IM3

INTEGRATED
MULTISECTOR
MULTISCALE
MODELING

Powering AI: The Energy-Water Implications of Data Centers

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Pacific Northwest National Laboratory
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The University of North Carolina at Chapel Hill
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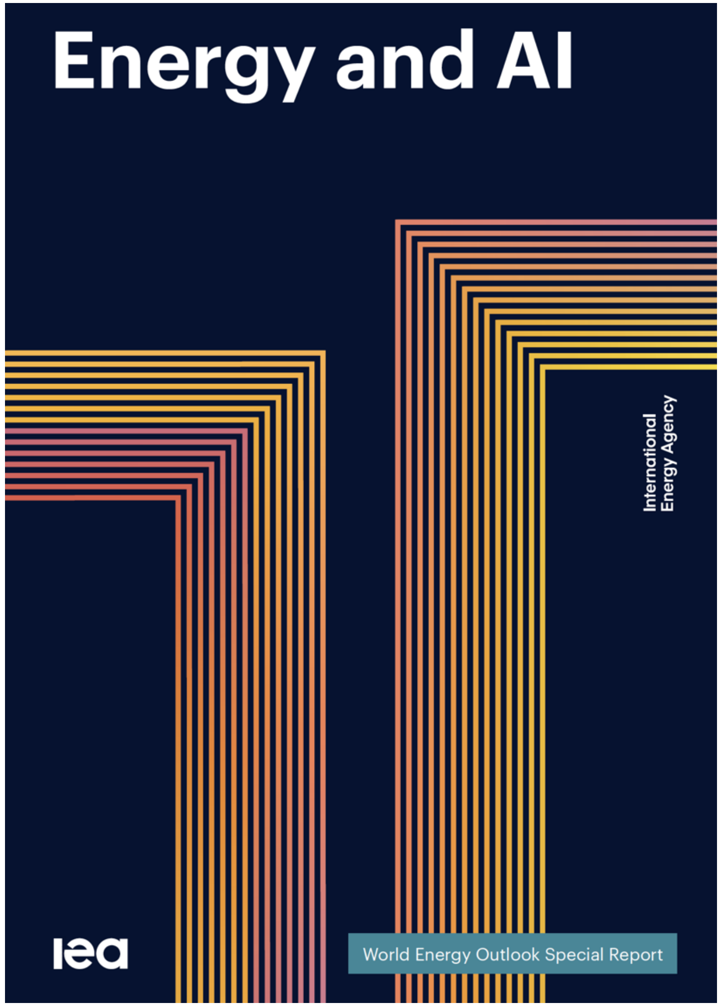
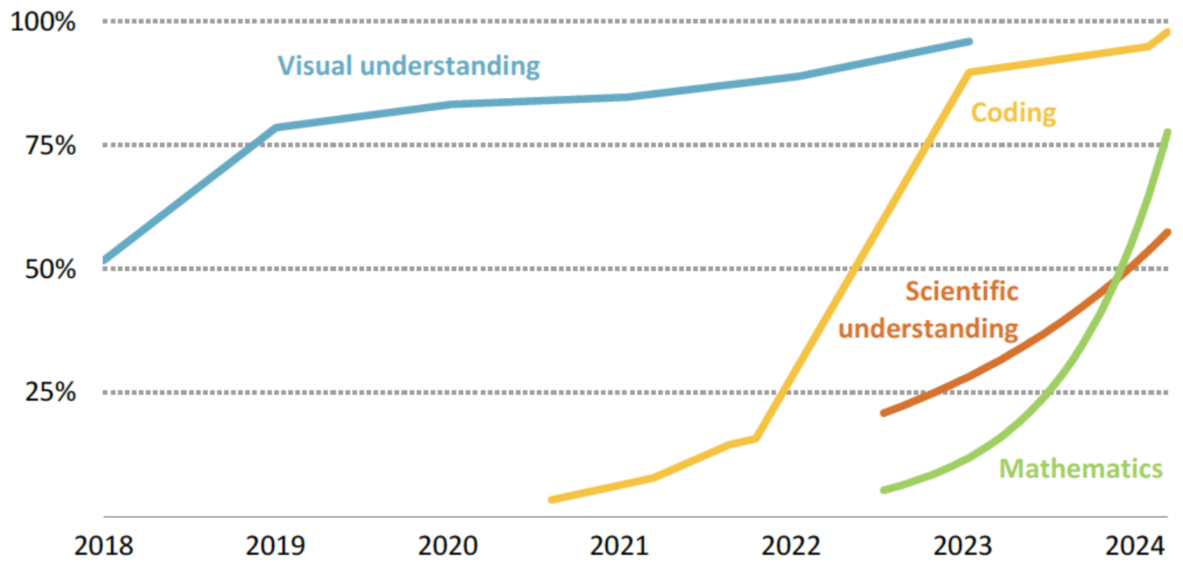
Energy and artificial intelligence are inextricably related



"The development and uptake of artificial intelligence (AI) has accelerated in recent years – elevating the question of what widespread deployment of the technology will mean for the energy sector. ***There is no AI without energy – specifically, electricity for data centers****."*

Figure 1.11 ▷ Accuracy of AI models in selected benchmarks, 2018-2024



The step change in AI performance is due in large part to widely available cheap computing

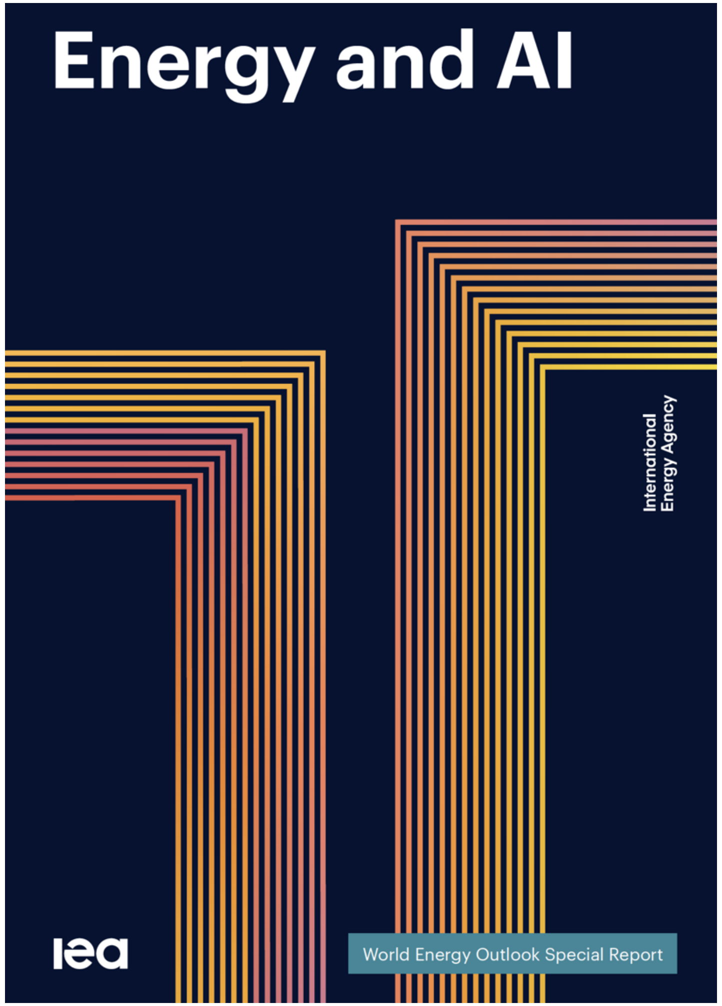
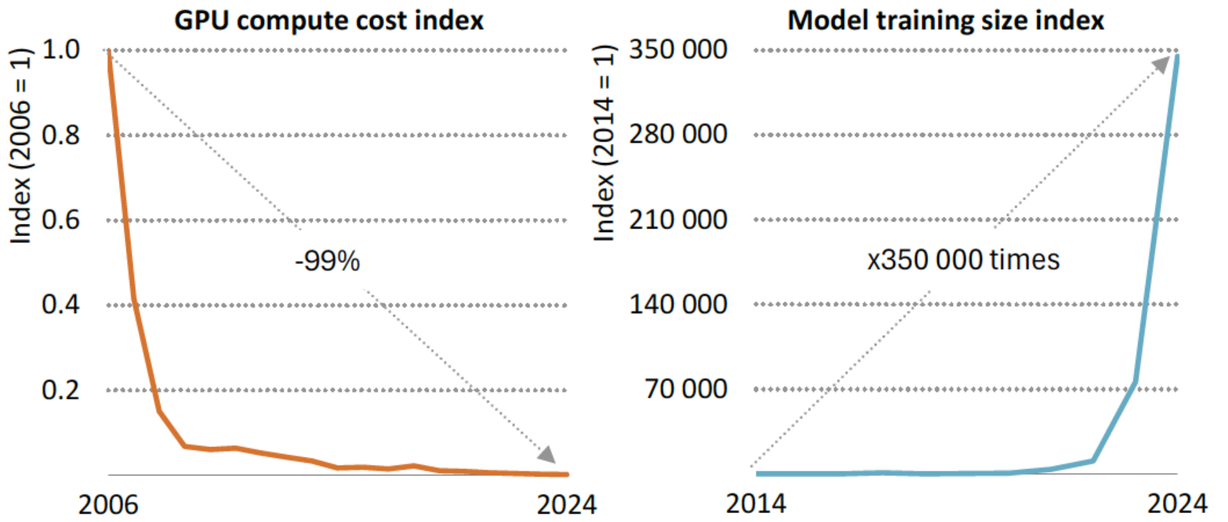


Figure 1.1 ⊳ GPU computation cost, 2006-2024, and notable AI model computational training size, 2014-2024



*"The amount of data used to train state of-the-art AI models has increased by nearly 30,000 times since 2008…**The amount of computational power used to train state-of-the-art AI models has increased by around 350,000 times since 2014**."*

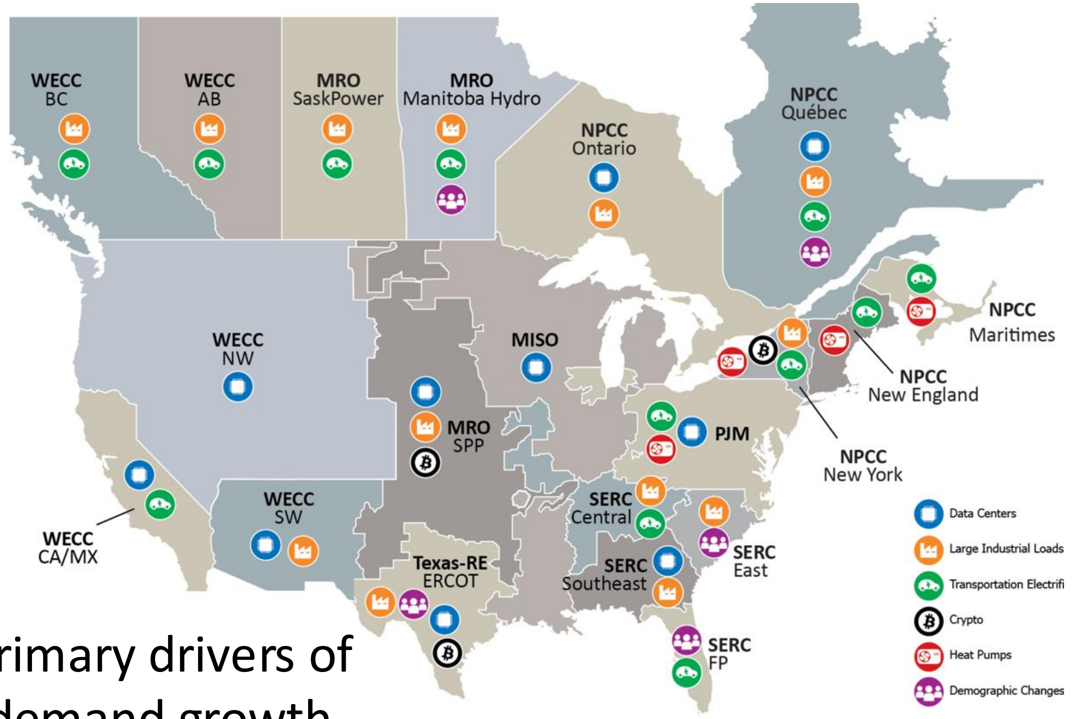
Projections of new data centers to support generative AI and cryptomining are large but highly uncertain

- Projections suggest up to a 15% annual growth in electricity demand from data centers within the next 5-10 years (EPRI 2024).
- Usage projections from more recent AI models suggest electricity demand could be much lower than ChatGPT-type models.
- Total electricity demand may grow 35-50% by 2040, driven by domestic manufacturing, data centers, and electrification (ACP 2025).
- Data centers are also potentially large consumers of fresh water, depending on the cooling technology (Siddik et al. 2021).

"Drought-stricken communities push back against data centers", 19-Jun 2021, NBC News

Rapid, uncertain growth in electricity demand poses reliability challenges for the grid

“Electricity peak demand and energy growth forecasts over the 10-year assessment period continue to climb; ***demand growth is now higher than at any point in the past two decades****. Increasing amounts of large commercial and industrial loads are connecting rapidly to the BPS. The size and speed with which data centers (including crypto and AI) can be constructed and connect to the grid presents unique challenges for demand forecasting and planning for system behavior.”*



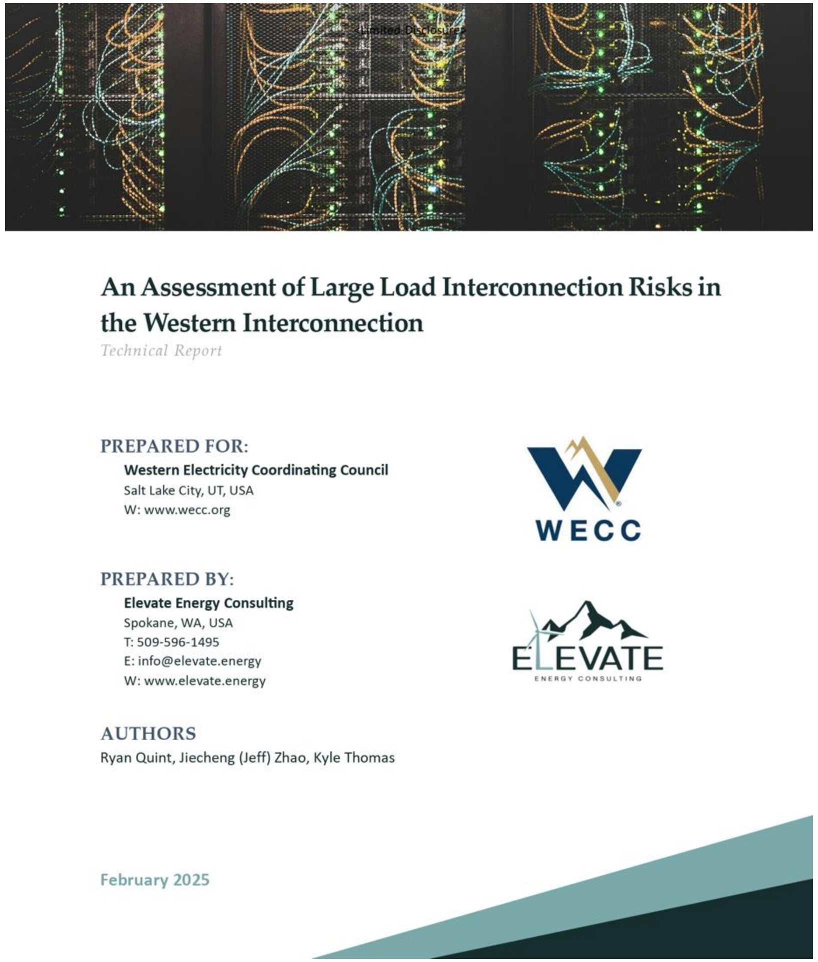
Primary drivers of demand growth

Table 12: Anticipated Reserve Margins with Announced Retirements

	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
MISO	17.7%	10.3%	10.3%	13.2%	8.6%	7.1%	10.6%	8.2%	7.5%	4.2%	-2.5%
MRO-Manitoba	12.5%	21.3%	18.4%	18.0%	15.0%	9.8%	0.5%	-0.6%	-1.7%	-2.9%	-4.2%
MRO-SaskPower	28.9%	27.8%	26.6%	31.1%	29.4%	7.0%	28.8%	28.0%	26.7%	26.8%	1.2%
MRO-SPP	28.3%	26.7%	26.0%	25.0%	20.8%	19.1%	26.7%	24.9%	23.5%	22.4%	8.1%
NPCC-Maritimes	18.9%	20.6+%	25.5%	25.1%	18.6%	3.9%	23.4%	20.7%	19.1%	17.7%	-1.5%
NPCC-New England	20.4%	25.0%	25.0%	26.3%	24.9%	23.5%	22.0%	20.1%	19.7%	17.1%	14.6%
NPCC-New York	18.4%	17.1%	21.4%	22.5%	22.4%	21.6%	20.7%	18.3%	16.7%	14.9%	13.6%
NPCC-Ontario	22.5%	20.8%	23.6%	15.7%	23.0%	9.5%	5.1%	-0.2%	-1.4%	-3.9%	-5.5%
NPCC-Quebec	12.5%	12.2%	13.1%	14.2%	12.6%	11.3%	9.8%	6.2%	3.5%	0.5%	-2.2%
PJM	29.8%	34.9%	35.7%	28.1%	21.4%	18.2%	23.1%	21.6%	20.1%	18.5%	10.3%
SERC-C	28.2%	18.9%	18.9%	15.0%	16.0%	15.2%	17.3%	17.1%	18.4%	21.1%	11.8%
SERC-E	30.4%	27.3%	25.8%	24.6%	20.6%	14.4%	14.3%	10.2%	6.3%	4.6%	-2.2%
SERC-FP	27.0%	25.4%	26.0%	23.2%	22.1%	20.9%	18.4%	22.0%	20.4%	18.2%	16.0%
SERC-SE	44.9%	39.9%	35.9%	31.5%	24.5%	21.4%	27.7%	25.8%	24.7%	23.7%	13.0%
TRE-ERCOT	24.3%	30.2%	32.5%	29.7%	25.6%	25.4%	27.8%	28.0%	28.4%	28.9%	24.9%
WECC-AB	36.3%	35.8%	35.7%	38.5%	41.7%	41.9%	35.4%	41.2%	33.6%	27.8%	27.0%
WECC-BC	20.9%	25.2%	25.2%	15.8%	15.9%	22.3%	22.1%	21.6%	21.2%	13.4%	19.9%
WECC-CA/MX	38.6%	45.5%	45.2%	38.4%	43.1%	28.8%	29.6%	23.3%	25.0%	15.2%	11.1%
WECC-NW	34.5%	40.3%	38.9%	35.6%	30.7%	24.5%	18.3%	12.2%	10.2%	8.1%	5.9%
WECC-SW	28.6%	37.0%	35.6%	31.6%	24.2%	17.4%	11.3%	7.7%	0.2%	-4.7%	-9.6%

Data centers come online faster than new generation or transmission can be built to serve them

*“**Large loads are often able to plan, permit, and build within one or two years (or quicker) whereas utility scale generation can take three to ten years.** Small transmission upgrades typically take two to three years from planning to energization whereas large transmission infrastructure projects often require more than ten years...”*



An Assessment of Large Load Interconnection Risks in the Western Interconnection
Technical Report

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Utilities are scrambling to adapt

"It took SRP 120 years to develop the generation capacity we have today. ***We will need to double or triple our capacity in the next decade to be able to meet the forecasted demand growth*** *of nearly 40% while becoming more sustainable. Rapid growth and supply chain issues add complexity, but we're making significant progress, adding 1,100 MW of new capacity this past summer alone."*

Salt River Project, March 2025

If we don't build it, somebody else will

Figure 1.13 ▹ Global map of large data centre clusters, 2024

*"You know, in the original Manhattan Project, Nazi Germany was also trying to develop [an] atomic bomb," Wright said. "**So, the cost of being second was just devastating. Like, that was a race not [that] you want to win. We had to win. And I think AI has similar overlay.**"* Chris Wright

AI and energy abundance are tightly coupled

"***The cost of AI will converge to the cost of energy...the abundance of it will be limited by the abundance of energy***."

Sam Altman's Senate Testimony, May 2025

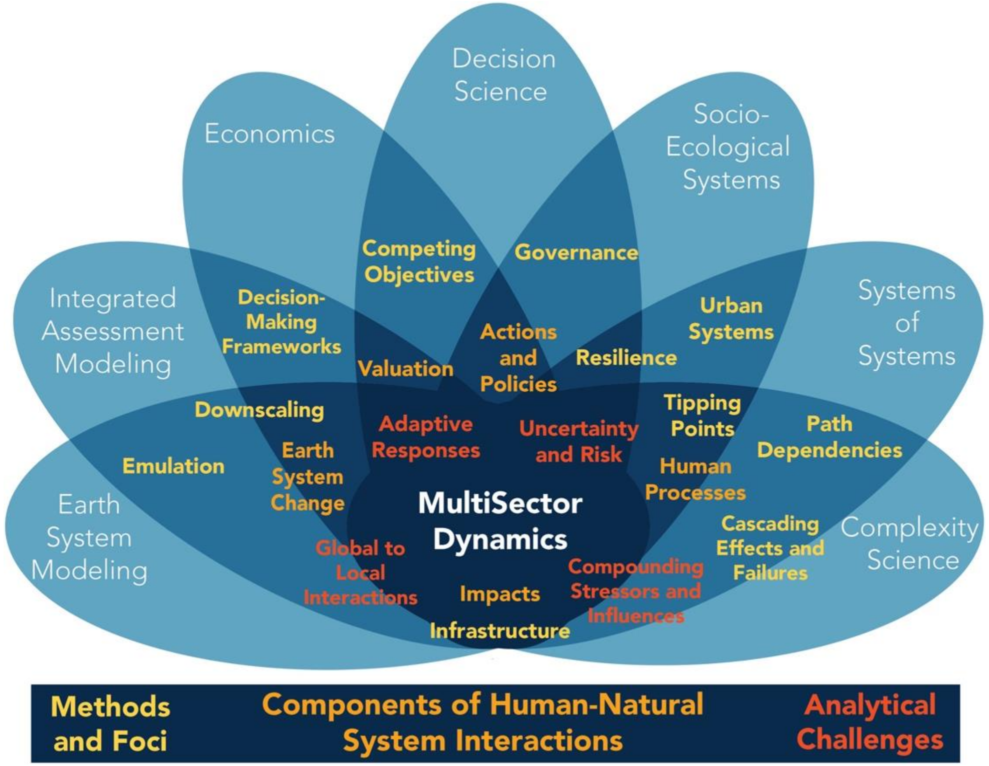
Energy sector data center risk is a classic MultiSector Dynamics problem

Connection to MSD themes:

- Systems of systems: Energy-water-economy interactions
- Economics: Supply chains and international trade
- Methods and analytical challenges:
  - Adaptive responses
  - Regulatory uncertainty and risk
  - Path dependencies

Challenges:

- Data limitations:
  - Rapid onset of highly non-linear growth rates
  - Proprietary and business-sensitive data
- Lack of models and frameworks:
  - How would one write an objective function for the growth rate of data centers?
  - How do you model their operations when their designs are constantly evolving?



Reed, P. M., and Coauthors, 2022: MultiSector Dynamics: Advancing the science of complex adaptive human-Earth systems. *Earth's Future*, 10, e2021EF002621, doi:10.1029/2021EF002621.

Task 1 – Impacts of alternative scenarios of data center electricity demand growth on grid stress

Science Questions:

1) What is the projected impact (i.e., on electricity prices, reliability, etc.) of data centers on grid operations if grid infrastructure is built without considering these demands? Under what growth rates do the projected data center demands stress the grid?
2) How might delaying scheduled generator retirements lessen grid stress due to data centers?
3) What is the impact of treating some data center loads as interruptible demands? If their loads were modeled as appropriate for demand response participation, how does that added flexibility reduce stress on the grid?

Study Parameters	
Time Horizon	2025-2035
Spatial Resolution	Balancing Authorities
Key Assumptions (also modeled as sensitivities)	• Growth rates of 3.71-15% annually • Data center hourly demand profiles are flat • No new generation explicitly to meet data center demand

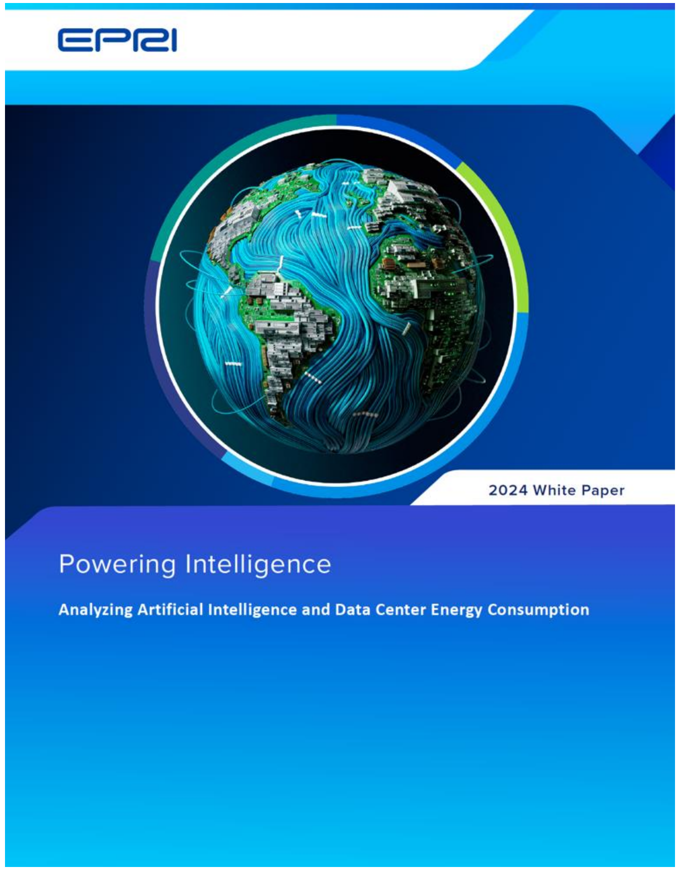
Task 1 – Impacts of alternative scenarios of data center electricity demand growth on grid stress

"*We have largely taken advantage of an overbuilt system.* ***We are now imposing a significant cost on that system***."

Brian George, Google, May 2025

Study Parameters	
Time Horizon	2025-2035
Spatial Resolution	Balancing Authorities
Key Assumptions (also modeled as sensitivities)	• Growth rates of 3.71-15% annually • Data center hourly demand profiles are flat • **No new generation explicitly to meet data center demand**

Projections of data center growth were sourced from the peer-reviewed and gray literature

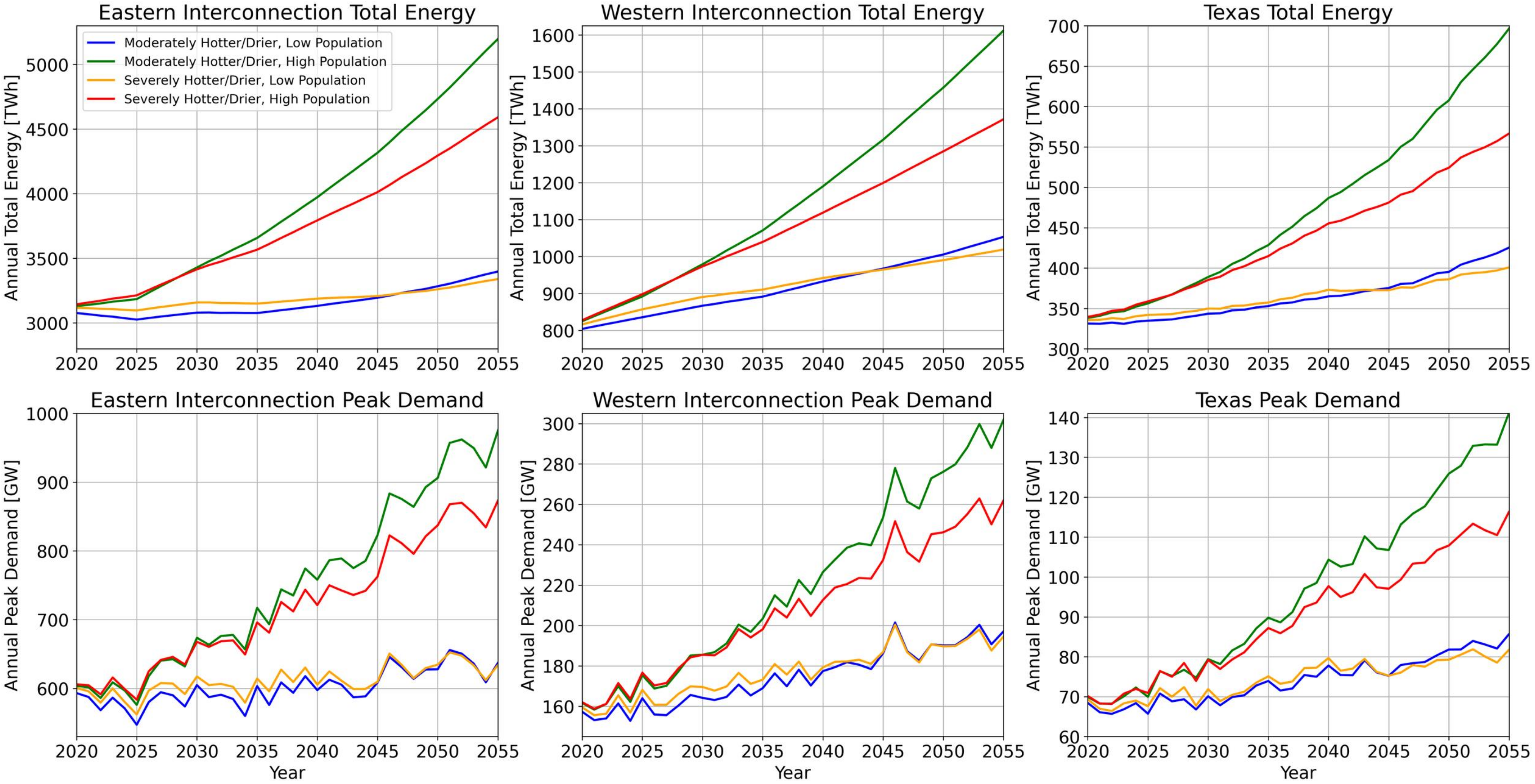


FORECASTED SCENARIOS: PROJECTIONS OF DATA CENTER ELECTRICITY CONSUMPTION IN TOP 15 STATES (2023—2030)

STATE	2023 Load		Low-growth scenario (3.71%)		Moderate-growth scenario (5%)		High-growth scenario (10%)		Higher-growth scenario (15%)	
	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)
Virginia	33,851,122	25.59%	43,683,508	29.28%	47,631,928	31.10%	65,966,260	38.47%	89,880,357	46.00%
Texas	21,813,159	4.59%	28,149,002	5.47%	30,693,306	5.94%	42,507,676	8.04%	57,917,564	10.64%
California	9,331,619	3.70%	12,042,078	4.43%	13,130,525	4.81%	18,184,686	6.54%	24,777,000	8.70%
Illinois	7,450,176	5.48%	9,614,151	6.53%	10,483,145	7.08%	14,518,285	9.54%	19,781,455	12.56%
Oregon	6,413,663	11.39%	8,276,574	13.39%	9,024,668	14.43%	12,498,415	18.93%	17,029,342	24.14%
Arizona	6,253,268	7.43%	8,069,590	8.81%	8,798,975	9.53%	12,185,850	12.73%	16,603,465	16.58%
Iowa	6,193,320	11.43%	7,992,230	13.44%	8,714,623	14.48%	12,069,029	18.99%	16,444,294	24.21%
Georgia	6,175,391	4.26%	7,969,093	5.08%	8,689,396	5.51%	12,034,090	7.48%	16,396,690	9.92%
Washington	5,171,612	5.69%	6,673,757	6.77%	7,276,977	7.34%	10,078,009	9.88%	13,731,490	13.00%
Pennsylvania	4,590,240	3.16%	5,923,520	3.78%	6,458,929	4.11%	8,945,079	5.61%	12,187,850	7.49%
New York	4,067,385	2.84%	5,248,796	3.40%	5,723,219	3.69%	7,926,182	5.05%	10,799,583	6.75%
New Jersey	4,038,360	5.42%	5,211,341	6.46%	5,682,378	7.00%	7,869,621	9.44%	10,722,517	12.44%
Nebraska	3,959,520	11.70%	5,109,601	13.75%	5,571,442	14.81%	7,715,984	19.41%	10,513,184	24.71%
North Dakota	3,915,720	15.42%	5,053,079	18.00%	5,509,811	19.31%	7,630,631	24.89%	10,396,888	31.11%
Nevada	3,416,707	8.69%	4,409,122	10.28%	4,807,649	11.10%	6,658,195	14.75%	9,071,924	19.07%

We are building on top of existing IM3 load projections

Burleyson et al. 2025: When do different scenarios of projected electricity demand start to meaningfully diverge? *Applied Energy*, 380, 124948, doi:10.1016/j.apenergy.2024.124948.



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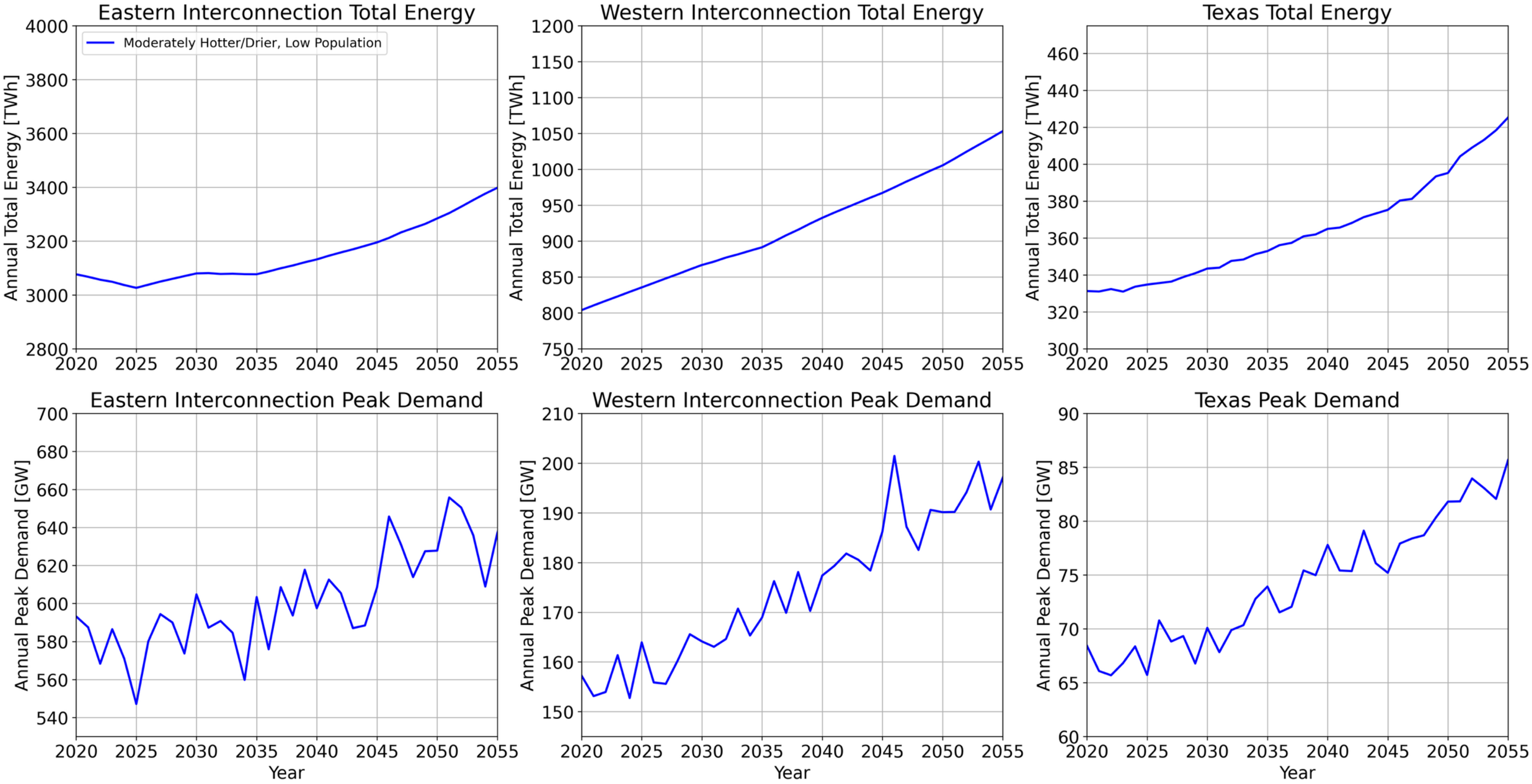
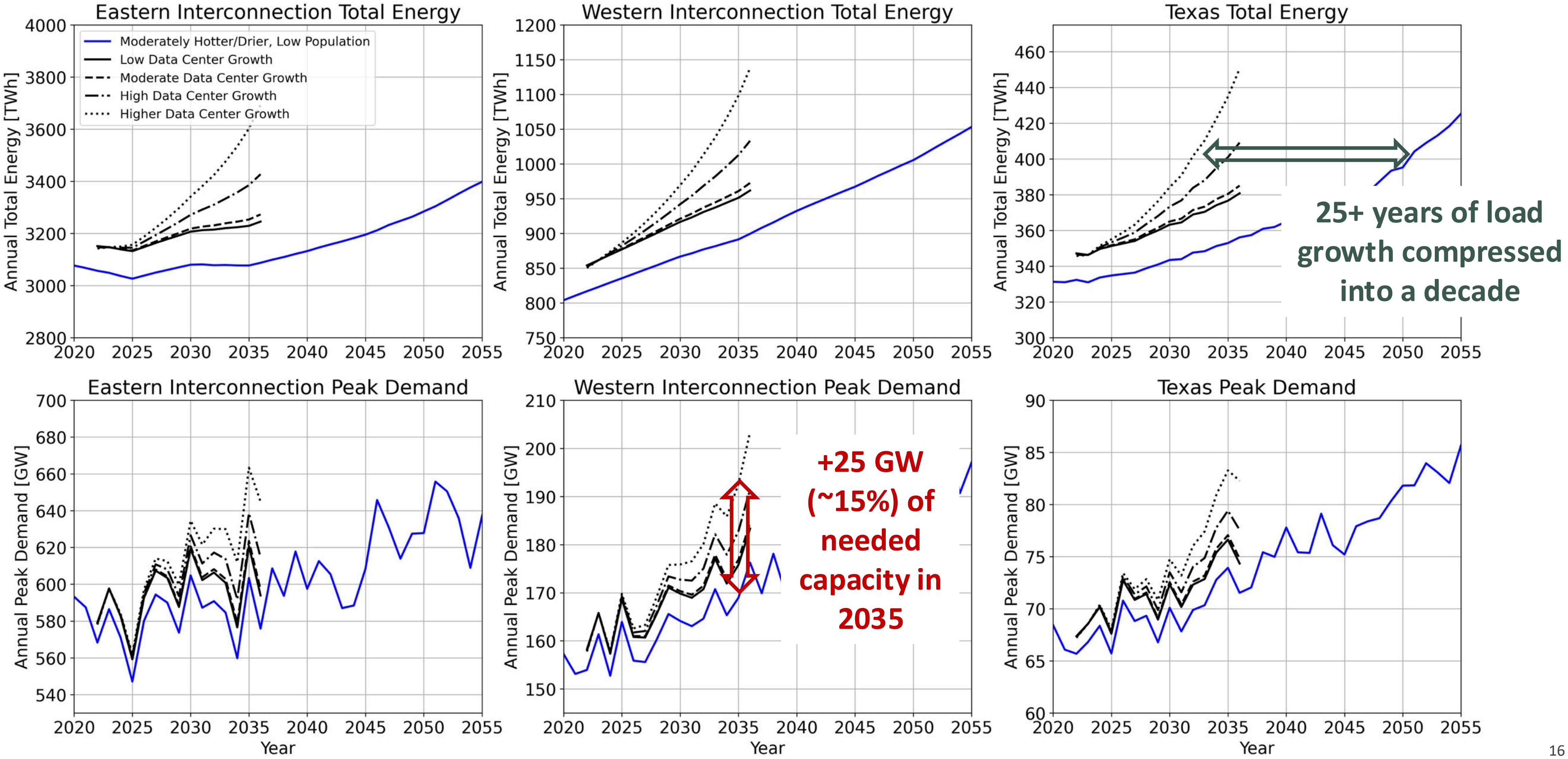
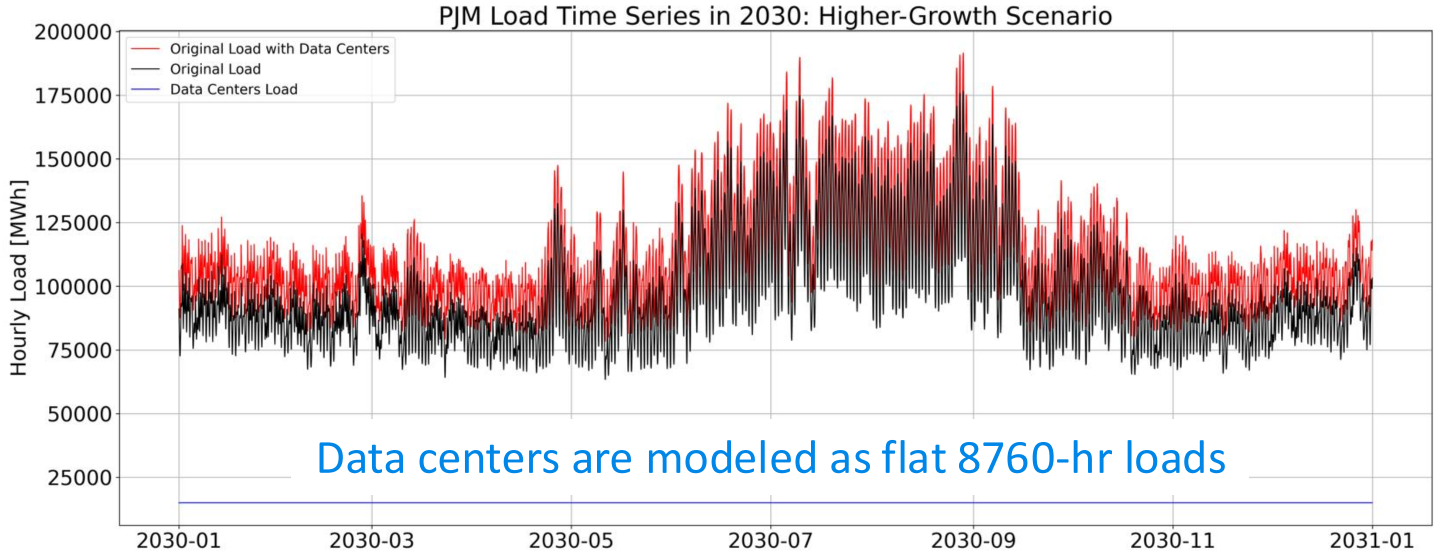
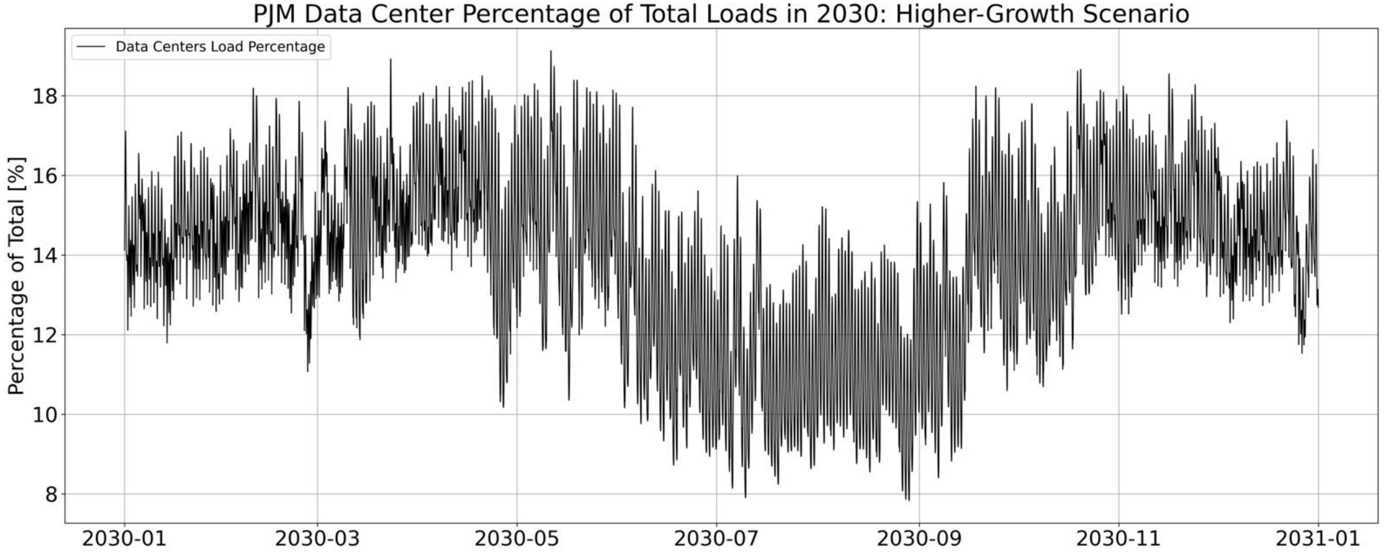


Data centers significantly accelerate load growth in all three grid interconnections

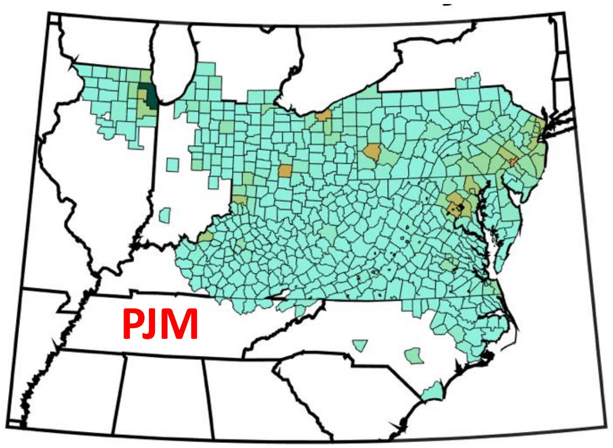


We created data center load growth projections for every Balancing Authority (BA) in the CONUS

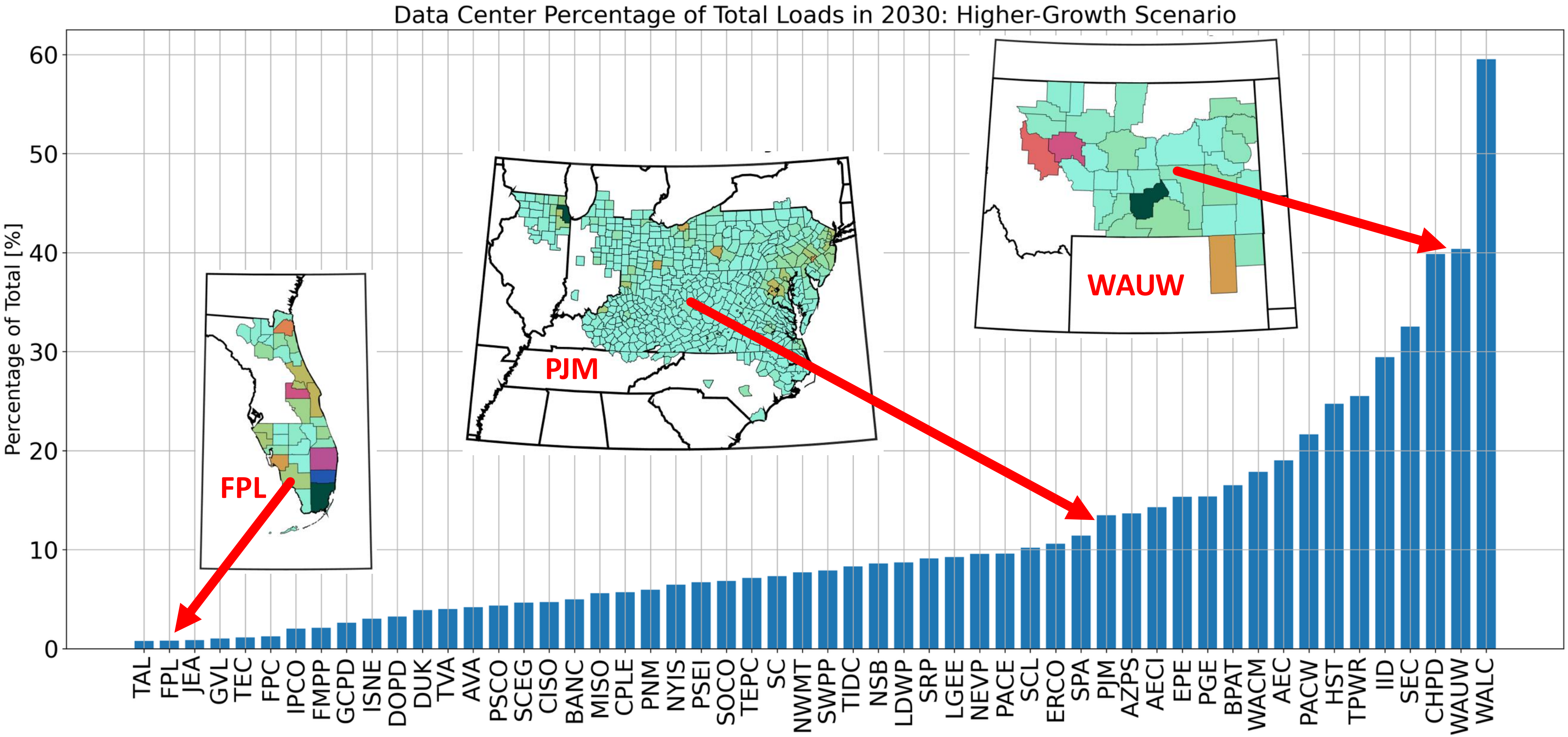




For PJM, a large BA in the Eastern Interconnection, the highest data center growth rates translate into +8-18% load growth due to data centers by 2030.

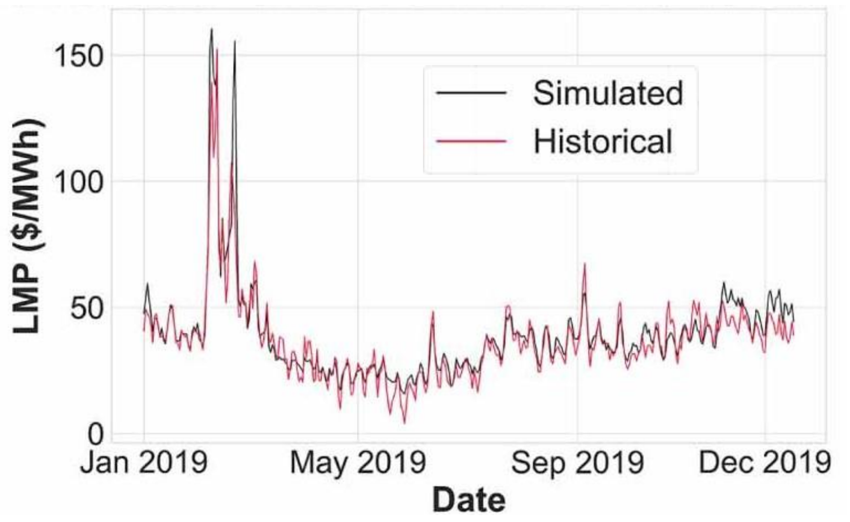


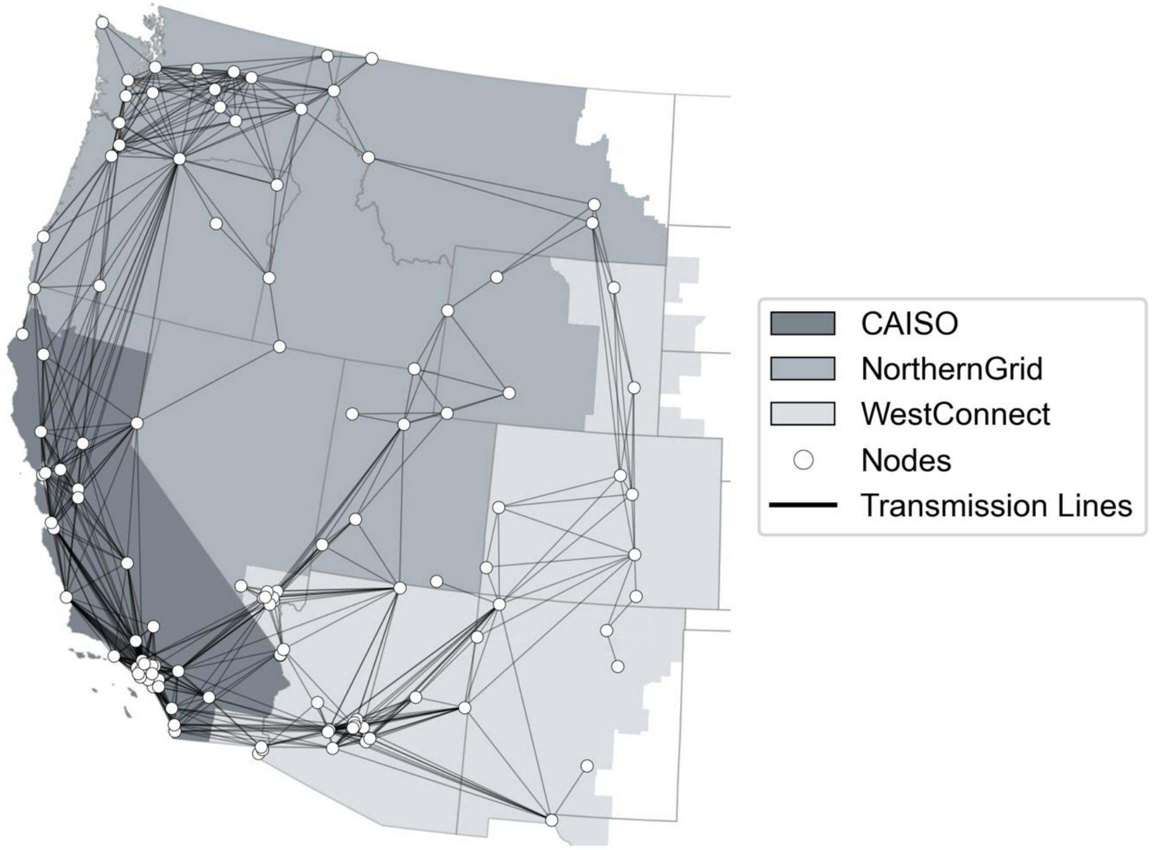
Data centers may account for 40-60% of the total load in some smaller rural BAs



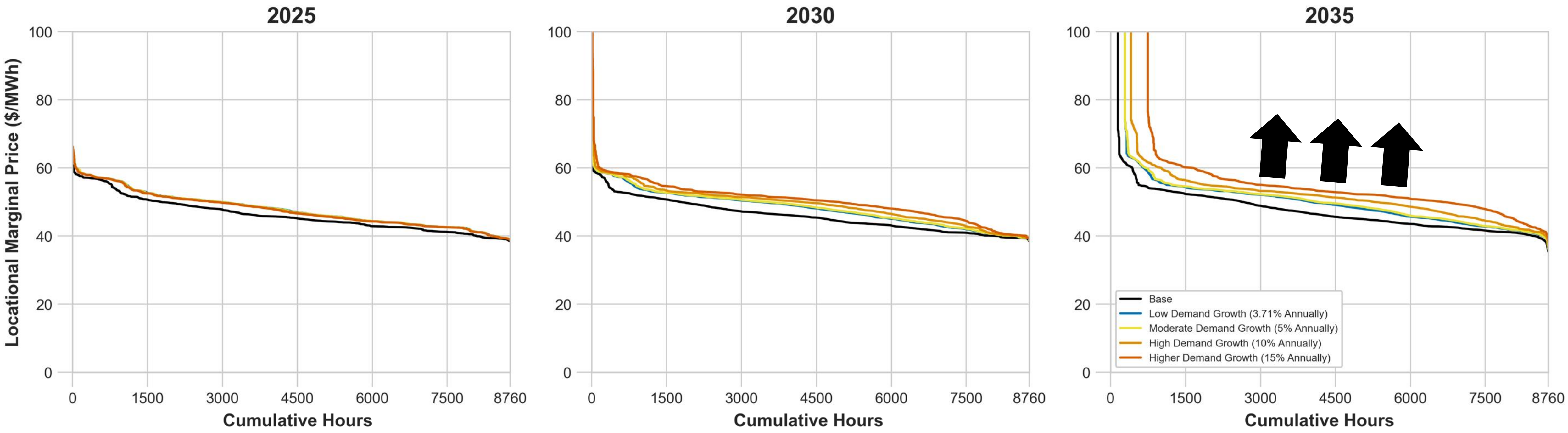
The Grid Operations (GO) model is an open-source and customizable grid operations modeling tool

- Creates simplified representations of the three U.S. interconnections to balance accuracy and computational complexity.
- Dispatches generators to balance hourly supply and demand with the optimization goal to minimize cost.
- Validated with historical grid outcomes such as electricity prices and the generation mix used to meet demand.



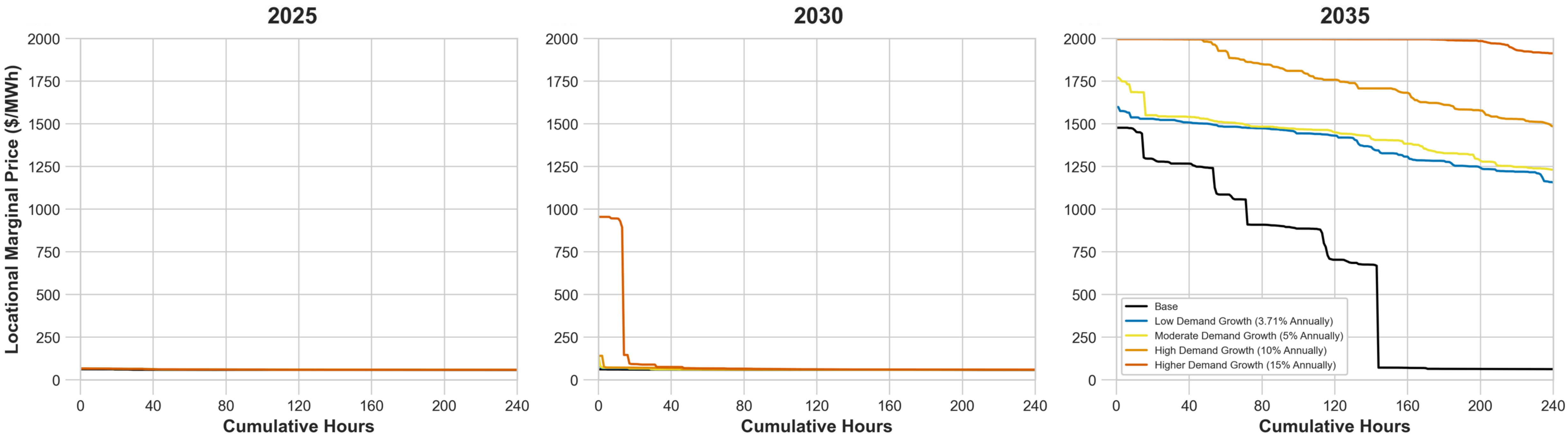


Data center growth leads to higher hourly electricity prices in the Western Interconnection



- The effect of data center loads on electricity prices is relatively small in 2025 (+3-4%) and in 2030 (+5-12%).
- Price divergence between different data center growth scenarios becomes clear in 2035.
- Compared to the base scenario, **yearly average electricity prices in 2035 increase 43%, 47%, 91%, and 202% under low, moderate, high, and higher data center load growth scenarios**, respectively. This extreme increase is largely driven by data centers exacerbating the prices during worst (most expensive) 10-15 days of the year.

Data center growth leads to higher hourly electricity prices in the Western Interconnection



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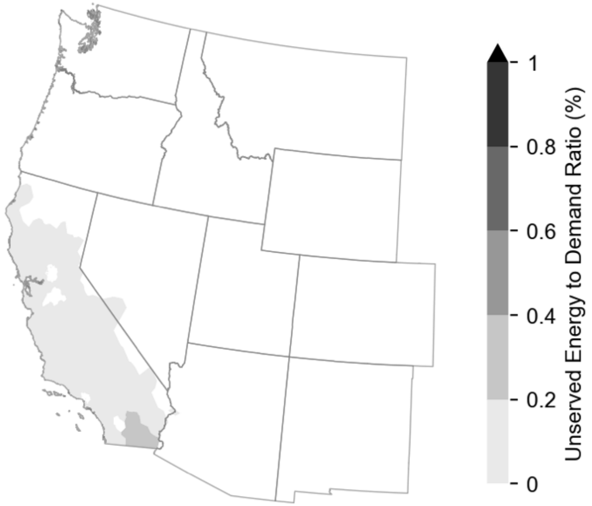
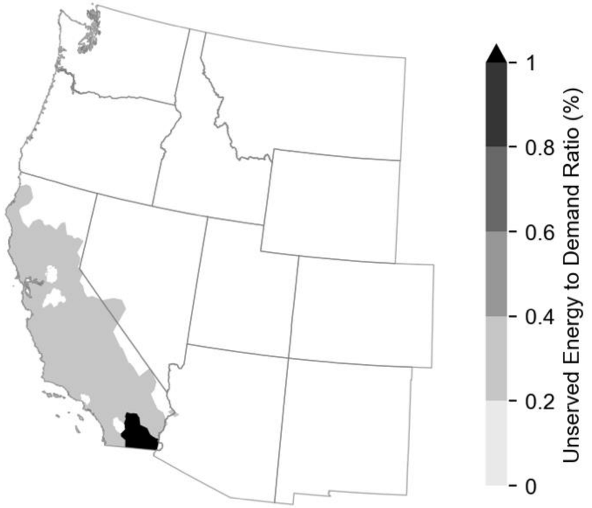
Unserved energy also increases, especially in California

- Despite some outage events in California, the grid has relatively high reliability in 2035 under the original IM3 projected loads.
- Adding data center loads worsened the severity of outage events, especially in California, and led to new load-shedding events in some BAs.

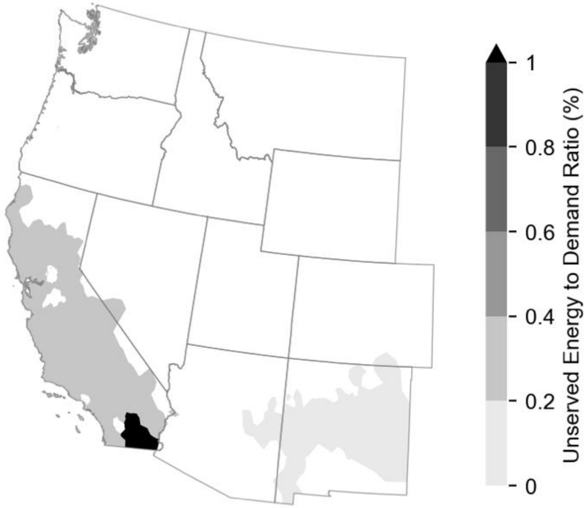
Base Case (No Data Centers)



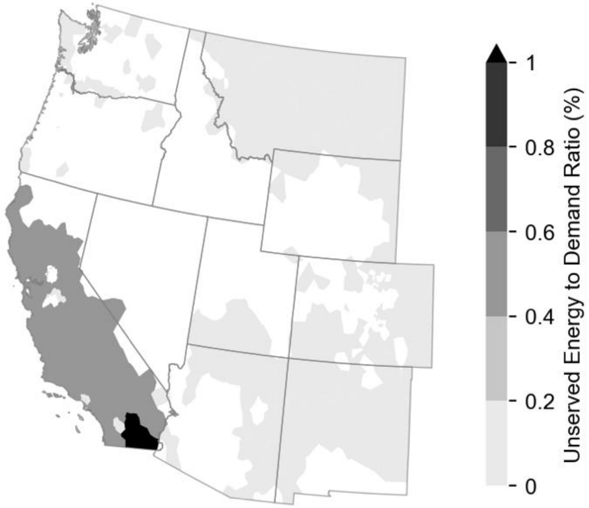
Low Growth (3.71% Annually)



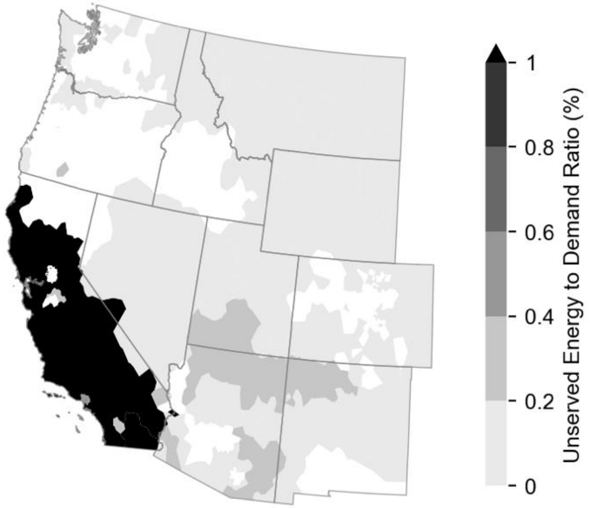
Moderate Growth (5% Annually)



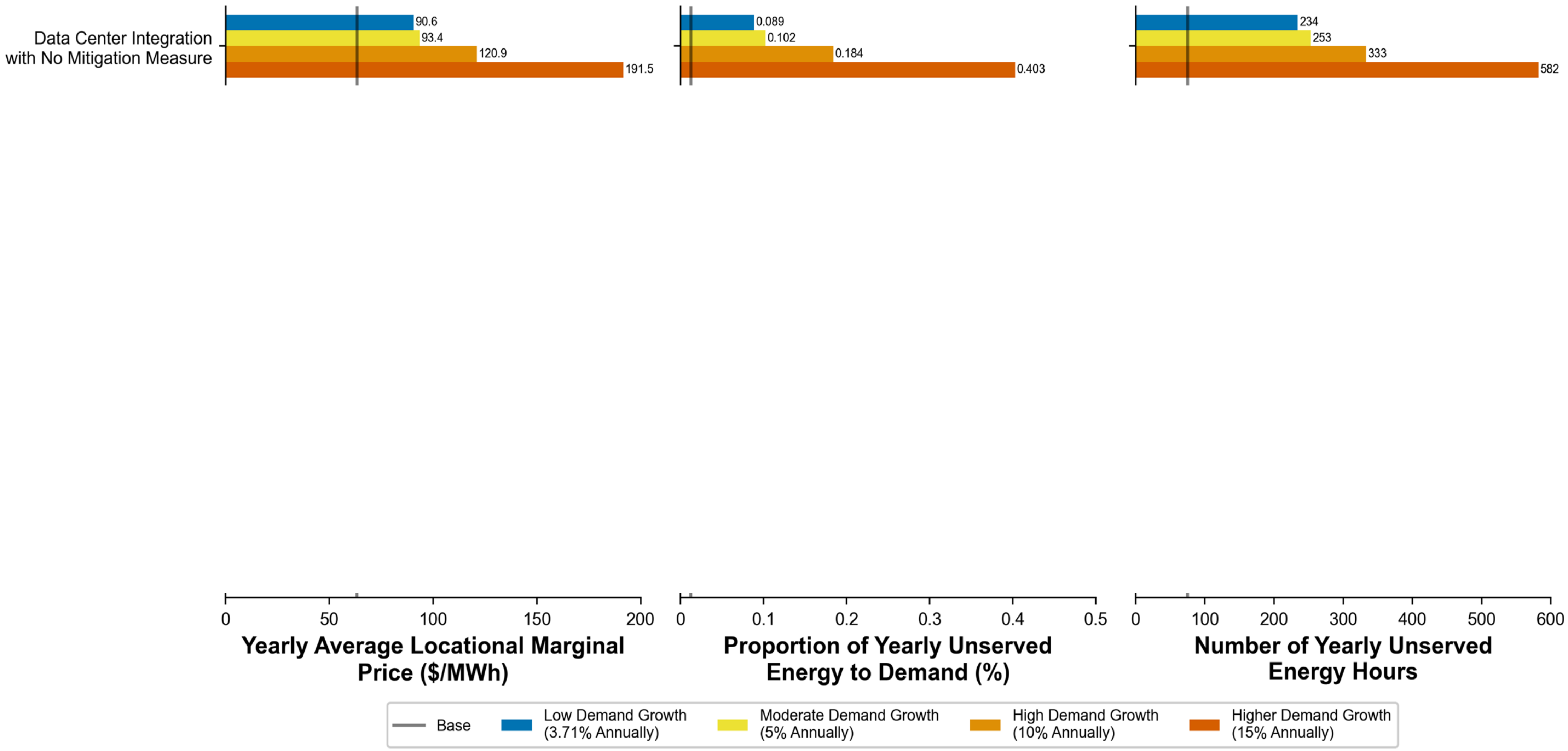
High Growth (10% Annually)



Higher Growth (15% Annually)



Can deferring scheduled generator retirements alleviate higher prices and unserved energy due to data centers?



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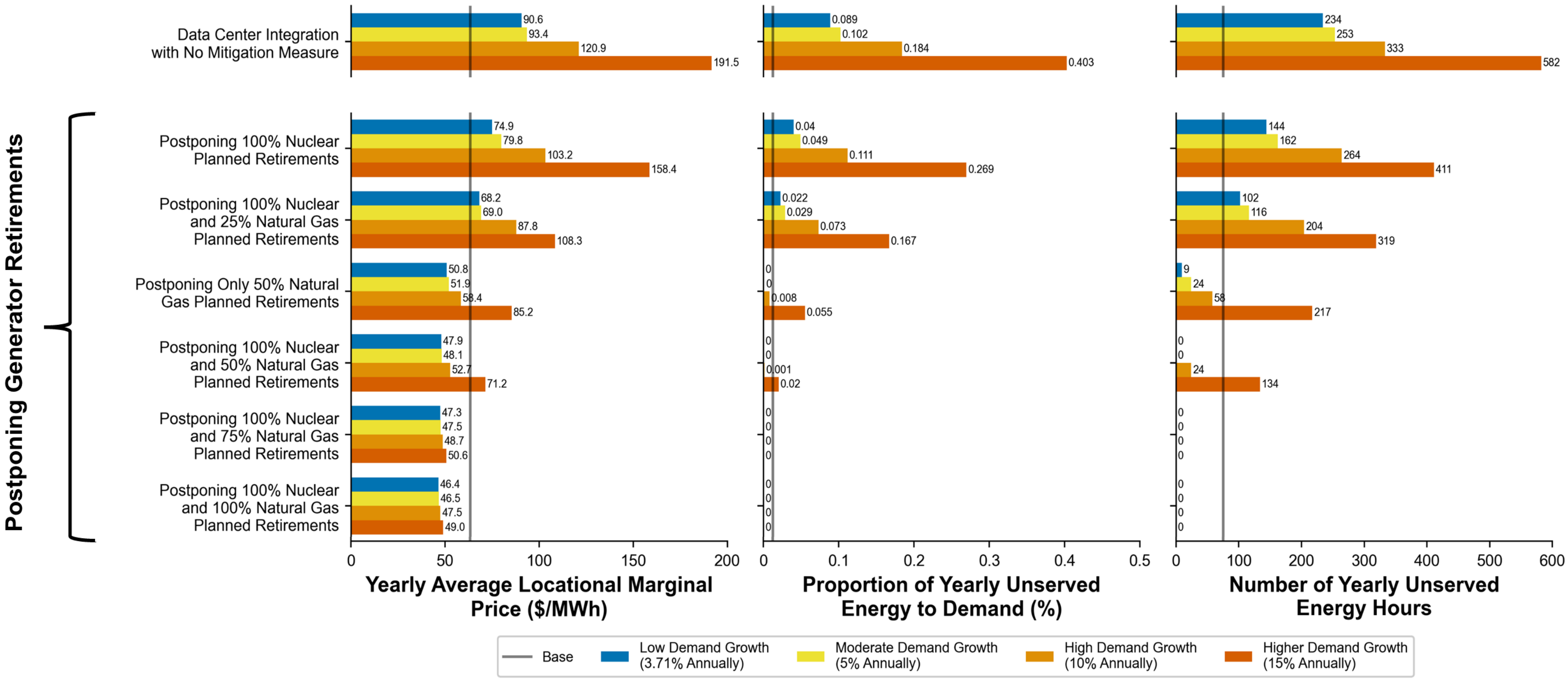
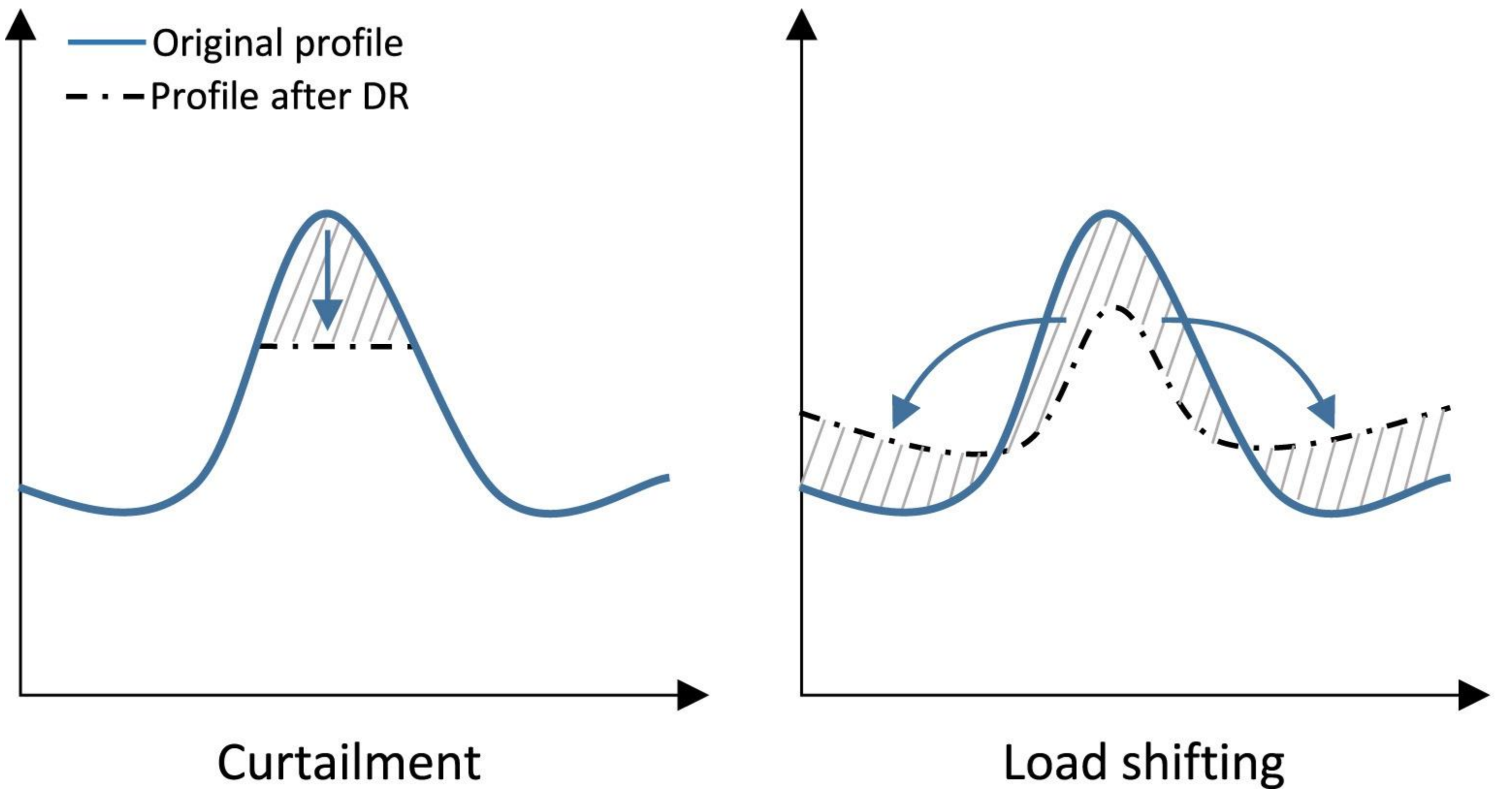


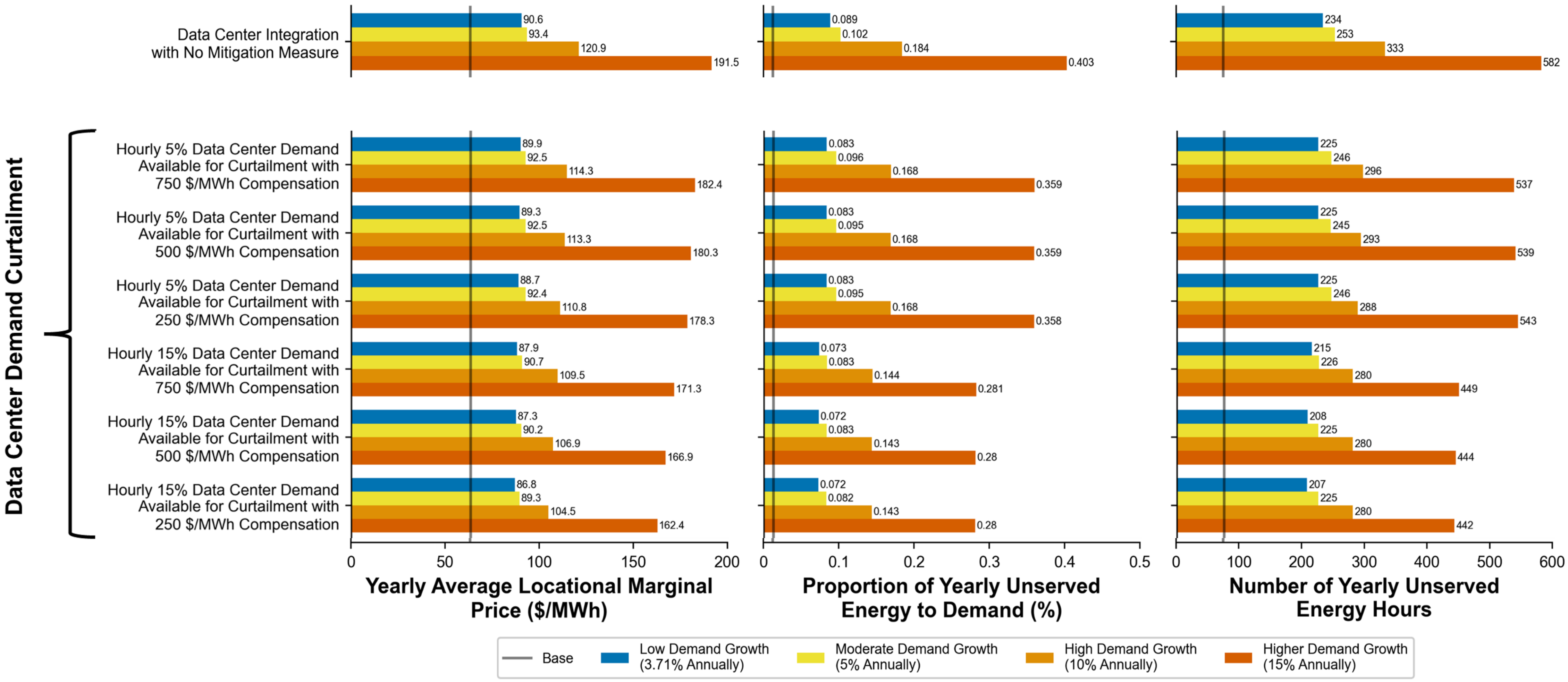
Modeling data center loads as interruptible demands may alleviate their worst impacts

We modified GO to enable two approaches to modeling a fraction of data center demands as flexible loads: Curtailment and load shifting.



Conceptual figure from Morales-España et al. 2022

Impact of data center demand curtailment is limited compared to deferring scheduled generator retirements



Task 2 – Impacts of data center demands, siting, and configuration on water stress and grid stress

Science Questions:

3) Where, when, and to what extent do data centers contribute to water scarcity? Where and when does water availability constrain data center siting? What are the most important constraints for data center siting?
4) What is the impact on the grid and on water stress of relying on co-located generation versus remote (i.e., in the same interconnection but not the same site) generation to support data center demands?

Study Parameters	
Time Horizon	2025-2055
Key Assumptions (also modeled as sensitivities)	• New data centers matched 1:1 with new generation • Generation can be co-located or off-site • Cooling water demands depend on cooling technology/water availability

Approach to siting new data centers

Step 1: Conduct extensive review of data center developer documents and reports to determine common factors in location decision making and technology choices.

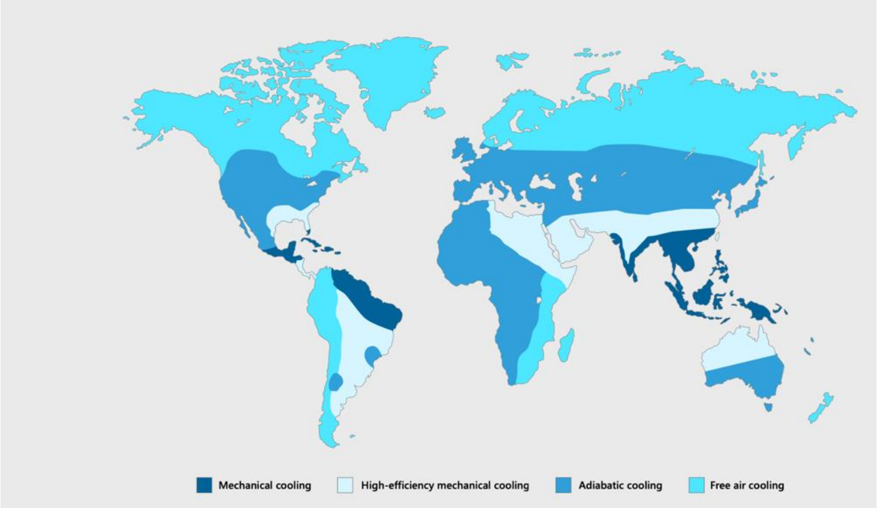
https://sabeydatacenters.com/locations/quincy-data-center

TECHNICAL SPECIFICATIONS

- Low risk of natural disasters
- Seismic site class C
- Sales tax exemption for tenants
- Below-average utility rates at 2.5 cents/kWh
- Air Cooled Chiller Plant with 800 tons at N+2 per data hall
- Free cooling below 30°F
- Variable Frequency Drives throughout
- Color-coded power room alignment

https://www.cyrusone.com/data-centers/north-america/quincy-washington

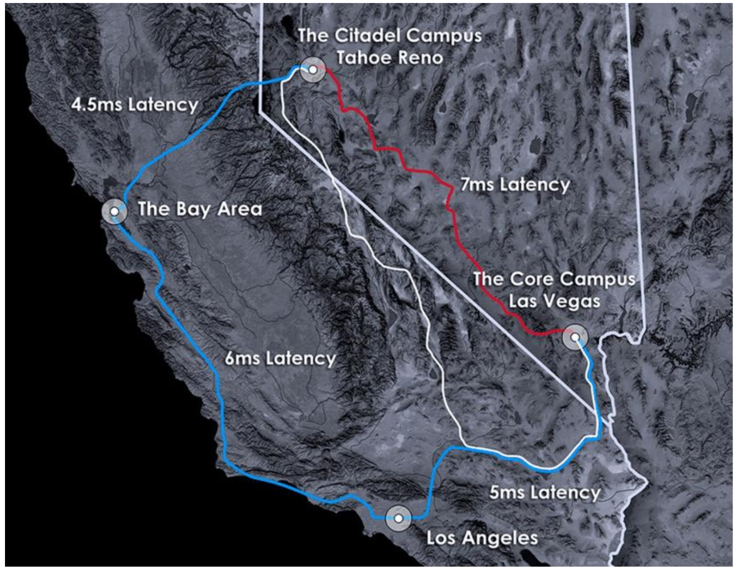
Cooling Methods



https://datacenters.microsoft.com/wp-content/uploads/2023/05/Azure_Modern-Datacenter-Cooling_Infographic.pdf

The Switch SUPERLOOP® includes:

- The world's first Tier 5® Platinum data centers geographically separated over 500 miles, connected with a dedicated and diverse fiber network
- Strategic location to California's technology hubs – Silicon Valley and Los Angeles
- One hour flight from most west coast client locations
- Built in the lowest risk area from natural disasters in western United States
- Low tax environment – significantly lowering overall costs compared with California
- Both campus locations are designed to operate indefinitely without water
- Connected with low-latency dual fiber paths between ecosystems
- 4.5 milliseconds from the Bay Area basin
- 5 milliseconds from Los Angeles metro

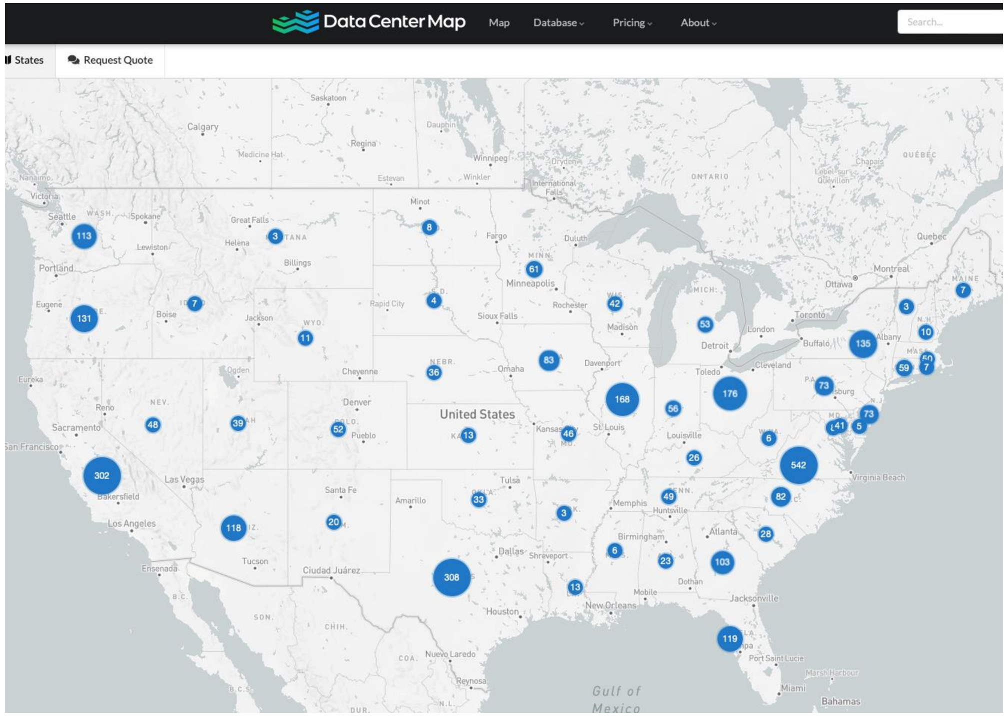


https://www.switch.com/switch-superloop/

Approach to siting new data centers

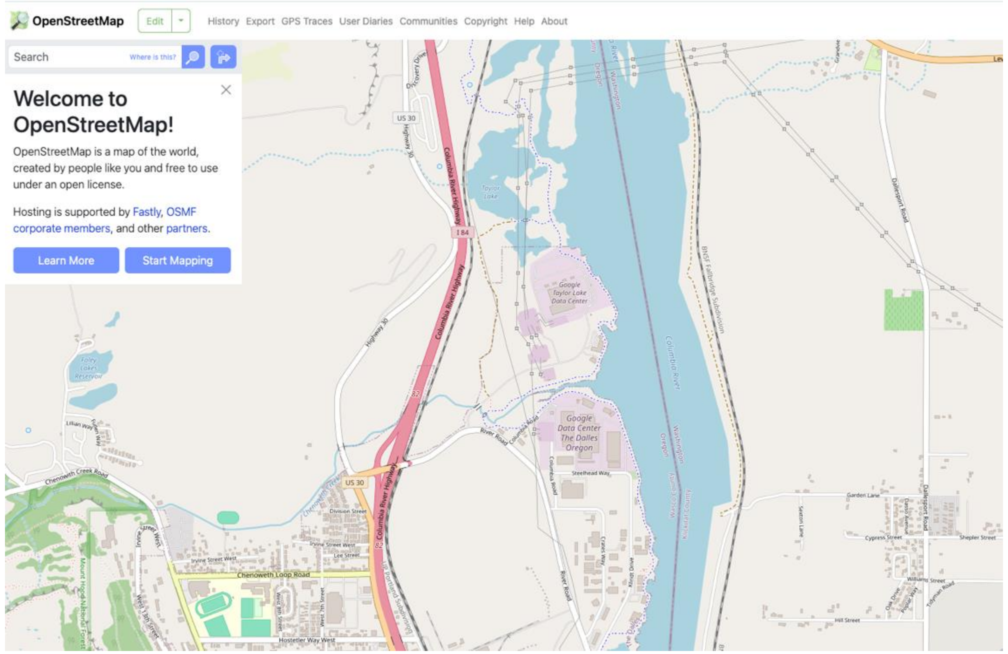
Step 2: Collect geospatial data of existing large scale data centers to spatially determine additional siting commonalities and validate siting suitability.

Proprietary



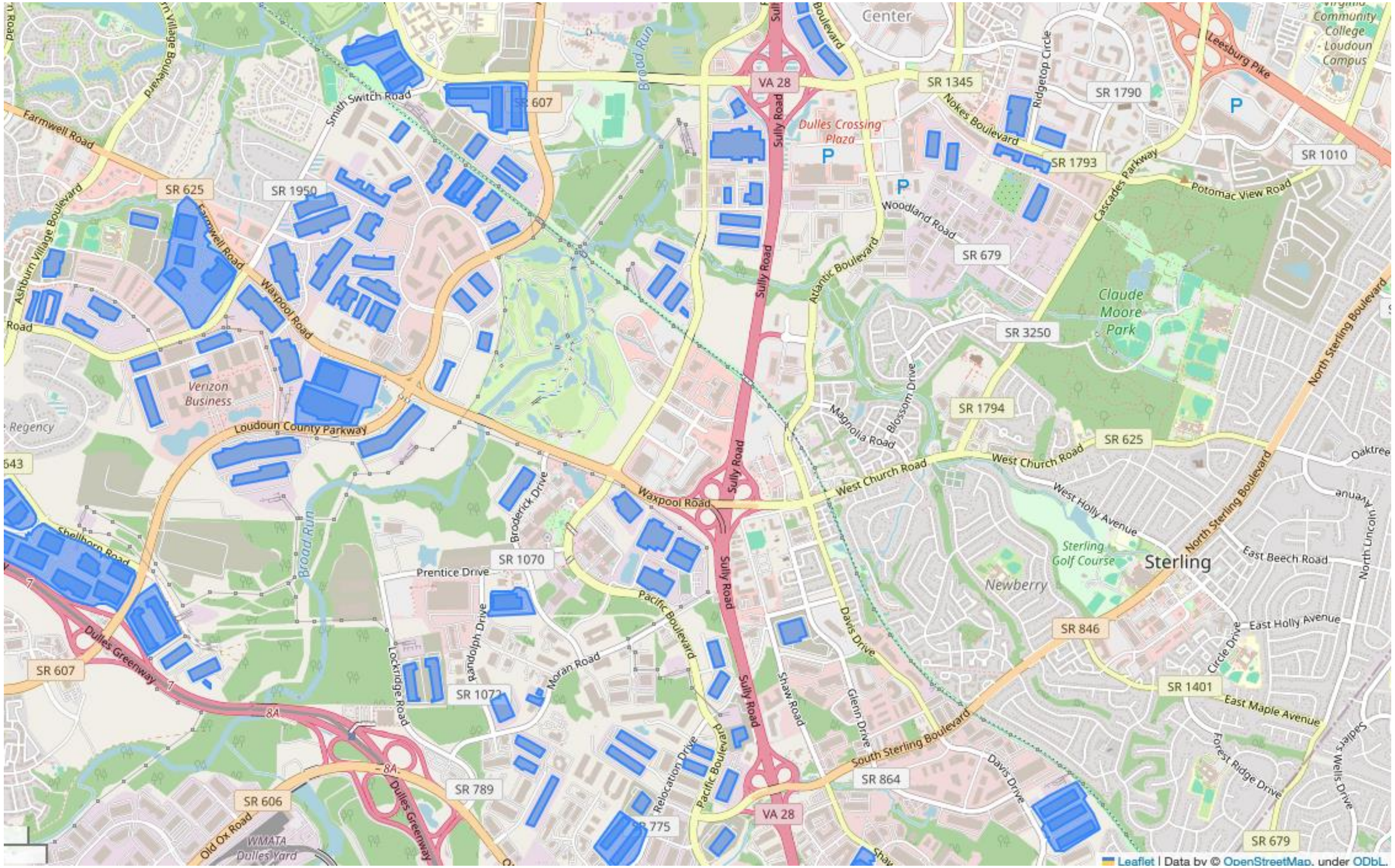
vs

Crowd-sourced

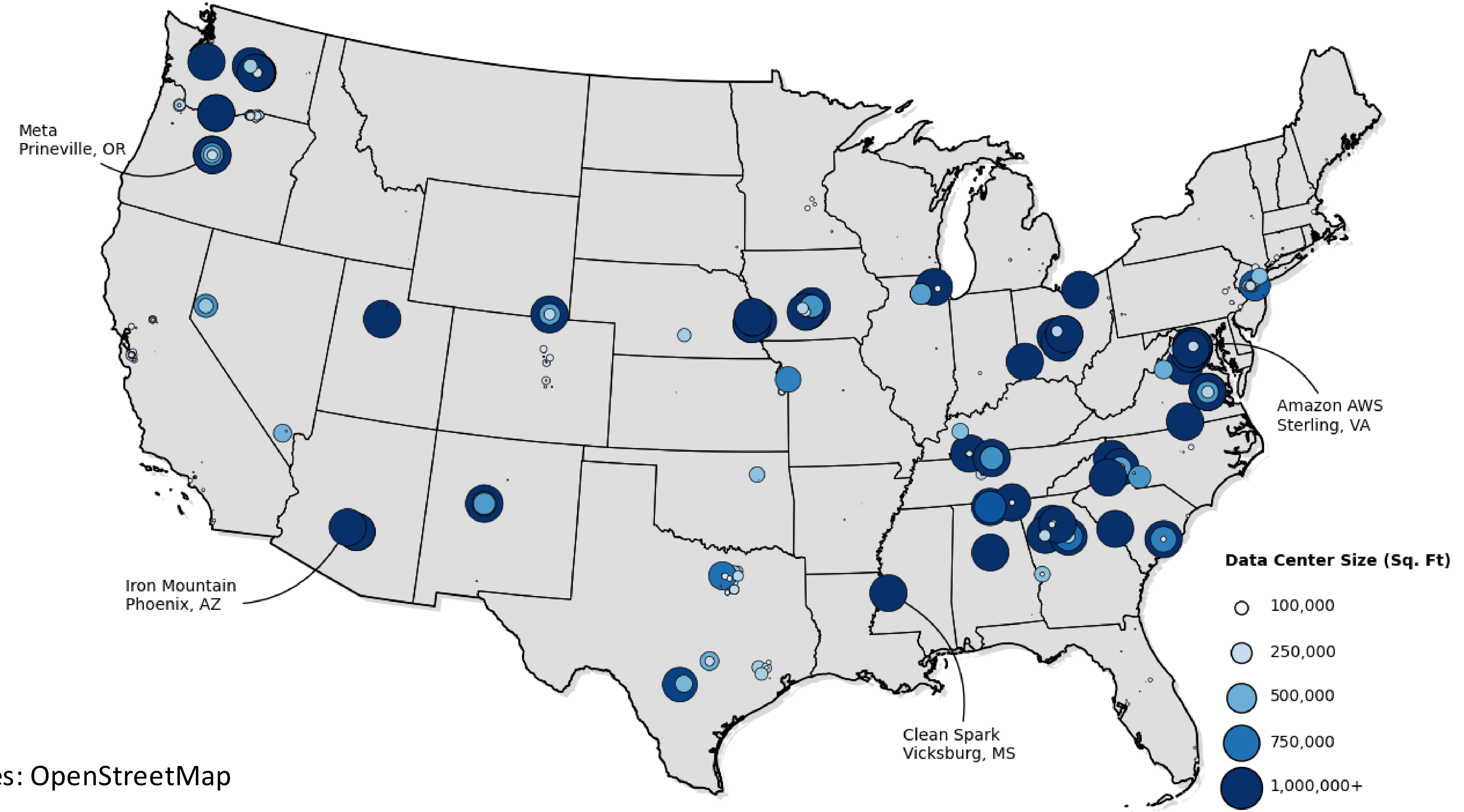


IM3

Virginia is for data centers



Data centers are being built in many places, but tend to be clumped together



Data Sources: OpenStreetMap

We need to spatially represent key drivers of data center locations

Step 3: Identify sources of geospatial data that can be used to represent data center siting influences.

- LAND AVAILABILITY & COST → USGS & US Census Bureau
- PROXIMITY TO FIBER NETWORK → US FCC
- CHEAP & RELIABLE ELECTRICITY → HIFLD & OPENEI
- ACCESS TO WATER SUPPLIER → US EPA
- TAX RATES & INCENTIVES → US Census Bureau
- LOW NATURAL HAZARD RISK → US FEMA

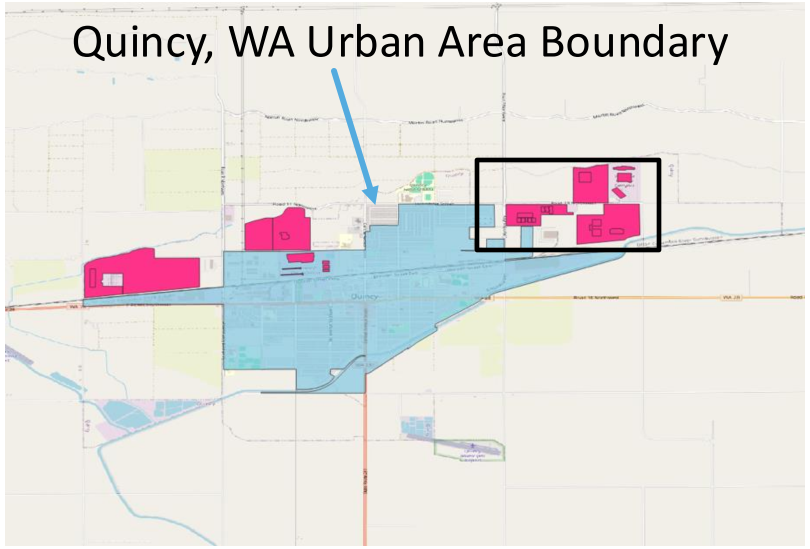
IM3

Large data centers are routinely purchasing large plots of inexpensive land outside of urban/developed areas

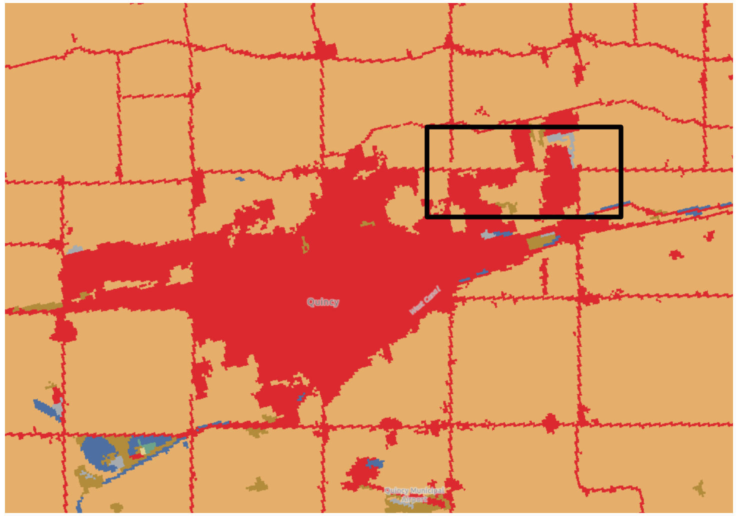
LAND AVAILABILITY & COST

We can extract these areas using high resolution (30m) land cover data to determine where available space may be for new development.

https://www.datacenterfrontier.com/site-selection/article/11430108/cyrusone-h5-bring-more-data-centers-to-quincy



Data Sources: OpenStreetMap, US Census Bureau, USGS

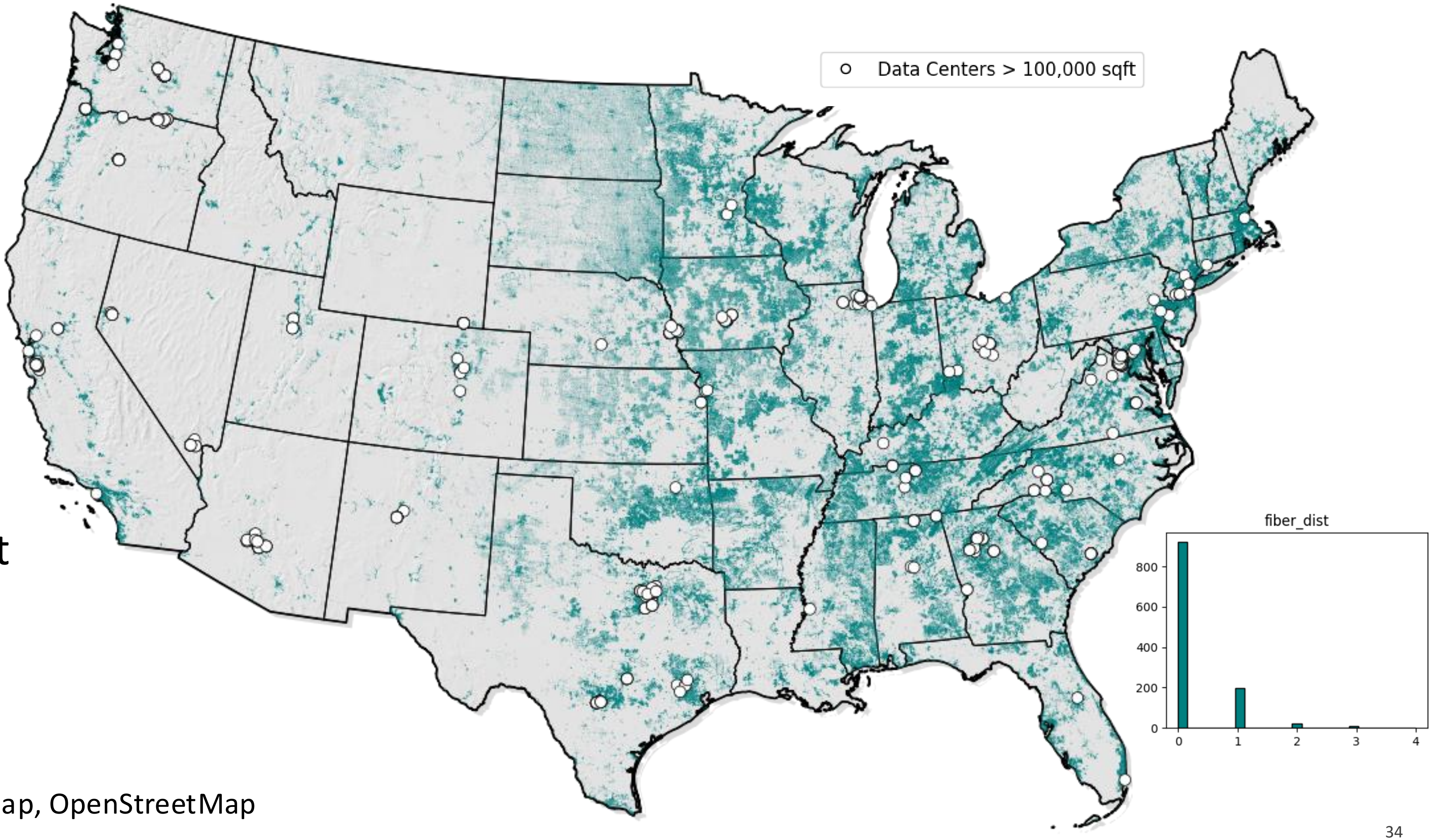


NLCD 2020 Land Cover, 30m resolution

>97% of data centers are located within 1km of a high-speed fiber provider service territory

PROXIMITY TO FIBER NETWORK

74% have access to at least two high speed fiber providers

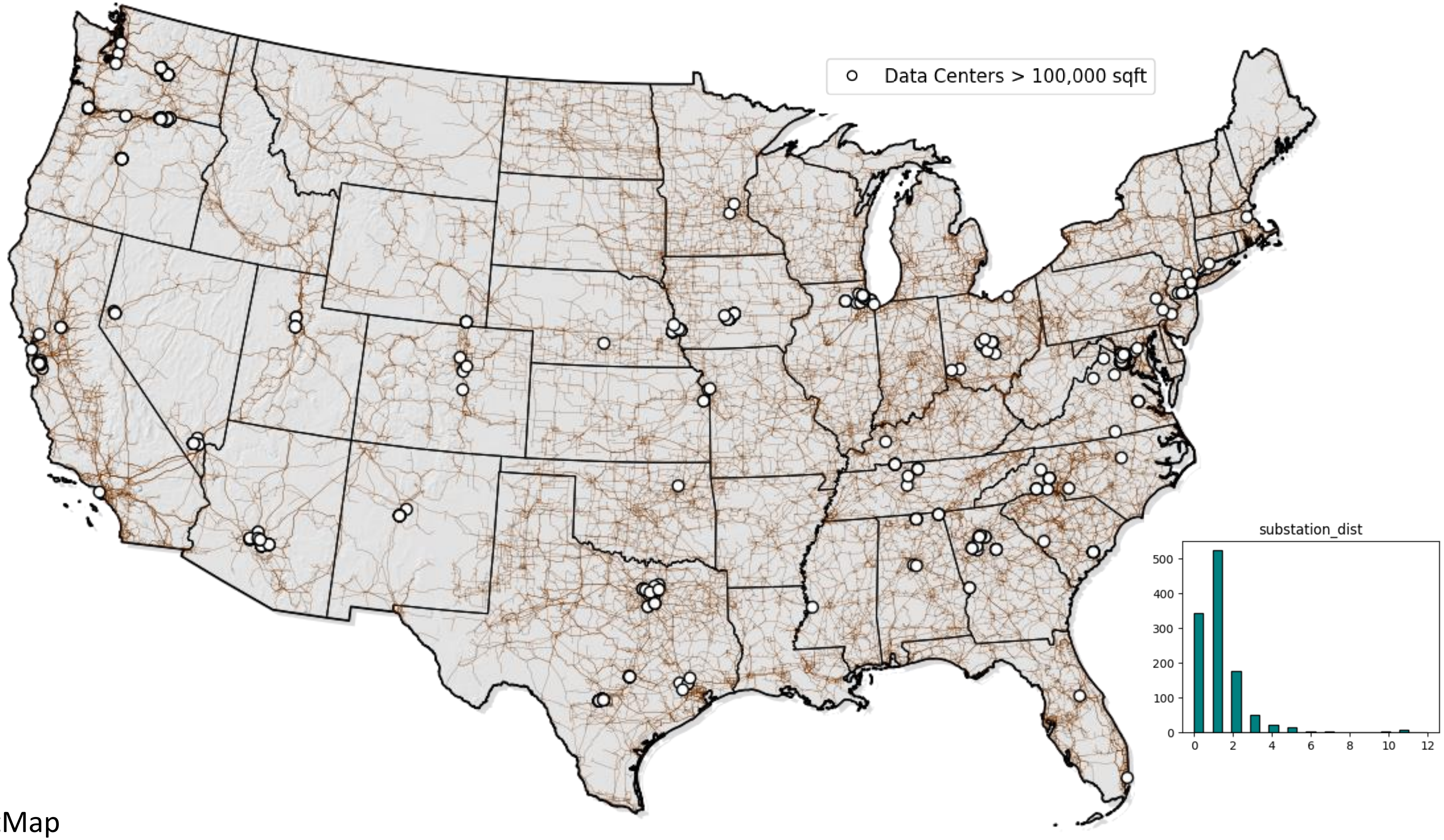


Data Sources: FCC Broadband Map, OpenStreetMap

Having more direct access to reliable power sources is prioritized because service disruptions are costly

CHEAP & RELIABLE ELECTRICITY

76% of data centers are located within 1 km of a substation

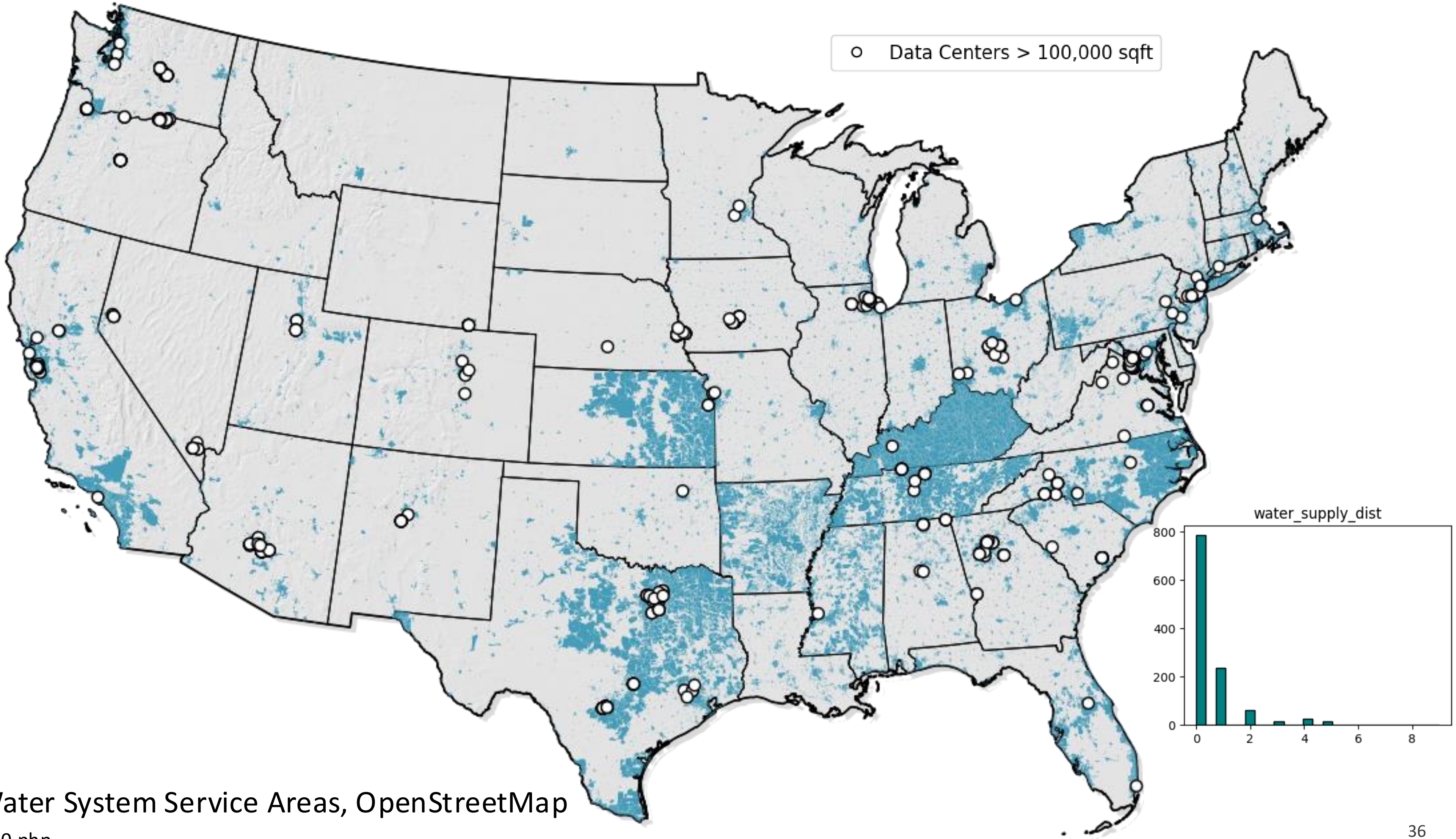


Data Sources: HIFLD, OpenStreetMap

Data centers need water for onsite workers as well as cooling if they have wet-cooled systems

ACCESS TO WATER SUPPLIER

89% of data centers are located within 1 km of a water supplier. In some cases, large data centers have paid for substantial water infrastructure investments in small towns.[1]



Data Sources: EPA Community Water System Service Areas, OpenStreetMap

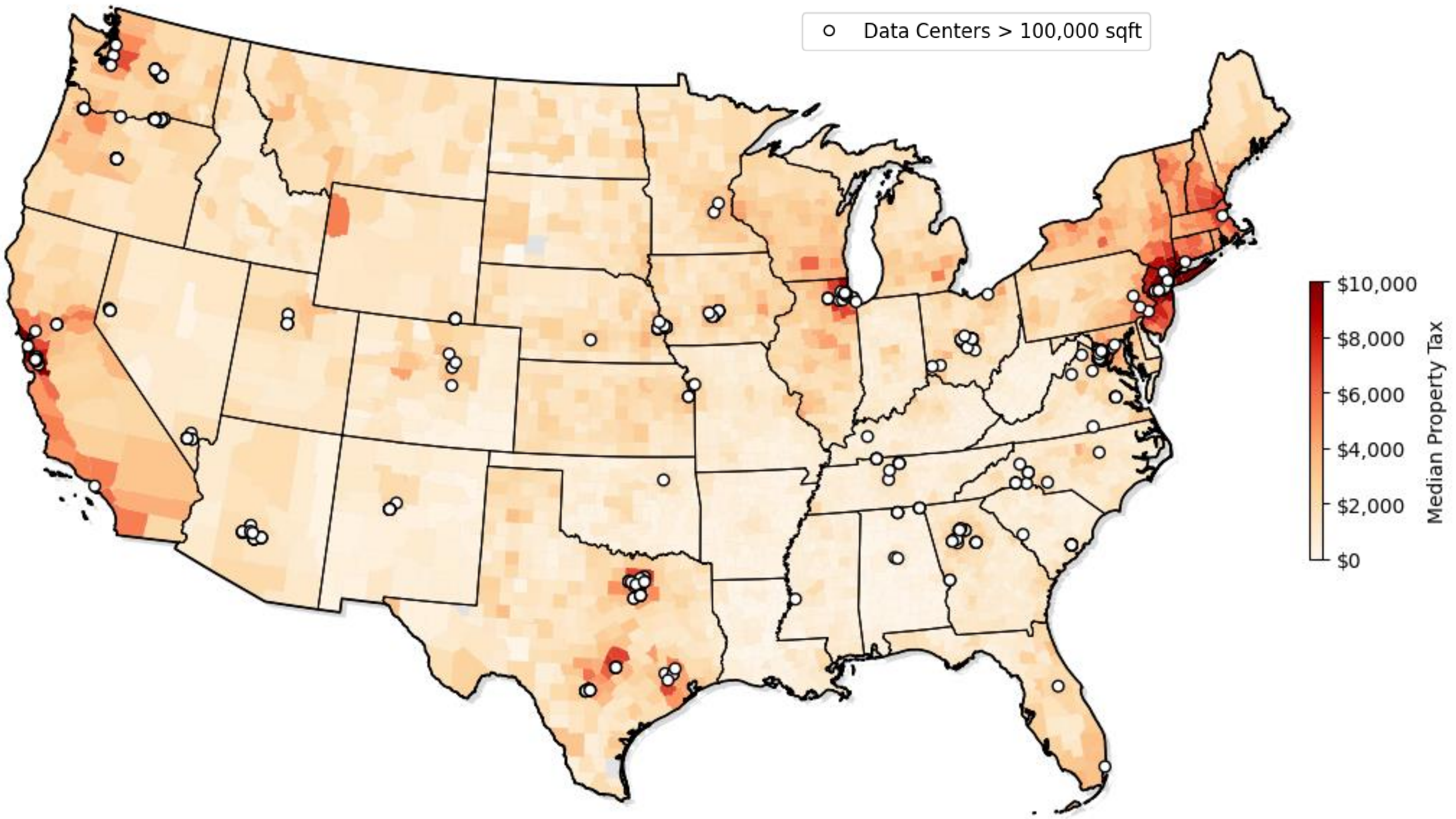
[1] https://www.thedalles.org/news_detail_T4_R180.php

Sales tax rates and property tax rates are two large drivers

TAX RATES & INCENTIVES

For large data centers, developers will sometimes choose to build in an entirely different state from their market and build long, expensive fiber lines to avoid higher taxes.

Median Property Tax by Region

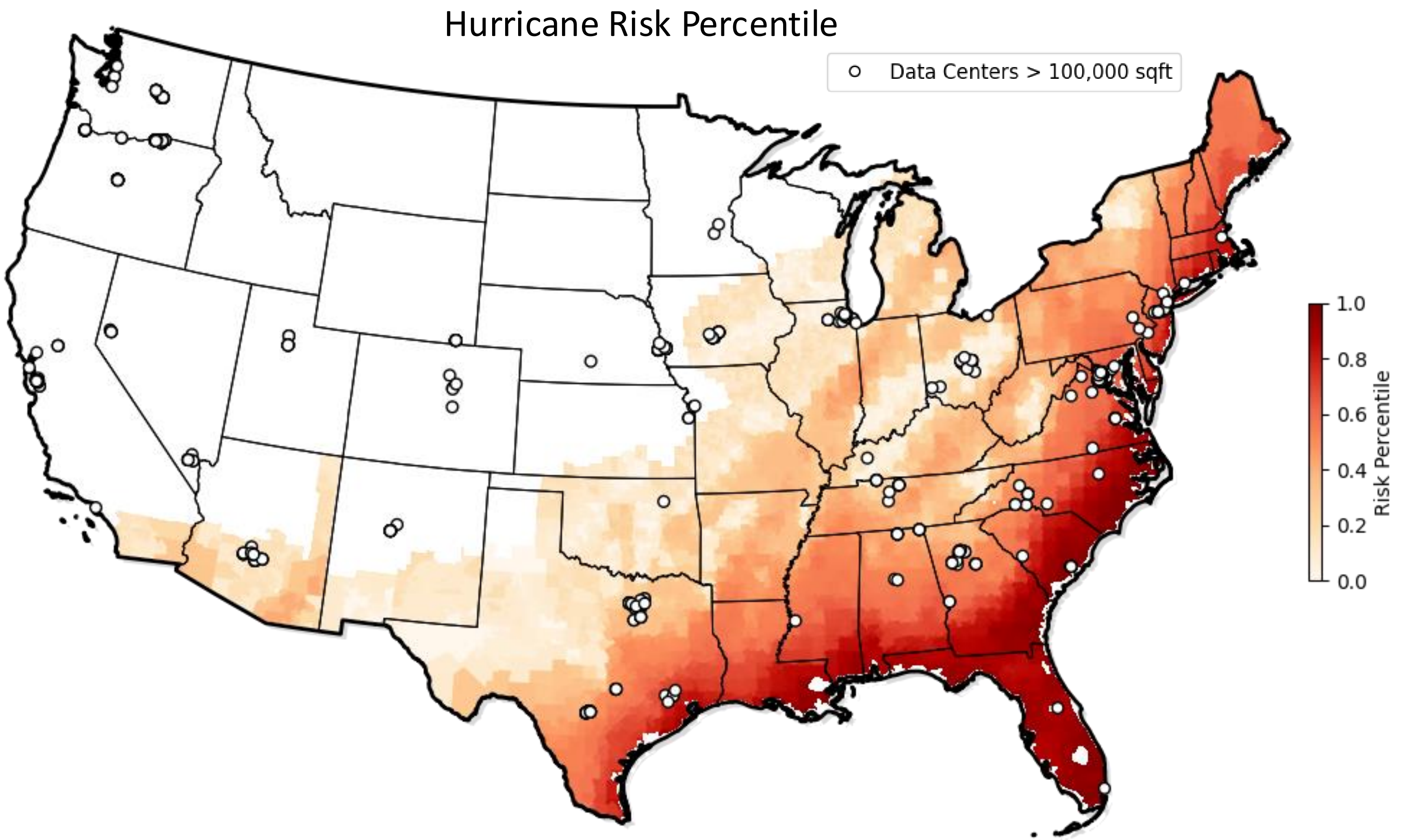


Data Sources: US Census Bureau 2023 American Community Survey, OpenStreetMap

There is limited evidence that high natural hazard risk dissuades developers from a particular region

LOW NATURAL HAZARD RISK

While data center developers mention this as a key consideration, they often site in areas with high natural hazard risk (e.g., earthquake, tornado, hurricane, flood).

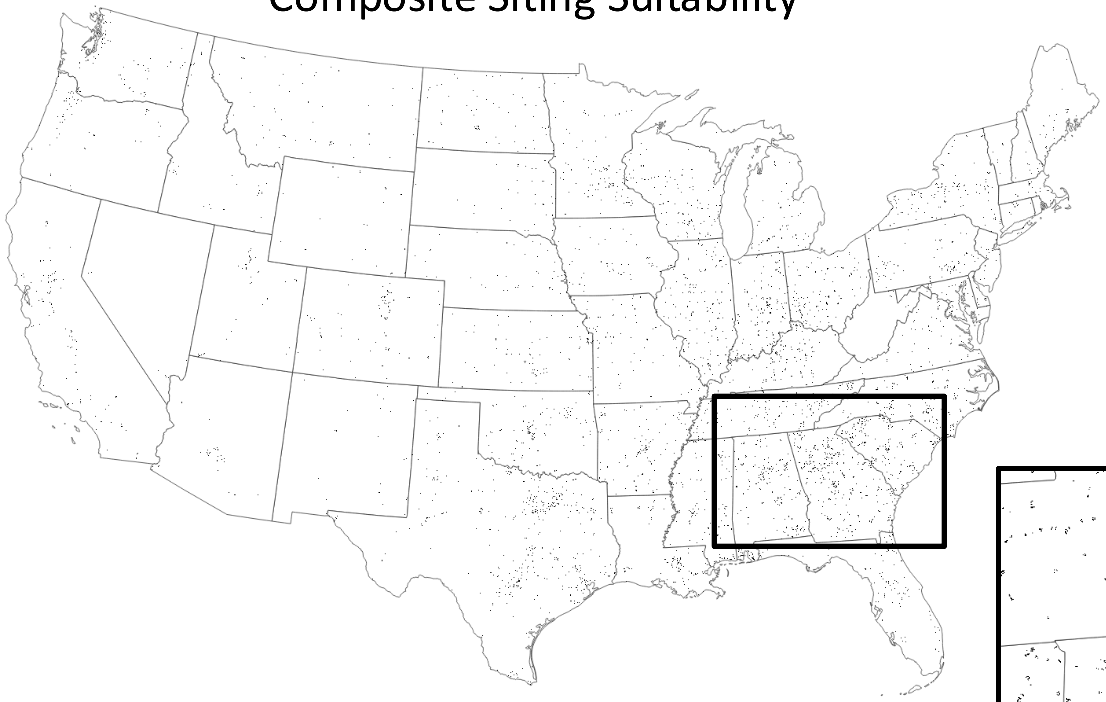


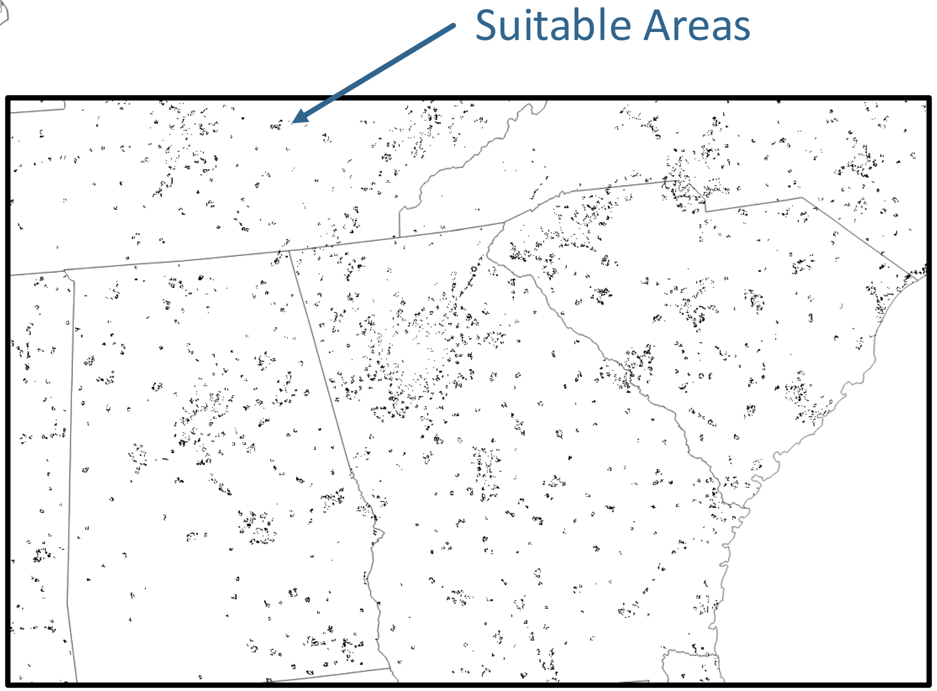
Data Sources: FEMA National Risk Hazard Map, OpenStreetMap

A new version of IM3's generation siting model will be used to determine which of the available locations is optimal

Example Composite Excluded Areas
Waterbodies
Developed land
Airport areas
Military zones and training areas
Areas with high slope
Local parks/leisure areas
Areas far from substations
Areas far from public water supplier
Areas without high-speed fiber
Protected areas

Composite Siting Suitability

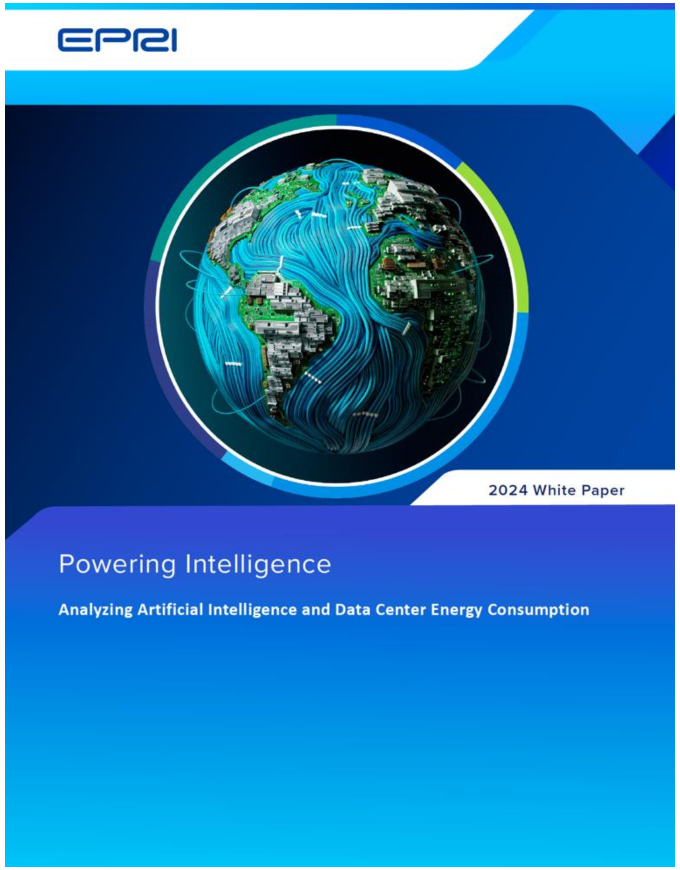




Siting locations based on factors such as:

- Property tax rate
- Sales tax rate
- Electricity prices
- Proximity to substations
- Amount of fiber needed to connect to network

Projections of data center growth were sourced from the peer-reviewed and gray literature

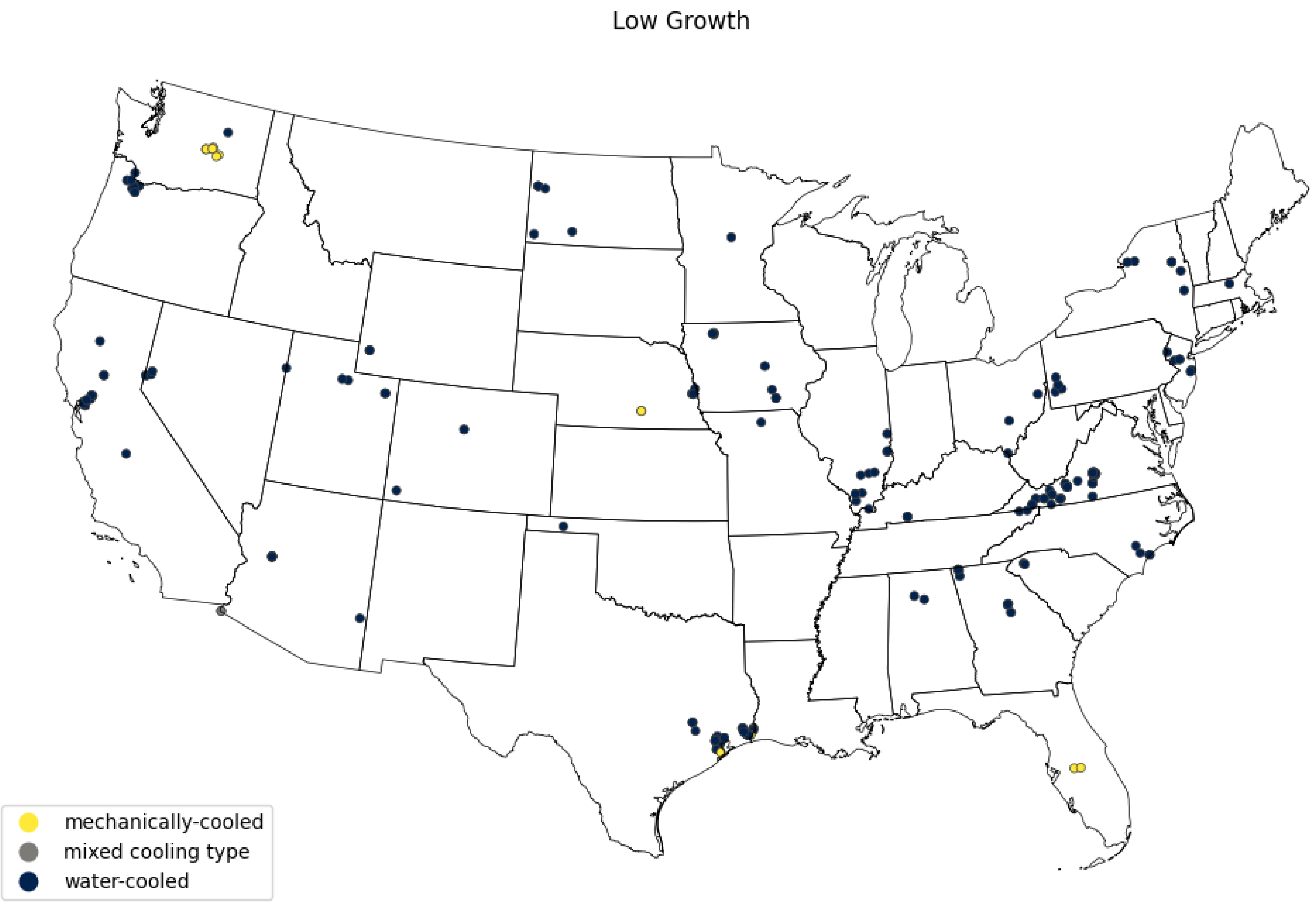


FORECASTED SCENARIOS: PROJECTIONS OF DATA CENTER ELECTRICITY CONSUMPTION IN TOP 15 STATES (2023—2030)

	2023 Load		Low-growth scenario (3.71%)		Moderate-growth scenario (5%)		High-growth scenario (10%)		Higher-growth scenario (15%)	
STATE	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)	MWh/y	% of Total State Electricity Consumed (%EC)
Virginia	33,851,122	25.59%	43,683,508	29.28%	47,631,928	31.10%	65,966,260	38.47%	89,880,357	46.00%
Texas	21,813,159	4.59%	28,149,002	5.47%	30,693,306	5.94%	42,507,676	8.04%	57,917,564	10.64%
California	9,331,619	3.70%	12,042,078	4.43%	13,130,525	4.81%	18,184,686	6.54%	24,777,000	8.70%
Illinois	7,450,176	5.48%	9,614,151	6.53%	10,483,145	7.08%	14,518,285	9.54%	19,781,455	12.56%
Oregon	6,413,663	11.39%	8,276,574	13.39%	9,024,668	14.43%	12,498,415	18.93%	17,029,342	24.14%
Arizona	6,253,268	7.43%	8,069,590	8.81%	8,798,975	9.53%	12,185,850	12.73%	16,603,465	16.58%
Iowa	6,193,320	11.43%	7,992,230	13.44%	8,714,623	14.48%	12,069,029	18.99%	16,444,294	24.21%
Georgia	6,175,391	4.26%	7,969,093	5.08%	8,689,396	5.51%	12,034,090	7.48%	16,396,690	9.92%
Washington	5,171,612	5.69%	6,673,757	6.77%	7,276,977	7.34%	10,078,009	9.88%	13,731,490	13.00%
Pennsylvania	4,590,240	3.16%	5,923,520	3.78%	6,458,929	4.11%	8,945,079	5.61%	12,187,850	7.49%
New York	4,067,385	2.84%	5,248,796	3.40%	5,723,219	3.69%	7,926,182	5.05%	10,799,583	6.75%
New Jersey	4,038,360	5.42%	5,211,341	6.46%	5,682,378	7.00%	7,869,621	9.44%	10,722,517	12.44%
Nebraska	3,959,520	11.70%	5,109,601	13.75%	5,571,442	14.81%	7,715,984	19.41%	10,513,184	24.71%
North Dakota	3,915,720	15.42%	5,053,079	18.00%	5,509,811	19.31%	7,630,631	24.89%	10,396,888	31.11%
Nevada	3,416,707	8.69%	4,409,122	10.28%	4,807,649	11.10%	6,658,195	14.75%	9,071,924	19.07%

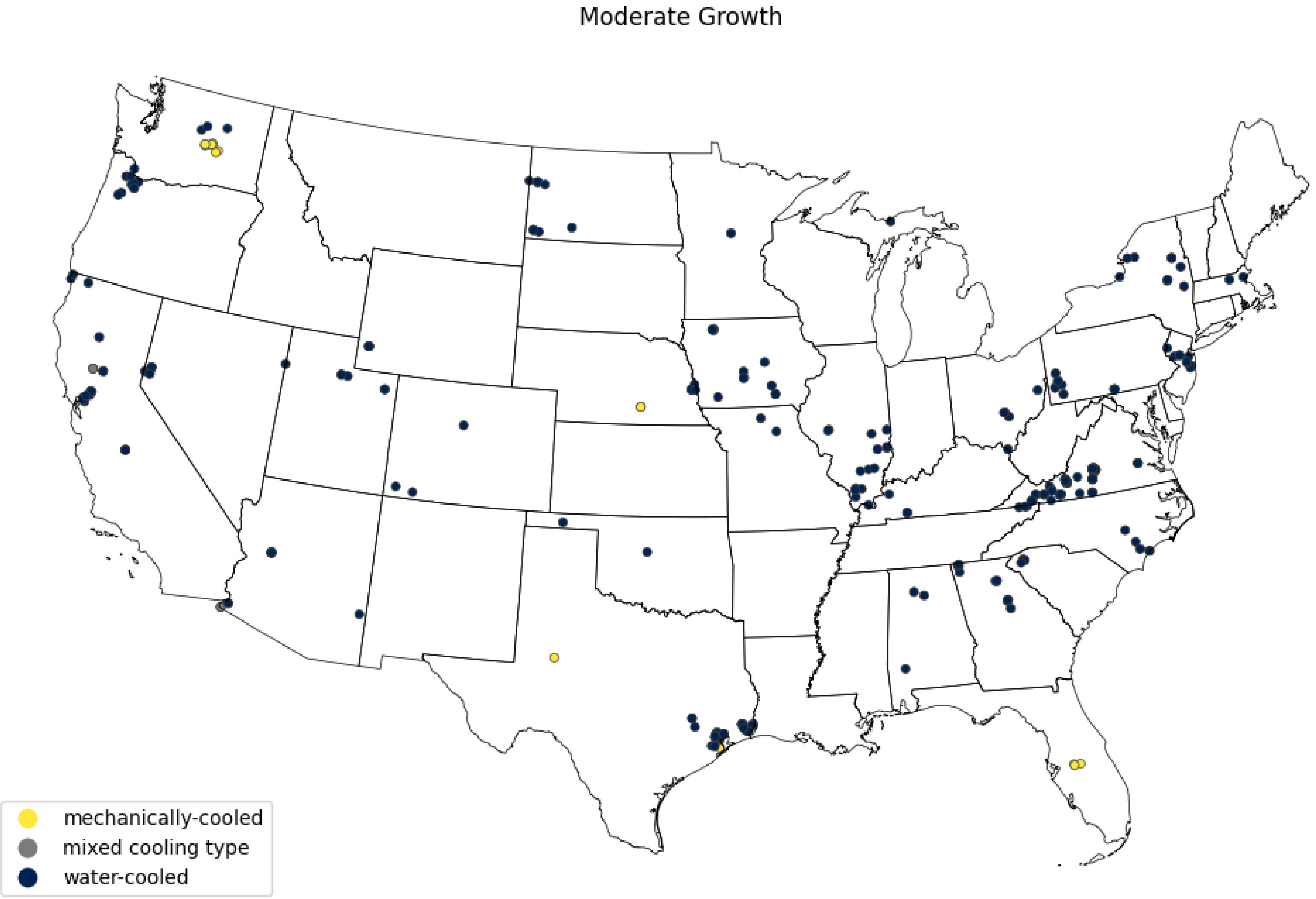
IM3

Low growth scenario sitings through 2035



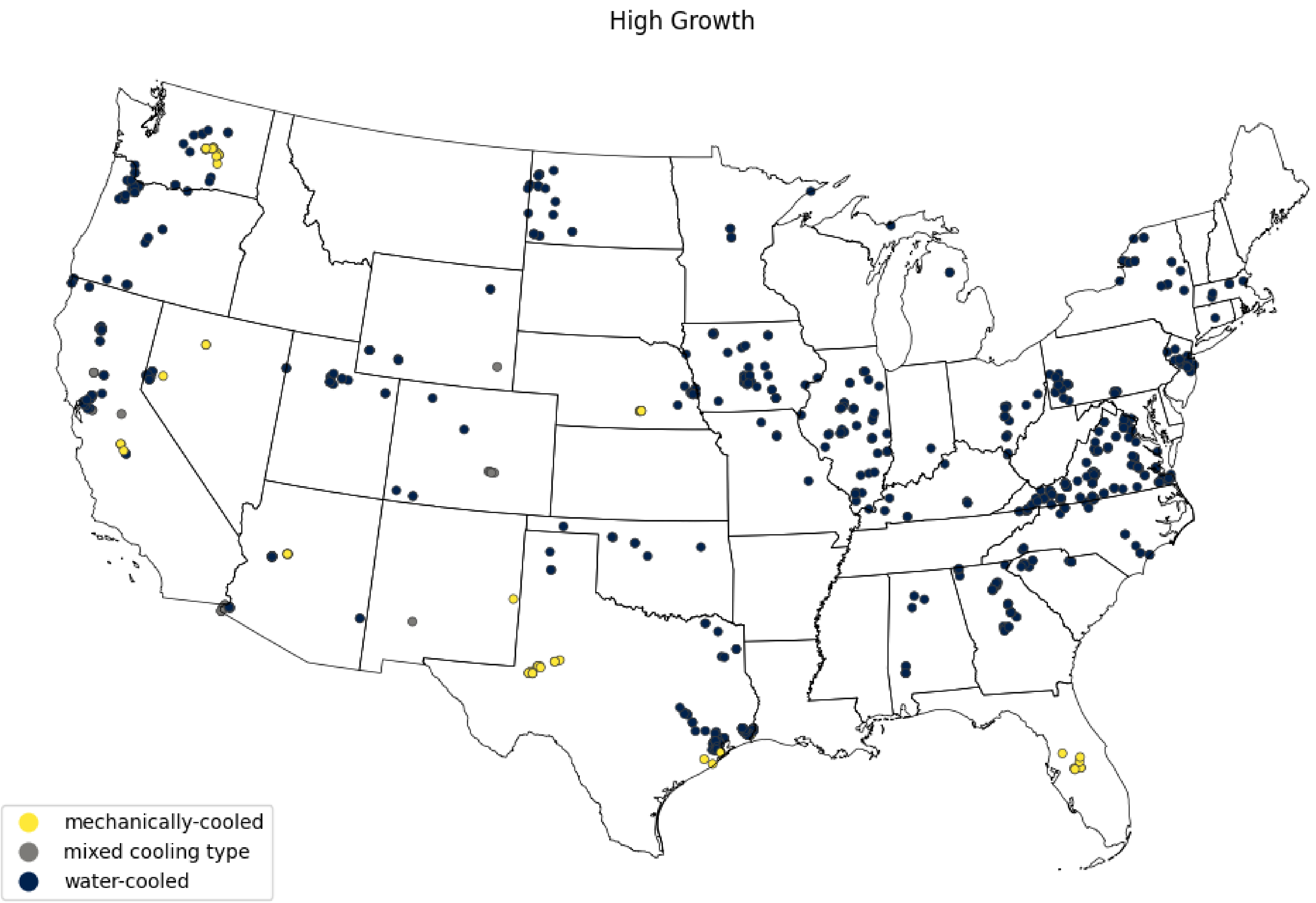
Preliminary results. Do not cite.

Moderate growth scenario sitings through 2035



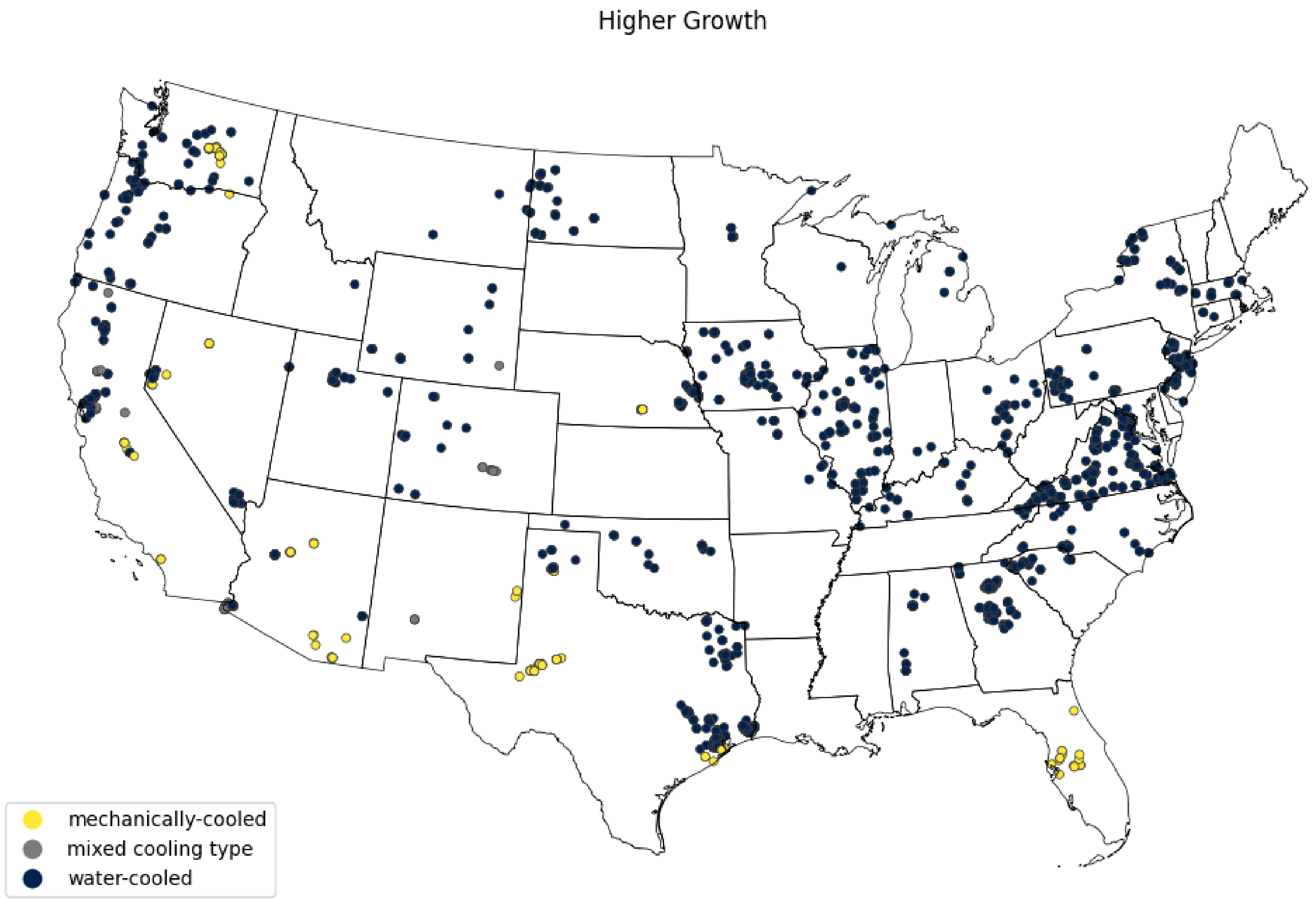
Preliminary results. Do not cite.

High growth scenario sitings through 2035



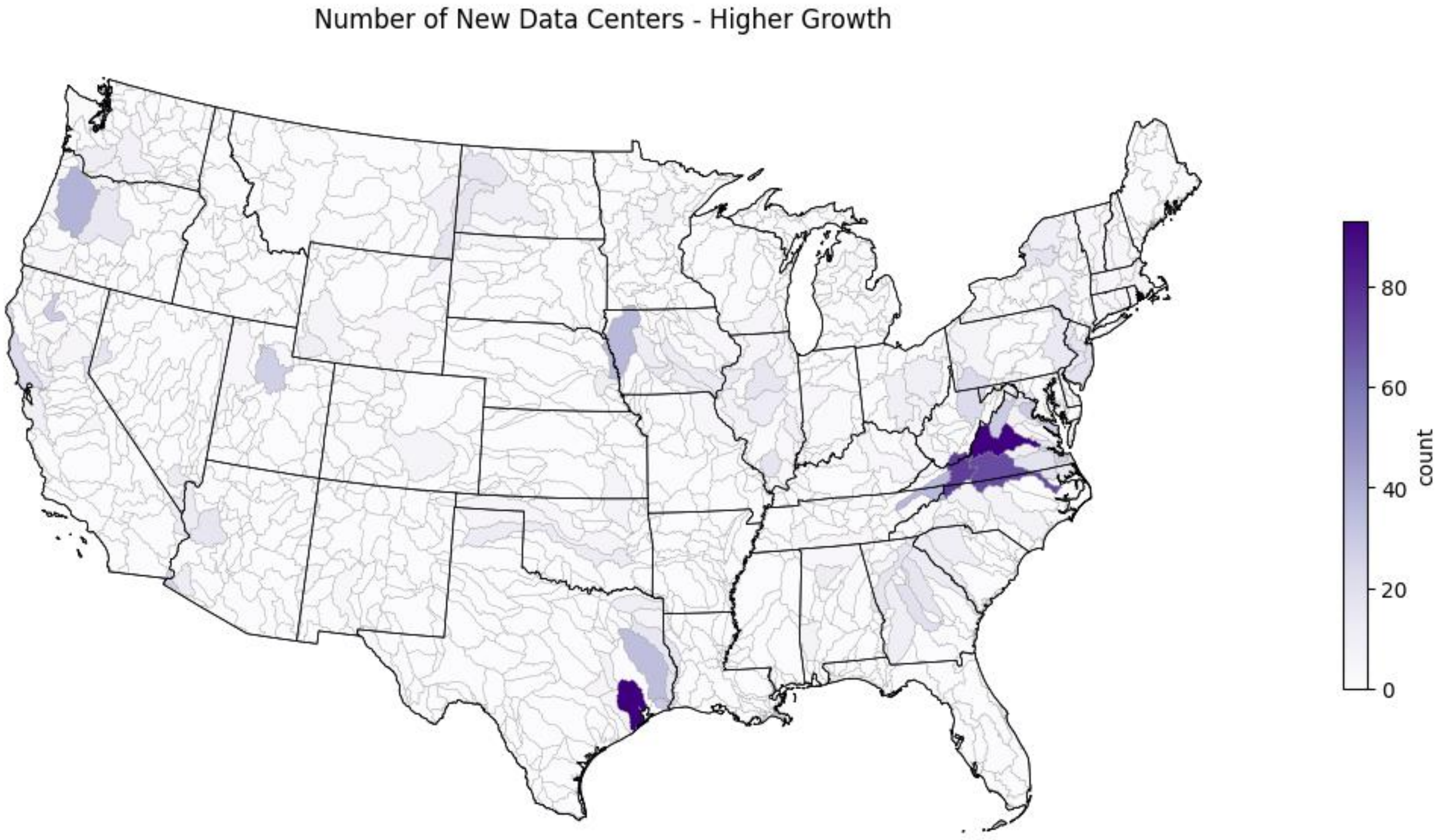
Preliminary results. Do not cite.

Higher growth scenario sitings through 2035



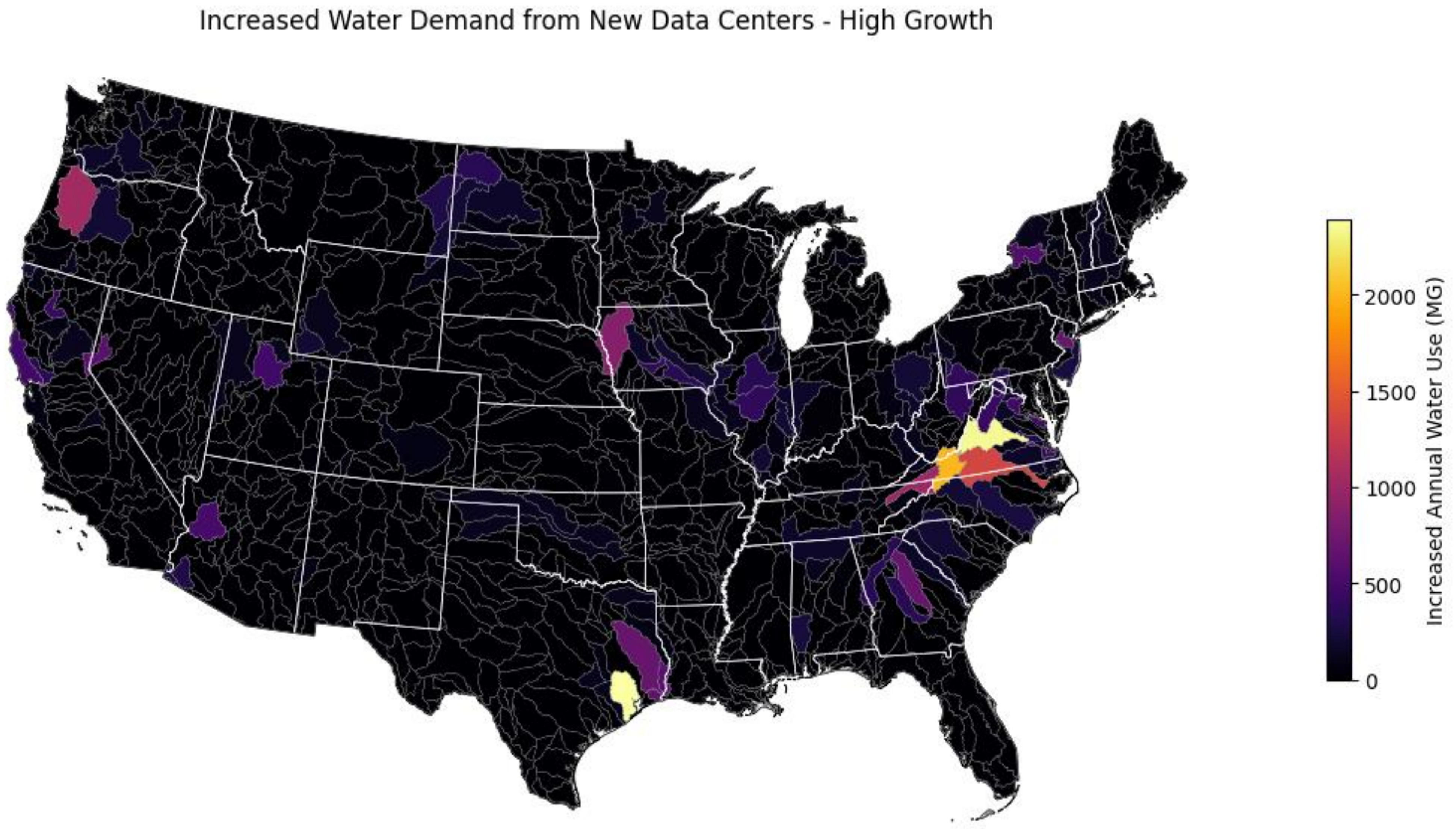
Preliminary results. Do not cite.

A small number of basins may see many new water-cooled data centers



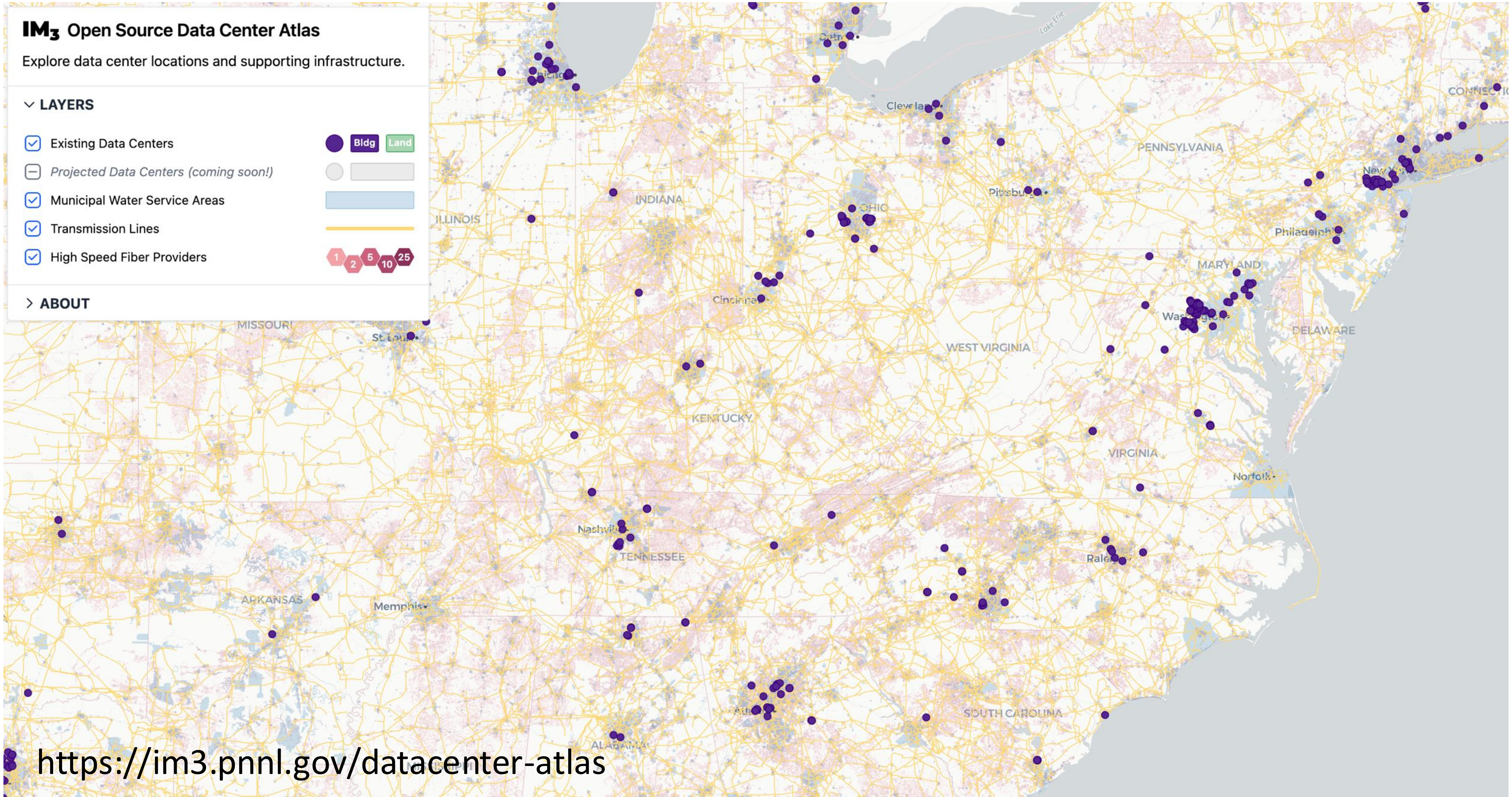
Preliminary results. Do not cite.

Basins in Texas, Virginia, Oregon, and Iowa may see large basin-level water use increases due to data centers



Preliminary results. Do not cite.

We are making the raw data publicly available



https://im3.pnnl.gov/datacenter-atlas

Soapbox thoughts

- We can move fast. Seed was planted on 23-Jan and SOWs for this effort were approved on 5-Mar.
- We were able to do this because IM3's tools were designed to be flexible and extensible:
  - TELL model for data center loads
  - GO model for demand flexibility
  - CERF model for data center siting
- Listen, think, adapt.

Conclusions

- Data centers significantly accelerate load growth in all three interconnections.
- Compared to our base scenario with no data centers, annual average electricity prices in 2035 increase 43%, 47%, 91%, and 202% under the EPRI low, moderate, high, and higher data center load growth scenarios, respectively.
- Postponing 100% of nuclear and 50% of natural gas planned retirements (≈22.6 GW) eliminates all price increases in 2035 due to data centers for the EPRI low, moderate, and high growth scenarios.
- Treating data center loads as flexible demands led to only marginal reductions in grid stress.
- Data center locations are sensitive to electricity prices, access to water, access to multiple fiber provides, and proximity to substations.

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