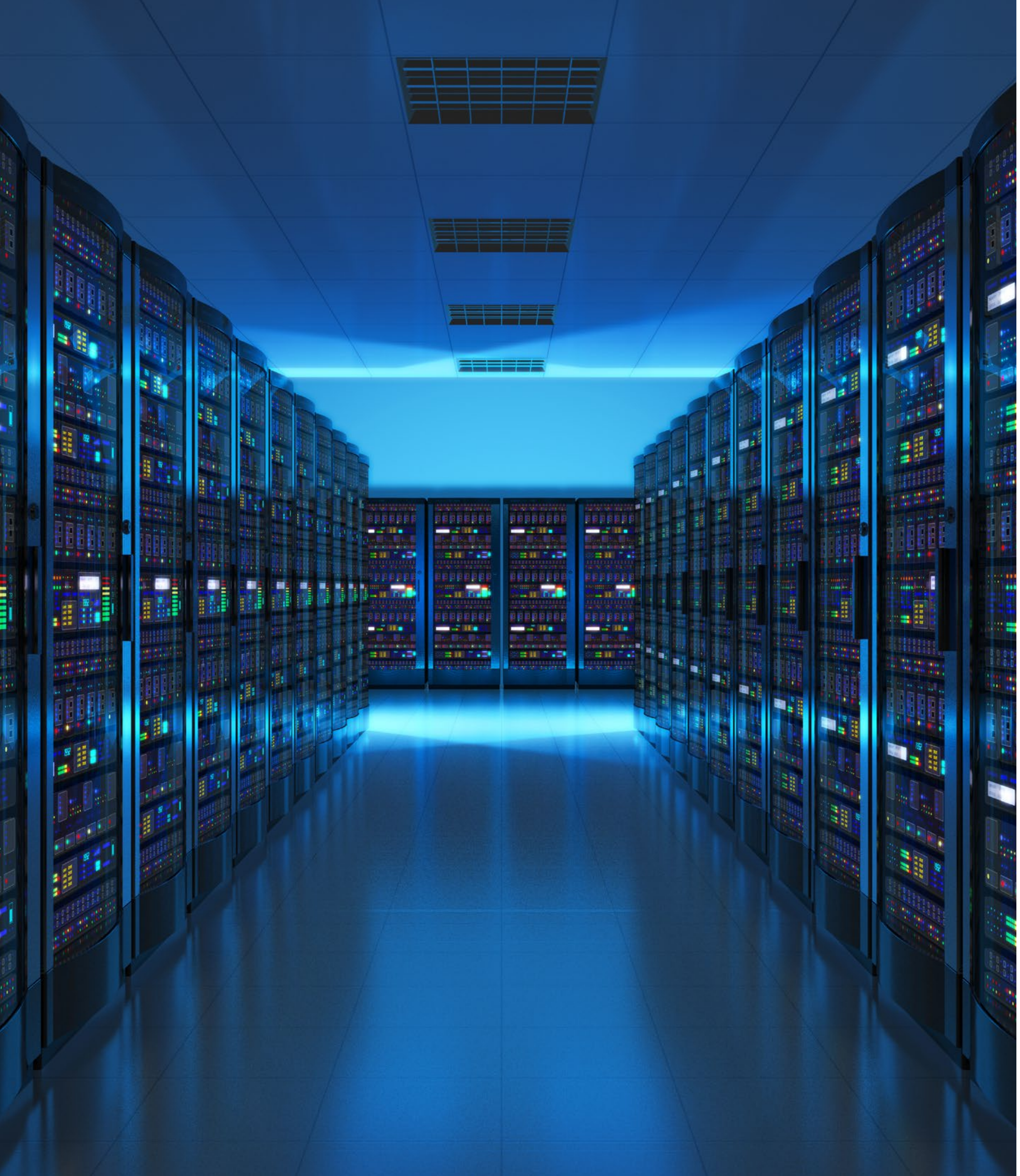

FEBRUARY 14, 2025

The Energy & Water Use Impacts of Building System Design for Data Centers

DESIGN CONSIDERATIONS FOR OREGON & WASHINGTON

STUDY PERFORMED BY:

PAE

ON BEHALF OF:

Confederated Tribes of the Umatilla Indian Reservation

Columbia River Inter-Tribal Fish Commission

The study used to inform this document was funded in part by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) for informative and exploratory purposes. The recommendations expressed herein may or may not represent CTUIR's current policy position. Any inquiries regarding CTUIR policy positions may be directed to Sterling Cosper, CTUIR Legislative Affairs Manager, 541-429-7392 or SterlingCosper@ctuir.org.

Executive Summary

Key Takeaways

Implementing data center energy efficiency and peak power reductions would provide some of the most significant energy savings available to the region.

STUDY OVERVIEW

Oregon and Washington are well suited for data centers, therefore the region has become a focus for this quickly growing sector. The energy and water impacts of this growth will depend on decisions implemented now to ensure this important market is leveraging the best solutions available to meet its increasing needs.

The focus of this study was on the building systems that support the core IT (server) loads of data centers. The study models were based on a simplified scenario comparing two systems in one climate zone to explore if the building systems had any impact. While these support loads can seem minimal in comparison to the server loads, the study results found building systems do have a measurable impact to the overall energy use of data centers and provide opportunity for innovation and improvement.

This study explored three key topics regarding building system selection:

— Impact on total annual building energy use
— Impact on peak power demand
— Impact on total annual water use

SUMMARY OF RESULTS

1. The study found notable differences in energy use of non-ITE loads as highlighted in their Power Usage Effectiveness (PUE) values for the following scenarios:
   — ASHRAE 90.4 baseline: 1.24 PUE
   — Best practices air cooled: 1.17 PUE
   — Best practices evaporative cooling: 1.10 PUE

2. The modeled scenarios found potential for total annual energy use savings of 2,000,000 MWh - 4,000,000 MWh by 2033 from the more efficient building system. These savings are equivalent to nearly half of all the wind power generated in Oregon in 2021[1] and resulted only from systems improvements without any reduction in data center quantity.

3. The models identified a potential 1,000 MW reduction in peak power demand between the system options. Peak demand is currently not considered in data center building standards, yet has important implications for regional energy systems.

   For the climate zone studied in this report, the "Peak-PUE" model results were:
   — ASHRAE 90.4 baseline: 1.59 Peak-PUE
   — Best practices air cooled: 1.52 Peak-PUE
   — Best practices evaporative cooling: 1.15 Peak-PUE

   It is recommended that a Peak-PUE metric be created and adopted to help ensure best practices regarding peak demand with system selections.

4. The interaction between water and energy use for the climate zone was modeled as a comparison between onsite direct water use and indirect water use for energy generation. The model found evaporative cooling results in a higher overall water use, even when reduced energy use is considered. Yet within the regional context, the total water use of evaporative cooling remains less than 0.1% of overall water use in the Washington and Oregon region while providing the previously noted improvements in data center energy use.

[1] https://www.nwcouncil.org/reports/columbia-river-history/megawatt/

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Table of Contents

How Data Centers Are Expanding

INTRODUCTION

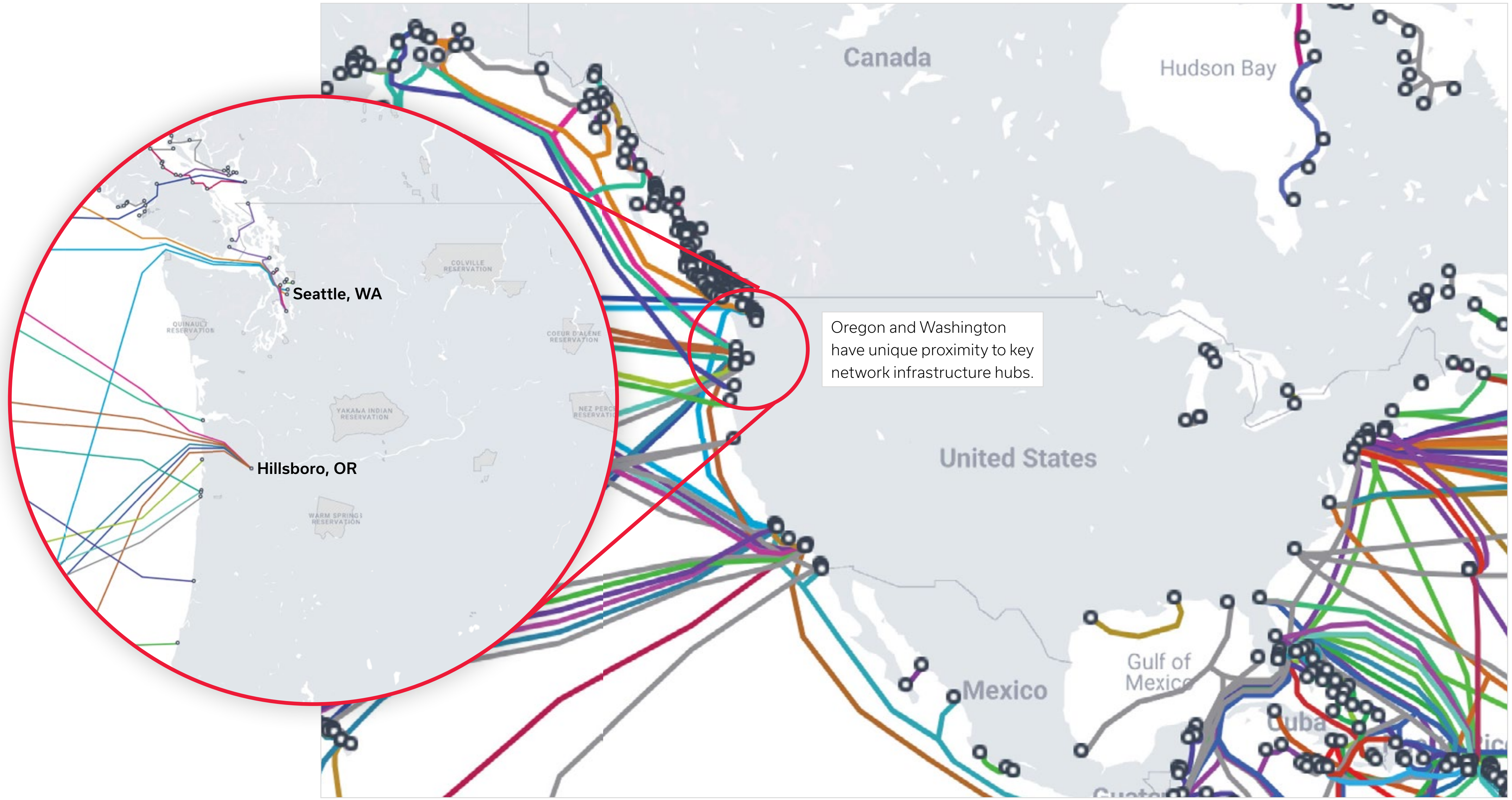
It has become well understood that the data center sector is expanding globally at a quickening rate. The impact of this growth is a topic of ongoing discussion as regions balance the requirements for increased data, energy, and water resources.

The focus of this report is on energy and water considerations specific to the northwest region of the United States, namely Oregon and Washington.

Oregon and Washington, like many regions of the US, are seeing an increased interest to expand their data center sector. Yet, while data centers are emerging in multiple locations around the country, Oregon and Washington offer unique benefits to the data center industry which make it a particularly intriguing option for this quickly growing market.

An ideal data center site has as many of the following attributes as possible, listed in general order of priority:

1. Reliable, available power
2. Proximity to network infrastructure
3. Sufficient land availability
4. Cool climate
5. Low risk of natural disasters
6. Security Considerations
7. Cost considerations, including
   - Land
   - Construction
   - Ongoing Operations
   - Electricity
   - Tax Breaks
   - Incentives



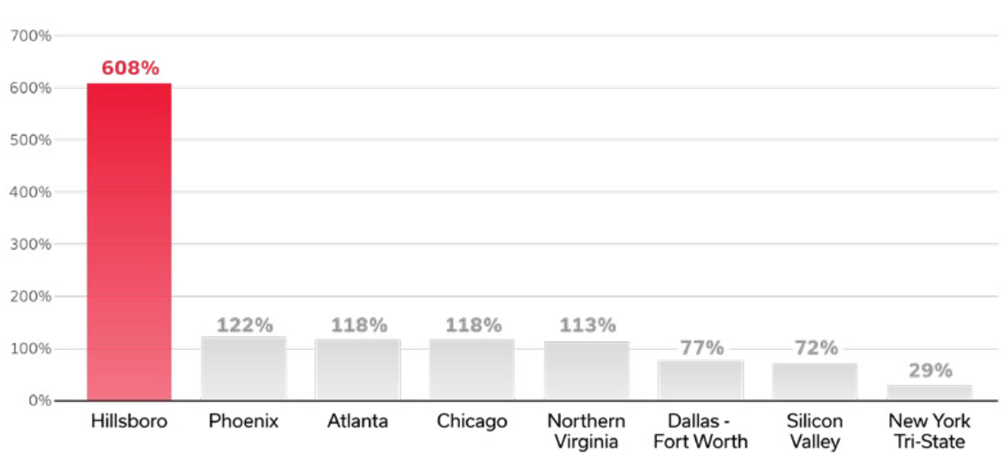
Source: https://www.submarinecablemap.com/

With Hillsboro, Oregon, already established as a primary data center market and eastern Oregon and Washington quickly growing in the secondary market, this has led the region to anticipate an increased interest in expansion from the data center market.

OREGON MARKET

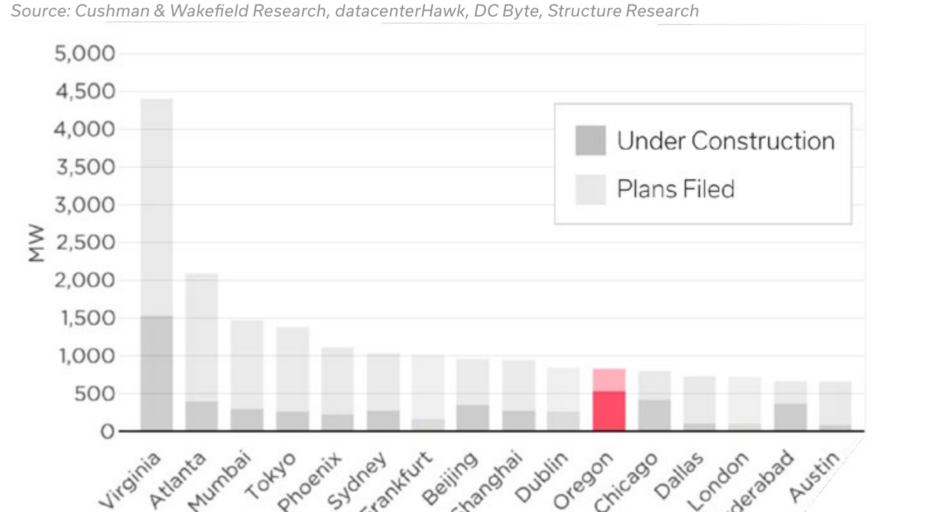
INVENTORY GROWTH OF PRIMARY DATA CENTER MARKETS SINCE 2020

Source: CBRE Research, CBRE Data Center Solutions, H1 2024



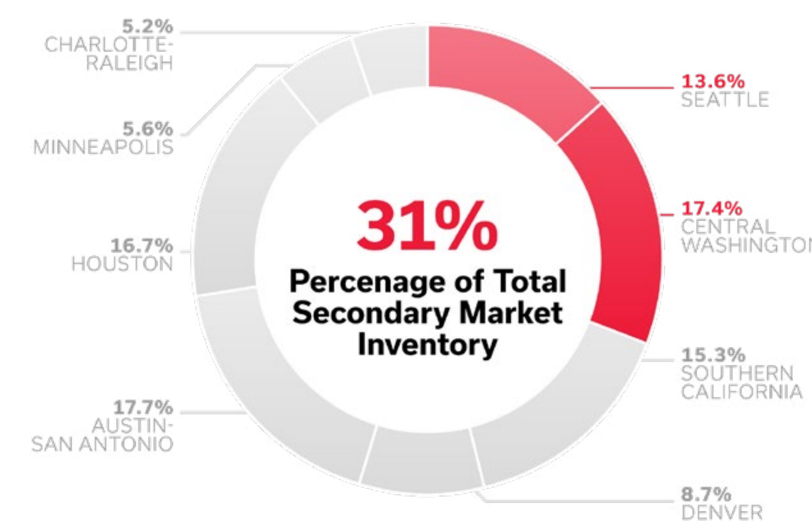
TOP MARKETS BY COMBINED IT LOAD UNDER CONSTRUCTION OR PLANS FILED

Source: Cushman & Wakefield Research, datacenterHawk, DC Byte, Structure Research



WASHINGTON MARKET

Source: CBRE Research, CBRE Data Center Solutions, H1 2024.



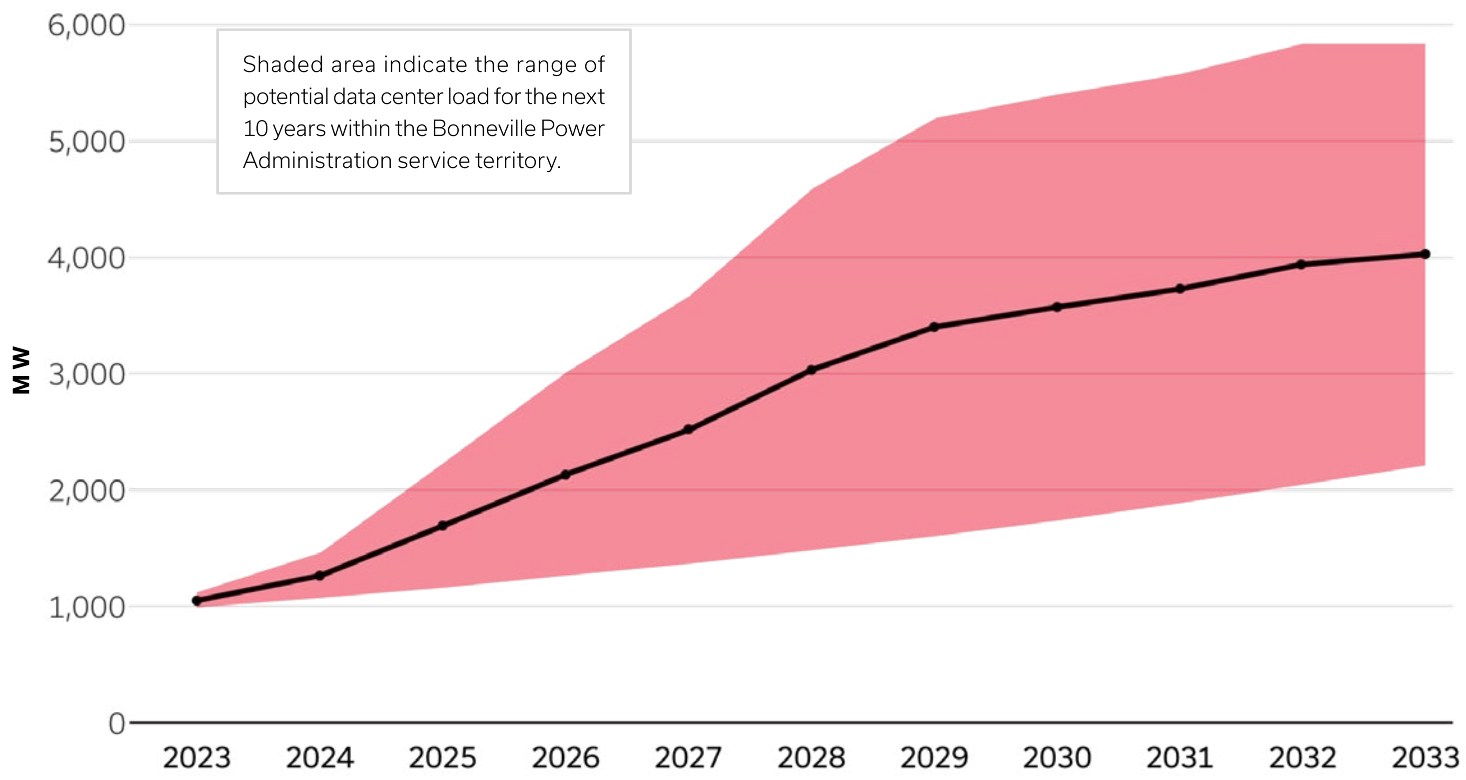
How Data Centers Are Expanding

LOOKING TO THE FUTURE

The Oregon and Washington region has started to evaluate the potential magnitude of impact in the coming years. If the market continues at the modeled rates, it is reasonable that an increase of 2x up to nearly 6x could occur within 10 years.

DATA CENTER LOAD GROWTH ASSUMPTION

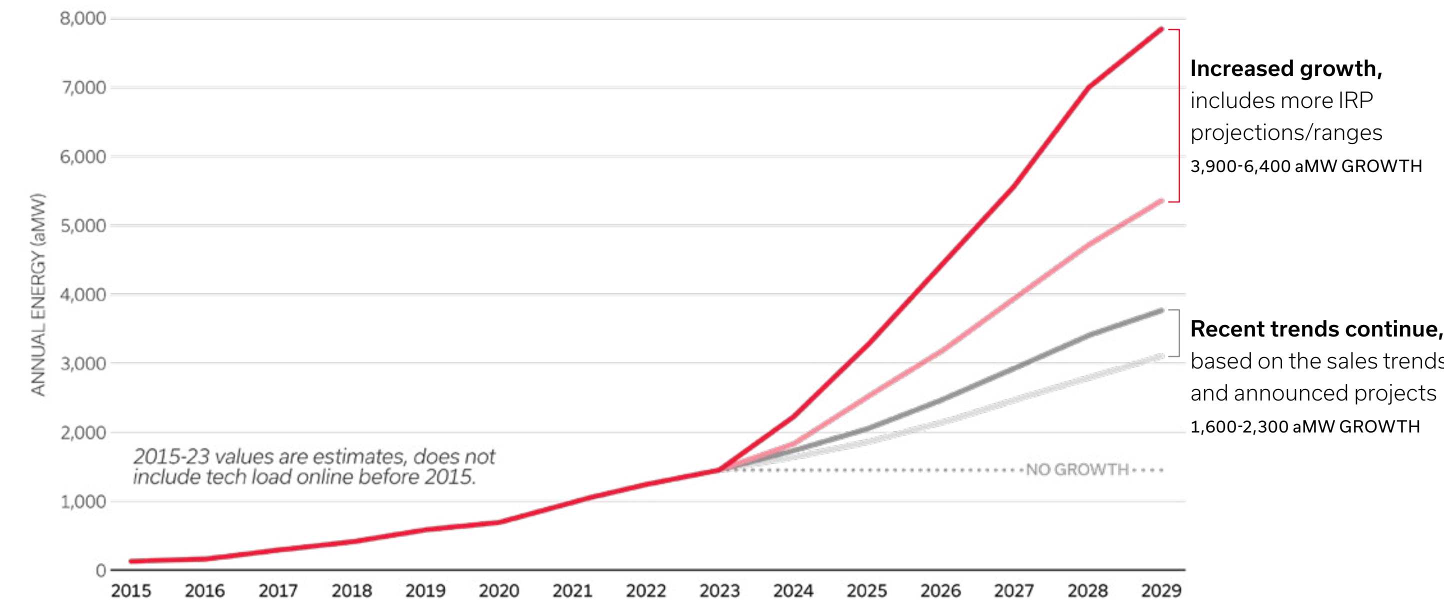
Source: BPA Loads Presentation NWPCC Power Committee Meeting March 12, 2024



Given the energy and water density of this market sector, this scale of increase has notable implications for the energy and water resources of the region. The intent of this study is to explore the options to influence these impacts with data-informed solutions for minimizing energy needs, balancing the interaction between water and energy use with different system options, and reducing the power demand during peak times.

DRAFT DATA CENTER AND CHIP FABRICATION FORECAST TO 2029

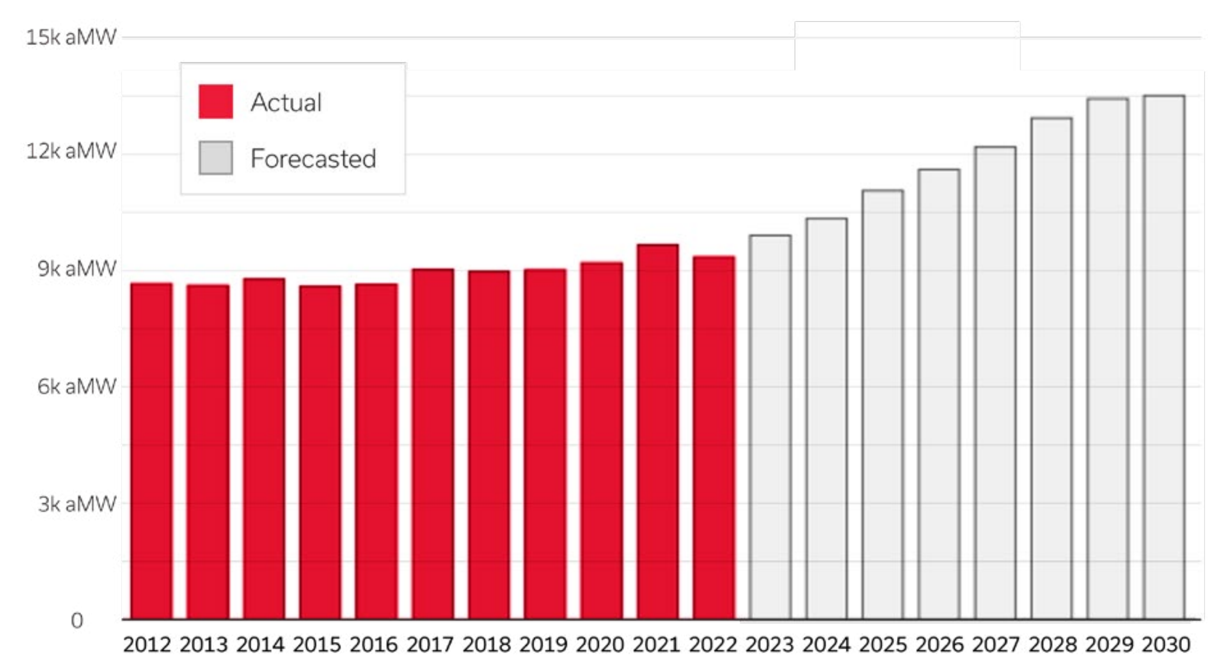
Source: Northwest Power and Conservation Council
Note: Forecast load growth is predominantly from data centers, although does include some semi-conductor facilities.



Not surprisingly, this projected growth is influencing the forecasts for the region's utilities regarding anticipated load growth and the need for additional generation and transmission capacity.

HISTORIC TOTAL RETAIL LOADS

Source: Bonneville Power Administration, 2024-2028 Strategic Plan



Annual Megawatt (aMW): A unit of energy output that measures the average amount of energy produced by a one megawatt capacity over a year.

What Does PUE Really Mean?

MEASURING EFFICIENCY

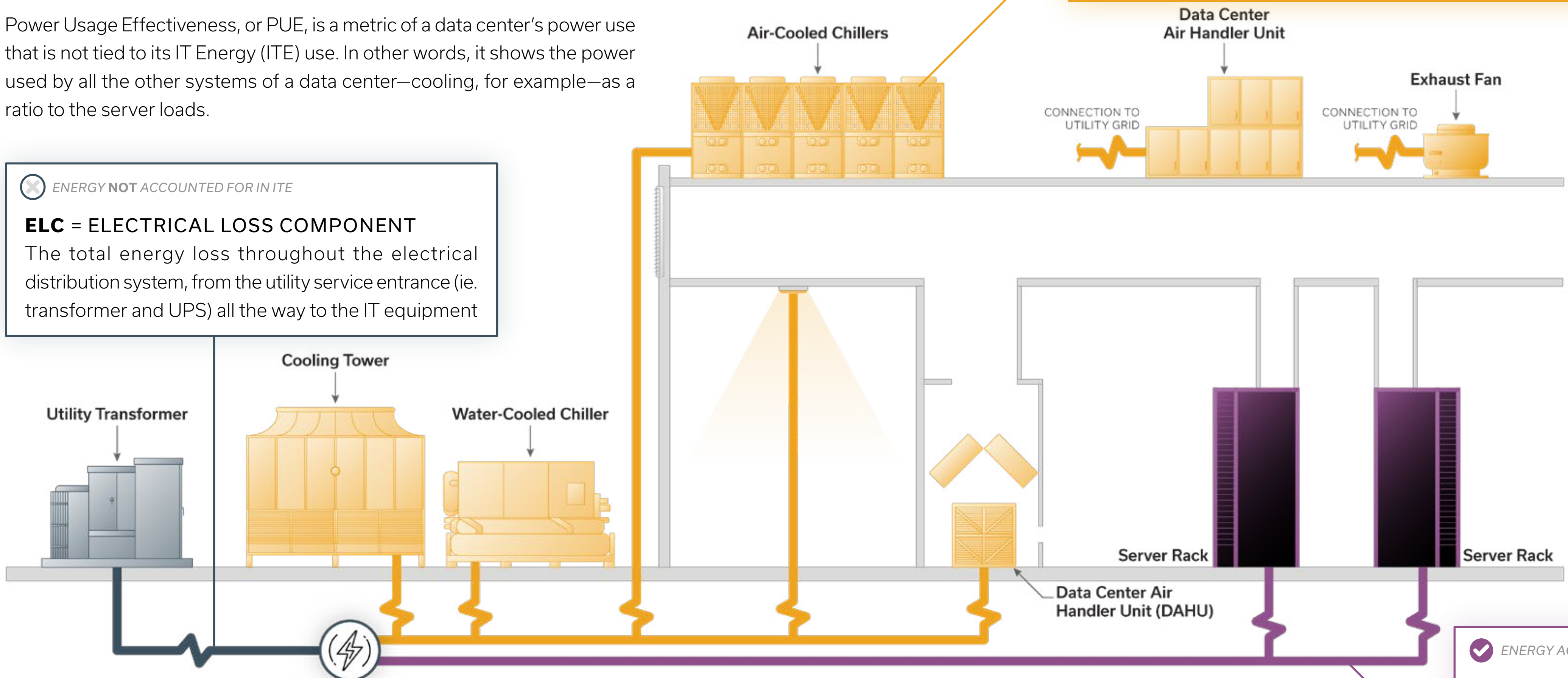
Power Usage Effectiveness, or PUE, is a metric of a data center's power use that is not tied to its IT Energy (ITE) use. In other words, it shows the power used by all the other systems of a data center—cooling, for example—as a ratio to the server loads.

*ENERGY **NOT** ACCOUNTED FOR IN ITE*

ELC = ELECTRICAL LOSS COMPONENT
The total energy loss throughout the electrical distribution system, from the utility service entrance (ie. transformer and UPS) all the way to the IT equipment

*ENERGY **NOT** ACCOUNTED FOR IN ITE*

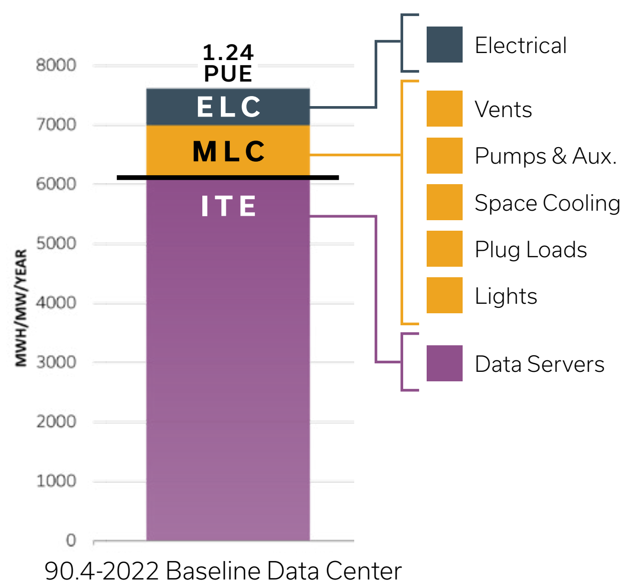
MLC = MECHANICAL LOSS COMPONENT
The power consumed by mechanical components like fans, pumps, and other equipment used to circulate coolant and reject heat, essentially representing the energy used to maintain the proper temperature within the data center



ENERGY ACCOUNTED FOR

ITE = IT ENERGY
Energy consumed directly by servers.

$$\text{PUE} = \frac{\text{TOTAL ENERGY (MLC + ELC + ITE)}}{\text{IT ENERGY (ITE)}}$$



90.4-2022 Baseline Data Center
AC CHILLERS

ASHRAE 90.4 Summary

Both Oregon and Washington have adopted ASHRAE 90.4 as the energy code standard for data centers. ASHRAE 90.4 defines a maximum PUE based on allowances for mechanical system loads and electrical efficiency.

CHAPTER 6 | MAXIMIZED ANNUALIZED MECHANICAL LOAD COMPONENT

Chapter 6 (Heating, Ventilation, and Air Conditioning) designates the Maximum Annualized Mechanical Load Component (Annualized MLC).

- MLC is defined as the total annual energy consumed by all mechanical equipment (e.g., fans, pumps, motors, drives, compressors, humidifiers, dehumidifiers, water filtration or treatment equipment).
- Mechanical equipment energy is calculated with Typical Meteorological Year Version 3 (TMY3) data with 8760 hourly data points or that is binned by dry bulb and wet bulb (or dew point) with a resolution ≤2°F (1°C).
- MLC is calculated as a weighted average of four runs at constant ITE loads of 25%, 50%, 75%, and 100% of the design ITE load.
- The MLC allowance is based on climate zone: Higher allowance in warmer climates, lower in cold climates. The allowance for both climate zones 4C and 5B (which cover all of Oregon and Washington) is 0.14.

CHAPTER 8 | MAXIMUM DESIGN ELECTRICAL LOSS COMPONENT

Chapter 8 (Power) defines the Maximum Design Electrical Loss Component (Design ELC). ELC applies only to electrical systems serving ITE loads.

- Design ELC is calculated based on the UPS segment loss and the ITE distribution segment losses, separately reported at each of four load levels: 100%, 75%, 50%, and 25% of the ITE design load. The electrical system must meet or exceed the ELC minimum requirements listed in Table 8.6 at each of the ITE design load levels.

CHAPTER 11 | ALTERNATIVE COMPLIANCE METHOD

Chapter 11 (Alternative Compliance Method) allows a 1:1 trade-off between MLC and ELC allowances, so a less efficient electrical system may be offset by a more efficient mechanical system, or vice-versa.

- Onsite Renewables may also be used to offset the overall PUE allowance and demonstrate compliance.

Table 8.6 Maximum Design ELC and ELC Segments (IT Design Load ≥ 100 kW)

	UPS Redundancy Configuration: Single-Feed UPS (*N*, *N+1*, etc.) or Active Dual-Feed UPS (*2N*, *2N+1*, etc.) [a]			
Calculation Percentage	100% of IT design load segment ELC	75% of IT design load segment ELC	50% of IT design load segment ELC	25% of IT design load segment ELC
Segments of ELC and Overall ELC	*Loss/efficiency*	*Loss/efficiency*	*Loss/efficiency*	*Loss/efficiency*
UPS Segment	5.5%/94.5%	5.5%/94.5%	6.0%/94.0%	7.0%/93.0%
ITE Distribution Segment	5.8%/94.2%	4.6%/95.4%	3.6%/96.4%	2.5%/97.5%
Electrical Loss/Efficiency Total	11.0%/89.0%	9.8%/90.2%	9.4%/90.6%	9.3%/90.7%
ELC	0.110	0.098	0.094	0.093

a. ***Informative Note:*** Example calculations are shown in Informative Appendix C.

Source: ©ASHRAE, www.ashrae.org. 2022 ASHRAE Standard-90.4.

Comparing Baseline with Best Practices

BASELINE

As described on the previous page, ASHRAE 90.4 sets the minimum performance for data centers in Oregon and Washington. 90.4 is fundamentally a performance standard and does not mandate the systems or design approach used to meet the efficiency target. For simplicity, two cold air distribution systems are considered for this study to demonstrate the different performance of compressor driven systems versus systems without compressors. The systems presented here are an air-cooled chiller system and a direct evaporative system.

GENERAL BEST PRACTICES

In order to reduce MLC, data centers are designed to maximize economizer, or free cooling operation. Specifically:

- Increasing temperature setpoints to reduce hours where supplemental mechanical cooling is needed and increase efficiency of mechanical cooling equipment when supplemental cooling is needed.
- Optimizing air paths to take advantage of passive airflow and reduce fan power.

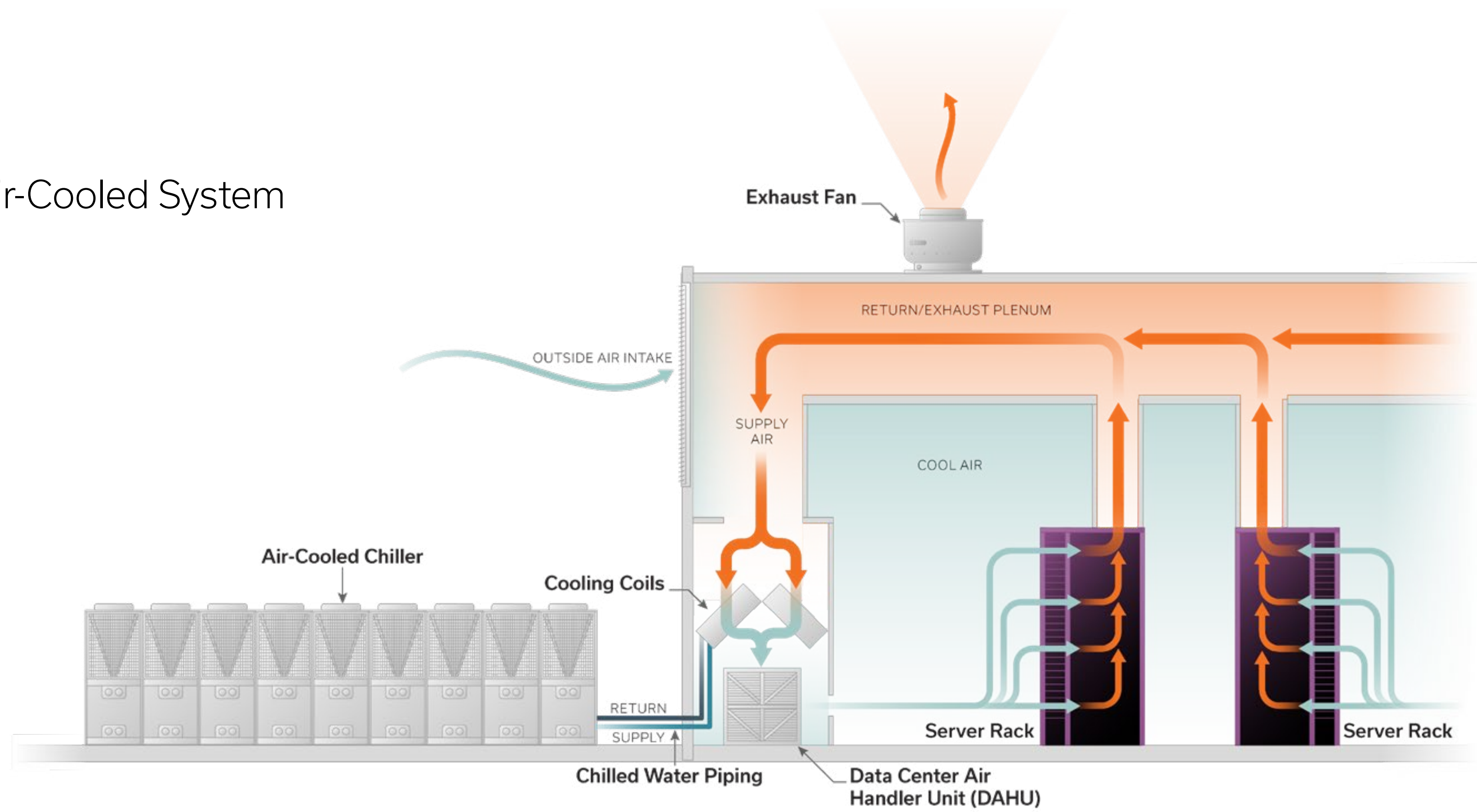
Strategies for reducing ELC revolve around design and selection of efficient electrical systems:

- Selecting high-efficiency UPS equipment.
- Reducing power transformation operations and selecting high-efficiency transformers and power distribution units.
- Minimizing conductor length and optimizing sizing to reduce distribution losses.

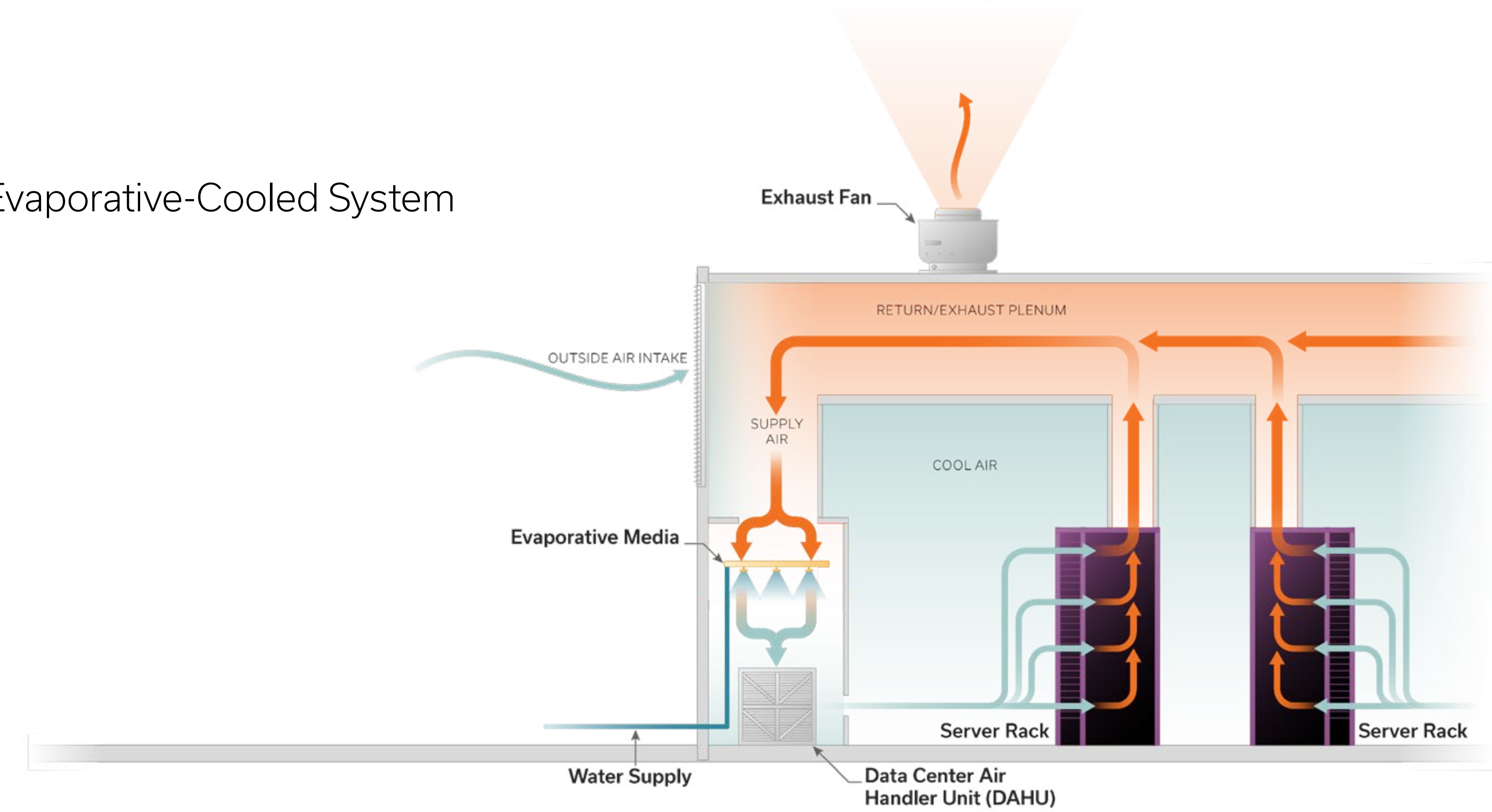
EVAPORATIVE COOLING SYSTEM

One strategy for efficient data centers in drier climates is to replace active mechanical cooling systems with direct evaporative cooling systems, which add moisture to the supply air stream to cool the air. Evaporative cooling systems substantially reduce peak and annual energy demand but require large quantities of water. Based on water availability and quality these systems are not always viable.

Air-Cooled System



Evaporative-Cooled System

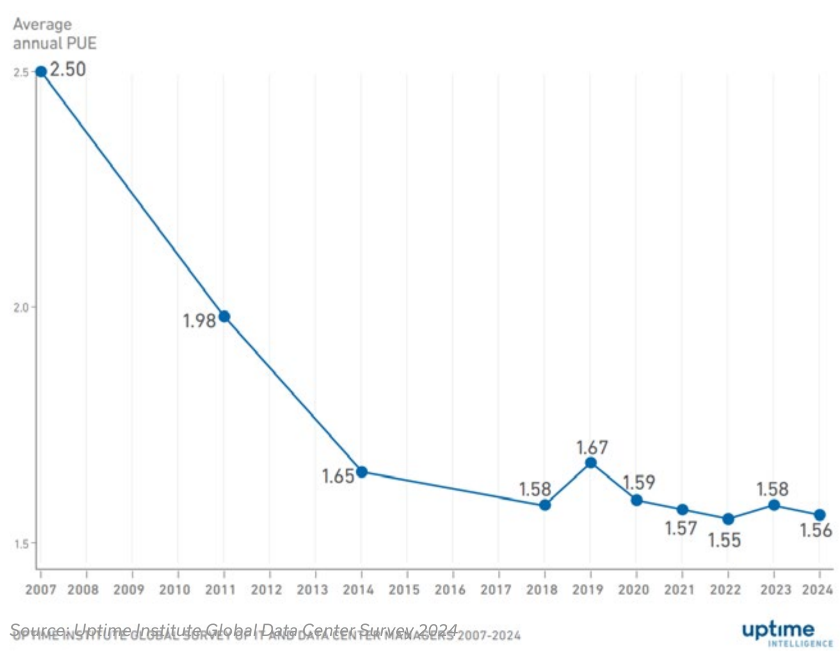


PUE Trends and Outlook

Data Centers: Market Context

PUE TRENDS

There is ongoing discussion within the data center industry on feasible PUE targets. Global PUE levels remain higher than the recommended ASHRAE minimums, yet this may be due to a lack of requirements rather than ability. Leaders in the data center sector have demonstrated that significant improvements over the ASHRAE 90.4 minimums are achievable with today's technologies.



Source: Uptime Institute Global Data Center Survey 2024
UPTIME INSTITUTE GLOBAL SURVEY OF IT AND DATA CENTER MANAGERS 2007-2024

As an example, Google has an average reported PUE of 1.10 across its global portfolio of large facilities, including its Oregon location. This is even after using a more stringent reporting method. The more standard methodology would indicate an average PUE of 1.06.

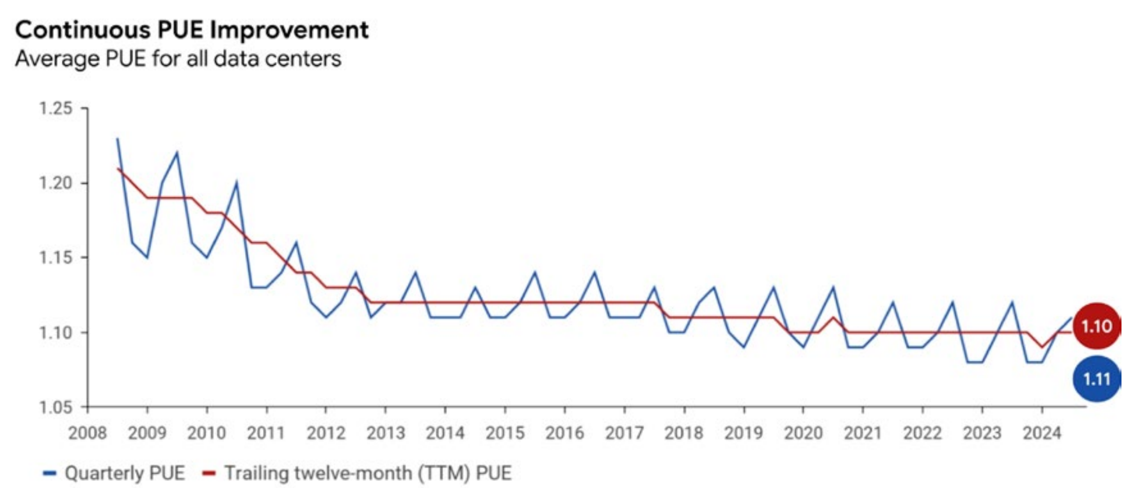


Figure 2: PUE data for all large-scale Google Data Centers

Source: https://www.google.com/about/datacenters/efficiency

FACILITY	QUARTERLY PUE	TRAILING 12-MONTH PUE
The Dalles, Oregon	1.10	1.10
The Dalles, Oregon 2ND FACILITY	1.06	1.07

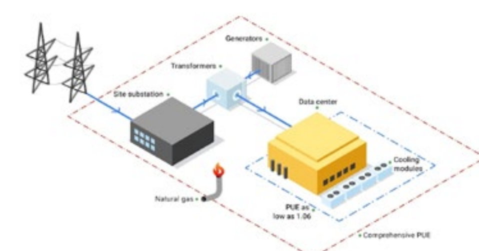


Figure 1: Google Data Center PUE measurement boundaries. The average PUE for all Google Data Centers is 1.10, although we could boast a PUE as low as 1.06 when using narrower boundaries.

Key Takeaways

Leaders in the data center industry have demonstrated that more efficient PUE numbers are achievable with current technology and system options.

Technology Outlook

WASTE HEAT AS A RESOURCE

Data centers generate significant amounts of heat through their processing loads. When considered at scale, there is intriguing potential for turning waste heat into a valuable resource by locating data centers adjacent to other building types, such as housing or hospitals, which have high space and hot water heating needs.

One example of this potential is NREL's High-Performance Computing (HPC) User Facility. Harnessing the heat output from the data center supports other facility energy needs with a process hot water PHW loop which supplies:

- Active chilled beams to heat the office space
- Air handlers to heat the conference and high bay spaces
- Snow melt loop in the courtyard of the ESIF's main entrance
- District heating loop

This is a topic that would benefit from additional study. The relatively low temperature of the waste heat may limit the potential benefits, yet it is still a topic worth more evaluation.

https://www.nrel.gov/computational-science/waste-heat-energy-reuse.html

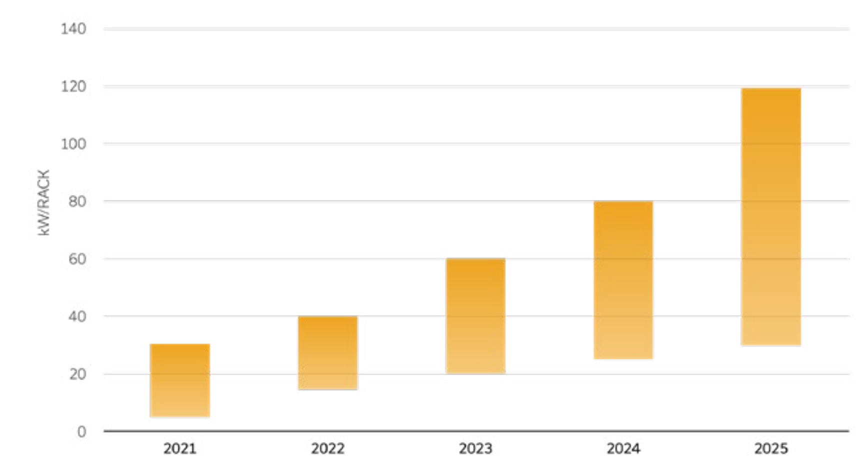
NEW SYSTEM TYPES

The power density for data center racks are expected to continue increasing over time. New technologies and building systems are being explored to support the increased needs.

System options, such as liquid cooled systems, are gaining adoption within the industry. Although not included in this report, an expanded comparison of system types could be explored in future studies.

AVERAGE SERVER RACK DENSITY RANGES | kW/RACK

Source: Cushman & Wakefield Research, Structure Research



Model Methodology and Results

Summary of Methodology

PAE developed a data center energy model in IES VE software to evaluate the expected energy performance and water consumption of a minimum code-compliant data center vs. current best practices for both air-cooled and evaporatively cooled systems. The model was patterned after an ASHRAE 90.4-2022 compliance model due to its wide adoption as a data center energy code throughout the U.S., including in Oregon and Washington. This provides a useful baseline for comparison with industry published PUE performance.

The following parameters were used as inputs in the model:

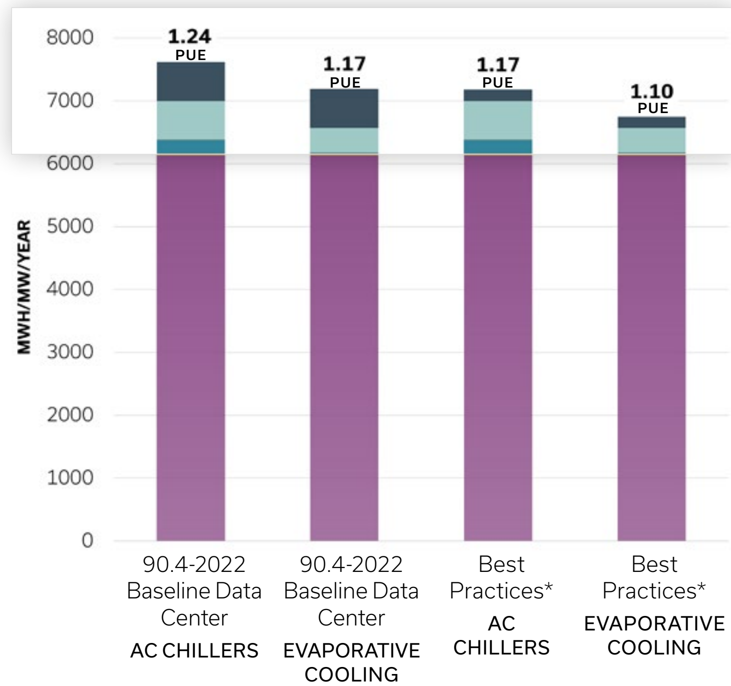
- **Weather File:** The Dalles Regional Airport TMYx.2009-2023, Climate Zone 5B
- **ITE Load:** 30MW
- **Supply Air Temperature/Economizer Setpoint:** 79°F

The model was simulated at 25%, 50%, 75%, and 100% of ITE loads. PUE is taken as the average of the sum of all runs. Peak PUE is taken at the peak hour of the 100% run.

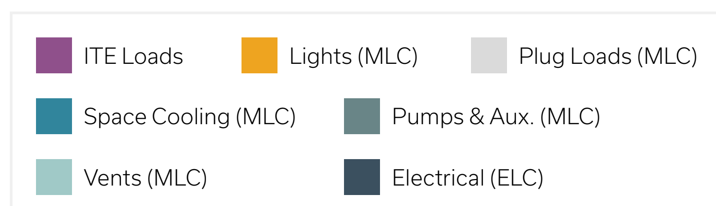
OPPORTUNITIES FOR ADDITIONAL STUDY

The models were based on a simplified scenario comparing two systems in one climate zone to explore if the building systems had any impact. The results indicate building systems do have a measurable impact, yet impacts of specific systems may vary depending on location. Additional study on these variables could provide beneficial information on the potential impact.

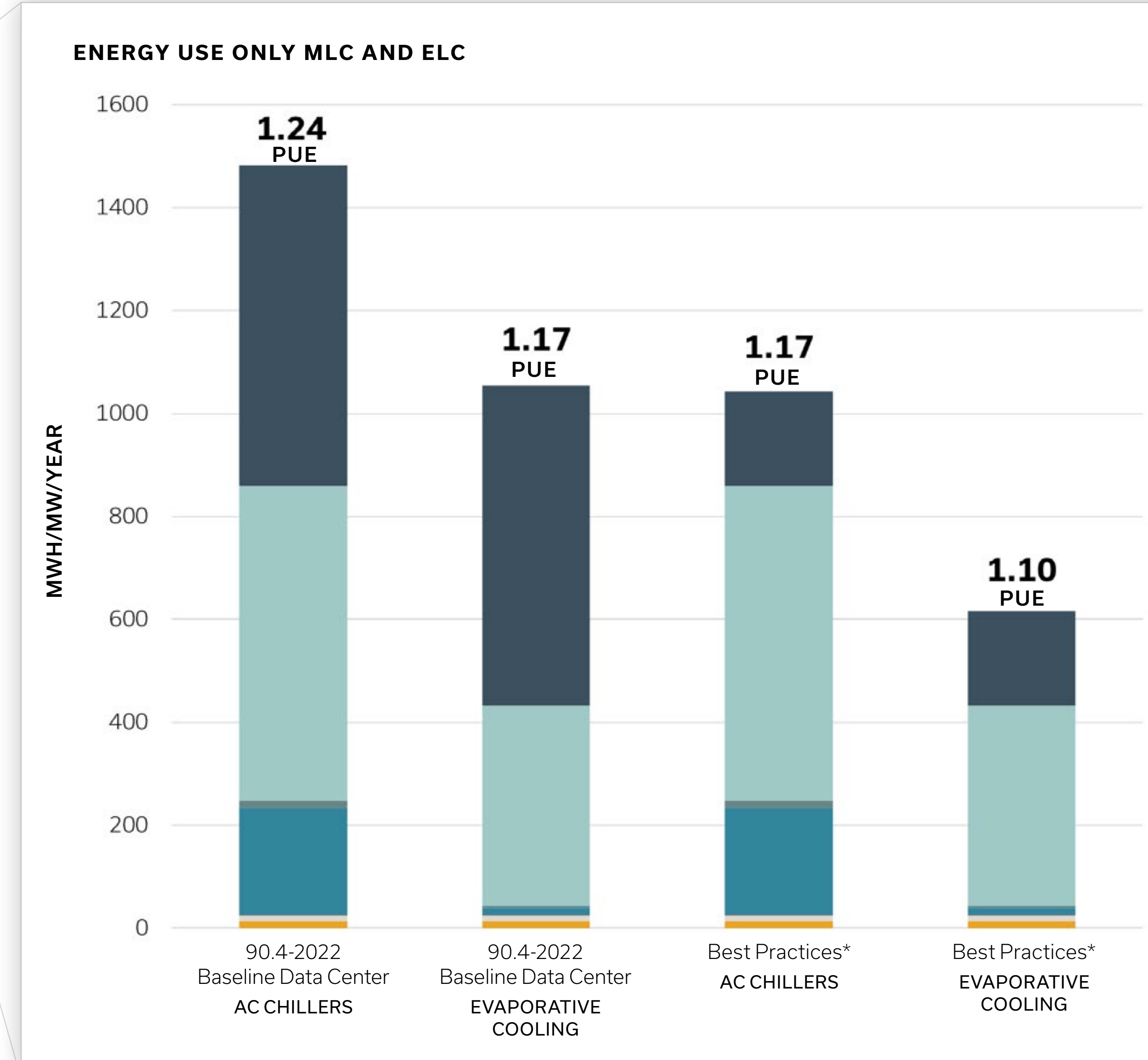
PUE RESULTS | ENERGY USE WITH ITE, MLC, AND ELC



** The results in this report are based on the weather models for Climate Zone 5b. The optimal system type for improved PUE will vary depending on the Oregon and Washington climate zone in which the data center is located.*

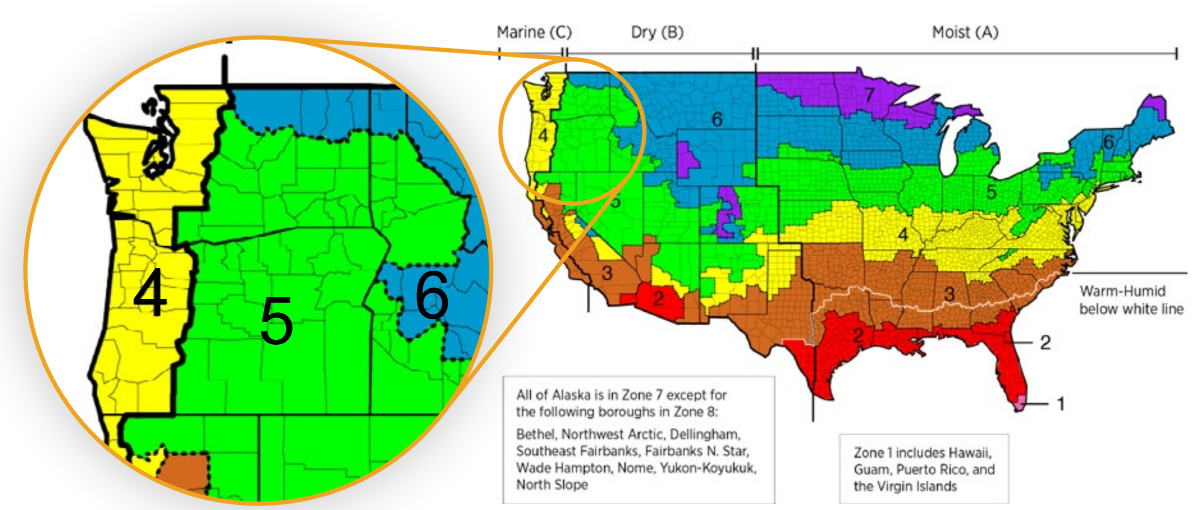


ENERGY USE ONLY MLC AND ELC



CLIMATE ZONE CONSIDERATIONS

The majority of Washington and Oregon are located in climate zones 4C (Mixed mild/Marine) and 5B (Cool/Dry). The modeled weather file from The Dalles, in Zone 5B, can be considered generally representative of the areas of eastern Oregon and Washington where many data centers are located, such as central Oregon and the greater Columbia River Gorge. The milder 4C climates are expected to show less dramatic energy savings from evaporative cooling systems. Peak power results are expected to be more widely applicable, as the peak conditions of hot, dry summer days are similar to the modeled weather in most areas of Zone 4C, with the exception of the true marine climates near the western coast.



PUE Scale Implications and Key Takeaways

UNDERSTANDING SCALE

The region's current total electricity use currently is roughly 58,000,000 MWh in Oregon and 92,000,000 MWh in Washington, for a total of nearly 150,000,000 MWh for the region. Accordingly, the near-term impact of data centers based on the midpoint projection is a 3% increase in total electricity load. This could increase to over 10% based on the growth projections.

Although the building system impacts seem minimal compared to the overall energy use, the savings are significant when considered in other contexts.

This scale speaks to the importance of ensuring best practices are adopted for all projects in the region to help minimize the overall long term impact.

SOURCES:
—https://www.oregon.gov/energy/Data-and-Reports/Documents/2022-BER-Energy-by-the-Numbers.pdf
—https://closup.umich.edu/sites/closup/files/2024-03/closup-wp-61-State%20of-Washington-Renewable-Energy-Policy-Analysis-Report.pdf
—https://www.oregon.gov/energy/energy-oregon/pages/electricity-mix-in-oregon.aspx
—https://www.energy.gov/sites/prod/files/2016/09/f33/WA_Energy%20Sector%20Risk%20Profile.pdf

Key Takeaways

The PUE model results (page 8) show approximately the following improvements in total annual energy use:

— 6% reduction between minimum code compliant design and best practices when compared with the same mechanical systems

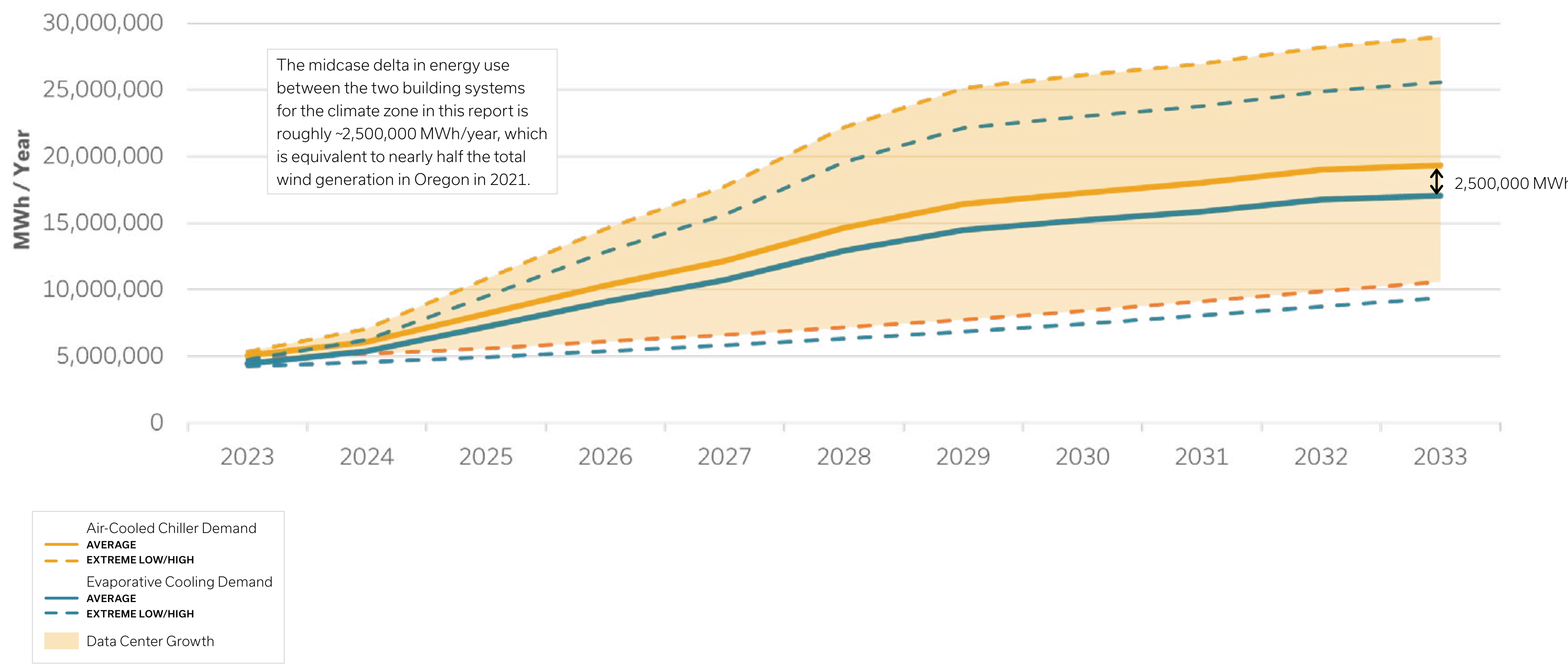
— 6% reduction between air-cooled chillers and direct evaporative cooling

— 12% cumulative reduction between a minimum code design and a best practices evaporatively cooled design

While these savings are incremental when compared to the overall ITE load, they still represent a potential savings of up to 850 MWh per MW of ITE load per year. When scaled to a regional level and contextualized with overall power consumption, this is a meaningful improvement.

REGIONAL IMPACT OF BUILDING SYSTEM SCENARIOS | ENERGY

Data Source: Regional growth projection is based on the Northwest Power and Conservation Council draft report Data Center and Chip Fabrication Forecast. Impact of the building systems scenario is based on the building system model results and the draft forecast.



Considering the Impacts of Peak Demand

There are multiple dimensions to consider when evaluating the system impact of data centers. Total energy use, which is a critical consideration, has historically received most of the attention.

But as Oregon and Washington grids come under additional stress in response to climate change, there is an additional consideration of increased loads during peak times. This becomes particularly important in summer when higher outside temperatures require increased cooling needs in all building types, but especially for data centers. This cumulative impact on the region's grids cannot be ignored.

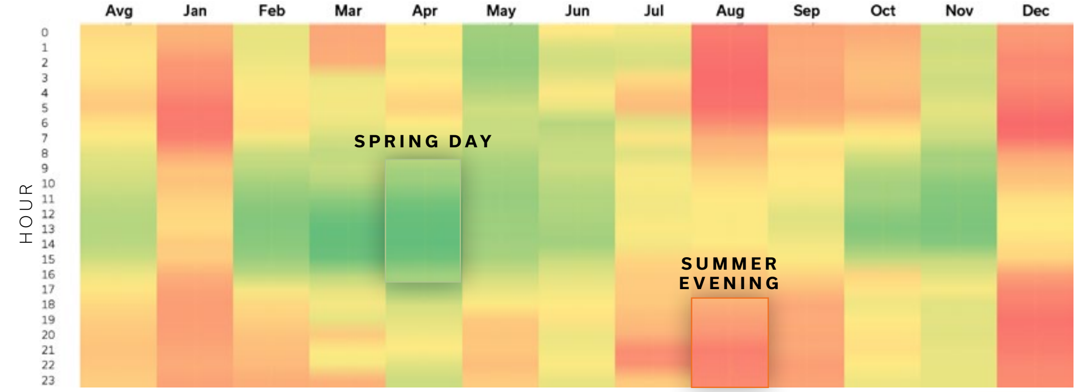
So while the total load increase to the region remains a key consideration, considerations around peak are of equal importance and yet have historically received less attention in data center forecasts and building codes.

As the results of the study presented here indicate, peaks are a key factor and should be considered in decisions around system requirements and codes. It is worth having the industry consider the addition of a metric for peak-demand evaluation in future versions of ASHRAE 90.4.

Looking at the Regional Data

In addition to the cost consideration of building a system to meet peak demand, there are environmental considerations as well. Increased coincident load often means increased use of higher emission resources. As a result, the emissions associated with peak times, such as summer afternoons and evenings, are often higher than the other times of year. Therefore reducing peak demand not only limits the stress on the grid systems but also helps reduce the overall operating emissions.

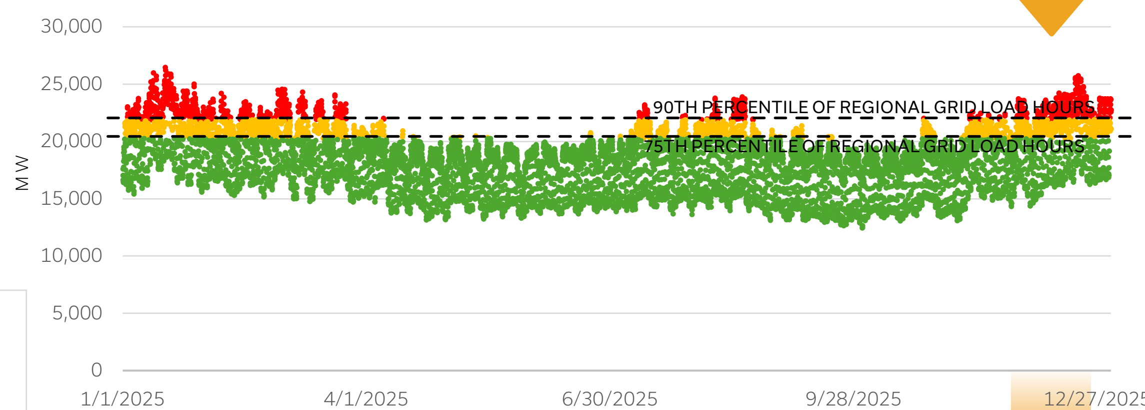
AVERAGE HOURLY GRID EMISSIONS PER MONTH | PACIFIC POWER

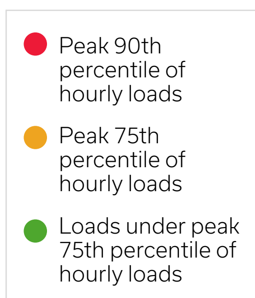


Grid emissions in Oregon and Washington are higher during summer evenings as compared to spring days.

TOTAL HOURLY LOADS IN THE NW GRID REGION

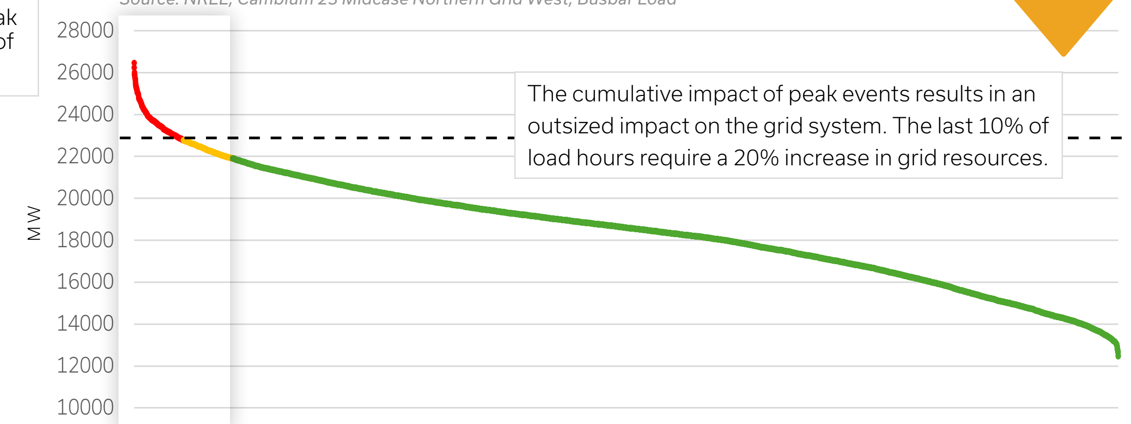
Source: NREL, Cambium 23 Midcase Northern Grid West, Busbar Load





REGIONAL HOURLY LOAD ORDERED FROM LARGEST TO SMALLEST

Source: NREL, Cambium 23 Midcase Northern Grid West, Busbar Load

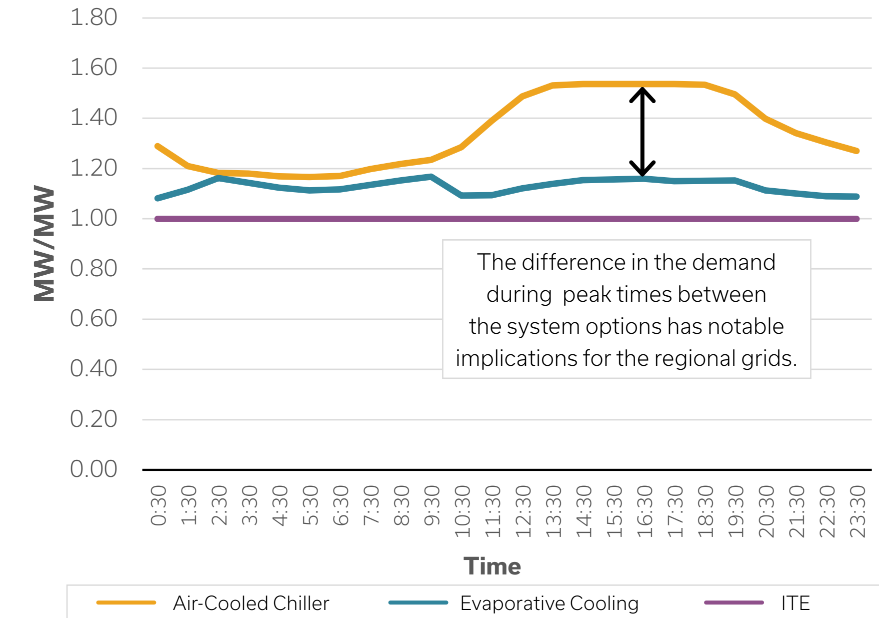


Difference in Peak Demand by System

SINGLE DATA CENTER

The difference in the demand during peak times between the system options has notable implications for the regional grids.

PEAK DAY ENERGY DEMAND

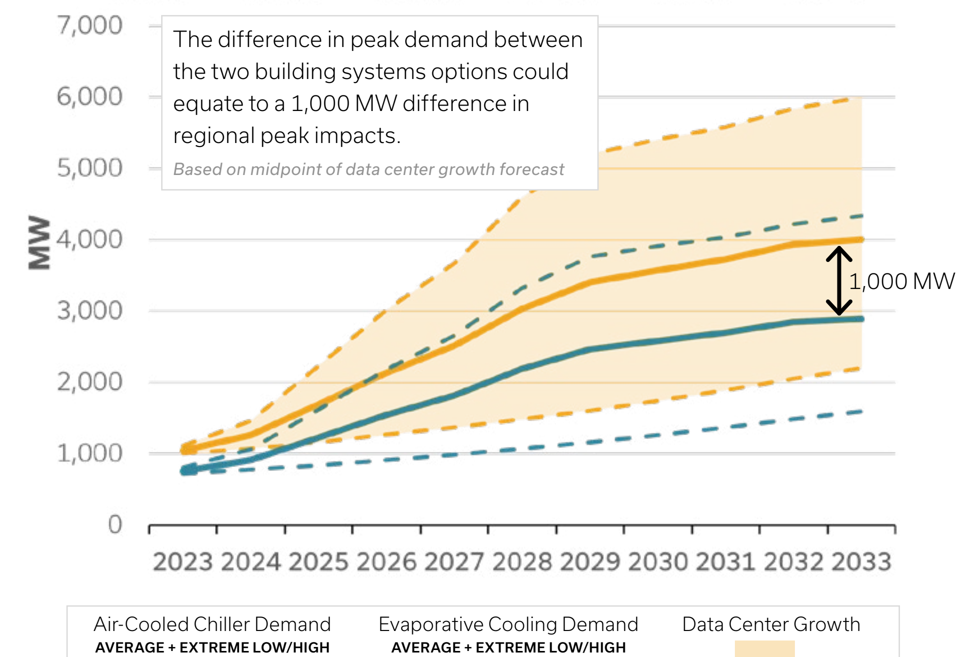


REGIONAL OUTLOOK

The difference in the demand during peak times between the system options has notable implications for the regional grids.

PEAK POWER DEMAND PROJECTION VS DATA CENTER LOAD GROWTH ASSUMPTION

Data Source: Northwest Power and Conservation Council | System Type Analysis: PAE



A Metric for Peak Demand

INTRODUCING PEAK PUE

As outlined in the "Considering the Impacts of Peak Demand" section, peak demand is potentially as much a consideration for the regional energy impacts of data centers as the total annual energy use. Yet this factor has generally been invisible in the system evaluations which typically focus only on total annual energy use.

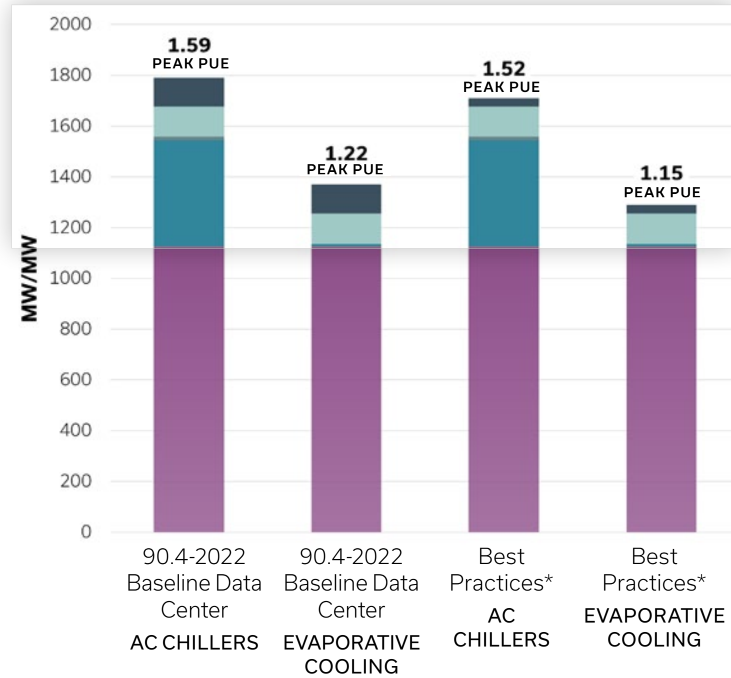
This report proposes the creation of a new metric to include visibility and consideration of peak demand factors in data center system decisions.

The proposed metric is a "Peak PUE" calculation. The current PUE metric is the PUE of the total annual energy use. As the name implies, Peak-PUE uses the same methodology from ASHRAE 90.4 for PUE but applies it only to the peak temperature hour* of the year.

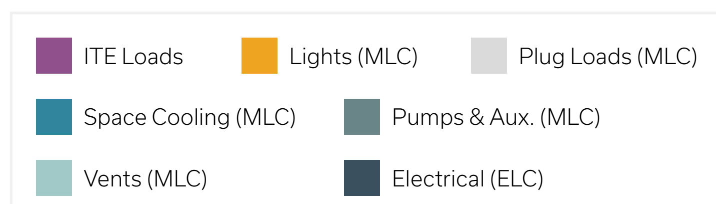
The result is a paired set of metrics that provide more nuanced information for comparing different system options.

** The analysis shown here is based on the peak temperature hour of the year, but this could be modified to a bin temperature approach which would calculate peaks based on the top bin of annual temperatures within a two degree spread based on the requirement of ASHRAE 90.4.*

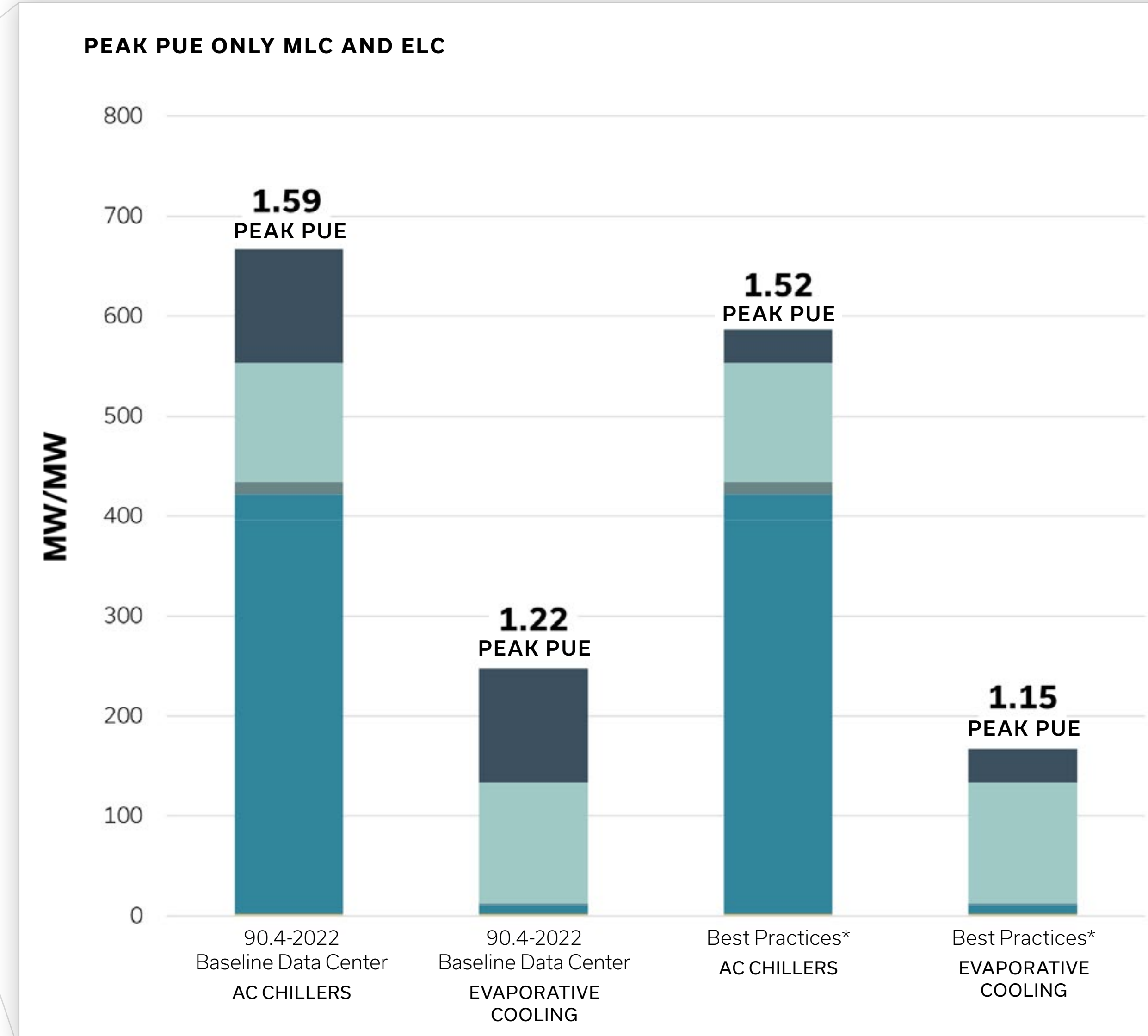
PEAK PUE WITH ITE, MLC, AND ELC



** The results in this report are based on the weather models for Climate Zone 5b. The optimal system type for improved PUE will vary depending on the Oregon and Washington climate zone in which the data center is located.*



PEAK PUE ONLY MLC AND ELC



Recommendations

Further exploration and development of a peak-demand metric in ASHRAE 90.4 for data center system evaluation.

Note: As part of the standard adoption, parameters for a maximum allowable Peak-PUE will also need to be established.

Water vs. Energy

A BALANCE OF RESOURCES

There can be an interesting dynamic between energy and water use with data centers. Decreasing use of one resource often requires an increase in the other. Yet the total impact of these onsite trades needs consideration beyond the footprint of the building.

It becomes more complicated when considering the water use associated with power generation. Most traditional power generation sources — natural gas, hydro, coal, nuclear, etc — also require water in their generation facilities. Therefore decreasing water use onsite may not decrease overall water use if it results in an increase in energy. It may simply have moved the water use "upstream" to the power generation facility.

This section of the report explores this dynamic between energy and water, both direct use at the site and the larger boundary of the energy source.

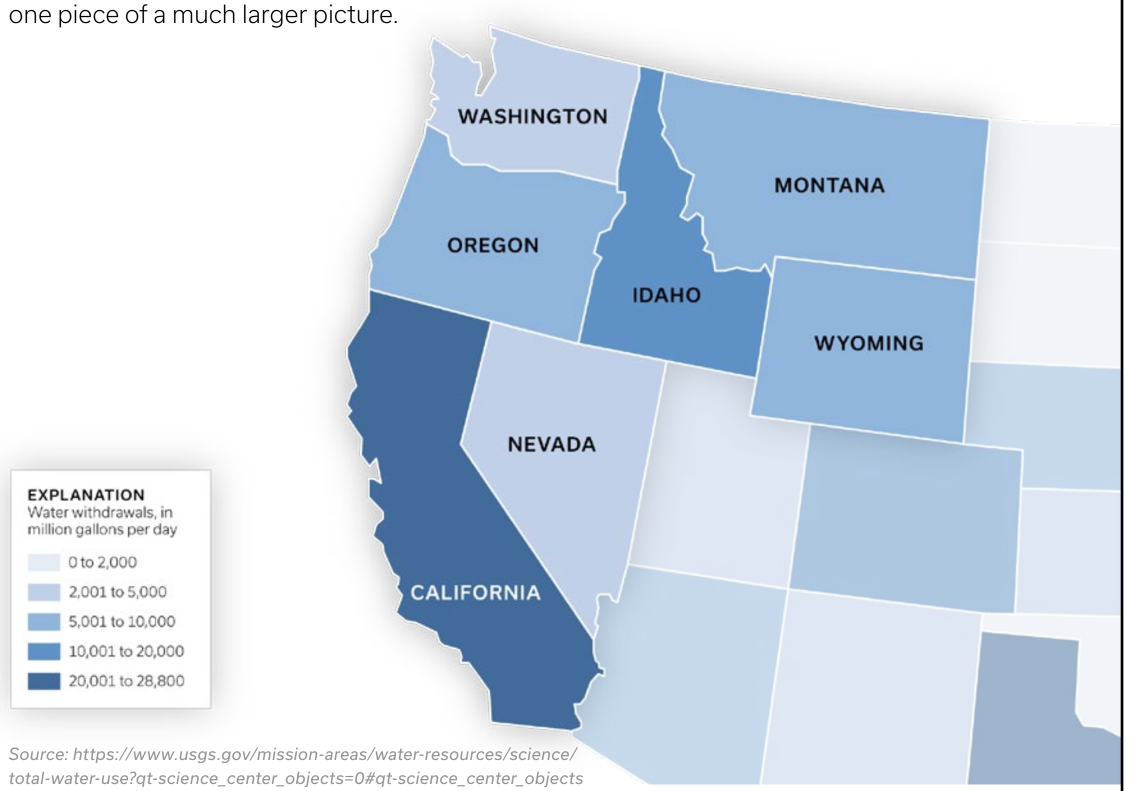
Understanding Scale

When evaluating the balance between energy and water use for the data center sector, it can be helpful to understand the magnitude of their impact to the region in the context of existing industries.

The state of Oregon withdrawals roughly 1,800-3,600 billion gallons of water per year. About 80% of that withdrawal is for use by the state's vital agriculture industry*, equaling about 2,000 billion gallons per year.

When this is compared to the projected data center growth for both Oregon and Washington, even with the higher water use associated evaporative cooling, data centers will equate to less than 0.2% of the overall water use of just the state of Oregon.

Water is a precious resource and efforts to minimize it's use should always be pursued. It is an area of great opportunity for innovation and advancement in the data center industry. But in terms of potential water stresses for the Oregon and Washington region, it is only one piece of a much larger picture.

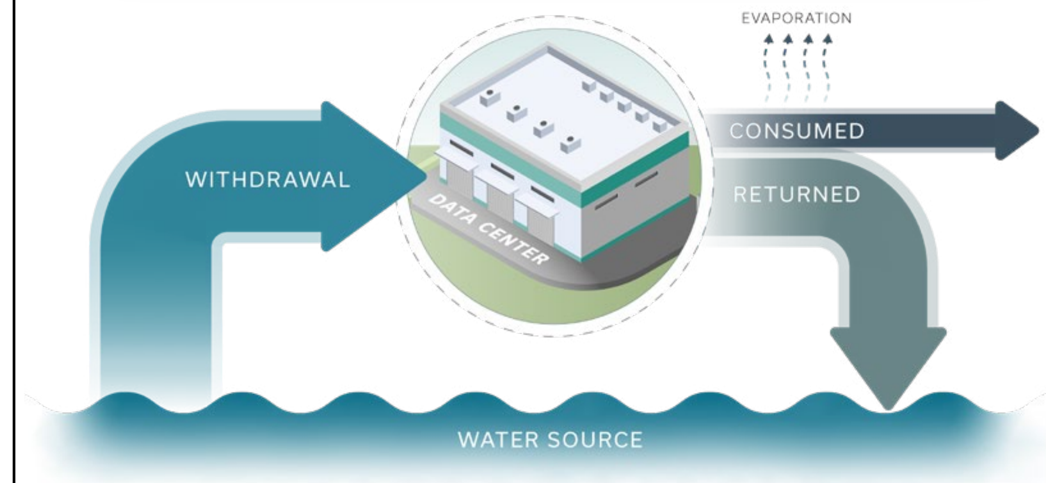


Source: https://www.usgs.gov/mission-areas/water-resources/science/total-water-use?qt-science_center_objects=0#qt-science_center_objects

	TOTAL OREGON WATER WITHDRAWAL	
	MINIMUM	MAXIMUM
Total Withdrawal BILLION GALS/YR	1,825	3,650
2033 Projected Data Center Withdrawal with Evaporative Cooling BILLION GALS/YR	4	4
Data Center Compared to Total BILLION GALS/YR	0.2%	0.1%

** Source: https://oeconline.org/wp-content/uploads/2014/12/Making-Water-Work_web.pdf*

[withdrawal] - [returned] = [consumption]



WATER WITHDRAWAL

A key factor in understanding the impact of water use is the relationship between withdrawal and consumption. Withdrawal refers to the volume of water extracted from the main source (river, aquifer, etc).

WATER CONSUMPTION

Depending on the use case, a portion of this withdrawal may be returned directly to the source. The remainder goes elsewhere, whether to municipal systems, evaporation to air, or other. This delta is what is considered to be "consumed".

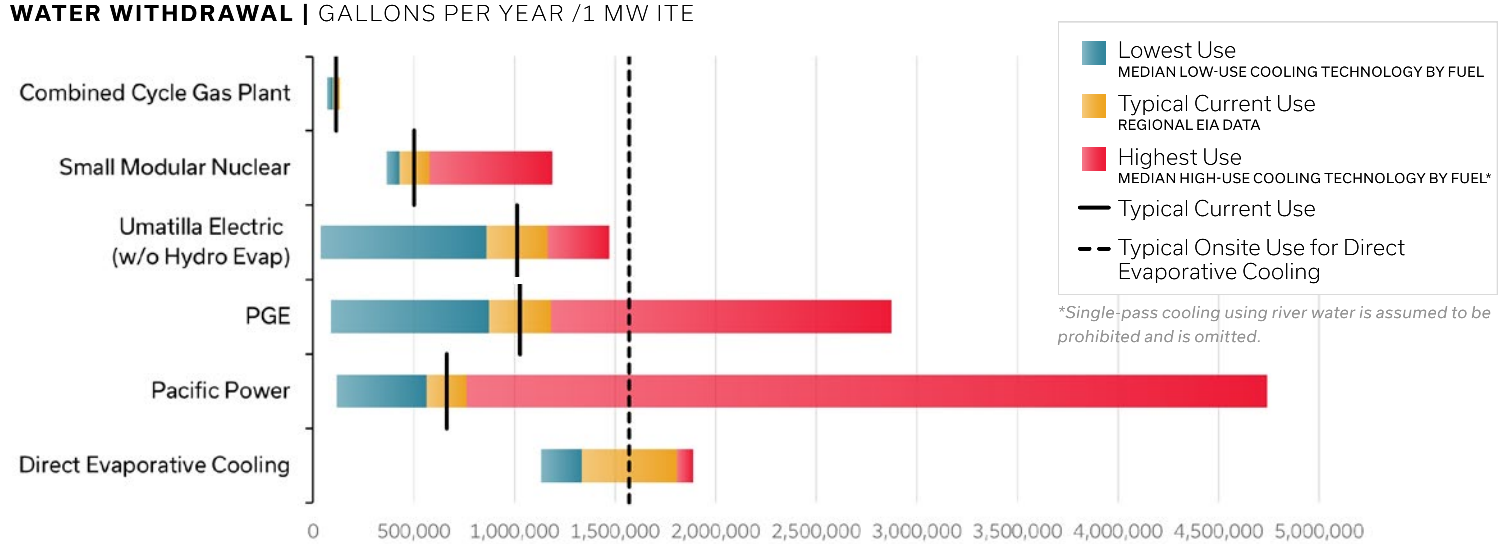
WATER WITHDRAWAL VS CONSUMPTION

Withdrawn, returned, and consumed water all have impacts when considered in the context of overall regional impact. Withdrawal, even when returned, is a change to the system which could carry impacts to the local ecology and water resources. Returned water is measured by volume and doesn't necessarily capture other changes such as temperature when the water is returned to the source. Consumed water may eventually reenter the local systems, such as evaporation into rain, but even this is a change to what the unaltered flows might be.

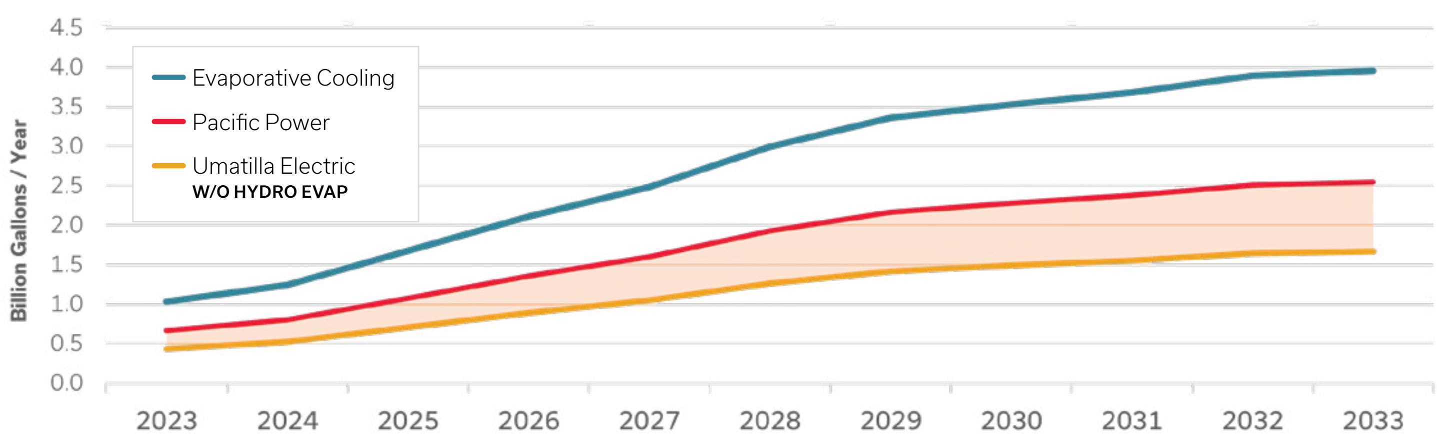
Water vs. Energy

Water Withdrawal

WATER WITHDRAWAL | GALLONS PER YEAR /1 MW ITE

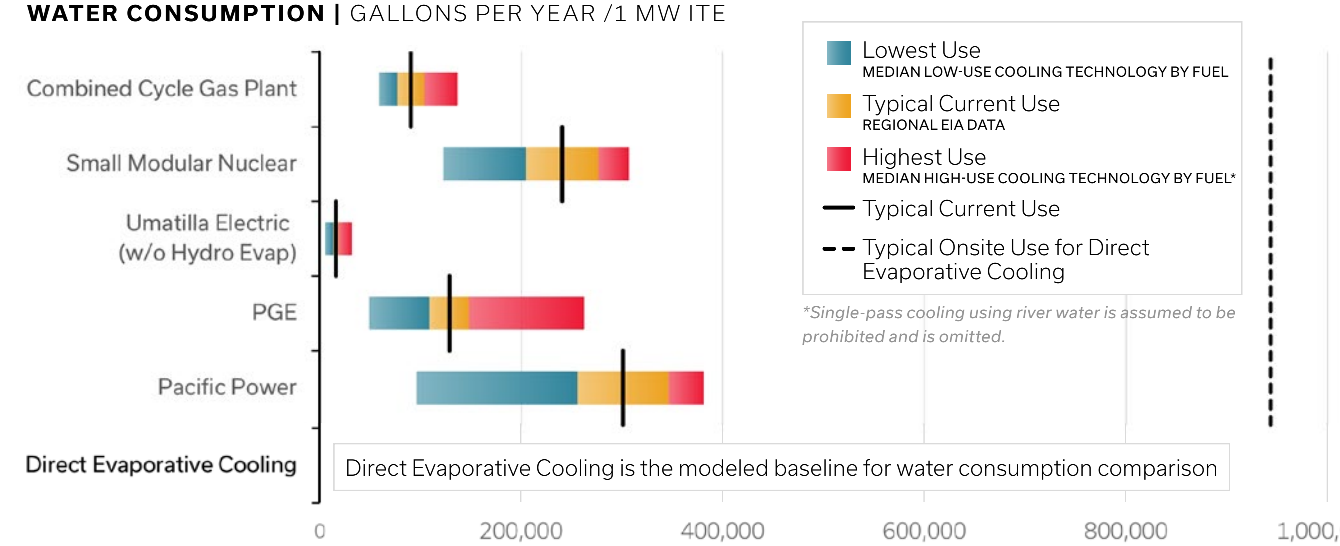


WATER WITHDRAWAL PROJECTION VS DATA CENTER LOAD GROWTH ASSUMPTION| BILLIONS GALLONS/YEAR

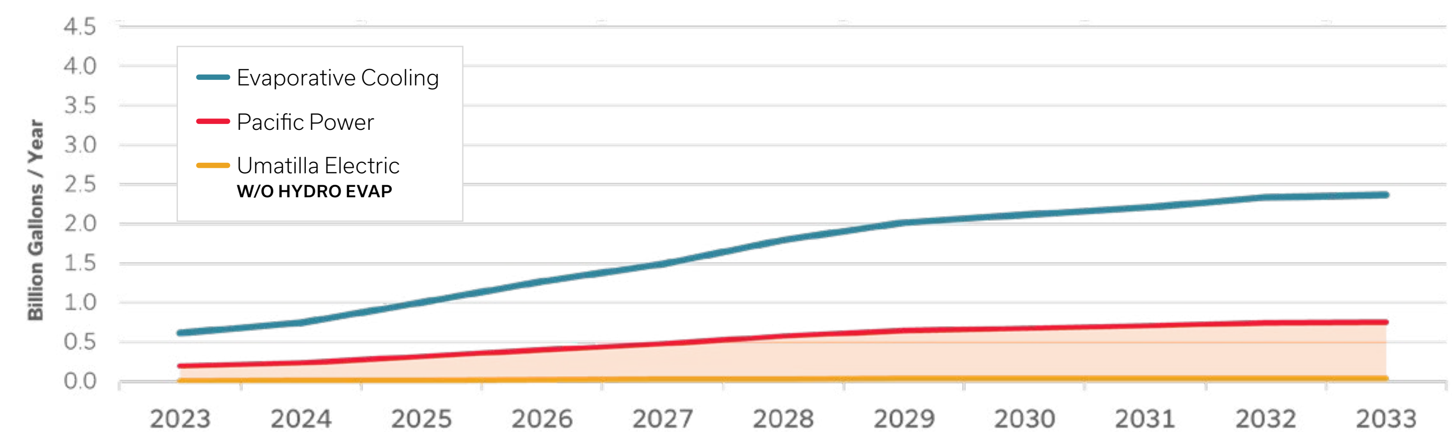


Water Consumption

WATER CONSUMPTION | GALLONS PER YEAR /1 MW ITE



WATER CONSUMPTION PROJECTION VS DATA CENTER LOAD GROWTH ASSUMPTION| BILLIONS GALLONS/YEAR



METHODOLOGY

Water withdrawal and consumption factors vary greatly both across and within different fuel sources. With fossil fuels in particular, the cooling technology used at a given plant is more predictive of water use than the fuel type.

Typical water factors for fuel sources were taken from 2023 EIA Form 923 data, filtered for generation plants in OR, WA, and CA. To provide an estimate of the likely water factor ranges for new generation plants, median factors for the highest and lowest water use cooling technologies for a given fuel were taken from NREL Technical Report TP-6A20-50900, "A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies".

In order to estimate water use for regional utilities, the fuel source values were applied to the fuel source mix of the utility as reported by the Washington Department of Commerce or Oregon Department of Environmental Quality.

Key Findings

Water use of direct evaporative cooling was compared against equivalent cooling energy water use for three existing utilities and individual fuel technologies. PGE and Pacific Power were selected to represent large scale regional utilities. Umatilla Electric can be considered a proxy for hydroelectric-heavy local utilities as well as Bonneville Power Administration generally. Combined cycle natural gas and small modular nuclear technologies are shown as they are believed to be the most likely technologies for rapid deployment of new electricity generation.

Evaporative cooling is shown to withdraw 50% - 150% more water than existing utilities. Consumption results show that evaporative cooling consumes between 3 times and 50 times the water of current utility generation. While these results are more dramatic, this water use should be weighed against the benefits of reduced energy consumption (and associated greenhouse gas emissions) as well as reduced peak demand.

RECOMMENDATIONS

Review future recommendations of the newly formed APMO WE-Stand Data Center Working Group for industry guidance on water efficiency for data centers.

Summary of Key Findings

Summary of Results

1. The study found notable differences in energy use of non-ITE loads as highlighted in their Power Usage Effectiveness (PUE) values for the following scenarios:
   - ASHRAE 90.4 baseline: 1.24 PUE
   - Best practices air cooled: 1.17 PUE
   - Best practices evaporative cooling: 1.10 PUE

2. The modeled scenarios found potential for total annual energy use savings of 2,000,000 MWh - 4,000,000 MWh by 2033 from the more efficient building system. These savings are equivalent to nearly half of all the wind power generated in Oregon in 2021[1] and resulted only from systems improvements without any reduction in data center quantity.

3. The models identified a potential 1,000 MW reduction in peak power demand between the system options. Peak demand is currently not considered in data center building standards, yet has important implications for regional energy systems.

   For the climate zone studied in this report, the "Peak-PUE" model results were:
   - ASHRAE 90.4 baseline: 1.59 Peak-PUE
   - Best practices air cooled: 1.52 Peak-PUE
   - Best practices evaporative cooling: 1.15 Peak-PUE

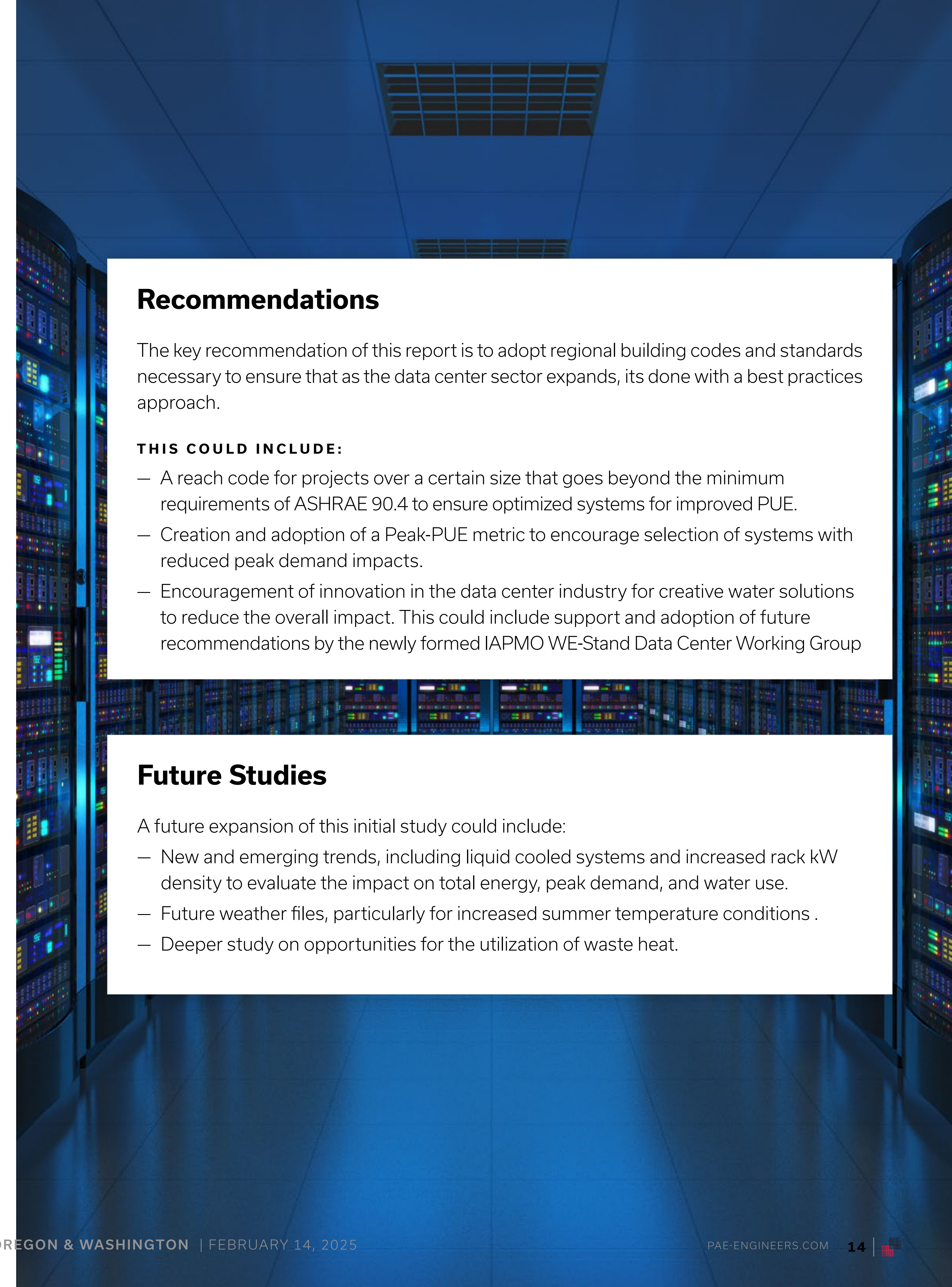
   It is recommended that a Peak-PUE metric be created and adopted to help ensure best practices regarding peak demand with system selections.

4. The interaction between water and energy use for the climate zone was modeled as a comparison between onsite direct water use and indirect water use for energy generation. The model found evaporative cooling results in a higher overall water use, even when reduced energy use is considered. Yet within the regional context, the total water use of evaporative cooling remains less than 0.1% of overall water use in the Washington and Oregon region provides the previously noted improvements in data center energy use.

[1] https://www.nwcouncil.org/reports/columbia-river-history/megawatt/

Key Findings

Implementing data center energy efficiency and peak power reductions would provide some of the most significant energy savings available to the region.



Recommendations

The key recommendation of this report is to adopt regional building codes and standards necessary to ensure that as the data center sector expands, its done with a best practices approach.

THIS COULD INCLUDE:

- A reach code for projects over a certain size that goes beyond the minimum requirements of ASHRAE 90.4 to ensure optimized systems for improved PUE.
- Creation and adoption of a Peak-PUE metric to encourage selection of systems with reduced peak demand impacts.
- Encouragement of innovation in the data center industry for creative water solutions to reduce the overall impact. This could include support and adoption of future recommendations by the newly formed IAPMO WE-Stand Data Center Working Group

Future Studies

A future expansion of this initial study could include:

- New and emerging trends, including liquid cooled systems and increased rack kW density to evaluate the impact on total energy, peak demand, and water use.
- Future weather files, particularly for increased summer temperature conditions .
- Deeper study on opportunities for the utilization of waste heat.

Water Consumption

Table 1. Water Consumption Factors for Renewable Technologies (gal/MWh)

Fuel Type	Cooling	Technology	Median	Min	Max	*n*	Sources
PV	N/A	Utility Scale PV	26	0	33	3	[10, 34, 35]
Wind	N/A	Wind Turbine	0	0	1	2	[11, 36]
CSP	Tower	Trough	865	725	1,057	17	[10, 34, 37-46]
		Power Tower	786	740	860	4	[34, 39-41]
		Fresnel	1,000	1,000	1,000	1	[47]
	Dry	Trough	78	43	79	10	[38, 42-44]
		Power Tower	26	26	26	1	[48]
	Hybrid	Trough	338	105	345	3	[42, 47]
		Power Tower	170	90	250	2	[47]
	N/A	Stirling	5	4	6	2	[34, 49]
Biopower	Tower	Steam	553	480	965	4	[49-51]
		Biogas	235	235	235	1	[52]
	Once-through	Steam	300	300	300	1	[50]
	Pond	Steam	390	300	480	1	[50]
	Dry	Biogas	35	35	35	1	[51]
Geothermal[1]	Tower	Dry Steam	1,796	1,796	1,796	1	[10]
		Flash (freshwater)	10	5	19	3	[19, 20, 49]
		Flash (geothermal fluid)	2,583	2,067	3,100	2	[53]
		Binary	3,600	1,700	3,963	3	[10, 54, 55]
		EGS	4,784	2,885	5,147	4	[10, 51, 54, 55]
	Dry	Flash	0	0	0	1	[51]
		Binary	135	0	270	2	[19, 51]
		EGS	850	300	1,778	2	[19, 51]
	Hybrid	Binary	221	74	368	1	[56]
		EGS	1,406	813	1,999	2	[51, 56]
Hydropower	N/A	Aggregated in-stream and reservoir	4,491	1,425	18,000	3	[22, 23]

1 Most geothermal facilities can use geothermal fluids or freshwater for cooling.

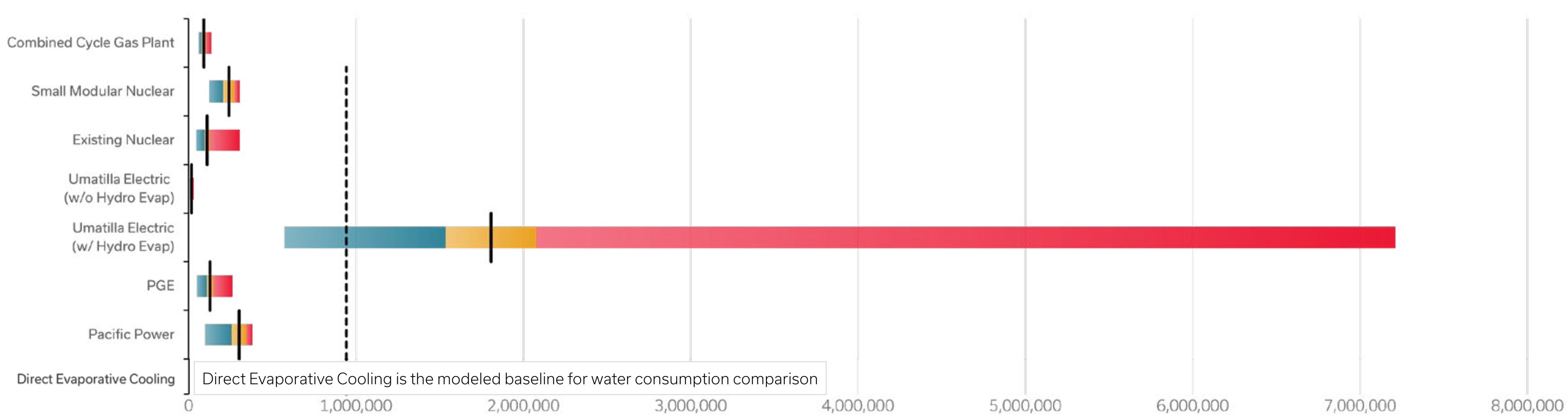
Used Data Hydro Reference

Table 2. Water Consumption Factors for Non-renewable Technologies (gal/MWh)

Fuel Type	Cooling	Technology	Median	Min	Max	*n*	Sources
Nuclear	Tower	Generic	672	581	845	6	[10, 14, 27, 50, 57]
	Once-through	Generic	269	100	400	4	[27, 50, 57, 58]
	Pond	Generic	610	560	720	2	[27, 50]
Natural Gas	Tower	Combined Cycle	198	130	300	5	[13, 34, 50, 57, 59]
		Steam	826	662	1,170	4	[10, 14, 49, 60]
		Combined Cycle with CCS	378	378	378	1	[59]
	Once-through	Combined Cycle	100	20	100	3	[50, 57, 60]
		Steam	240	95	291	2	[10, 49]
	Pond	Combined Cycle	240	240	240	1	[57]
	Dry	Combined Cycle	2	0	4	2	[50, 57]
	Inlet	Steam	340	80	600	1	[49]
Coal	Tower	Generic	687	480	1,100	5	[10, 14, 27, 50, 58]
		Subcritical	471	394	664	6	[13, 57, 59, 61]
		Supercritical	493	458	594	6	[13, 57, 59, 61]
		IGCC	372	318	439	7	[13, 59]
		Subcritical with CCS	942	942	942	1	[59]
		Supercritical with CCS	846	846	846	1	[59]
		IGCC with CCS	540	522	558	3	[59]
	Once-through	Generic	250	100	317	4	[10, 27, 50, 58]
		Subcritical	113	71	138	3	[57]
		Supercritical	103	64	124	3	[57]
	Pond	Generic	545	300	700	2	[27, 50]
		Subcritical	779	737	804	3	[57]
		Supercritical	42	4	64	3	[57]

Used Data Hydro Reference

WATER CONSUMPTION - COMPLETE | GALLONS PER YEAR /1 MW ITE



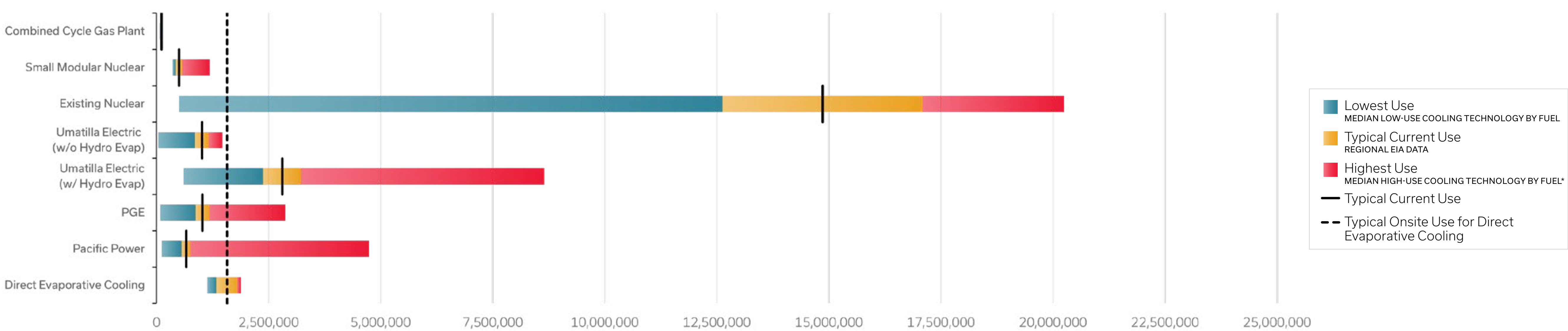
Water Withdrawal

Table 3. Water Withdrawal Factors for Electricity Generating Technologies (gal/MWh)

Fuel Type	Cooling	Technology	Median	Min	Max	*n*	Sources
Nuclear	Tower	Generic	1,101	800	2,600	3	[27, 50, 57]
	Once-through	Generic	44,350	25,000	60,000	4	[27, 50, 57, 58]
	Pond	Generic	7,050	500	13,000	2	[27, 50]
Natural Gas	Tower	Combined Cycle	253	150	283	6	[12, 13, 50, 57, 59]
		Steam	1,203	950	1,460	2	[49, 60]
		Combined Cycle with CCS	496	487	506	2	[12, 59]
	Once-through	Combined Cycle	11,380	7,500	20,000	2	[50, 57]
		Steam	35,000	10,000	60,000	1	[49]
	Pond	Combined Cycle	5,950	5,950	5,950	1	[57]
	Dry	Combined Cycle	2	0	4	2	[50, 57]
	Inlet	Steam	425	100	750	1	[49]
Coal	Tower	Generic	1,005	500	1,200	4	[27, 35, 50, 58]
		Subcritical	531	463	678	7	[12, 13, 57, 59, 61]
		Supercritical	609	582	669	7	[12, 13, 57, 59, 61]
		IGCC	390	358	605	11	[12, 13, 35, 59]
		Subcritical with CCS	1,277	1,224	1,329	2	[12, 59]
		Supercritical with CCS	1,123	1,098	1,148	2	[12, 59]
		IGCC with CCS	586	479	678	6	[12, 59]
	Once-through	Generic	36,350	20,000	50,000	4	[11, 27, 50, 58]
		Subcritical	27,088	27,046	27,113	3	[57]
		Supercritical	22,590	22,551	22,611	3	[57]
	Pond	Generic	12,225	300	24,000	2	[27, 50]
		Subcritical	17,914	17,859	17,927	3	[57]
		Supercritical	15,046	14,996	15,057	3	[57]
Biopower	Tower	Steam	878	500	1,460	2	[49]
	Once-through	Steam	35,000	20,000	50,000	1	[50]
	Pond	Steam	450	300	600	1	[50]

Used Data | Hydro Reference

WATER WITHDRAWAL - COMPLETE | GALLONS PER YEAR /1 MW ITE



References

American Society of Heating, Refrigeration, and Air Conditioning Engineers. 2022. *Energy Standard for Data Centers (ASHRAE Standard 90.4)*. ASHRAE.

Bonneville Power Administration (BPA). 2023. *2024-2028 Strategic Plan***.** DOE/BP-5255, Portland, OR: BPA.

—. 2025. "BPA Loads Presentation." *NWPCC Power Committee Meeting*. Portland, OR: NW Power Conservation Council, March 12.

CBRE. 2024. *North American Data Center Trends H1 2024*. August 19. Accessed November 8, 2024. https://www.cbre.com/insights/reports/north-america-data-center-trends-h1-2024.

Cushman & Wakefield. 2024. *Global Data Center Market Comparison*. New York: Cushman & Wakefield.

Daudon, Sophie, Spencer Checkoway, and Caroline Resor. 2023. *State of Washington Renewable Energy Policy Analysis Report*. Ann Arbor, Michigan: Center for Local, State, and Urban Policy.

Dieter, Cheryl A., Molly A. Maupin, Rodney R. Caldwell, Melissa A. Harris, Tamara I. Ivahnenko, John K. Lovelace, Nancy L. Barber, and Kristin S. Linsey. 2018. *Estimated Use of Water in the United States in 2015*. Circular 1441, Reston, VA: U.S. Geological Survey.

Electric Power Research Institute (EPRI). 2024. *Utility Experiences and Trends Regarding Data Centers: 2024 Survey*. Palo Alto, CA: EPRI.

Gagnon, Pieter, Pedro Andres Sanchez Perez, Kodi Obika, Marty Schwarz, James Morris, Jianli Gu, and Jordan Eisenman. n.d. *Cambium 2023 Data*. National Renewable Energy Laboratory. https://scenarioviewer.nrel.gov.

Macknick, Jordan, Robin Newmark, Garvin Heath, and KC Hallett. 2011. *A Review of Operational Water Consumption and Withdrawal Factors for Electricity Generating Technologies*. Technical Report, Golden, CO: NREL.

NuScale Power. 2024. *VOYGR Power Plants: Water-Efficient Technology*. Accessed October 30, 2024. https://www.nuscalepower.com/en/products/voygr-smr-plants.

Oregon Environmental Council (OEC). 2012. *Making Water Work: Strategies for Advancing Water Conservation in Oregon Agriculture*. Portland, OR: OEC.

Pacific Northwest Utilities Conference Committee, May 2024. Northwest Regional Forecast of Power Loads and Resources - August 2024 through July 2034. https://www.pnucc.org/system-planning/northwest-regional-forecast/

Portland General Electric Company (PGE). 2023. *Clean Energy Plan and Integrated Resource Plan 2023*. Portland, OR: PGE.

TeleGeography. 2024. *Submarine Cable Map*. November 1. Accessed November 5, 2024. https://www.submarinecablemap.com/.

U.S. Department of Energy, The Energy Information Administration (EIA). 2023. *Annual Source and Disposition of Electricity for Non-Utility Generators, 2023 Final Data*. EIA-923, Washington, DC: EIA.