Data Centers: Future Challenges

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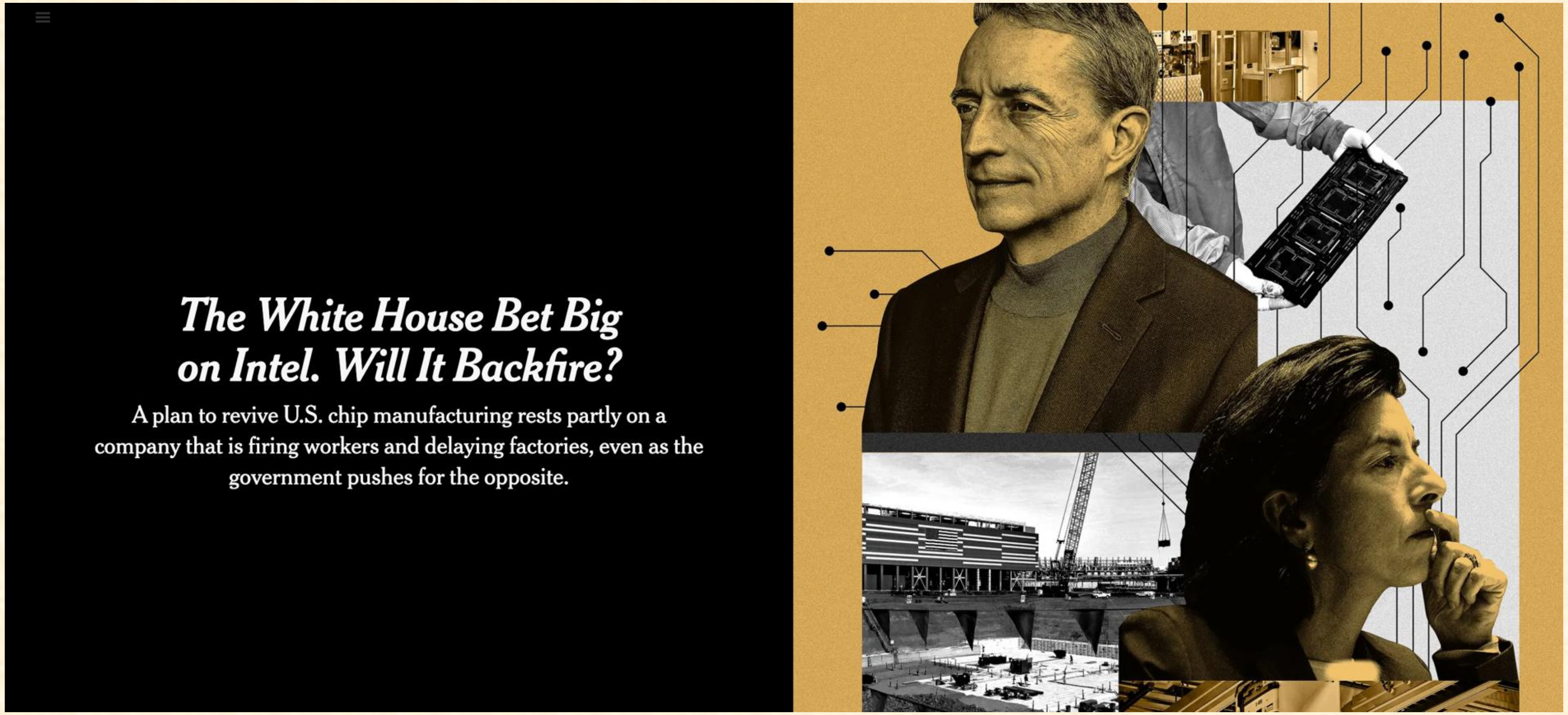
Approx 400 New Factories Announced Since CHIPS and IRA Passed - These Are Largest Electricity Demand

State	
AL	Nucor steel
AZ	$1.2 billion start up battery mfg; **TSMC** (Taiwan) chip plant largest outside Taiwan expected near Phoenix
CA	Lithium extraction; EV auto battery plant
CT	Farmington $40 mil sheet metal
DE	Castle/Wilmington PA & NJ microfilm surfacing
GA	Greater Atlanta & other parts EV related, EcoPlastic, Pratt & Whitney
KS	Panasonic- no details
IL	TBA for chocolate factory, Tilamook ice cream – factories surpassed by data center load expected
IN	$3 billion by Samsung SDI-GM battery mfg.; GM $491 Marion metal center for EVs w/ArcelorMittal steel scrap expansion
MA	Bristol Meyers Squib $40 mil personalized cancer treatment- generated AI expected to support
KY	Unnamed steel & EV factories
MI	Toyota $50 mil battery lab; $1 bil paper plant; unnamed pharmaceutical plant (state has always had some power shortages along Canadian border with imported power from Canada)
	$35 million investment in existing plant w/new filtration equipment upgrades for biotech companies; Hitachi $1.5 billion for new distribution transformers
MN	Medical lab with heavy data demand
MS	Siemens EV charging distribution center (essential for Dallas plant)
NM	Intel packaging $3.5 billion investment in NM
NE	Plattsmouth NE (near Omaha)
NY	CHIPS Act funding up to 9 semiconductor plants in upstate NY (Micron & AMD); Syracuse & Saratoga

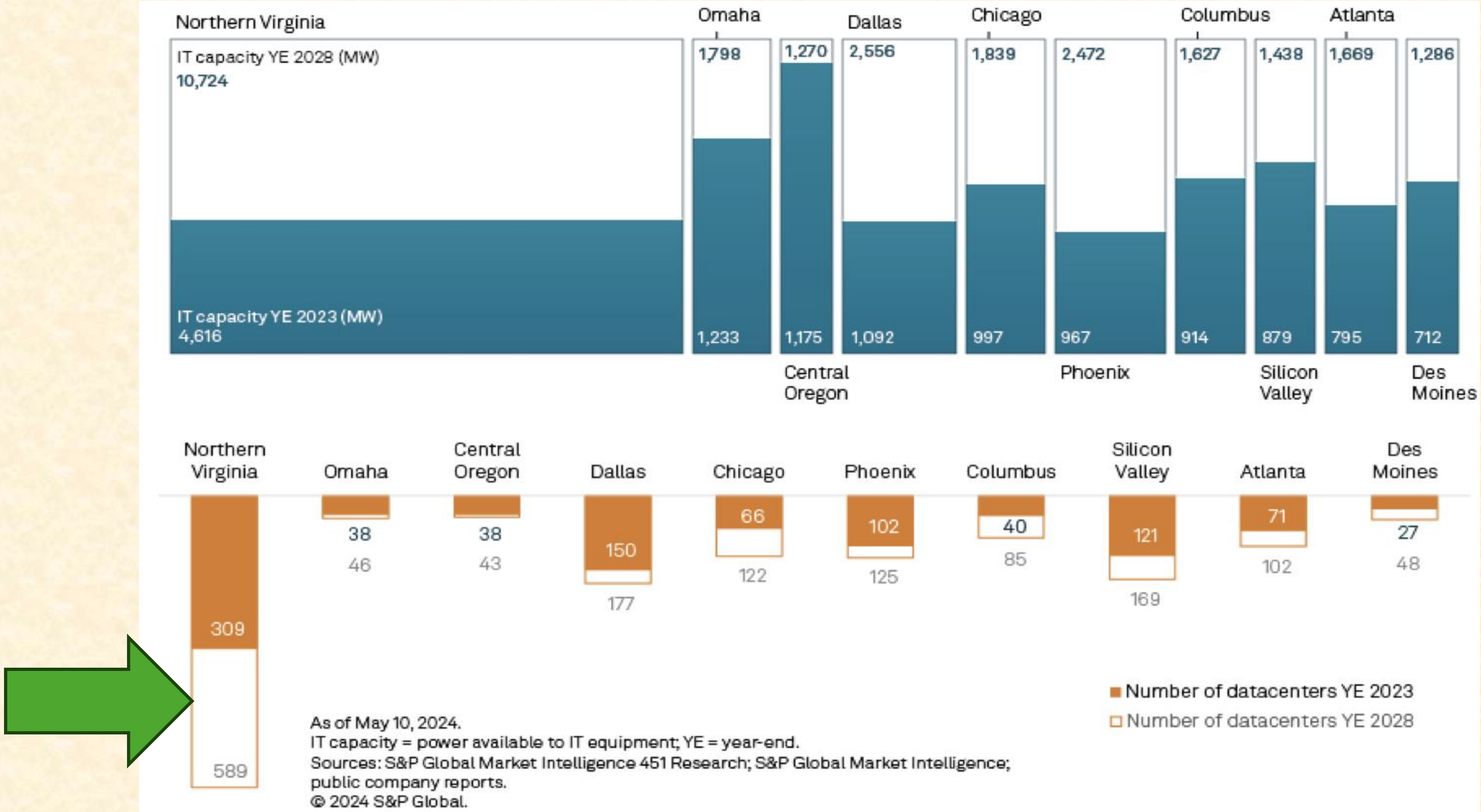
State	
NC	$450 million unnamed; $180 million for lithium plant; Henkel adhesives, Nucor steel & Eli Lilly
NV	TBD primary gigafactory and two secondary plants in Sparks NV
OH	Abbott $536 million, 2 Intel fab plants w/optional 6 more fab plants; Ultium lithium product; Nth Cycle; Abbott mfg.
OR	GM specialty & PHARMA chemicals
PA	EcoLabs, G&S Foods
RI	Polaris and defense mfg. consortium
SC	1,000 jobs; $130 million, **$3.5 billion auto mfg.**; $60 million **BorgWarner, VW** $1.5 billion; NEPHRON pharm & $4 billion more sm. factories; Schneider Electric distribution transformers
TN	GKN Aerospace; GM battery plant with either Samsung or LG
TX	$17 billion **AMD/Global Foundries** semiconductor plant, $150 mil Siemens; 4 phase semiconductor fab expansion DFW;TX Instruments Fab plant for Apple Computer; GKN Aerospace titanium jobs to FW
UT	Possible semiconductor plant
VA	LEGO
VT	GM GlobalFoundries essential for NY new plant- VT is state with Canadian imported power
WV	$150 million facility; $760 million in **iron-air battery**; **Omnis Bldg Technologies** $40 million in Bluefield
WA	Nestle- few details
WI	

Complexities of Counting on US Semiconductor Industry and Relationship to Economics of Data Centers Under CHIPs Act



https://www.nytimes.com/2024/10/24/us/politics/intel-chips-biden.html?unlocked_article_code=1.Uk4.UmsE.Vk_xHVTftGru&smid=em-share

Estimated Operational and Planned U.S. Data Center Space and Power Consumption

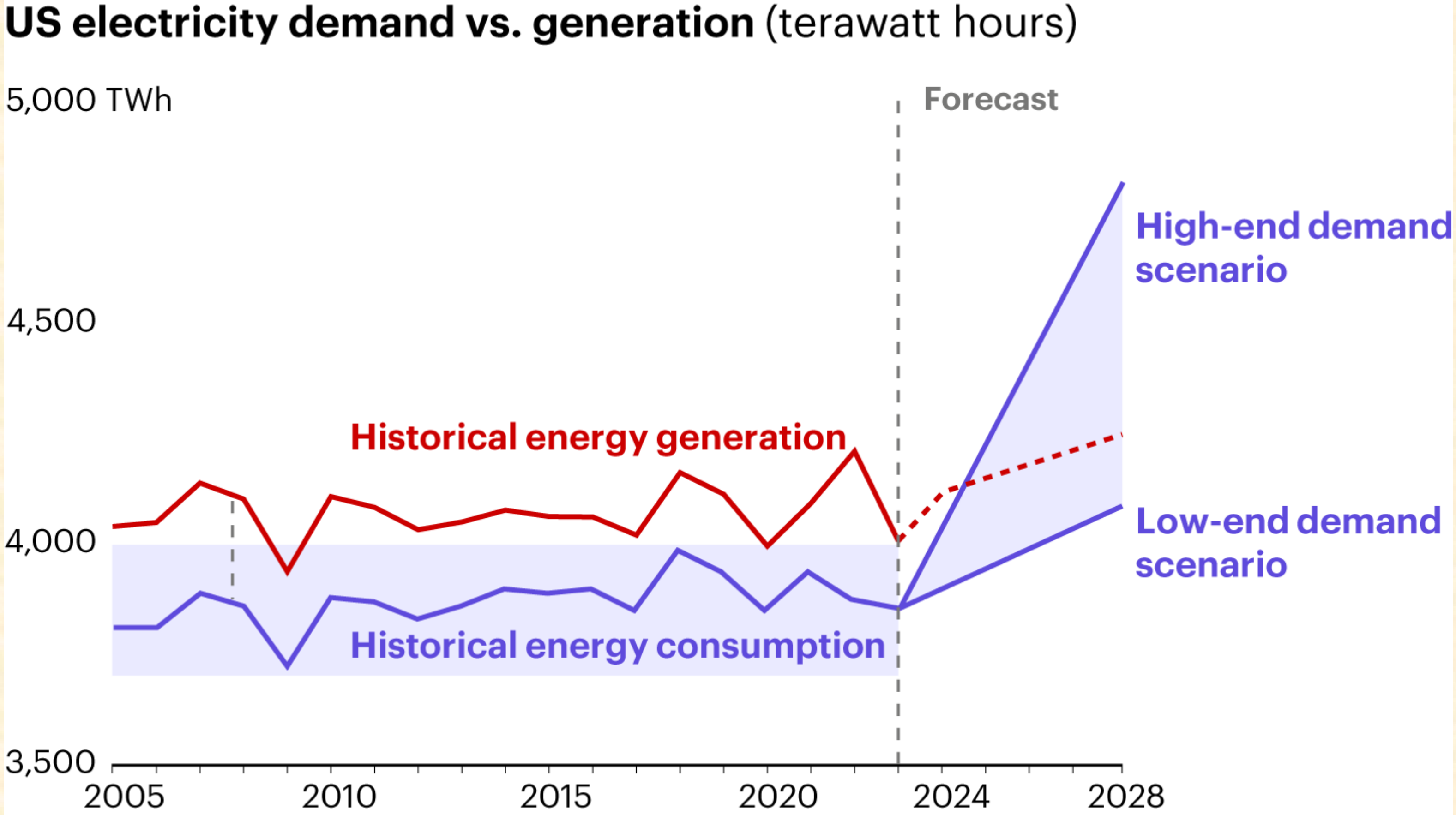


Power Consumption

Number of Data Centers

Data Visualization by Chrisallen Villanueva

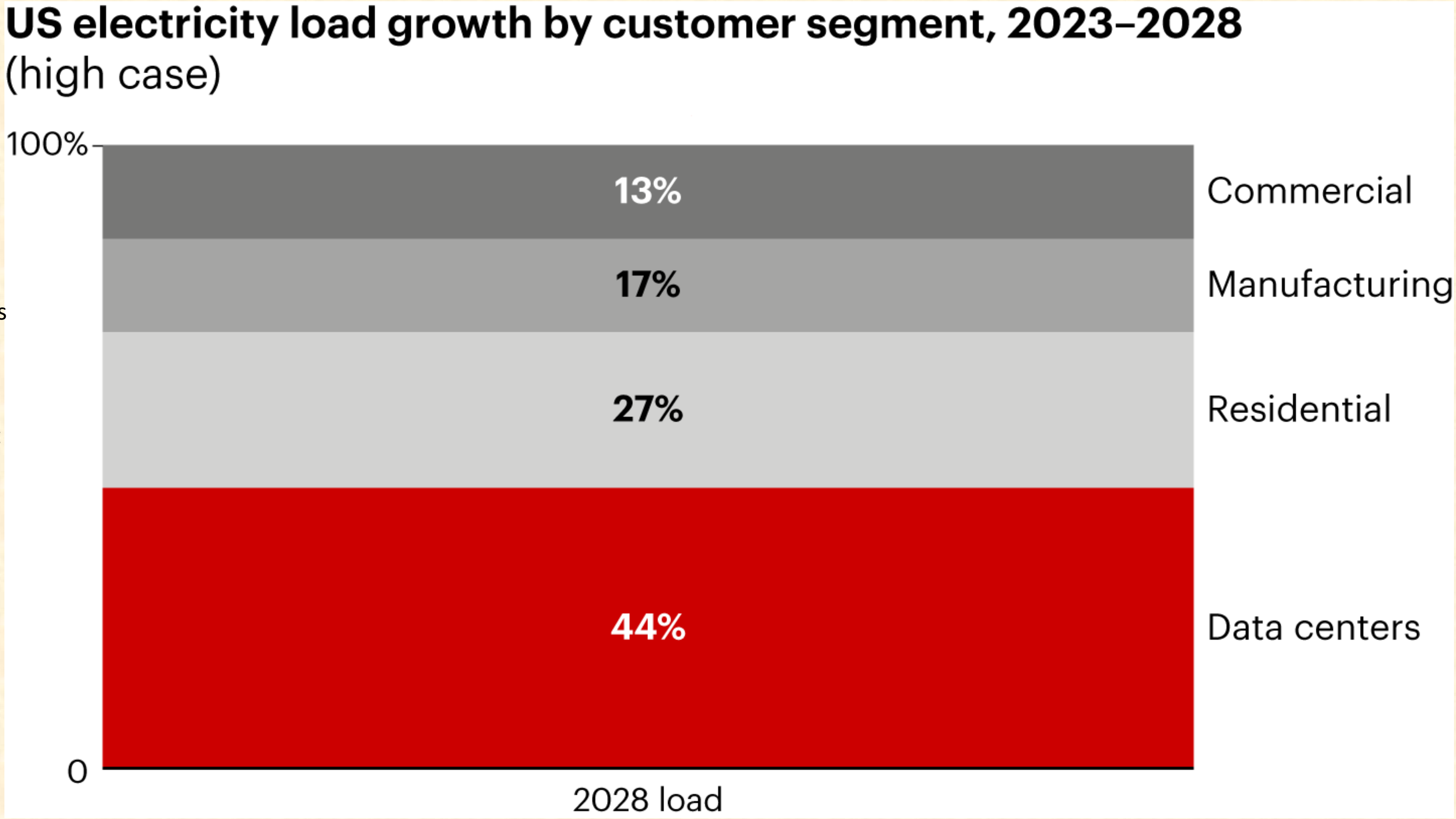
U.S. Electricity Demand Could Exceed Supply Within The Next Few Years



All told, meeting global data center demand could cost more than $2 trillion in new energy generation resources, according to Bain estimates.

Notes: Demand forecast is an aggregate of multiple industry forecasts; historical numbers and generation forecast based on EIA data; historical gap between energy generation and consumption necessary to ensure sufficient load that accounts for some energy loss in transmission
Sources: EIA 2023–2025 Short-Term Energy Outlook (May 2024); EIA 2025–2028 Energy Outlook (March 2023); ISO reports (H2 2023 – H1 2024); FERC; Grid Strategies; Goldman Sachs and Bank of America analyst forecasts (April 2024); Bain analysis

Data Centers Will Account For The Largest Share Of New Electricity Demand Growth In The U.S. Over The Next Few Years



Notes: Values are rounded; commercial excludes data centers; residential includes electric vehicles

Sources: Bank of America and Goldman Sachs analyst forecasts (April 2024); EIA Short-Term Energy Outlook (May 2024); EIA 2023 Outlook; IDC Datacenter Deployment and Spend Forecast (H2 2023); Bain analysis

Getting Creative On Pricing And Financing To Protect The Balance Sheet And Existing Customers

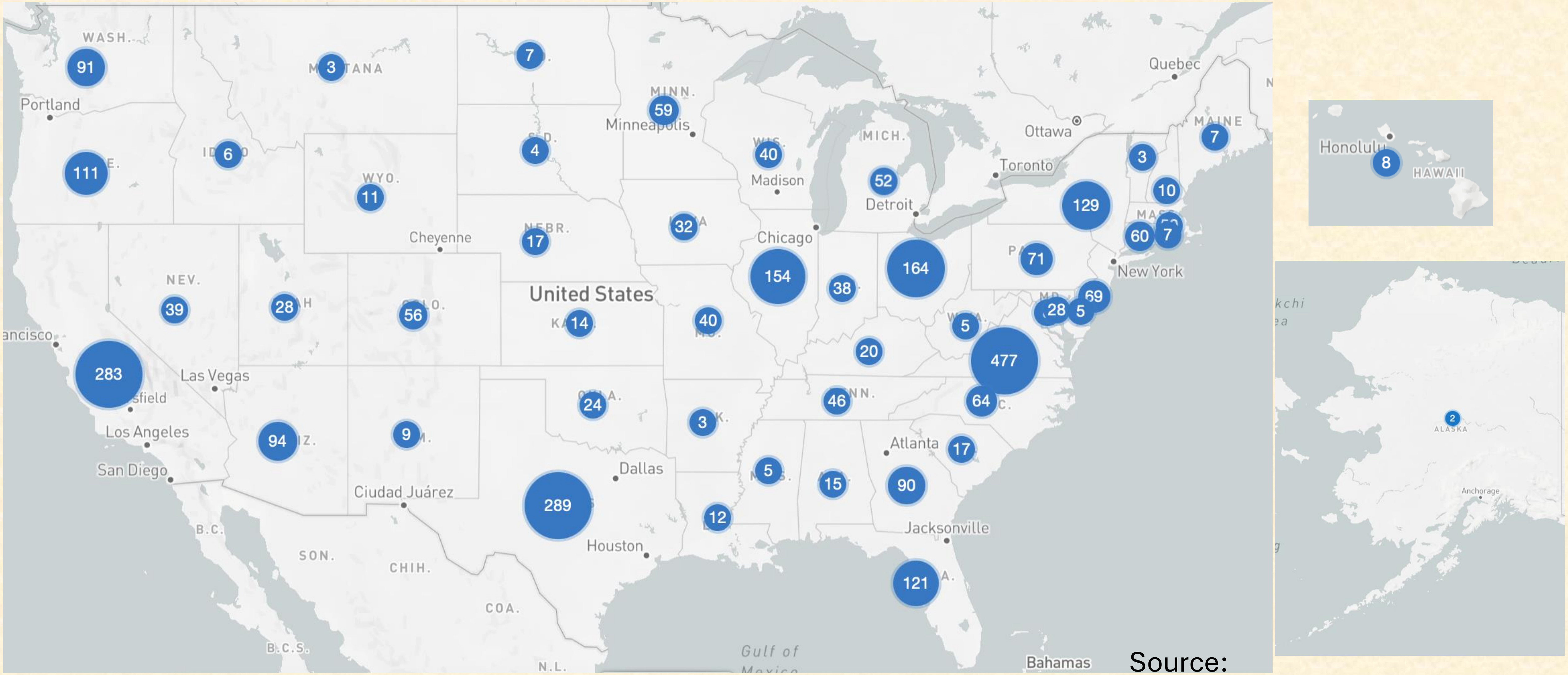
Traditional rate structures, which spread costs evenly across customer groups, are inadequate for the vast energy demands of data centers.

Some utilities are developing new rate designs that ensure data centers bear the full incremental costs of their energy usage, including long-term contracts with minimum charges.

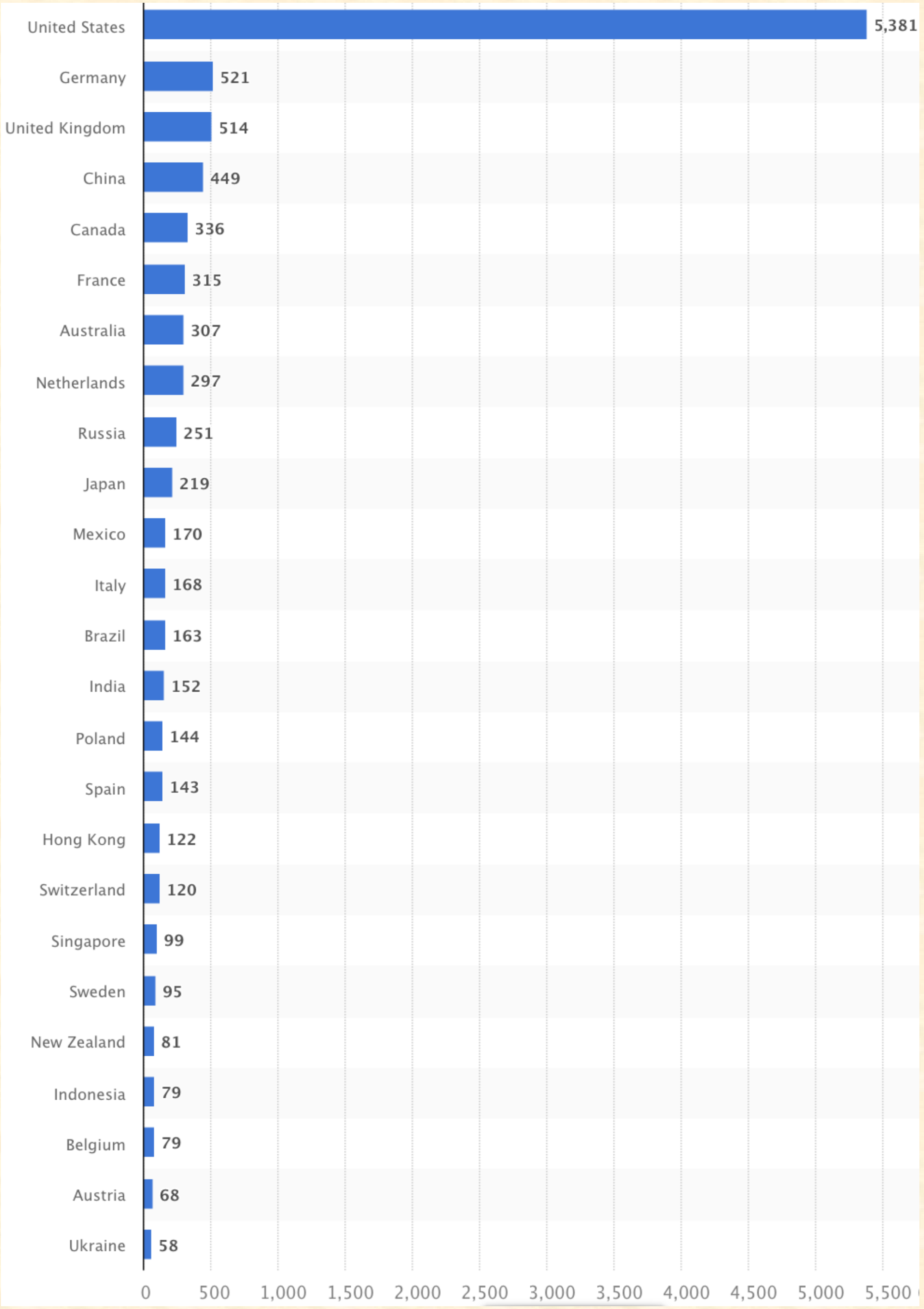
These deals help protect other customer groups’ rates and ensure that the utility can recoup its investment in case data center energy consumption fluctuates.

Source: Bain & Company

US Data Center Map



Source:
https://www.datacentermap.com/usa/



Leading Countries By Number Of Data Centers As Of March 2024

We assume all new data centers might be built here- there are some foreign locations of retired coal fired power plants, steel mills, chemical plants and simply wide open spaces with enormous electric transmission that provide great opportunities for AI growth.

As of March 2024, there were a reported 5,381 data centers in the United States, the most of any country worldwide.

Source: Statista https://www.statista.com/statistics/1228433/data-centers-worldwide-by-country/#statisticContainer

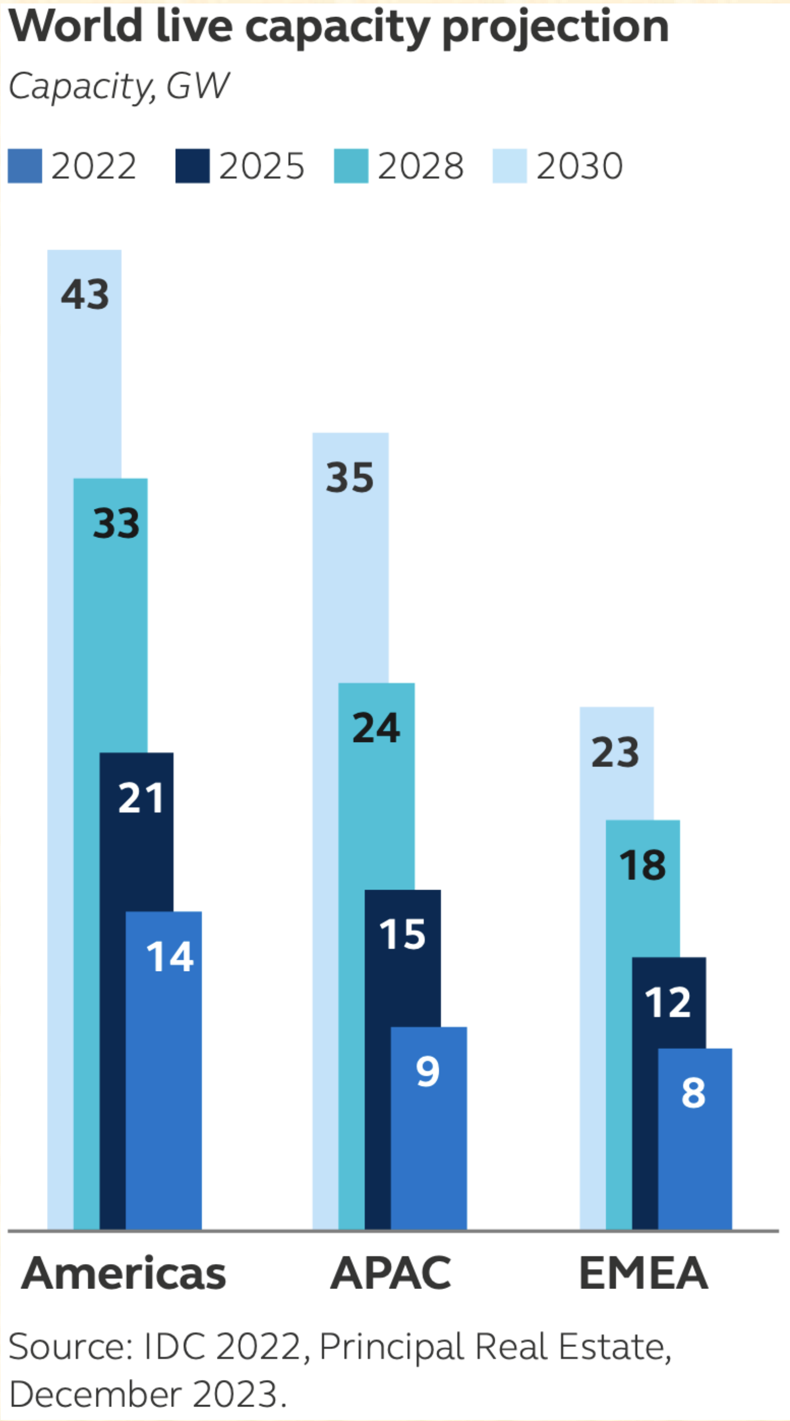
Pugh is Not as Smart as Bain But Wonders

- Available nuclear and hydropower generation in countries like Germany, UK, Canada, Sweden and abundance of water for data center growth
- Limited nuclear energy options in Europe now- will data centers and semiconductor plan opportunities force Germany to revisit nuclear power?
- Countries like Germany may desire data center tax revenue with drop in manufacturing- but how to still meet decarbonization goals?
- Watch for India and SE Asia if they can use Indian coal or get LNG imports & nat gas pipelines fast enough

Predicting Why AI Drives Higher Electricity Demand & Water Use for Cooling Than Typical Data Centers

AI are far more power-hungry than traditional CPUs, often consuming over 1000W per chip. AI racks can require 50-100kW, compared to 5-10kW for typical enterprise workloads. This means data centers must provide significantly more power and cooling capacity per square foot to keep up with AI demands.

Source: Principal Asset Management



Scary Fun Facts About Water Use and Data Centers

“Roughly two-week training for the GPT-3 AI program in Microsoft’s state-of-the-art U.S. data centers consumed about 700,000 liters of freshwater, about the same amount of water used in the **manufacture of about 370 BMW cars or 320 Tesla electric vehicles**.”

“Training GPT3 in Microsoft’s state of the art U.S. data centers can consume a total of 5.4 liters of water for on-site water consumption or 500 ml bottle of water for roughly 10-50 responses”.

AI-Generated Data Center Image

Source:
[“Making AI Less “Thirsty”: Uncovering and Addressing the Secret Water Footprint of AI Models”]

If 40% of Data Center Electricity Consumption is Based Upon Zombie Space and Cooling Towers…

Watch for these two promising energy efficiency improvements:

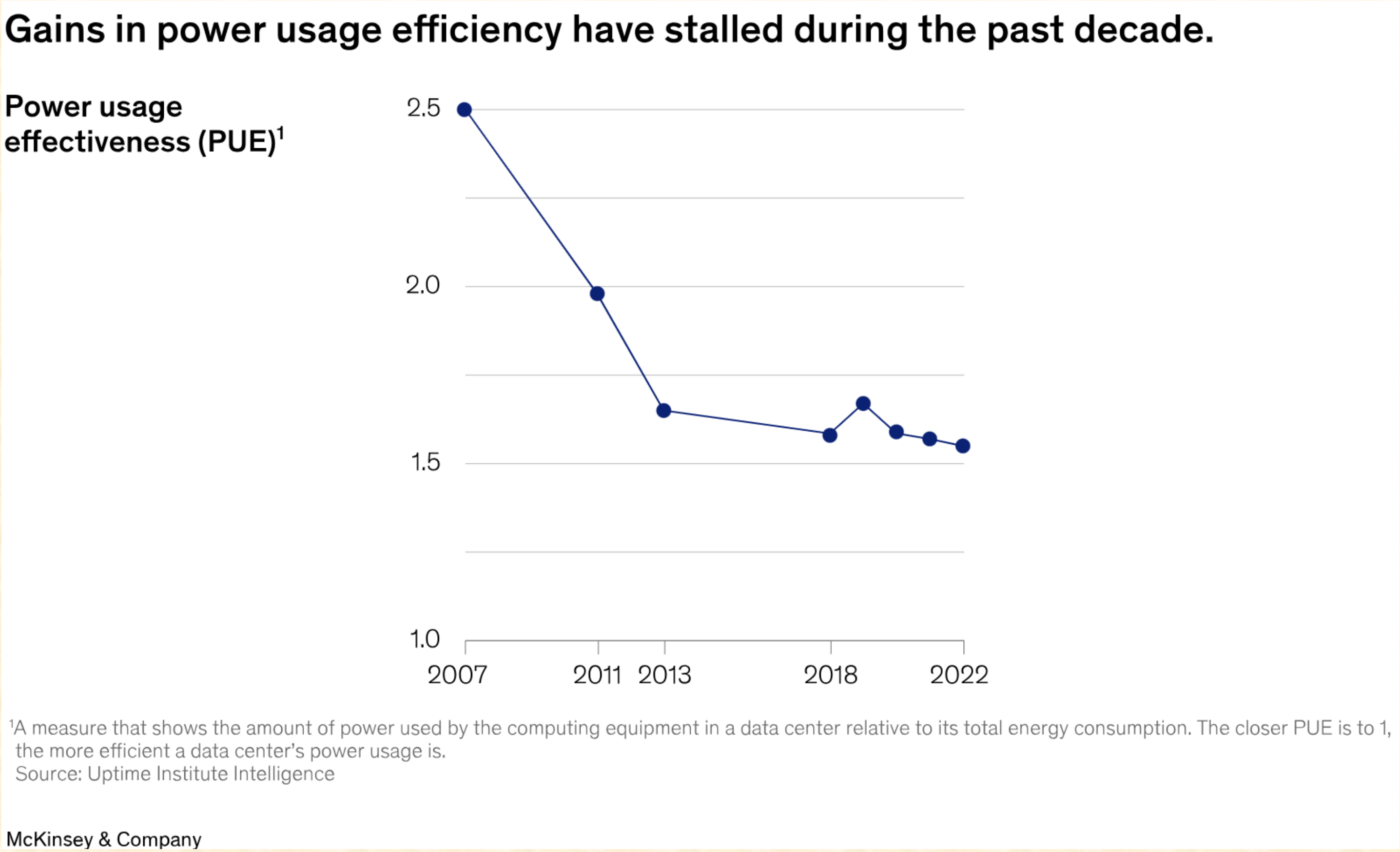
- Siemens' new White Space Cooling Optimization (elimination of Zombie or Ghost space)
- 3M's non-water chilling 'chemicals' products that look like water and can cool the racks faster

Estimate of Microsoft's Water Consumption Footprint as of July 2023

Location	PUE	WUE (L/kWh)	Electricity Water Intensity (L/kWh)	Water for Training (million L)			Water for Each Inference (mL)			# of Inferences for 500ml Water
				On-site Water	Off-site Water	Total Water	On-site Water	Off-site Water	Total Water	
U.S. Average	1.170	0.550	3.142	0.708	4.731	**5.439**	2.200	14.704	**16.904**	**29.6**
Wyoming	1.125	0.230	2.574	0.296	3.727	**4.023**	0.920	11.583	**12.503**	**40.0**
Iowa	1.160	0.190	3.104	0.245	4.634	**4.879**	0.760	14.403	**15.163**	**33.0**
Arizona	1.223	2.240	4.959	2.883	7.805	**10.688**	8.960	24.259	**33.219**	**15.1**
Washington	1.156	1.090	9.501	1.403	14.136	**15.539**	4.360	43.934	**48.294**	**10.4**
Virginia	1.144	0.170	2.385	0.219	3.511	**3.730**	0.680	10.913	**11.593**	**43.1**
Texas	1.307	1.820	1.287	2.342	2.165	**4.507**	7.280	6.729	**14.009**	**35.7**
Singapore	1.358	2.060	1.199	2.651	2.096	**4.747**	8.240	6.513	**14.753**	**33.9**
Ireland	1.197	0.030	1.476	0.039	2.274	**2.313**	0.120	7.069	**7.189**	**69.6**
Netherlands	1.158	0.080	3.445	0.103	5.134	**5.237**	0.320	15.956	**16.276**	**30.7**
Sweden	1.172	0.160	6.019	0.206	9.079	**9.284**	0.640	28.216	**28.856**	**17.3**
Mexico*	1.120	0.056	5.300	0.072	7.639	**7.711**	0.224	23.742	**23.966**	**20.9**
Georgia*	1.120	0.060	2.309	0.077	3.328	**3.406**	0.240	10.345	**10.585**	**47.2**
Taiwan*	1.200	1.000	2.177	1.287	3.362	**4.649**	4.000	10.448	**14.448**	**34.6**
Australia*	1.120	0.012	4.259	0.015	6.138	**6.154**	0.048	19.078	**19.126**	**26.1**
India*	1.430	0.000	3.445	0.000	6.340	**6.340**	0.000	19.704	**19.704**	**25.4**
Indonesia*	1.320	1.900	2.271	2.445	3.858	**6.304**	7.600	11.992	**19.592**	**25.5**
Denmark*	1.160	0.010	3.180	0.013	4.747	**4.760**	0.040	14.754	**14.794**	**33.8**
Finland*	1.120	0.010	4.542	0.013	6.548	**6.561**	0.040	20.350	**20.390**	**24.5**

Source:
"Making AI Less "Thirsty": Uncovering and Addressing the Secret Water Footprint of AI Models"

Isn't Efficiency Guaranteed To Improve Over Time?



"Efficient cooling is therefore a crucial driver of a data center's profitability. Cooling accounts for some 40 percent of a data center's energy consumption. The cost of downtime from overheating can be high.

Cooling technology has improved rapidly over the past decade. Most large data centers have replaced old air-conditioning-like systems that keep entire rooms cool with in-row or rotodynamic heater-based cooling designs: heat emitted from servers is drawn away by fans and then cooled with water or a refrigerant. Yet even better performance is required because today's more advanced systems can struggle to control the temperatures associated with global warming. Google and Oracle, for instance, both faced downtime during a heatwave in Europe this past summer."

Source: McKinsey & Company

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