improvements to resiliency strategies, including weather and fire experts and specialists in emergency transportation route planning would also strengthen resilience. Additionally, consulting stakeholders and subject matter experts to validate the findings of the risk assessment (see the Risk Assessment Report) and the prioritized RMMs is recommended.

Continued and expanded studies, including After Action Reports and regular review of resilience plans is recommended. Development and maintenance of risk maps and system models along with detailed vulnerability assessments of assets and comprehensive, site-specific risks, which reflect evolving climate change impacts would strengthen resilience. As introduced above, feasibility studies are necessary to execute the action plan in the most effective manner possible. Analyzing cost-effectiveness of RMMs via cost-benefit analysis, regional economic models, input-output models, and/or life cycle analysis would work toward this end. It is recommended that ODOE and PUC coordinate these efforts with utilities and energy companies, and increase involvement in such programs that may already be underway by utilities and energy companies.

Finally, utilities/energy companies establishing agreements with government and private sector entities to provide incident response support, such as equipment staging and maintenance (e.g., for debris clearing) and to secure secondary key suppliers is recommended. Importantly, data-sharing agreements between Oregon State Government and utilities/energy companies are of highest priority for improved understanding of vulnerabilities in the energy system. For example, publicly accessible data pertaining human-caused threats is limited and aggregated. Agreements facilitating access to granular data on exposure, sensitivities, impacts, and adaptive capacity for cyberattacks and physical attacks would be needed in order to conduct a comprehensive risk assessment that is not dependent on self-reporting. Most importantly, agreements between Oregon State Government and utilities/energy companies that secure access to data in the natural gas and electric subsectors would allow Oregon government to work with energy companies and third-party consultants to conduct a technical, geospatial analysis of vulnerability, which will serve to refine the action plan.

Statewide and Regional Priorities and Measures of Success

Below, **Table 27** summarizes the measures of success for each of the goals highlighted in the action plan. These measures apply to the respective goals included for the statewide and regional perspectives. **Table 28** summarizes priorities on a statewide, all systems level. **Tables 29-34** consolidate priorities for each of the six regions (listed in alphabetical order), including subsectors and threats emphasized for specific RMMs, as applicable. As a reminder, no feedback on RMM prioritization was received in the Northwest Region and very limited feedback on prioritization was received in the Eastern (n = 2) and Southwest (n = 1) Regions. Priorities for these regions are based on analytic results, as described in the Methods section. However, a summary of the feedback that was available in the Eastern and Southwest Regions was generated and is presented for awareness only in **Tables 35 and 36**, respectively.

***Table 27**: Measures of success for statewide and regional goals.*

Themes	Goals	Measures of Success
Human-caused Threats	Improve RMM Maturity	• RMMs are responsive to the current threat landscape • RMMs utilize available technology in appropriate ways • Number of stakeholders engaged in RMM activities increases over time • Impact and effectiveness of RMMs increases over time
Rapid Detection/Recovery	Secure Equipment/Supplies	• Equipment and suppliers are in place • Equipment inventories are maintained • Stakeholders are trained on equipment • Stakeholders can utilize equipment • Mutual aid agreements for equipment and supplies are in place • Secondary suppliers are in place
Rapid Detection/Recovery	Improve Impact Response	• Response measures and systems are in place • Stakeholders are trained on response measures and systems • Stakeholders can utilize response measures and systems • Response measures and systems are tested/exercised on a regular basis
Rapid Detection/Recovery	Improve Situational Awareness	• Situational awareness systems are in place • Data is timely and correctly collected • Stakeholders are trained on situational awareness systems • Stakeholders can utilize situational awareness systems • Stakeholders receive timely and actionable information from situational awareness systems
Redundancy	Establish Backup Communications	• Backup communications systems are in place • Stakeholders are aware of backup communications systems • Stakeholders are trained on backup communications systems • Stakeholders can utilize backup communications systems • Backup communications systems are tested/exercised on a regular basis
Redundancy	Establish Backup Energy Sources	• Energy systems have increased capacity • Backup energy systems are in place • Backup energy systems have increased capacity • Backup energy systems are tested/exercised on a regular basis

Table 27 *(continued).*

Redundancy	Establish Backup Facilities	• Alternate facilities are identified • Alternate facilities are equipped and supplied with critical systems and materials • Alternate facilities are exercised on a regular basis
Research, Planning, Training	Expand Planning	• Response plans are in place • Stakeholders are trained on response plans • Stakeholders are able to execute response plans • Response plans are reviewed or exercised on a regular basis and corrective actions are identified and implemented • Minimum design specifications for new and retrofitted energy system assets are provided
Research, Planning, Training	Expand Research	• Resiliency strategies and plans are regularly updated based on the latest research • Vulnerability assessments of system assets are conducted • Risk maps and system modeling are maintained • Research products are accurate and precise
Research, Planning, Training	Expand Training	• Stakeholders are trained in incident command • Stakeholders are trained on energy systems, equipment/suppliers, and response measures • Stakeholders successfully master/execute content from trainings
Robustness	Harden, Upgrade, Weatherize Assets	• The number of hardened energy system assets increases • The number of upgraded energy system assets increases • The number of weatherized energy system assets increases • Measurable reductions in impact to hardened, upgraded, and/or weatherized assets is achieved
Robustness	Implement Demand Response Programs	• Peak demand reduction programs are implemented • Measurable reductions in peak demand are achieved • Artificial intelligence is implemented into energy system operational plans
Robustness	Remove Assets	• Energy system assets are moved out of hazard zones
Robustness	Segment Systems	• Energy systems are subdivided to isolate damaged areas

***Table 28**: Statewide, all systems priorities. Priority goals were identified via stakeholder feedback (n = 20; LF = Liquid Fuels; E = Electric; NG = Natural Gas)*

Statewide		
Themes	**Goals**	**Strategies**
Human-caused Threats	**1.** Improve RMM Maturity	**1.1** Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities **1.2** Protect – develop and implement appropriate safeguards to ensure delivery of services **1.3** Detect – develop and implement appropriate activities to identify occurrence of a security event **1.4** Respond – develop and implement appropriate activities to take action regarding a detected security event **1.5** Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event
Robustness	**2.** Remove Assets	**2.1** Move assets out of hazard zones
	3. Segment Systems	**3.1** Subdivide energy systems to efficiently isolate damaged areas
	4. Implement Demand Response Programs	**4.1** Develop peak Demand Reduction Programs
Rapid Detection/Recovery	**5.** Improve Situational Awareness	**5.1** Integrate artificial intelligence into operational plans/monitoring **5.2** Develop drone inspection capabilities and procedures **5.3** Implement automated and remote monitoring systems (remote grid monitoring emphasized for electricity subsector) (Windstorms and Winter Storms)
	6. Secure Equipment/Supplies	**6.1** Have secondary key suppliers in place **6.2** Maintain inventories of equipment and inter-operability/mutual aid

***Table 29**: Cascades Region priorities. Priority goals were identified via stakeholder feedback (n = 4; LF = Liquid Fuels; E = Electric; NG = Natural Gas).*

Cascades Region				
Themes	**Goals**	**Strategies**	**Subsectors Emphasized**	**Threats Emphasized**
Human-caused Threats	**1.** Improve RMM Maturity	**1.1** Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities	LF, E, NG	Cyberattack, Physical Attack
		1.2 Protect – develop and implement appropriate safeguards to ensure delivery of services	LF, E, NG	Cyberattack, Physical Attack
		1.3 Detect – develop and implement appropriate activities to identify occurrence of a security event	LF, E, NG	Cyberattack, Physical Attack
		1.4 Respond – develop and implement appropriate activities to take action regarding a detected security event	LF, E, NG	Cyberattack, Physical Attack
		1.5 Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event	LF, E, NG	Cyberattack, Physical Attack
Robustness	**2.** Remove Assets	**2.1** Move assets out of hazard zones	LF, E, NG	Flood
	3. Segment Systems	**3.1** Subdivide energy systems to efficiently isolate damaged areas	LF, E, NG	N/A
	4. Harden, Upgrade, Weatherize Assets	**4.1** Implement geotechnical and foundation interventions and ground improvements	E	CSZ
		4.2 Improve fire protection measures (e.g., vegetation management, defensible space)	LF	Wildfire
		4.3 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Lightning
		4.4 Protect critical facilities (e.g., gas regulator vents)	NG	Flood
		4.5 Underground transmission lines	E	Windstorms, Winter Storms

Table 29 *(continued).*

Rapid Detection/Recovery	5. Improve Distribution Management	**5.1** Implement automated distribution	E	Windstorms, Winter Storms
	6. Improve Situational Awareness	**6.1** Develop drone inspection capabilities and procedures	LF, E, NG	N/A
		6.2 Implement advanced early warning systems with seismometers and sensors	E	CSZ
		6.3 Improve detection capabilities and install automated monitoring systems	LF	Wildfire
		6.4 Integrate artificial intelligence into operational plans/monitoring	LF, E, NG	N/A
		6.5 Utilize thunderstorm warning system	E	Lightning

***Table 30**: Eastern Region priorities. Priority goals were identified via counts of recommended risk mitigation measures due small sample size in stakeholder feedback (n = 2; LF = Liquid Fuels; E = Electric; NG = Natural Gas).*

Eastern Region				
Themes	**Goals**	**Strategies**	**Subsectors Emphasized**	**Threats Emphasized**
Research, Planning, Training	**1.** Expand Research	**1.1** Audit resilience strategies and recommend improvement plans	LF, E, NG	
		1.2 Conduct regular reviews/updates of resiliency plans based on incidents or annual evaluations	LF	Lightning
		1.3 Develop detailed vulnerability assessment of system assets	NG	CSZ, Flood, Windstorms,
		1.4 Engage external consultants or partners to audit and recommend improvements to resiliency strategies	LF	Wildfire
		1.5 Generate After Action Reviews	LF, E, NG	
		1.6 Maintain risk maps and system modeling	NG	Flood
		1.7 Study comprehensive, site-specific risks to inform CIPs and AMPs	LF, E, NG	
		1.8 Study lifeline service delivery systems disaster resilience	LF, E, NG	
		1.9 Study projected climate change impacts to hydropower	E	Drought
		1.10 Study supply chain resilience for continuity planning	LF, E, NG	
		1.11 Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices	LF	Windstorms, Winter Storms
Robustness	**2.** Harden, Upgrade, Weatherize Assets	**2.1** Adopt dry-cooling technologies to reduce water use	E	Drought
		2.2 Anchor equipment securely to prevent displacement or overturning during high winds	NG	Windstorms
		2.3 Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	NG	CSZ
		2.4 Harden and upgrade components	LF, E, NG	
		2.5 Harden pipelines (e.g., ties, flexible joints)	NG	CSZ
		2.6 Harden substations	E	CSZ

Table 30 *(continued).*

		2.7 Improve fire protection measures (e.g., vegetation management, defensible space)	LF	Wildfire
		2.8 Improve site drainage/flood protection (e.g., levees)	LF	Windstorms, Winter Storms
		2.9 Install barriers/shields	NG	Windstorms
		2.10 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Lightning
		2.11 Manage vegetation	E	Drought
		2.12 Manage vegetation	E	Wildfire
		2.13 Protect critical facilities (e.g., gas regulator vents)	NG	Flood
		2.14 Replace overhead with underground cables	LF, E, NG	
		2.15 Underground transmission lines	LF, E, NG	
		2.16 Upgrade transmission and distribution lines and equipment	E	Windstorms
		2.17 Utilize fire resistant materials and retrofits (e.g., resistant poles and transmission lines)	E	Wildfire
		2.18 Weatherize energy system assets	LF, E, NG	
Rapid Detection/ Recovery	**3.** Improve Situational Awareness	**3.1** Develop drone inspection capabilities and procedures	LF, E, NG	
		3.2 Establish automated and remote monitoring systems	LF, E, NG	
		3.3 Implement advanced early warning systems with seismometers and sensors	E	CSZ
		3.4 Implement remote grid monitoring	E	Windstorms
		3.5 Implement weather monitoring combined with public-safety shut-off programs	E	Wildfire
		3.6 Improve detection capabilities and install automated monitoring systems	LF	Wildfire
		3.7 Improve forecasting and situational awareness abilities	LF, E, NG	
		3.8 Integrate artificial intelligence into operational plans/monitoring	LF, E, NG	

***Table 31**: Northwest Region priorities. Priority goals were identified via counts of recommended risk mitigation measures due no stakeholder feedback (n = 0; LF = Liquid Fuels; E = Electric; NG = Natural Gas).*

Northwest Region				
Themes	**Goals**	**Strategies**	**Subsectors Emphasized**	**Threats Emphasized**
Robustness	**1.** Harden, Upgrade, Weatherize Assets	**1.1** Anchor equipment securely to prevent displacement or overturning during high winds	NG	Windstorms
		1.2 Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	NG	CSZ
		1.3 Harden pipelines (e.g., ties, flexible joints)	NG	CSZ
		1.4 Harden substations	E	CSZ
		1.5 Implement geotechnical and foundation interventions and ground improvements	E	CSZ
		1.6 Implement tank foundation seismic retrofits	NG	CSZ
		1.7 Improve fire protection measures (e.g., vegetation management, defensible space)	NG, E	Wildfire
		1.8 Improve site drainage/flood protection (e.g., levees)	LF	Windstorms, Winter Storms
		1.9 Install barriers/shields	NG	Windstorms
		1.10 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Windstorms, Winter Storms
		1.11 Underground transmission lines	E	Windstorms, Winter Storms
		1.12 Upgrade transmission and distribution lines and equipment	E	Windstorms, Winter Storms
		1.13 Utilize fire resistant materials and retrofits (e.g., resistant poles and transmission lines)	E	Wildfire

Table 31 *(continued).*

		1.14 Utilize flexible connections, control valves	LF	CSZ
Research, Planning, Training	**2.** Expand Planning	**2.1** Develop Integrity Safety Plans and Supply Chain Continuity plans	NG	CSZ
		2.2 Develop protocols for de-energization for firefighting response	E	Wildfire
		2.3 Develop Standard Operating Procedures for winter storm workforce response	E	Windstorms, Winter Storms
		2.4 Engage in local and state emergency transportation route planning	NG	CSZ
		2.5 Implement industry best practices through OPUC safety programs	E	Windstorms, Winter Storms
		2.6 Maintain risk maps and system modeling	NG	Wildfire
		2.7 Provide minimum design specifications for new construction and retrofitting	NG	Windstorms
		2.8 Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices	LF	CSZ
		2.9 Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	NG	CSZ
Rapid Detection/ Recovery	**3**. Improve Situational Awareness	**3.1** Implement advanced early warning systems with seismometers and sensors	E	CSZ
		3.2 Implement remote grid monitoring	E	Windstorms, Winter Storms
		3.3 Implement weather monitoring combined with public-safety shut-off programs	E	Wildfire

***Table 32**: Portland Metro Region priorities. Priority goals were identified via stakeholder feedback (n = 8; LF = Liquid Fuels; E = Electric; NG = Natural Gas).*

Portland Metro Region				
Themes	**Goals**	**Strategies**	**Subsectors Emphasized**	**Threats Emphasized**
Human-caused Threats	**1.** Improve RMM Maturity	**1.1** Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities	LF, E, NG	Cyberattack, Physical Attack
		1.2 Protect – develop and implement appropriate safeguards to ensure delivery of services	LF, E, NG	Cyberattack, Physical Attack
		1.3 Detect – develop and implement appropriate activities to identify occurrence of a security event	LF, E, NG	Cyberattack, Physical Attack
		1.4 Respond – develop and implement appropriate activities to take action regarding a detected security event	LF, E, NG	Cyberattack, Physical Attack
		1.5 Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event	LF, E, NG	Cyberattack, Physical Attack
Robustness	**2**. Remove Assets	**2.1** Move assets out of hazard zones	LF, E, NG	
		2.2 Improve site drainage/flood protection (e.g., levees)	LF	Windstorms, Winter Storms
	3. Harden, Upgrade, Weatherize Assets	**3.1** Install barriers/shields	NG	Windstorms
		3.2 Install breakaway disconnect systems to preserve poles	E	Windstorms, Winter Storms
		3.3 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Windstorms, Winter Storms
		3.4 Utilize fire resistant materials and retrofits (e.g., resistant poles and transmission lines)	E	Wildfire
Redundancy	**4.** Establish Backup Communications	**4.1** Supply backup communications (e.g., satellite phones, two-way radios)	LF	Windstorms, Winter Storms
	5. Establish Backup Energy Sources	**5.1** Increase backup power systems capacity	LF, E, NG	

Table 32 *(continued).*

		5.2 Increase fuel storage capacity and diversity	LF	CSZ
		5.3 Provide backup power systems (e.g., generators, batteries)	LF, E, NG	
Rapid Detection/ Recovery	**6.** Improve Impact Response	**6.1** Implement containment measures for spills	NG	CSZ
		6.2 Implement emergency shutdown systems	NG	Windstorms
		6.3 Develop drone inspection capabilities and procedures	LF, E, NG	
	7. Improve Situational Awareness	**7.1** Implement automated and remote monitoring systems	E	Windstorms, Winter Storms
		7.2 Implement weather monitoring combined with public-safety shut-off programs	E	Wildfire
		7.3 Integrate artificial intelligence into operational plans/monitoring	LF, E, NG	

***Table 33**: Southwest Region priorities. Priority goals were identified via counts of recommended risk mitigation measures due small sample size in stakeholder feedback (n = 1; LF = Liquid Fuels; E = Electric; NG = Natural Gas).*

Southwest Region				
Themes	Goals	Strategies	Subsectors Emphasized	Threats Emphasized
Research, Planning, Training	**1**. Expand Research	**1.1** Develop detailed vulnerability assessment of system assets	NG	Wildfire
		1.2 Engage external consultants or partners to audit and recommend improvements to resiliency strategies	LF	Lightning
		1.3 Maintain risk maps and system modeling	NG	Flood
		1.4 Perform seismic vulnerability studies of critical infrastructure	LF	CSZ
		1.5 Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices	LF	Windstorms, Winter Storms
	2. Expand Planning	**2.1** Consult with weather & fire experts	NG	Wildfire
		2.2 Develop Integrity Safety Plans and Supply chain continuity plans	NG	CSZ
		2.3 Engage in local and state emergency transportation route planning	NG	CSZ
		2.4 Implement industry best practices through Oregon Public Utilities Commission (OPUC) safety programs	E	Windstorms, Winter Storms
		2.5 Maintain risk maps and system modeling	NG	Flood
		2.6 Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices	LF	CSZ
		2.7 Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	NG	CSZ
Robustness	**3**. Harden, Upgrade, Weatherize Assets	**3.1** Apply seismic upgrades to critical infrastructure (e.g., flexible connections, control valves)	LF	CSZ
		3.2 Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	NG	CSZ
		3.3 Harden pipelines (e.g., ties, flexible joints)	NG	CSZ
		3.4 Harden substations	E	CSZ
		3.5 Implement fire protection measures (e.g., remote operated valves, subdivide pipeline networks to isolate damage)	NG	Wildfire

Table 33 *(continued).*

		3.6 Implement geotechnical and foundation interventions and ground improvements	E	CSZ
		3.7 Improve site drainage/flood protection (e.g., levees)	LF	Windstorms, Winter Storms
		3.8 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Windstorms, Winter Storms
		3.9 Maintain defensible space around assets, especially above ground gas facilities	NG	Wildfire
		3.10 Manage vegetation	E	Wildfire
		3.11 Protect critical facilities from landslide by identifying high risk slopes	LF	CSZ
		3.12 Protect critical facilities (e.g., gas regulator vents)	NG	Flood
		3.13 Underground transmission lines	E	Windstorms, Winter Storms
		3.14 Upgrade transmission and distribution lines and equipment	E	Windstorms, Winter Storms
		3.15 Utilize fire resistant materials and retrofits (e.g., resistant poles and transmission lines)	E	Wildfire
Rapid Detection/ Recovery	**4**. Secure Equipment/ Supplies	**4.1** Provide debris clearing equipment staging and maintenance	LF	Windstorms, Winter Storms
		4.2 Provide stormwater pumps to remove flood water and prevent submersion	NG	Flood
		4.3 Provide winter weather equipment and supplies (e.g., shovels, plows, ice melt)	E	Winter Storms
	5. Improve Situational Awareness	**5.1** Implement advanced early warning systems with seismometers and sensors	E	CSZ
		5.2 Implement remote grid monitoring	E	Windstorms, Winter Storms
		5.3 Implement weather monitoring combined with public-safety shut-off programs	E	Wildfire

***Table 34**: Willamette Valley Region priorities. Priority goals were identified via stakeholder feedback (n = 5; LF = Liquid Fuels; E = Electric; NG = Natural Gas).*

Willamette Valley Region				
Themes	**Goals**	**Strategies**	**Subsectors Emphasized**	**Threats Emphasized**
Human-caused Threats	**1.** RMM Maturity	**1.1** Identify – develop an organizational understanding to manage risk to systems, assets, data, and capabilities	LF, E, NG	Cyberattack, Physical Attack
		1.2 Protect – develop and implement appropriate safeguards to ensure delivery of services	LF, E, NG	Cyberattack, Physical Attack
		1.3 Detect – develop and implement appropriate activities to identify occurrence of a security event	LF, E, NG	Cyberattack, Physical Attack
		1.4 Respond – develop and implement appropriate activities to take action regarding a detected security event	LF, E, NG	Cyberattack, Physical Attack
		1.5 Recover – develop and implement appropriate activities to maintain plans for resilience and to restore any capabilities or services that were impaired due to a security event	LF, E, NG	Cyberattack, Physical Attack
Robustness	**2.** Implement Demand Response Programs	**2.1** Develop peak Demand Reduction Programs	LF, E, NG	
	3. Segment System	**3.1** Subdivide energy systems to efficiently isolate damaged areas	LF, E, NG	
	4. Harden, Upgrade, Weatherize Assets	**4.1** Improve site drainage/flood protection (e.g., levees)	LF	Windstorms, Winter Storms
		4.2 Install barriers/shields	NG	Windstorms
		4.3 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Windstorms, Winter Storms

Table 34 *(continued).*

		4.4 Upgrade transmission and distribution lines and equipment	E	Windstorms, Winter Storms
		4.5 Utilize fire resistant materials and retrofits (e.g., resistant poles and transmission lines)	E	Wildfire
Redundancy	**5.** Establish Backup Energy Sources	**5.1** Increase backup power systems capacity	LF, E, NG	CSZ
		5.2 Increase fuel storage capacity and diversity	LF	
		5.3 Provide backup power systems (e.g., generators, batteries)	LF, E, NG	
	6. Establish Backup Communications	**6.1** Supply backup communications (e.g., satellite phones, two-way radios)	NG	Wildfire

***Table 35**: Eastern Region summary of stakeholder feedback priorities (n = 2). FOR AWARENESS ONLY.*

Eastern Region				
Themes	**Goals**	**Strategies**	**Subsectors Emphasized**	**Threats Emphasized**
Robustness	**1.** Remove Assets	**1.1** Move assets out of hazard zones	LF, E, NG	
		1.2 Protect facilities in flood zone or move out of flood zone	NG	Flood
		1.3 Adopt dry-cooling technologies to reduce water use	E	Drought
	2. Harden, Upgrade, Weatherize Assets	**2.1** Improve fire protection measures (e.g., vegetation management, defensible space)	E	Wildfire
		2.2 Improve site drainage/flood protection (e.g., levees)	LF	Windstorms, Winter Storms
		2.3 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Lightning
		2.4 Protect critical facilities (e.g., gas regulator vents)	NG	Flood
Research, Planning, Training	**3.** Expand Training	**3.1** Provide incident command system training for all staff	NG	Windstorms
		3.2 Utilize exercises and drills to identify improvement actions and train workforce	LF, E, NG	CSZ, Wildfire
		3.3 Engage external consultants or partners to audit and recommend improvements to resiliency strategies	LF	Wildfire
	4. Expand Research	**4.1** Generate After Action Reviews	LF, E, NG	
		4.2 Study projected climate change impacts to hydropower	E	Drought
		4.3 Study supply chain resilience for continuity planning	LF, E, NG	
		4.4 Utilize feedback from exercises (drills, tabletop, or functional) and real incident responses to adjust and improve resiliency practices	LF	Windstorms, Winter Storms
	5. Expand Planning	**5.1** Develop Integrity Safety Plans and Supply Chain Continuity plans	NG	CSZ
		5.2 Engage in local and state emergency transportation route planning	NG	CSZ
		5.3 Maintain risk maps and system modeling to inform long term investments and programs	LF, E, NG	

Table 35 *(continued).*

		5.4 Provide minimum design specifications for new construction and retrofitting	NG	Windstorms
		5.5 Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	NG	CSZ
Redundancy	**6.** Establish Backup Facilities	**6.1** Identify alternate facility sites (e.g., backup operations centers)	LF, E, NG	Cyberattack, Physical Attack
	7. Establish Backup Communications	**7.1** Supply backup communications (e.g., satellite phones, two-way radios)	LF	Wildfire, Lightning

***Table 36**: Southwest Region summary of stakeholder feedback priorities (n = 1). FOR AWARENESS ONLY.*

Southwest Region				
Themes	**Goals**	**Strategies**	**Subsectors Emphasized**	**Threats Emphasized**
Robustness	**1.** Harden, Upgrade, Weatherize Assets	1.1 Design and retrofit in-ground tanks to withstand buoyant force in liquefiable soil	NG	CSZ
		1.2 Harden pipelines (e.g., ties, flexible joints)	NG	CSZ
		1.3 Harden substations	E	CSZ
		1.4 Implement geotechnical and foundation interventions and ground improvements	E	CSZ
		1.5 Improve fire protection measures (e.g., vegetation management, defensible space)	NG, E	Wildfire
		1.6 Improve site drainage/flood protection (e.g., levees)	LF	Windstorms, Winter Storms
		1.7 Install weather coverings, roofs, and enclosures to protect critical infrastructure	LF	Windstorms, Winter Storms
		1.8 Protect critical facilities (e.g., gas regulator vents)	LF	Flood
		1.9 Underground transmission lines	E	Windstorms, Winter Storms
		1.10 Upgrade transmission and distribution lines and equipment	E	Windstorms, Winter Storms
		1.11 Utilize fire resistant materials and retrofits (e.g., resistant poles and transmission lines)	E	Wildfire
		1.12 Utilize flexible connections, control valves	LF	CSZ
Research, Planning, Training	**2.** Expand Planning	**2.1** Develop Integrity Safety Plans and Supply Chain Continuity plans	NG	CSZ
		2.2 Engage in local and state emergency transportation route planning	NG	CSZ
		2.3 Implement industry best practices through OPUC safety programs	E	Windstorms, Winter Storms

Table 36 *(continued).*

		2.4 Maintain risk maps and system modeling	NG	Flood
		2.5 Rely on updates to local, state, and federal regulations to guide improvements in resiliency practices	LF	CSZ
		2.6 Strengthen Oregon Public Utilities Commission's (OPUC) seismic oversight authority	NG	CSZ
Rapid Detection/ Recovery	**3.** Secure Equipment/ Supplies	**3.1** Provide debris clearing equipment staging and maintenance	LF	Windstorms, Winter Storms
		3.2 Provide stormwater pumps to remove flood water and prevent submersion	NG	Flood
		3.3 Provide winter weather equipment and supplies (e.g., shovels, plows, ice melt)	LF	Windstorms, Winter Storms
	4. Improve Situational Awareness	**4.1** Implement advanced early warning systems with seismometers and sensors	E	CSZ
		4.2 Implement remote grid monitoring	E	Windstorms, Winter Storms
		4.3 Implement weather monitoring combined with public-safety shut-off programs	E	Wildfire

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