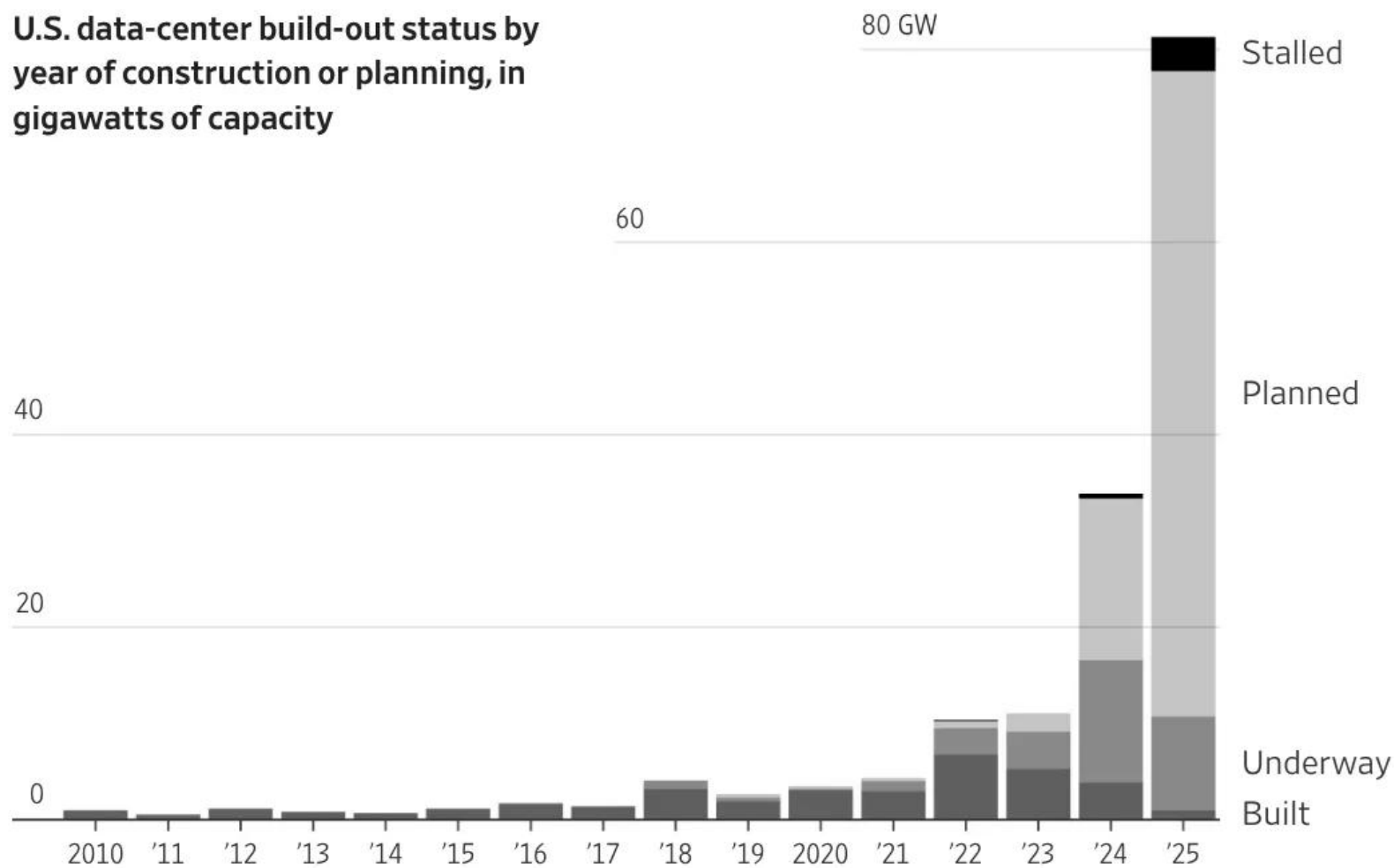


The Energy-Water Nexus of Data Centers

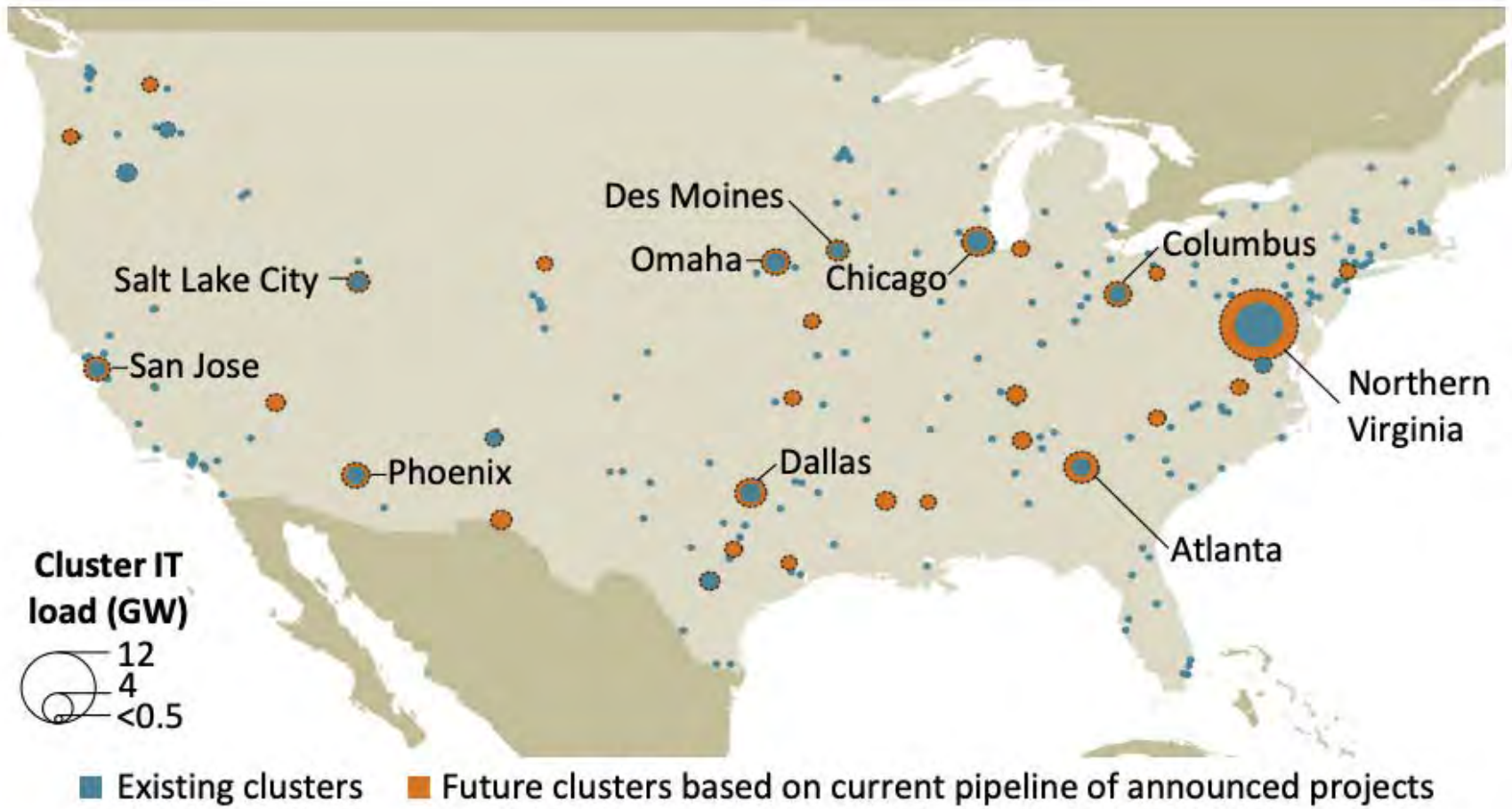
Eric Sjöstedt, Ph.D.
Postdoctoral Fellow
Virginia Tech

The U.S. data center fleet



Note: 2025 data as of October.
Source: MSCI Real Assets via JPMorgan Chase

The U.S. data center fleet



IEA. CC BY 4.0.

Data centre development is expanding into new locations, but around 50% of the capacity under development in the United States is in markets with over 1 GW of installed capacity

[IEA, 2025](#)

So what does a data center look like?

Enterprise/Onsite/Internal



Colocation



Edge

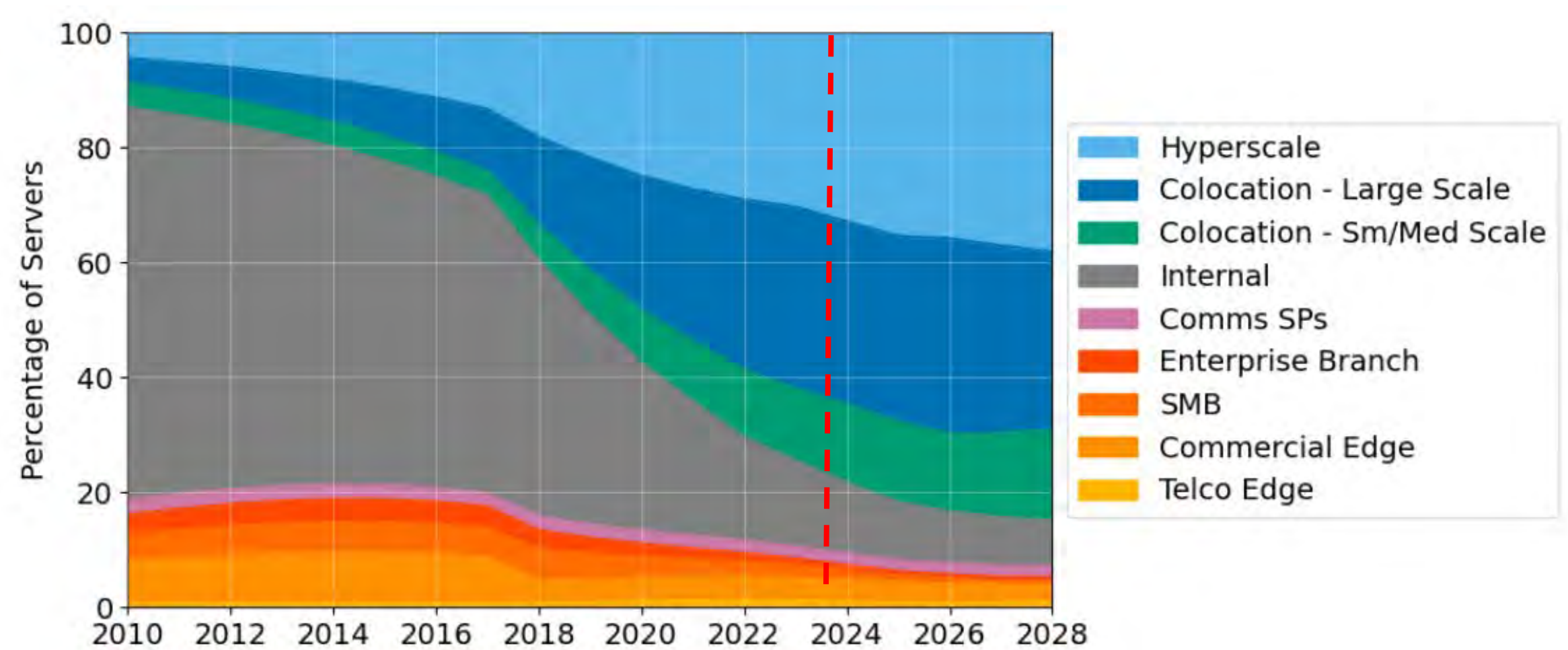


Hyperscale

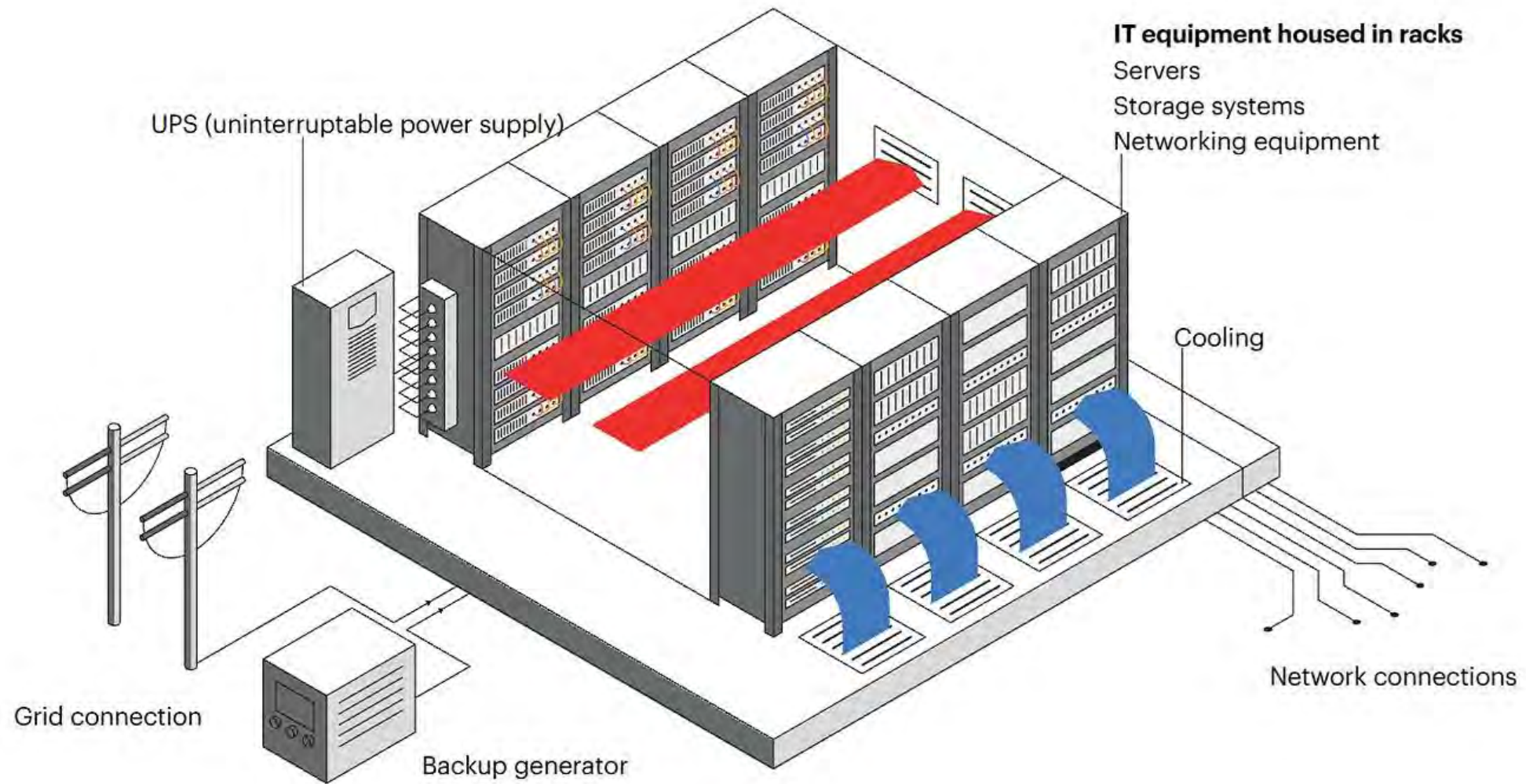


So what does a data center look like?

[Shehabi et al., 2024](#)

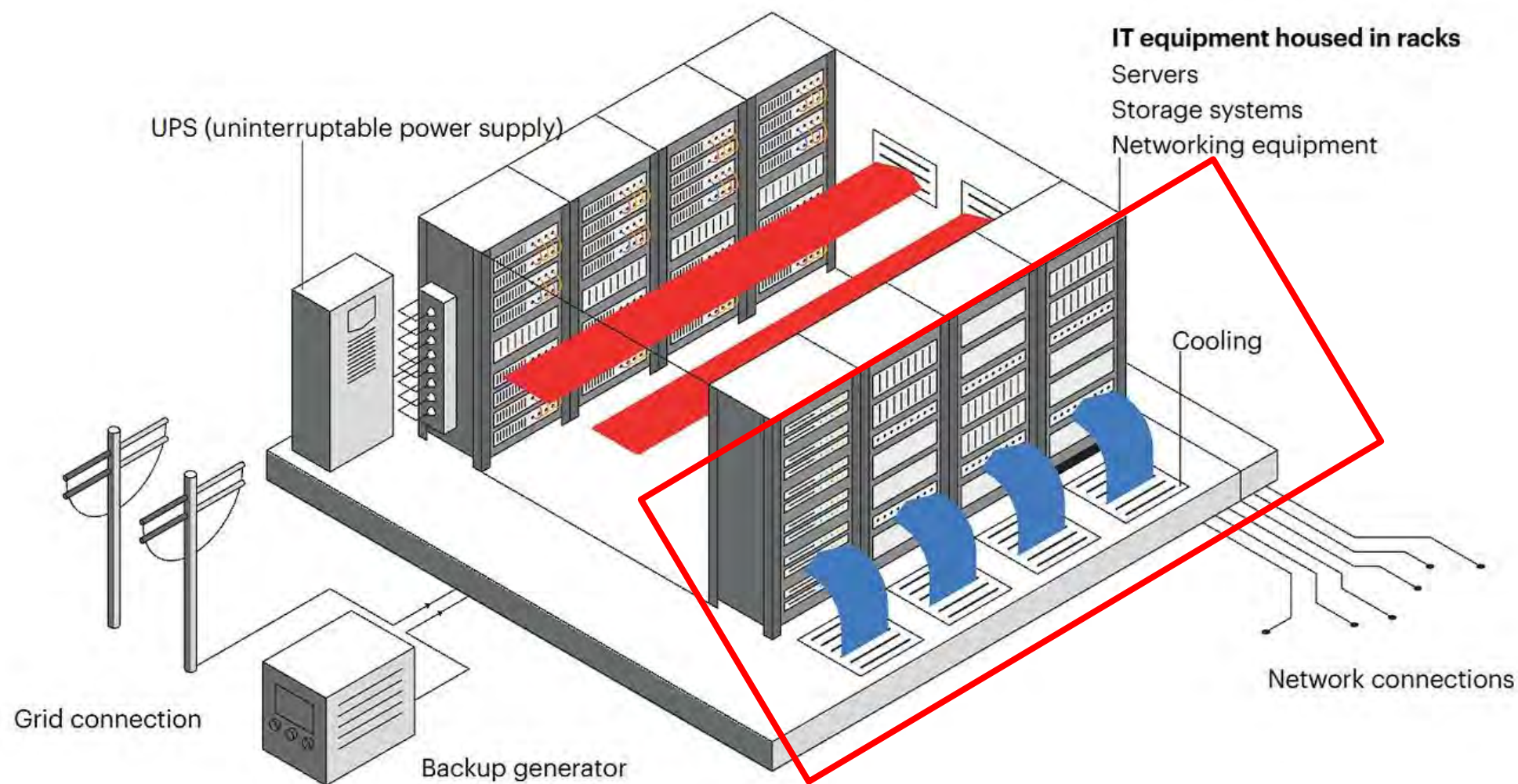


A general composition of a data center facility



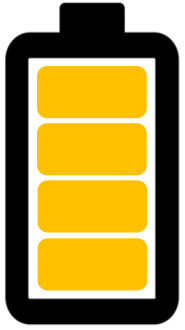
[IEA, 2025](#)

A general composition of a data center facility



[IEA, 2025](#)

Data center resource use metrics

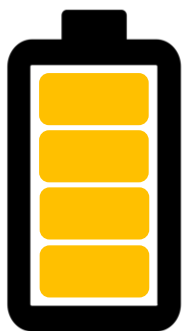


$$\textit{Power Usage Efficiveness (PUE)} = \frac{\textit{Total Facility Energy}}{\textit{IT Equipment Energy}}$$

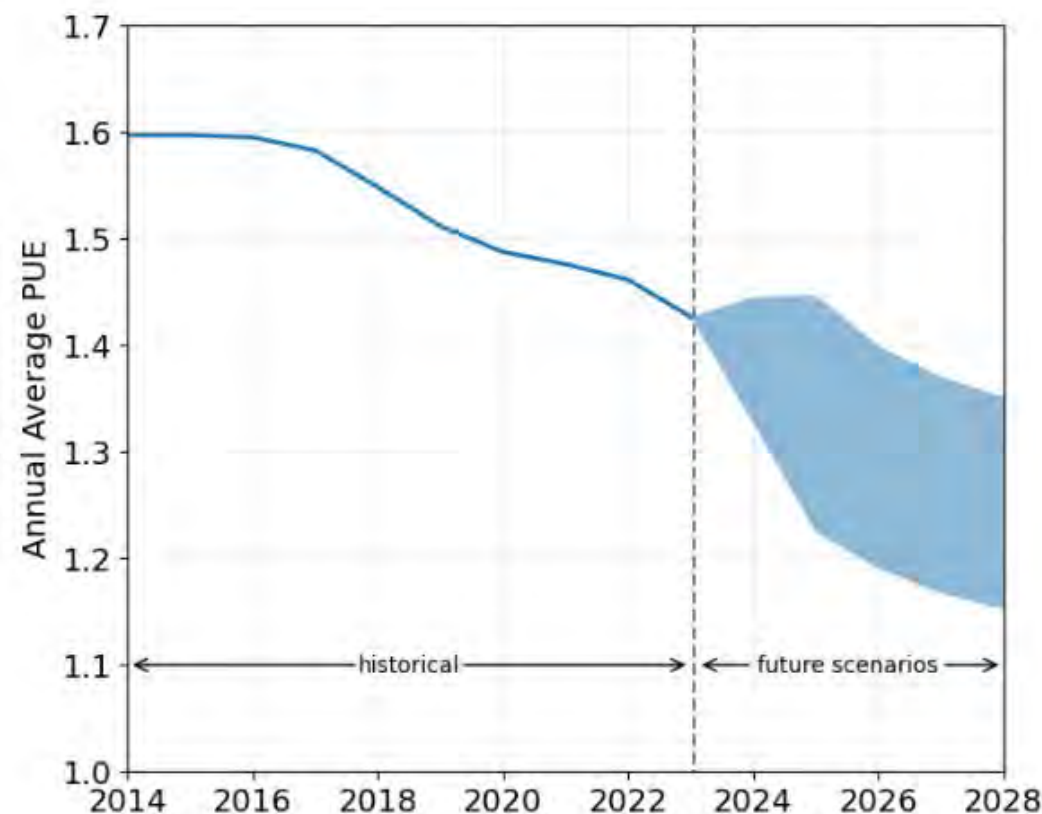
[The Green Grid, 2011](#)

[Shehabi et al., 2024](#)

Data center resource use metrics



Power Usage Efficiveness (PUE) = $\frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}}$



Lower is better

[The Green Grid, 2011](#)

[Shehabi et al., 2024](#)

Data center resource use metrics



$$\text{Water Usage Effectiveness (WUE}_{SITE}) = \frac{\text{Data center water consumption}}{\text{IT equipment energy consumption}}$$

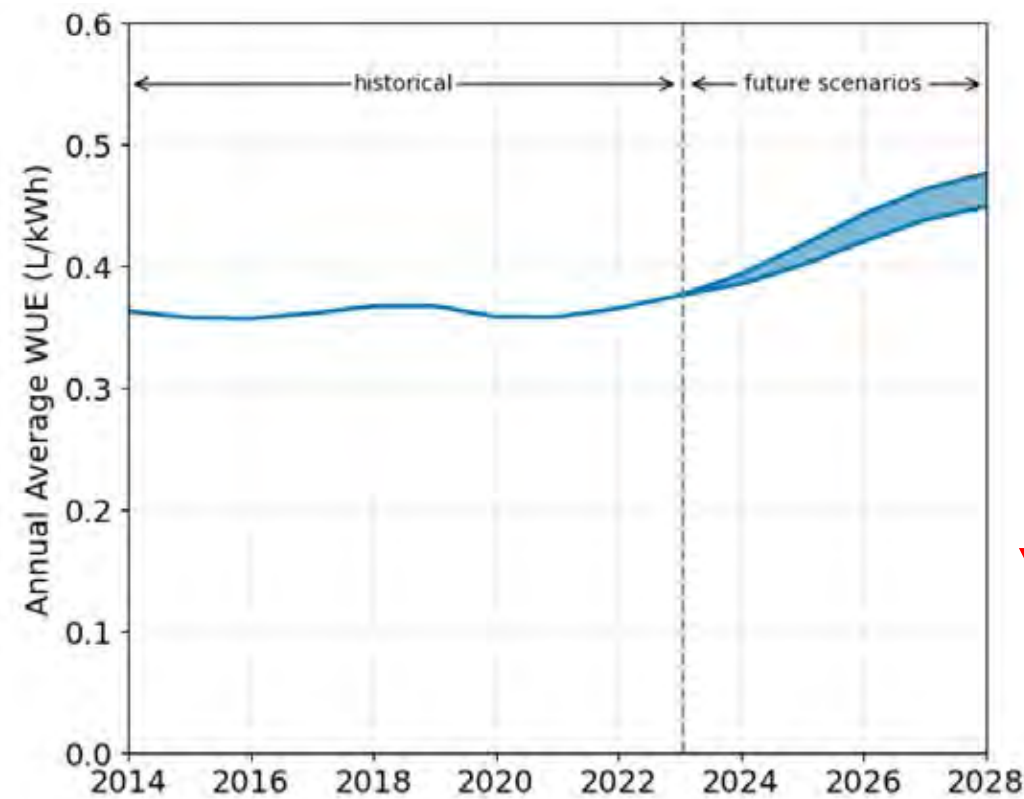
[The Green Grid, 2011](#)

[Shehabi et al., 2024](#)

Data center resource use metrics



Water Usage Effectiveness (WUE_{SITE}) = $\frac{\text{Data center water consumption}}{\text{IT equipment energy consumption}}$

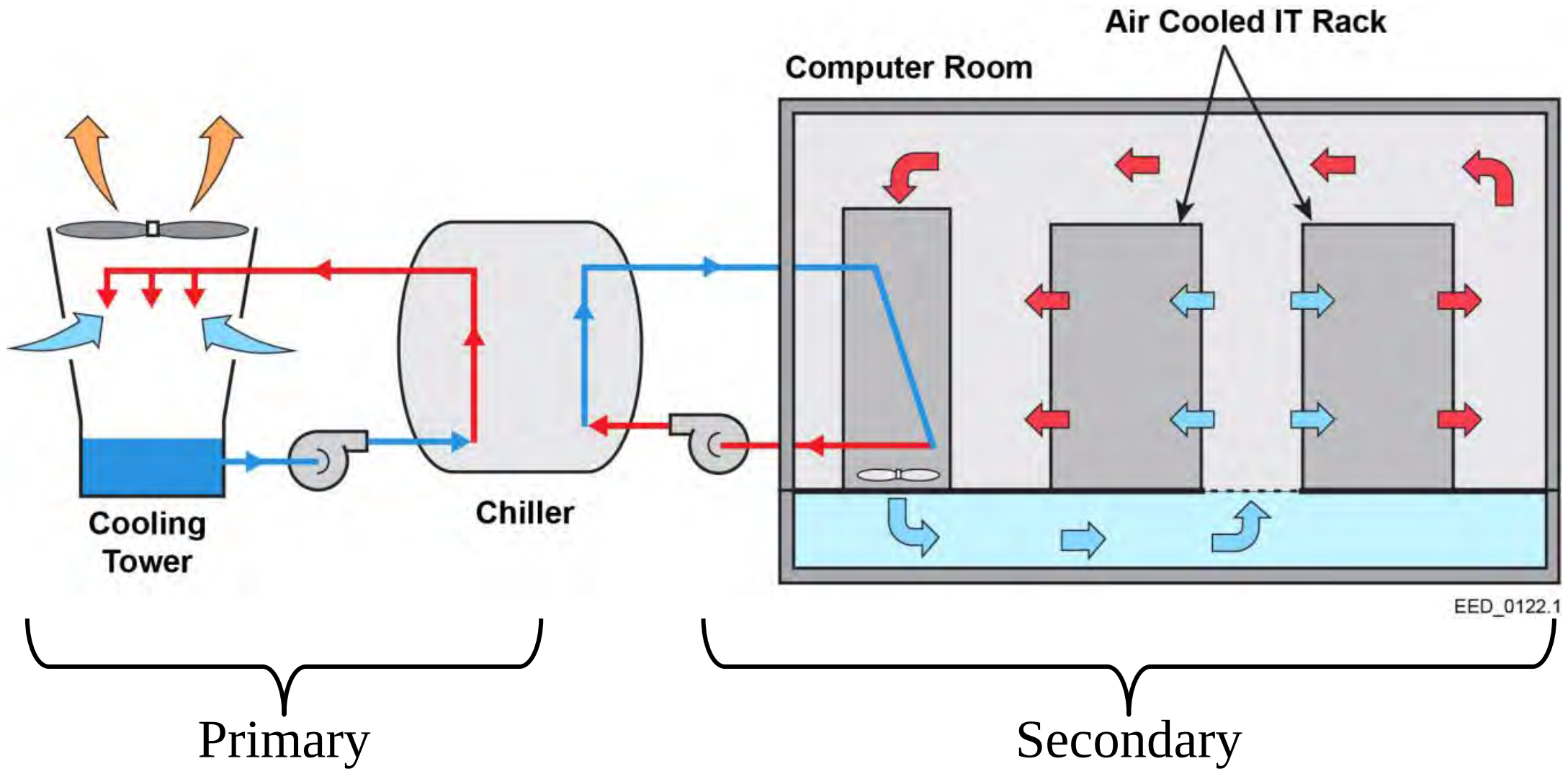


Lower is better

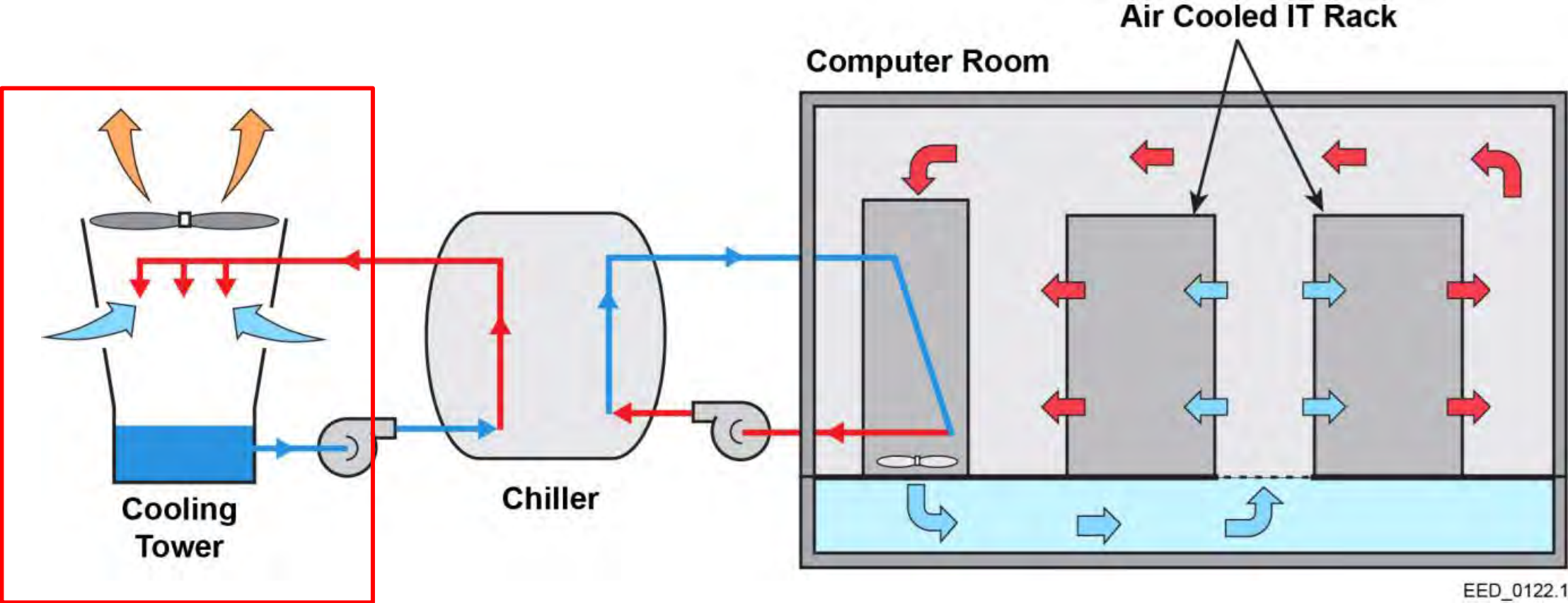
[The Green Grid, 2011](#)

[Shehabi et al., 2024](#)

Cooling Technology



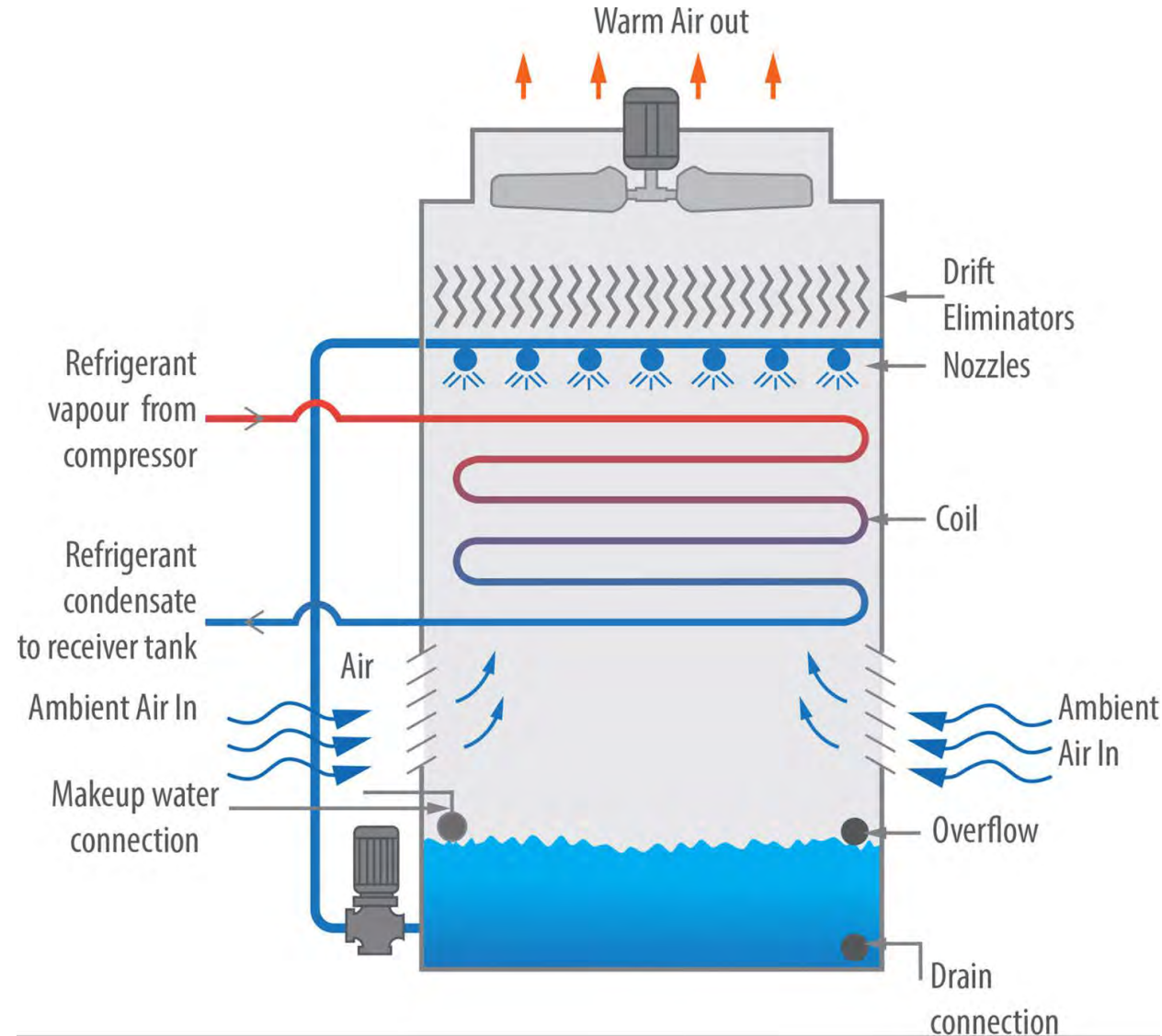
Evaporative Cooling



Evaporative Cooling



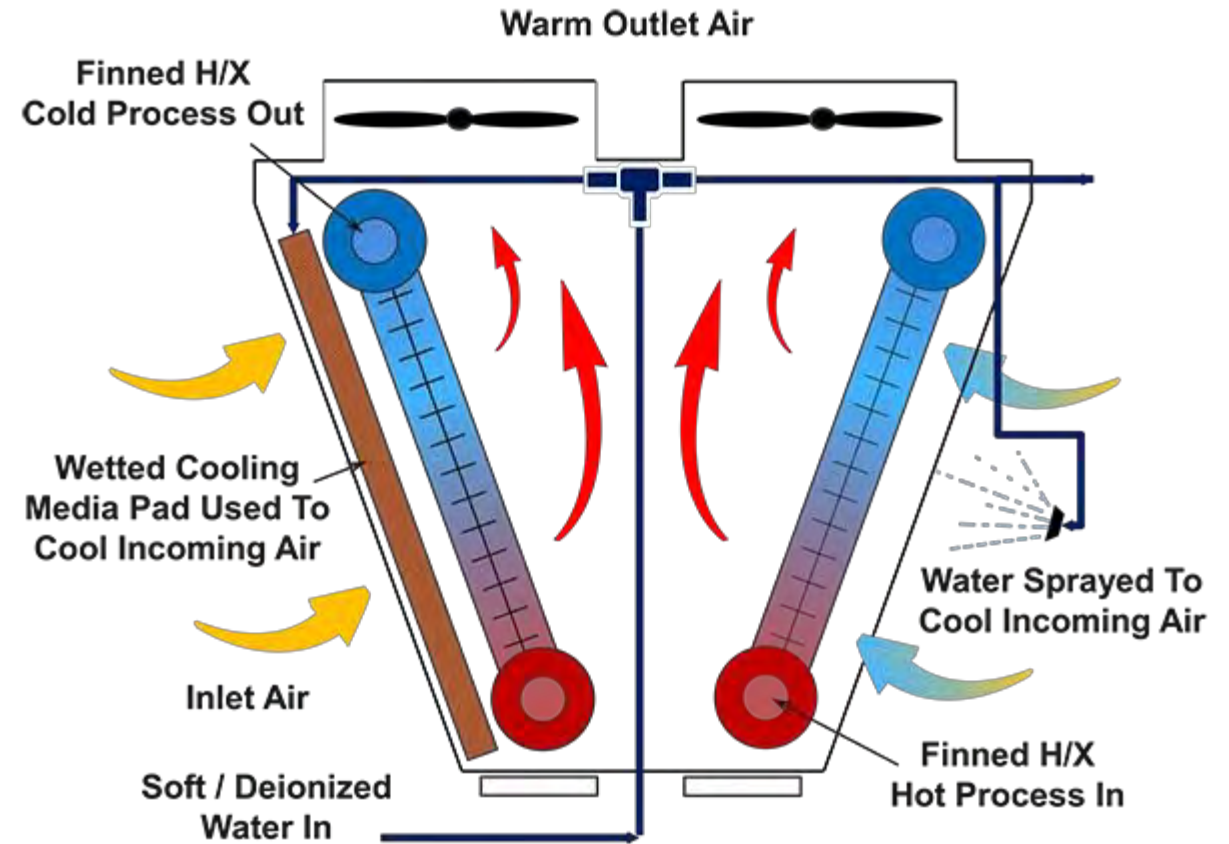
Evaporative Cooling



Adiabatic Cooling



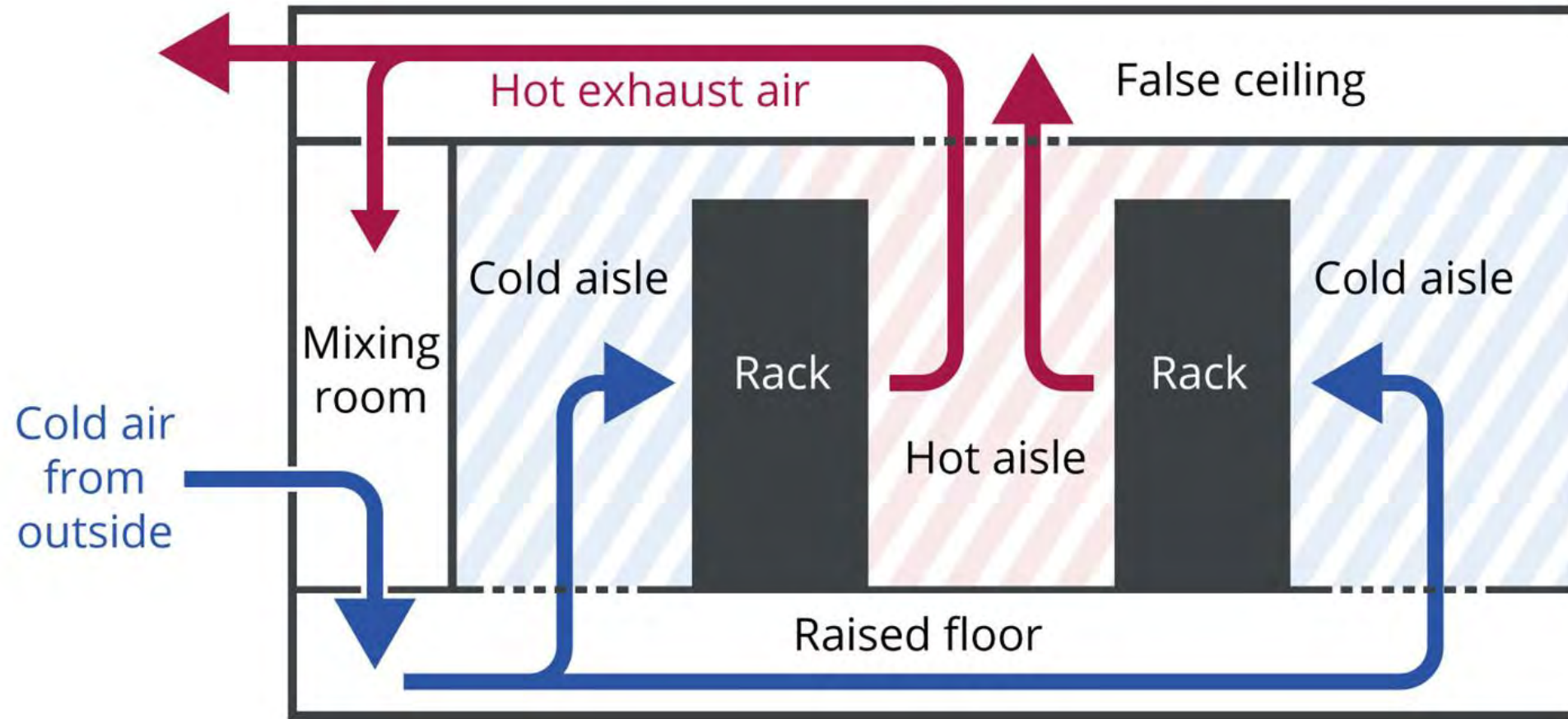
Adiabatic Cooling



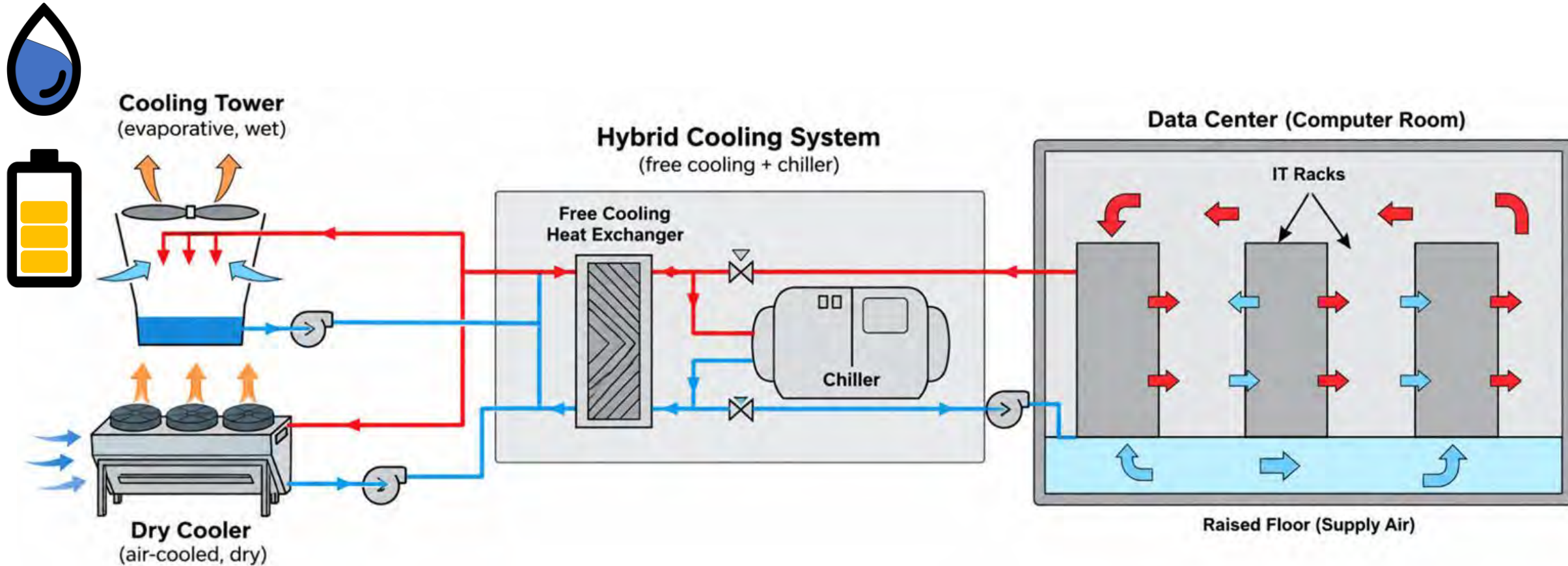
Air / Dry Cooling



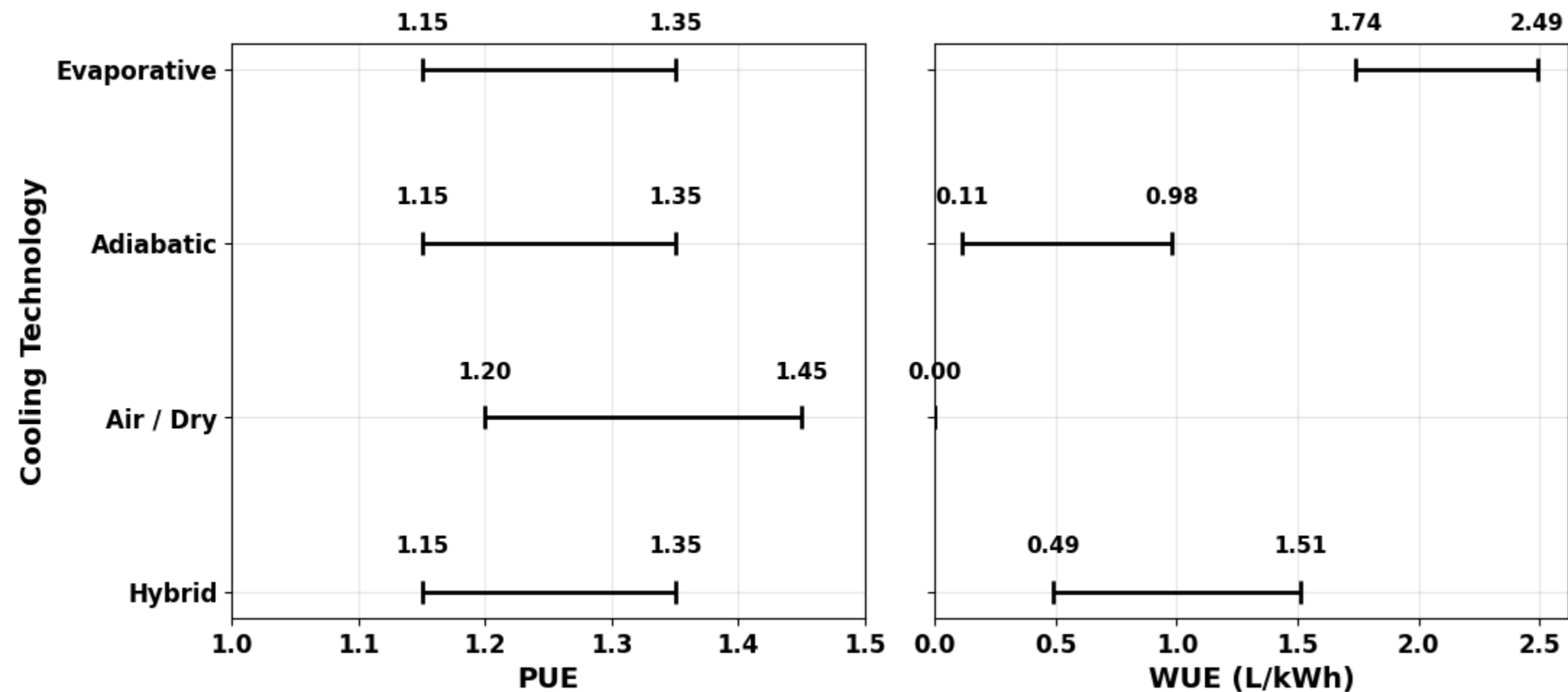
Air / Dry Cooling



Hybrid Cooling



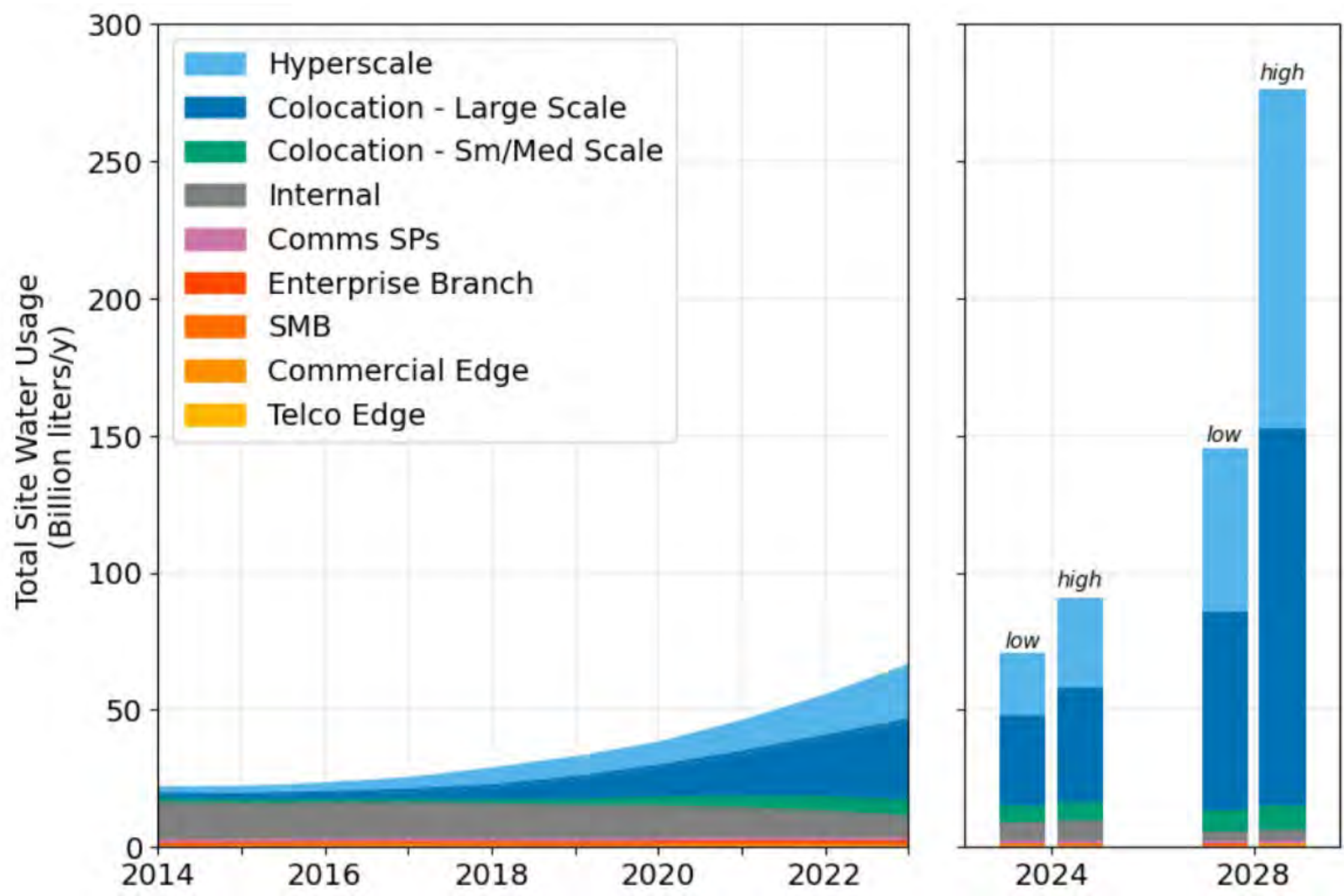
Comparing Cooling Technologies



[Arzumanyan et al., 2025](#)

U.S. Data center water consumption

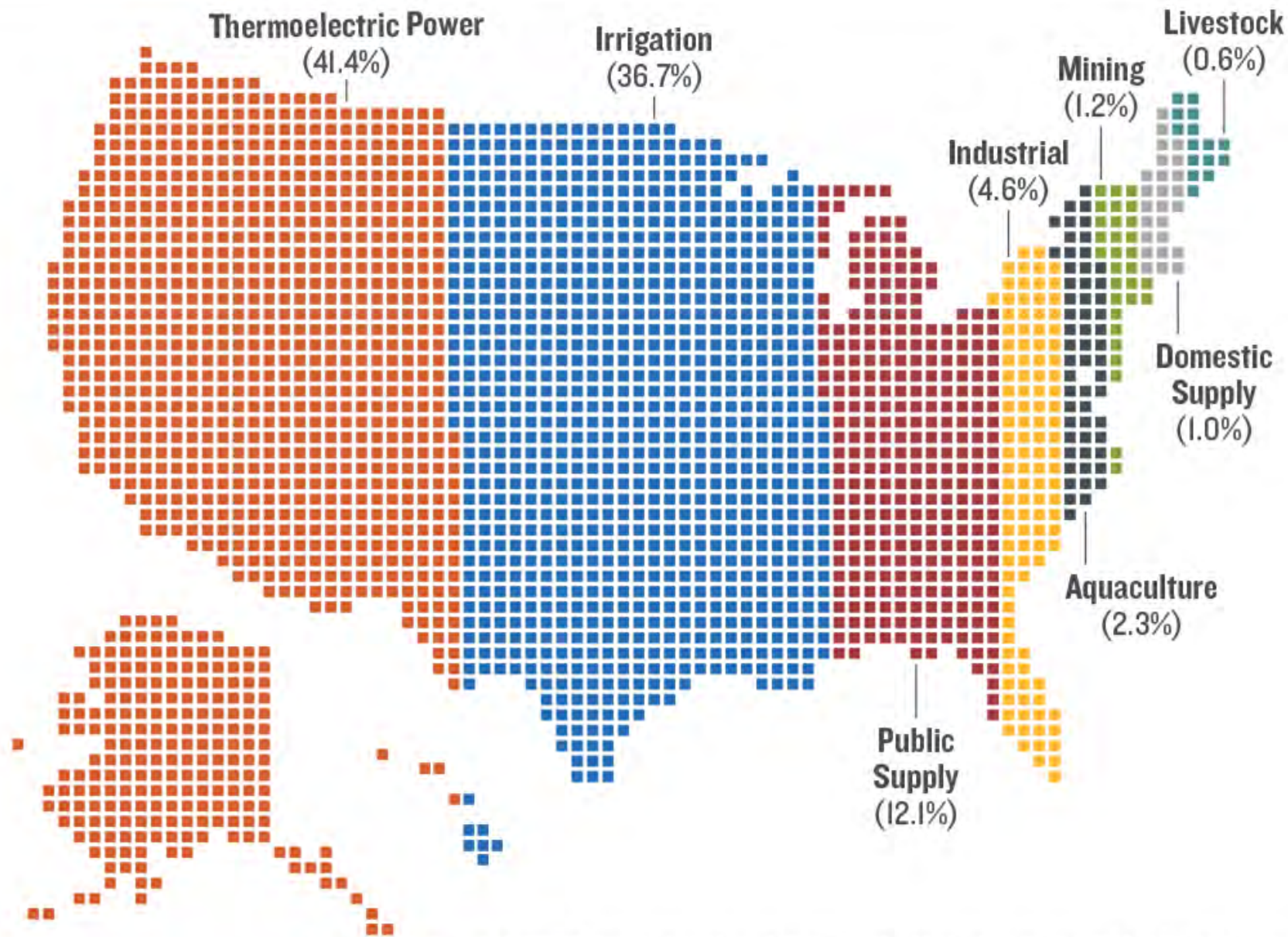
On-site **water consumption** is expected to increase significantly



[Shehabi et al., 2024](#)

Scope 1 water

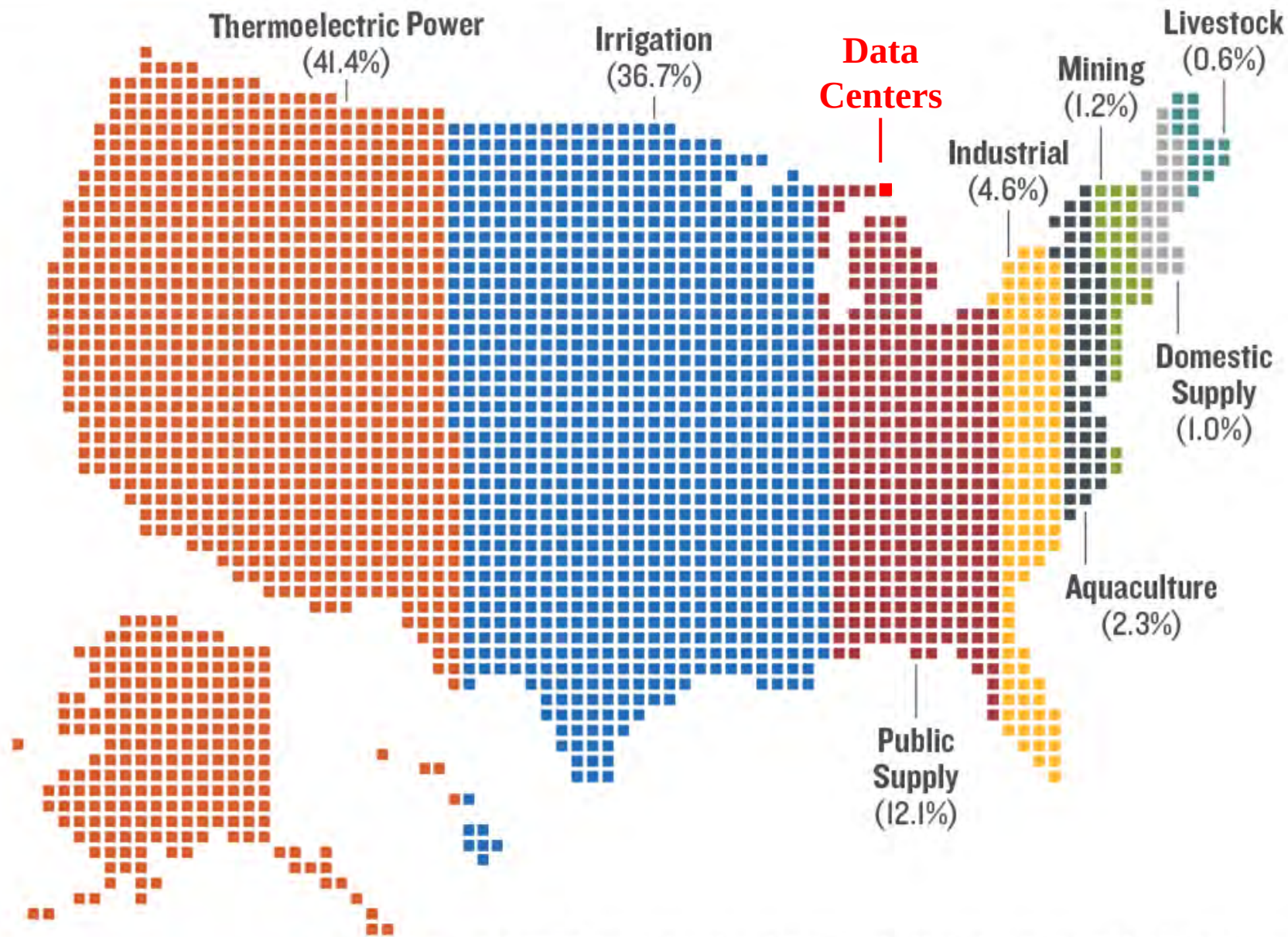
In 2015, total U.S. water withdrawal was ~322 billion gallons per day



Source: Dieter et al. (2018) Estimated Use of Water in the United States in 2015. USGS Circular 1441.

Scope 1 water

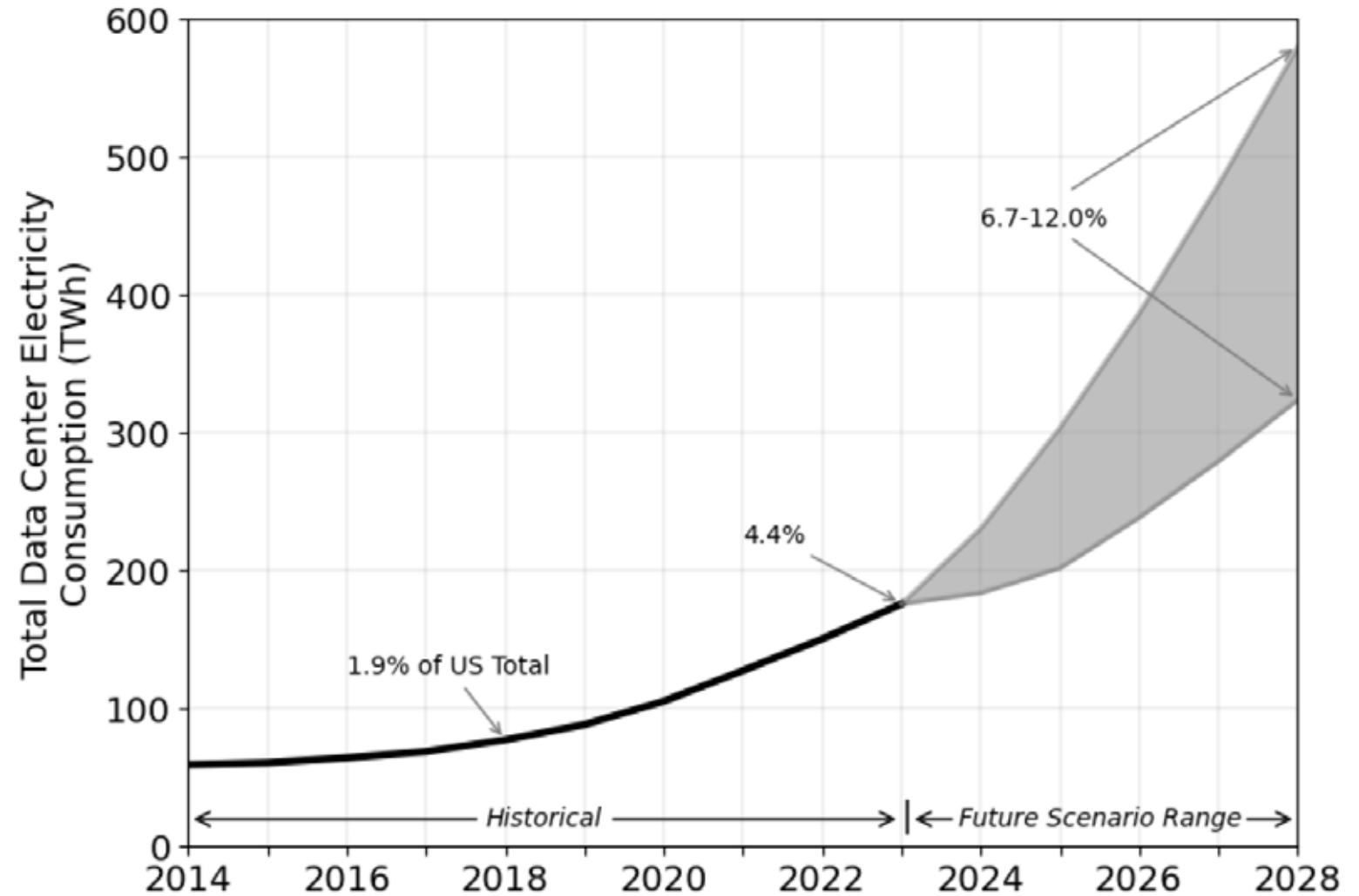
Data center direct
water withdrawals
represent **<0.04% of
U.S. total**



Source: Dieter et al. (2018) Estimated Use of Water in the United States in 2015. USGS Circular 1441.

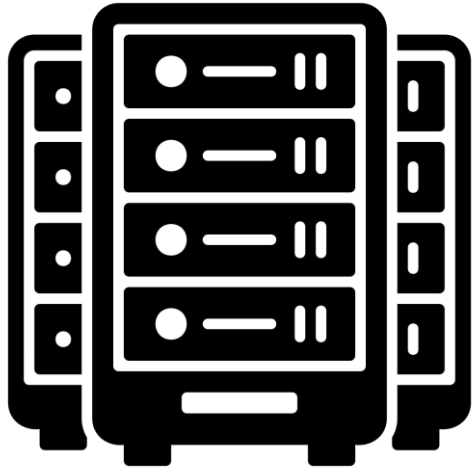
U.S. Data center electricity consumption

On-Site **electricity consumption** is estimated to increase significantly



[Shehabi et al., 2024](#)

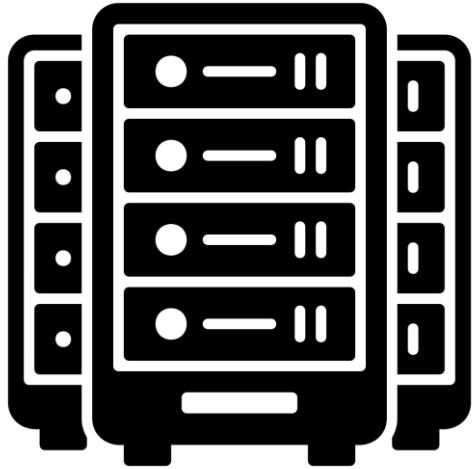
Following the water



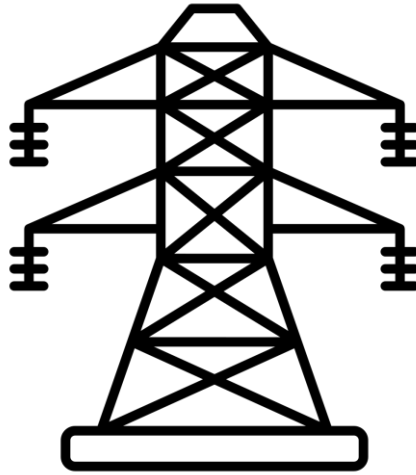
Scope 1

**Direct Water Footprint
[Onsite water consumption]**

Following the water

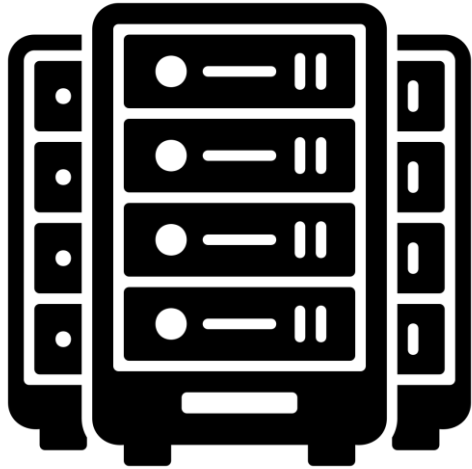


Scope 1
Direct Water Footprint
[Onsite water consumption]

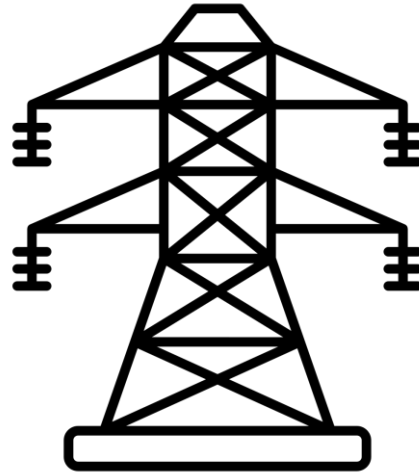


Scope 2
Indirect Water Footprint
[Water consumption from energy]

Following the water



Scope 1
Direct Water Footprint
[Onsite water consumption]

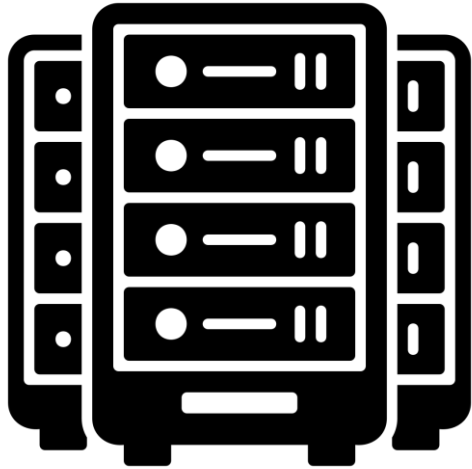


Scope 2
Indirect Water Footprint
[Water consumption from energy]

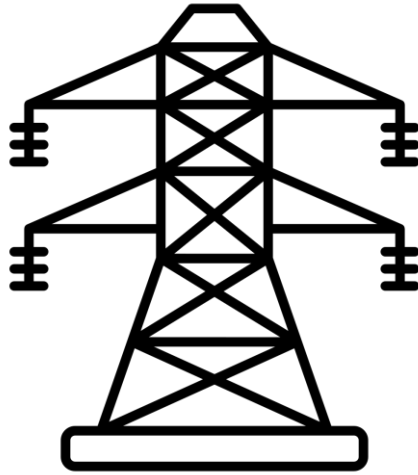


Scope 3
Embedded Water Footprint
[Water consumption of supply chain]

Following the water



Scope 1
Direct Water Footprint
[Onsite water consumption]



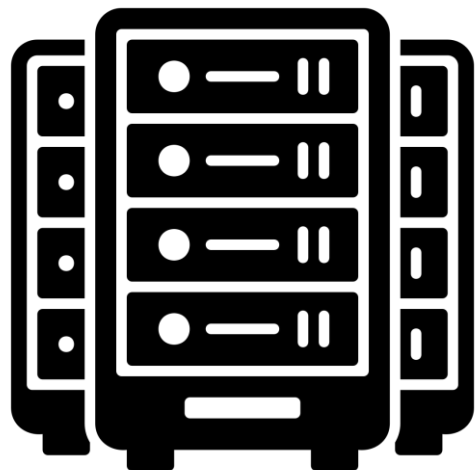
Scope 2
Indirect Water Footprint
[Water consumption from energy]



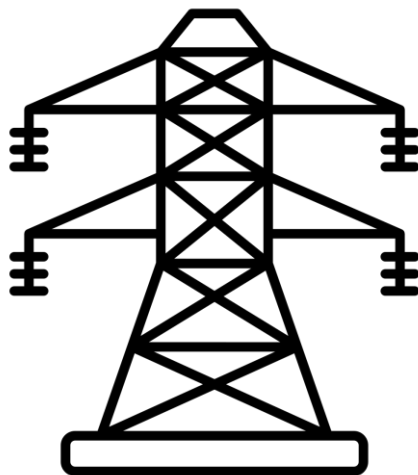
Scope 3
Embedded Water Footprint
[Water consumption of supply chain]

Following the water

Nationwide, ~75% of the water footprint of data centers is offsite.



Scope 1
Direct Water Footprint
[Onsite water consumption]

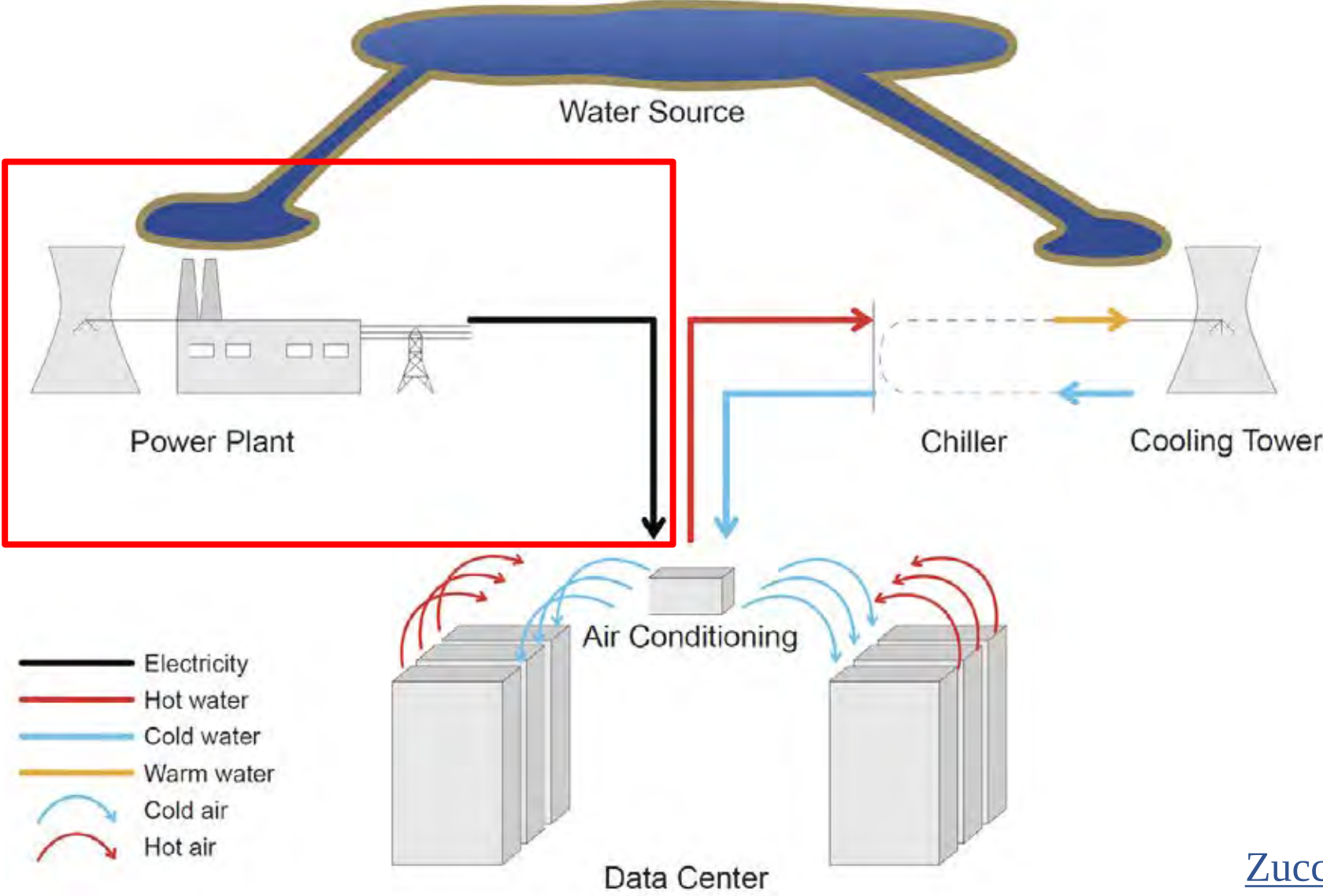


Scope 2
Indirect Water Footprint
[Water consumption from energy]



Scope 3
Embedded Water Footprint
[Water consumption of supply chain]

What does scope 2 look like?



[Zuccon et al., 2023](#)

Scope 1 + Scope 2 water consumption

2023 U.S. Estimates

Direct
Water Consumption

17.4 billion gallons
≈119,420 average
U.S. households

[Shehabi et al., 2024](#)

Scope 1 + Scope 2 water consumption

2023 U.S. Estimates

Direct Water Consumption	+	Indirect Water Consumption
17.4 billion gallons ≈119,420 average U.S. households		211 billion gallons ≈1.45 million average U.S. households

[Shehabi et al., 2024](#)

Scope 1 + Scope 2 water consumption

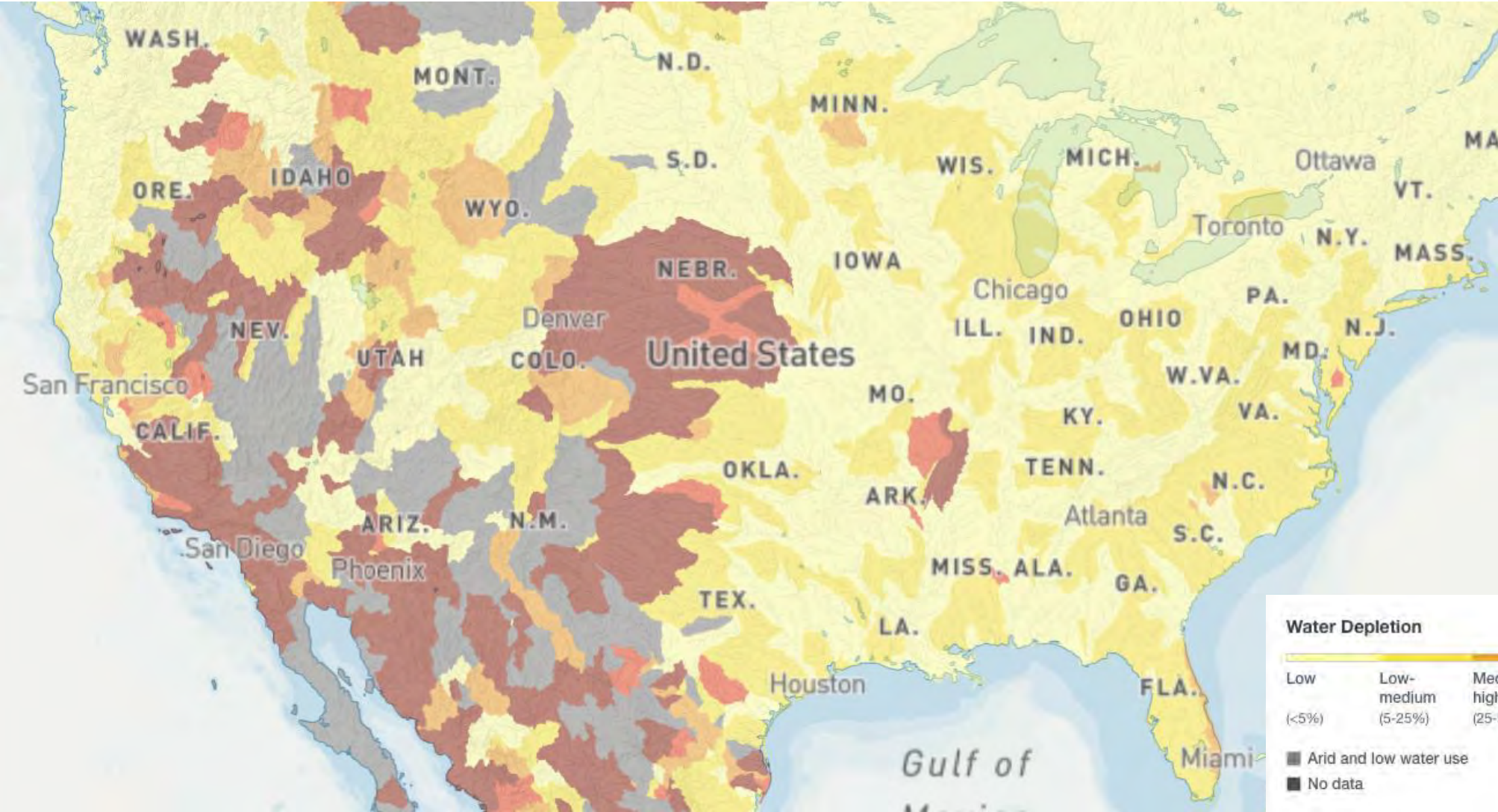
2023 U.S. Estimates

Direct Water Consumption	+	Indirect Water Consumption	=	Total Water Consumption
17.4 billion gallons ≈119,420 average U.S. households		211 billion gallons ≈1.45 million average U.S. households		228.8 billion gallons ≈1.57 million average U.S. households

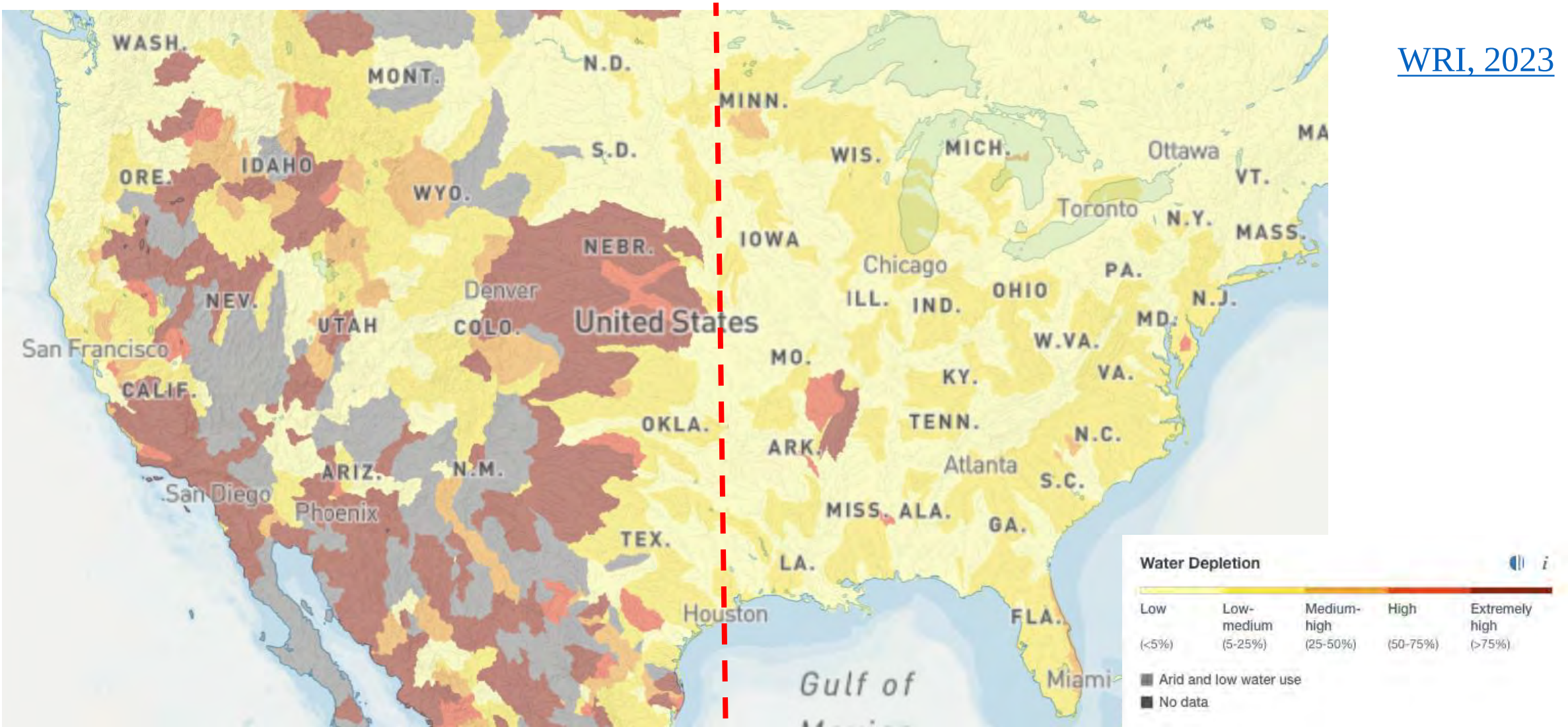
[Shehabi et al., 2024](#)

Location, Location, Location

[WRI, 2023](#)

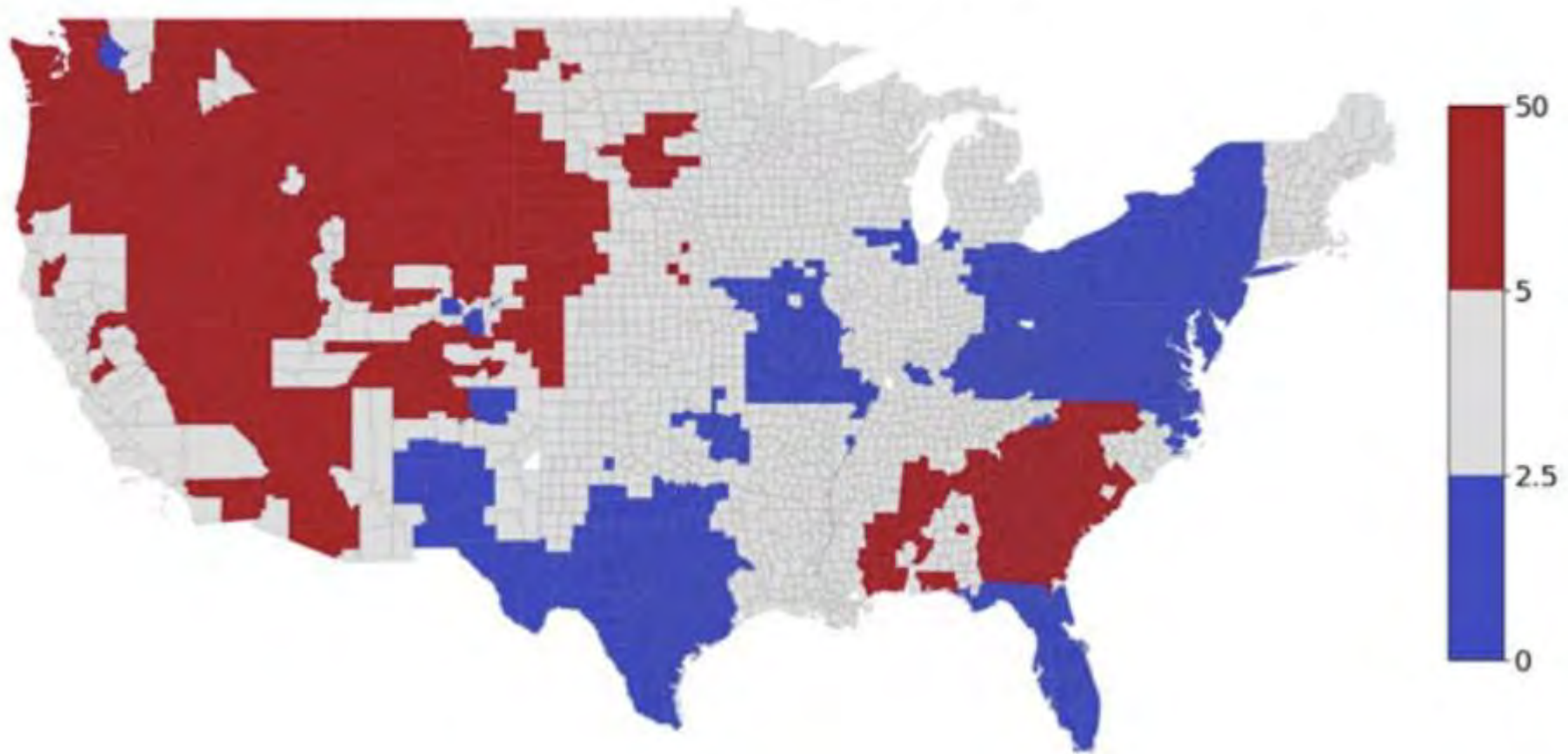


Location, Location, Location



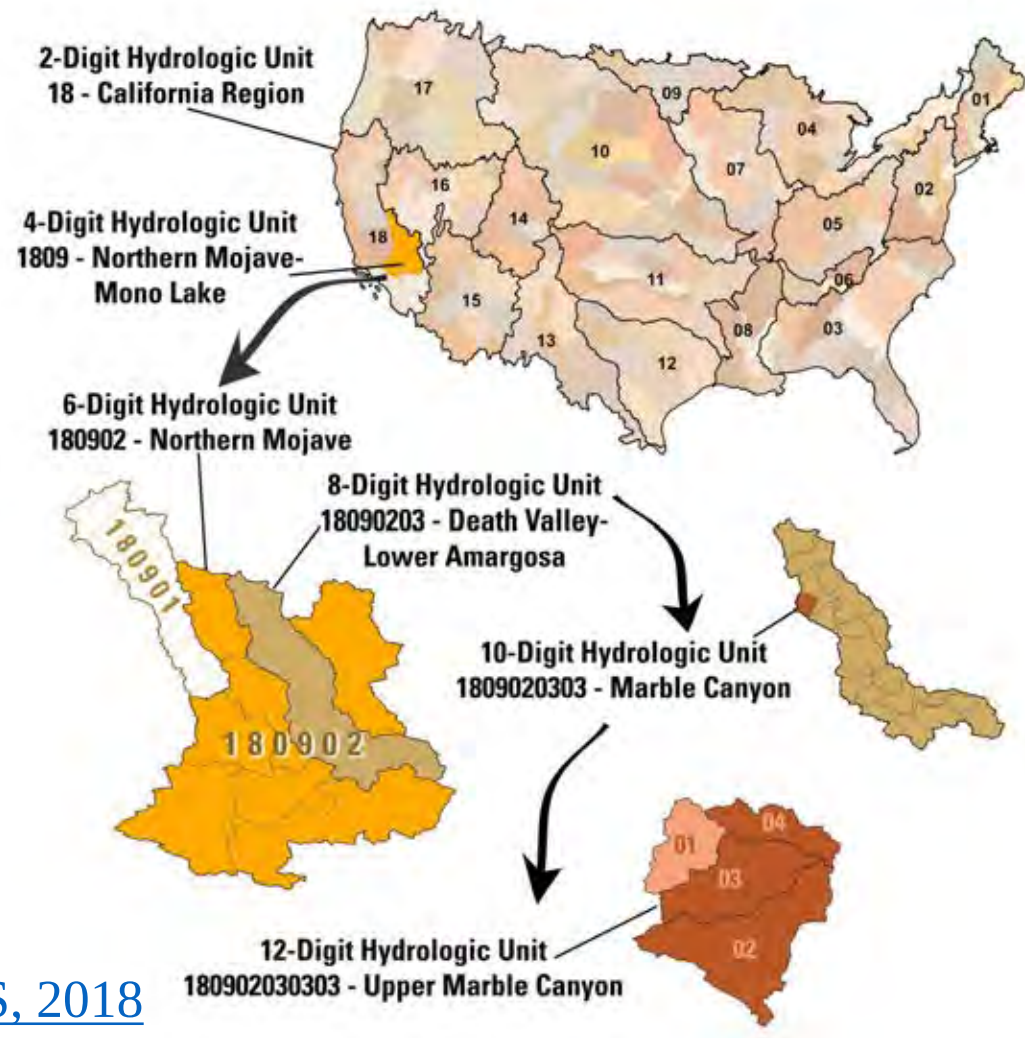
Location, Location, Location

(A) Water consumption intensity (L/kWh)



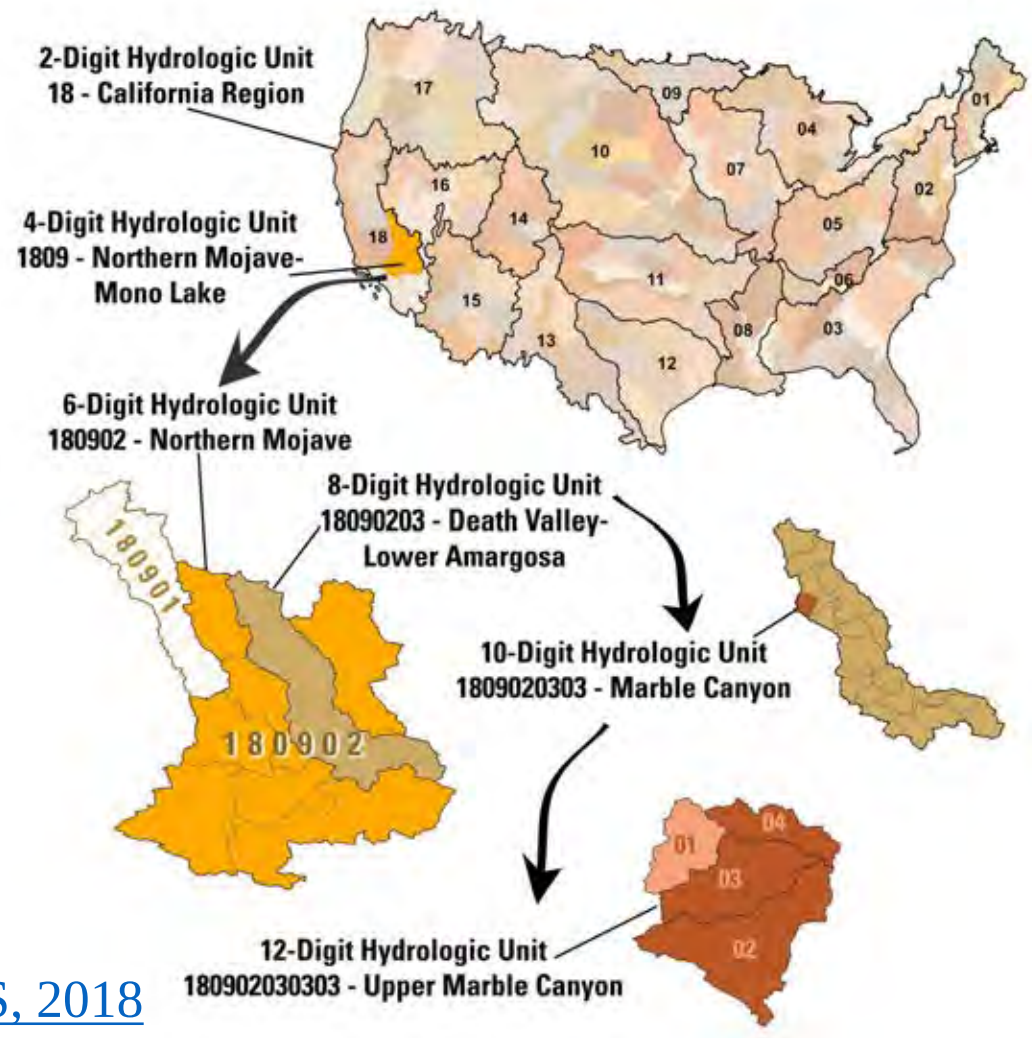
[Shehabi et al., 2024](#)

Location, Location, Location

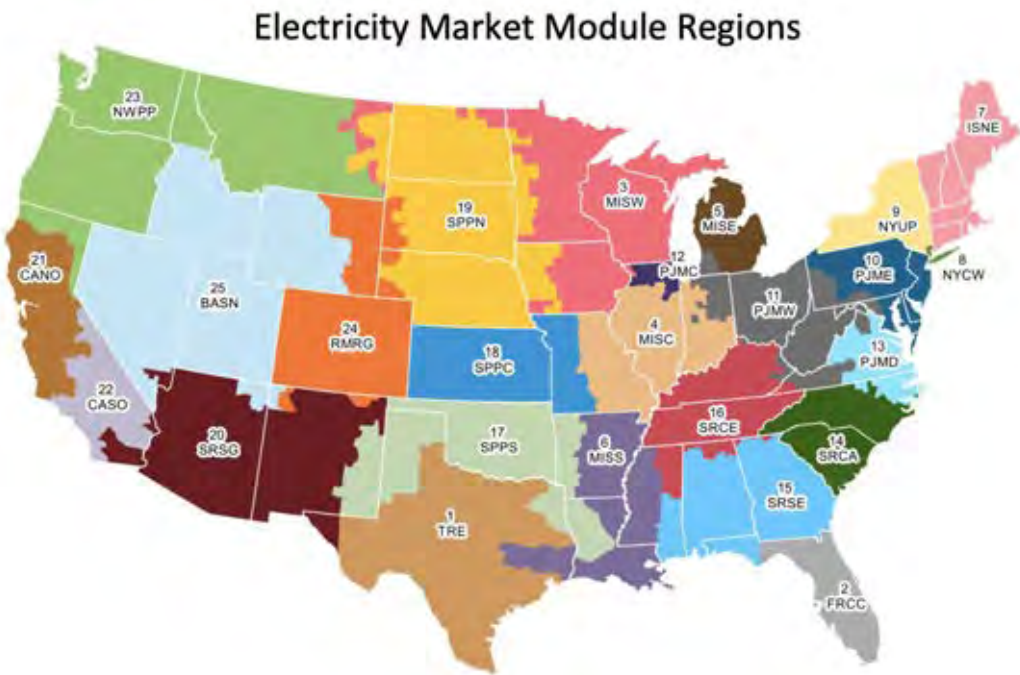


[USGS, 2018](#)

Location, Location, Location

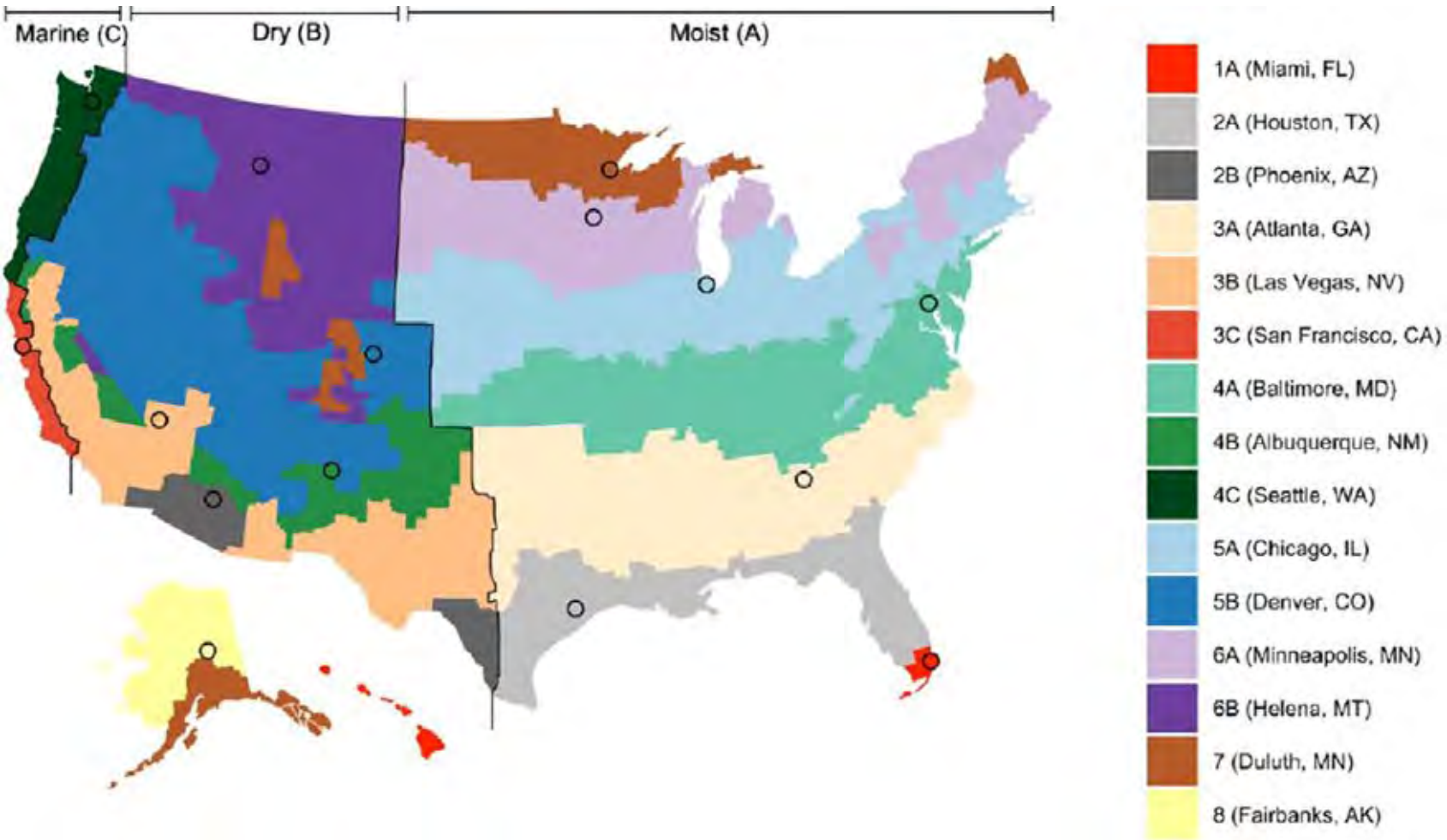


[USGS, 2018](#)

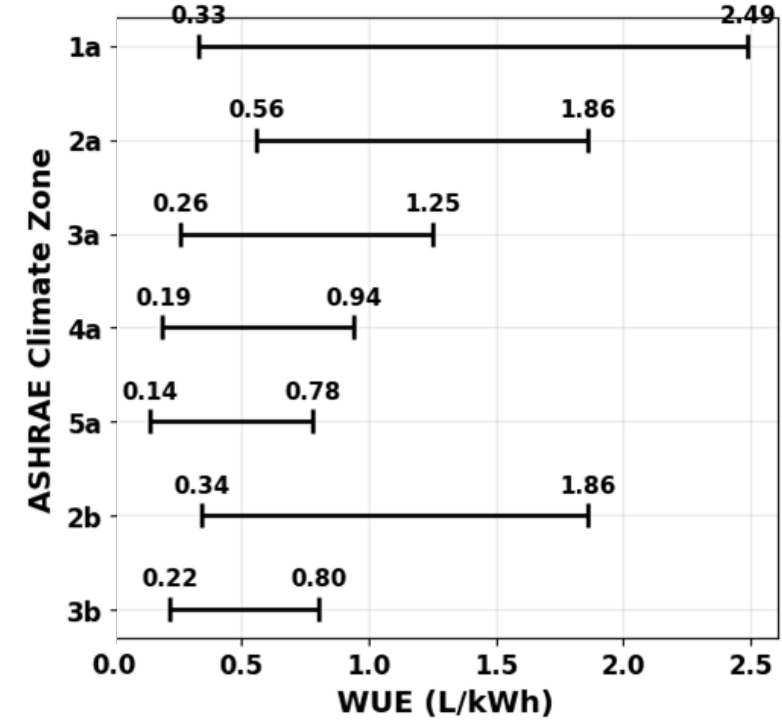
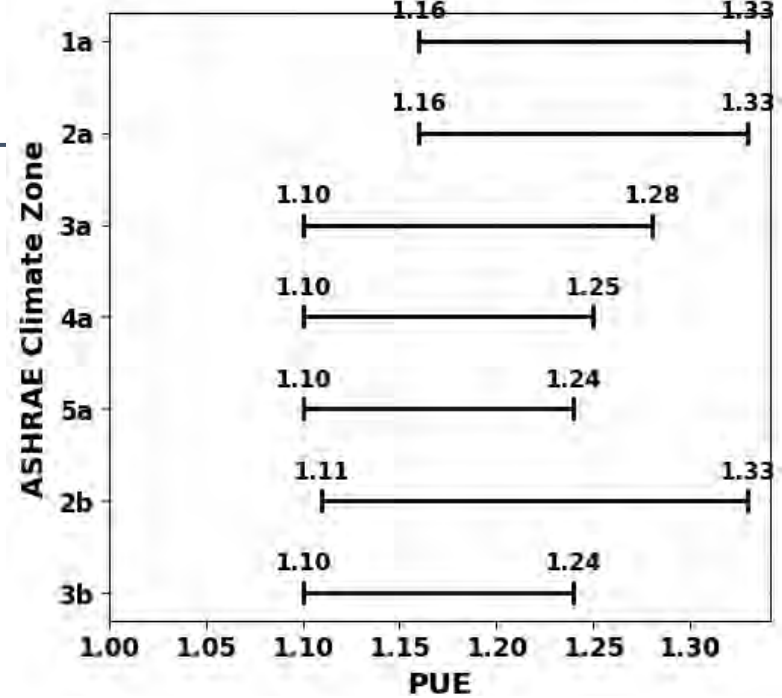


[EIA, 2025](#)

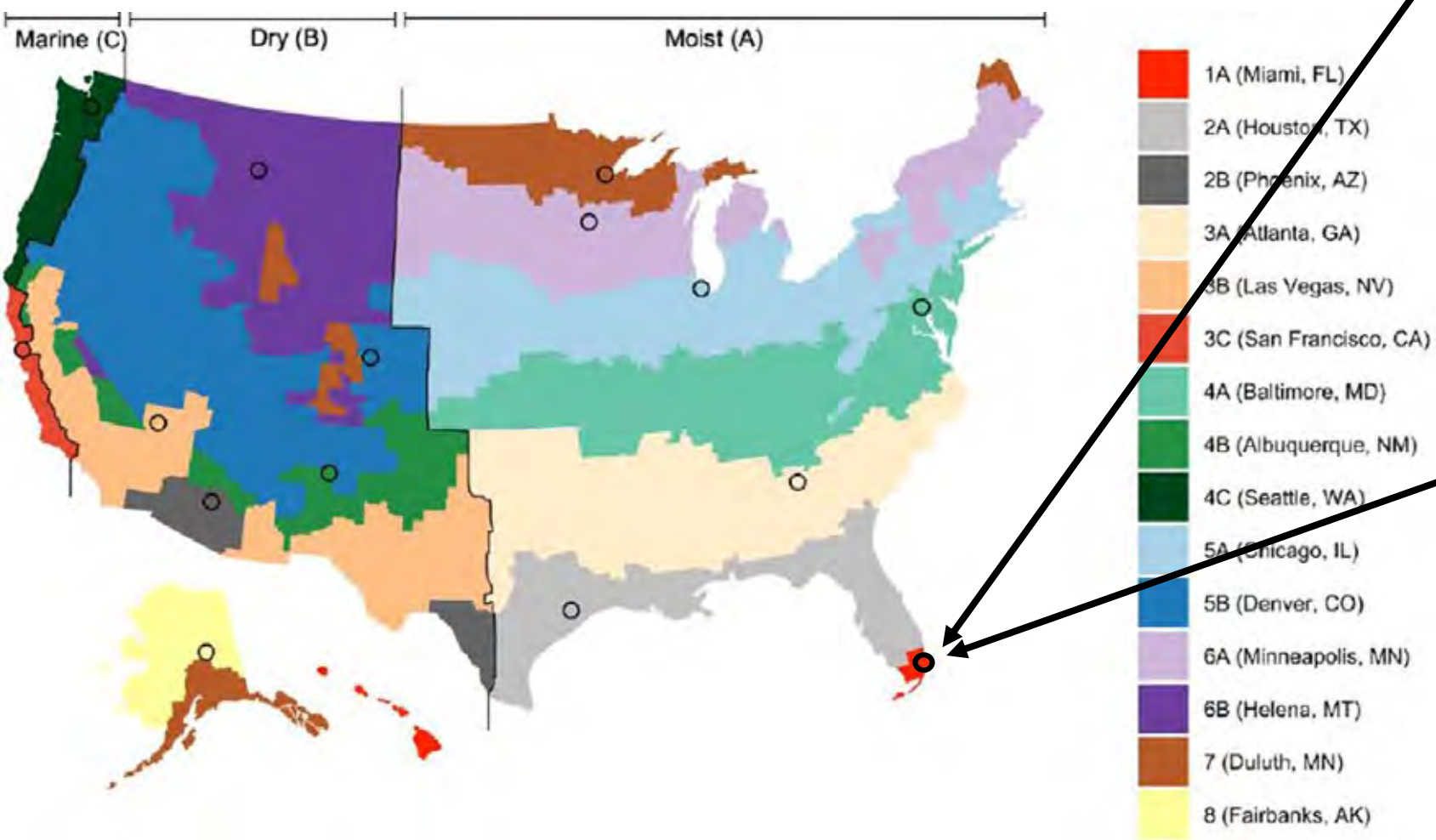
Location, Location, Location



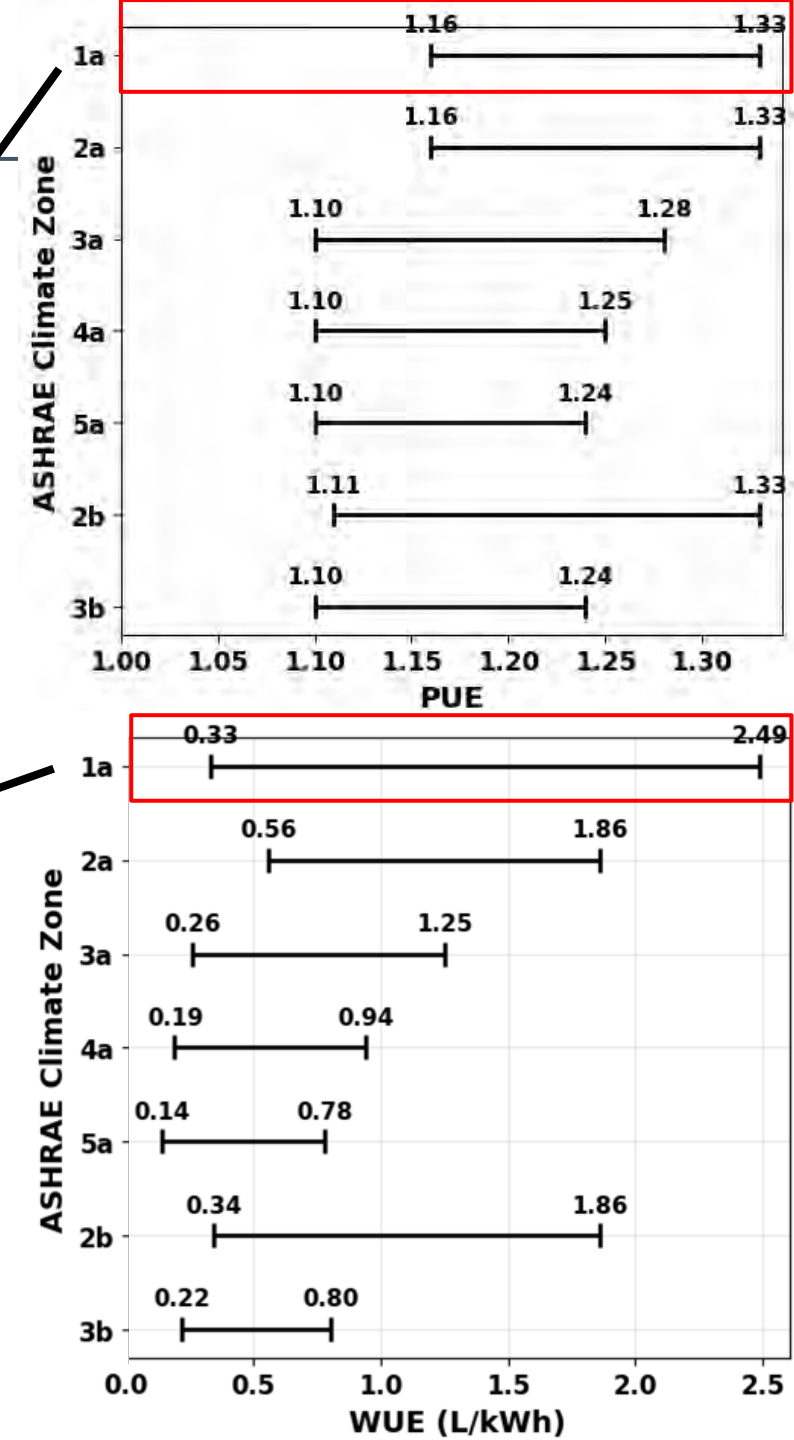
[Lei & Masanet, 2023](#)



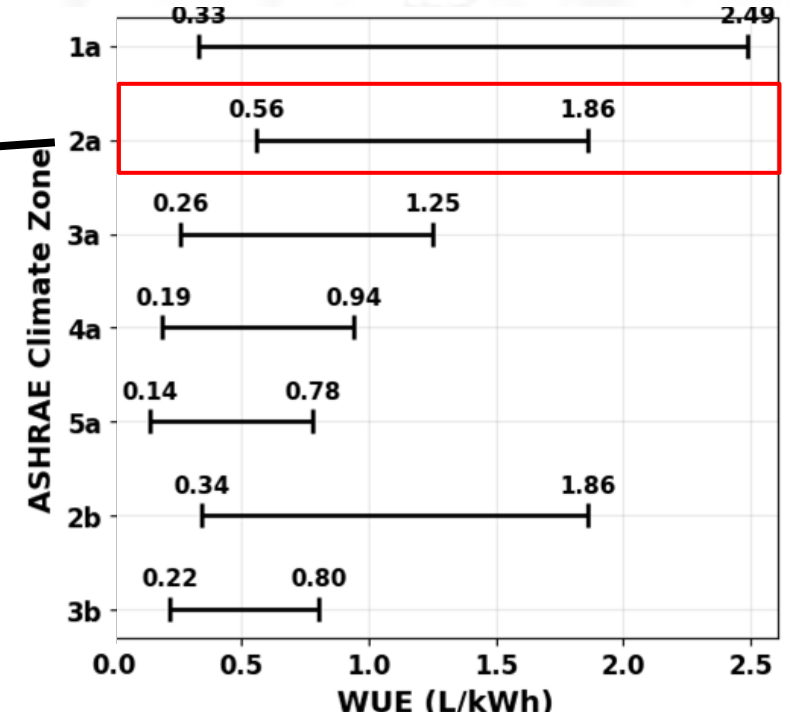
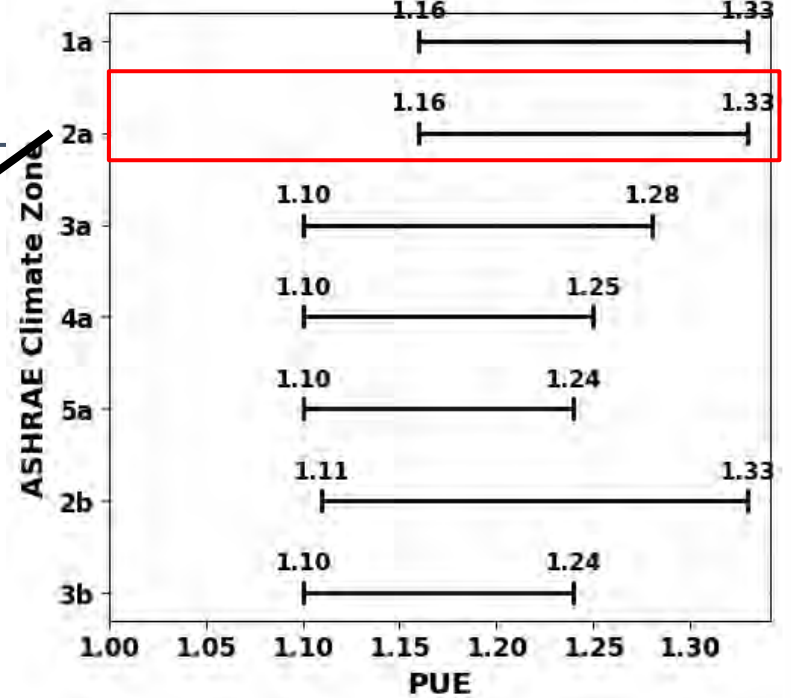
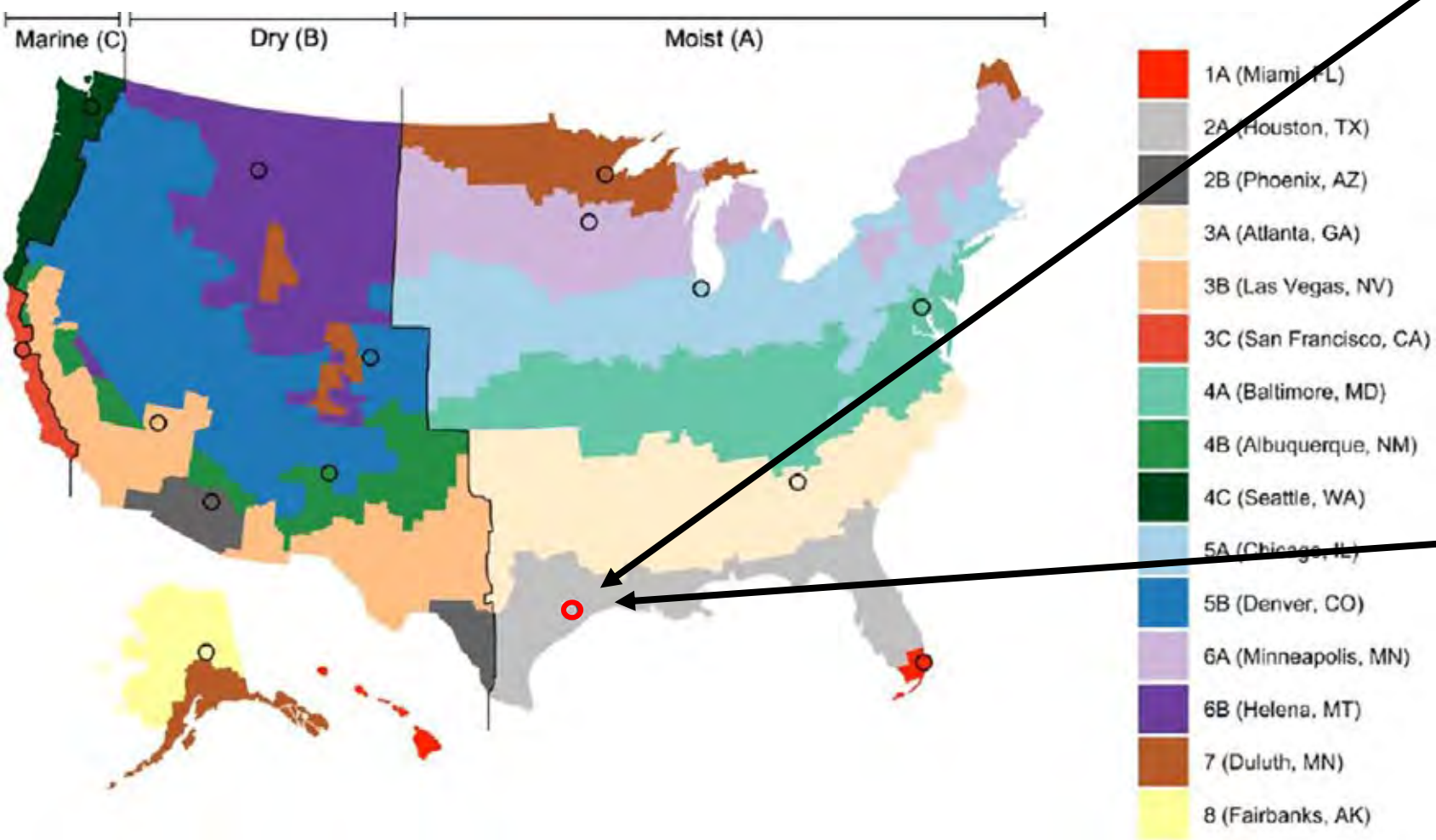
Location, Location, Location



[Lei & Masanet, 2023](#)

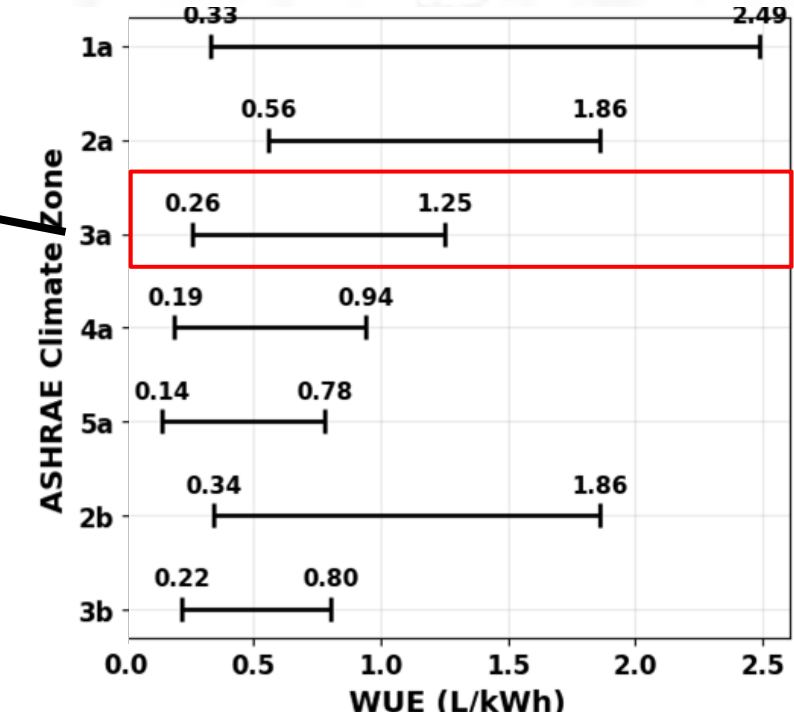
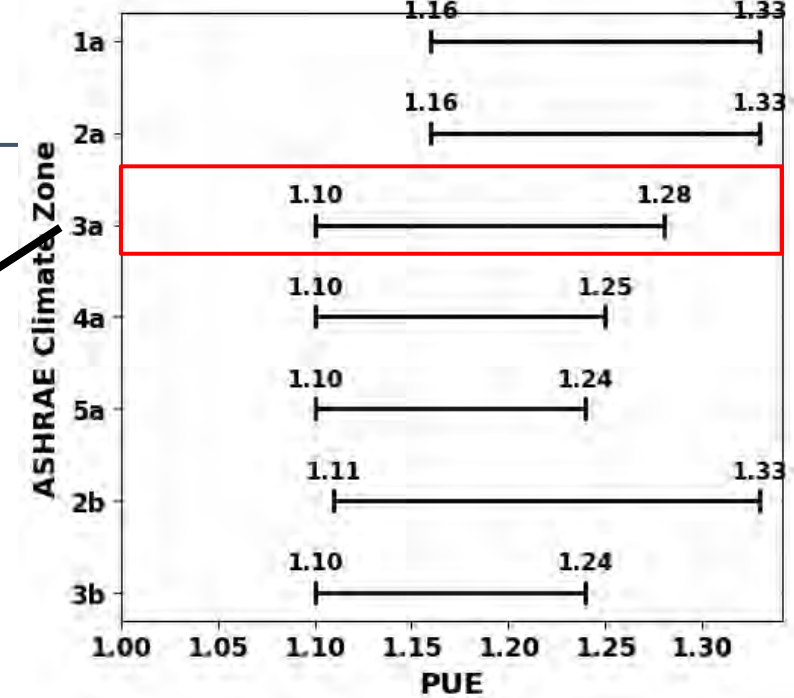
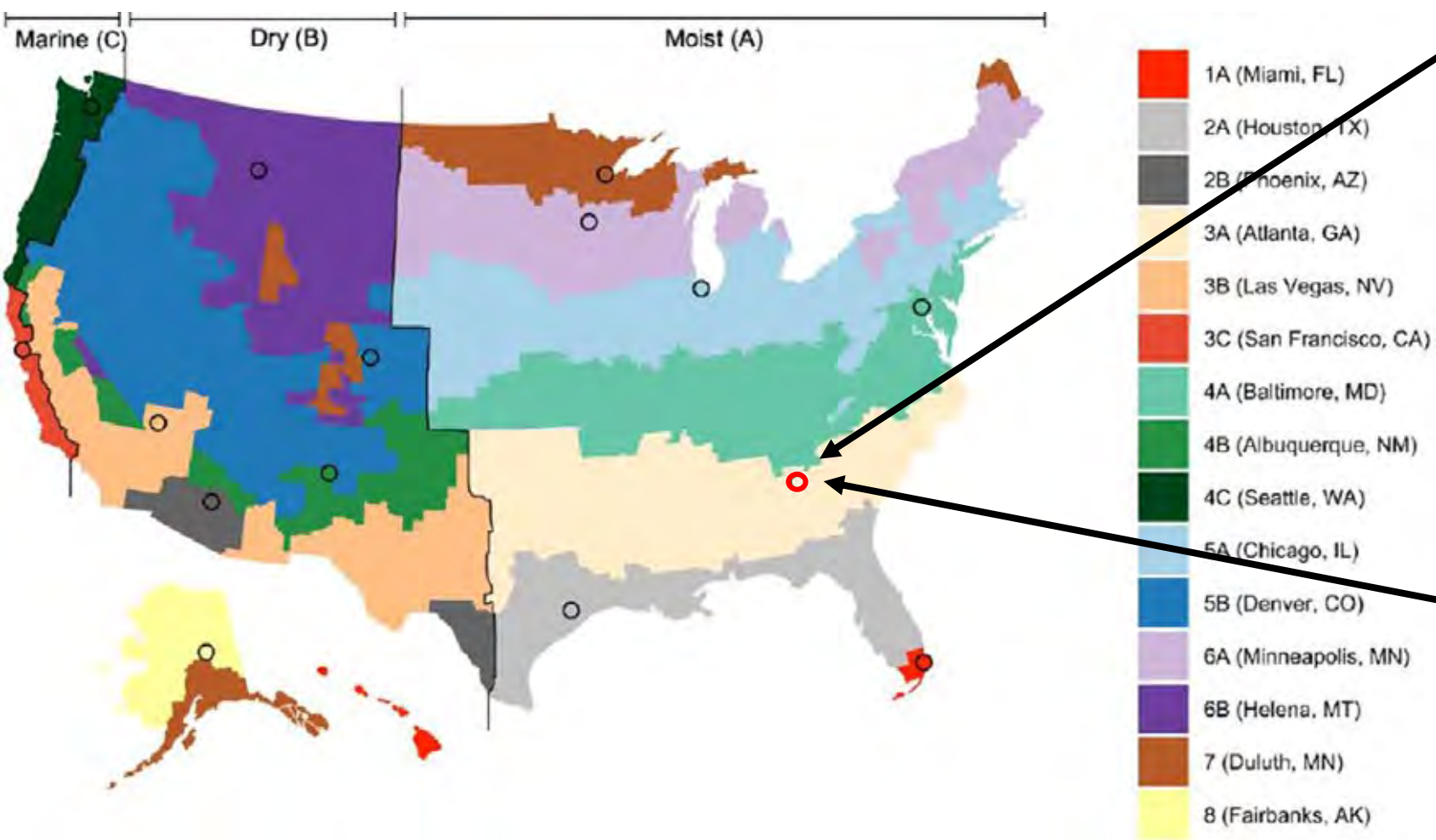


Location, Location, Location



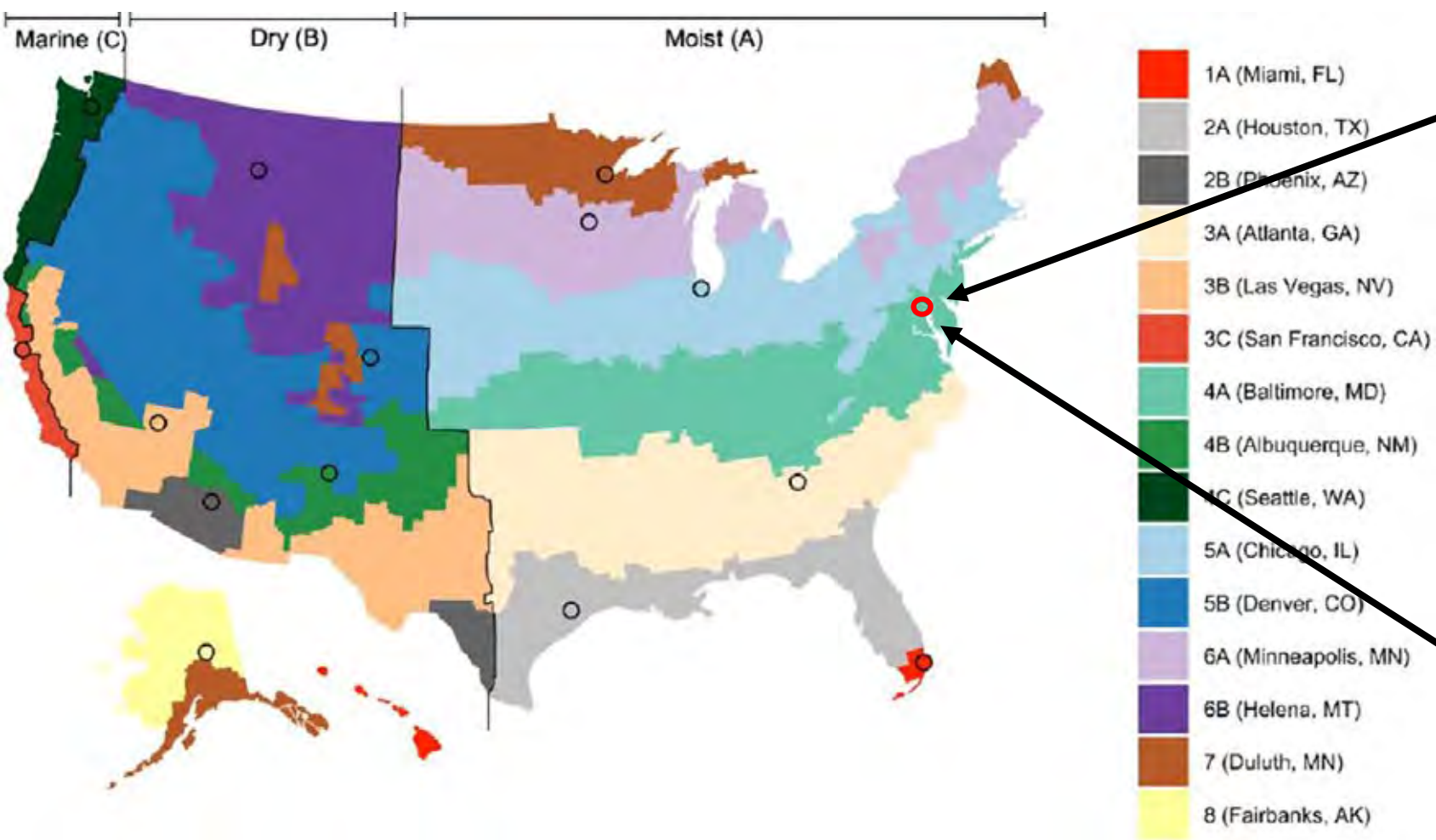
[Lei & Masanet, 2023](#)

Location, Location, Location

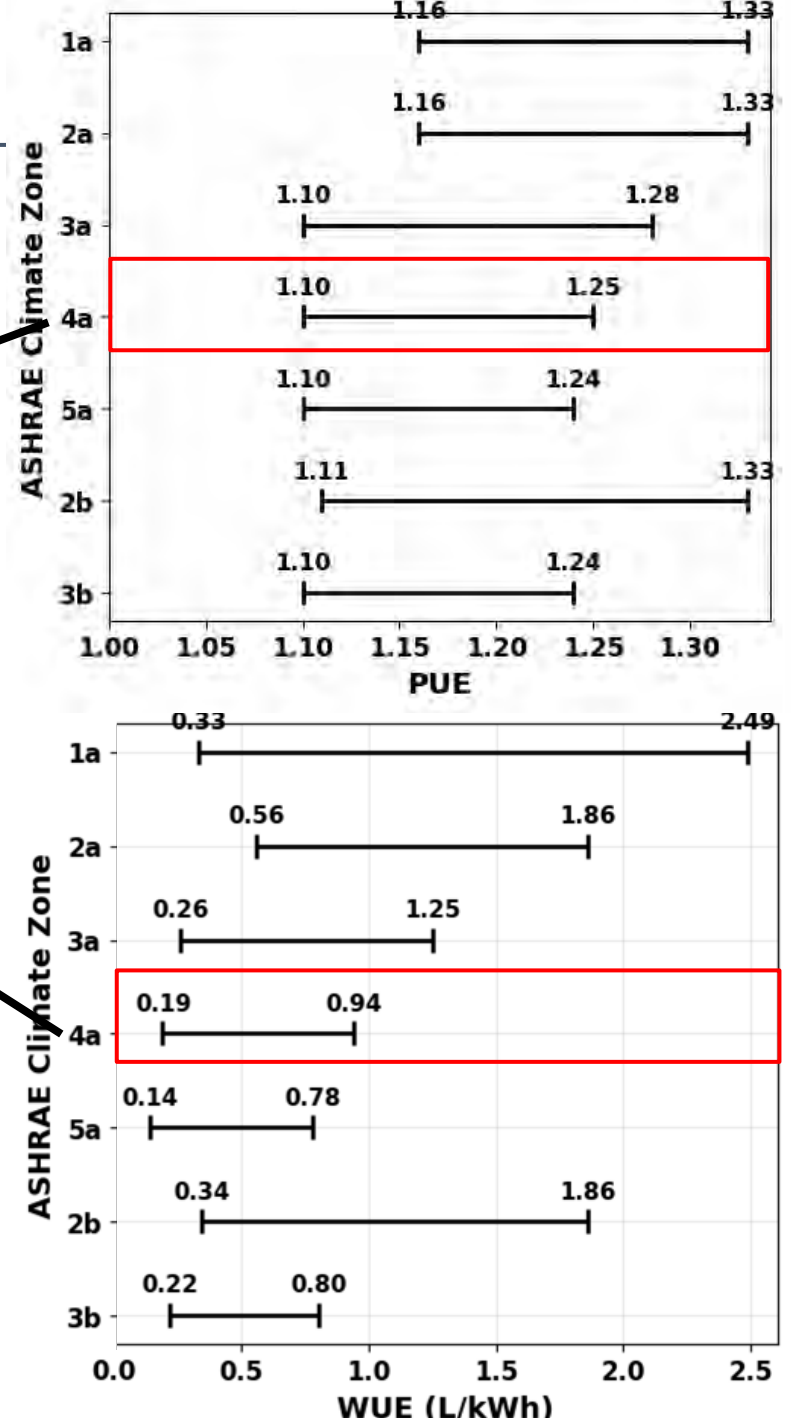


[Lei & Masanet, 2023](#)

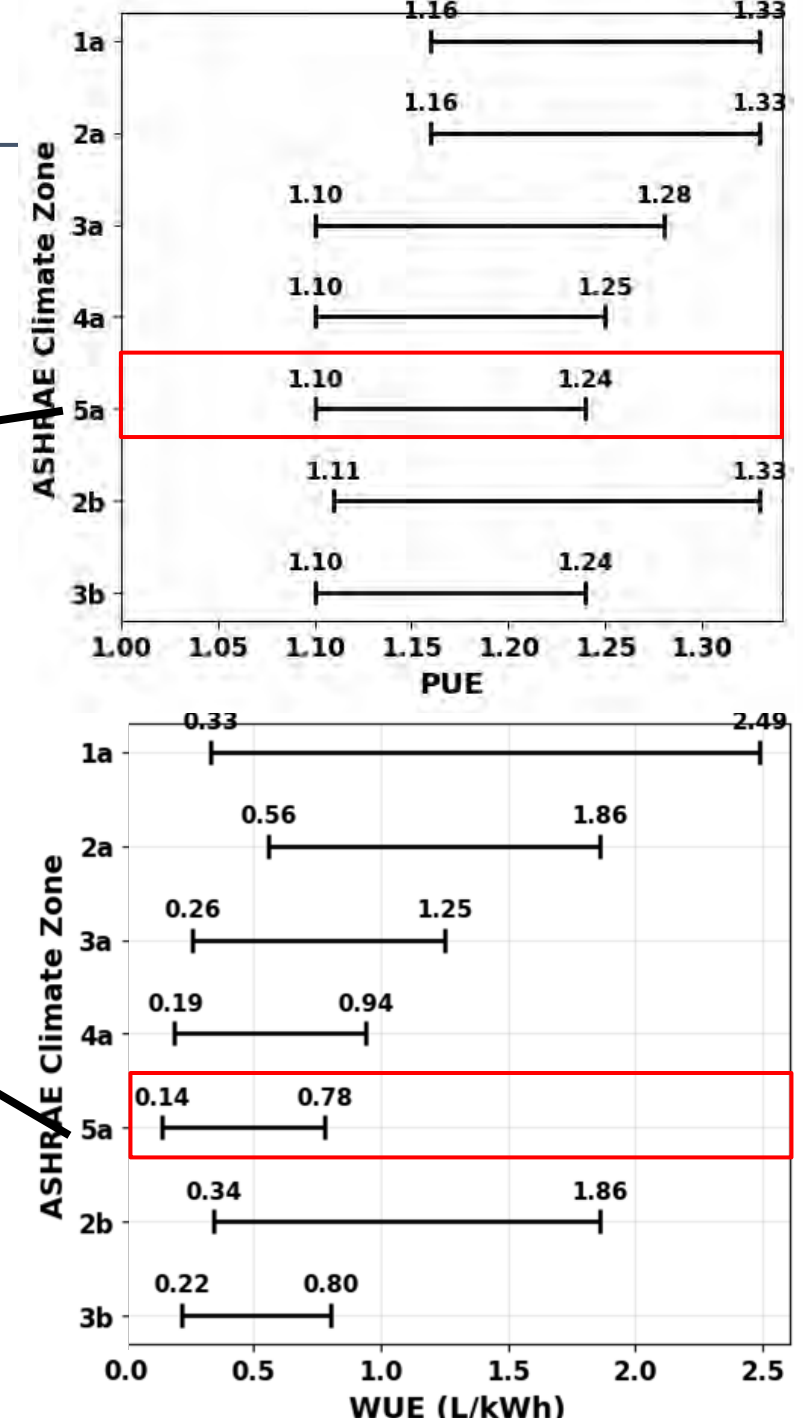
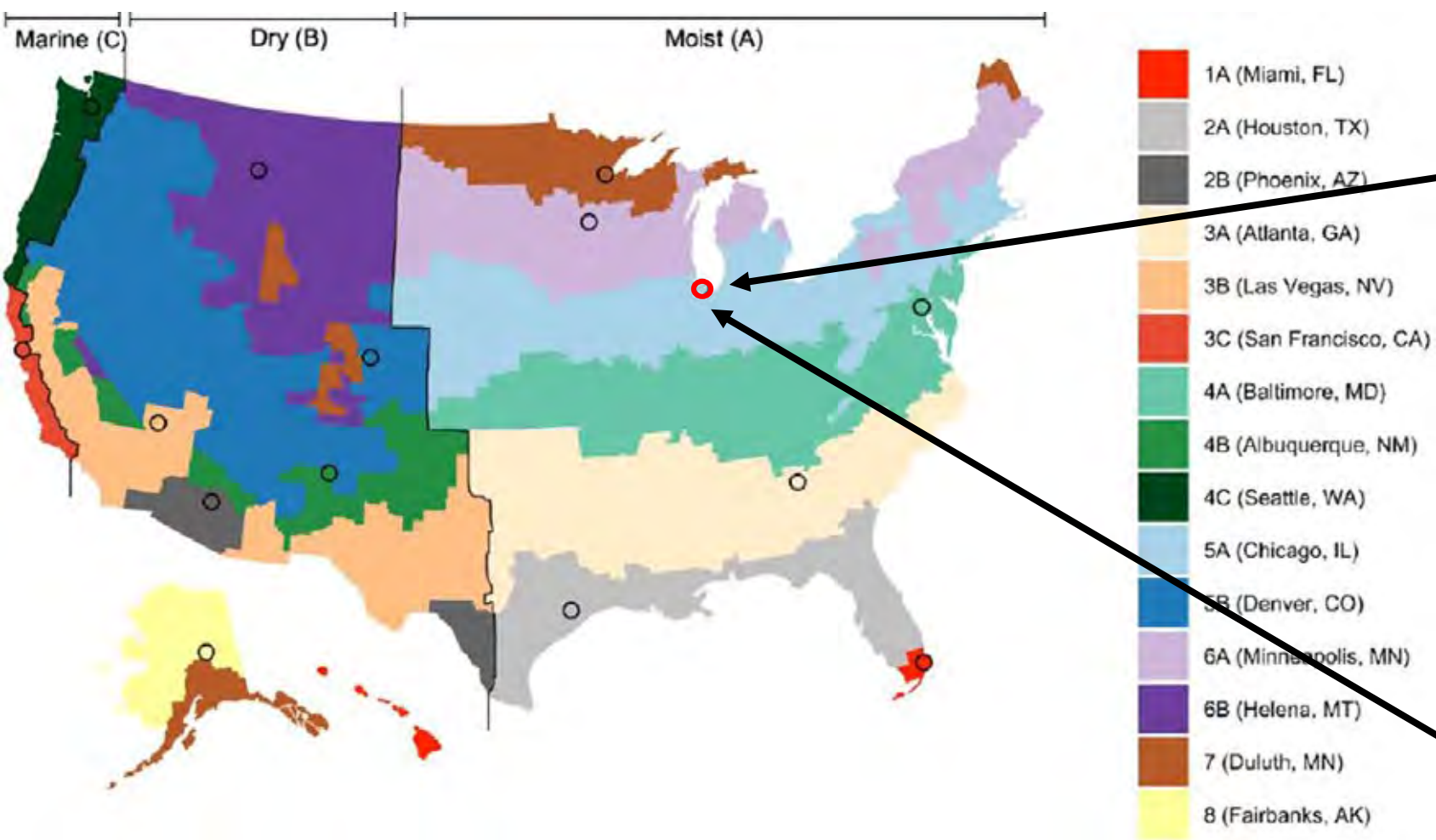
Location, Location, Location



[Lei & Masanet, 2023](#)

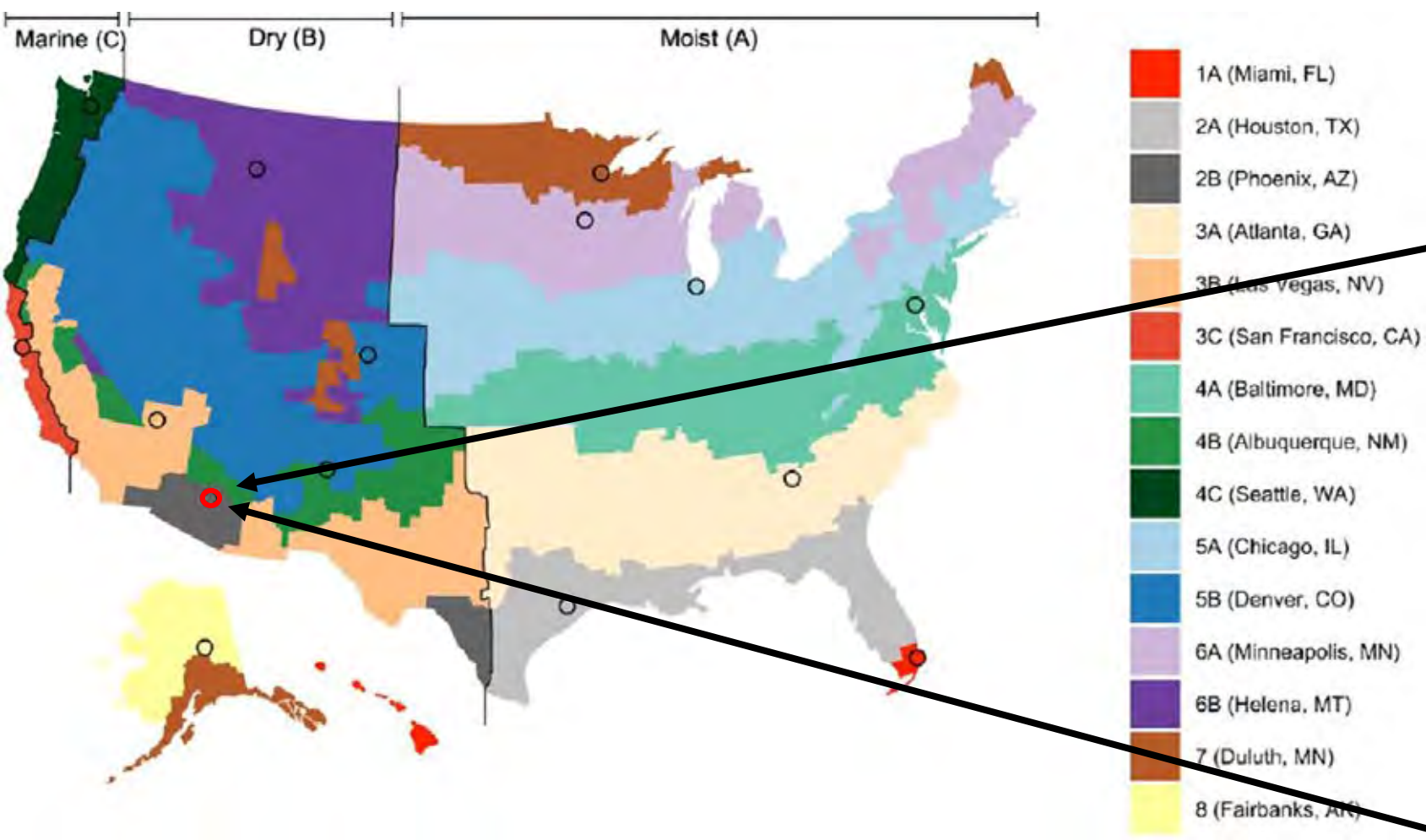


Location, Location, Location

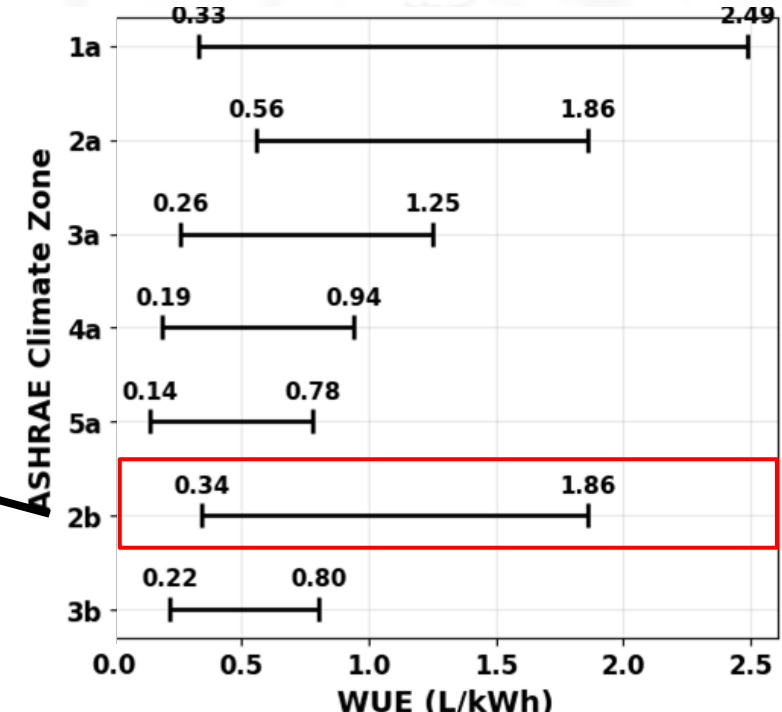
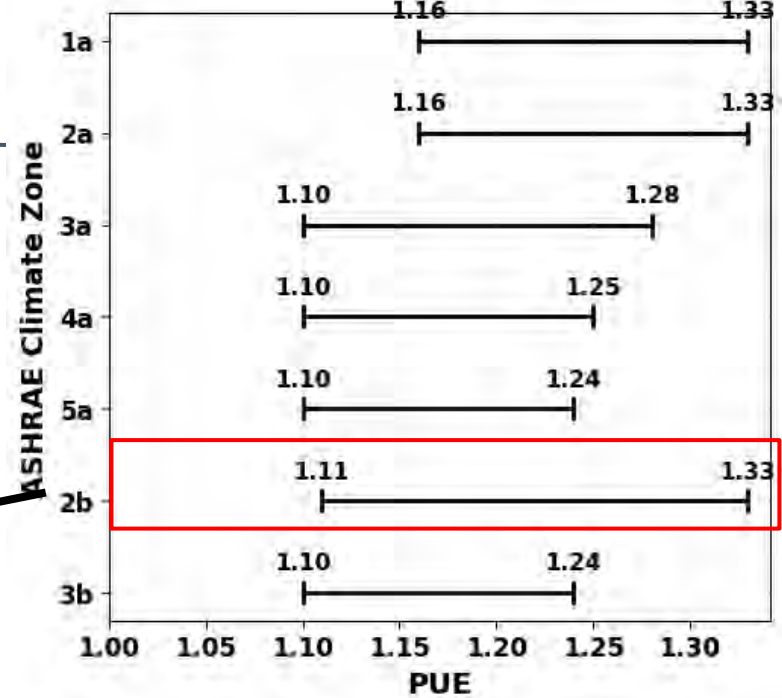


[Lei & Masanet, 2023](#)

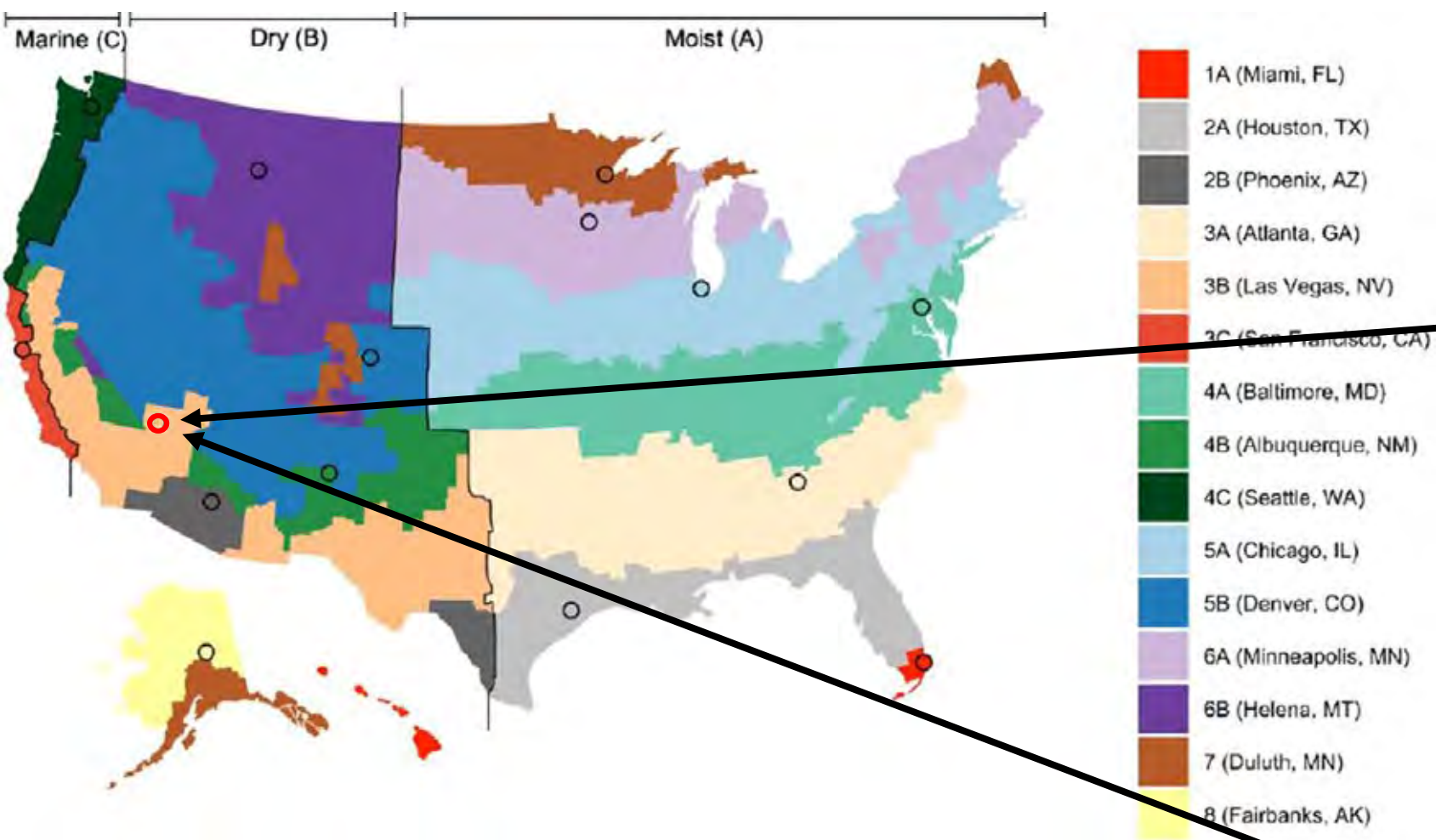
Location, Location, Location



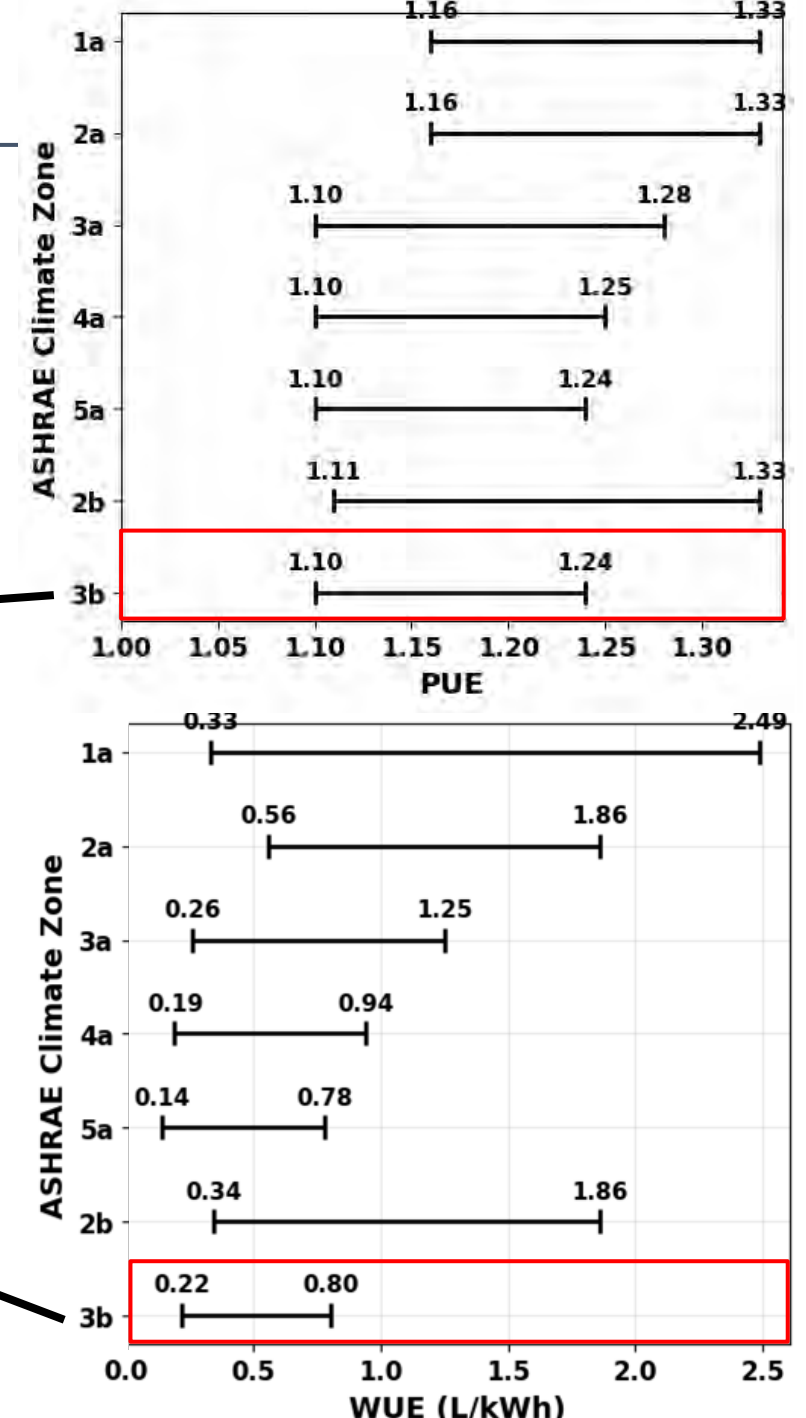
[Lei & Masanet, 2023](#)



Location, Location, Location



[Lei & Masanet, 2023](#)



Ok, so what do we know?

- Resource demand is large and growing
- Technology and climate drives energy-water tradeoffs
- Impacts extend beyond the facility boundary

... and what don't we know?

- Actual facility-level resource use
- How future technologies will shift demand
- Where and when infrastructure constraints will emerge

So, what do we need?

- Better data transparency & accessibility
- Real-world cooling technology benchmarks
- Spatial & temporal demand profiles (direct & indirect)

Thank you

Eric Sjöstedt, Ph.D

esjostedt@vt.edu

Project 5367

Data Centers: Understanding Economic Considerations and Opportunities for Water and Wastewater Utilities

DATE STARTED
Aug 1, 2026

PRINCIPAL INVESTIGATOR
Landon T. Marston, Ph.D., P.E.

RESEARCH PRINCIPAL
Sydney D Samples

RESEARCH INVESTMENT	COMPLETION YEAR
\$450,993	2028

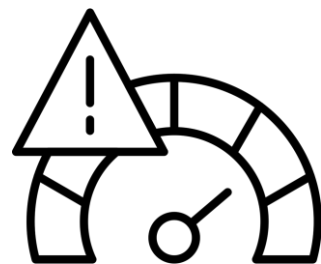
CONTRACTOR
Virginia Polytechnic Institute & State University

IN PROGRESS

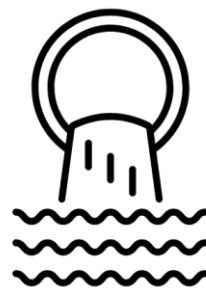
Appendix - Water & Wastewater Utilities



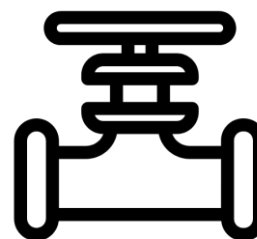
Demand
Volume
& Profile



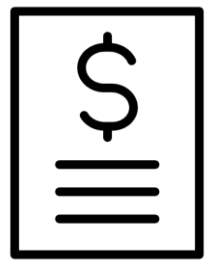
Ramp up
time



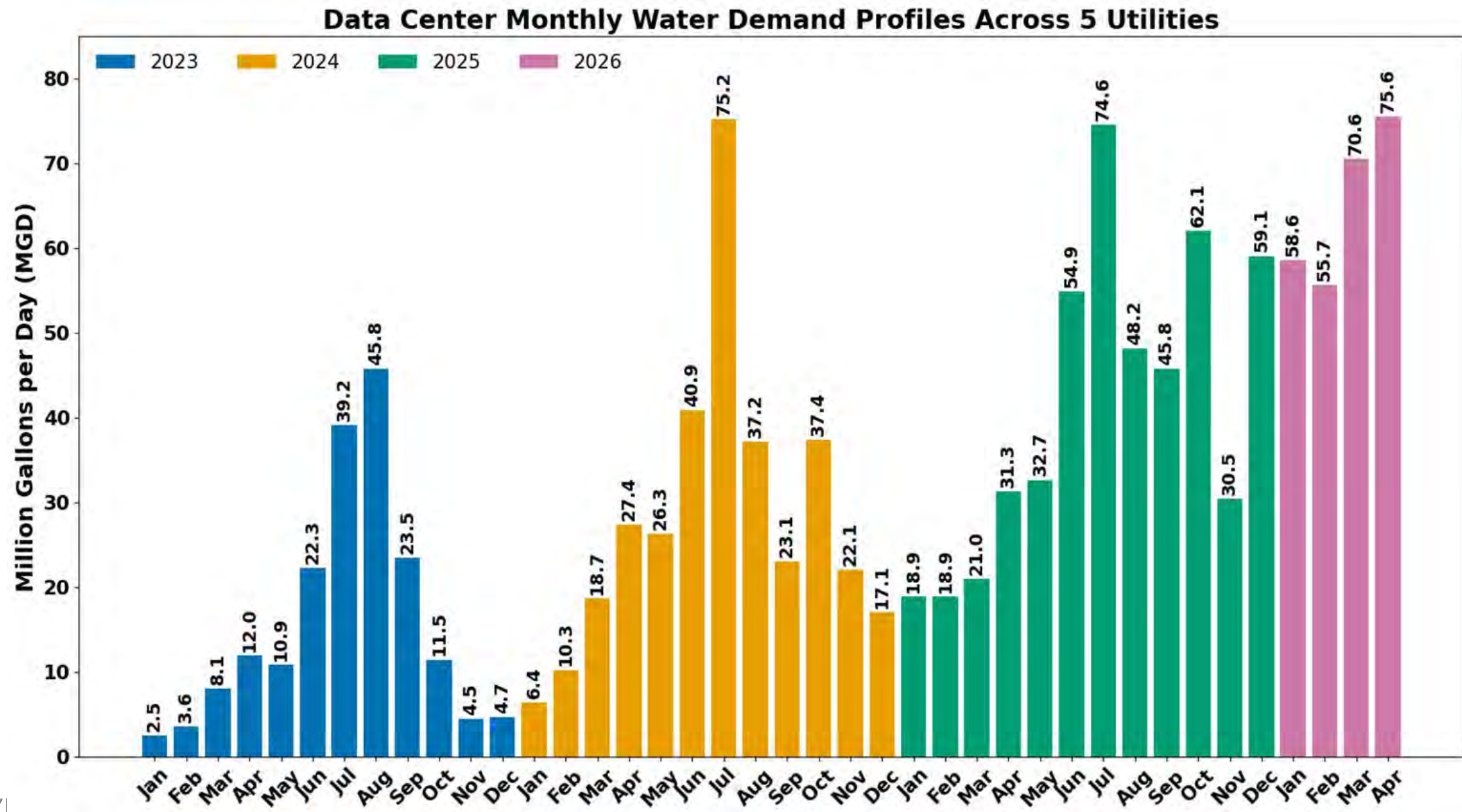
Discharge
volume &
chemistry



Infrastructure
capacity &
source

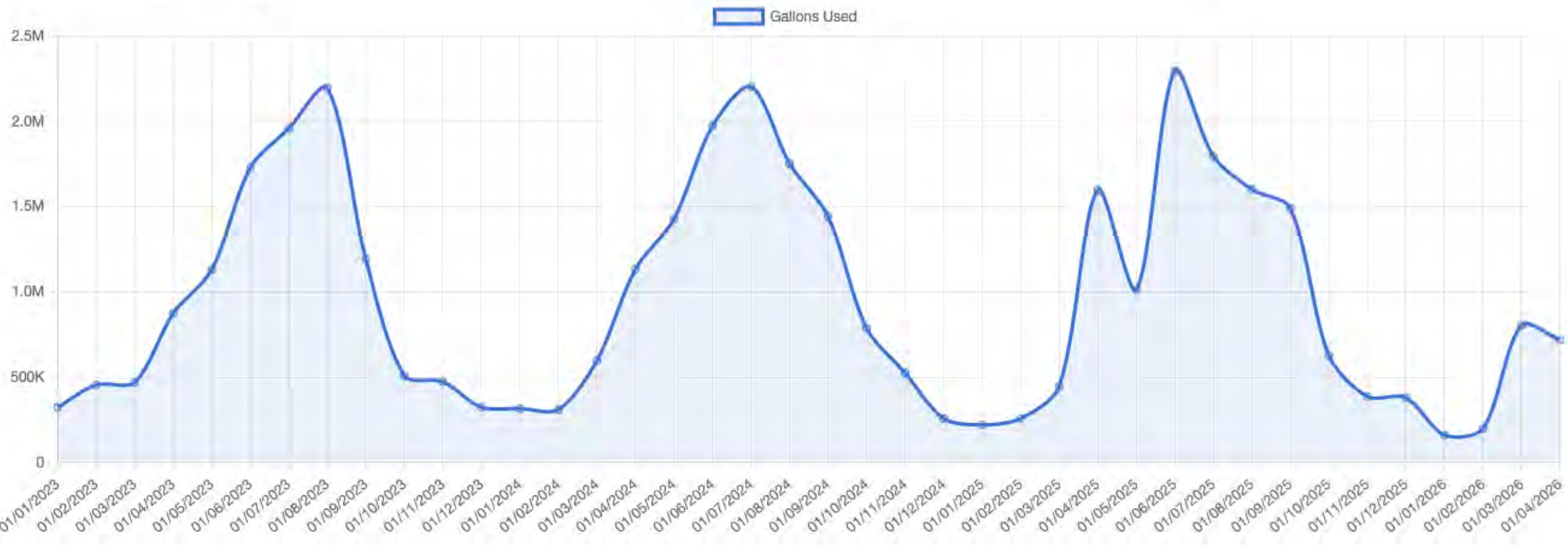


Rate
Structure



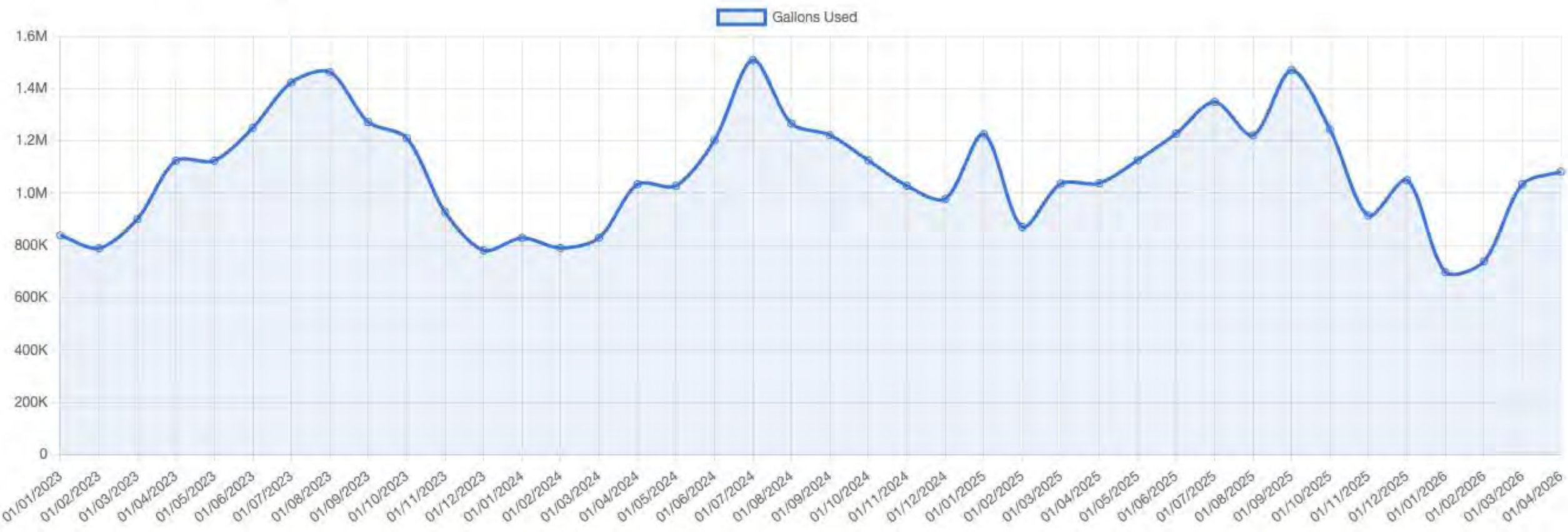
AWS Data Center

Usage: 7505 Mason King Ct



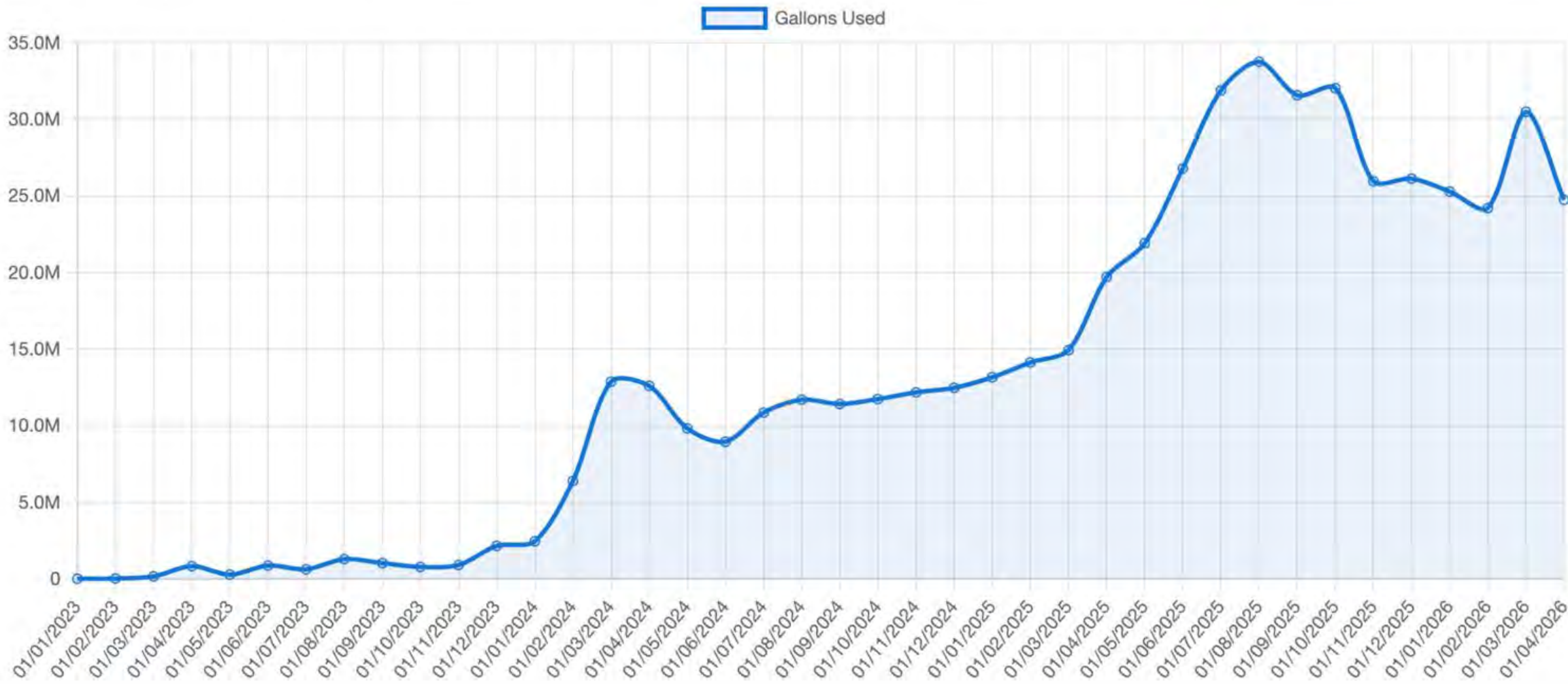
Equinix Data Center

Usage: 7400 Infantry Ridge Rd



Usage: 13051 Rollins Ford Rd

Google Data Center Campus



Appendix - Demand Profiles

