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Grid Resilience Reports

Idaho OER

Energy & Resources | Networks
11/12/2024

Table of contents

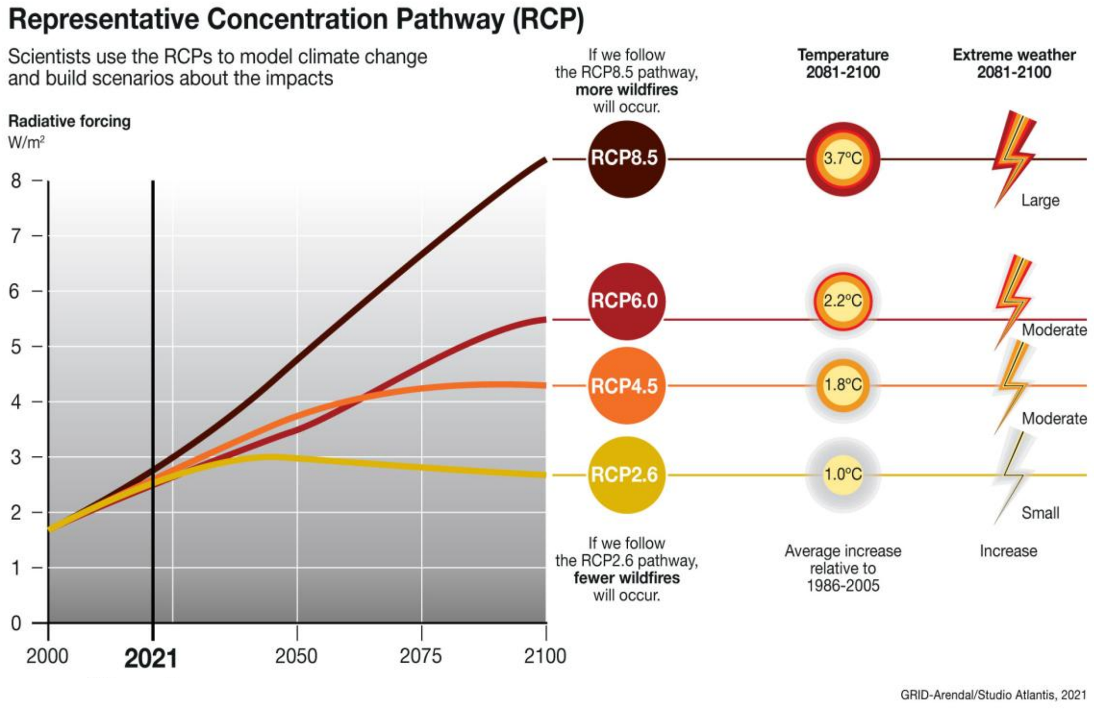
Grid Resilience Reports

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 • Accessible, open-source data allows for our methodology to be reproduced/quality checked • Provides climate projections for hazards with a significant climate signal • More than sufficient spatial resolution to gauge climate exposure at a county level	• Reputable data provider • Climate projections forecast change in exposure over time • Same spatial resolution as outage data (county level) • 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 • Wind does not have a strong climate signal, so projections were not required • Sufficient density of stations per state to assign to counties • Quality checked • 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

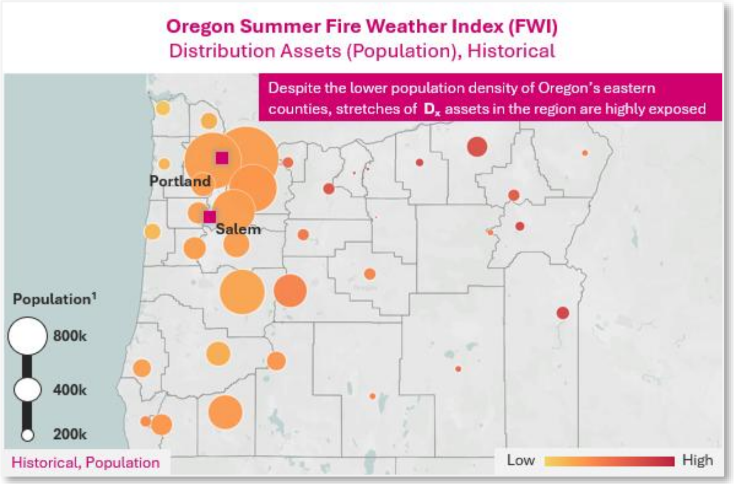
Output: Input metrics applied from a grid cell level to a county level

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)

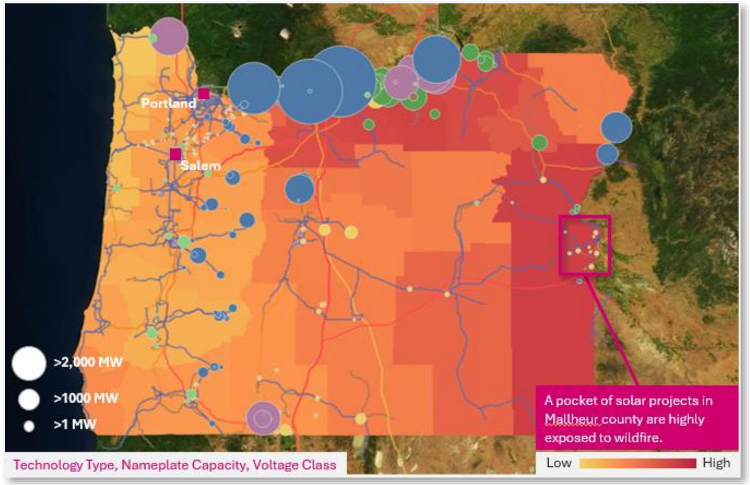
This report is standardized to include 3 different data visualizations that provide insights for Distribution, Transmission, and Generation across 7 extreme weather hazards

1 Distribution Maps



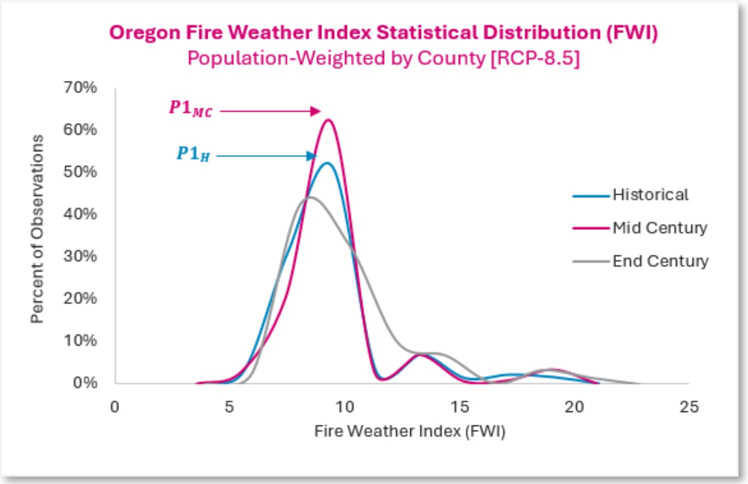
- **Purpose:** Uses population as proxy for volume of distribution assets given that the location of distribution assets is restricted.
- **Interpretation*:** Locate areas of high exposure by identifying counties with coincident large bubbles and dark colors. This indicates a combination of high volume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

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

IGOEMR could consider prioritizing heat and fire resilience upgrades in the SE, while projects addressing cold exposure could be concentrated in the eastern counties

Key Takeaways

- Consider new programs addressing generator wildfire exposure and focus T&D hardening on SW counties and transmission junctions.
- Explore DER opportunities to combat derating from heat and consider funding substation upgrade projects to mitigate the risk of direct asset failure.
- Consider new weatherization programs for highly exposed generators and prioritize T&D hardening in eastern population centers.

Hazard	Exposure	Change to Mid-Century	Generation	Transmission & Distribution	AWPI*	Description
FIRE	H	↑	**Consider projects to combat soot/ash and harden operational facilities in SE counties** • Explore potential O&M practices that combat derates for wind and solar from ash and soot. • Harden control houses and operational infrastructure for hydro and natural gas assets in SW counties exposed to fire.	**Focus hardening efforts in SW counties and consider Dx pole upgrades** • Several population centers in the SW are heavily exposed to wildfire, posing a threat to a high volume of Dx assets. • MV/HV lines in Elmore, Ada, and Owyhee Counties could be prioritized for hardening.	M	**Gen:** No proposed awards address generator wildfire exposure, marking a potential area for future investment. **T&D:** Prevalence of undergrounding, veg management, and monitoring proposals address fire, but IGOEMR could also consider Dx pole upgrades.
HEAT	M	↑	**Explore flexible DER options to offset derating of supply** • DER proliferation could minimize reliance on a band of highly exposed natural gas and solar generators in the SW.	**Consider substation upgrades and more cost-effective Tx hardening methods** • Significant exposure to days >105 °F requires substation upgrades to avoid direct failure. • Widespread heat exposure necessitates upgrades that harden longer segments of HV transmission lines to combat capacity derates.	M	**Gen:** No proposed awards for DERs or generator heat exposure mitigation. **T&D:** Undergrounding and veg management proposals address heat, but IGOEMR could consider substation upgrades given extreme heat exposure and a high likelihood of failure.
COLD	M	↓	**Consider weatherizing natural gas plants and pipeline systems to combat cold exposure** • Many generators face continued exposure to icing and other cold-related failures. • Highly exposed hydro and wind assets could also be prioritized for resilience upgrades.	**Prioritize investments in eastern and north-central regions of the state** • Peak cold exposure coincides with a pocket of relatively populated eastern counties, posing a threat of Dx and Tx icing and asset failure. • IGOEMR could evaluate whether current investments align with geographic exposure.	M	**Gen:** No proposed awards address generator cold exposure. **T&D:** Undergrounding addresses cold exposure, but Dx pole upgrades would more effectively address icing risk.

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

IGOEMR could consider substation and pole upgrades to address flood and wind exposure, and prioritize data collection to better understand future drought and precipitation impacts

Key Takeaways

- IGOEMR could prioritize substation fortification for low-lying assets in northern counties that are heavily exposed to flooding.
- Consider prioritizing Dx pole upgrades, Tx structure reinforcements, and enhanced wind design standards to address exposure in SW counties.
- Consider gathering additional data regarding drought and precipitation exposure to better asses the impact on hydroelectric output.

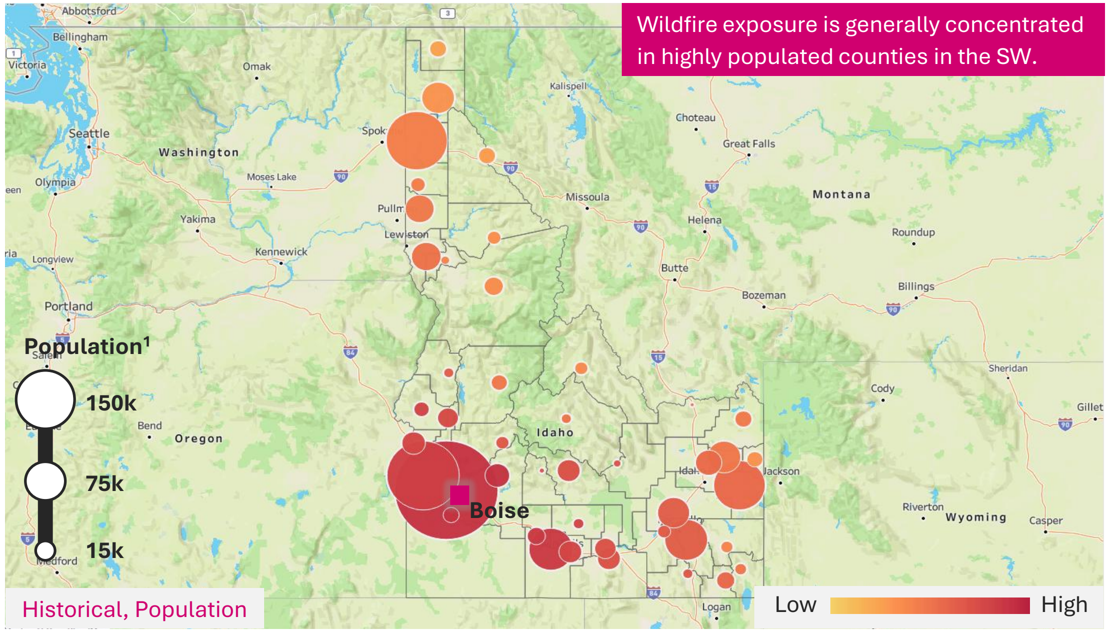
Hazard	Exposure	Change to Mid-Century	Generation	Transmission & Distribution	AWPI*	Description
FLOOD	M	↑	**Most electricity generation technologies are not significantly exposed to flood** • Hydro generators in northern counties are significantly exposed, which can cause dam overtopping and operational issues.	**IGOEMR could prioritize substation and Dx fortifications in northern counties** • High density of HV substations are heavily exposed to flooding, which can cause direct failure with a high cost of replacement.	L	**Gen:** Lack of exposure makes gen a lower priority for investment. **T&D:** No projects targeting substations, despite significant exposure. Undergrounding may increase T&D flood exposure.
WIND	M	→	**Consider encouraging the use of generator components rated for higher wind speeds** • Solar plants in the SW are highly exposed to wind, and some panels are only rated to 90 mph.	**IGOEMR could prioritize Dx pole upgrades and Tx structure reinforcement in SW counties** • High density of Dx assets are exposed to peak state wind exposure in SW counties • MV/HV Tx lines passing through Ada and Gem counties are highly exposed to wind.	M	**Gen:** No projects addressing generator exposure. **T&D:** Undergrounding addresses wind exposure but is restricted to short distances given its high cost.
DROUGHT	M	↑	**Grid operators could consider using climate-adjust inputs for hydro output forecasting** • Drought forecasts range from 40% increases to 40% decreases across the state. • ID'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.**	M	**Gen:** No projects addressing generator exposure. IGOEMR could consider solar O&M processes to address production derates from drought (these adaptations also address heat and fire).
RAIN	L	→	**IGOEMR could seek out additional data to understand future hydroelectric production** • Coordinate with WSDOC and ODOE to gather information about upstream conditions. • 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:** No projects addressing generator exposure, but IGOEMR could gather additional information to assess the true impact on hydro output and its implications for resource planning and scheduling.

Wildfire

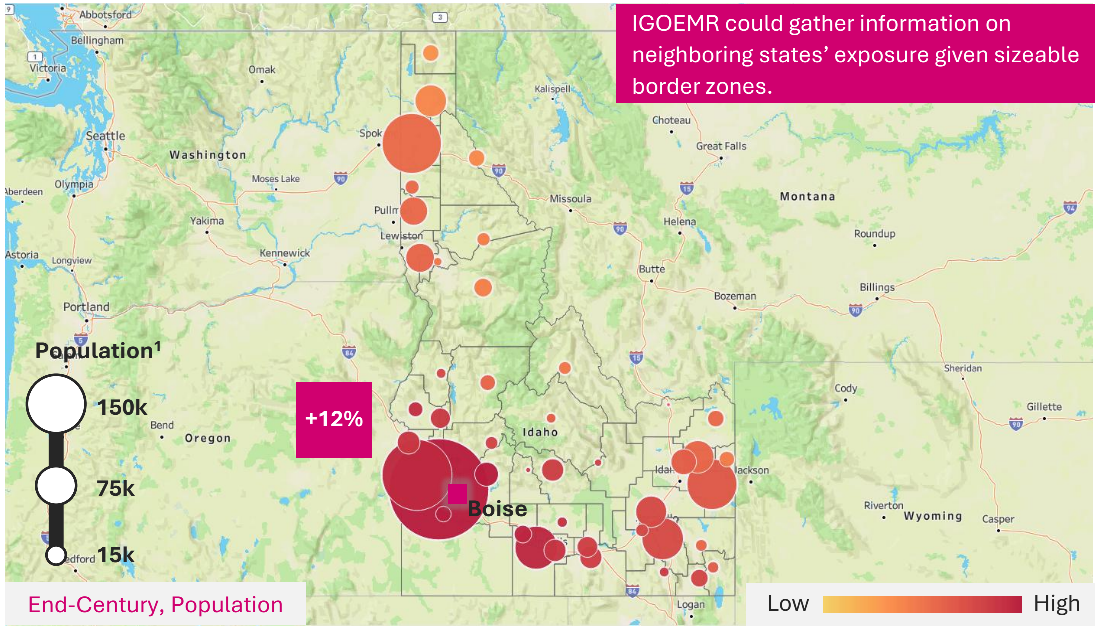
Asset Analysis

IGOEMR could evaluate whether current fire mitigation investments align with geographic exposure in the SW and consider other adaptation strategies such as pole upgrades

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



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



KEY OBSERVATIONS

- Several **population centers in the SW are highly exposed to wildfire**, posing a threat to a high volume of Dx assets in the state.
- High percentage of **undergrounding, vegetation management, and monitoring** proposals address wildfire exposure.
- IGOEMR could **evaluate whether current fire mitigation investments align with geographic fire exposure.**

KEY OBSERVATIONS

- FWI increases about 10-25% across the state by end-century, demonstrating the importance of utilizing **forward-looking climate projections for state-wide fire mitigation planning.**

Ada County Large population center exposed to high levels of FWI (~50 by end-century), indicating a priority area for future Dx hardening and vegetation management projects.

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

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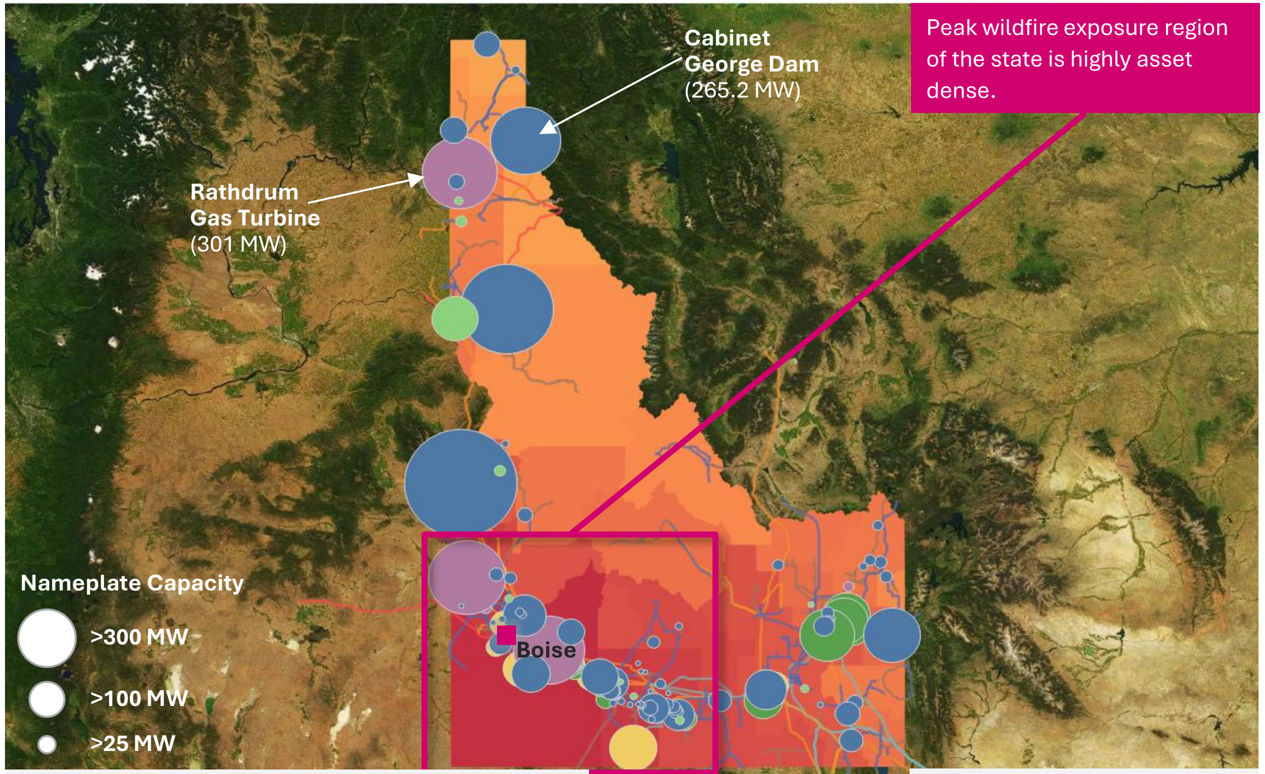
IGOEMR could consider prioritizing hardening for Tx and generator operational facilities in SW counties, and explore methods to combat renewables derating from soot and ash

Idaho Summer Fire Weather Index (FWI)

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



Technology Type, Nameplate Capacity, Voltage Class

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, US Census Bureau, City and Town Population Totals

Key Highlights	Analysis
Renewables	• Wind and solar assets in Owyhee and surrounding SW counties face high levels of wildfire exposure. • Soot and ash from burns **decrease capacity factors for both wind and solar assets.** • **Very few proposed projects address generator exposure,** indicating a potentially overlooked resilience topic area for the state.
Transmission	• **Remote transmission assets are critical** for last mile rural customers and are highly exposed in SW counties. • High density of MV/HV lines in Elmore, Ada, and Owyhee Counties are heavily exposed to wildfire and could be **prioritized for hardening upgrades.**
Restoration	• Wildfire causes **ingress/egress issues** through destruction of roads and transportation, slowing restoration times for all assets. • Wildfire poses a threat to **control houses and other operational infrastructure** for electricity generation facilities, prolonging outages.

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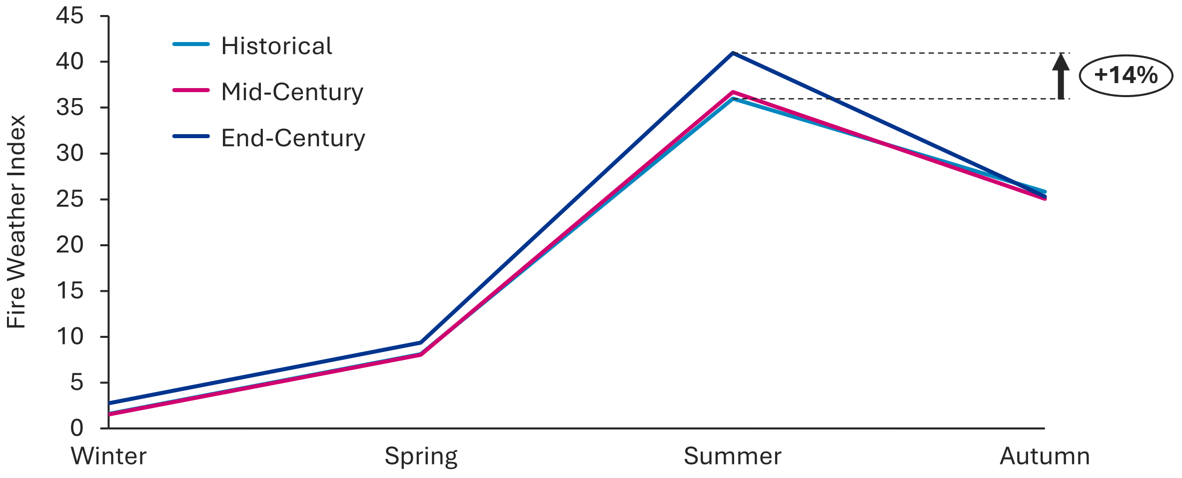
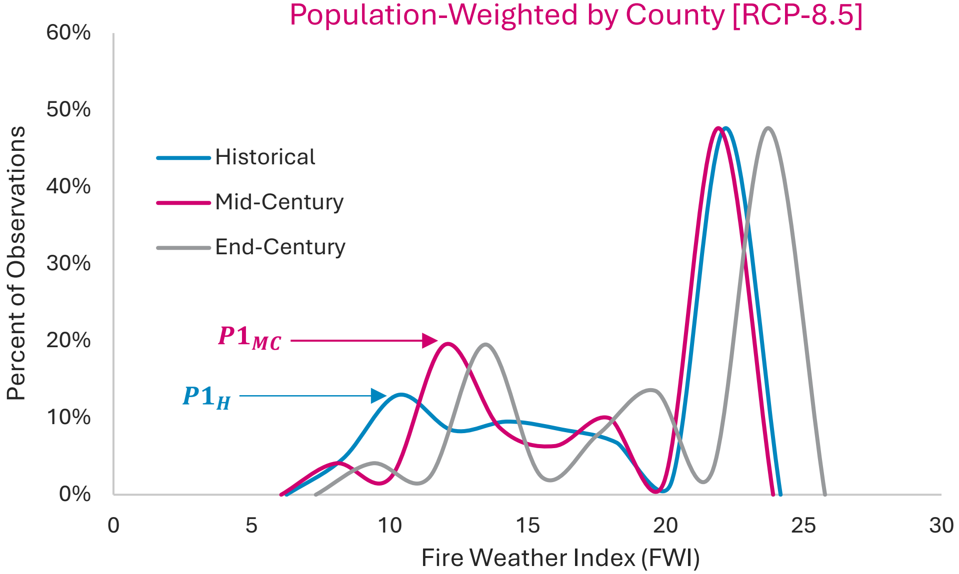
By mid-century, fire exposure will increase in the least exposed regions, and by end-century exposure will become more severe across the state

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



Idaho 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 suggests that **the window for scheduled maintenance during the shoulder seasons could be diminishing.**

KEY OBSERVATIONS

- Rightward shift of the curve by end-century indicates that wildfire exposure will become **more severe over time.**
- 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.
- Peak 1 (P1) shifting right and up by mid-century indicates that **fire exposure will increase across previously least exposed regions,** indicating a potentially overlooked area for fire mitigation investment.

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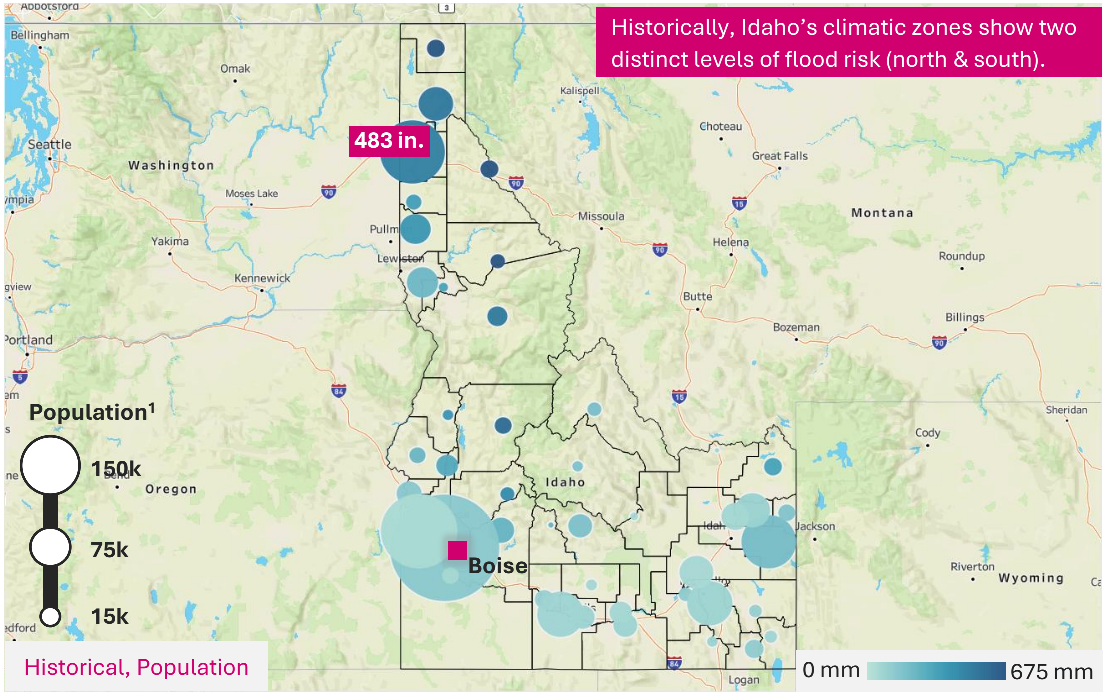
Flood

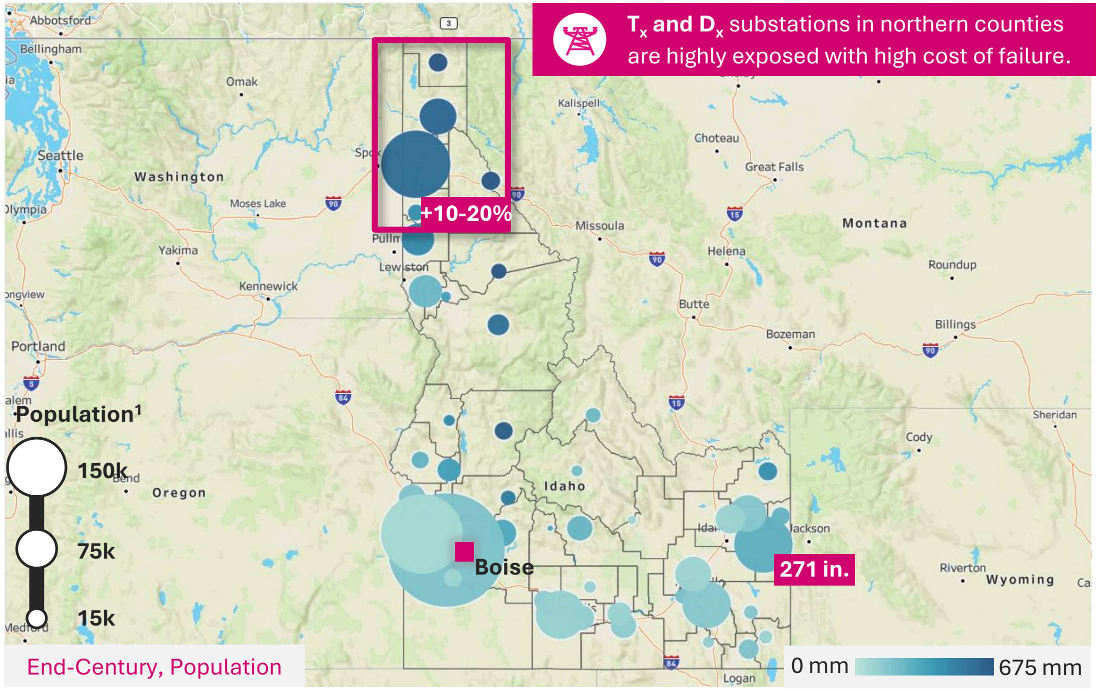
Asset Analysis

IGOEMR could consider funding projects to fortify Dx infrastructure in northern counties given the high volume of assets exposed to increasingly severe flooding over time

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



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



KEY OBSERVATIONS

- Most flood exposure lies in the **northern counties** given their relatively low elevations and high density of rivers and lakes.
- IGOEMR could consider evaluating whether undergrounding projects are being implemented in regions highly exposed to flooding and **consider if these projects increase the likelihood of flood-related failure.**

KEY OBSERVATIONS

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

Kootenai County — Populous county exposed to high levels of flooding, **posing a threat to a high volume of unfortified Dx substation and poles.**

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

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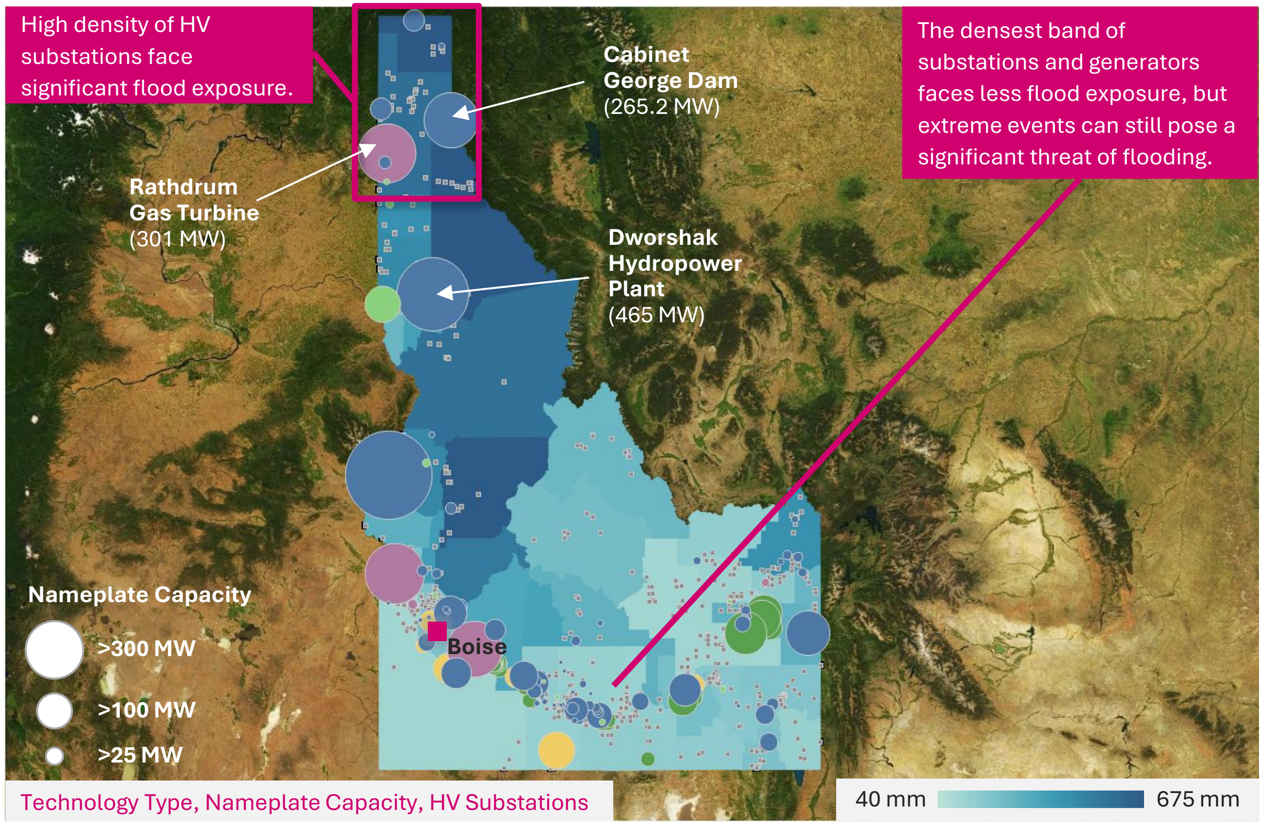
IGOEMR could prioritize the fortification of high voltage substations in northern counties given the high density of assets facing significant exposure and their high cost of failure

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



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

HV Substation

Key Highlights	Analysis
Substation	• High voltage substations will be exposed to fluvial flooding if located in a flood plain or riverbank without necessary protections. • High density of **HV substations in Shoshone and Bonner Counties are heavily exposed to flood risk**, marking a priority area for future hardening projects.
Restoration	• Flooding causes **ingress/egress complications** by washing out access roads, contributing to restoration issues. • Flooding can **affect on-site buildings or facilities**, making it more difficult to maintain adequate staffing for oversight and restoration.
Generators	• Large hydroelectric plants in Bonner and Clearwater Counties are significantly exposed to flood, which can contribute to **dam overtopping/failure and pose a threat to control houses.** • The Rathdrum Gas Turbine is high exposed to flooding, which can inundate critical equipment, causing plant failure.

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

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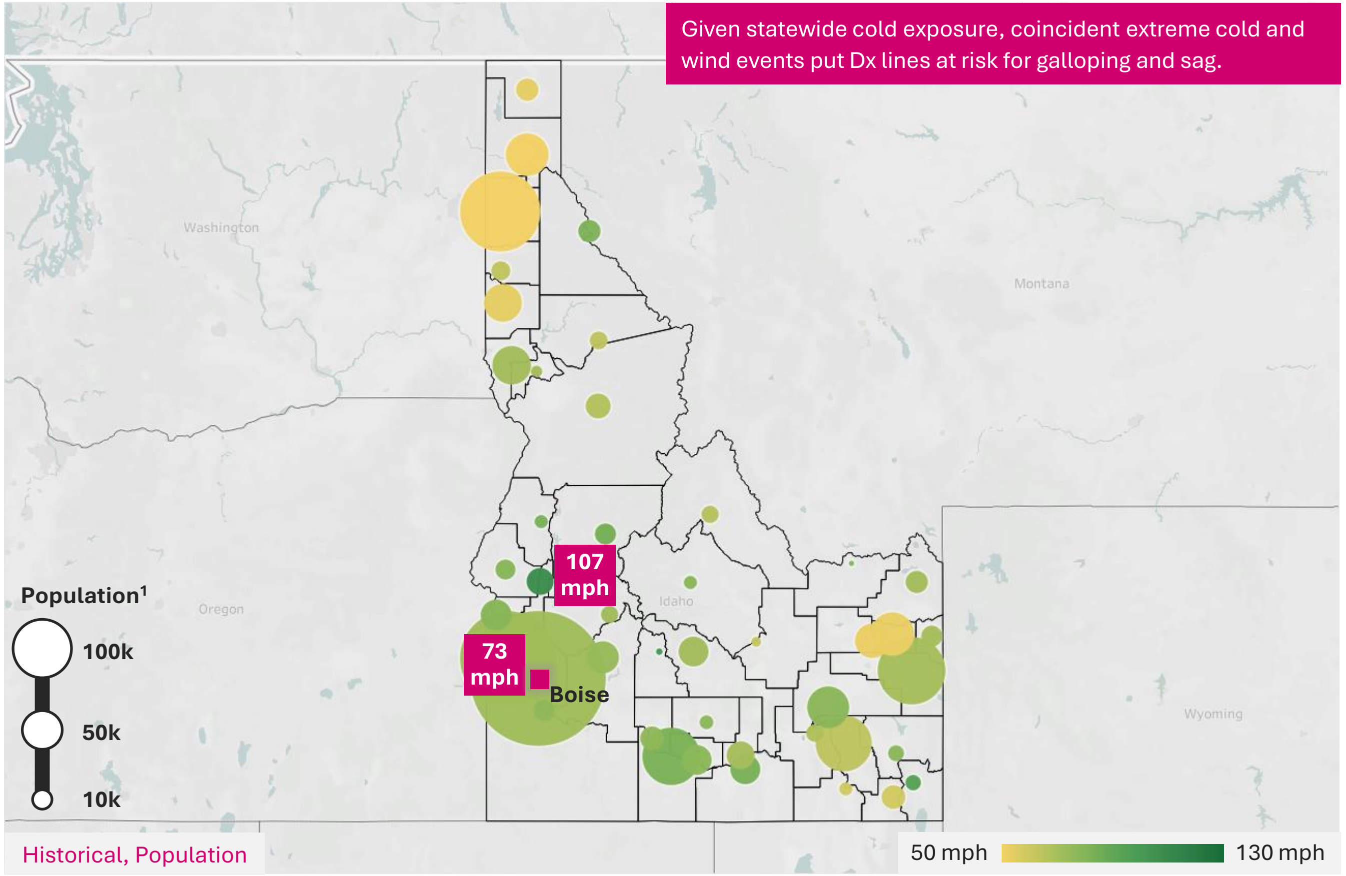
Wind

Asset Analysis

IGOEMR could encourage utilities to adopt upgraded wind design standards and consider Dx pole upgrade projects for highly-populated SW counties

Idaho 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. • Rather than targeted investments, wind exposure could be addressed through **upgraded design standards** across a utility service territory.
Ada County	• Ada County has a population of over 500k and 100-year return value of 73 mph, **indicating a high exposure area for Dx assets**. • High wind speeds can also contribute to fire proliferation in this region.
SW Counties	• SW counties generally exhibit high wind gust speeds and population levels, exposing a high volume of Dx assets. • IGOEMR's undergrounding and veg management projects generally address wind exposure, but Dx pole upgrades could also be considered in high exposure regions.

Source: DRI, EIA860, HIFLD

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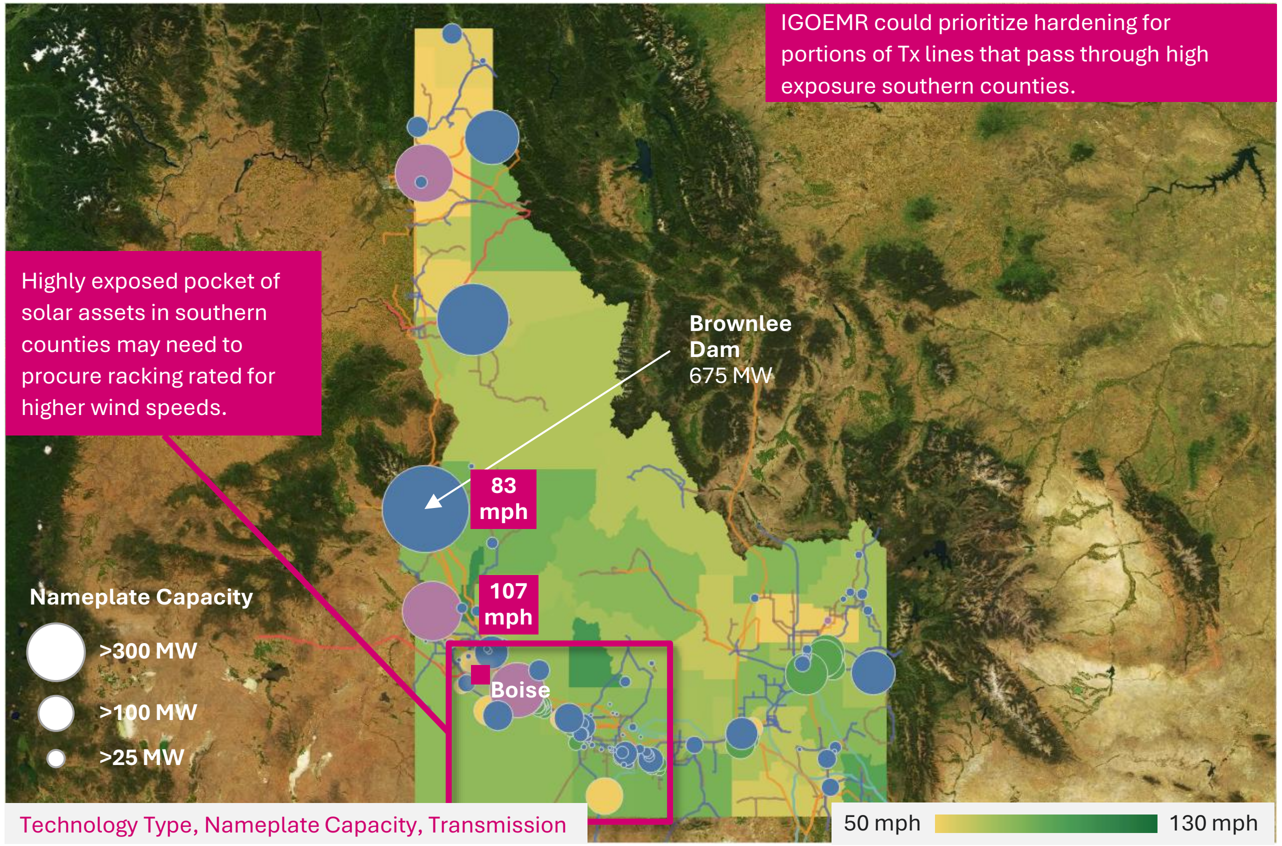
IGOEMR could consider reinforcing Tx structures for MV/HV lines and explore rating of panels at solar facilities in the SW region of the state

Idaho 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

Source: DRI, EIA860, HIFLD

Key Highlights	Analysis
Transmission	• Multiple MV-HV transmission pass through Gem and Ada Counties, where they are exposed to high wind return values. • IGOEMR could consider **reinforcing Tx structures** to complement existing undergrounding and vegetation management projects to address exposure.
Hydroelectric	• Brownlee Dam is exposed to relatively high peak wind gust speeds. • Extreme wind events can cause debris to accumulate in the water and clog intake, and poses a threat to operational staff, both resulting in **plant derating**.
Solar	• A handful of solar farms in southern counties are exposed to relatively high extreme wind gust levels. • Depending on OEM, solar panels are only rated to 90 mph, **indicating the potential need for rack reinforcement and vegetation management.**

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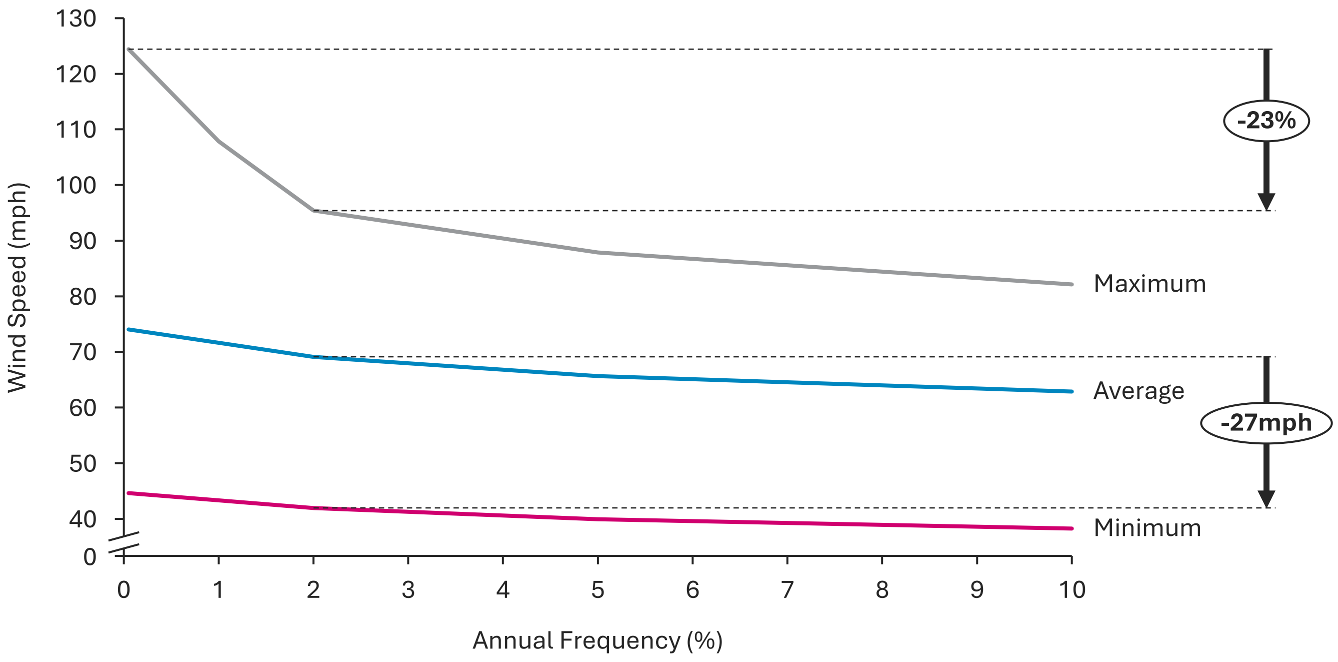
Historically, there is a 1% chance that the average wind speed seen across Idaho counties is ~70 mph annually.

Idaho 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 Idaho counties is ~70 mph annually. • Further out on the curve, the 10% annual likelihood drops to 62 mph.
Volatility Across Counties	• There is a wide band between the maximum and minimum counties around the mean. • This indicates that wind adaptations should be focused on a county basis rather than over large service territories.
Extreme Values in Camas County	• Sharp decline in return values for the most exposed county reflects a low but significant probability of extreme wind speeds (> 100 mph). • The drastic difference indicates that this exposure may not be apparent from historical wind data, but utilities in Camas County could account for this worst-case scenario.

DRI

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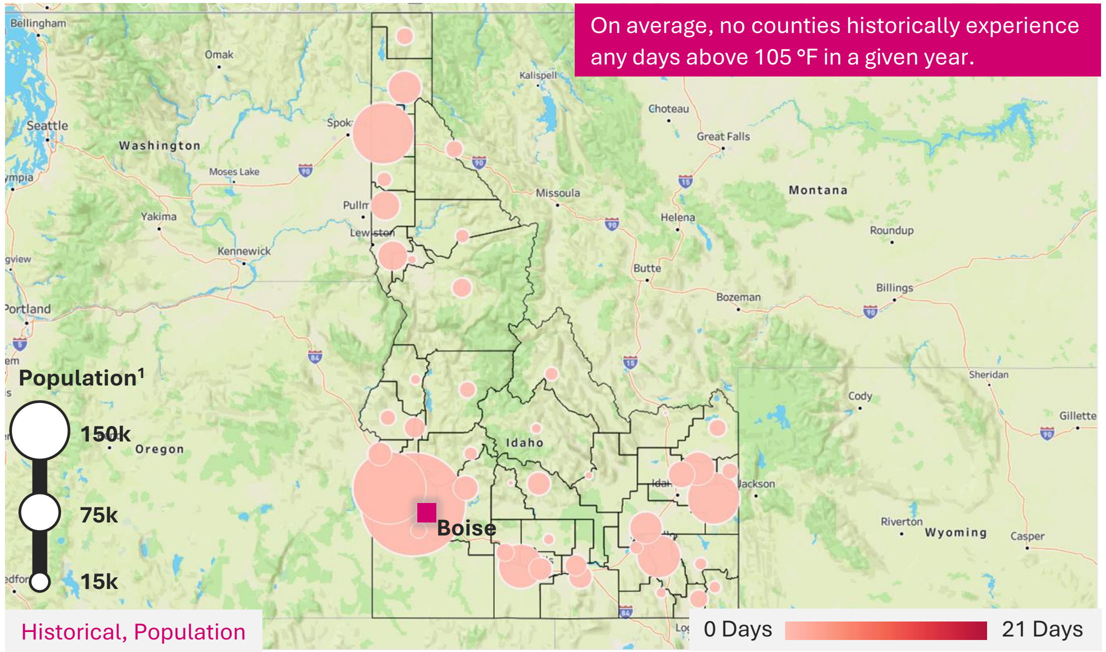
Heat

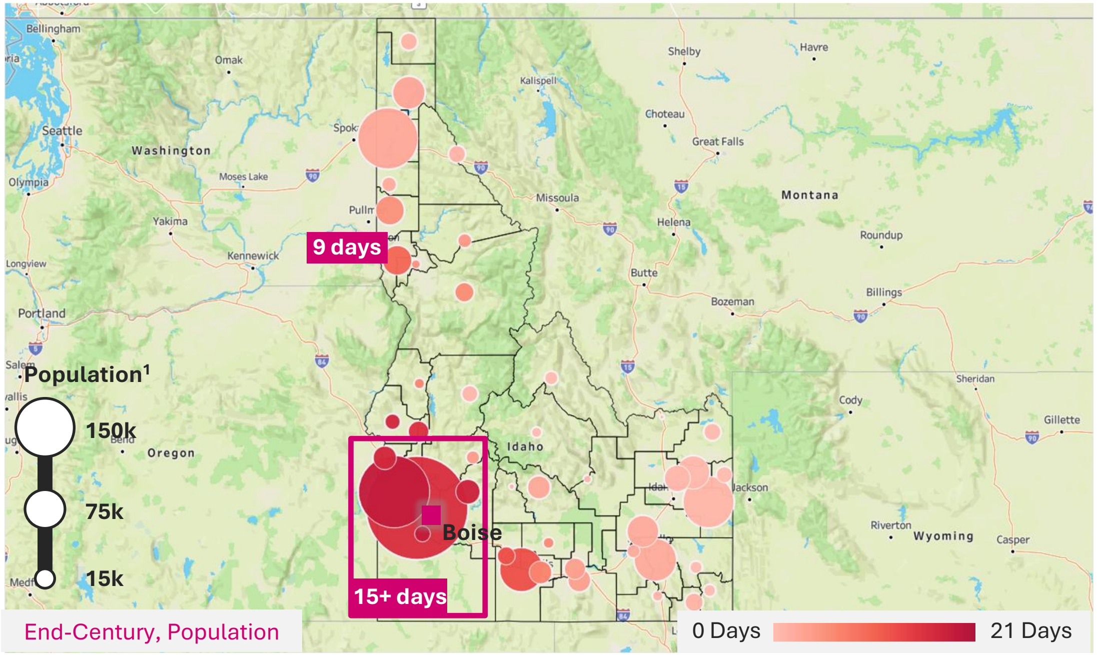
Asset Analysis

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

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



Idaho 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

- Counties in the SW are expected to face **about 15+ days >105 °F annually, causing high asset utilization, derating, and potential failure. Undergrounding/veg management** proposals address some exposure.

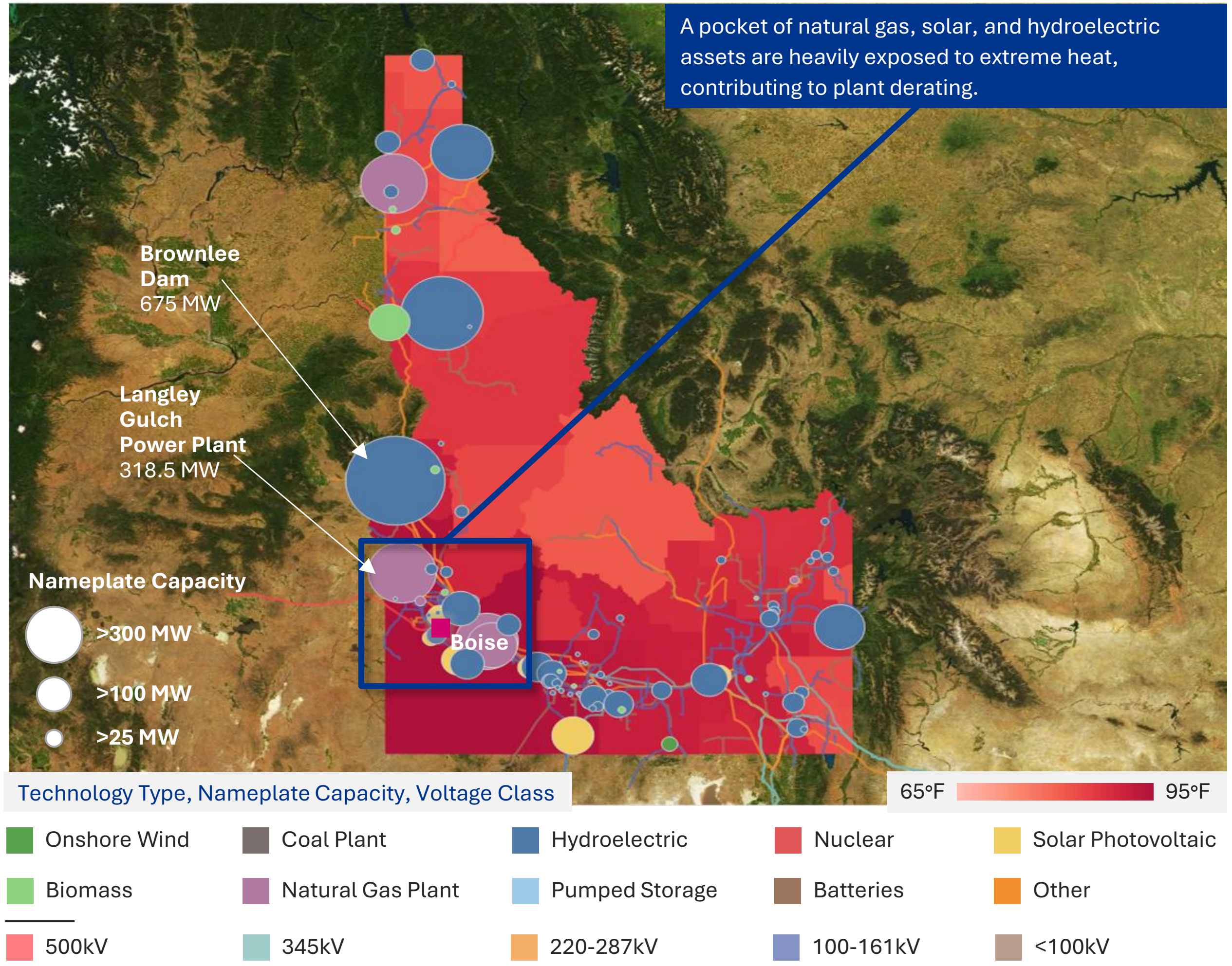
Canyon County Populous county facing 18 days of extreme heat exposure by end-century, potentially justifying substation and Dx line upgrades to mitigate potential failure and derating.

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

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

IGOEMR could prioritize DER development and cost-effective line adaptations to combat generator/Tx derating and line sag resulting from extreme heat exposure in SW counties

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



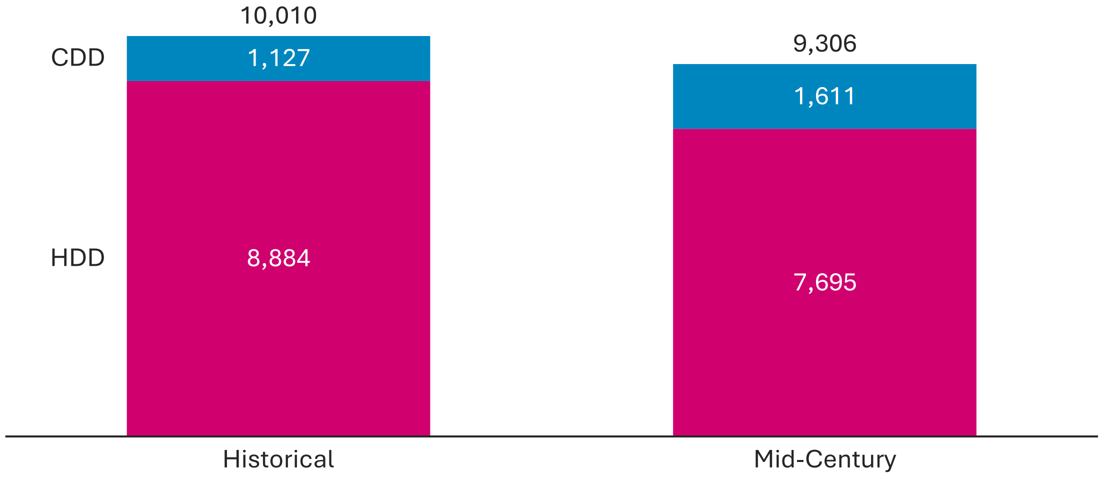
Source: ClimRR, US Census Bureau, City and Town Population Totals

Key Highlights	Analysis
Thermoelectric	• Thermoelectric generators that rely on water-based cooling methods will **experience production derates** as extreme heat raises average water temperatures.
Renewables	• Brownlee Dam and other hydro assets in the SW are susceptible to extreme heat, which **increases the likelihood of algal blooms that reduce output.** • Solar assets in SW 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 in the SW, which can cause capacity derates and line sag. • Undergrounding and veg management proposals address these issues, but IGOEMR could consider **other adaptations to fortify longer portions of transmission lines.**

 |

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

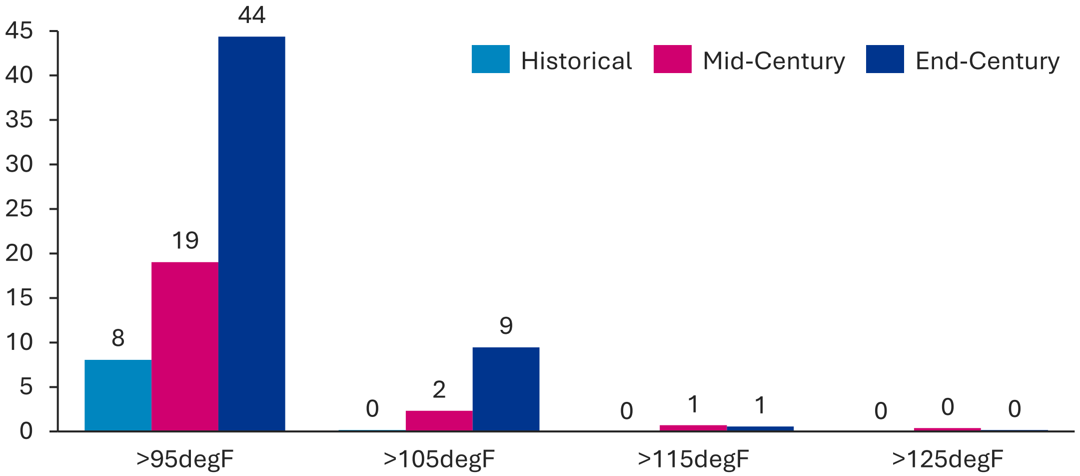
Idaho Average Annual Cooling & Heating Degree Days (CDD & HDD)
Population-Weighted by County [RCP-8.5]



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 12% to 20%.
- 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.

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



KEY OBSERVATIONS

- Over 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.
- Significant increase in days > 105°F by end-century poses a **substantial risk to distribution transformers**, which can fail after two consecutive days above 104 °F without sufficient cooling infrastructure, indicating a crucial focus area for IGOEMR in future funding allocation processes.

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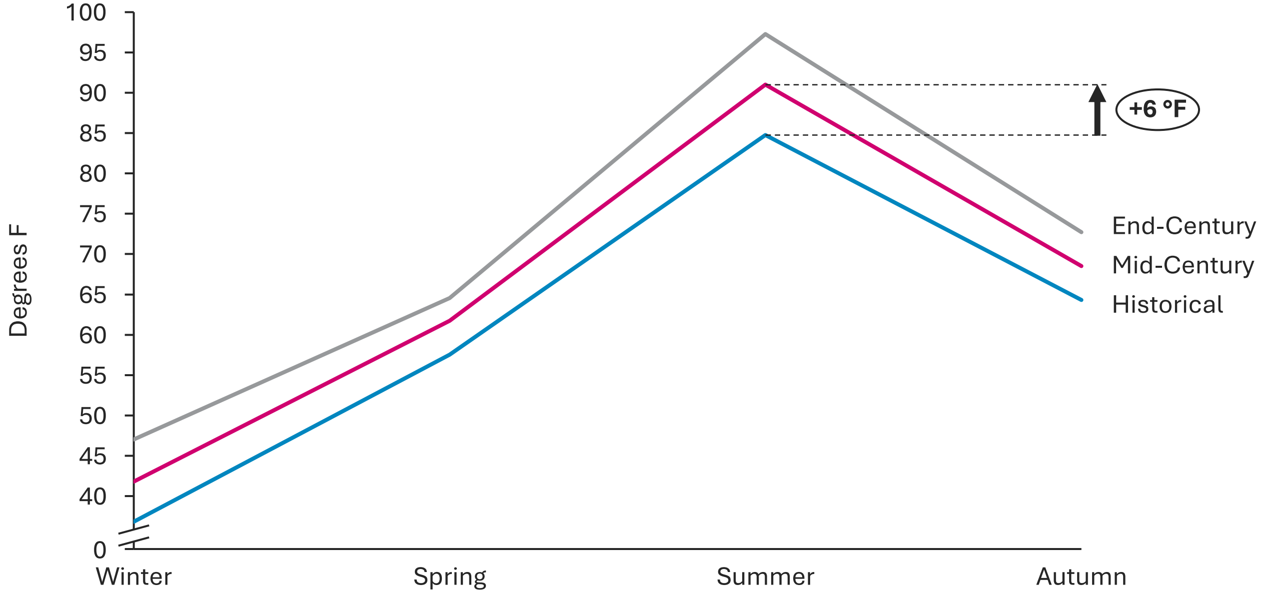
Average summer temperature maximums are projected to increase by mid-century, increasing the duration and magnitude of high system utilization

Idaho 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 6 °F increase in the average seasonal max by mid-century, **increasing system utilization and 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.**

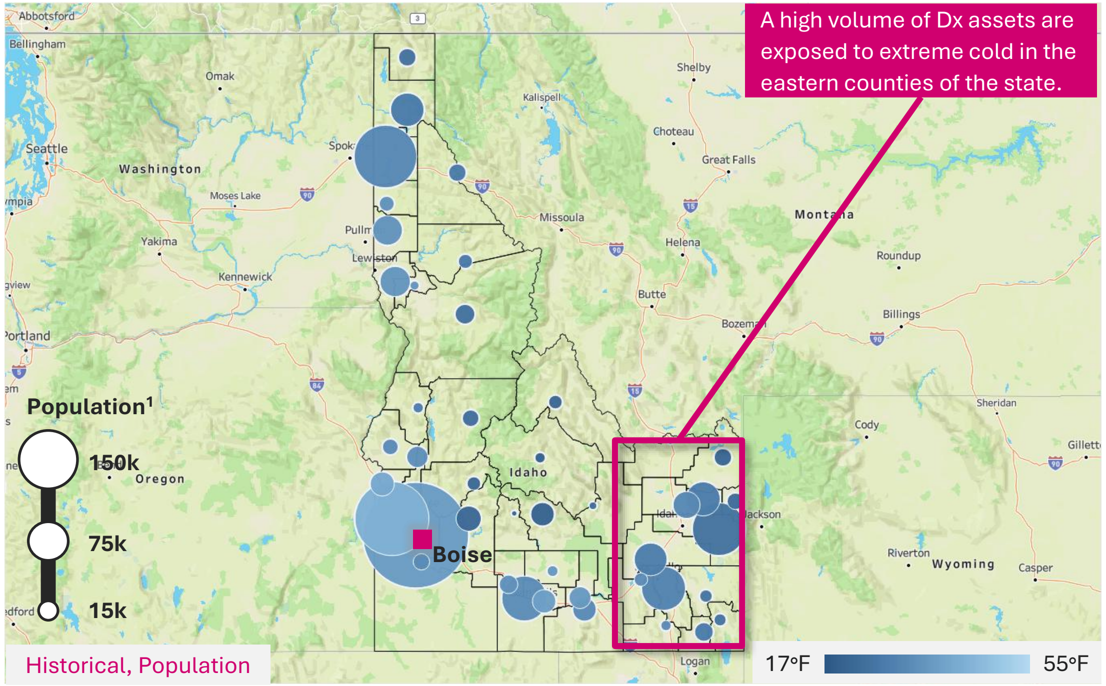
 |

Cold

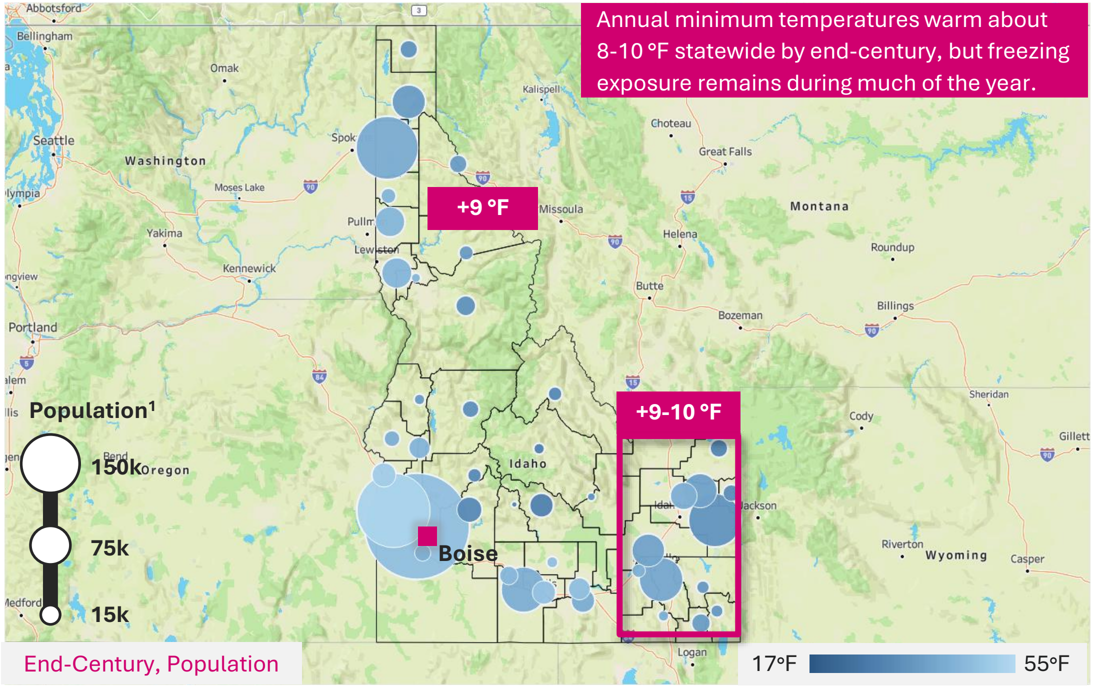
Asset Analysis

IGOEMR could evaluate whether current undergrounding projects align with geographic cold exposure and consider Dx pole upgrades to address continued freezing risk

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



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



KEY OBSERVATIONS

- Extreme cold is concentrated in the **eastern and northern regions** of ID.
- Annual minimums are below 32 °F across much of the state, indicating **widespread historical freezing exposure.**
- Prevalence of proposals including undergrounding addresses extreme cold exposure, but IGOEMR could also consider **Dx pole upgrade projects.**

KEY OBSERVATIONS

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

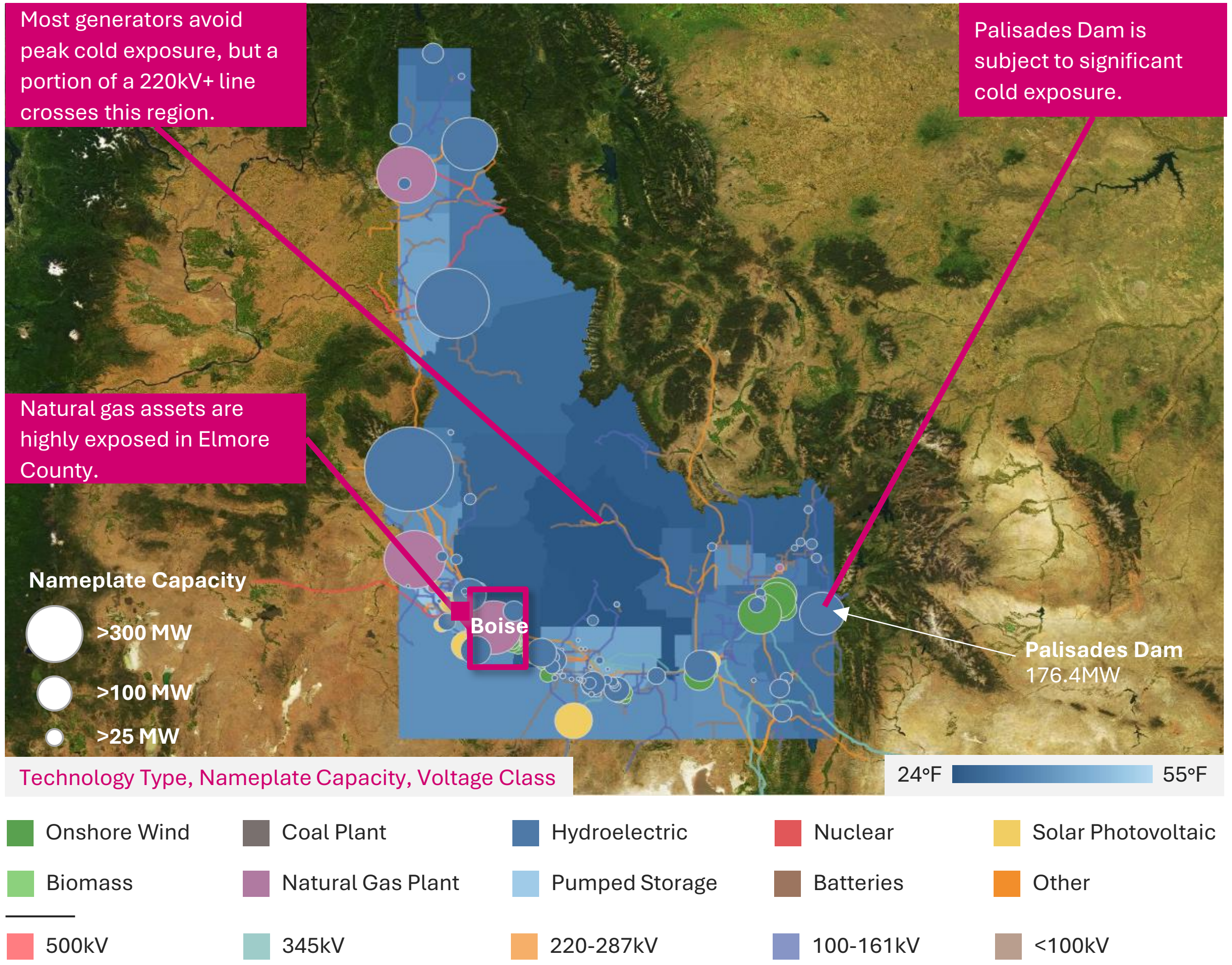
Bonneville County — By end-century, Bonneville County will be exposed to annual minimums of about 36 °F, indicting potential **icing exposure for Dx assets during most of the year.**

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

 |

IGOEMR could consider resilience upgrades to gas plants and pipeline systems to combat cold exposure, and Tx hardening addressing freezing, such as structure reinforcement

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



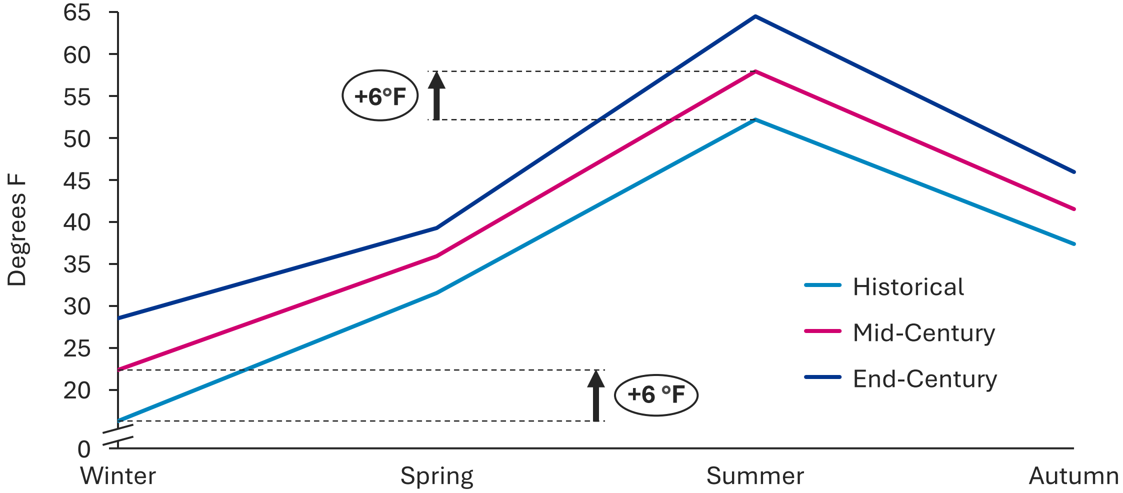
Source: ClimRR, US Census Bureau, City and Town Population Totals

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 Elmore County are exposed to average annual minimums of 25°F, which could cause **ignition failure or performance issues.** • **No proposals addressing aging gas infrastructure**, which requires hardening or replacement to mitigate cold exposure.
Wind	• Wind plants in Bonneville and Elmore 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. • The portion of a 220+kV line owned by BPA that runs through Custer County is particularly exposed.

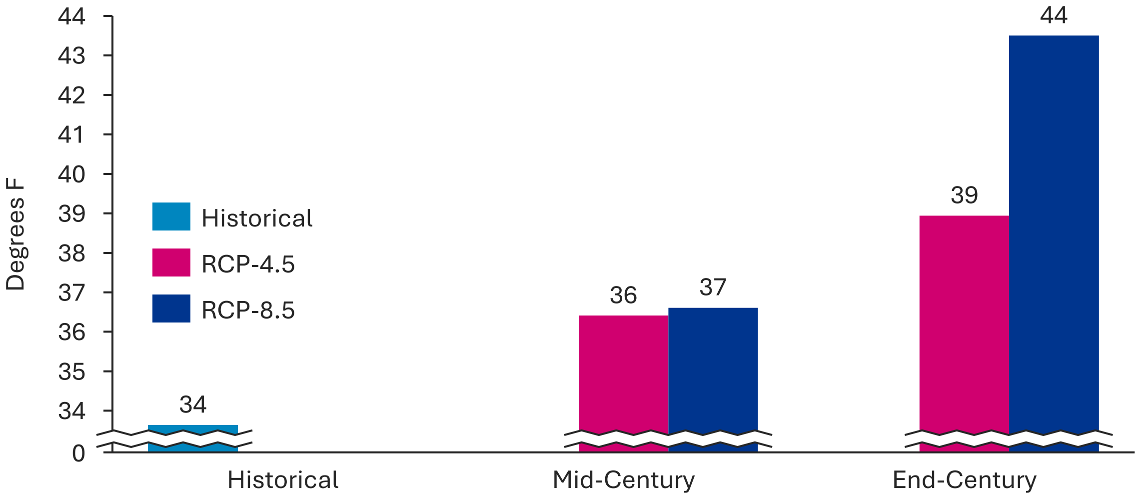
 |

Despite warming over time, winter temperature minimums remain below 32 °F, indicating that IGOEMR could consider pole and cable upgrade projects to address freezing exposure

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



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



KEY OBSERVATIONS

- Significant winter warming (+6 °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 and end-century winter minimums remain below 32 °F, indicating that **freezing and icing exposure persists despite warming.**
- IGOEMR's undergrounding projects address cold exposure, but pole and cable upgrades could be considered to combat freezing.

KEY OBSERVATIONS

- ~8% increase in average annual temperature minimums by mid-century (RCP-8.5) 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 vortices, so **assets could still face similar levels of exposure to cold-related failures.**

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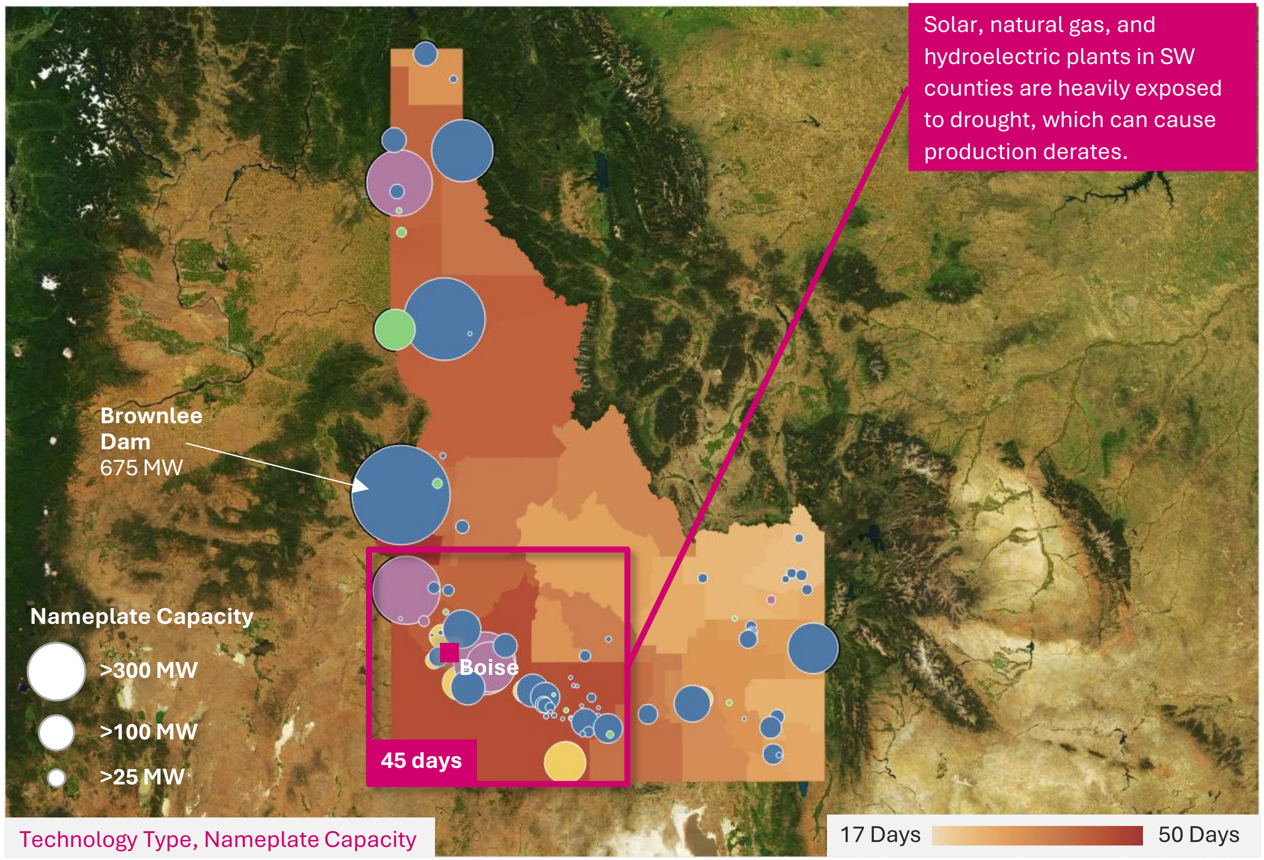
Drought

Asset Analysis

Facing significant drought exposure, IGOEMR could consider climate-adjusted hydroelectric production forecasting and innovative cleaning and cooling solutions for solar and natural gas

Idaho 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

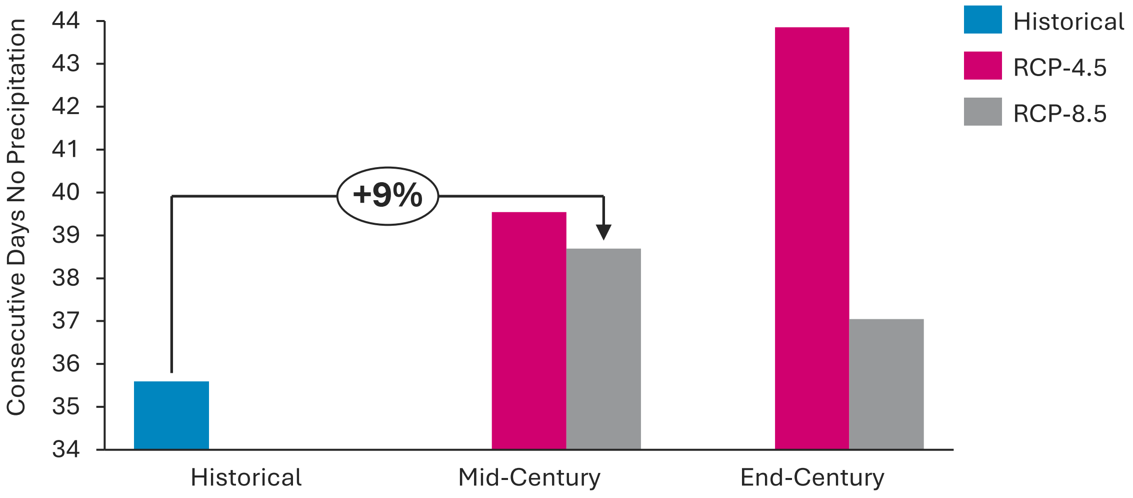
Key Highlights	Analysis
Hydroelectric	• **Brownlee Dam is exposed to peak state-wide drought exposure,** which could significantly impact output. • Asset owners and grid operators could be forecasting long-term production from these hydro facilities with **climate-adjusted inputs, as drought exposure exhibits increases and decreases of up to 40% across different counties.**
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 generator. • Lack of water availability can **reduce natural gas cooling ability**, resulting in power production curtailments.
Solar	• Drought conditions cause dust buildup on solar panels, hurting capacity factors. • In areas that also have high wildfire exposure, **panel cleaning projects address two hazards simultaneously.**

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

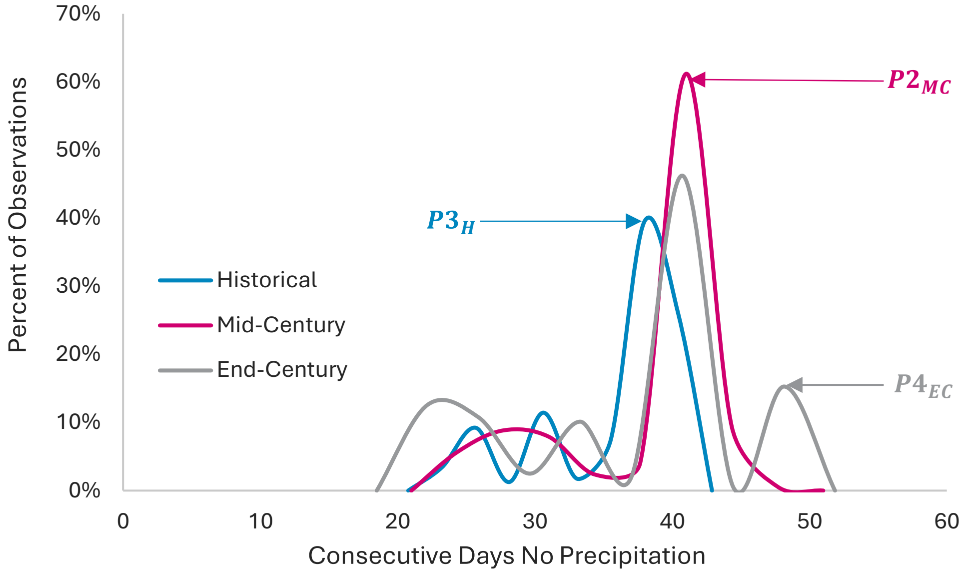
 |

Under RCP-8.5, drought exposure peaks by mid-century, but a pocket of more severe exposure emerges by end-century, marking a potential area for future investment

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



Idaho Average Consecutive Days w/ 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 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, P2 increases and shifts right relative to historical P3, indicating **drought exposure will increase in spatial extent and severity.**
- P4 shifts right to 50 days by end-century, indicating that **drought exposure will reach new levels of severity across 15% of the state.**
- Bimodal distribution for mid-century shifting to a multi-modal shape by end-century indicates **converging exposure followed by divergence.**

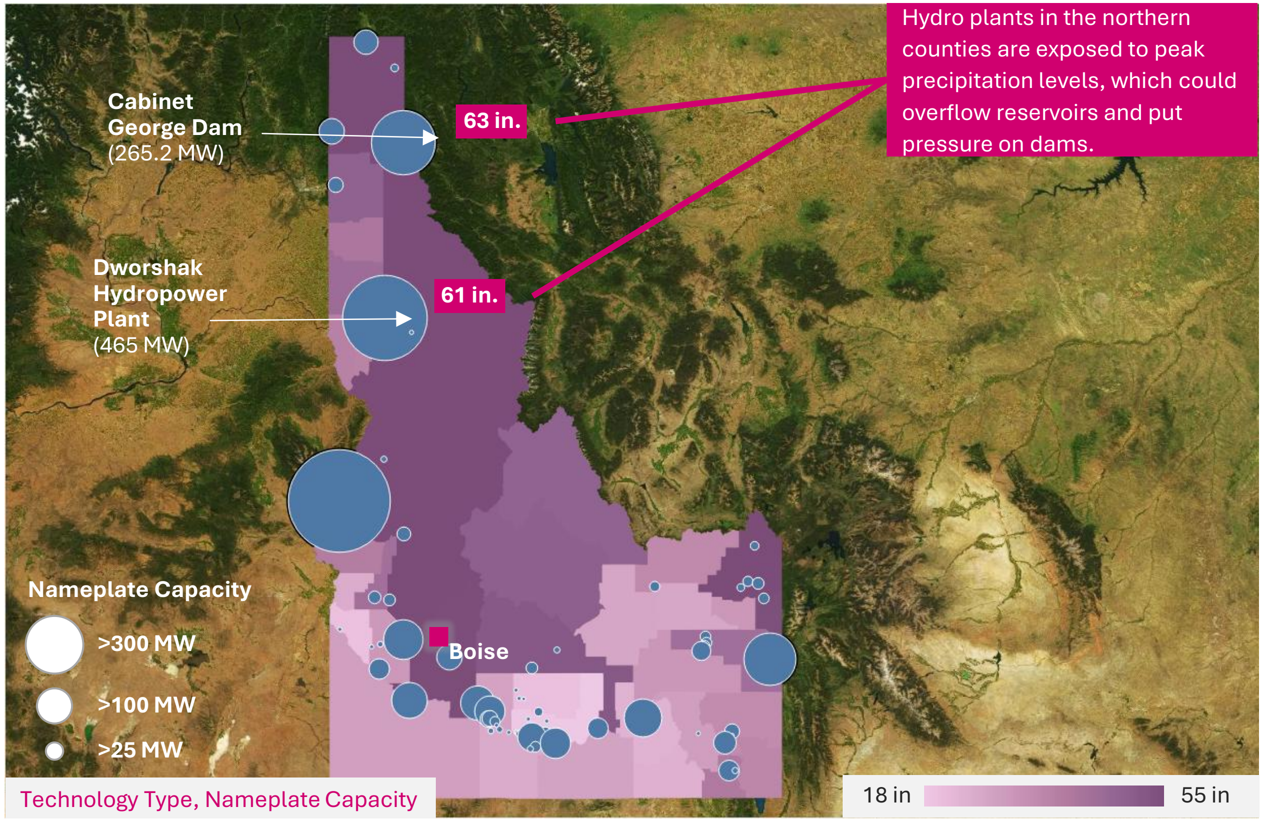
 |

Precipitation

Asset Analysis

Precipitation levels increase slightly by mid-century, but IGOEMR could consider the impacts of precipitation timing, upstream conditions, and changing snow patterns on hydro output

Idaho Annual Max Precipitation (in)
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
Timing	• Timing of precipitation has an important impact of hydro output. • Extreme rainfall events may overflow reservoirs and put more pressure on dams, increasing risk of failure. • Projections of both increased drought and 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. • IGOEMR could **establish a relationship with ODOE and WSDOC** to share information about precipitation conditions and hydro output on shared waterways.
Changes to Snow Patterns	• While precipitation levels increase by mid-century, precipitation type and timing is likely to change and could be monitored. • Grid operators could **consider the impacts of less snow and earlier snow melt when conducting long-term planning.**

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

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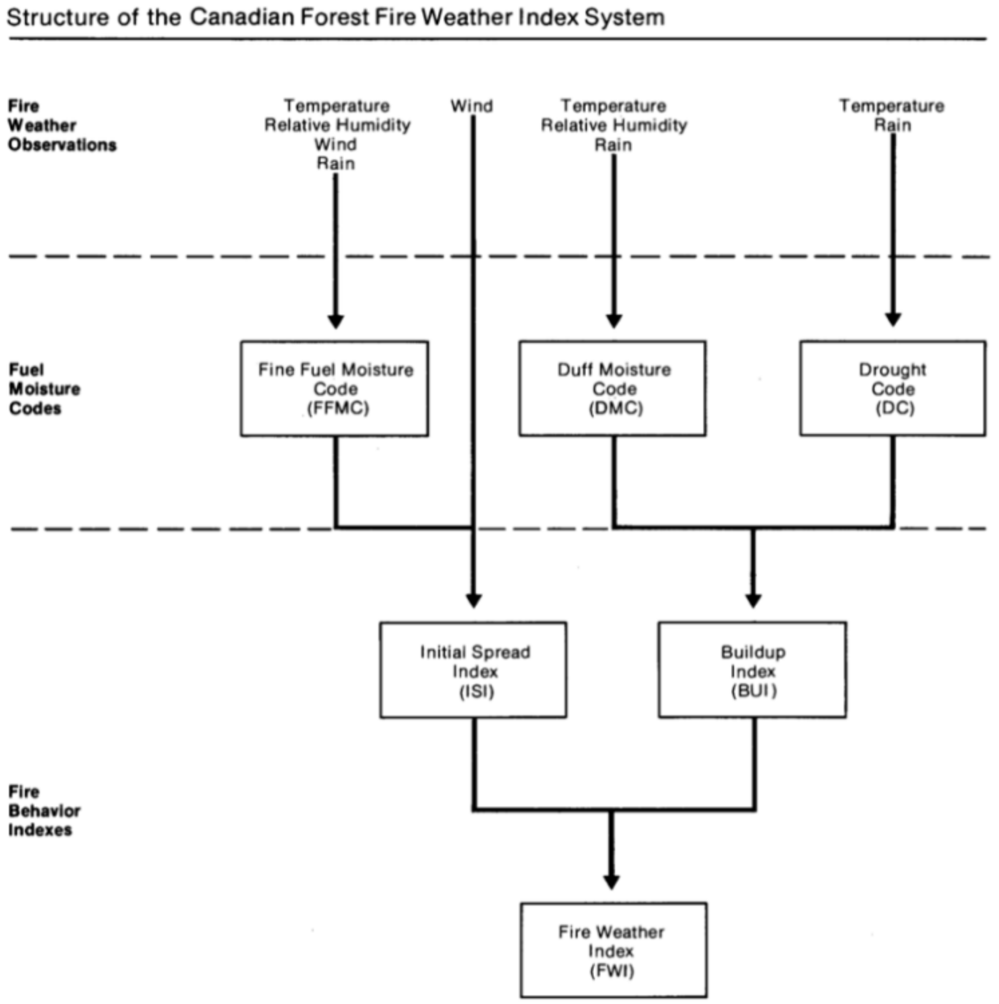
Appendix

Fire Weather Index synthesizes weather and moisture content data into a normalized value representing the danger of fire spread once ignition has occurred.



KEY TAKEAWAYS

- FWI is a useful metric for evaluating weather-based conditions that heighten the **danger of wildfire spread once ignition has occurred.**
- **Initial Spread Index**: Measures the **expected rate of fire spread,** based on wind speed and moisture content of fine fuels/forest litter (Fine Fuel Moisture Code).
- **Buildup Index:** Measures **the total amount of forest fuel available for consumption,** based on the **moisture content of intermediate organic layers**, such as decomposing plant matter (Duff Moisture Code), and the **moisture content of deep organic layers and soils,** which corresponds to drought measures (Drought Code).
- Daily FWI values were calculated using readings from Argonne's downscaled 12km climate data and averaged annually or seasonally across RCP-4.5 and RCP-8.5.
- Percentiles (below) were calculated based on **FWI values across all 12km grid cells in the contiguous U.S.**

FWI Class	Percentile range in historical period	FWI values in Class
Low	0–25th percentile	0–9 FWI
Medium	25–50th percentile	9–21 FWI
High	50–75th percentile	21–34 FWI
Very High	75–90th percentile	34–39 FWI
Extreme	90–98th percentile	39–53 FWI
Very Extreme	Above 98th percentile	Above 53 FWI

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

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