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GRID DEPLOYMENT OFFICE

Grid Resilience Reports

Utah

Energy & Resources | Networks
11/26/2024

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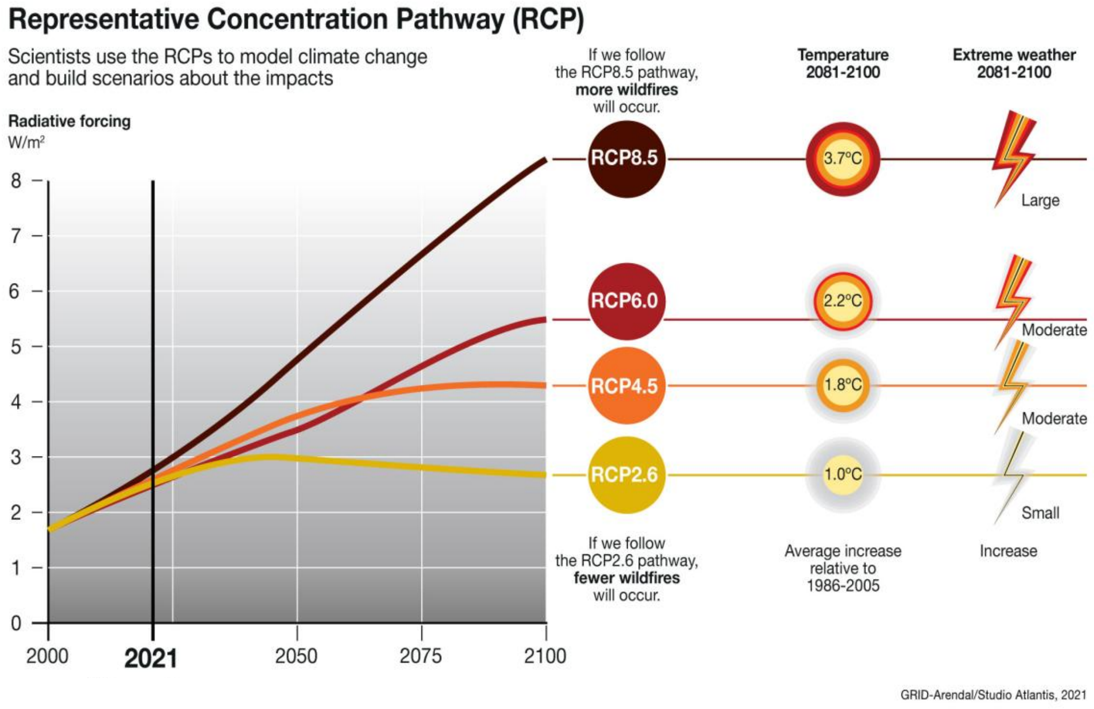
Grid Resilience Reports

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]
- CO_2 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]
- CO_2 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

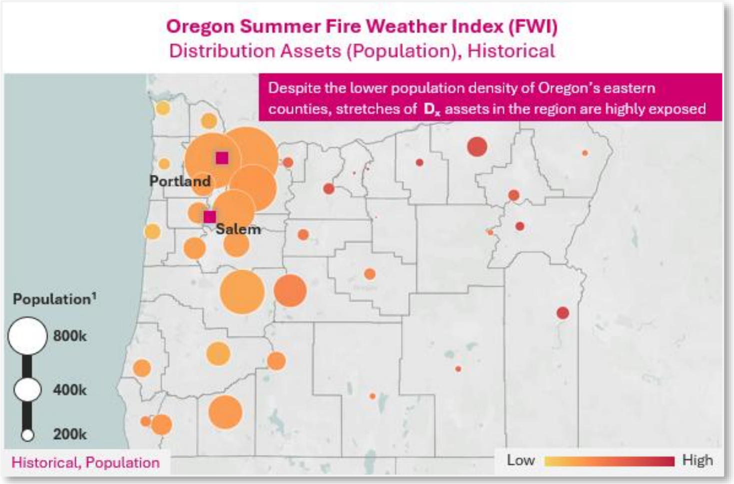
Output: Input metrics applied from a grid cell level to a county level

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)

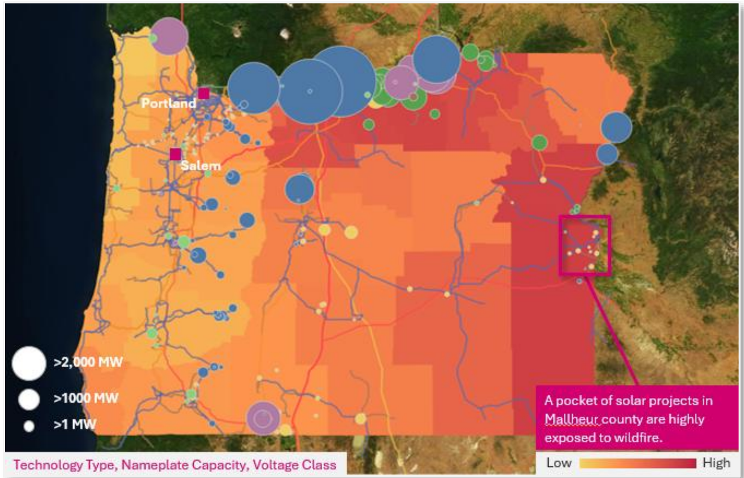
This report is standardized to include 3 different data visualizations that provide insights for Distribution, Transmission, and Generation across 7 extreme weather hazards

1 Distribution Maps



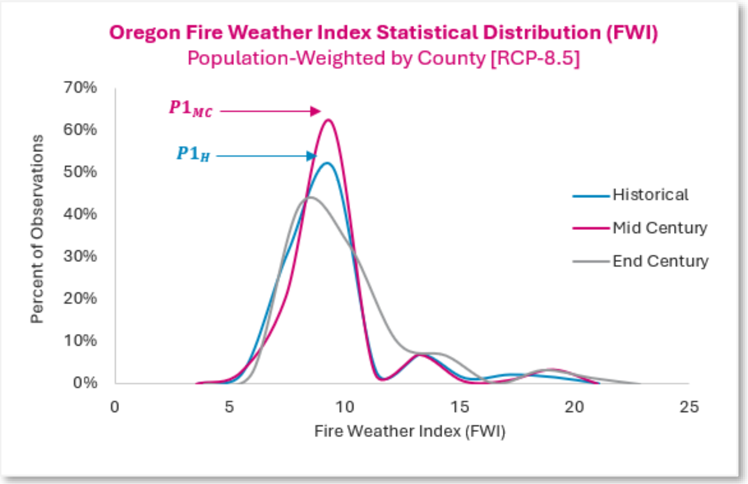
- **Purpose:** Uses population as proxy for volume of distribution assets given that the location of distribution assets is restricted.
- **Interpretation*:** Locate areas of high exposure by identifying counties with coincident large bubbles and dark colors. This indicates a combination of high volume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

UOED could consider Dx hardening to address escalating wildfire risk, substation upgrades to mitigate extreme warming, and system weatherization given continued freezing risk

Key Takeaways

- Focus T&D undergrounding in S and W counties, especially in rural SW counties, Washington County, and W counties bordering population centers.
- Consider expansion of reconductoring and deployment of DER to combat generator derating due to extreme heat.
- Prioritize Tx and Dx hardening and veg. management against cold in N counties and hardening of fossil fuel-based generators to address extreme cold exposure.

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** • Standardized PSPS and emergency response planning could decrease restoration times. • Innovative solar cleaning projects or optimized maintenance scheduling could help combat low solar capacity factors during fires.	**Focus hardening efforts on southern and western Tx and Dx assets** • Tx assets in Washington, Iron, and San Juan Counties are particularly exposed. • UOED could consider Dx hardening in rural SE counties as well as more populated W counties, especially those bordering population centers in the north-central region.	M	**Gen:** No proposed awards address generator wildfire exposure, marking a potential area for future investment. **T&D:** Undergrounding and pole/line upgrade proposals addresses fire risk, only consist of 3mi. UOED could also consider vegetation management, AI monitoring tools, etc.
HEAT	H	↑	**Explore flexible DER options or innovative cooling methods to offset derating of supply** • DER proliferation minimizes reliance on a pocket of large thermoelectric generators that will be heavily exposed to extreme heat. • Innovative thermoelectric cooling combats production derates and drought exposure.	**Consider substation upgrades and Tx reconductoring to combat line sag and derating** • Significant exposure to days >105°F requires substation upgrades to avoid direct failure, especially in S and north-central counties. • HV import/export lines are highly exposed in S counties and could be prioritized for hardening.	M	**Gen:** No proposed awards address generator derating. **T&D:** No mention of substation upgrades, which can fail in extreme heat. UOED could expand approach from Project RELIEF to reconductor additional highly expose Tx lines.
COLD	M	↓	**Focus weatherization technologies on large generators in the central portion of the state** • Natural gas and coal plants in central counties face continued exposure to icing and other cold-related failures through mid-century.	**Consider Tx and Dx hardening in N counties** • Rural LV lines are highly exposed in Duchesne and Uintah Counties. • Population centers in the north-central region are highly exposed, posing a threat of icing to a high density of Dx assets	M	**Gen:** No proposed awards address generator cold exposure. **T&D:** Awarded projects for pole replacement and undergrounding address cold exposure. Substation enclosures could also be considered.

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

UOED could prioritize substation upgrades to address flood exposure, updated wind design standards, and enhanced data collection regarding precipitation and drought patterns

Key Takeaways

- UOED could prioritize substation fortification for low-lying assets and Dx pole fortifications in north-central counties that are heavily exposed to flooding.
- Consider more rigorous design standards for wind and solar components as well as Tx structure reinforcement and Dx pole upgrades in SE counties.
- While precipitation levels are projected to increase, UOED could monitor drought and other relevant factors to assess the impact on electricity generation.

Hazard	Exposure	Change to Mid-Century	Generation	Transmission & Distribution	AWPI*	Description
FLOOD	M	↑	**Most supply technologies are not significantly exposed to flood** • A handful of solar plants in Iron County are significantly exposed, which can inundate inverters and other ground-based equipment, potentially causing generator failure.	**UOED could prioritize substation fortification** • High density of HV substations are heavily exposed to flooding in north-central counties, which can cause direct failure. • UOED could also consider upgrades to weak Dx poles given increasing flood exposure.	L	**Gen:** Lack of exposure makes gen a lower priority for investment. **T&D:** No projects targeting substations, unaligned with the significant substation exposure.
WIND	M	N/A	**UOED could consider investments to buttress solar racking and anticipate turbine cutouts** • Solar plants in Beaver and Sevier Counties are exposed to high 100-year return values.	**SE import/export Tx lines could be prioritized for structure reinforcement** • Critical MV and HV ties are highly exposed in Beaver, Piute, and Sevier Counties	M	**Gen:** No wind/solar reinforcement despite significant exposure. **T&D:** Undergrounding & pole upgrades are aligned but veg management projects could also be considered.
DROUGHT	M	↓	**UOED could consider supporting enhanced cooling and innovative panel cleaning projects** • SE natural gas and solar assets are heavily exposed to drought. • UOED could continue to monitor drought closely given diverging projections.	**Drought exposure does not have a material impact on transmission and distribution assets.**	M	**Gen:** Solar panel cleaning projects would allow UOED to address drought and fire risks simultaneously given high levels of exposure to all these hazards in the SE.
RAIN	L	↑	**UOED could seek out additional data to understand future hydroelectric production** • Precipitation levels are projected to increase slightly, but UOED could consider other factors that impact hydroelectric output.	**Precipitation exposure does not have a material impact on transmission and distribution assets.**	M	**Gen:** While less urgent than other hazards, UOED could gather additional information to assess the true impact on hydro output and its implications for resource planning and scheduling.

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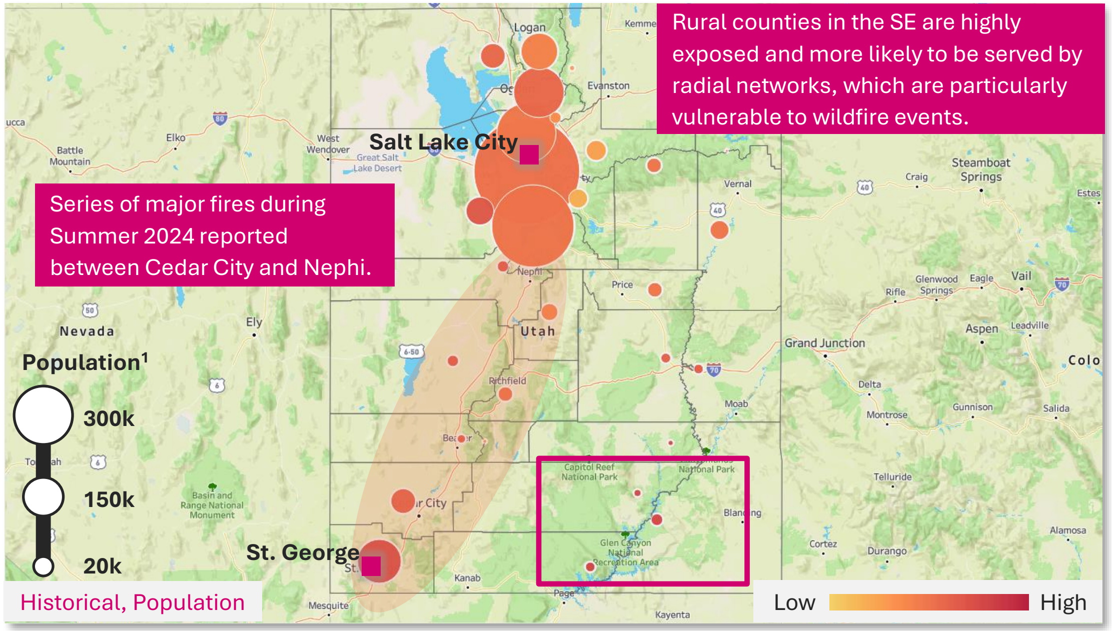
Wildfire

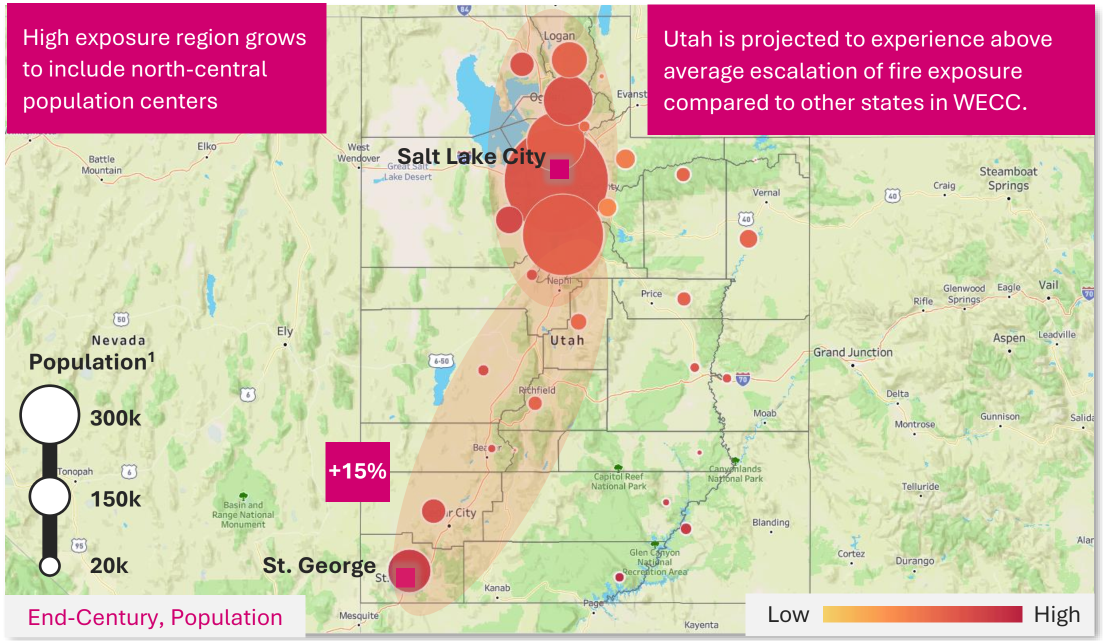
Asset Analysis

UOED could continue to fund wildfire mitigation upgrades given escalating exposure over time, especially in highly exposed western counties and rural SE counties served by radial lines

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



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



KEY OBSERVATIONS

- Historical wildfire exposure is concentrated in Utah's SW counties.
- **High exposure counties in the west border population centers in the north-central region of the state,** posing a threat of fire proliferation.
- Undergrounding and protective device proposals indicate general alignment with wildfire exposure, but **UOED could also consider vegetation management projects.**

KEY OBSERVATIONS

- FWI increases by about 3-8 points across the state, demonstrating the importance of utilizing **forward-looking climate projections for state-wide fire mitigation planning.**

Washington County — Well-populated county facing peak state wildfire exposure, presenting a potential priority area for future wildfire mitigation investment.

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

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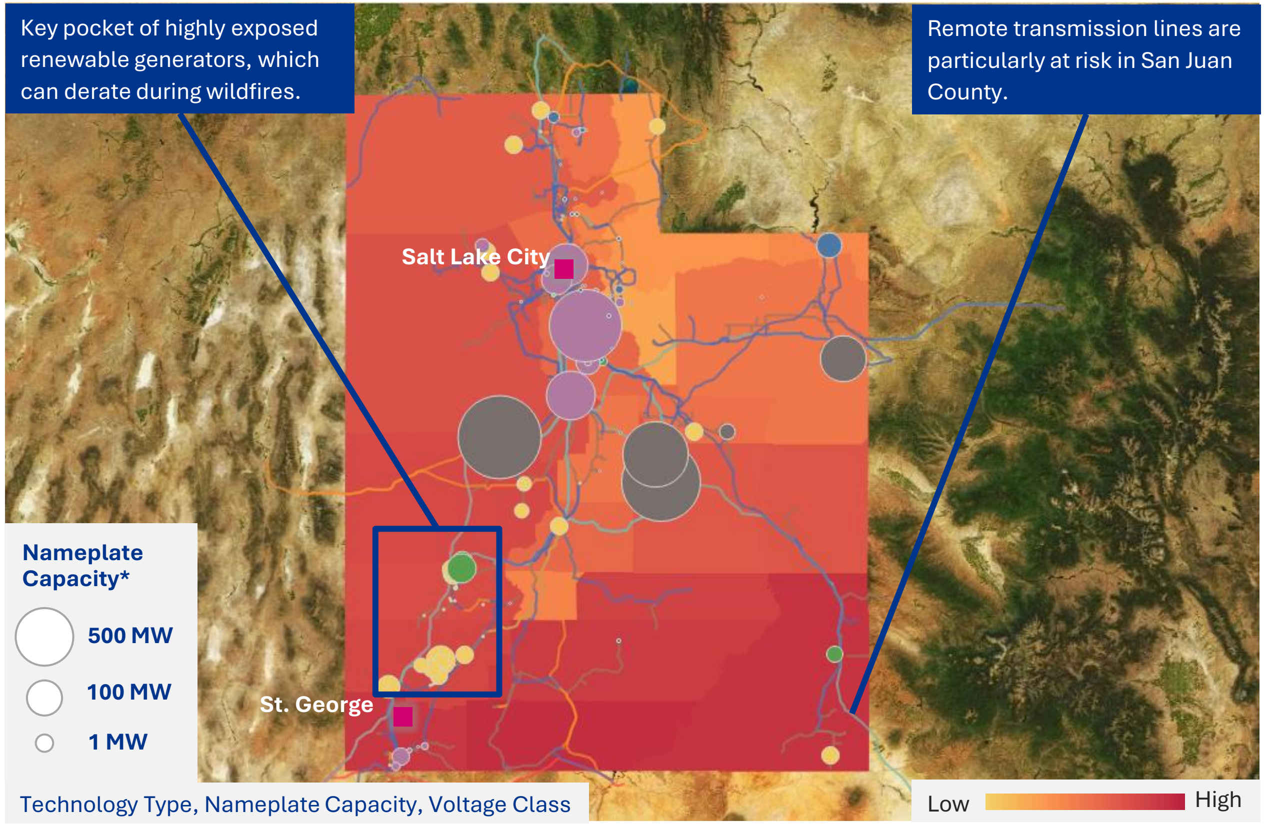
UOED could consider prioritizing hardening for southern transmission assets and explore novel operational procedures for renewables facing derating from soot and ash

Utah 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 San Juan County. • **A crucial import/export HV line in Washington County is highly exposed** and could be considered for upgrades given its key role during extreme weather events. • UOED could **consider vegetation management projects to address Tx wildfire exposure.**
Renewables	• Wind and solar assets across the state 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.
Restoration	• Wildfire causes **ingress/egress issues** through destruction of roads and transportation, slowing restoration times for all assets. • UOED could **consider funding projects addressing wildfire-related access issues** given its impact across all asset classes.

*Generator nameplate capacities may exceed those shown in the legend

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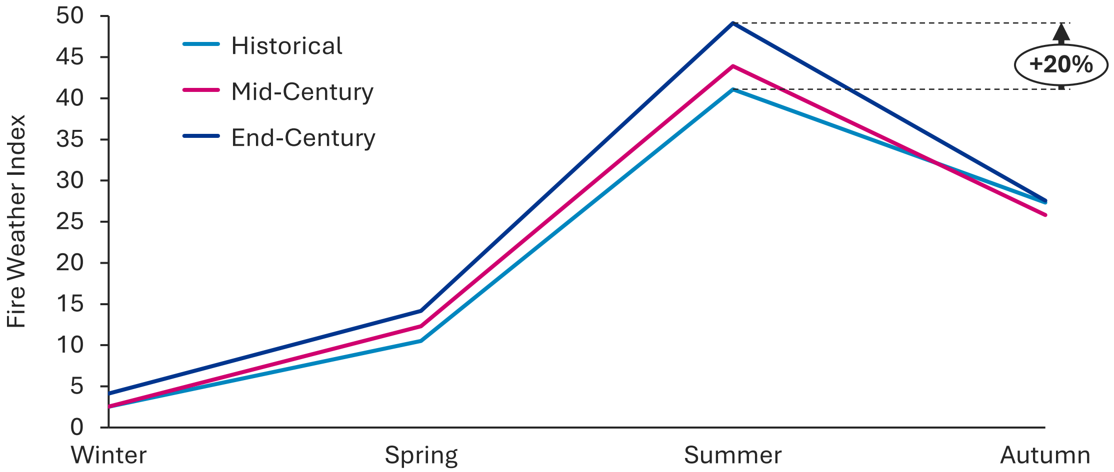
Baringa

Fire exposure is projected to increase in severity over time, especially between mid- and end-century, lengthening the fire season and potentially shrinking the maintenance window

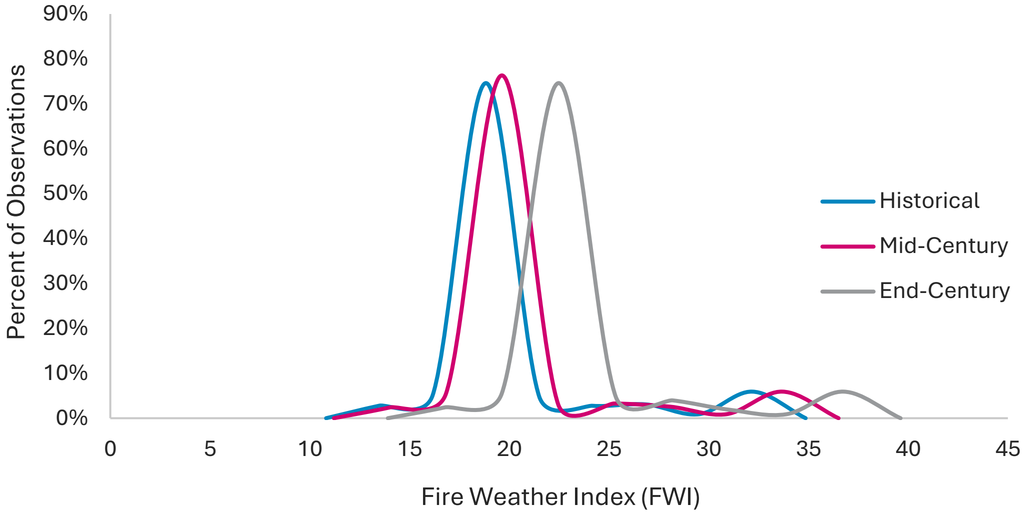
Utah Average Seasonal Fire Weather Index (FWI)
Population-Weighted by County [RCP-8.5]



KEY OBSERVATIONS

- **End-century wildfire exposure is elevated**, with the sharpest increase occurring between spring and autumn by about 20% 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.**

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



KEY OBSERVATIONS

- Rightward shift of the curve by end-century indicates **increasing severity of wildfire exposure over time.**
- The magnitude of the shifts indicate a much **larger increase in severity between mid-century and end-century than historical and mid-century.**
- The bi-modal shape of the curve represents **one large region of exposure between 15-25 FWI, and a smaller pocket in southern counties exposed to FWI levels from 30-40.**

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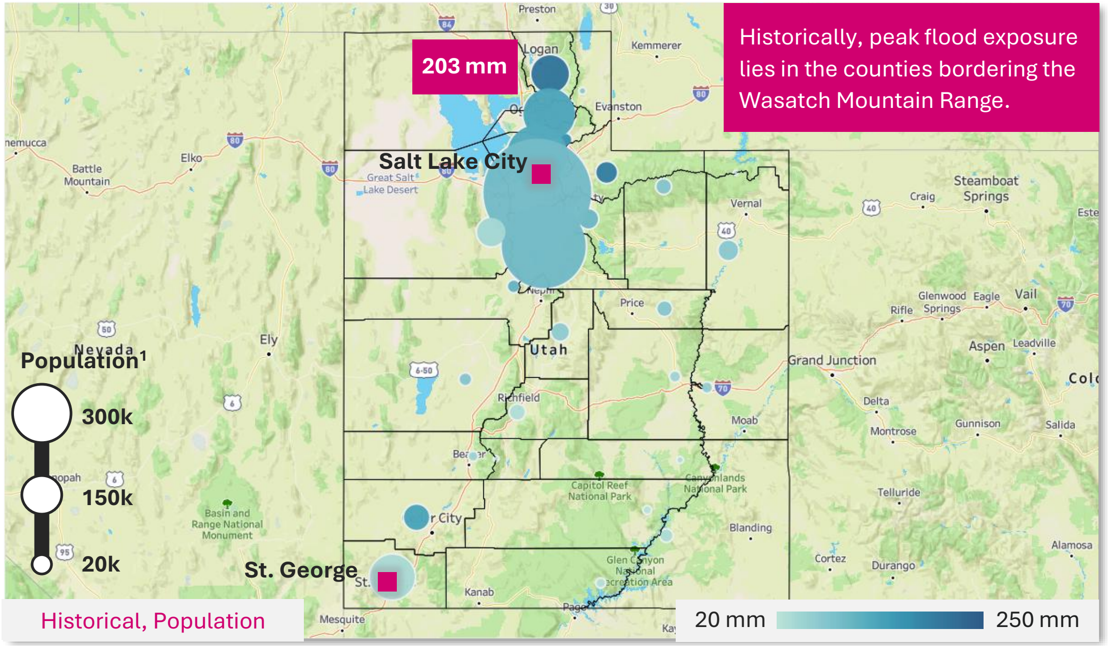
Flood

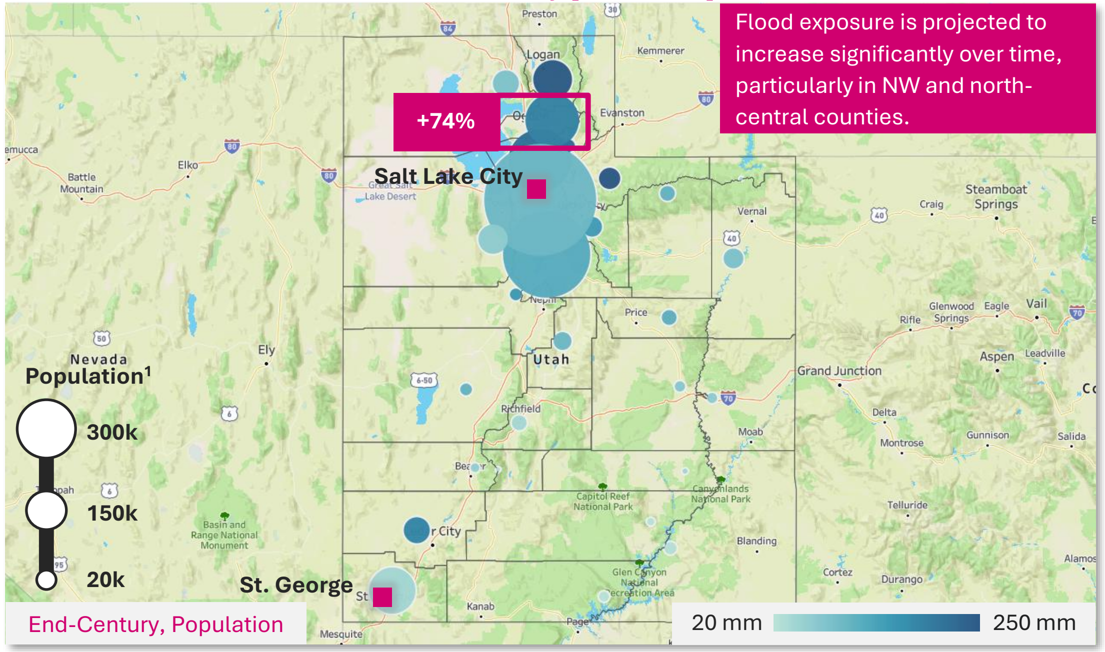
Asset Analysis

UOED could consider funding projects to fortify substations and distribution poles in north-central counties given the high volume of assets exposed to increasingly severe flooding

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



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



KEY OBSERVATIONS

- Most flood exposure lies in the **north-central counties** given their low elevations and proximity to mountain ranges and bodies of water.
- **Davis, Weber, and Cache 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 in north-central counties given the increase in flood exposure over time.

Davis County

Flood exposure is projected to increase ~74% 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

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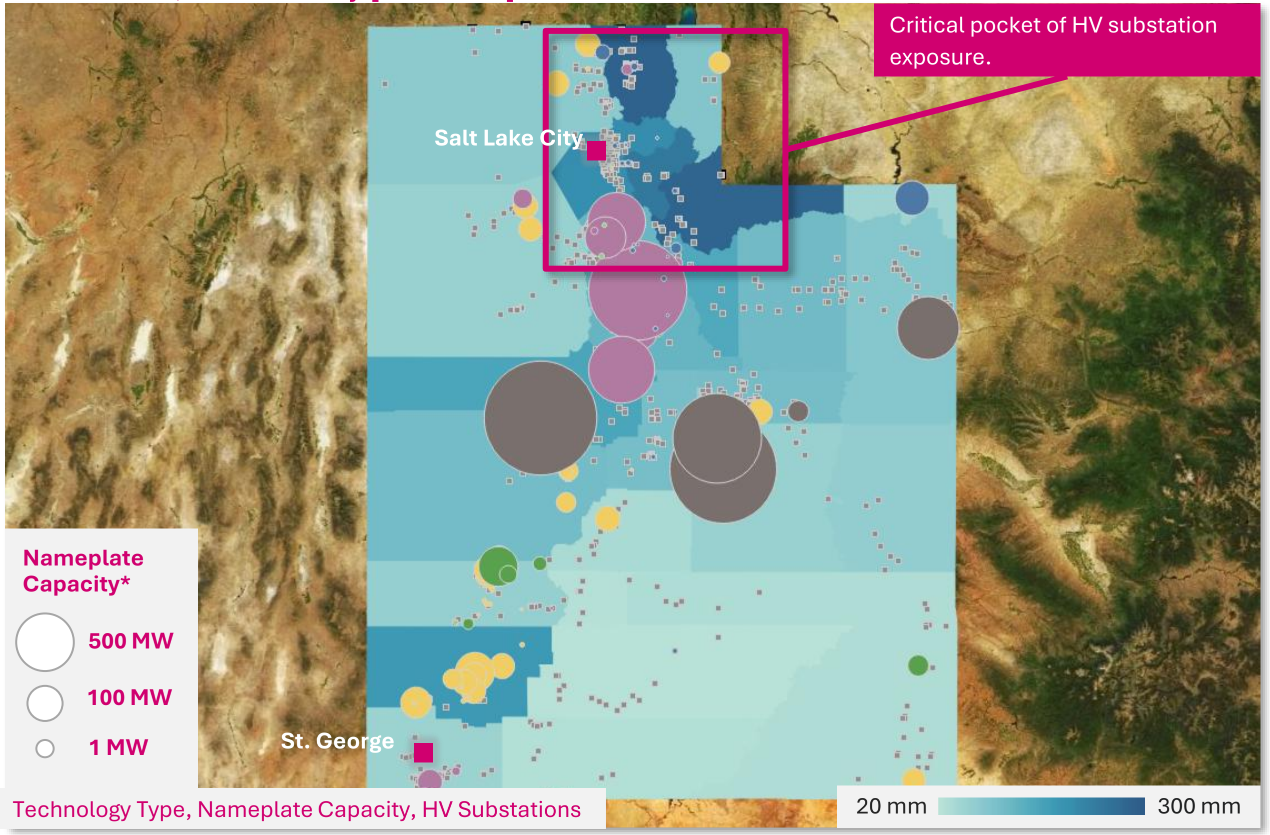
UOED could prioritize the fortification of HV substations in a highly-exposed north-central pocket given the high density of assets facing significant exposure and their high cost of failure

Utah 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

Source: ClimRR, EIA860, HIFLD

Key Highlights	Analysis
Substation	• High voltage substations will be exposed to pluvial flooding, with increased risk if located in a flood plain or riverbank without necessary protections. • High density of **HV substations in Weber and Cache 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. • 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 **UOED could prioritize Tx & Dx projects to address the hazard.** • A handful of **solar plants in Iron County are significantly exposed to flooding,** which can inundate inverters and other ground-based equipment, causing plant failure.

*Generator nameplate capacities may exceed those shown in the legend

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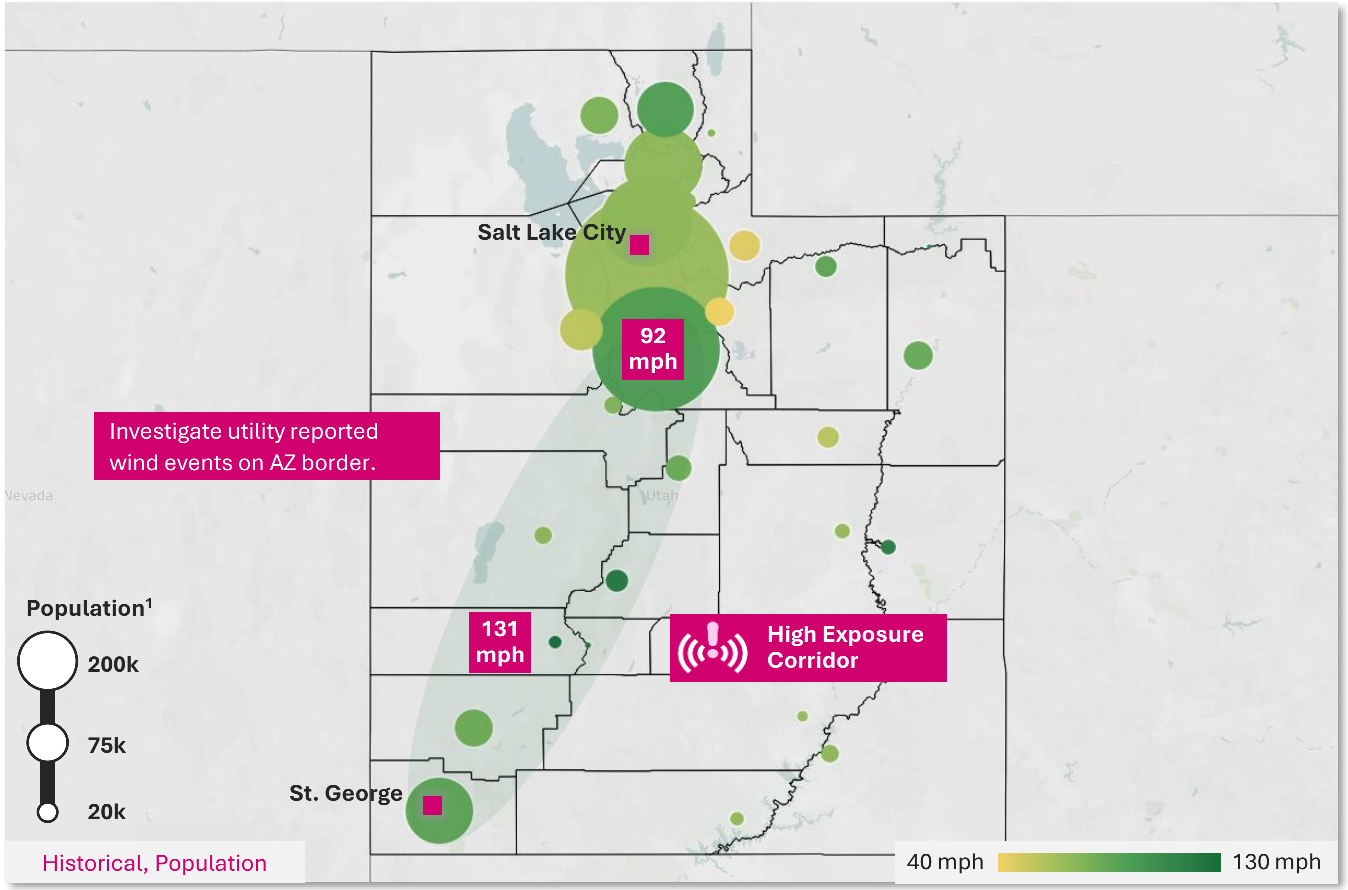
Wind

Asset Analysis

UEOD could consider prioritizing vegetation management and pole reinforcement projects in highly exposed counties to mitigate damage from wind

Utah 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 should be addressed through **upgraded design standards** across a utility service territory.
Utah County	• Utah County has a population of over 700k and a 100-year return value of 92 mph, **indicating a high exposure area for a large volume Dx assets**. • Coincident extreme cold events put Dx lines at risk for galloping and asset failure due to ice loading on conductors.
Beaver County	• **Beaver County** has the highest return value of 131 mph, indicating high failure likelihood for lower class poles. • 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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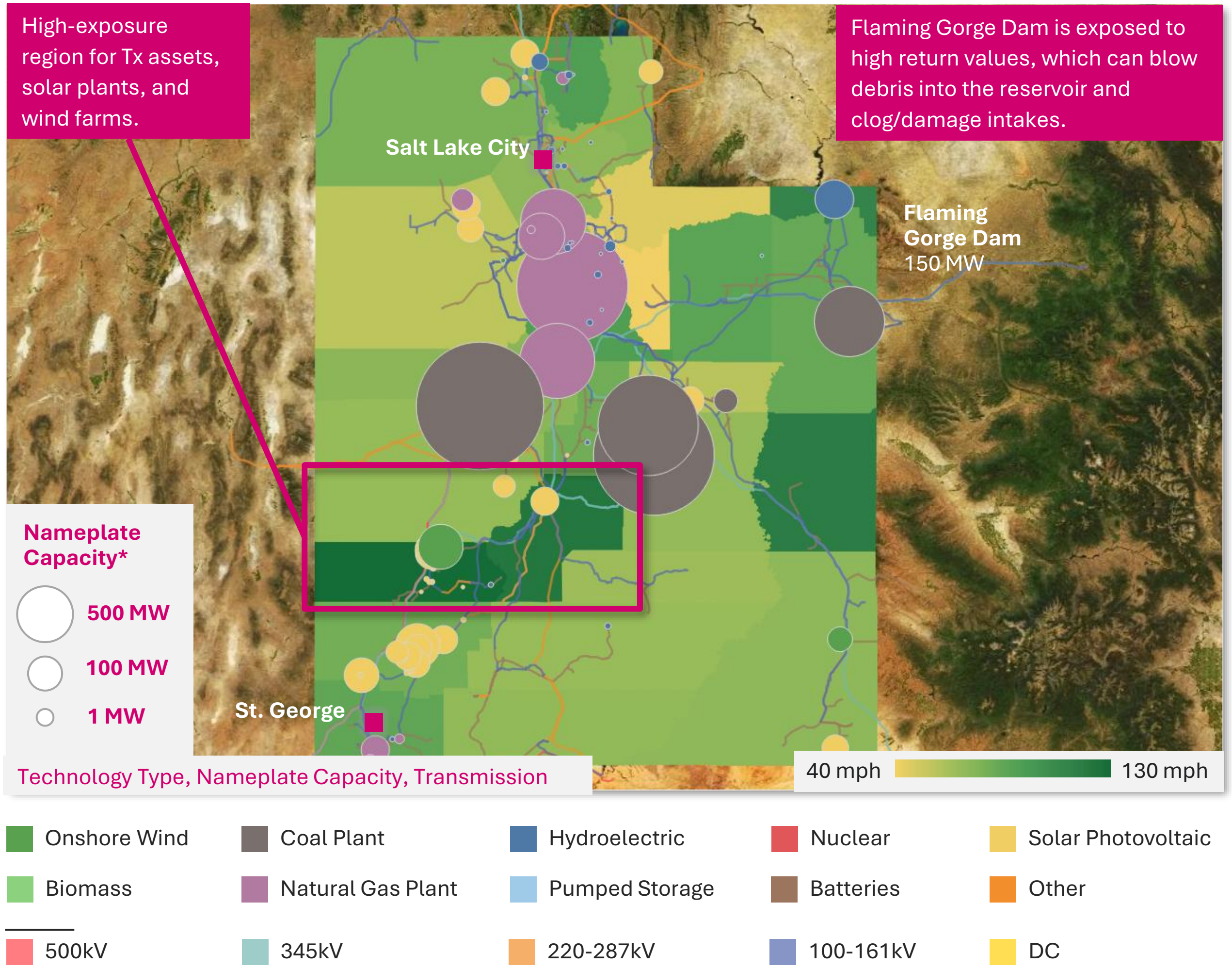
UOED could consider prioritizing hardening projects for Tx assets and renewable generators in Beaver, Piute, and Sevier Counties to address high levels of wind exposure

Utah 100-year Wind Speed (mph)
Historical



Source: DRI, EIA860, HIFLD

Key Highlights	Analysis
Transmission	• A series of MV transmission lines in Beaver, Piute, and Sevier Counties are exposed to high historical wind speeds. • These lines are critical for **import/export capability** during extreme weather events. **UOED could consider reinforcing Tx structures to mitigate risk.**
Solar	• Solar farms in Beaver and Sevier Counties are historically exposed to 120-130mph wind speeds at the 100-year return period. • 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. • Wind farms in Beaver County are exposed to 100-year return period values far greater than the cutout threshold, **reducing generation during extreme events.**

*Generator nameplate capacities may exceed those shown in the legend

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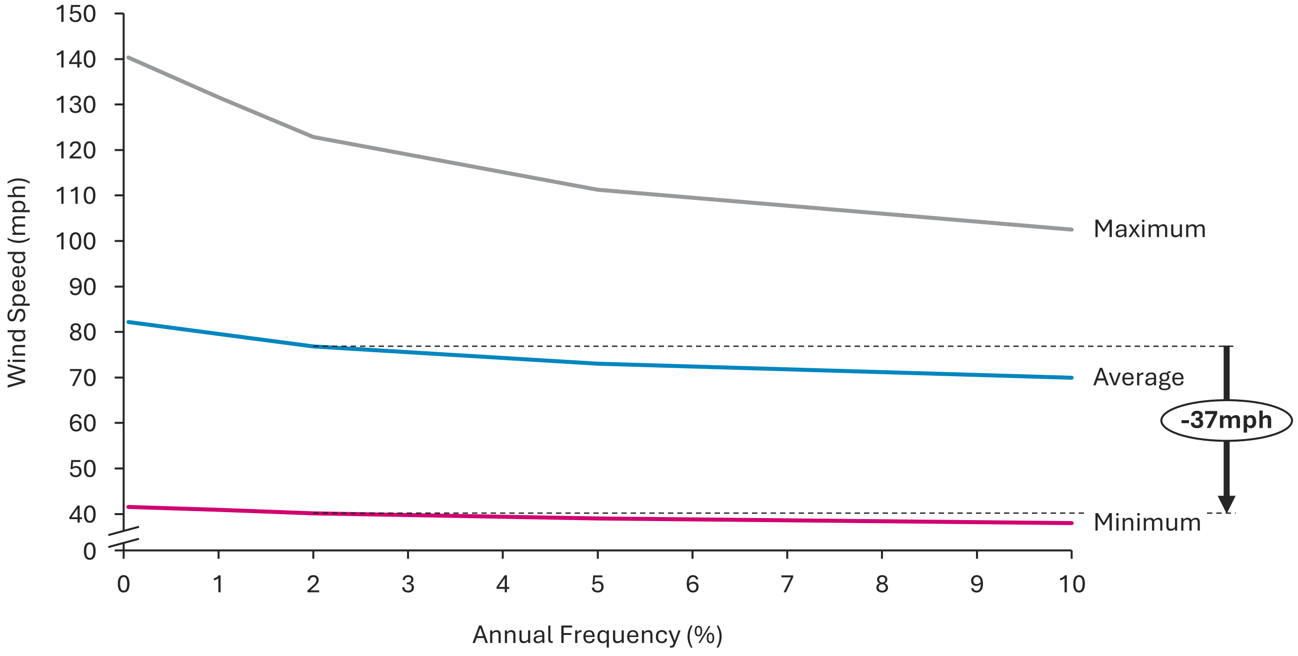
Historically, there is a 1% chance that the average wind speed seen across Utah counties is ~80mph annually.

Utah 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 Utah counties is ~80 mph annually. • The 10% annual likelihood drops to 70 mph, 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. • This range is above average compared to other states in WECC, indicating that wind adaptations could be focused on a county basis rather than over large territories.

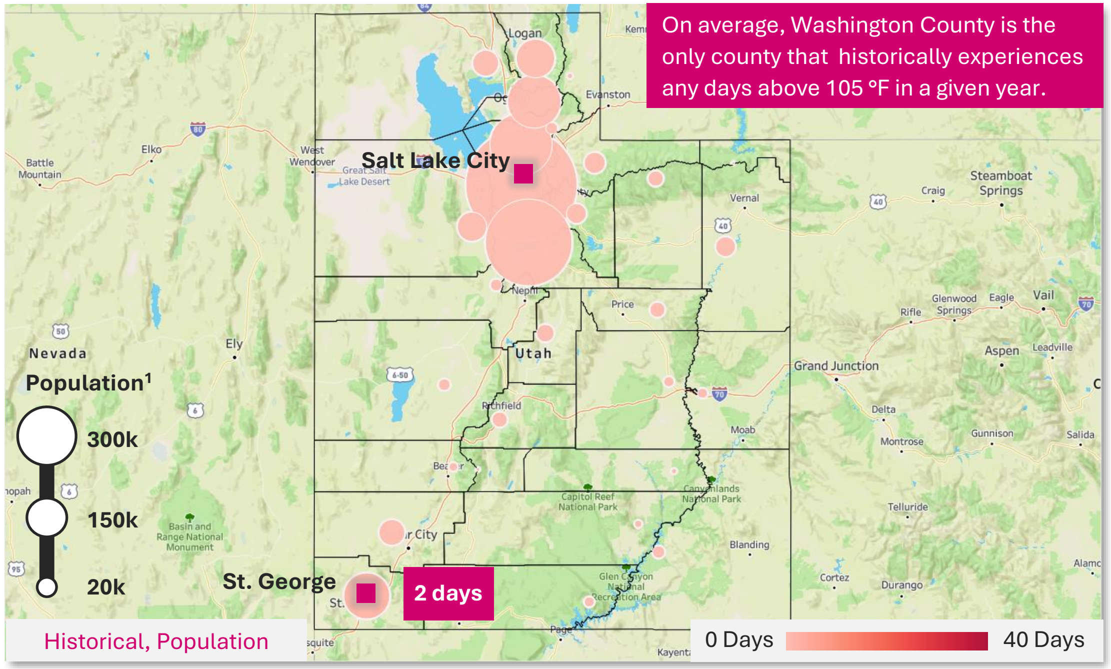
Heat

Asset Analysis

UOED could prioritize substation and Dx line upgrades in Washington County and north-central counties to address derating, degradation, and risk of failure from extreme heat

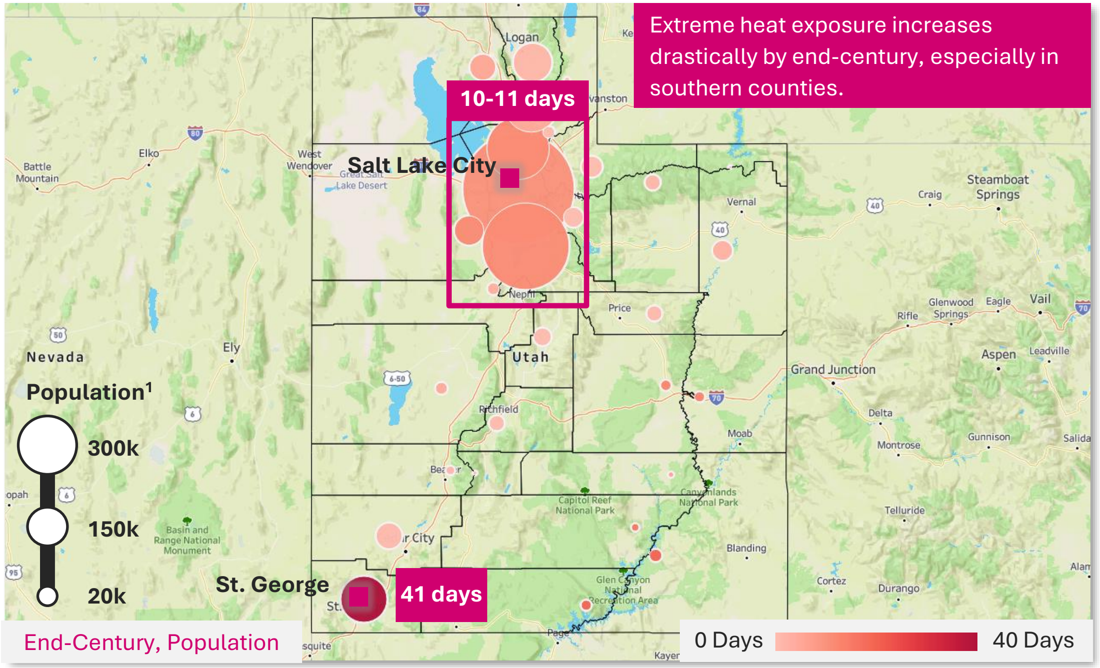
Utah Days Above 105 °F

Distribution Assets (Population), Historical



Utah Days Above 105 °F

Distribution Assets (Population), End-Century [RCP-8.5]



KEY OBSERVATIONS

- Currently T_x and D_x assets have **minimal 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 (Utah, Salt Lake, Davis) are expected to face **about 10-11 days >105 °F annually, causing high asset utilization, derating, and potential failure.**

Washington County	41 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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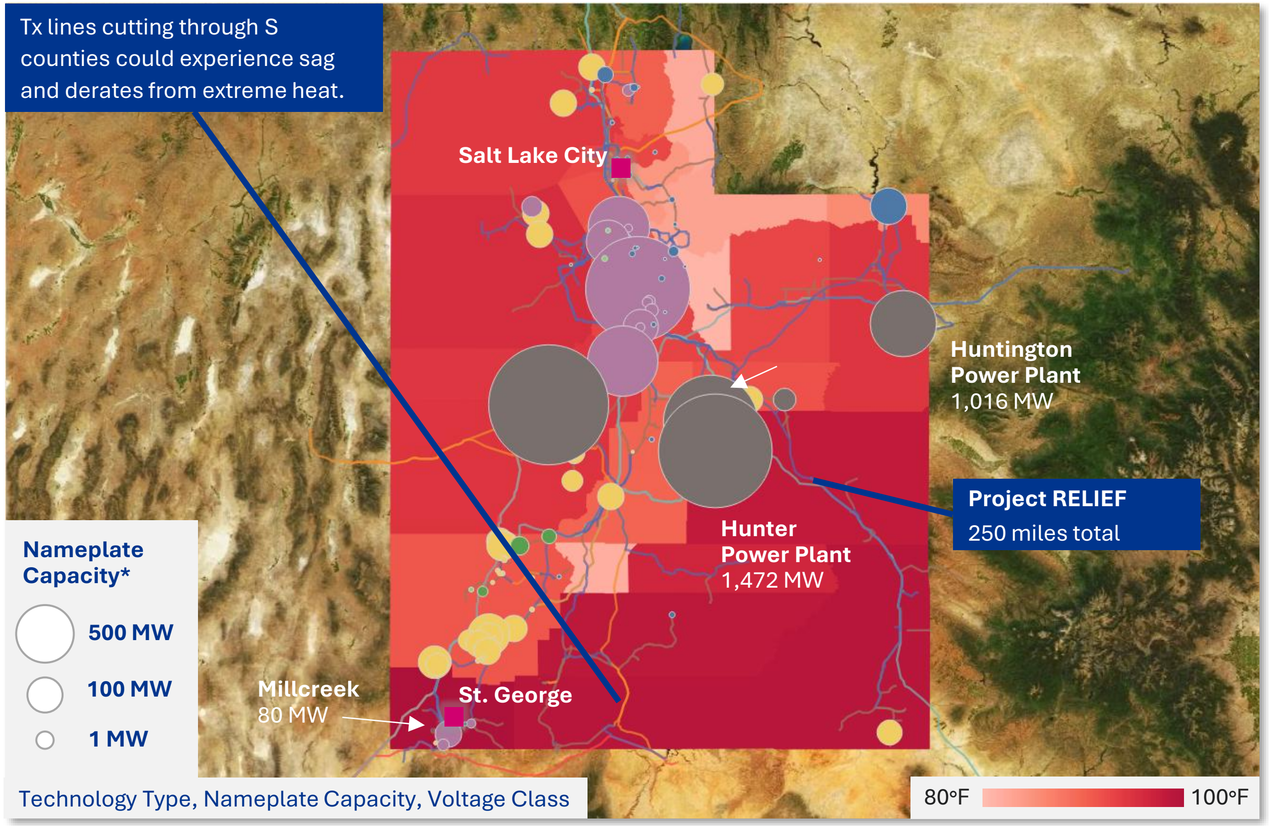
UOED could consider Tx hardening and thermoelectric cooling upgrades in the S/SE portion of the state to combat increasing extreme heat exposure

Utah 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. • **Hunter and Huntington coal plants in Emery County are significantly exposed to extreme heat,** causing derates that could have a sizeable impact on the state's energy supply given their size. • **Millcreek Power Generation Facility in Washington County faces summer average temperatures > 100 °F,** which could cause significant derates for a generator located in a demand center with a large cooling load.
Transmission	• All the state's 500kV Tx infrastructure is exposed to extreme heat in the SE, which can cause line sag and capacity derates. • **Project RELIEF** targets large transmission line near Hunter power Plant for installation of advanced conductors to improve capacity. • UOED could consider other adaptations to fortify longer portions of transmission lines, such as **vegetation management**.

*Generator nameplate capacities may exceed those shown in the legend

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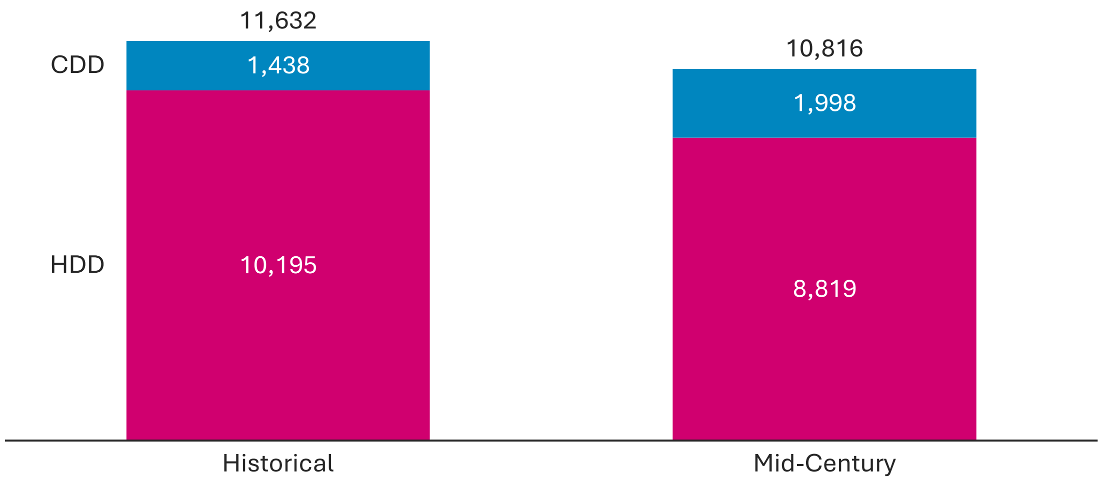
Extreme heat days will become more common in Utah, contributing to high levels of asset utilization, derating, capacity violations, and potentially direct failure for Dx substations

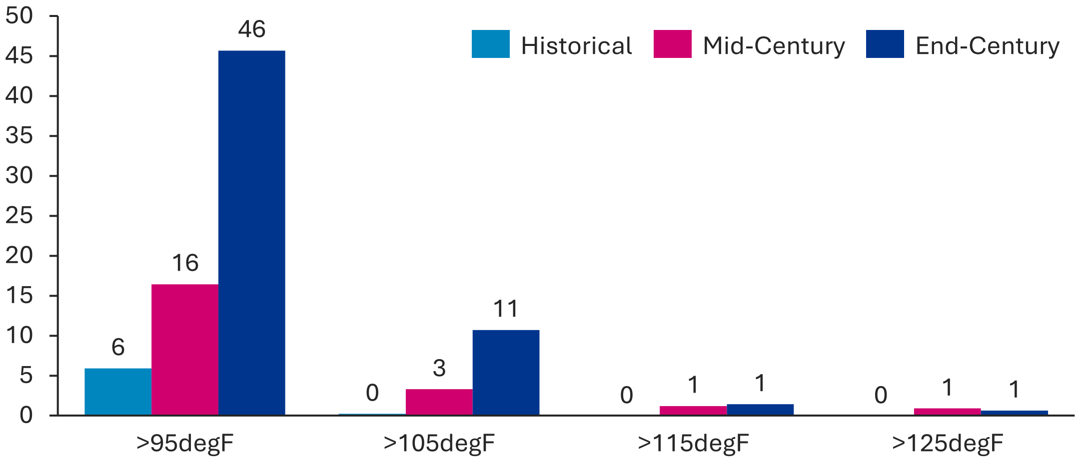
Utah Average Annual Cooling & Heating Degree Days (CDD & HDD)
Population-Weighted by County [RCP-8.5]



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 14% to 22%.
- 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.

Utah 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 will likely **increase asset utilization** and could 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 substations**, which can fail after two consecutive days above 104 °F without sufficient cooling infrastructure, indicating a potential focus area for UOED in future funding allocation processes.

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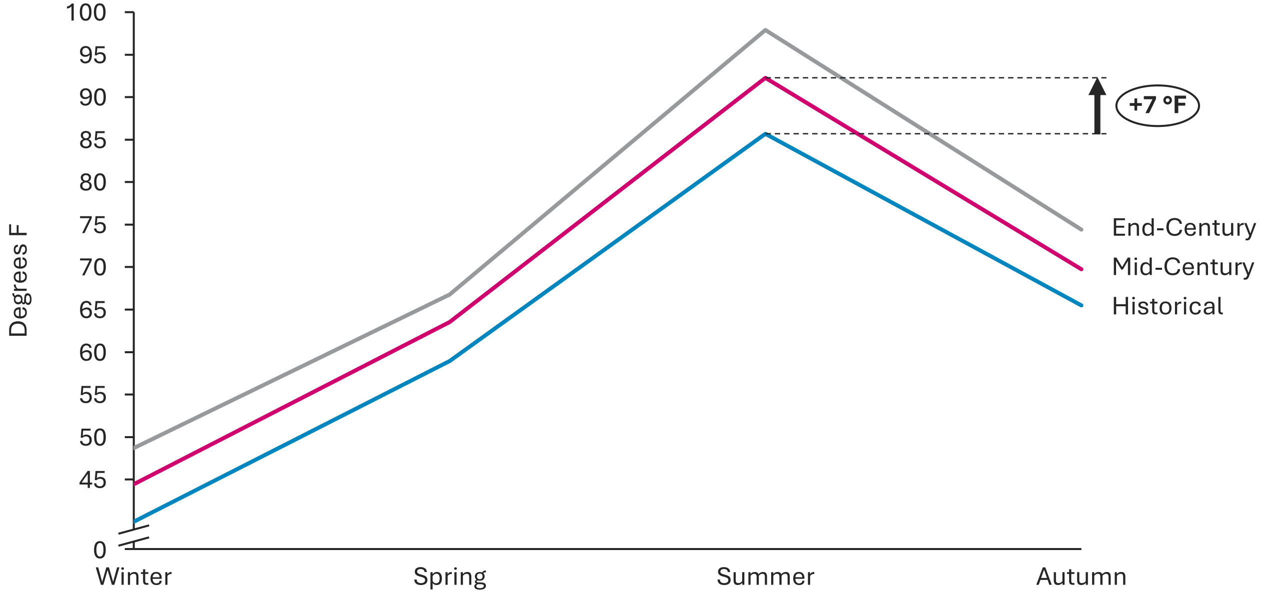
Average summer temperature maximums are projected to increase by mid-century, increasing the duration and magnitude of high system utilization

Utah 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 7 °F increase in the average seasonal max by mid-century, **increasing summer peaking and capacity violations.**
Shorter Shoulder Seasons	• Warming is generally less pronounced in shoulder seasons, although increased spring and autumn maximums could **extend the duration of high system utilization and shorten maintenance windows.**

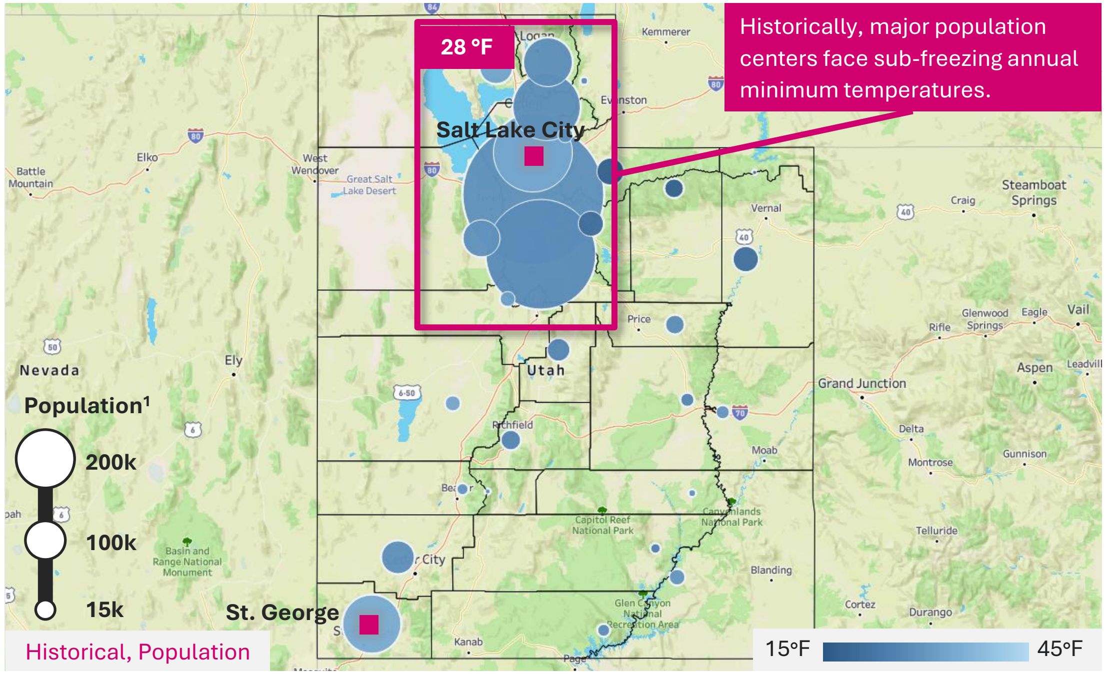
 |

Cold

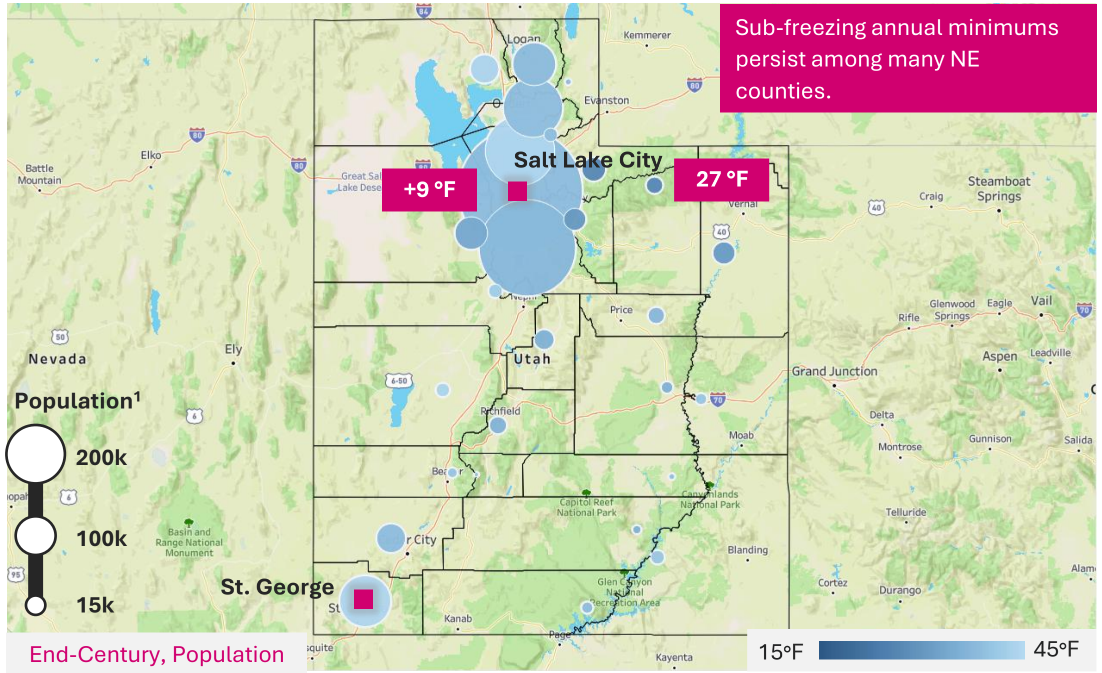
Asset Analysis

Despite warming, UOED could consider continuing to fund Dx hardening addressing cold exposure given sustained sub-freezing annual minimum temperatures in NE counties

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



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



KEY OBSERVATIONS

- While cold exposure is most extreme in NE counties, **annual minimum temperatures are below 32°F across most of the state, indicating widespread risk of asset freezing/icing.**
- Proposals including pole replacements and line upgrades address icing risk, but **UOED could also consider enclosure projects.**

KEY OBSERVATIONS

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

Summit County

Summit County is exposed to average annual minimum temperatures of about 27 °F, indicting **continued freezing exposure for Dx assets.**

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

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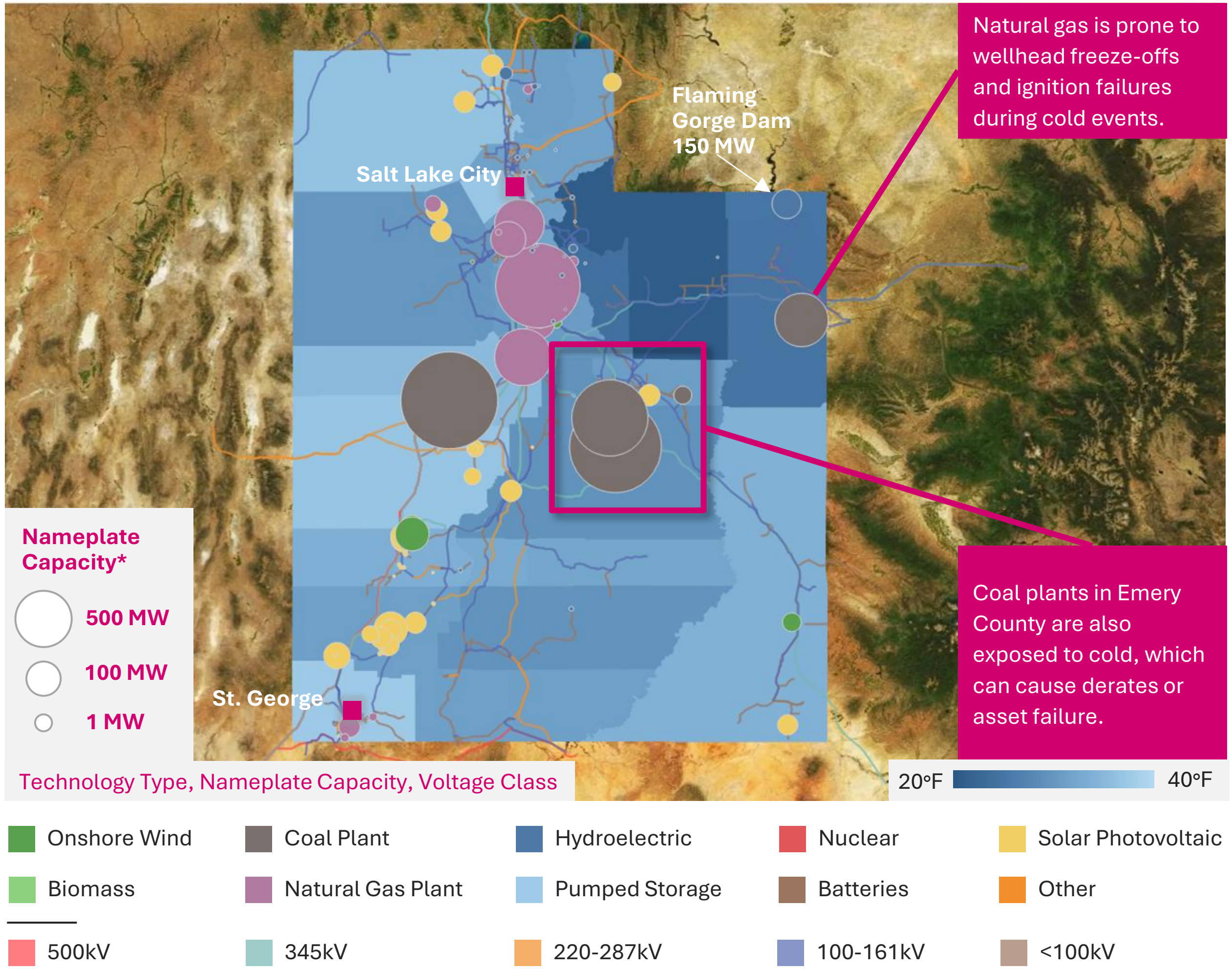
UOED could consider resilience upgrades to gas plants and pipeline systems to combat cold exposure, as well as continued transmission hardening addressing freezing in NE counties

Utah Average Annual Minimum Temperature (°F)

Generators, Mid-Century [RCP-8.5]



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 about 30°F, which could cause **ignition failure or performance issues if these plants lack heating equipment.** • **No proposals addressing aging gas infrastructure**, which requires hardening or replacement to mitigate cold exposure.
Transmission	• Despite warming, the **prevalence of sub-freezing annual minimums** in many counties contributes to **Tx freezing/icing risk** that can cause asset failure. • **Rural sub-Tx lines** are crucial for last-mile customers and **are heavily exposed in Duchesne and Uintah Counties.** • UOED appears to be addressing this issue through pole replacement and undergrounding but could **also consider vegetation management projects.**

*Generator nameplate capacities may exceed those shown in the legend

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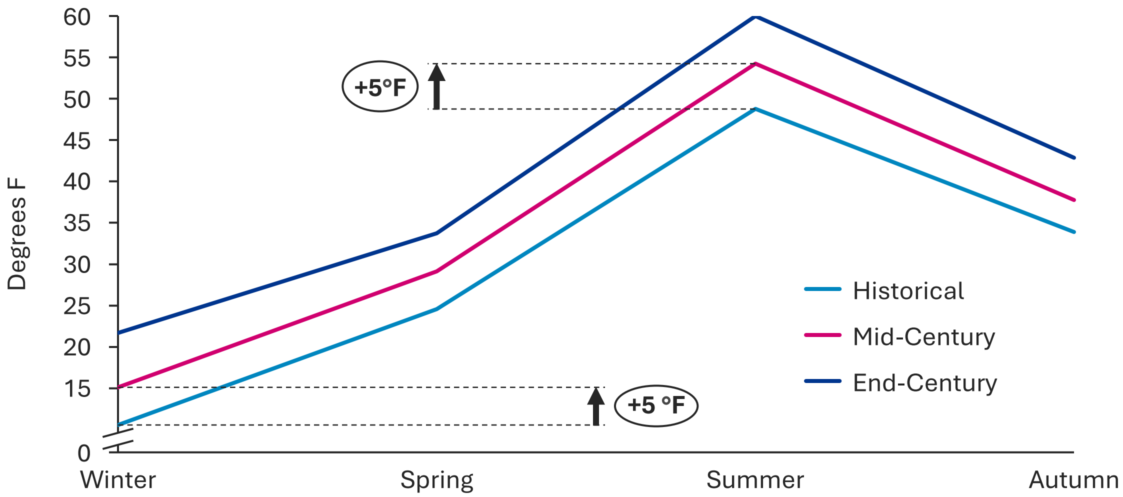
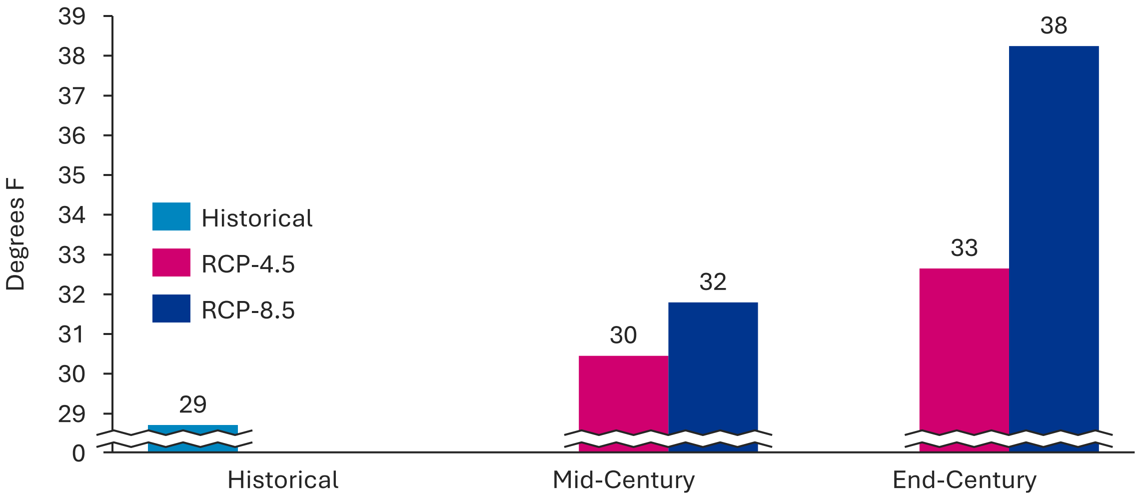
Despite warming across all seasons, cold exposure will largely remain constant in the near future, indicating the UOED could continue to invest in hardening addressing freezing/icing

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



Utah 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 and end-century winter minimums remain below 32 °F, indicating that **freezing and icing exposure persists despite warming.**
- UOED could **ensure that natural gas pipelines and generators are sufficiently hardened for cold** given the state's increased reliance on the fuel for electricity generation.

KEY OBSERVATIONS

- Minimal warming of annual min temperatures by mid-century indicates **cold exposure will remain relatively constant in the near future.**
- 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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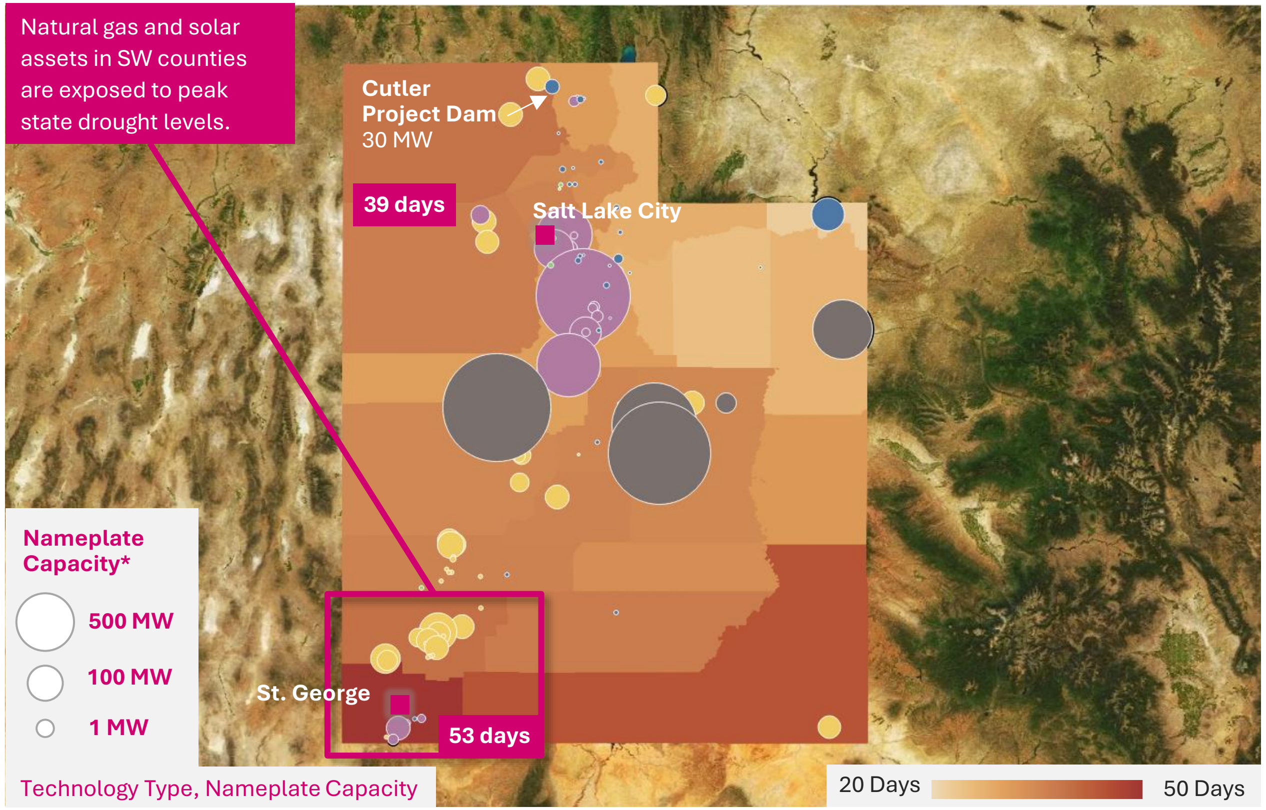
Drought

Asset Analysis

Significant drought exposure could warrant thermoelectric cooling and solar panel cleaning innovations in SE counties and continued monitoring of drought conditions on the Bear River

Utah 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	• **Cutler Project Dam** on the Bear River **is exposed to above average state drought levels.** • Despite a projected decline in drought exposure over time, asset owners and grid operators could continue to **monitor drought conditions** given a divergence in drought projections by warming scenario (see p. 38).
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. • 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 (i.e. Washington and Iron Counties), **panel cleaning projects address two hazards simultaneously.**

*Generator nameplate capacities may exceed those shown in the legend

Source: ClimRR, EIA860, HIFLD

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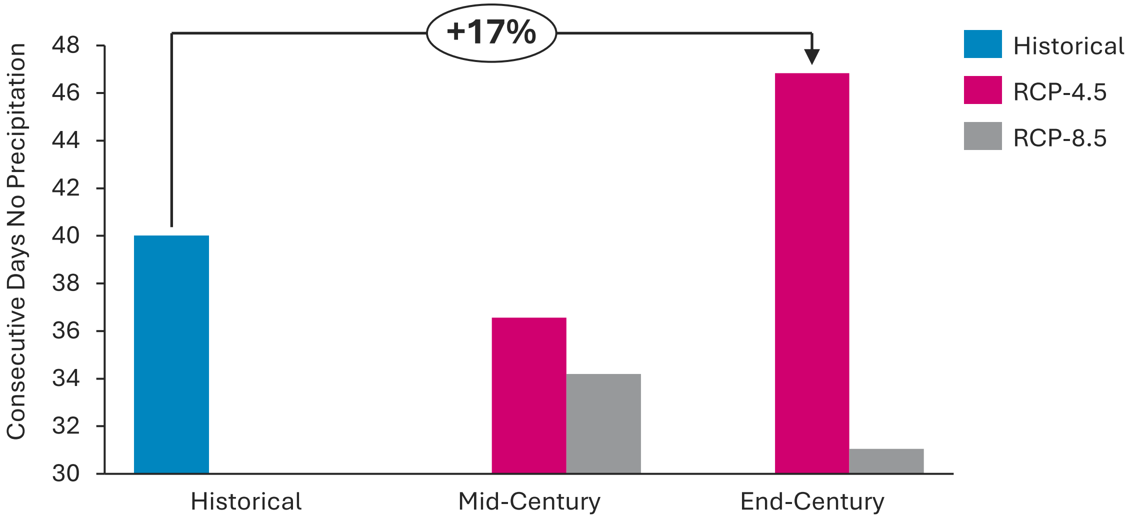
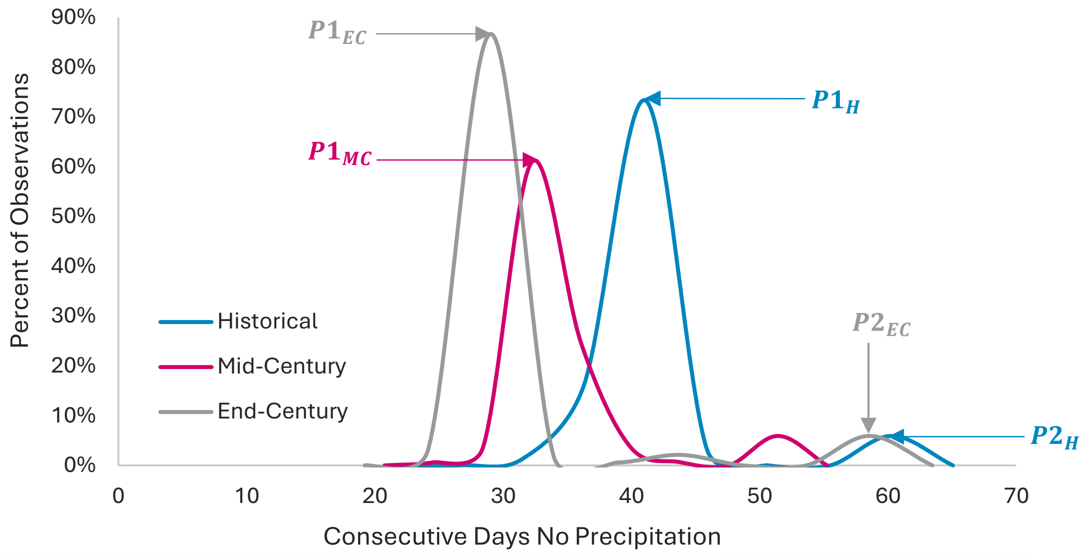
Drought exposure is generally projected to decrease over time, but UOED should continue to monitor drought trends given the divergence in projections across warming scenarios

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



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



KEY OBSERVATIONS

- **Drought exposure increases by ~17% by end-century** (under RCP 4.5), contributing to potential asset cooling failures, reduced hydroelectric generation, and solar derating resulting from dust buildup.
- Significant divergence of drought projections based on the time horizon and warming scenario indicates that **drought risk does not scale linearly with temperature** and could be monitored closely over time, especially by hydroelectric asset owners.

KEY OBSERVATIONS

- The leftward shift of the curve indicates a **general decline in drought severity over time, especially in the least exposed regions.**
- P2 remaining in a relatively similar position between historical and end-century indicates **relatively constant levels of drought exposure for the most exposed counties (i.e. Washington, Kane, San Juan).**
- P1 levels indicate that **drought exposure becomes less concentrated by mid-century but more concentrated by end-century vs. historical.**

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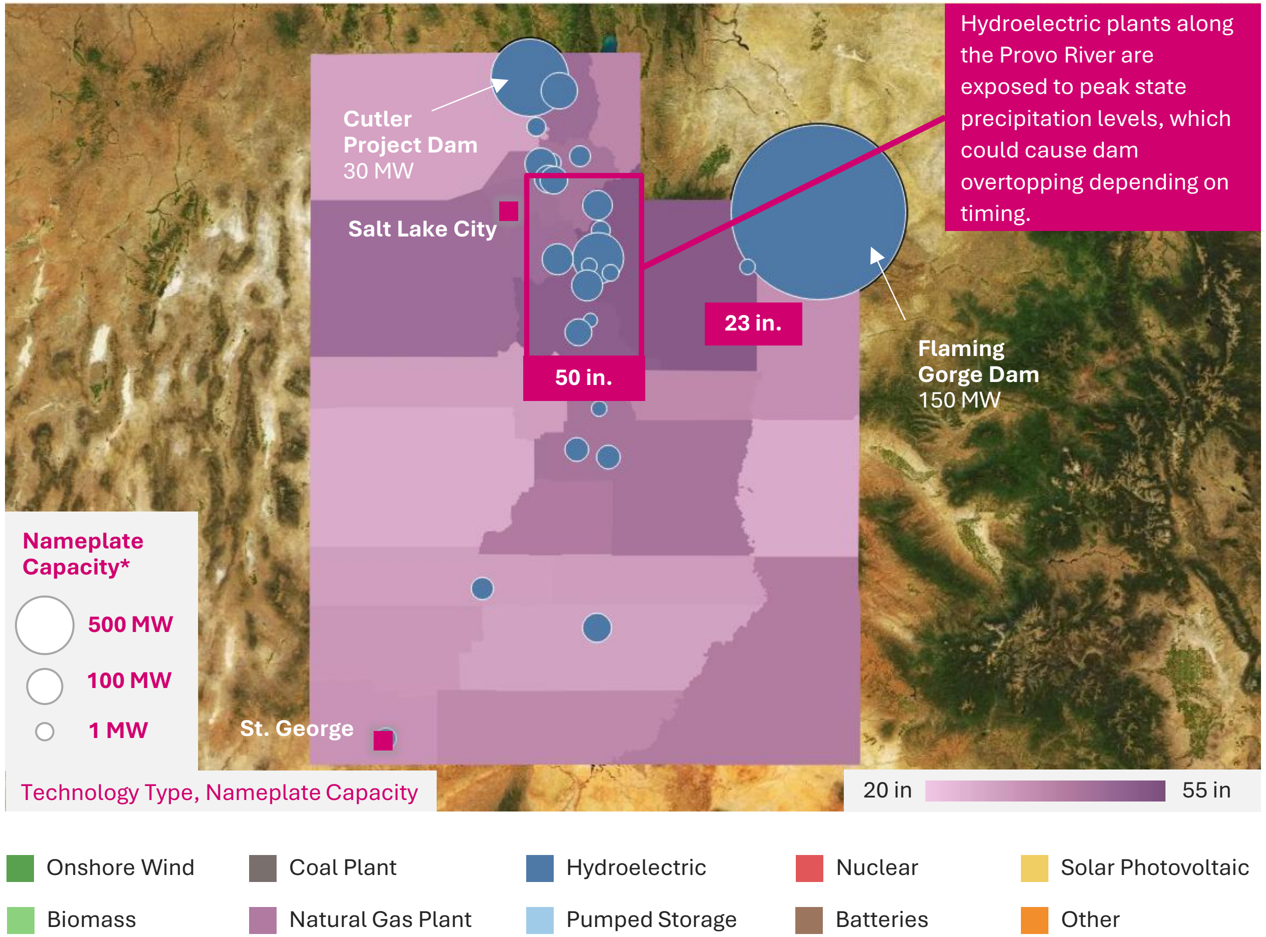
Precipitation

Asset Analysis

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

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



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 increased 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. • UOED could **establish a relationship with WEA and IGOEMR** to share information about precipitation conditions and hydro output along the Bear and Green Rivers.
Changes to Snow Patterns	• While precipitation levels are expected to increase slightly 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.**

*Generator nameplate capacities may exceed those shown in the legend

Source: ClimRR, EIA860, HIFLD

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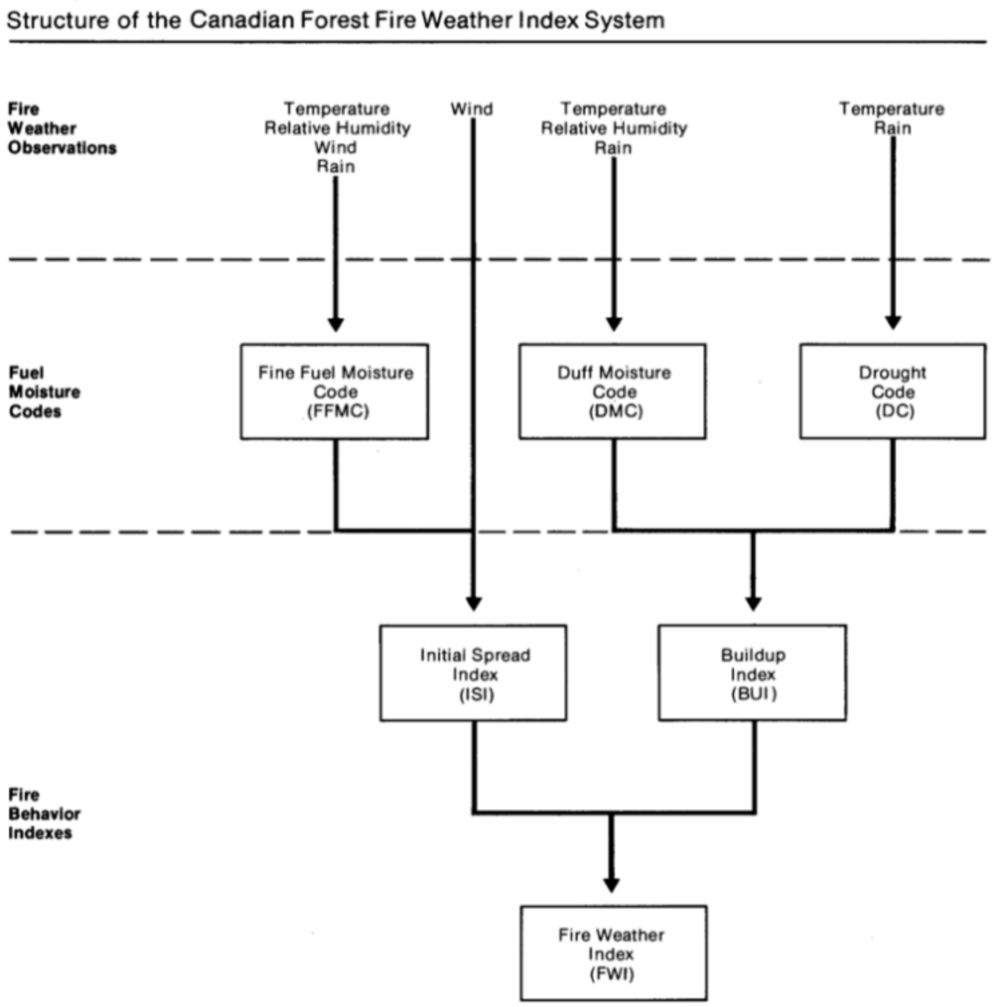
Appendix

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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