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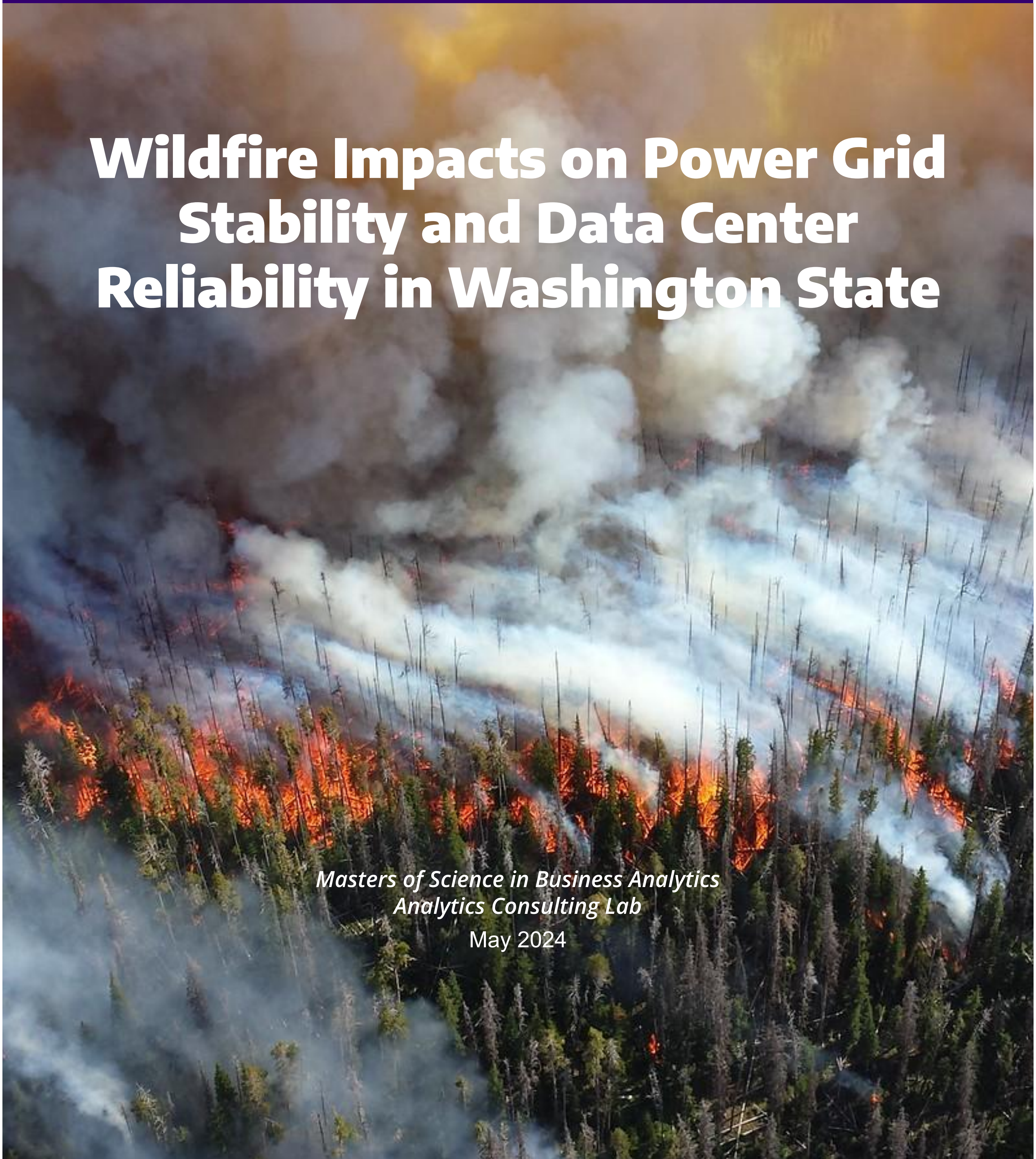

Wildfire Impacts on Power Grid Stability and Data Center Reliability in Washington State

Masters of Science in Business Analytics
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Introduction

In a world of increasing climate hazard risks, it is vital to analyze the impact of these risks on public utilities power supply, as well as the downstream effects on a wide range of supply chains. To analyze and assess this problem, we will focus on the climate hazard risk of wildfires to the supply chains of data centers.

Why analyze the impact wildfires could have on data center operations?

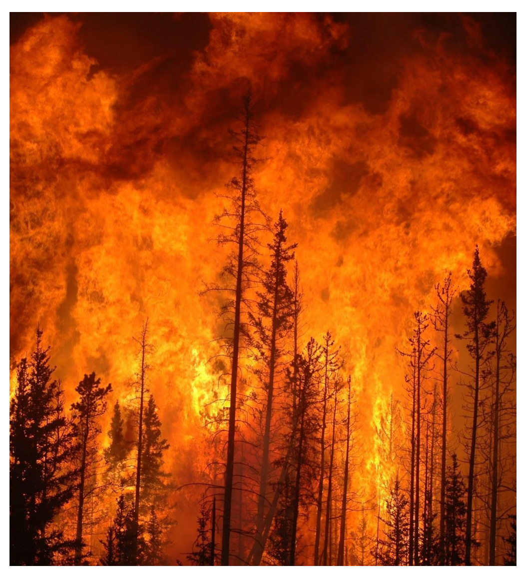
"Data centers are the new unit of compute" Jensen Huang, Nvidia CEO

Data is now an assumed part of everyday life. Any disruption to its availability can range from small-scale impacts, like a nuisance for an individual struggling to watch the latest viral video, to large-scale real-world impacts like causing downtime in the software system at a local hospital, which could inhibit the ability to access patient medical history.

A massive proportion of today's data, especially sensitive and valuable data, is housed in physical data centers. Historically, these were owned and operated by the company collecting the data stored in it, and relied on only a small amount of power. Today's world is almost entirely dominated by hyperscale facilities housing numerous stakeholders' data and requiring an ever-increasing supply of power to meet the demands of cloud computing and generative artificial intelligence. Billions of dollars are being spent in this industry to meet the increasing data demand, which in turn pressures utilities to meet these higher energy demands.

One of the biggest barriers for public utilities to meet the increased power demand is climate hazard risks, like wildfires, which not only can affect power supply but can also physically damage the infrastructure with lasting impacts. Eastern Washington is a net exporter of hydroelectric energy and has historically been considered a favorable location for data center investment due to the lower electricity costs. However, the lower costs come with an increased threat of wildfires.

This paper will examine the increasing prevalence, severity, and expense of wildfires in Eastern Washington and their downstream impacts. By not pursuing preventive risk mitigation strategies to limit wildfire disruption and damage to utilities, the state of Washington might forego an opportunity to further develop its data center industry – and the tax revenue and jobs that accompany it.



SWOT Analysis

With a growing population, the state of Washington needs a dependable energy supply to meet the increasing demand. By examining the strengths, weaknesses, threats, and opportunities of utility providers, the state can prepare for increasing climate hazard risks, especially wildfires, that pose a significant threat to the utility infrastructure in Eastern Washington.

What are the strengths and weaknesses of Washington state utilities?

Strengths:

Eastern Washington utility agencies, such as Pacificorp and the Chelan County Public Utility District (PUD), have very strong revenue streams as opposed to other public utilities across the country. In addition, there are many opportunities for them to apply to and receive state and federal grants to fund and facilitate grid resilience and modernization efforts across the state.

Because most counties rely on hydropower facilities for their energy generation, they often generate more energy than needed. The excess electricity is then sold to surrounding counties and even other states in the Western U.S. In the case of Chelan County PUD, more than 80% of their generated energy can be sold to organizations outside of their jurisdiction. Energy sales enable utility agencies to fund improvements to their grid infrastructure and diversify their means of production, all things that contribute towards the mitigation and prevention of wildfires.

Additionally, robust funding from federal level grants exists for modernization efforts through initiatives such as the Department of Energy (DOE) Grid Resilience Utility and Industry Grants' program. Since the program's inception in 2023, it has provided nearly $8B in grants for agencies to revamp their energy distribution grids to mitigate the impact from natural disasters like heat waves and wildfires (U.S. Department of Energy. n.d.).

At the state level, the Washington Department of Commerce has similarly provided nearly $13M within the last year for grid modernization and diversification efforts. This facilitated funding uniquely positions Washington utility agencies to drive needed advancements for mitigating the impact of wildfires on their distribution systems.

Weaknesses:

Since many Washington utilities rely on few hydroelectric sites, they are prone to severe energy service disruptions if one of the facilities is impacted. In 2023, the Sourdough Fire came within miles of the Lake Diablo Dam, rendering it out of commission for weeks and reducing Seattle's electricity supply by a fifth (Ryan, 2023). Utilities throughout Eastern Washington are vulnerable to these types of severe outages due to their centralized grid.

Additionally, much of the grid in Eastern Washington is vulnerable to outages during high heat events as many of the transformers and power lines are outdated and unable to withstand the higher than expected temperatures in the 21st century. This problem is exacerbated by energy lines extending into rural land identified as high risk locations for wildfires. As seen in California, Texas, and Hawaii, this combination could lead to public utility companies being the cause of wildfires if not appropriately addressed.

Another weakness public utilities face in Eastern Washington is aging hydroelectric facilities that require costly investments to maintain and upkeep. The 1943 Grand Coulee dam, which provides about 7% of that region's electricity, is in need of an overhaul to continue its operations will last years and require millions of dollars to complete (Todd, 2019). Across the state these maintenance costs on hydropower dams reduce the capacity for utility agencies to improve other parts of the energy grid and production capacities.

What opportunities and threats do Washington state utilities face?

Opportunities:

The primary opportunity for Eastern Washington utility agencies to mitigate wildfire and heat-related impacts on their infrastructure is through grid modernization.

Grid modernization consists of upgrades that can be implemented to make distribution networks more resilient to high heat, smoke, and demand scenarios. For example, burying transmission lines serves to protect the lines from heat and the impacts of smoke, and prevents them from causing fires. Other examples include increasing the amount of batteries throughout the grid, replacing transformers with newer, higher heat resiliency ones, and replacing wooden power line poles with fire-resistant metal ones. There are numerous government grants available for utility agencies to pursue these and other modernization efforts.

There are also opportunities for utilities to diversify and decentralize their grids by integrating more renewable energy systems into electric grids. Eastern Washington is well positioned to implement both windmills and solar panels because of the open landscape, consistent winds, and sunny climate. These diversification efforts would mitigate wildfire and heatwave risk by reducing the load stress on powerlines, making both the grid and energy production more resilient to outages. Grants for these diversification efforts also exist at both the state and federal level.

In terms of general wildfire prevention, there is strong support at the state level from the Department of Natural Resources (DNR) in the form of wildfire mitigation resources and detection capabilities. DNR has developed a comprehensive cohort of firefighters, land managers, utilities, and scientists to monitor wildfire threats, implement wildfire prevention and mitigation strategies throughout the state (Franz, 2019). This task force advises local agencies on how they can protect their infrastructure and resources from wildfires and on land use strategies they can use to prevent them from occurring. Utility companies can use these existing resources to implement planned outages more effectively and to prioritize grid modernization and prevention measures at the highest risk locations.

Threats:

Climate change threatens to increase wildfire severity in the state by decreasing the amount of snow, raising temperatures, and causing more storms. These climate change impacts will make wildfires spread faster, burn hotter, and grow larger (Environmental Protection Agency, n.d.). These changes serve to make wildfires far more destructive and to raise the risk for catastrophic damage to infrastructure. Additionally, the increases in both the temperature and the severity of heat wave events serves to put more stress on the already aging utility grid in Eastern Washington. High heat events impact utilities in two ways. First, they increase the load demand on the grid from downstream customers trying to keep their homes, buildings, and resources cool. And second, they reduce the efficiency and capacity of transmission lines, transformers and power plants to distribute electricity. When any of these systems are pushed past their capacity from heat or demand, they are liable to explode or fail – which itself is a dominant source of wildfires (Penn, 2024).

Another concerning impact from the increase in wildfires is that it suppresses the power generation of solar panels and can physically damage power lines. During wildfire season, much of the sky is covered in wildfire smoke for weeks at time, varying from near blackout conditions to widespread amber clouds of dust. The impact of these wildfires' emissions has been shown to decrease the amount of energy generation by at least 10% throughout the wildfire season (Cai et al.,2023). This climate impact also threatens the efficacy of solar energy in wildfire prone areas like Eastern Washington. Wildfire smoke also could prevent power lines from transporting electricity. The ionized particles from the wildfire smoke can cross or arc power lines, which prevents them from functioning, and in some this can even cause fires (Alsaeed, 2018).

What does this mean for Washington utilities?

Washington utilities, and particularly public utilities in Eastern Washington, face severe challenges in a warming world. Their transmission lines, grid design, and production sources will all need to adapt to high heat and demand scenarios to continue serving energy to the customers in a safe and reliable manner. Abundant opportunities exist in the form of renewable energy sources and new transmission technologies to make their grid resilient. However, the greatest obstacle they face is funding these adaptive and preventive measures while still expanding the resources they need to keep their aging infrastructure afloat. To achieve these funding goals, these agencies should make use of the existing incentives that exist for implementing clean energy sources and pursue government grants to implement grid modernization and diversification efforts.

Consequence Assessment

Building off the SWOT analysis on Eastern Washington utilities, we will now evaluate the short- and long-term consequences of wildfire risks to Washington state power supply and the impacts that can have on data center operations.

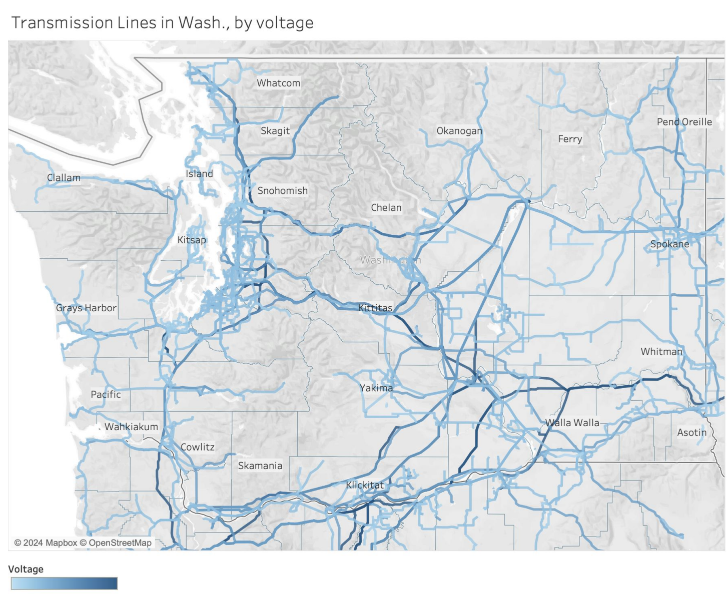
Short-Term Consequences Assessment

There are many factors of importance when considering the short-term risks posed to the power grid and public utilities by climate change-related phenomena, with severe consequences if appropriately addressed. We can consider these factors as comprising three categories, not discreet but deeply interrelated: physical, financial, and social. For the purposes of this assessment, the primary focus will be physical risk factors.

The Environment Around the Grid Infrastructure is Changing

Electricity first came to Washington state in the late 1800s (with the first hydropower facility arriving in the early 1900s), and a lot has changed since then (Foundation for Water & Energy Education, n.d.). Analyses performed by the University of Washington College of the Environment Climate Impacts Group show that "the Pacific Northwest warmed about +1.3°F between 1895 and 2011, with statistically-significant warming occurring in all seasons except for spring" (University of Washington. n.d.). It is not just past changes and temperature trends that are concerning for utilities entities – precipitation is trending down. Eastern Washington in particular, a region which has always been markedly drier and hotter than the coastal rainforest zones of Western Washington, is projected by the National Oceanic and Atmospheric Association to experience a decrease in precipitation of between 5-10% between now and the mid-21st century (Kunkel et al., n.d.). All of these trends are distressing considering the pre-existing body of research which substantiates a relationship between warmer, drier climates and increased wildfires (U.S. Global Change Research Program, n.d.). Wildfire risk assessment studies in the U.S. indicate that massive areas of land are at risk of wildfire – one 2015 study asserted that 460 million acres, mostly in the West, range from moderate to very high wildfire risk (U.S. Department of Agriculture, 2022).

Figure 1



Grid Infrastructure & Historical Wildfire Trends in Eastern Washington

At present, tremendous swaths of lands east of the Cascade Mountains are criss-crossed with power grid infrastructure, including transmission lines (see Figure 1 on the previous page) and substations. Eastern Washington, in particular, hosts numerous transmission lines with voltages well into the hundreds of kilovolts. These lines are major thoroughfares for the excess power generated by Eastern Washington utilities that is sold to Western Washington consumers (Esri, n.d.). For context, in a typical year, Western Washington utilities providers like Seattle City Light and Puget Sound Energy purchase between 30% and 60% of their energy from Eastern Washington hydroelectric dams like Priest Rapids, Rocky Reach, and others (Chelan Public Utility District, 2023).

Risks to grid infrastructure, which were once remote, now seem to increase in likelihood each year. Studies cited by the Washington Department of Ecology show that in the Western U.S., “the number of large fires has doubled between 1984 and 2015”. (U.S. Global Change Research Program, 2017). Even more alarmingly, “projections show that an average annual one degree Celsius rise in temperature may increase the area burned in a typical year by as much as 600 percent.” (U.S. Department of Agriculture, 2012). From a WA Department of Natural Resources dataset recording wildfires from 1973-2023 (Washington State Department of Natural Resources, 2023), we can observe that there is a clear concentration of fire activity east of the Cascade Mountains (Figure 2). Incredibly, of the 630 fires recorded between 1973 and 2023 which burned over 300+ acres, over 90% were recorded after 2000. For a geographic representation of these fires, as well as an overlay showing their locations relative to power grid infrastructure and a county-level breakdown of FEMA’s Wildfire Risk Index, see Figure 3 on the next page (The Federal Emergency Management Agency, 2024).

What does this mean for producers and providers of electricity? The short answer is increased risk, increased responsibility, and increased cost. Most utility providers in Eastern Washington are quasi-governmental entities or cooperatives called Public Utility Districts (PUDs). Unlike investor-owned utilities, these PUDs have an elevated social responsibility to provide cheap and reliable energy to the communities in their service areas. These responsibilities include ensuring that physical infrastructure is well-maintained and that concerted efforts are taken by the utilities entities to mitigate any factors under their control that contribute to wildfire risk. Efforts may encompass wildfire preparedness practices like vegetation management, investment in costly infrastructure improvements like line hardening or undergrounding and shutting down or limiting power when circumstances are conducive to wildfire ignition (Washington State Utilities and Transportation Commission, 2022). .

Figure 2

Large Fires (300+ acres) in Washington, 1973 - 2023

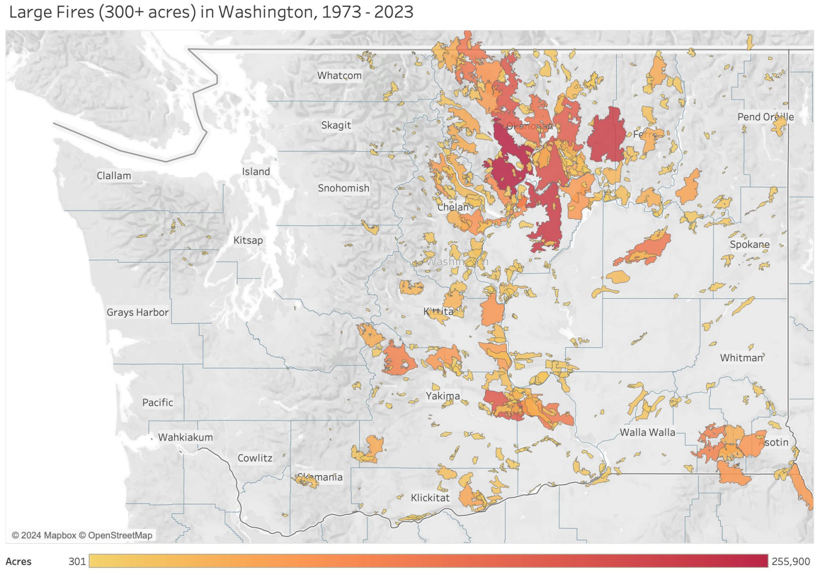
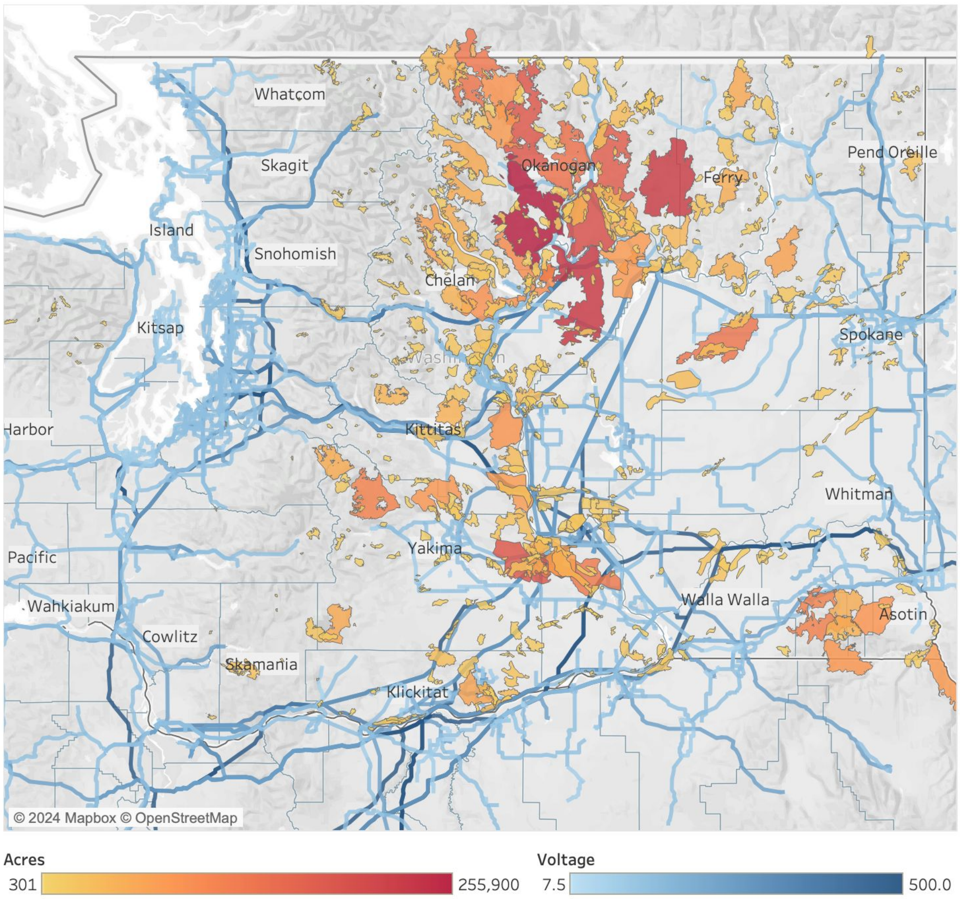


Figure 3

Grid Infrastructure, Historical Wildfires & FEMA Risk Ratings

PNW Transmission Lines and Major Fires (300+ acres) between 1973-2023



County-Level FEMA Risk Rating

County	
Adams	Relatively Low
Asotin	Relatively Low
Benton	Relatively Moderate
Chelan	Relatively High
Clallam	Very Low
Clark	Very Low
Columbia	Relatively Low
Cowlitz	Very Low
Douglas	Relatively Moderate
Ferry	Relatively Moderate
Franklin	Relatively Low
Garfield	Relatively Low
Grant	Relatively Moderate
Grays Harbor	Very Low
Island	Very Low
Jefferson	Very Low
King	Relatively Low
Kitsap	Very Low
Kittitas	Relatively High
Klickitat	Relatively High
Lewis	Very Low
Lincoln	Relatively Moderate
Mason	Very Low
Okanogan	Relatively High
Pacific	Very Low
Pend Oreille	Relatively Low
Pierce	Relatively Low
San Juan	Very Low
Skagit	Very Low
Skamania	Relatively Low
Snohomish	Very Low
Spokane	Relatively Moderate
Stevens	Relatively Moderate
Thurston	Very Low
Wahkiakum	Very Low
Walla Walla	Relatively Low
Whatcom	Very Low
Whitman	Very Low
Yakima	Relatively High

Learning by Example: The Consequences of Inaction

Recent catastrophic fires across the Western U.S. provide stark examples of what kind of damage can be caused by utilities companies' failure to mitigate risks appropriately.

The Smokehouse Creek Fire, which burned over one million acres between February 26th, 2024 and March 16th, 2024, is the largest recorded fire in Texas history (Asch, 2024). The 2023 wildfires in Maui, Hawaii, killed over 100 people and caused over $5 billion in damage (*Preliminary After-Action Report: 2023 Maui wildfire*, n.d.). California's 2018 Camp Fire claimed more than 19,000 homes and destroyed the entire town of Paradise (Fire.ca.gov, n.d.). All three of these wildfires have one thing in common, the initial sparks were caused by poorly-maintained utilities infrastructure: decaying poles, downed power lines, and overgrown vegetation.

Industry regulation is moving in the right direction. In 2016, the Federal Energy Regulatory Commission published Electric Reliability Standard FAC-0034, which mandates that "each utility develops and implements its own tree trimming or vegetation management plan" (*Transmission line vegetation management,* n.d.) This standard applies to high-voltage transmission lines over 200kV, as well as some between 100-200kV. Failure to adhere to FERC standards opens utilities companies up to civil suits – which the utilities companies associated with the above wildfires are now all navigating. In the case of the Camp Fire, Pacific Gas & Energy (PG&E) filed for bankruptcy in early 2019 due to incurring over $30 billion in civil liabilities related to the fire (Wamsley, 2019).

In Washington state, inaction could have severe consequences. If the condition of the physical infrastructure isn't monitored and maintained, any of the high-voltage transmission lines which run through counties in Eastern Washington are capable of igniting wildfires under the right weather conditions. And climate change trends in the state increase the risk that these ignitions could create catastrophic wildfires. The five counties in Washington which FEMA has designated at a relatively high risk of wildfire (*National Risk Index*, n.d.) – Chelan, Kittitas, Klickitat, Okanogan, and Yakima – have a combined population of almost 450,000 individuals (US Census Bureau, 2023), in addition to contributing over $25 billion to Washington state's GDP in 2022 (Stacker, 2023).

The Cost of Doing Business: Tradeoffs in Wildfire Risk Mitigation

There are some less quantifiable "costs" associated with wildfire risk mitigation, such as preventative shutoffs. In California, Pacific Gas & Energy made headlines when phased public safety power shut offs were implemented due to increased wildfire risk. Nearly 750,000 businesses and homes in Northern California – millions of customers – had their power preventatively shut off by PG&E for two days in October 2019 (Gorman, 2023). It is not just "non-essential" customers impacted; schools, traffic signals, businesses, governmental entities, grocery stores, and even hospitals experienced power interruptions. Those without backup power generators had no choice but to wait for PG&E to determine the weather risks had abated enough to restore service. A preventative shutoff from even one utility entity in the wildfire-prone counties in Central Washington could result in service interruption to hundreds of thousands of customers, both residential and commercial.

Mini-Case Study: Chelan County

As we will focus on Chelan County for a data center-centric case study later in this report, let's consider general short-term risks in this area. Chelan County PUD's 2022 annual report states that:

> *In 2021, as part of the wildfire mitigation program, the PUD began implementing an operational change in fire-prone areas to reduce risk of electrical equipment causing sparks during wildfire season. The utility expanded these operational changes into other fire-prone areas in 2022, including Antoine Creek near Chelan, upper Blewett Pass and Colockum. These changes are consistent with industry best practices and strive to balance electrical reliability and the safety of workers, the public, and the communities the PUD serves.*

Chelan County has a population of almost 80,000 and contributed $6 billion to Washington's GDP in 2022. Their three hydropower generation facilities provide power not only to the county, through Chelan County PUD, but also to many others through their contract with Puget Sound Energy. Chelan County PUD owns and manages over $168 million in transmission-specific assets as of January 1, 2023 (Public Utility District No. 1 of Chelan County, 2023). Under low-humidity, high-wind conditions, neglect of or damage to these transmission-specific assets could easily cause a wildfire, which would likely result in extensive damage to both public and private property (especially if ignition occurred in or near a developed area such as Wenatchee), significant lost revenues – one single day lost could cost the company $1.5 million in lost revenue – and even loss of life. From a more holistic perspective, Chelan's overall economy is largely driven by tourism and energy production (*Chelan County Spotlight – Washington State Association of Counties*, n.d.) industries which could both suffer drastic hits from wildfire damage. Even Chelan's lucrative winemaking industry could be impacted – in the aftermath of 2020 wildfires in California and Oregon, winemakers reported over $3.7 billion in losses from "smoke-tainted" batches of wine (Savin, 2023).

Short-Term Consequences: Closing Remarks

Grid modernization requires massive capital outlays. Fortunately, federal grants can help offset these costs – in 2023 alone, three PUDs in Washington state received almost $70 million in federal funding, specifically from the Department of Energy's Grid Resilience and Innovation Partnerships Program, for wildfire-based grid modernization (Savin, 2023).

Although some of the costs of wildfire mitigation (e.g., lost revenue from preventative shut offs) are less avoidable than others (e.g., capital expenditure for the portion of modernization projects which the federal government can't or won't subsidize), Washington state PUDs are setting themselves up for longer-term success by investing in grid reliability and wildfire resilience. But what factors must these entities consider when planning for the needs of future generations of utilities customers?

Long-Term Consequences

To expand on the physical short-term consequences detailed before, this section analyzes the long-term impact of wildfires by expanding the lens to social and financial implications.

Wildfires in the United States have seen a notable increase over the past three decades, resulting in significant environmental, health, and economic impacts. The average annual acreage burned by wildfires has more than doubled since the late 1980s, reaching about 8 million acres per year between 2017 and 2021. This increase has been attributed to several factors, including climate change, land management practices, and the expansion of the wildland-urban interface. Hotter, drier conditions due to climate change have made vegetation more susceptible to ignition, leading to longer and more severe wildfire seasons (Risk Factor, 2023).

Economic

The economic costs of wildfires are substantial, with federal spending on wildfire suppression averaging $2.5 billion annually between 2016 and 2020 (Campbell, 2022). This spending includes direct firefighting costs as well as indirect costs such as health care for smoke-related illnesses and loss of revenue from federal timber sales. The adverse impacts of wildfires extend beyond immediate firefighting efforts, affecting health care, agriculture, and military operations. Despite efforts to mitigate wildfires through forest management practices, the increasing frequency and intensity of wildfires underscore the need for comprehensive strategies to address the complex challenges posed by wildfires in the United States.

Environmental

The environmental effects of wildfires are extensive, particularly in the immediate vicinity of the burned areas. Smoke and air pollution from wildfires can travel long distances, impacting air quality and exacerbating respiratory conditions for individuals. Additionally, wildfires can lead to soil erosion, water contamination, and changes in vegetation that can persist for several years. The increase in carbon dioxide emissions from wildfires also contributes to climate change, further exacerbating the conditions that lead to wildfires.

Social

Lower-income populations are disproportionately affected by the impacts of wildfires, facing heightened risks to their health, safety, and economic well-being (.Int J Environ Res Public Health, 2021). These communities often lack the resources to mitigate their exposure to wildfire smoke, such as access to indoor air filtration systems or the ability to evacuate to cleaner air during fire events. As a result, individuals with preexisting respiratory and cardiovascular conditions, older adults, children, pregnant people, and developing fetuses are at increased risk of adverse health effects from wildfire smoke. Additionally, lower-income individuals may be more likely to work outdoors, increasing their exposure to smoke during fire events. The economic impacts of wildfires can also be more severe for lower-income populations, who may struggle to recover from the loss of homes, possessions, and livelihoods. Access to affordable insurance coverage can also be a challenge for these communities, leaving them financially vulnerable in the aftermath of a wildfire.

Climate change already has profound and lasting effects on our world, as is particularly evident with the increasing frequency and severity of wildfires. Wildfires are the leading contributor to air pollutants in Washington state and may impact future generations. In addition, the drying out of forests due to higher temperatures coupled with longer droughts that are exacerbated by rising vapor pressure deficits (VPD) can makes forests more susceptible to ignition and rapid spread of wildfires, leading to devastating impacts on ecosystems, communities, and economies.

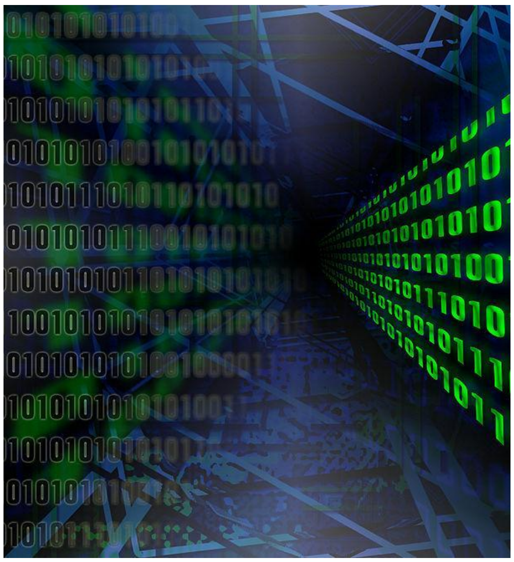
The long-term consequences of these trends are alarming. Continued rises in VPD and temperatures are projected to further escalate wildfire risks. From 1984 to 2015, human-caused climate change contributed significantly to increased VPD in western US forests, nearly doubling the total burned area during this period. This trend indicates the urgency of reducing emissions to mitigate climate change's effects while highlighting the necessity of adapting to our changing climate reality (Philips, 2023).

To combat these challenges, strategies like prescribed burning around communities and at the wildland-urban interface are being increasingly utilized to reduce wildfire risks. However, these efforts must be accompanied by broader actions to address the root causes of climate change. This includes transitioning to renewable energy sources, implementing sustainable land management practices, and reducing overall carbon emissions. Only through comprehensive and concerted efforts can we hope to minimize the long-term consequences of climate change on our forests and communities.

Compound Impacts on Data Centers

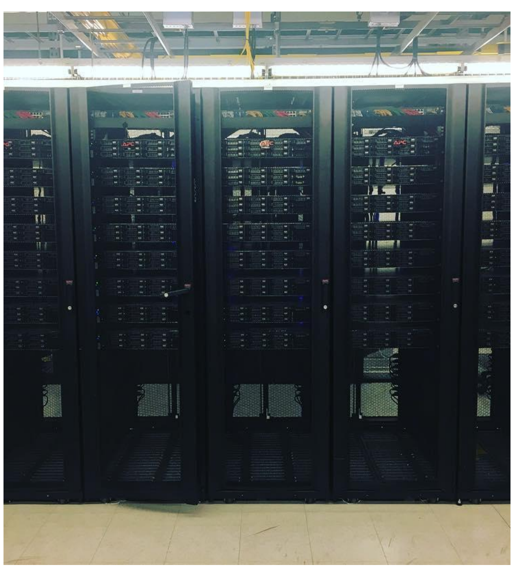
According to the 2024 Allianz Risk Barometer, business interruptions, natural catastrophes, and fire-related risks to supply chains are top risks faced by companies (Allianz, 2024). By evaluating the impact wildfires can have on data centers, stakeholders can take preventative actions to fortify existing facilities and strategically select new locations.

How can wildfires impact data center operations?



Data has grown into one of the most important resources companies use to conduct business, and any disruption in its availability could prove disastrous. Due to data center outages in 2021, it is estimated that "Amazon lost $34M in revenue, Facebook lost $100M in revenue, and Alibaba lost $1B in revenue" (Moore, 2023).

The primary causes for data center disruptions are human error, uninterruptible power supply system (UPSS) and power failure, and cooling system error (Moore, 2023). While the data center industry is fairly comparable to the investment real estate industry – with companies renting space and outsourcing most of the operational responsibilities – it differs in the ultimate needs of companies. Instead of concerns related to square feet, the primary concerns of companies for data centers is reliable power and connectivity, scalability, flexibility, and speed to market. Since almost half of all data center downtime is tied to UPSS and power failure and one of the primary needs for companies is reliable power and connectivity, the need for exhaustive analysis on rising climate related risks, especially the increased threat of wildfires, is crucial for long term sustainability of data center operations.

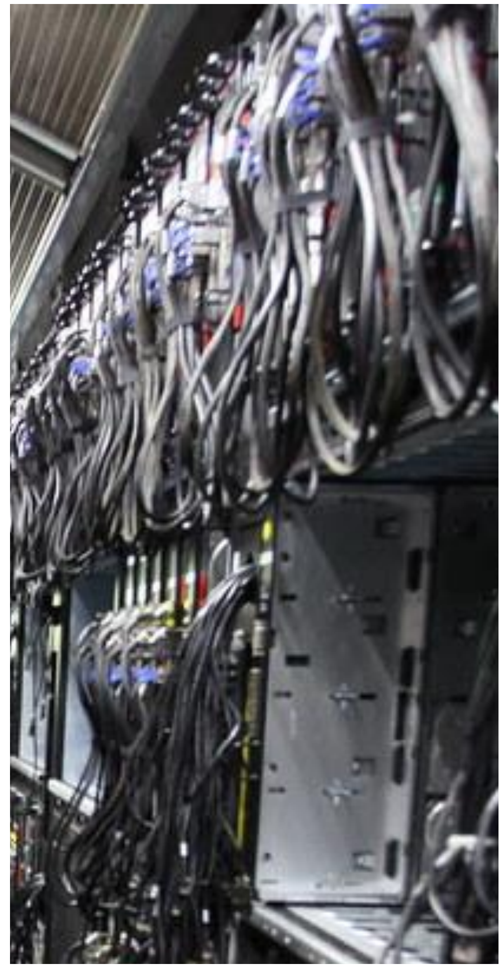


Traditionally, data centers were located at the physical location of the company or in colocation centers. The retail colocation facility uses a smaller portion of energy and might house the data of a small healthcare company. The wholesale colocation facilities use slightly more energy and might contain, for example, the data of a mature financial institution.

Today, the most common type of new data center being built is the hyperscale facility which uses a massive amount of energy and is primarily owned and operated by the major technology companies. These facilities will continue to grow in size and scope as companies continue to transition to cloud computing and integrate generative artificial intelligence into their business.

Regardless of size and scope, these facilities and companies' assets can be worth billions of dollars, so risk mitigation efforts are paramount when evaluating new locations or enhancing existing ones.

For example, Amazon just announced a $150 billion dollar investment in data center expansion to keep up with data storage demands of cloud computing and increasing consumption necessitated by the growth of generative artificial intelligence (Day, 2024). While Amazon might have greater needs than the average company, this provides an example of the magnitude of capital companies are willing to invest today for scalability and speed to market in this area – and it's only expected to increase over time.



With the steady growth and reliance on immediate data availability and storage, data center energy consumption is proving to be a massive challenge for users. Across the world, data center energy demand accounts for about 1-1.5% of global electricity use and will only continue to grow (International Energy Agency, n.d.). Around 30% of the data centers in the world are located in the United States (Dagle, 2021) and, in 2019, roughly 70% of internet traffic was housed in Northern Virginia with a heavy reliance on "dirty" electricity sources like coal, petroleum and natural gas (Monserrate, 2022).

In an effort to decentralize data center locations, companies are looking for locations with low climate hazard risks and electricity costs. This has led to new data centers to be built in close proximity to hydroelectric facilities or even nuclear power plants due to the massive amounts of electricity produced and fairly low costs. For example, Umatilla County, Oregon, has become a favorable spot for data centers due to low electricity costs from hydroelectric power, favorable tax structures, and low climate risks. Sabey, a commercial real estate company, is building a $950 million data center there which is expected to open in 2027 (Rogoway, 2023). Due to the explosion of data center facilities in the northwest, electricity demand is expected to grow 30% in the next decade (Baumhardt, 2024) so utility companies will need to adjust supply planning to meet this increased demand. We will further analyze these trends by conducting a case study on Chelan County.

Case Study: Power Loss and Data Centers in Chelan County, WA

Using Chelan County as an example, we'll explore the potential impacts that wildfire-caused power grid disruptions might have on data center operationality. Chelan has three generation stations, all hydroelectric: Rocky Reach, Rock Island, and Lake Chelan. The generation figures for 2023 are shown below (Chelan County Public Utilities District):

Generation Station	***Net Power Delivered (in 000 MWh)***	***As % of total***
Rocky Reach System	4,790	65.3%
Rock Island System	2,218	30.2%
Lake Chelan System	333	4.5%

In fiscal year 2023, 211,000 MWh – over 10% – of the retail energy sold by Chelan PUD was to customers designated as "high density load/cryptocurrency", which encompasses both data centers and bitcoin/crypto mining operations.

Considering that only eight of Chelan County PUD's 51,284 customers are designated in this category, the energy usage is staggering. Extrapolating from the table before, let's assume that:

Generation Station	***Power used by "high density load/cryptocurrency" customers in 2023 (in 000 MWh)***	***As % of total energy produced by station in 2023***
Rocky Reach System	137.8	2.9%
Rock Island System	63.7	2.9%
Lake Chelan System	9.5	2.9%
Total	211	8.7%

Based on the above assumptions and calculations, almost 9% of the energy produced by Chelan County's three hydropower facilities is consumed by data centers and bitcoin/crypto mining operations – which make up **less than 0.02%** of their customer base.

Assuming even distribution throughout the year (an extreme simplification for the purposes of exploratory analysis), the high density load customers consumed approximately 578 MWh per day, and generation figures per day are as follows:

Generation Station	***MWh generated per day***
Rocky Reach System	13,123
Rock Island System	6,076
Lake Chelan System	912
Total	20,111

Using the 2023 Sourdough Fire (Whatcom County, WA) as an example (KUOW, 2023), we see that the forced evacuation of a power generation facility can result in total loss of energy produced by that station until it can be safely staffed and operated again. Whatcom is rated by FEMA as having a "very low" wildfire risk designation, whereas Chelan is rated as "relatively high".

Let's consider six scenarios for power loss. Typically, the high-density load/cryptocurrency customers would be using around 3% of total MWh produced daily by all three sites. However, in these circumstances we can see them using up to 8% of total MWh produced daily if just one site goes offline. These numbers can jump up dramatically in the event of two sites being taken out. Rocky Reach and Rock Island are geographically close and could conceivably be impacted by the same wildfire event (Scenario #4). In the event that both of these generation facilities were taken offline at the same time, MWh used by high density load/cryptocurrency customers could make up as much as 63% of total output:

Scenario	*Total daily energy (no shutdown)*	*Reduction (in daily MWh)*	*Output (in daily MWh)*	*Daily MWh used by HDL/crypto customers*	*As % of total available output*
Scenario #1: Rocky Reach shutdown	*20,112*	(13,123)	6,989	*578*	8%
Scenario #2: Rock Island shutdown		(6,077)	14,036		4%
Scenario #3: Lake Chelan shutdown		(912)	19,200		3%
Scenario #4: Rocky Reach and Rock Island shutdown		(19,200)	912		63%
Scenario #5: Rocky Reach and Lake Chelan shutdown		(14,036)	6,077		10%
Scenario #6: Rock Island and Lake Chelan shutdown		(6,989)	13,123		4%

From a financial perspective, the losses are significant. Total average daily revenue for Chelan County PUD was $1,514,534 in 2023. Shutdown of one site could result in a reduction to revenue of up to 28%, and multiple sites going down at once (again, Rock Island and Rocky Reach are geographically close and a dual shutdown is feasible) could result in losses of up to 46%:

Scenario	*Total daily revenue (no shutdown)*	*Reduction (in daily revenue)*	*Total daily revenue (with shutdown)*	*% change in revenue*
Scenario #1: Rocky Reach shutdown	*1,514,534*	(276,981)	1,237,553	-18%
Scenario #2: Rock Island shutdown		(420,416)	1,094,118	-28%
Scenario #3: Lake Chelan shutdown		(29,175)	1,485,359	-2%
Scenario #4: Rocky Reach and Rock Island shutdown		(697,397)	817,137	-46%
Scenario #5: Rocky Reach and Lake Chelan shutdown		(306,156)	1,208,378	-20%
Scenario #6: Rock Island and Lake Chelan shutdown		(449,592)	1,064,942	-30%

For the data centers served by Chelan PUD, the consequences aren't any less severe. A 2018 study by Uptime Institute (Lawrence, 2018) surveyed over 1,000 data centers on service interruptions – 36% of which were caused by power outages – and found that the costs can be astronomical. Over a third of respondents reported that the outage cost over $250,000 and in the case of thirty-nine respondents, the cost was over $1 million.

Data centers are equipped with both backup generators (traditionally diesel-fueled (Coulston, 2023)) and backup power systems called *uninterruptible power supply systems*, or UPSS, which are powered by batteries. It is increasingly common for UPSS to be powered by lithium-ion batteries, which despite boasting almost twice the longevity of a traditional valve-regulated lead-acid (VRLA) battery, come with their own unique set of risks and challenges (EATON, n.d.), including – ironically – increased fire risk due to the high combustibility.

By themselves, the UPSS are unlikely to keep the power on for more than 30 minutes to an hour – their purpose is largely to ensure that data centers don't experience a hard crash, giving the operators time to switch over to backup generator power – but in conjunction with a backup generator they are able to provide power for even extended utilities outages (Kohler, 2023). Unfortunately, it is not uncommon for UPSS to fail (especially VRLA battery-powered UPSS) due to age or failure to provide adequate maintenance.

We can think of utility interruptions to a data center as having multiple phases or waves of impact – the first phase being risk of UPSS failure during switchover to backup power and the second phase being direct downtime costs. But what is even more alarming is considering the compound impacts that can occur from service interruptions. How might a service interruption to any of the data centers in Chelan County impact the customers of those data centers?

Let's look at some examples. In September 2023, a Microsoft-owned data center in Australia went offline, resulting in interruptions to Azure cloud service and multiple applications (Ghoshal, 2023). In October 2023, a data center outage in Singapore resulted in 2.5 million Citibank transactions failing to be completed, including payments and ATM withdrawals (*A history of AWS cloud and data center outages*, 2024). Notably, both of these outages were due to overheating, which is a serious concern especially in the switchover window between utility power and backup power because UPSS are typically not powerful enough to provide essential cooling to the data center. In 2021, a data center outage in Virginia resulted in Workday and Canvas going completely down (Deja, 2023). And just last month, a data center outage resulted in interruptions to 911 emergency call services in all of South Dakota and parts of Texas, Nebraska, and Nevada (Lipscombe, 2024).

The customers impacted by data center outages aren't just online retailers and productivity apps. In Chelan County, data centers are owned by entities as massive as Blackrock (Miller, 2012) and Microsoft (Gonzalez, 2023), which through Azure OpenAI recently partnered with the widely-used healthcare IS software Epic (Beatman, 2023). Hospitals, emergency services, and major financial institutes could all be disrupted. Extended outages due to shutoffs – whether preventative, emergency, or due to fire damage – could have devastating economic and social effects.

Historically, data centers have sought property in Eastern Washington due to low property costs and dependable, affordable energy due to the prevalence of hydropower. On a longer time horizon, this region is starting to look less and less attractive as wildfire risk increases and energy costs shoot up to accommodate the mitigation, modernization, and infrastructure costs PUDs across the state are absorbing. Socioeconomically, this is not great news for the communities in which they're interested. Although data centers are frequently criticized for their carbon footprints and the caliber of their energy usage, they also bring massive amounts of tax revenue and significant employment opportunities to the areas in which they are developed. The U.S. Chamber of Commerce estimates that in the construction phase, a typical data center will provide over 1,600 local jobs and $77.7 million in local wages; and during the operation phase, over 150 local jobs, $7.8 million in local wages, and over $1 million in local tax revenue annually (Day & Pham, 2017).

Based on the case of Chelan County PUD and its data center customers: short- and long-term wildfire mitigation, grid modernization, and infrastructure improvement are critical to reducing property damage and economic loss and ensuring the region remains an attractive real estate investment for high-density load customers.

In addition to the energy consumption concerns as defined in the Chelan County case study, any sort of physical damage to the data center infrastructure could affect operations. As climate hazard risks increase due to climate change, data center location and resiliency is key. While a data center might not be located in a high wildfire risk area, the fiber connectors could be destroyed or power supply could be disrupted thus affecting the operations of the data center which then would affect the end-user downstream. In an ever expanding cloud environment, any sort of disruption or delay of data availability could result in major real-world complications.

From the workforce perspective, data centers require a specialized work force to maintain operations, especially the cooling systems which are crucial to a data center running effectively. So if wildfires cause evacuations or limit employees' ability to access the facility, this could also impact the data center operations resulting in downstream effects. Because of this heavy reliance on cooling systems, like HVAC or massive amounts of water, data centers are taking drastic measures like building facilities underwater to potentially naturally cool these facilities (Nield, 2023).

Compound Impacts: Closing Remarks

In conclusion, by analyzing the risks wildfires can have on data center operations, companies can make informed decisions and plans for the longevity of their data storage. Based on our analysis and the case study on Chelan County, while Eastern Washington seems like a strategic choice for data centers due to its close proximity to hydroelectric energy production and low costs, companies should be cautious when building new facilities in this region due to the increased wildfire risks posed there. Going forward, data centers will need to transition towards more sustainable energy sources to decrease the direct impact they have on the same climate related risks they are trying to mitigate.

Conclusion

Many entities recognize the critical nature of adapting stringent and pervasive risk mitigation strategies to combat the growing risks of wildfire hazards. From 2017 to 2021, the average annual acreage burned by wildfire in the U.S. was 68% greater than the yearly average from 1983 to 2016. The need to implement mitigation strategies becomes more and more pressing as time progresses, and many entities have looked to take on significant actions to address this issue.

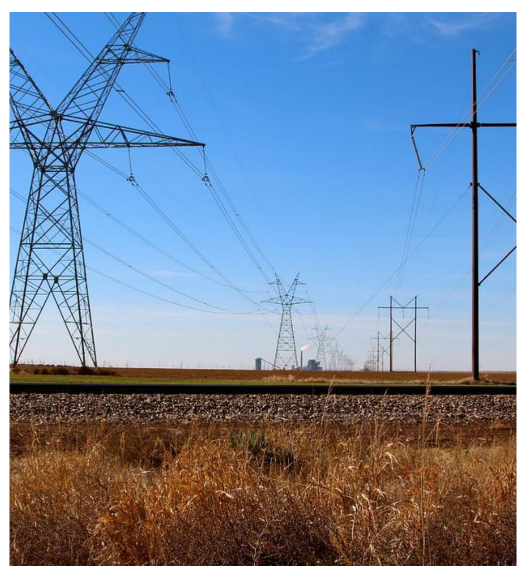
Practical Recommendations for Risk Mitigation and Adaptation Strategies

Infrastructure Improvements

Infrastructure improvements allow pre-existing buildings to adapt in the short-term against the threat of wildfires. Building materials play a key role in a buildings' susceptibility to wildfires. Combustible exterior walls such as timber increases burn probability by 25%. Replacing materials such as timber with non-combustible or ignition resistant siding, especially for the first 6 inches from the ground, significantly cuts down the risk of immediate burn. Installing ember-resistant vents is another common risk reduction strategy, and it is advised that other infrastructure improvements could include installing Class A rated roofing, clearing nearby debris, and hardening external infrastructure such as decks and fences (Risk Factor, n.d.).

Vegetation Management

Vegetation management is crucial in reducing the risk of wildfires. Vegetation within 50 ft of a building provides fuel and increases burn probability by up to 50% (Risk Factor, n.d.). Additionally, trees and other vegetation growing too close to power lines can lead to power outages and potentially cause sparks. Programs like PSE's Vegetation Management regularly inspect and trim or remove hazardous trees and vegetation near power lines, mitigating the risk of fire (Puget Sound Energy, n.d.).



System Hardening

System hardening projects are essential for improving the safety and reliability of the electric system. These projects involve replacing and upgrading equipment such as poles, wires, and transformers. In areas of high wildfire risk, special measures like installing "tree wire" (specially-coated overhead wire) are taken to reduce the likelihood of vegetation-related fires. Additionally, installing electrical devices that provide greater operational flexibility enhances the system's ability to respond to fire risks. Strategic undergrounding of power lines is also considered to reduce wildfire risks, improving overall resiliency and reducing the impacts of Public Safety Power Shutoffs (PSPS) in high-risk areas. Enhanced power line settings (EPS) are another critical measure, making the electric system more sensitive to potential hazards and automatically shutting off power when wildfire risk is high, reducing the risk of wildfire spread.

Eastern and Central WA 20 Year Forest Health Plan

In response to the forest health crisis leading to catastrophic wildfires, Washington state has initiated a 20-Year Forest Health Strategic Plan. With over 2.7 million acres of unhealthy forest in central and eastern Washington, the plan aims to restore 1.25 million acres to healthy conditions, enhancing fire resilience and protecting communities. Led by the Commissioner of Public Lands, Hilary Franz, the plan, grounded in science, is an unprecedented collaboration among more than 33 organizations and agencies since 2017. By actively managing forests through strategies like prescribed burns and thinning, the plan seeks to restore forests to a more natural and resilient state. The Forest Health Treatment Tracker, launched in 2021, maps planned, completed, and in-progress treatments, providing transparency and illustrating the scale of restoration efforts. Through partnerships and strategic planning, the state is working towards a future where forests are safer, more productive, and better protected against wildfires (Washington State Department of National Resources, n.d.).

Washington state AI-powered Wildfire Detection System

The Washington Department of Natural Resources is leveraging artificial intelligence through a wildfire detection pilot program to enhance its real-time response to fires. This initiative integrates video feeds from nine ultra-high-definition, 360-degree cameras equipped with AI tools from Pano AI, a disaster-preparedness technology provider. These AI cameras, powered by satellite data, can swiftly pinpoint the location of smoke or fire as soon as it ignites, enabling rapid transmission of this information to firefighters over T-Mobile's 5G network, even in remote areas. The system has already proven its effectiveness, aiding the department in its initial response to several fires, including the significant Crater Creek fire that burned over 5,000 acres across Canada and Washington state. Washington plans to further bolster its wildfire detection capabilities by installing three additional Pano AI cameras in summer of 2024 (Quinlan, 2023).

Starlink Wildfire Early Detection

In addition to the Pano AI-powered cameras, the Washington Department of Natural Resources is employing Starlink satellite packages, an expanded radio repeater network, portable cell towers, and other resources to ensure connectivity for firefighters and incident command management systems. Commissioner of Public Lands Hilary Franz emphasized the importance of early detection, stating that "every second counts" in wildfire response. Enhanced early detection through technologies like Pano AI enables faster response to small fires, ultimately saving lives, properties, and reducing costs, which is crucial as wildfire seasons become more prolonged and challenging (Bennett, 2023).

Data Center Strategies

Data centers are at the forefront of processing and storing vast amounts of data, but they also face the challenge of doing so sustainably. Efficient power usage, renewable energy adoption, and water management are crucial components of sustainable data center design. Tech giants like Facebook, Apple, and Google have committed to using 100% renewable energy for their data centers, with some investing directly in new renewable energy sources. Tidal power is emerging as a reliable alternative due to its predictability. Managing water consumption and implementing recycling measures are also essential to reduce the strain on local water resources. Resilience to extreme weather events, which are becoming more frequent due to climate change, is another key consideration. Data center designers must choose locations and implement disaster recovery plans for potential impacts such as floods, droughts, and other climate-related events. By adopting these sustainable practices and enhancing resilience, data centers can meet the digital age demands and lead in clean, efficient technology (Malone & Higgins, n.d.).

Reducing the Carbon Footprint of Data Centers

Minimizing the carbon footprint of data centers is a critical goal in the face of their significant energy consumption and contribution to greenhouse gas emissions. Data centers currently consume 1% to 3% of global electricity, a figure expected to rise to 3% to 8% by 2030. The reliance on grid electricity, often derived from fossil fuels, directly impacts their carbon footprint. To address these challenges, organizations can implement energy-efficient hardware and software, utilize renewable energy sources like solar or wind power, and improve cooling systems to reduce energy consumption. Building data centers in cooler climates and implementing innovative design strategies can also help minimize their environmental impact. These efforts are crucial in mitigating the growing carbon footprint of data centers and combating climate change (Earls, 2023).

Closing Remarks

As a companion piece to this paper, we have built a data story on Tableau Public to visualize the relationship between historical and forecasted wildfire risk, Washington state grid infrastructure, and data center geolocations. All GIS data was publicly sourced from:

- Washington State Department of Natural Resources
- Federal Emergency Management Agency
- United States Energy Information Administration
- United States Environmental Protection Agency

...and an Overpass API query executed by Dr. Phillip Bruner of the University of Washington Foster School of Business Climate Risk Lab.

Forecasting

We used a Vector Autoregression (VAR) model to analyze the relationship between wildfire severity and Washington's various EPA-designated ecological zones, or "ecoregions". With this model we were able to predict fire risks across the state with wildfire data from just a few regions. Given the stochastic nature of wildfires this type of modeling is invaluable in providing comprehensive risk assessments across the state. Future researchers could improve on this model by including wind speeds, temperature and rainfall data for each region or using AI to create more accurate ecoregion clusters from GIS data.

L4 Ecoregions	
Loess Islands	100.00%
Okanogan Valley	94.00%
Okanogan Drift Hills	92.25%
Channeled Scablands	89.00%
Mesic Forest Zone	87.75%
Western Okanogan Semiarid Foothills	81.50%
Yakima Folds	79.00%
Pasayten/Sawtooth Highlands	78.75%
Deep Loess Foothills	76.50%
Pleistocene Lake Basins	75.50%
Yakima Plateau and Slopes	74.50%
Canyons and Dissected Highlands	73.50%
Dissected Loess Uplands	71.00%
Okanogan Pine/Fir Hills	69.25%
Canyons and Dissected Uplands	65.50%
Maritime-Influenced Zone	64.50%
North Cascades Highland Forests	52.75%
Western Cascades Lowlands and Valleys	52.50%
Subalpine-Alpine Zone	50.75%
Chelan Tephra Hills	50.25%
Wenatchee/Chelan Highlands	49.50%
Palouse Hills	45.50%
Okanogan Highland Dry Forest	44.75%
Western Cascades Montane Highlands	43.00%
High Northern Rockies	42.75%
Okanogan-Colville Xeric Valleys and Foothills	41.00%
Chiwaukum Hills and Lowlands	39.75%
North Cascades Subalpine/Alpine	30.75%
Selkirk Mountains	30.75%
Grand Fir Mixed Forest	30.25%
North Cascades Lowland Forests	28.25%
Spokane Valley Outwash Plains	20.25%
Lower Snake and Clearwater Canyons	19.25%
Oak/Conifer Foothills	16.50%
Cascade Crest Montane Forest	12.25%
Western Selkirk Maritime Forest	9.75%
Cascade Subalpine/Alpine	9.00%
Inland Maritime Foothills and Valleys	4.50%
Northern Idaho Hills and Low Relief Mountains	3.50%

Next Steps & Future Research

While we were able to accomplish a lot in 10 weeks, there were numerous areas we wish we could have further investigated. Future research should dive deeper into the financial implications of data center downtime and the cost to individual users. Also, would be worth further analyzing the environmental impacts of data center emissions.

In addition, it would have been interesting to expand our research to include all climate hazard risks to public utilities to identify optimal geographic locations for new data center locations.

Conclusion

As the world continues to become more digital, data centers are the key to drive this transition. Public utilities need to adapt to the increased power demands and mitigate climate change related risks like increased wildfires to meet society's need for data. We appreciate you for taking the time to read this and please provide feedback to the UW Climate Risk Lab for future research in this space. Thank you!

Foster School of Business Climate Risk Lab

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