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# Grid Resilience Reports

Oregon

**Energy & Resources | Networks**
10/23/2024

# Table of contents

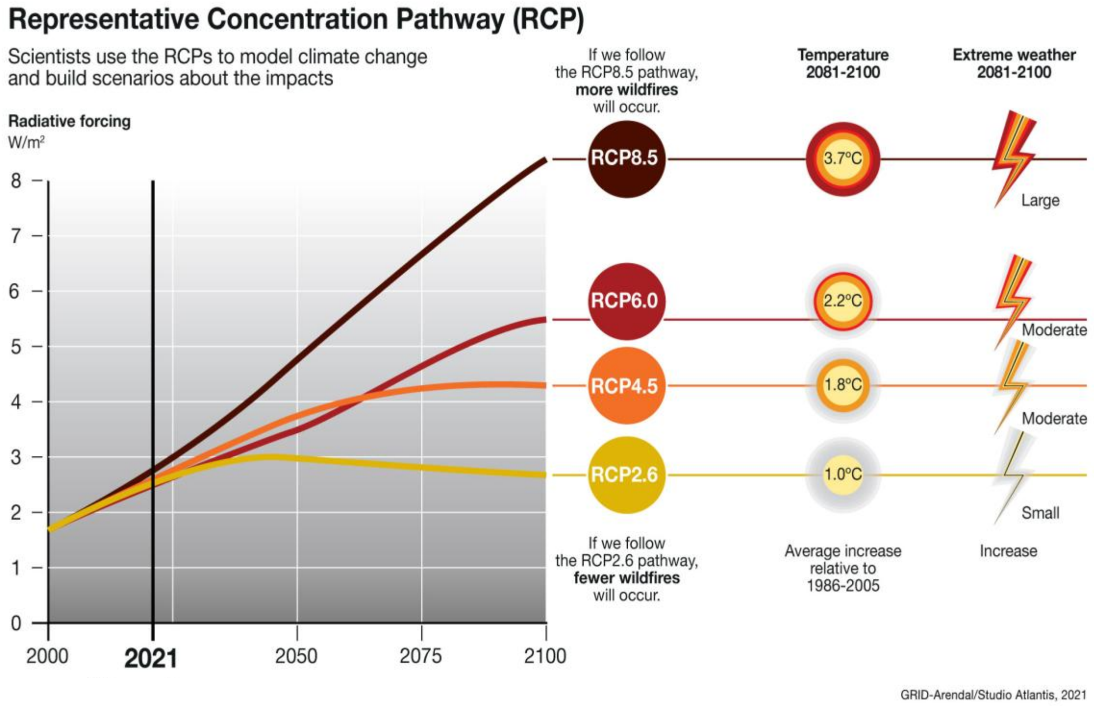
# Grid Resilience Reports

Climate Science Background, Data Sources, and Analysis Approach

# RCPs and SSPs provide viable climate pathways for an uncertain future

## Generating Emission Scenarios

- **Representative concentration pathways (RCPs) project GHG concentrations:** Defined by the IPCC in 2014 as scenarios of future emission concentrations and other radiative forcing that align to climate projections.[1] RCPs use assumptions relating to policy decisions and individual behavior that may change future GHG emissions concentrations.[1] SSPs have largely replaced RCPs.
- **Shared socioeconomic pathways (SSPs) provide 5 'storylines' to contextualize RCPs** and to provide the various future pathways possible.[2] They consider how the world could evolve socioeconomically and politically, including how various levels of climate change mitigation and adaptation could be achieved and will influence future climate scenarios.[3]
- RCPs included in the CLIMRR dataset include RCP 4.5 and RCP 8.5.
- SSPs included in the Hydrosource dataset include SSP585, SSP370, SSP245, and SSP126.




### Modeling Scenario: RCP 4.5

- **"Moderate" scenario**: Emissions peak around 2040 and then slowly begin to decline.[4] Temperatures warm about 3.2 °F from a 2000 baseline.[5]
- CO2 emissions plateau before falling mid-century, as energy use sharply declines and there is large scale reforestation.[6]

### Modeling Scenario: RCP 8.5

- **"Rapid growth" scenario:** Emissions continue to rise throughout the twenty-first century.[4] Temperatures warm about 6.6 °F from a 2000 baseline.[5]
- CO2 emissions are three times higher than the present by end-century, with a large increase in methane emissions and continued fossil fuel use.[6]

[1] Source: ComEd Vulnerability Study 2023
[2] Source: Jupiter
[3] Source: Carbon Brief
[4] Source: Help (cal-adapt.org)
[5] CoastAdapt
[6] Climate Copernicus

 | 

# Baringa leverages national downscaled climate datasets with high granularity to assign county-level climate exposure

| | CLIMRR by Argonne National Lab (ANL) | HydroSource by Oak Ridge National Lab (ORNL) | RAWS by Western Regional Climate Center (WRCC) |
|---|---|---|---|
| Dataset Description | The Climate Risk and Resilience Portal (CLIMRR) provides highly localized climate projections from mid- to end-century using a supercomputer to model 60 climate variables. | HydroSource is a comprehensive national water energy digital platform consisting of hydropower-related data set, models, visualizations, and analytics tools. | The Wildland Fire Remote Automated Weather Stations (RAWS) data set provided by WRCC is a quality-controlled repository of hourly data for 17 select weather metrics from a network of weather stations across western states. |
| Data Provider Description | Argonne National Lab is a federally-funded science and engineering research center sponsored by the Department of Energy. | Oak Ridge National Lab is a federally funded research and development center sponsored by the Department of Energy. | The Western Regional Climate Center is one of 6 Regional Climate Centers in the United States. WRCC works jointly with NOAA to coordinate climate activities and conduct applied research on climate issues in the West. |
| Years Covered | Historical, Mid-Century, End-Century | 1980-2099 | 2000-2022 |
| Spatial Resolution | 12 km (aggregated to county) | County | Weather station (aggregated to county) |
| Hazards | RAIN, FIRE, HEAT, COLD, DROUGHT | FLOOD | WIND |

# Baringa leverages national downscaled climate datasets with high granularity to assign county-level climate exposure (cont.)

| | CLIMRR by Argonne National Lab (ANL) | HydroSource by Oak Ridge National Lab (ORNL) | RAWS by Western Regional Climate Center (WRCC) |
|---|---|---|---|
| **Key Metrics** | Seasonal Fire Weather Index; Annual Precipitation; Cons. Days w/o Precipitation; Days Above X°F Heat Index; Annual Cooling Degree Days; Seasonal Max Temperature; Annual Min Temperature; Annual Heating Degree Days; Seasonal Min Temperature | Annual VIC Runoff (SSP585) | Hourly Max Wind Gust |
| **Mapping/Analysis** | Used a Python script that returned the most extreme value (high or low depending on hazard) from grid cells intersecting a particular county. | Averaged across the 7 different climate model values provided for the SSP585 warming scenario to return a single, composite runoff level for each county in each year. 2000 was used for historical, 2050 for mid-century, and 2090 for end-century. | Mapped weather stations to their respective counties. If a county had multiple weather stations, the station with the highest average hourly value was selected to represent the county. Counties with no stations were mapped to the closest station in a neighboring county. GEV analysis was conducted using the pyextremes EVA function to derive return periods. |
| **Rationale** | • Reputable data provider<br>• Accessible, open-source data allows for our methodology to be reproduced/quality checked<br>• Provides climate projections for hazards with a significant climate signal<br>• More than sufficient spatial resolution to gauge climate exposure at a county level | • Reputable data provider<br>• Climate projections forecast change in exposure over time<br>• Same spatial resolution as outage data (county level)<br>• Data set includes pluvial flooding (from flash floods and surface runoff) which is more likely to contribute to outages because it is faster-acting and can hit urban centers | • Reputable data provider<br>• Wind does not have a strong climate signal, so projections were not required<br>• Sufficient density of stations per state to assign to counties<br>• Quality checked<br>• Hourly resolution was sufficient for deriving return periods |

# Baringa is leveraging forward-looking climate projections to inform its technical assistance work for states in WECC

## Wind

Source: **Western Regional Climate Center (WRCC)**
**Input metric**: Hourly max wind speed (mph)
**Output:** Wind speed at key return periods via GEV distribution

## Wildfire

- Source: **CLIMRR (ANL)**

**Input metric:** Fire weather index (FWI) by grid cell
**Output:** Maximum fire weather index by county

## Precipitation

Source: **CLIMRR (ANL)**
**Input metric:** Annual total precipitation (in/year) by grid cell
**Output:** Max annual total precipitation (in/year) by county

## Drought

Source: **CLIMRR (ANL)**
**Input metric:** Consecutive days with no precipitation by grid cell
**Output:** Max consecutive days with no precipitation by county

## Heat

Source: **CLIMRR (ANL)**
**Input metrics:**

- Days above 95, 105, 115, 125 °F
- Annual cooling degree days
- Seasonal maximum temperatures

**Output:** Input metrics applied from a grid cell level to a county level

## Cold

Source: **CLIMRR (ANL)**
**Input metrics:**

- Annual minimum temperature
- Annual heating degree days
- Seasonal minimum temperatures

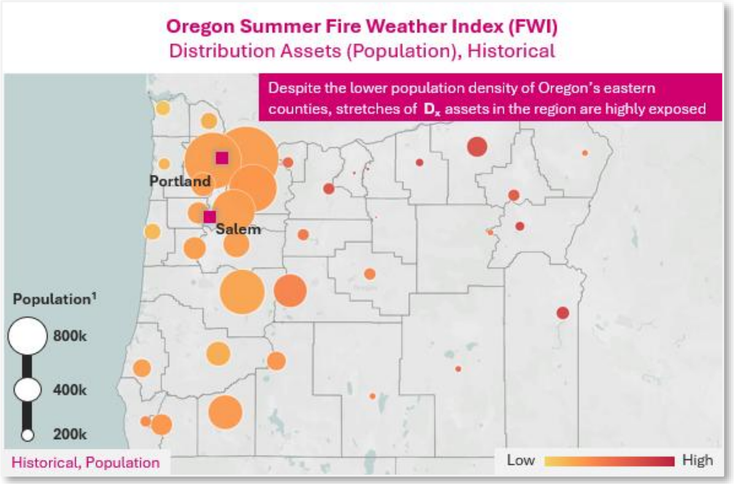
**Output:** Input metrics applied from a grid cell level to a county level

## Flood

Source: **Hydrosource (ORNL)**
**Input metric:** Annual Variable Infiltration Capacity (VIC) model runoff (mm/year)
**Output:** Average annual VIC runoff (pluvial flooding) for 4 warming scenarios and 3 time periods (historical, mid-century, end-century)

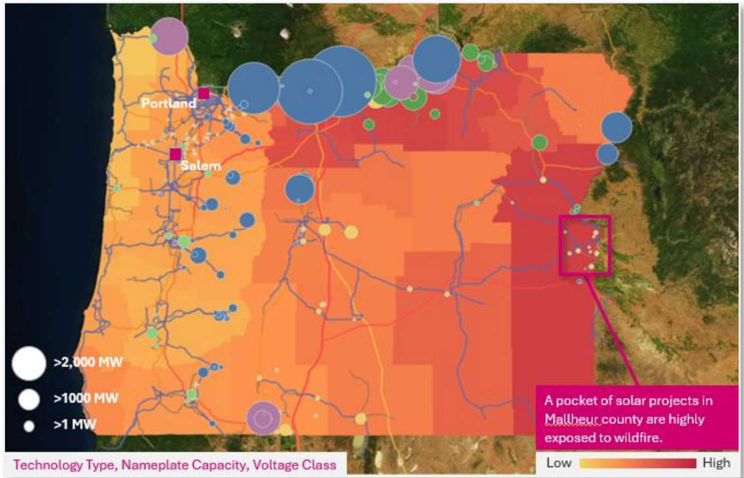
# This report is standardized to include 3 different data visualizations that provide insights for Distribution, Transmission, and Generation across 7 extreme weather hazards

## 1 Distribution Maps



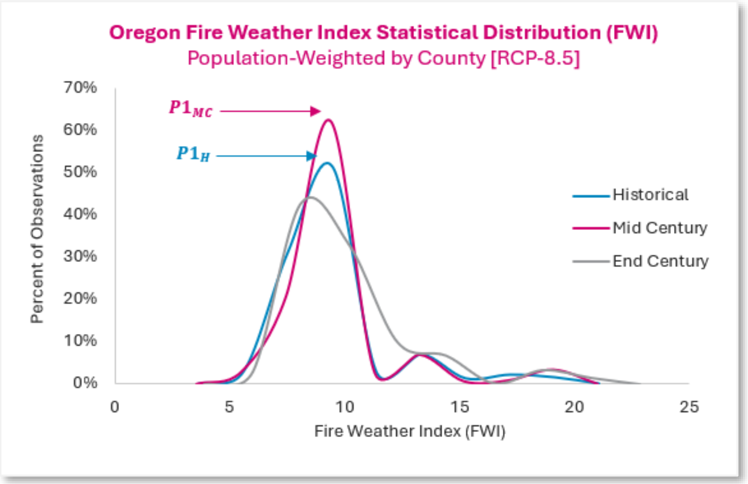

- **Purpose:** Uses population as proxy for volume of distribution assets given that the location of distribution assets is restricted.
- **Interpretation*:** Locate areas of high exposure by identifying counties with coincident large bubbles and dark colors. This indicates a combination of high volume of Dx assets and significantly high extreme weather projections.

## 2 Transmission & Generation Maps




- **Purpose:** Overlays transmission and generation assets on climate projections by county.
- **Interpretation:** Locate areas of high exposure by identifying assets in counties of high risk. Exposure differs by asset class and will be highlighted in Key Insights tables throughout.

## 3 Statistical Distribution Graphs




- **Purpose:** Contains statistical insights related to each metric. Indicates change in dispersion and severity of risk over time on average
- **Interpretation:** An increase in the width of the peak indicates a decrease in concentration of exposure, meaning more counties are exposed to more severe weather. A shift right in the curve indicates that on average, counties are experiencing more severe weather.

***Note:** Analysis addresses risk given volume of assets and does not account for risk to remote customers at end of radial distribution grids.

# Asset Class Overviews

Executive Summaries

*** AWPI = Alignment with proposed investment** L Low M Moderate H High

# ODOE could prioritize hardening of T&D infrastructure for heat and cold exposure, and consider new programs to address generator extreme weather exposure

**Key Takeaways**

- Focus T&D hardening on the wildland-urban interface and eastern HV lines to address wildfire proliferation.
- Consider new weatherization programs for thermoelectric and hydroelectric assets in the NE and prioritize T&D hardening in western population centers.
- Continue DER investment to combat derating from heat and consider funding substation upgrade projects to mitigate the risk of direct asset failure.

| Hazard | Exposure | Change to Mid-Century | Generation | Transmission & Distribution | AWPI* | Description |
|---|---|---|---|---|---|---|
| FIRE | H | ↑ | **Consider investment in innovative solar O&M processes and emergency response planning**<br>• Standardized PSPS and emergency response planning could decrease restoration times.<br>• Innovative solar cleaning projects or optimized maintenance scheduling could help combat low solar capacity factors during fires. | **Focus hardening efforts on border counties and eastern HV Tx assets**<br>• Major population centers border high-exposure counties, posing a threat to Dx and Tx assets in the case of wildfire spread and growing by 22% to 2100 [RCP-8.5].<br>• High voltage Tx lines in Wasco and Malheur counties could be prioritized for hardening given their high levels of fire exposure. | M | **Gen:** No proposed awards address generator wildfire exposure, marking a potential area for future investment.<br>**T&D:** Prevalence of undergrounding awards addresses fire risk, but their expense limits widespread implementation. ODOE could consider pole upgrades, vegetation management, AI monitoring tools, etc. |
| HEAT | M | ↑ | **Explore flexible DER options or innovative cooling methods to offset derating of supply**<br>• DER proliferation minimizes reliance on a pocket of natural gas plants that will be heavily exposed to extreme heat.<br>• Innovative thermoelectric cooling combats production derates and drought exposure. | **Consider substation upgrades and more cost-effective Tx hardening methods**<br>• Significant exposure to days >105°F requires substation upgrades to avoid direct failure.<br>• Widespread heat exposure necessitates upgrades that harden the entire length of a high voltage transmission line. | M | **Gen:** Microgrid funding through the Community Renewable Energy Grant Program addresses derating risk.<br>**T&D:** No mention of substation upgrades, which face considerable extreme heat exposure and a high likelihood of failure. |
| COLD | M | ↓ | **Focus weatherization technologies on thermoelectric & hydroelectric assets in NE**<br>• Many generators face continued exposure to icing and other cold-related failures through mid-century. | **Prioritize investments in western population centers**<br>• Peak cold exposure coincides with population centers in the northwestern counties of the state, posing a threat of Dx and Tx icing and asset failure. | M | **Gen:** No proposed awards address generator cold exposure.<br>**T&D:** Awarded projects for pole replacement and undergrounding address cold exposure. |

* AWPI = Alignment with proposed investment — L Low, M Moderate, H High

# ODOE could prioritize substation upgrades in the face of flood exposure, and fund data collection and analysis to better understand future drought and precipitation impacts

**Key Takeaways**

- ODOE could prioritize substation fortification for low-lying assets in western counties that are heavily exposed to flooding.
- Significant increase in drought exposure by mid-century suggests the importance of using climate-adjusted inputs for hydro generation forecasting.
- While precipitation has a weak climate signal, ODOE could seek out information about upstream precipitation and snow patterns to better assess risk.

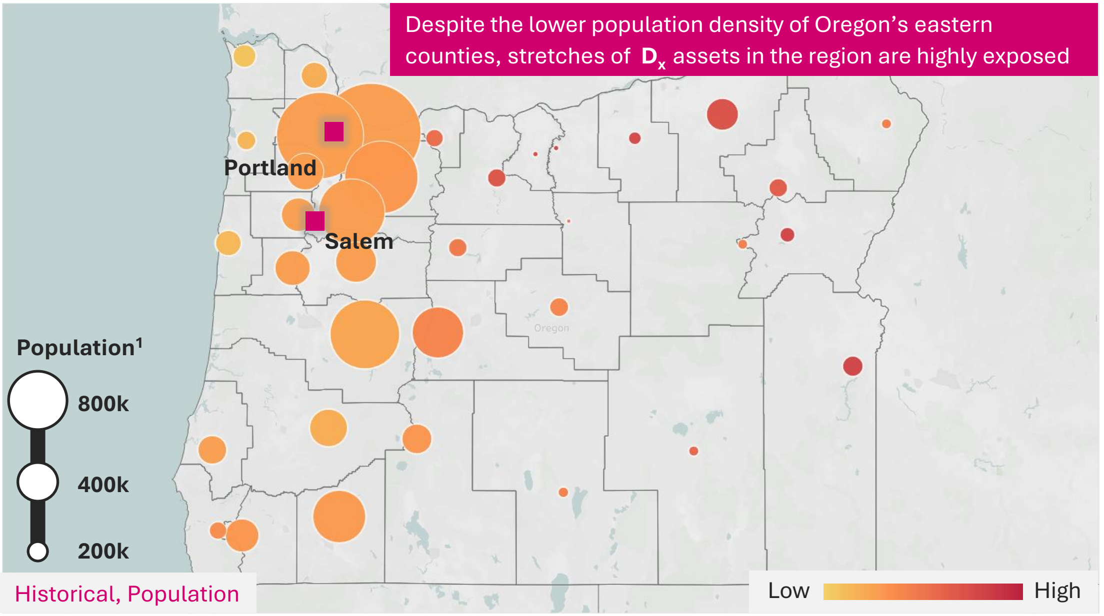
| Hazard | Exposure | Change to Mid-Century | Generation | Transmission & Distribution | AWPI* | Description |
|---|---|---|---|---|---|---|
| FLOOD | M | ↑ | **Most supply technologies are not significantly exposed to flood**<br>• A handful of hydro generators in western counties are moderately exposed, which can cause dam overtopping and operational issues. | **ODOE could prioritize substation fortification**<br>• High density of HV substations are heavily exposed to flooding, which can cause direct failure.<br>• ODOE could also consider upgrades to aging or weak distribution poles. | L | **Gen:** Lack of exposure makes gen a lower priority for investment.<br>**T&D:** No projects targeting substations, unaligned with the significant substation exposure. |
| WIND | M | N/A | **ODOE could consider investments to buttress solar racking and anticipate turbine cutouts**<br>• Supply-side planning for wind farms could include probability of cutout to anticipate supply shortages during wind events. | **Critical HV ties in south-central OR could be prioritized for structure reinforcement**<br>• Consider rethinking regional design standards for poles given historical thresholds. | M | **Gen:** No wind/solar reinforcement despite significant exposure.<br>**T&D:** Undergrounding & pole upgrades are aligned, but veg management projects could also be considered. |
| DROUGHT | M | ↑ | **Grid operators could consider using climate-adjust inputs for hydro output forecasting**<br>• Drought exposure for the two largest hydro facilities increases 20-40% by 2050.<br>• OR's heavy reliance on hydro generation means potential hydro output decreases could factor into resource planning. | **Drought exposure does not have a material impact on transmission and distribution assets.** | L | **Gen:** Microgrid funding is not sufficient to address risk of decreased hydro output. Suggested projects for heat and fire exposure could also address drought, including solar O&M advances. |
| RAIN | L | → | **ODOE could seek out additional data to understand future hydroelectric production**<br>• Coordinate with WSDOC to assess upstream precipitation effects on hydro output.<br>• Consider the effect of warming on snow volume and melt timing. | **Precipitation exposure does not have a material impact on transmission and distribution assets.** | M | **Gen:** Weak climate signal makes addressing exposure less urgent, but ODOE could gather additional information to assess the true impact on hydro output and its implications for resource planning and scheduling. |

# Wildfire

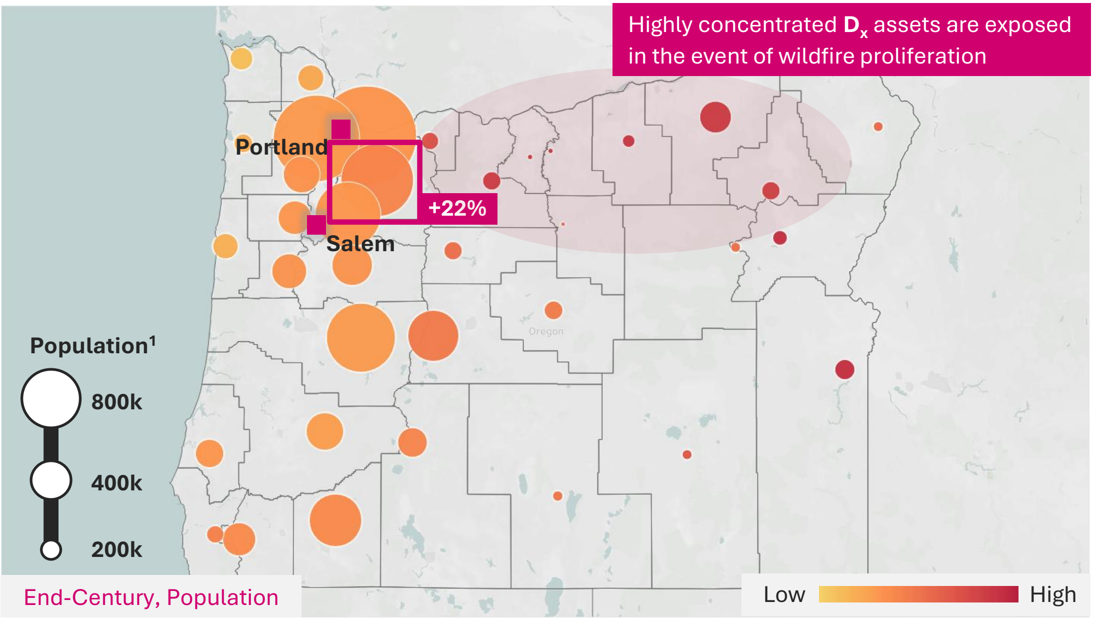
Asset Analysis

# ODOE could prioritize funding wildfire mitigation projects in Umatilla County and the wildland-urban interface bordering northwestern counties

**Oregon Summer Fire Weather Index (FWI)**
Distribution Assets (Population), Historical




**Oregon Summer Fire Weather Index (FWI)**
Distribution Assets (Population), End-Century [RCP-8.5]




## KEY OBSERVATIONS

- Historical wildfire exposure is concentrated in Oregon's **eastern counties.**
- **Dx assets in Umatilla County exhibit high exposure** while western population centers with the most assets generally face lower exposure.
- High percentage of undergrounding and covered conductor proposals indicate general alignment with wildfire exposure; **ODOE could prioritize projects in eastern counties or counties bordering population centers.**

## KEY OBSERVATIONS

- FWI increases by about 2-6 points across the state, demonstrating the importance of utilizing **forward-looking climate projections for state-wide fire mitigation planning.**

**Clackamas County** Large population center bordering high exposure counties, demonstrating the need for **fire mitigation projects in the wildland-urban interface.**

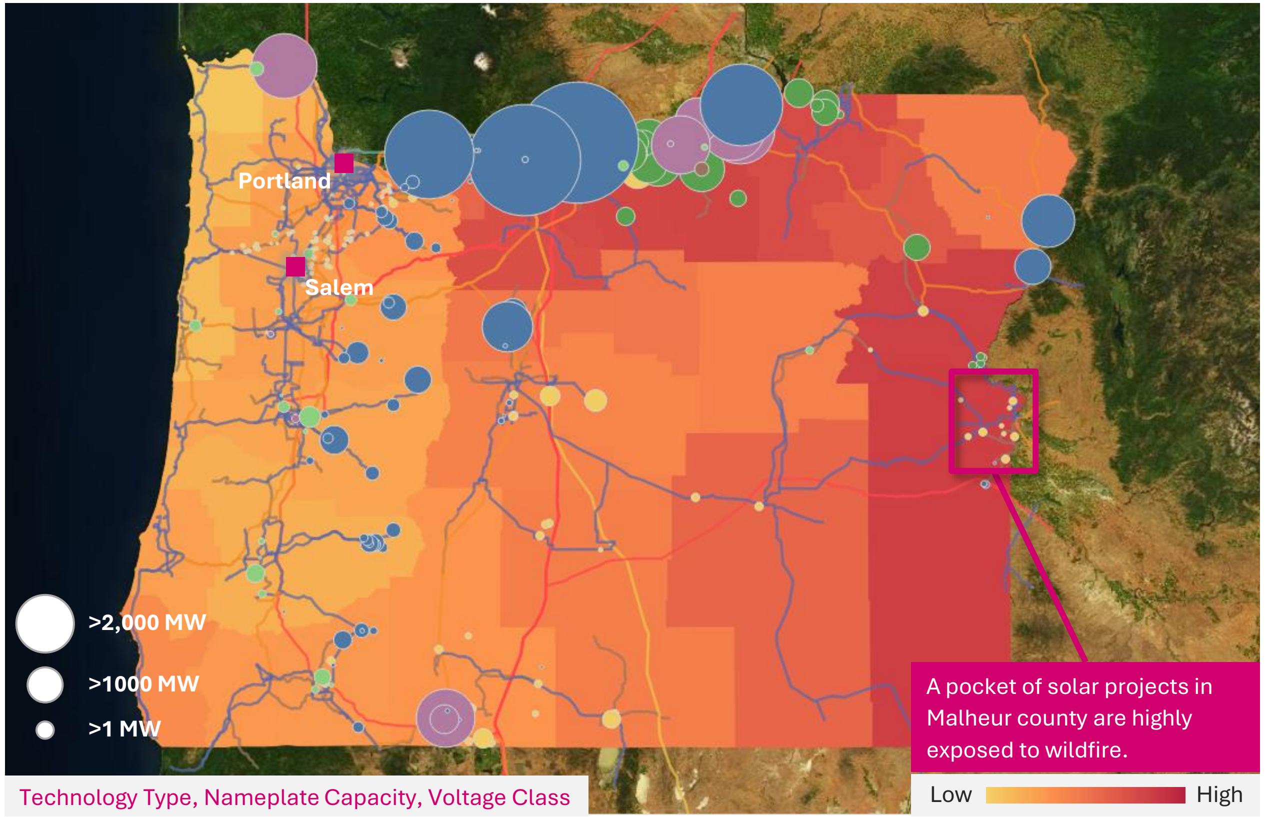
Source: ClimRR, US Census Bureau, City and Town Population Totals

# ODOE could consider prioritizing hardening for highly exposed remote transmission assets and explore novel operational procedures for renewables facing derating from soot and ash

## Oregon Summer Fire Weather Index (FWI)

Generators & Transmission, Mid-Century [RCP-8.5]




Onshore Wind · Coal Plant · Hydroelectric · Nuclear · Solar Photovoltaic

Biomass · Natural Gas Plant · Pumped Storage · Batteries · Other

500kV · 345kV · 220-287kV · 100-161kV · <100kV

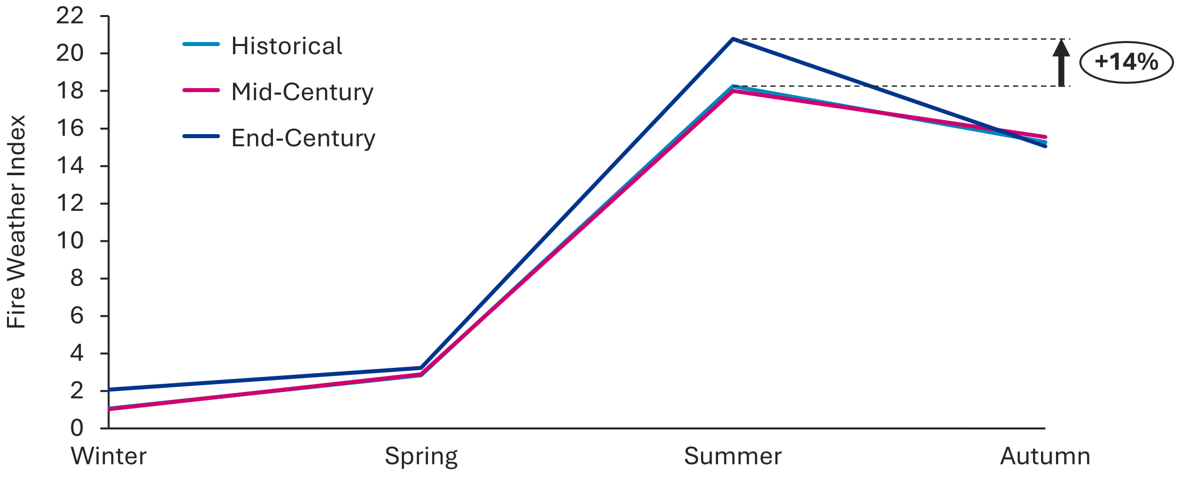
Source: ClimRR, EIA860, HIFLD

| Key Highlights | Analysis |
| --- | --- |
| Transmission | • **Remote transmission assets are critical** for last mile rural customers and are highly exposed in eastern counties.<br>• Wildfire smoke can ionize the air around transmission lines, creating a conductor that can cause a line to arc directly to the ground.<br>• HV lines in Wasco and Malheur counties could be **prioritized for hardening upgrades.** |
| Renewables | • Wind and solar assets in Sherman, Gilliam, and Malheur counties face high levels of wildfire exposure.<br>• Soot and ash from burns **decrease capacity factors for both wind and solar assets.**<br>• **Very few proposed projects address generator exposure,** indicating a potentially overlooked resilience topic area for the state. |
| Restoration | • Wildfire causes **ingress/egress issues** through destruction of roads and transportation, slowing restoration times for all assets.<br>• ODOE could **consider funding projects addressing wildfire-related access issues** given its impact across all asset classes. |

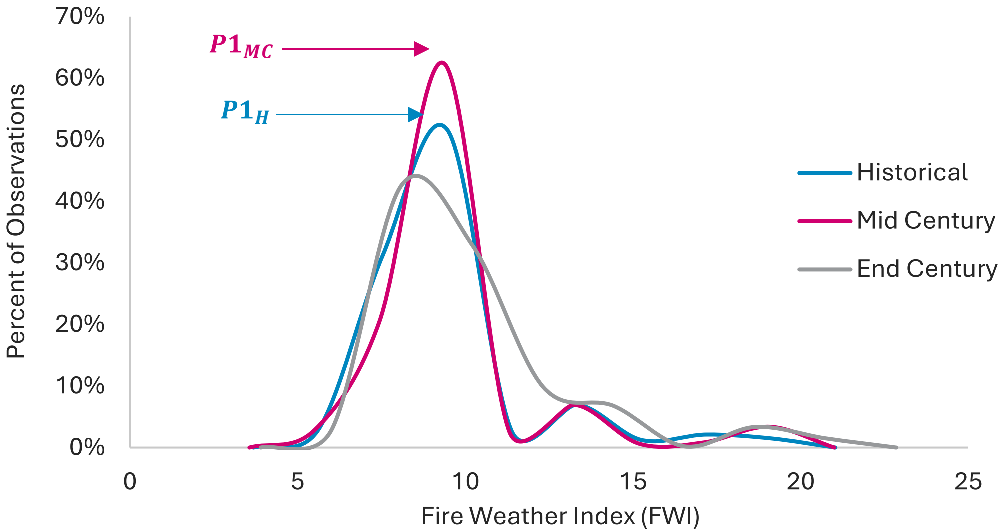
 | 

# By mid-century, fire exposure is expected to increase in spatial extent, while by end-century it is expected to increase in severity and duration, shortening the maintenance window

**Oregon Average Seasonal Fire Weather Index (FWI)**
Population-Weighted by County [RCP-8.5]




**Oregon Fire Weather Index Statistical Distribution (FWI)**
Population-Weighted by County [RCP-8.5]




## KEY OBSERVATIONS

- **End-century wildfire exposure is elevated**, with the sharpest increase occurring between spring and autumn by about 14% from historical FWI.
- Elevated wildfire exposure around the summer suggests a **lengthening of the wildfire season** combined with an **increase in severity.**
- The change in length of wildfire seasons suggest that **the window for scheduled maintenance during the shoulder seasons is diminishing.**

## KEY OBSERVATIONS

- Increase in peak 1 (P1) by mid-century indicates that an **increasing percentage of the population** will be exposed to a **FWI level of about 10.**
- The tri-modal shape of the curve represents **three regions of the state that face distinct levels of fire risk** given differences in climate zones.
- A kink in the distribution between FWI 10-15 by end-century demonstrates **an increasing volume of the population being exposed to these increasingly severe FWI levels.**

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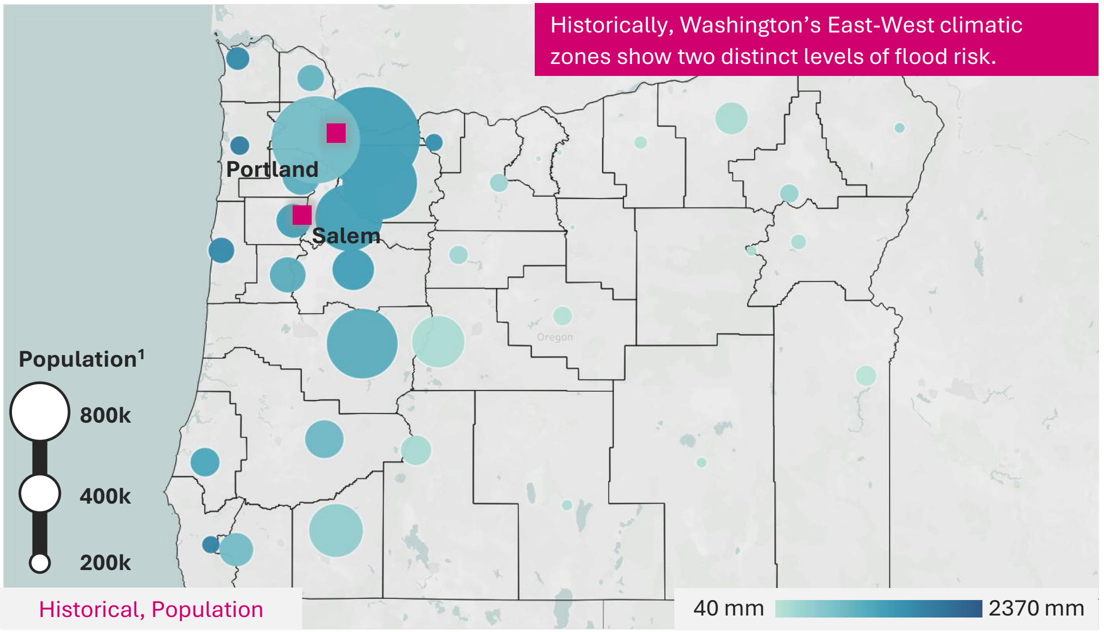
Baringa

# Flood

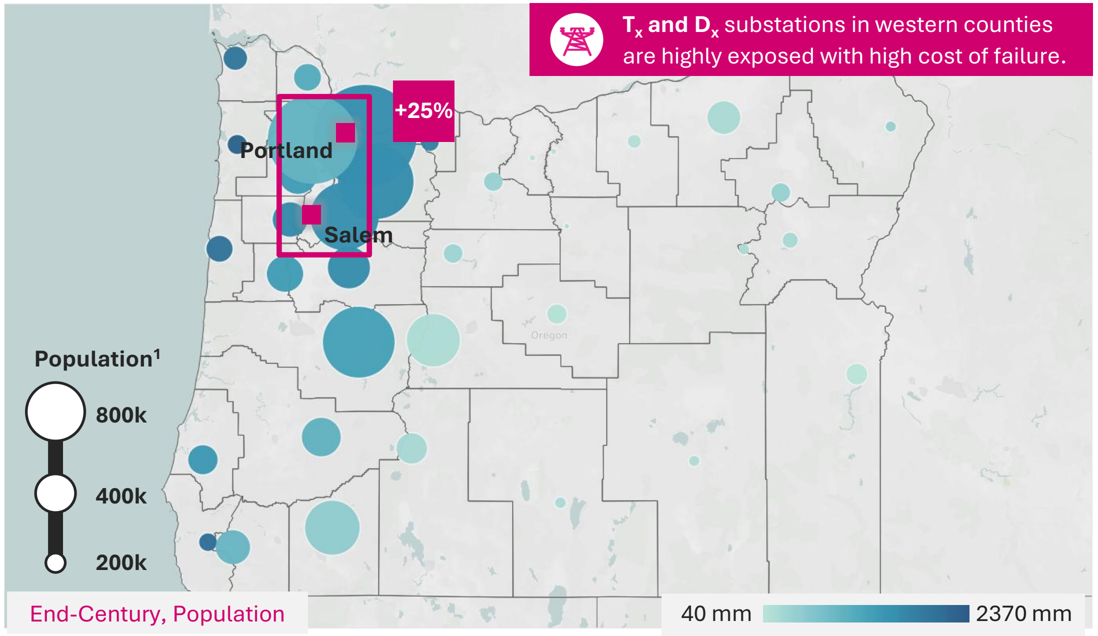
Asset Analysis

# ODOE could consider funding projects to fortify substations and distribution poles in western counties given the high volume of assets exposed to increasingly severe flooding

## Oregon Average Annual Surface Runoff (mm/year)
Historical [SSP5-8.5]




## Oregon Average Annual Surface Runoff (mm/year)
End-Century [SSP5-8.5]




### KEY OBSERVATIONS

- Most flood exposure lies in the **northwest counties** given their relatively low elevations and proximity to the coast.
- **Multnomah and Clackamas counties have a large volume of Dx substations with high exposure** given their high population.
- Currently no proposed projects explicitly address flood exposure.

### KEY OBSERVATIONS

- ODOE could consider funding projects to fortify low-lying Dx substations given the increase in flood exposure over time in western counties.

**Multnomah County**

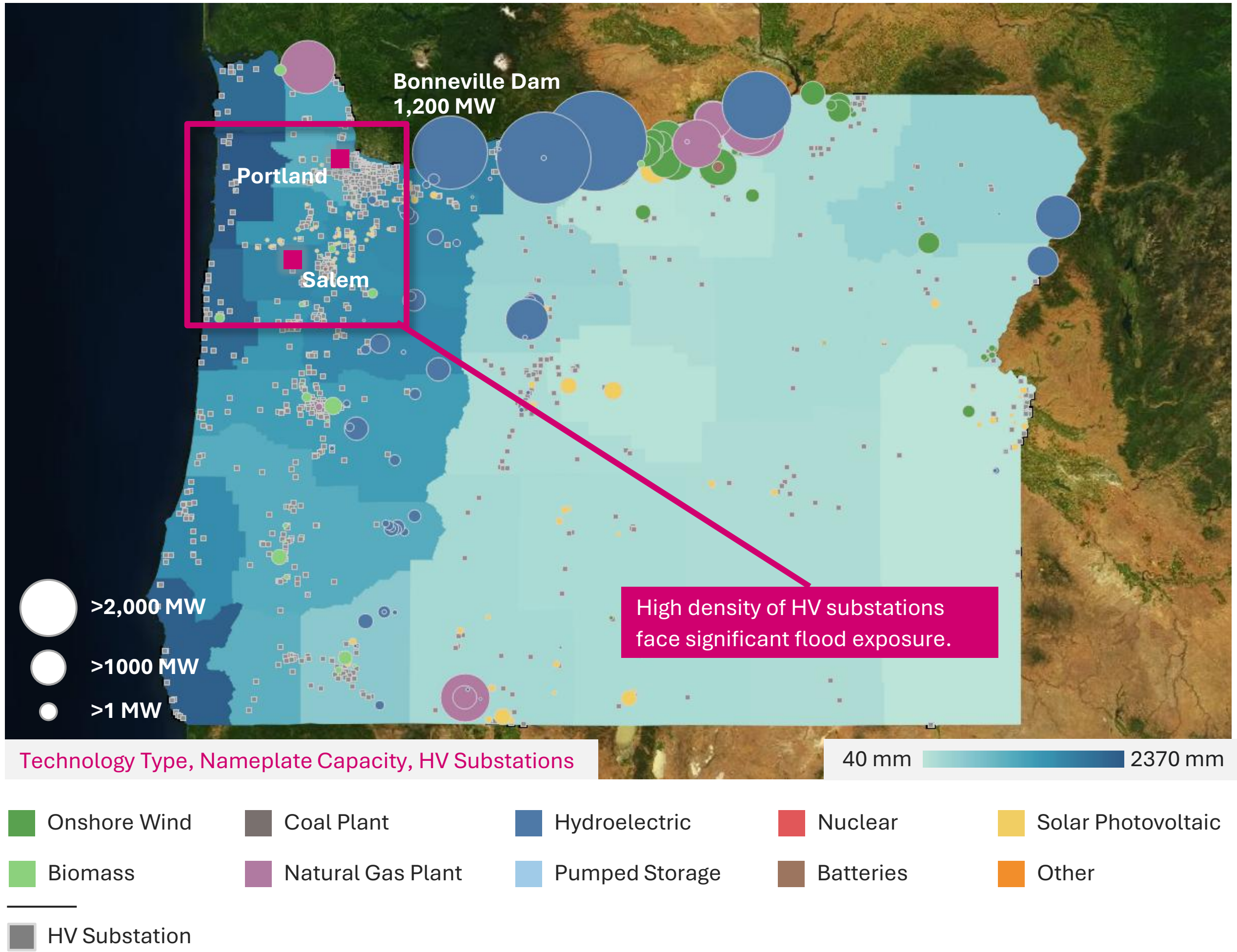
**Flood exposure is projected to increase ~23% by end-century**, posing a substantial threat to a high density of substations and distribution poles.

Source: ClimRR, US Census Bureau, City and Town Population Totals

 | 

# ODOE could prioritize the fortification of high voltage substations given the high density of assets facing significant exposure and their high cost of failure

**Oregon Average Annual Surface Runoff (mm/year)**
Generators, Mid-Century [SSP5-8.5]




Source: ClimRR, EIA860, HIFLD

| Key Highlights | Analysis |
|---|---|
| Substation | • High voltage substations will be exposed to fluvial flooding if located in a flood plain or riverbank without necessary protections.<br>• High density of **HV substations in western counties are heavily exposed to flood risk**, marking a priority for future hardening projects. |
| Restoration | • Flooding causes **ingress/egress complications** by washing out access roads, contributing to restoration issues.<br>• Flooding can **affect on-site buildings or facilities**, making it more difficult to maintain adequate staffing for oversight and restoration. |
| Generators | • Most generator sites are not exposed to significant flood risk, indicating that **ODOE could prioritize Tx & Dx projects to address the hazard.**<br>• A handful of hydro plants in Linn, Clackamas, and Multnomah counties are significantly exposed to flood, which can contribute to dam overtopping/failure and pose a threat to control houses. |

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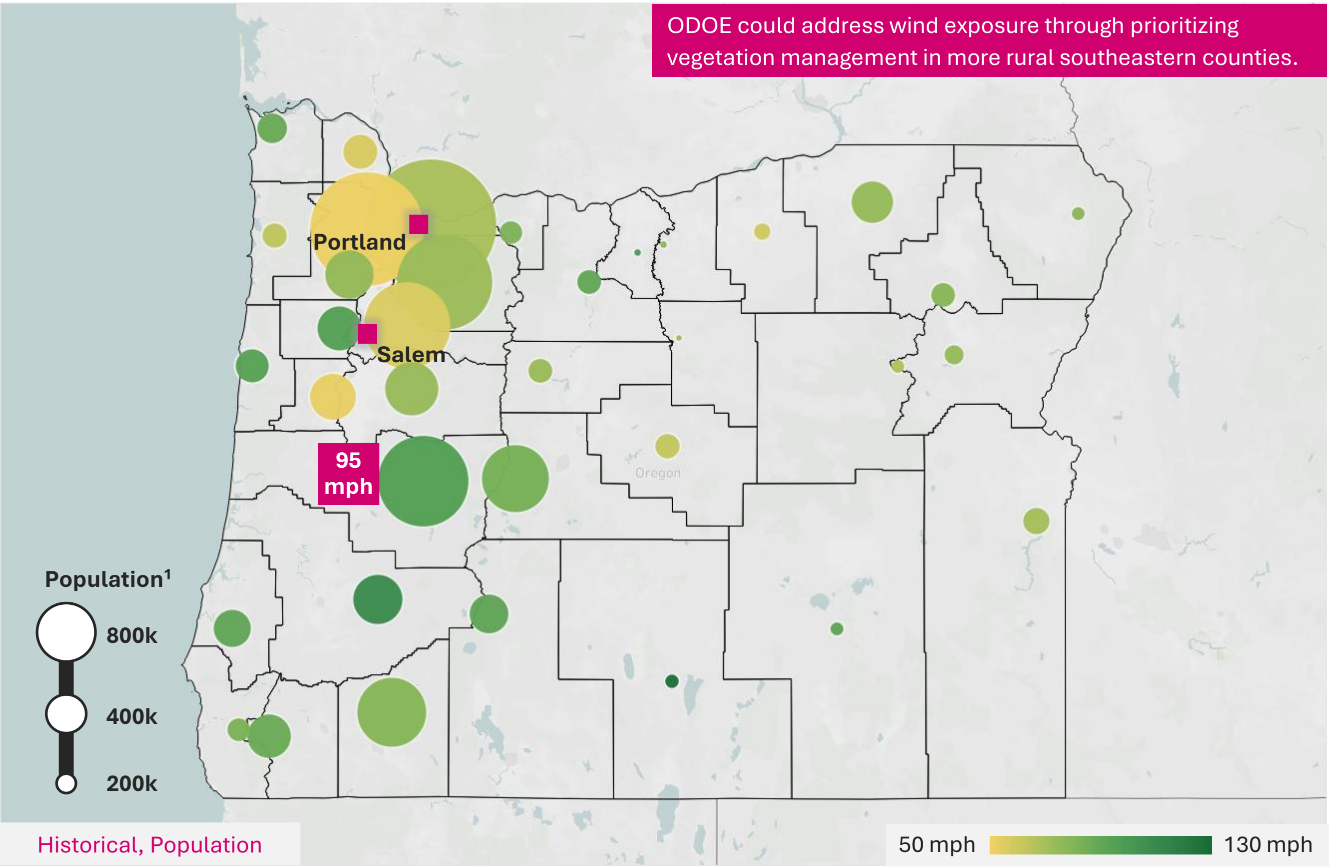
# Wind

Asset Analysis

# Vegetation management and pole reinforcing could be prioritized for metro centers in southeastern counties as well as for remote customers in the south-central region

## Oregon 100-year Wind Speed (mph)
Historical




| Key Highlights | Analysis |
|---|---|
| Distribution | • Given weak climate signals, wind speeds are derived using historical data and do not vary at high spatial resolution.<br>• Rather than targeted investments, wind exposure should be addressed through **upgraded design standards** across a utility service territory. |
| Lane County | • Lane County has a population of approximately 400k and 100-year return value of 95 mph, **indicating a high exposure area for Dx assets**.<br>• Coincident extreme cold events put Dx lines at risk for galloping and asset failure due to ice loading on conductors. |
| Lake County | • **Lake County** has the highest return value of 126 mph, indicating high failure likelihood for lower class poles.<br>• Although there might be less volume of Dx infrastructure, **remote customers are at significant risk of prolonged outages**. |

Source: DRI, EIA860, HIFLD

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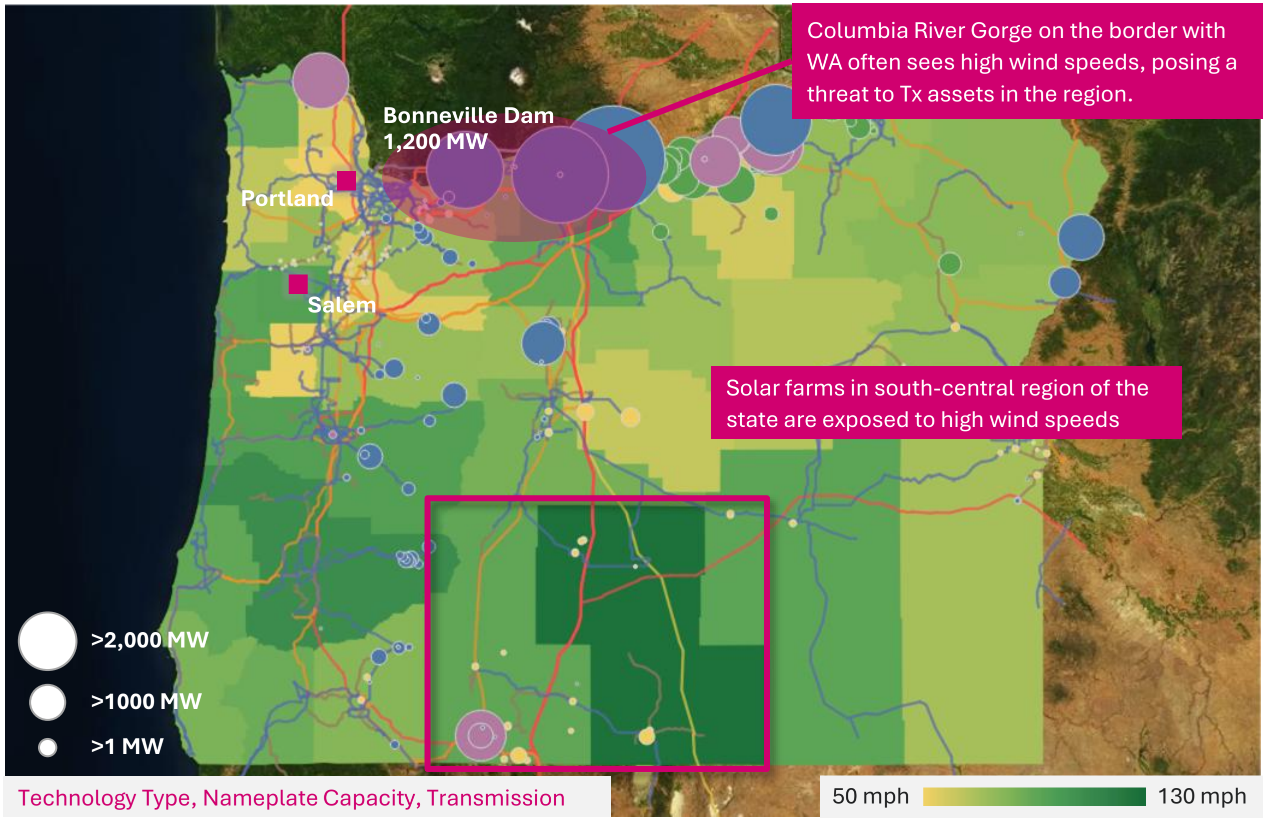
# HV transmission lines in south-central region of the state could be prioritized for mitigation investment given their critical import/export capacity with neighboring supply centers

**Oregon 100-year Wind Speed (mph)**
Historical




Onshore Wind | Coal Plant | Hydroelectric | Nuclear | Solar Photovoltaic
Biomass | Natural Gas Plant | Pumped Storage | Batteries | Other

500kV | 345kV | 220-287kV | 100-161kV | DC

Source: DRI, EIA860, HIFLD

| Key Highlights | Analysis |
|---|---|
| **Transmission** | • A series of MV-HV transmission lines in the south-central portion of the state are exposed to high historical wind speeds.<br>• These are California-Oregon tie lines and are critical for **import/export capability** during extreme weather events. ODOE could focus on reinforcing Tx structures to mitigate risk. |
| **Solar** | • A pocket of solar farms in the south-central portion on the state are historically exposed to ~126 mph at the 100-year return period.<br>• Depending on OEM, solar panels are only rated to 90 mph, **indicating need for rack reinforcement and vegetation management.** |
| **Wind** | • Wind farms cutout speeds can vary between 45-70 mph, indicating that in high wind speed events, there the turbines stop producing.<br>• The cluster of wind farms located in the north-central area of the state are exposed to 100-year return period values of greater than the cutout threshold, impacting **critical supply near population centers**. |

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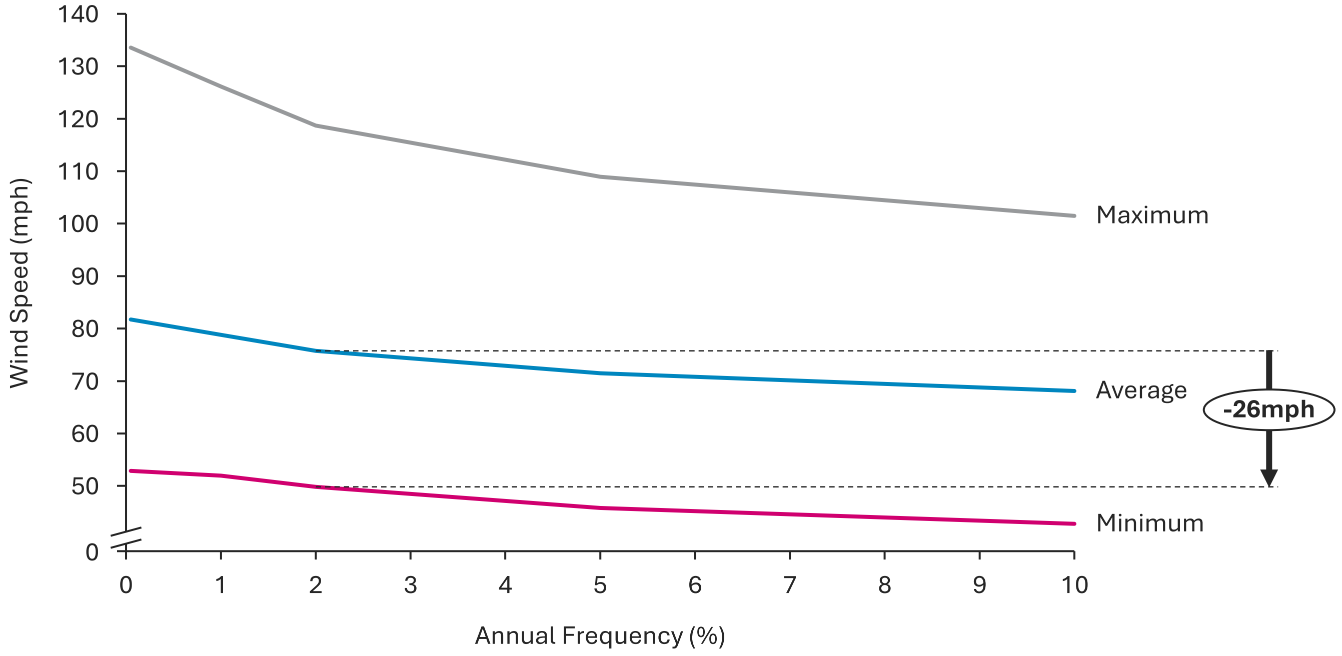
# Historically, there is a 1% chance that the average wind speed seen across Oregon counties is ~80mph annually.

**Oregon Wind Frequency vs Severity (2000 – 2022)**
Historical, Average by County




| Key Highlights | Analysis |
|---|---|
| **High System Averages** | • Historically, there is a 1% chance that the average wind speed seen across Oregon counties is ~80mph annually.<br>• The 10% annual likelihood drops to 70mph, indicating high system wind speeds are common across counties. |
| **Volatility Across Counties** | • There is a wide band between the maximum and minimum counties around the mean.<br>• This indicates that wind adaptations should be focused on a county basis rather than over large service territories. |

DRI

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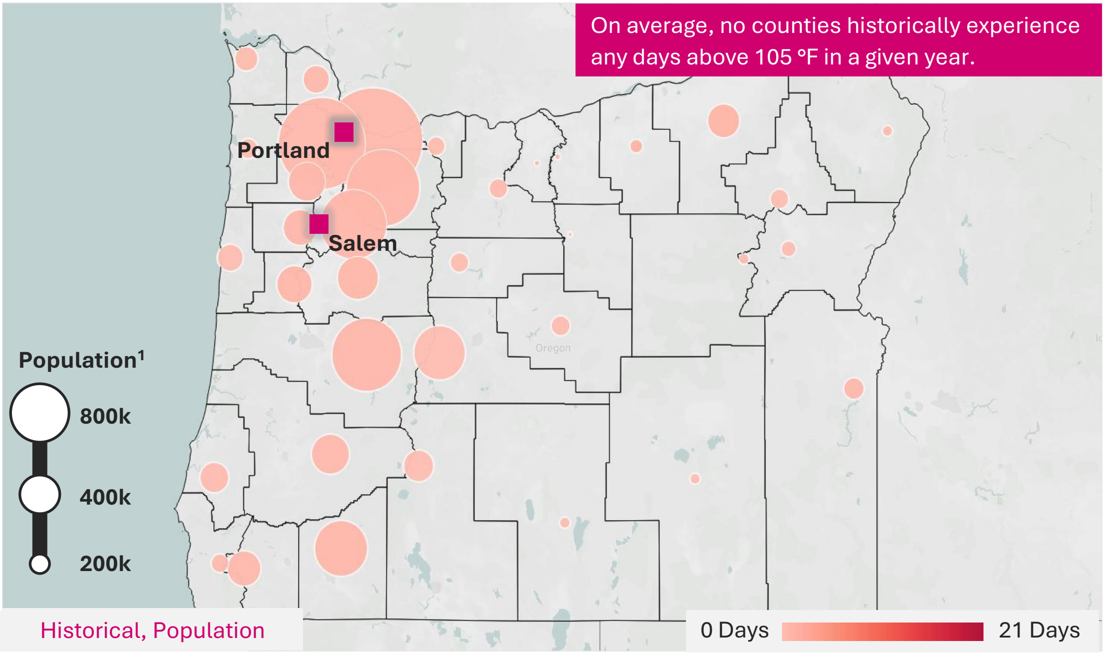
# Heat

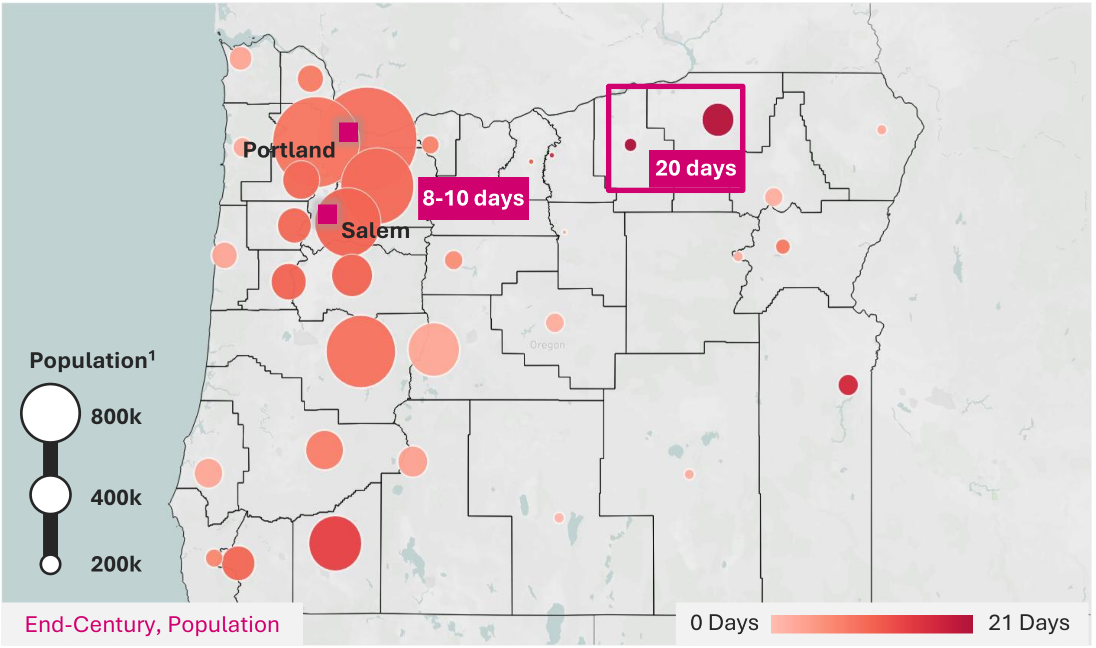
Asset Analysis

# Significant increases in extreme heat exposure across the state suggest that ODOE could prioritize substation and Dx line upgrades to address derating, degradation, and risk of failure

**Oregon Days Above 105 °F**
Distribution Assets (Population), Historical




**Oregon Days Above 105 °F**
Distribution Assets (Population), End-Century [RCP-8.5]




## KEY OBSERVATIONS

- Currently $T_x$ and $D_x$ assets have **no exposure to days above 105 °F.**
- 105 °F is a particularly important threshold for distribution assets and substations, **which can fail when exposed to two consecutive days above 104 °F.**[2]

## KEY OBSERVATIONS

- Highly populated counties (Multnomah, Clackamas, Marion) are expected to face **about 8-10 days >105 °F annually, causing high asset utilization, derating, and potential failure.**

**Umatilla and Morrow Counties** — 20 days of extreme heat exposure necessitates substation and Dx line upgrades to mitigate potential failure and avoid derating.

[1]Population bubbles are continuous and therefore labels are approximate. [2]EPRI Climate READi

Source: ClimRR, US Census Bureau, City and Town Population Totals

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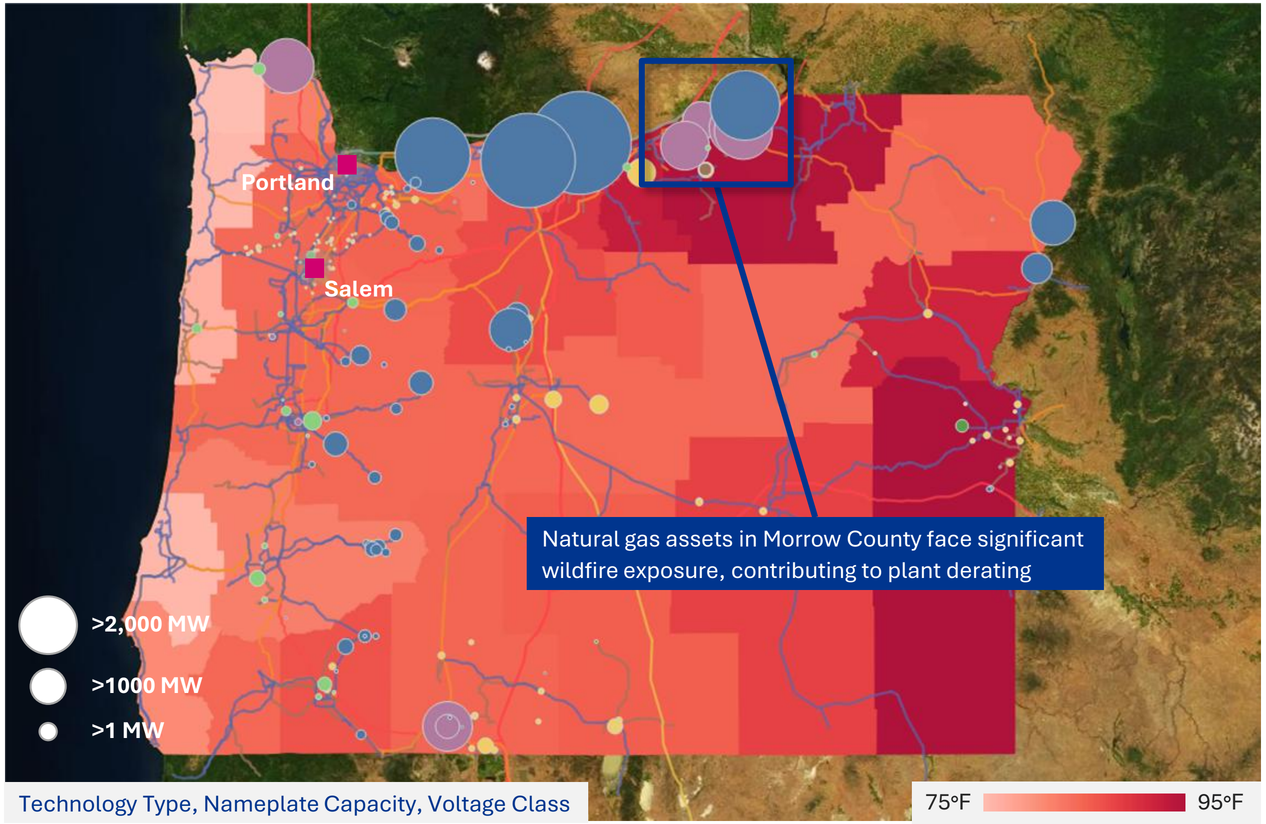
# ODOE could prioritize cooling technology development and cost-effective line adaptations to combat derating and line sag resulting from extreme heat exposure

**Oregon Summer Average Maximum Temperature (°F)**
Generators, Mid-Century [RCP-8.5]




Onshore Wind | Coal Plant | Hydroelectric | Nuclear | Solar Photovoltaic
Biomass | Natural Gas Plant | Pumped Storage | Batteries | Other
500kV | 345kV | 220-287kV | 100-161kV | <100kV

Source: ClimRR, EIA860, HIFLD

| Key Highlights | Analysis |
|---|---|
| Thermoelectric | • Thermoelectric generators that rely on water-based cooling methods will **experience production derates** as extreme heat raises average water temperatures.<br>• ODOE could explore innovative cooling methods as a resilience topic area, as derates occur coincidentally with peak load. |
| Renewables | • McNary Dam in Umatilla County is susceptible to extreme heat, which **increases the likelihood of algal blooms that reduce output.**<br>• Solar assets in Malheur and Gilliam counties are significantly exposed to extreme heat, contributing to **production derating** at temperatures above 77°F. |
| Transmission | • A significant portion of 220kV+ transmission lines are exposed to high levels of extreme heat, which can cause capacity derates and line sag.<br>• Undergrounding proposals address these issues, but ODOE could consider **more cost-effective adaptations to fortify longer portions of transmission lines.** |

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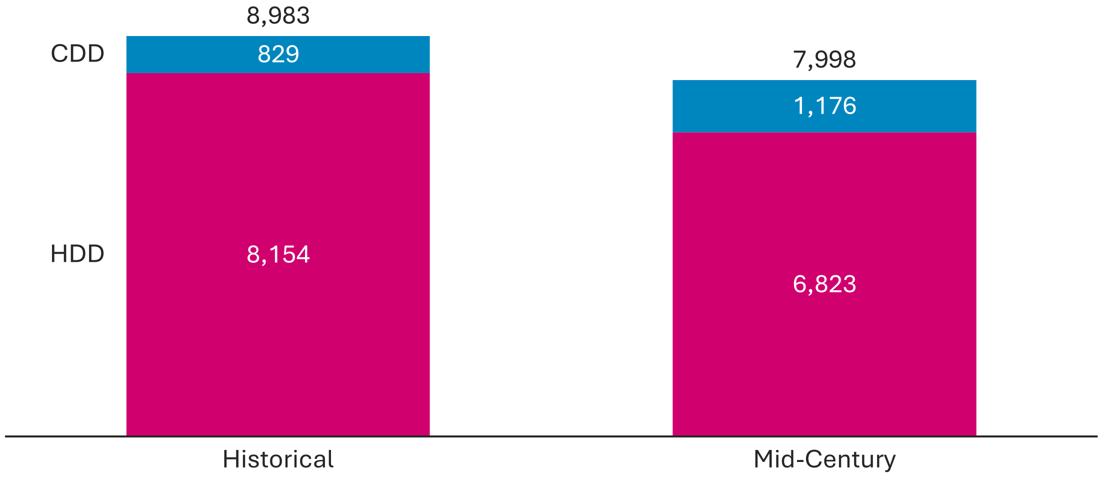
# Extreme heat days will become more common in Oregon, contributing to derating and capacity violations as well as substation failure, indicating the need for state-wide substation upgrades

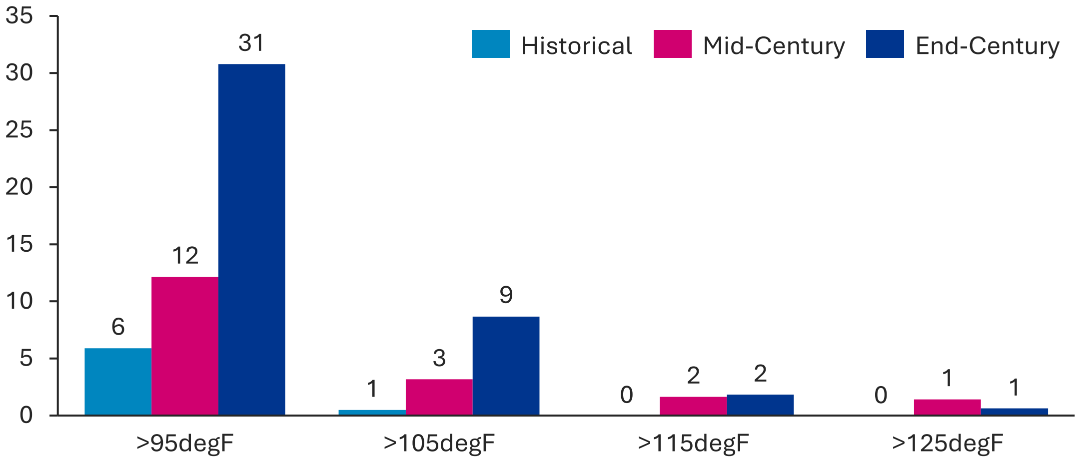
**Oregon Average Annual Cooling & Heating Degree Days (CDD & HDD)**
Population-Weighted by County [RCP-8.5]




### KEY OBSERVATIONS

- Between historical and mid-century, **the ratio of CDD to HDD increases,** with the share of average number of CDD jumping from about 9% to 15%.
- This results in **increased summer asset utilization and degradation**, but **impacts to winter utilization remain unclear** depending on heating electrification trends.
- Larger gap between HDD values than CDD values indicates that heating load will be more significantly impacted than cooling load.

**Oregon Average Annual Days Exceeding Daily Max Heat Index Thresholds**
Population-Weighted by County [RCP-8.5]




### KEY OBSERVATIONS

- 2x increase in days with heat index >95 °F by mid-century demonstrates an **increase in peak load** and will likely contribute to **derating** and **capacity violations** for transmission and thermal generating units.
- 3x increase in days > 105 °F and 115 °F by poses a **substantial risk to distribution substations**, which can fail after two consecutive days above 104 °F without sufficient cooling infrastructure, indicating a potential focus area for ODOE in future funding allocation processes.

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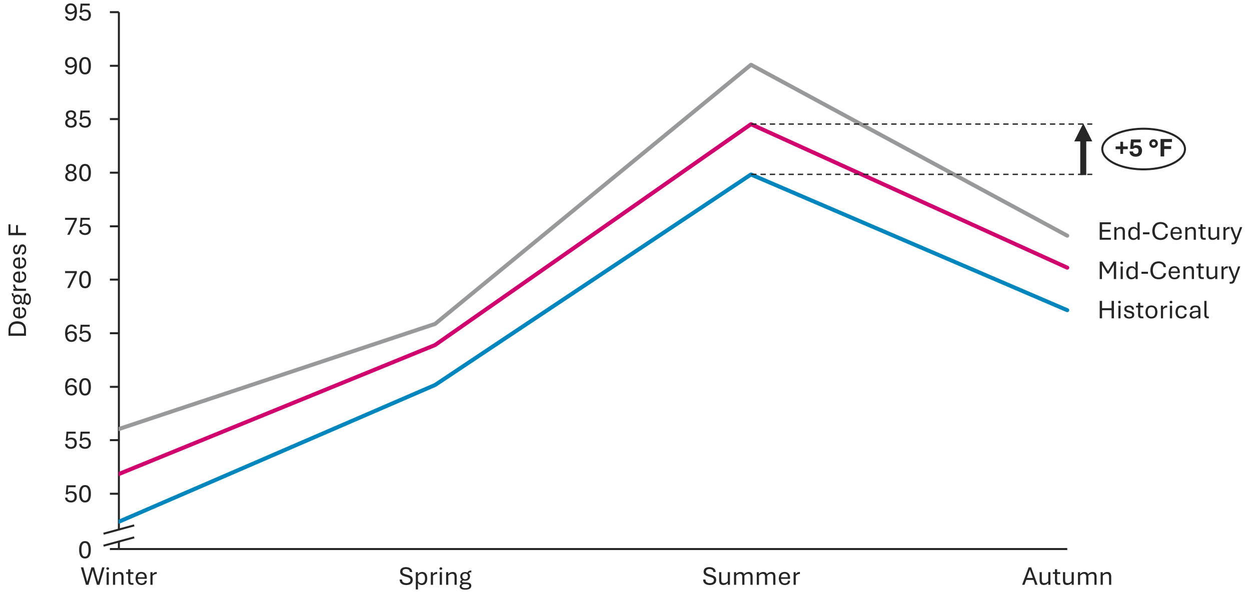
# Average summer temperature maximums are projected to increase by mid-century, increasing the duration and magnitude of high system utilization

**Oregon Average Seasonal Maximum Temperature (°F)**
Population-Weighted by County [RCP-8.5]




| Key Highlights | Analysis |
|---|---|
| **Summer Warming** | • **Heat risk increases most drastically in summer**, with a 5 °F increase in the average seasonal max by mid-century, **increasing system utilization and accelerating degradation.** |
| **Shorter Shoulder Seasons** | • Warming is generally less pronounced in shoulder seasons, although increased autumn maximums could **extend the duration of high system utilization and shorten maintenance windows.** |

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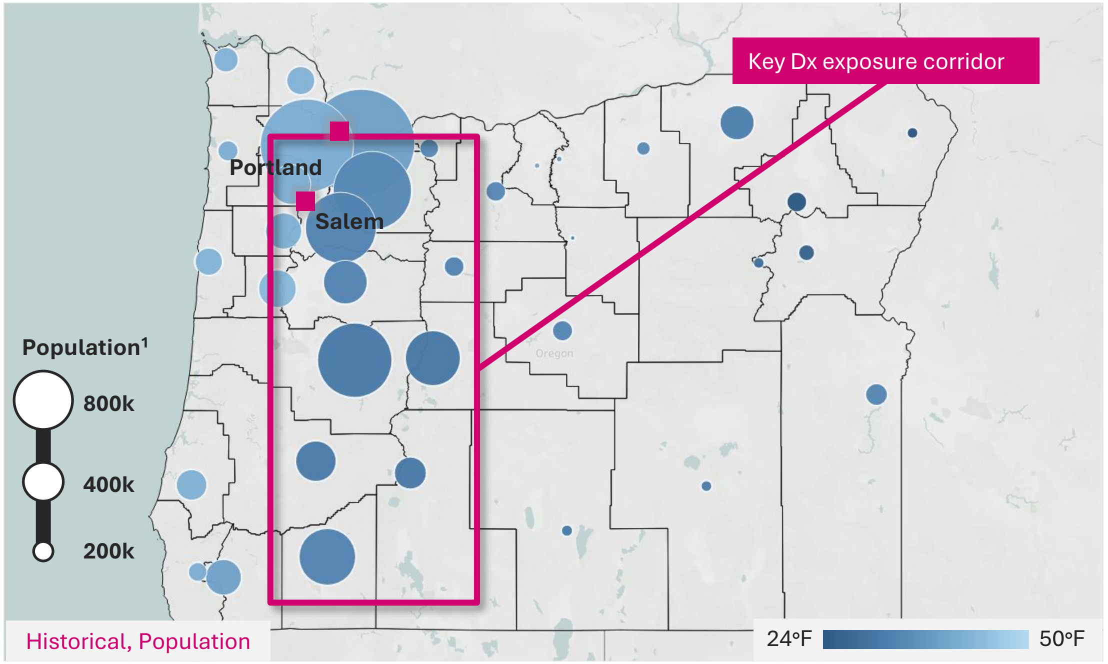
# Cold

Asset Analysis

# ODOE could continue to fund distribution asset hardening and ensure that investment is aligned with Dx asset density given continued extreme cold exposure

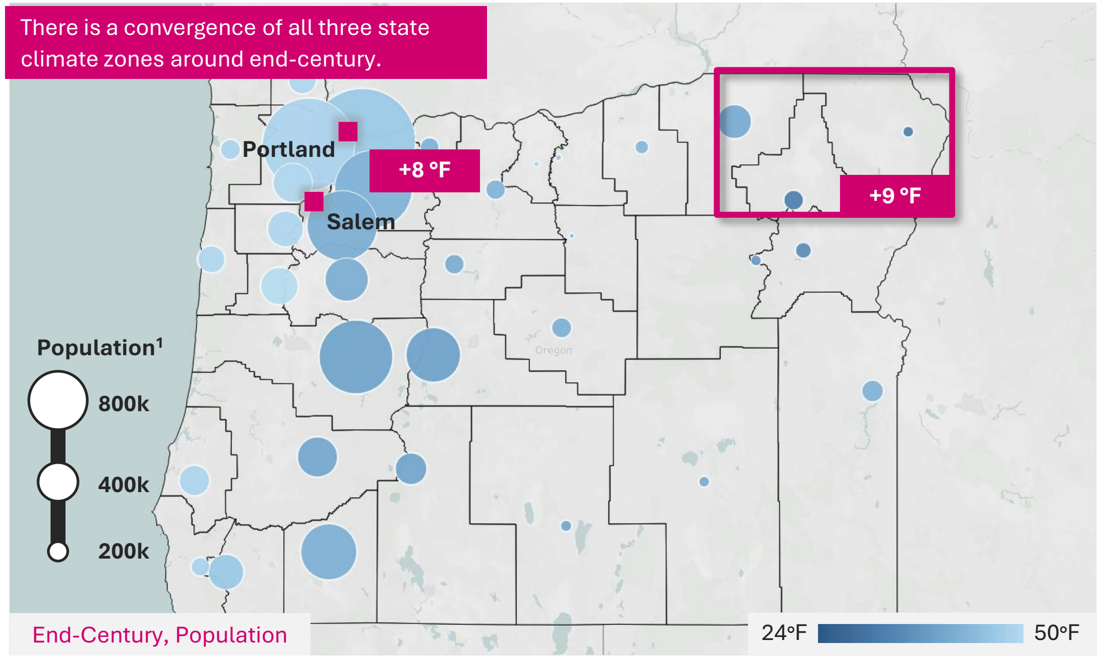
**Oregon Average Annual Minimum Temperature (°F)**
Distribution Assets, (Population) Historical




## KEY OBSERVATIONS

- Extreme cold coincides with large population centers in the western portion of the state, indicating **high levels of Dx asset exposure.**
- Prevalence of proposals including undergrounding and pole upgrades seems to address extreme cold exposure, but ODOE could **consider Dx asset density in its project awards going forwards.**

**Oregon Average Annual Minimum Temperature (°F)**
Distribution Assets, (Population), End-Century [RCP-8.5]




## KEY OBSERVATIONS

- Climate projections cannot predict acute extreme events like polar vortices and winter storms, **underrepresenting cold exposure.**

**Lane County** — Lane County is exposed to average annual minimum temperatures of about 36 °F, indicting potential **icing and freezing exposure for distribution assets.**

Source: ClimRR, US Census Bureau, City and Town Population Totals

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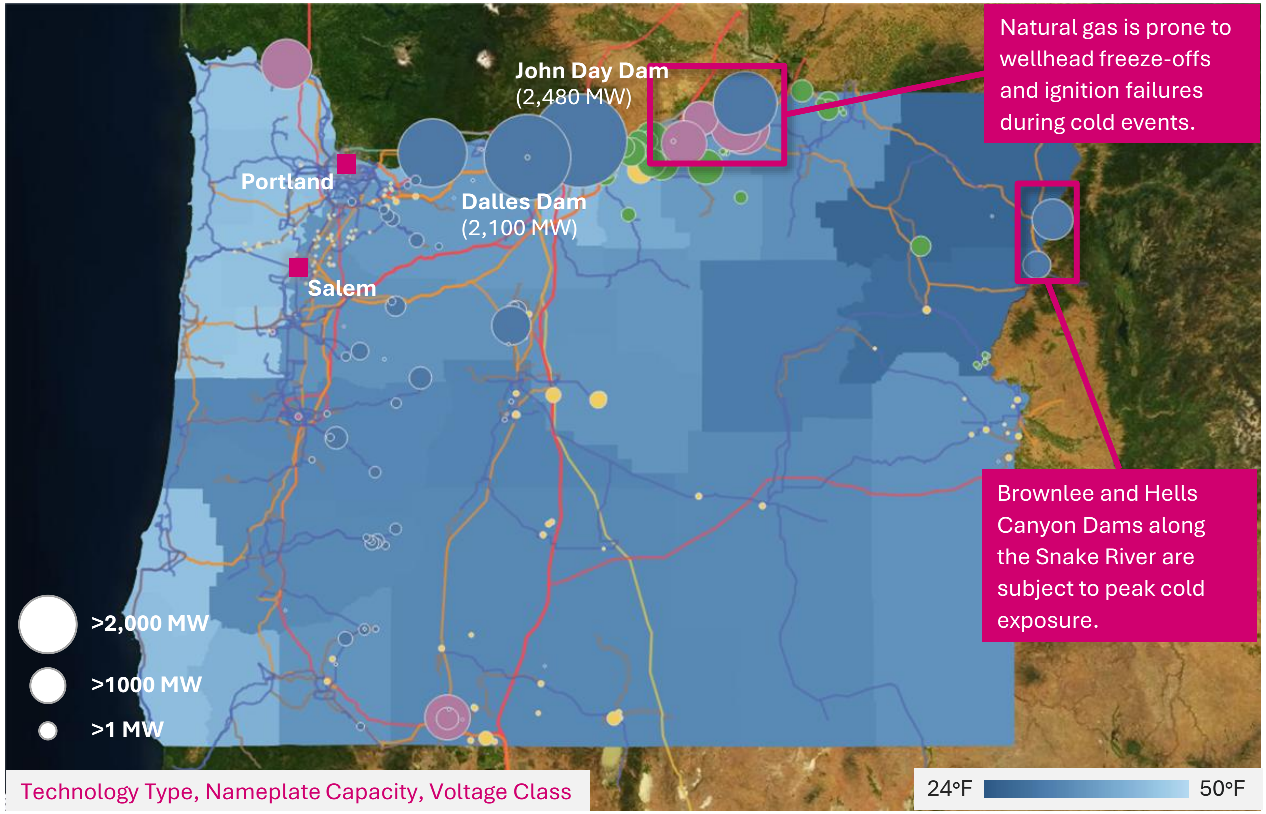
# ODOE could consider resilience upgrades to gas plants and pipeline systems to combat cold exposure, as well as continued transmission hardening addressing freezing

**Oregon Average Annual Minimum Temperature (°F)**
Generators, Mid-Century [RCP-8.5]




Onshore Wind | Coal Plant | Hydroelectric | Nuclear | Solar Photovoltaic
Biomass | Natural Gas Plant | Pumped Storage | Batteries | Other

500kV | 345kV | 220-287kV | 100-161kV | <100kV

Source: ClimRR, EIA860, HIFLD

| Key Highlights | Analysis |
|---|---|
| Hydroelectric | • Frazil ice formation and maloperation of spill gate motors can result in **plant faults or production derates.** |
| Natural Gas | • Natural gas plants in the north-central region are exposed to average annual minimums of 37°F, which could cause **ignition failure or performance issues if these plants lack heating equipment.**<br>• **No proposals addressing aging gas infrastructure**, which requires hardening or replacement to mitigate cold exposure. |
| Wind | • Wind plants in Gilliam and Union counties face cold exposure that contributes to **asset failure and ice throw.** |
| Freezing/Icing | • Despite warming, the **prevalence of near-freezing annual minimums** in many counties contributes to **Tx freezing/icing risk** that can cause asset failure.<br>• ODOE appears to be addressing this issue through pole replacement and undergrounding. |

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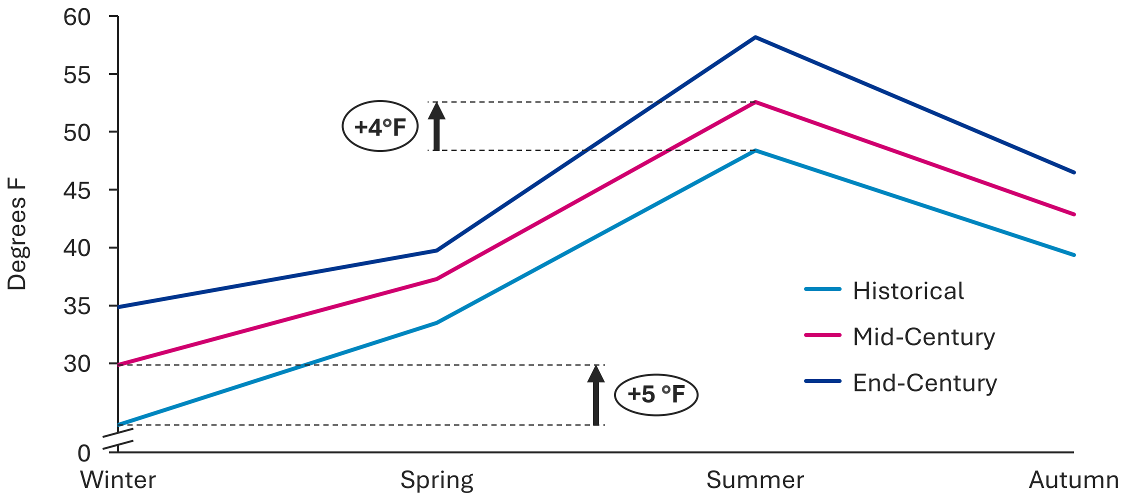
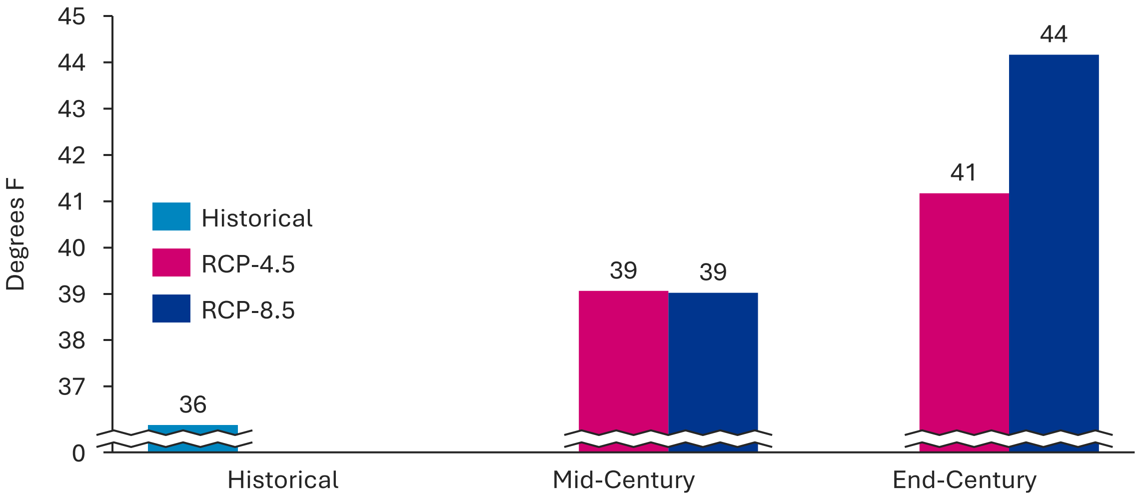
# Seasonal and annual temperature minimums are projected to increase over time across all seasons, indicating that ODOE could prioritize projects that address both heat and cold

**Oregon Average Seasonal Minimum Temperature (°F)**
Population-Weighted by County [RCP-8.5]




**Oregon Average Annual Minimum Temperature (°F)**
Population-Weighted by County [RCP-4.5, RCP-8.5]




**KEY OBSERVATIONS**
- Significant winter warming (+5 °F by mid-century) will decrease overall heating load, but the **impact on electricity demand ultimately depends on the speed of heating electrification.**
- Mid-century winter minimums remain below 32 °F, indicating that **freezing and icing exposure persists despite warming.**
- Resilience upgrades like **undergrounding, covered conductors, or cable upgrades can address heat and cold exposure simultaneously.**

**KEY OBSERVATIONS**
- ~8% increase in average annual minimum temperatures by mid-century indicates a reduction in heating load.
- Diverging temperature projections by end-century demonstrates projection uncertainty and the importance of continued monitoring.
- Regarding extreme cold, global climate models do not resolve for extreme cold events like polar vortexes, so **assets could still face similar levels of exposure to cold-related failures.**

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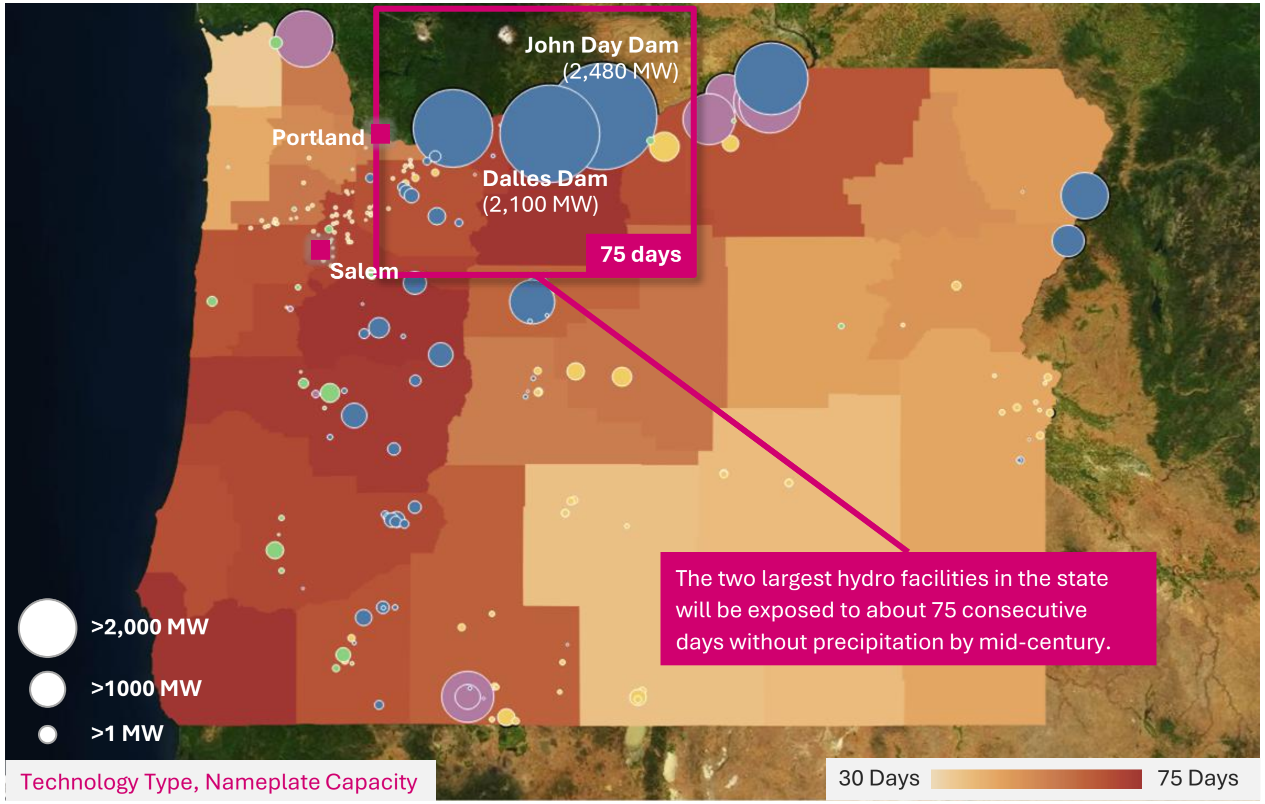
# Drought

Asset Analysis

# Significant drought exposure increases necessitate climate-adjusted hydroelectric production forecasting and innovative cleaning and cooling solutions for solar and natural gas

**Oregon Consecutive Days No Precipitation**
Generators, Mid-Century [RCP5-8.5]




Onshore Wind | Coal Plant | Hydroelectric | Nuclear | Solar Photovoltaic
Biomass | Natural Gas Plant | Pumped Storage | Batteries | Other

| Key Highlights | Analysis |
|---|---|
| Hydroelectric | • A string of **hydroelectric plants along the Columbia River** bordering Sherman and Wasco Counties are exposed to peak state-wide drought levels.<br>• Asset owners and grid operators could be forecasting long-term production from these hydro facilities with **climate-adjusted inputs, as drought exposure in these counties increases by 20-40%.** |
| Natural Gas | • In arid conditions, **air intakes for CCGTs and CTs can clog and degrade** due to dust and sand particles, decreasing efficiency and longevity of the generator.<br>• Lack of water availability can **reduce natural gas cooling ability**, resulting in power production curtailments. |
| Renewables | • Drought conditions cause dust buildup on solar panels, hurting capacity factors.<br>• In areas that also have high wildfire exposure, **panel cleaning projects address two hazards simultaneously.** |

Source: ClimRR, EIA860, HIFLD

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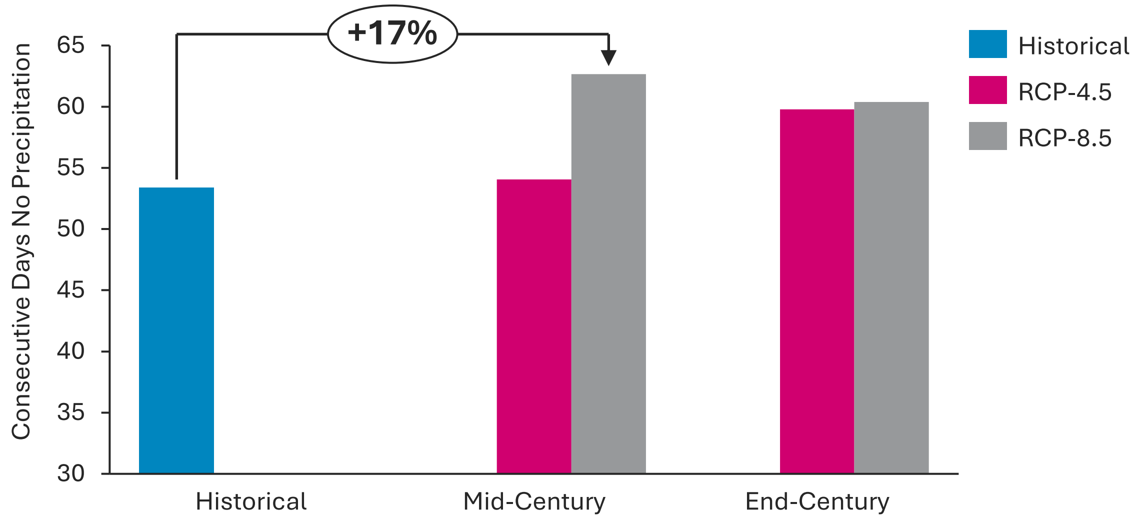
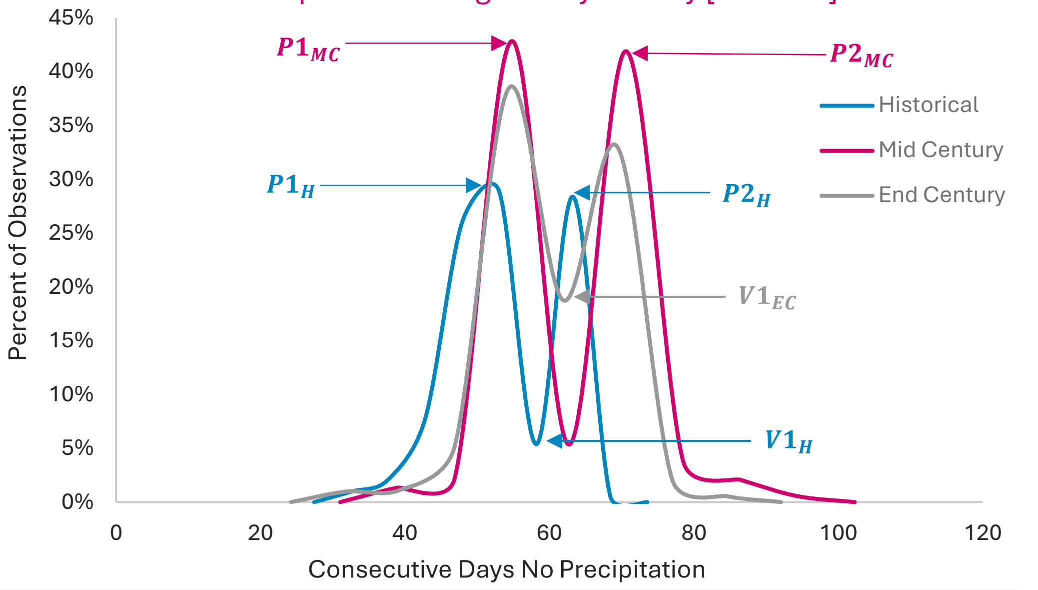
# Drought exposure will increase in spatial extent and severity by mid-century, but will become more evenly distributed by end-century

**Oregon Average Annual Consecutive Days with No Precipitation**
Population-Weighted by County [RCP 4.5, RCP-8.5]




**Oregon Average Consecutive Days with No Precipitation Statistical Distribution**
Population-Weighted by County [RCP-8.5]




**KEY OBSERVATIONS**

- **Drought exposure increases by ~17% by mid-century** (under RCP 8.5), contributing to potential asset cooling failures and reduced hydroelectric generation.
- Higher drought exposure for mid-century than end-century (RCP-8.5) demonstrates that **drought risk does not scale linearly with temperature** and could be monitored closely over time, especially by hydroelectric asset owners.

**KEY OBSERVATIONS**

- By mid-century, P1 and P2 increase and shift right, indicating **drought exposure will increase in spatial extent and severity.**
- Higher valley 1 (V1) level for end-century represents a significantly higher percentage of the population facing drought exposure of about 60 days and a **more even exposure distribution across the state.**
- Bimodal distribution for all time periods indicates **two distinct regions of drought exposure** within the state of about equal size.

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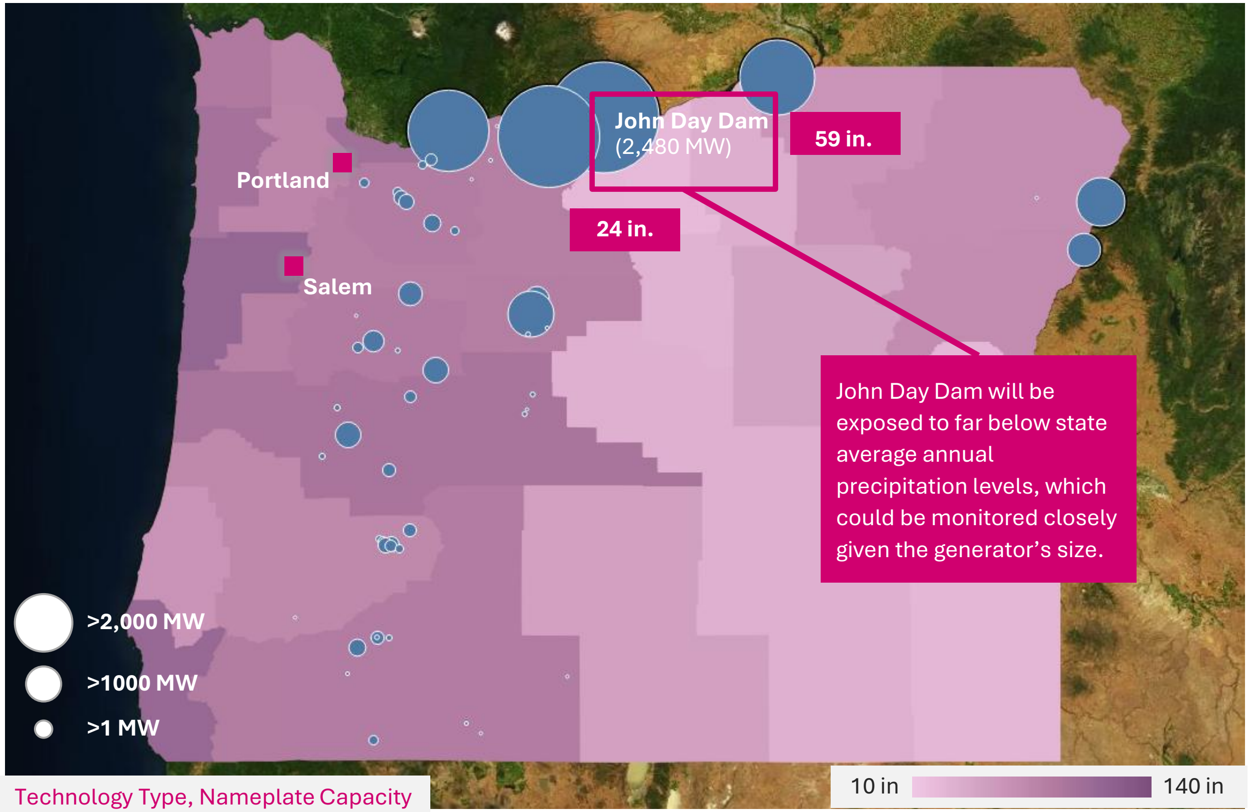
# Precipitation

Asset Analysis

# Precipitation levels stay consistent to mid-century, but ODOE could consider the impacts of precipitation timing, upstream conditions, and changing snow patterns on hydro output

**Oregon Annual Max Precipitation (in)**
Generators, Mid-Century [RCP5-8.5]




Technology Type, Nameplate Capacity

Onshore Wind | Coal Plant | Hydroelectric | Nuclear | Solar Photovoltaic
Biomass | Natural Gas Plant | Pumped Storage | Batteries | Other

| Key Highlights | Analysis |
|---|---|
| Timing | • Timing of precipitation has an important impact of hydro output.<br>• Extreme rainfall events may overflow reservoirs and put more pressure on dams, increasing risk of failure.<br>• Projections of increased drought and relatively constant annual precipitation indicate that **extreme precipitation events may become more likely over time.** |
| Upstream Coordination | • **Upstream precipitation and drought** will have significant impacts on hydro production.<br>• ODOE could **establish a relationship with WSDOC** to share information about precipitation conditions and hydro output. |
| Changes to Snow Patterns | • While precipitation levels remain relatively constant to mid-century, precipitation type and timing is likely to change and could be monitored.<br>• Grid operators could **consider the impacts of less snow and earlier snow melt when conducting long-term planning.** |

Source: ClimRR, EIA860, HIFLD

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