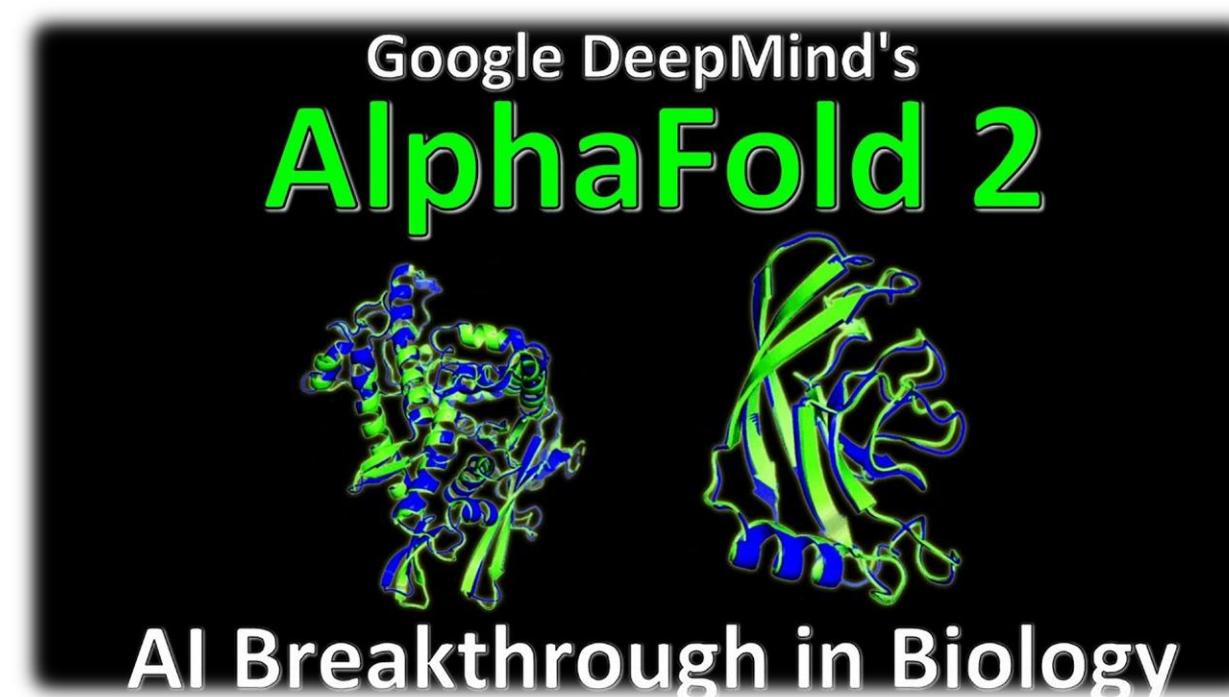


Towards Environmentally *Sustainable & Equitable* Computing

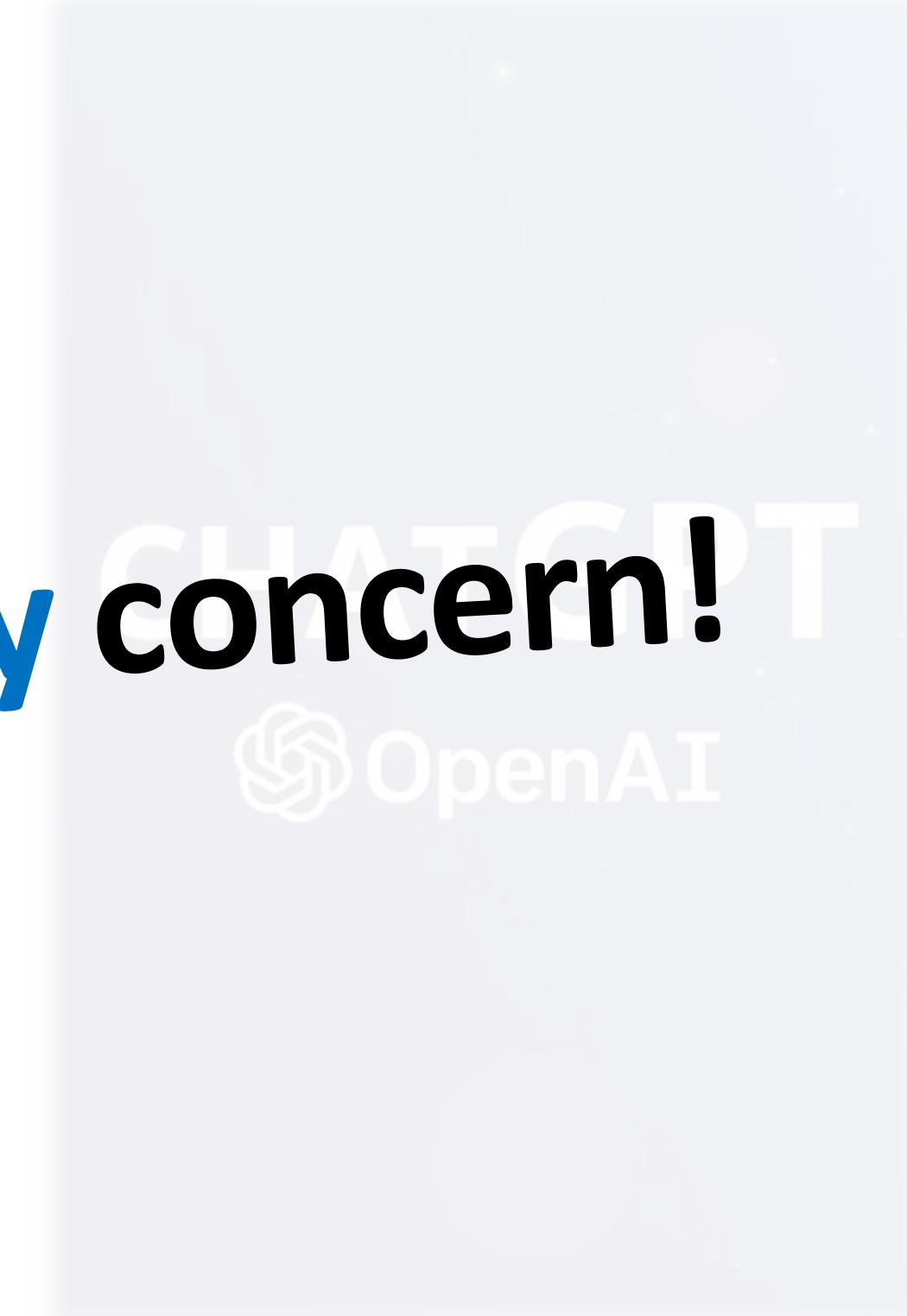
Shaolei Ren



The demand for AI and computing is soaring!

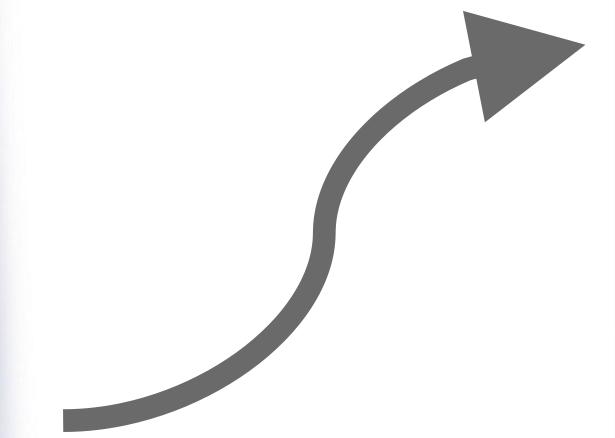


The demand for AI and computing is soaring!



... and so is the **sustainability** concern!

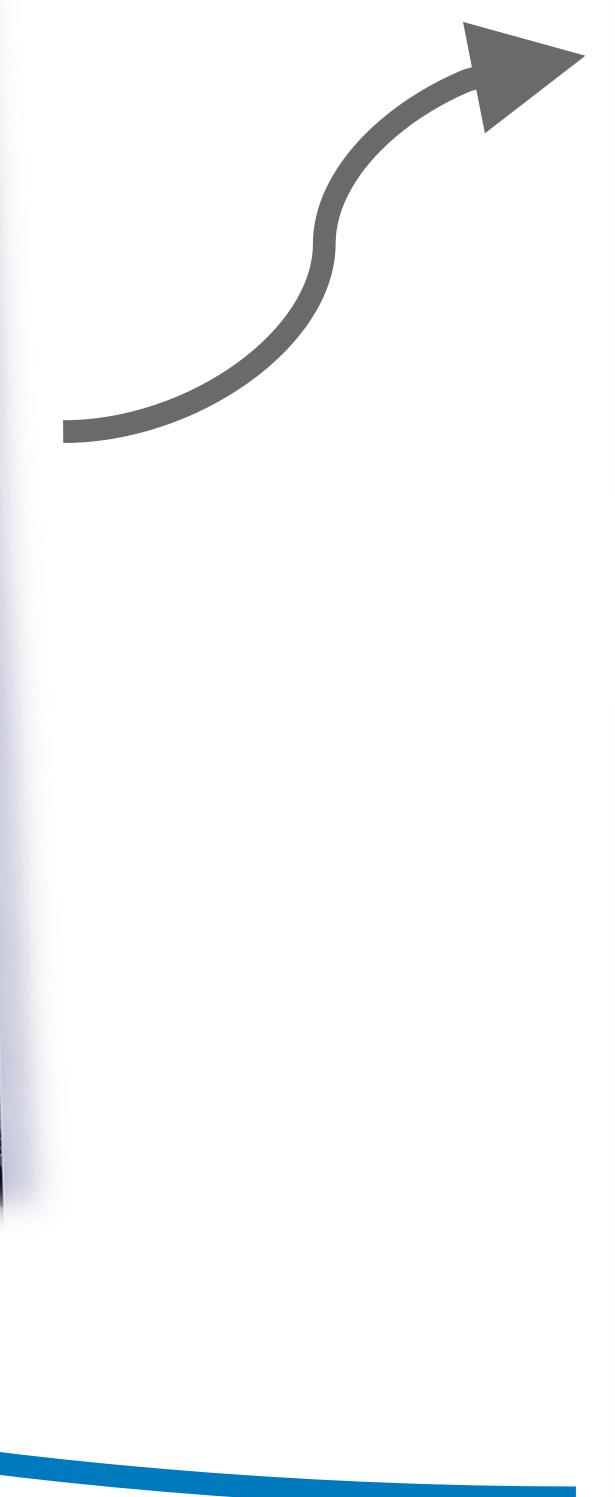
Computing is resource-intensive and power-hungry



Electronic waste or e-waste

Is the fastest growing waste stream

Computing is resource-intensive and power-hungry



Electronic waste or e-waste

Is the fastest growing waste stream



Computing is resource-intensive and power-hungry



Per IEA, data centers use about **300 TWh electricity** in 2022, or 1-2% of the global electricity demand (0.2-0.4% global energy demand).



Electricity = Carbon



Electricity = Carbon + Water + Air & thermal pollution + ...



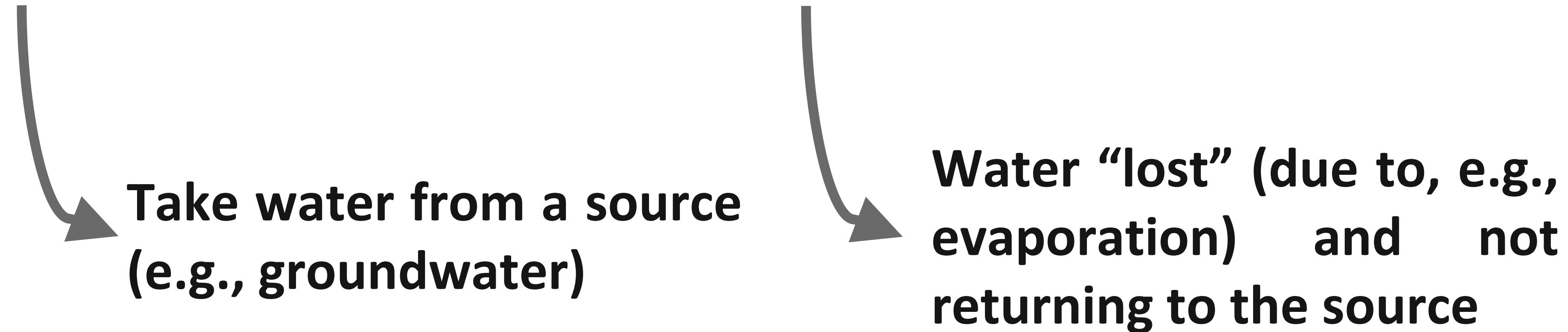
Electricity = Carbon + Water + Air & thermal pollution + ...



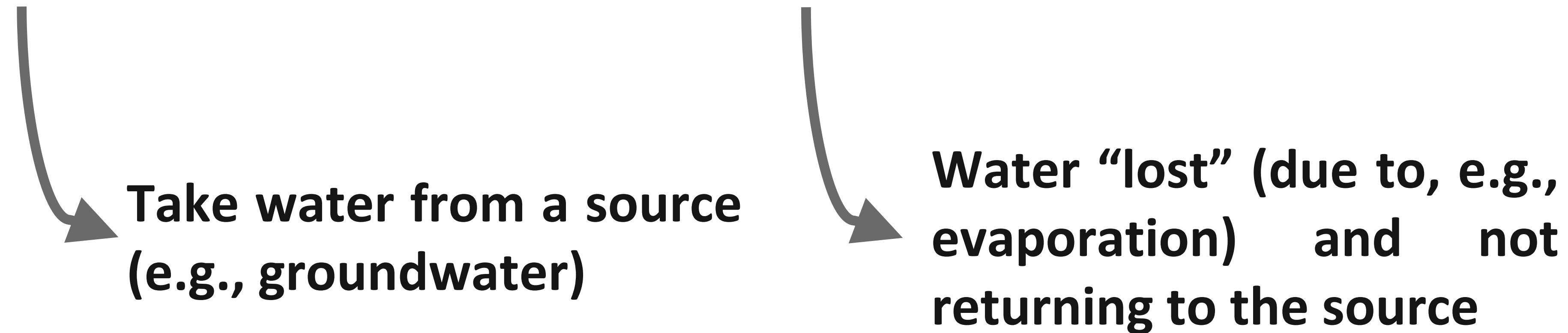
Carbon != Water

One footprint is “*a complement to and not a substitute for*” the other.

Water withdrawal vs. water **consumption** for electricity



Water withdrawal vs. water **consumption** for electricity



1 kWh = roughly 44-100 L water withdrawal (excluding hydropower)

1 kWh = 3.14 L water **consumption**

Data centers are guzzling water!

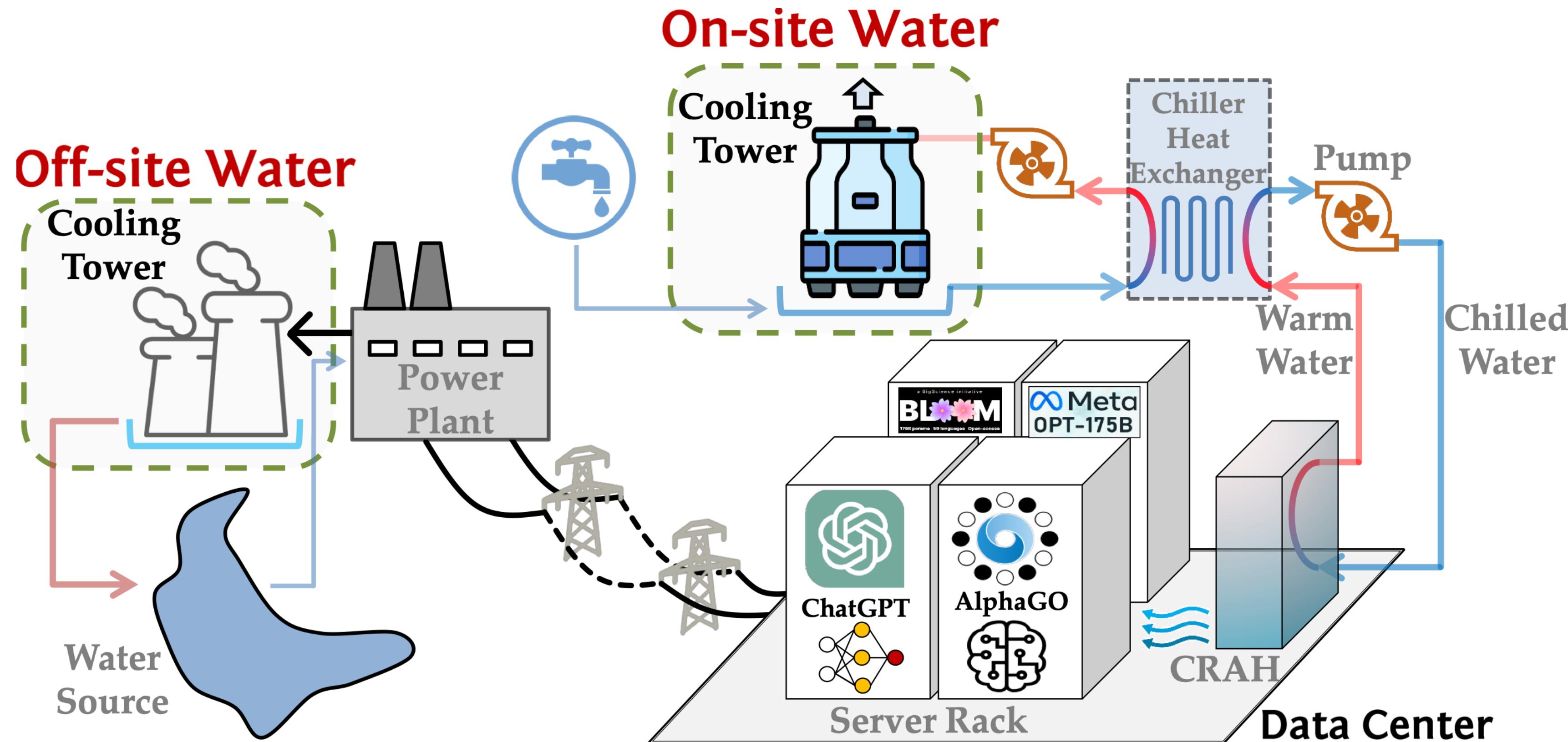


Figure 2. Multiple AI models are trained and/or deployed in the data center. Data center water footprint consists of two parts: on-site water and off-site water consumption

Data centers are guzzling water!

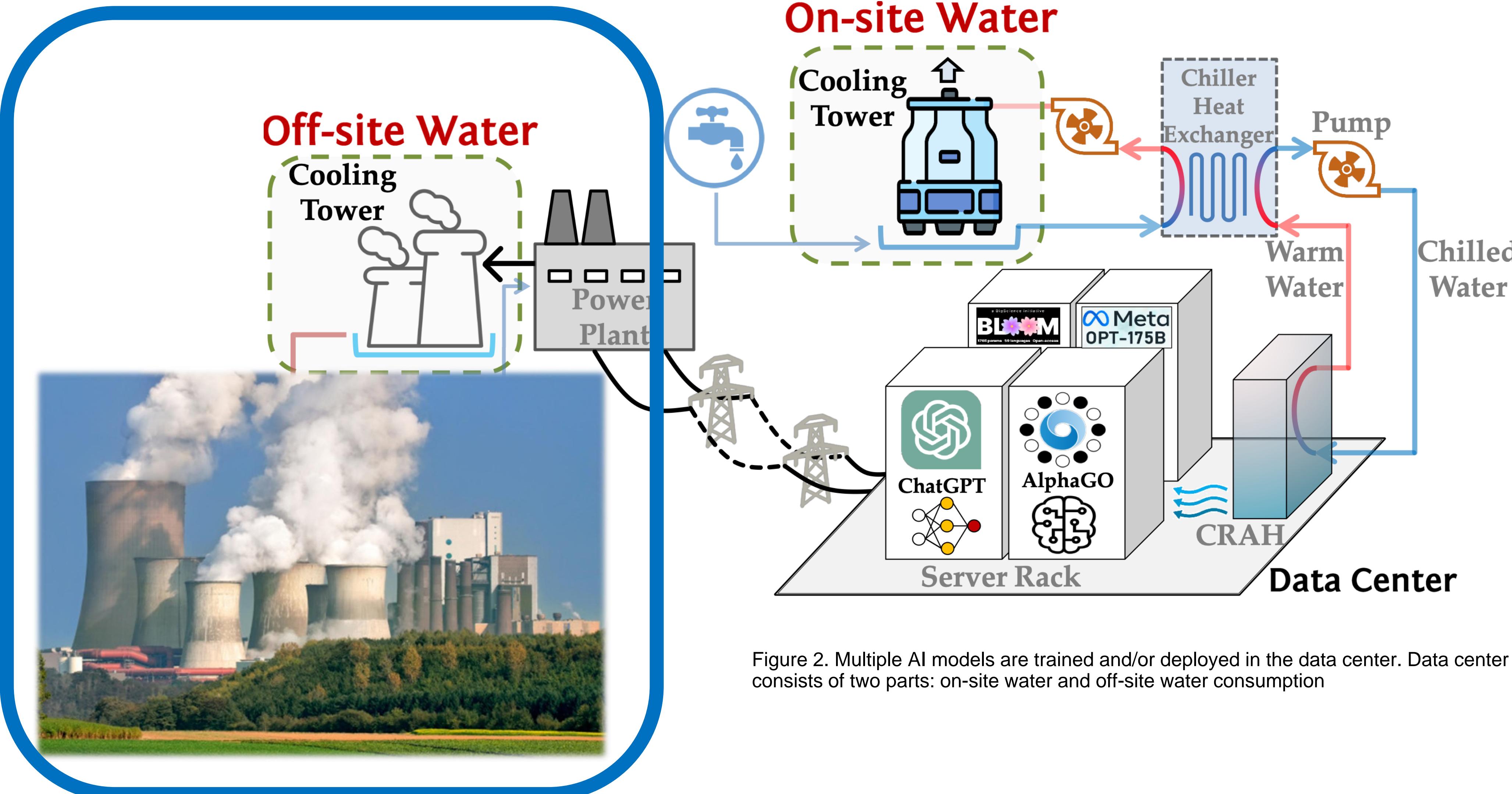


Figure 2. Multiple AI models are trained and/or deployed in the data center. Data center water footprint consists of two parts: on-site water and off-site water consumption

Data centers are guzzling water!

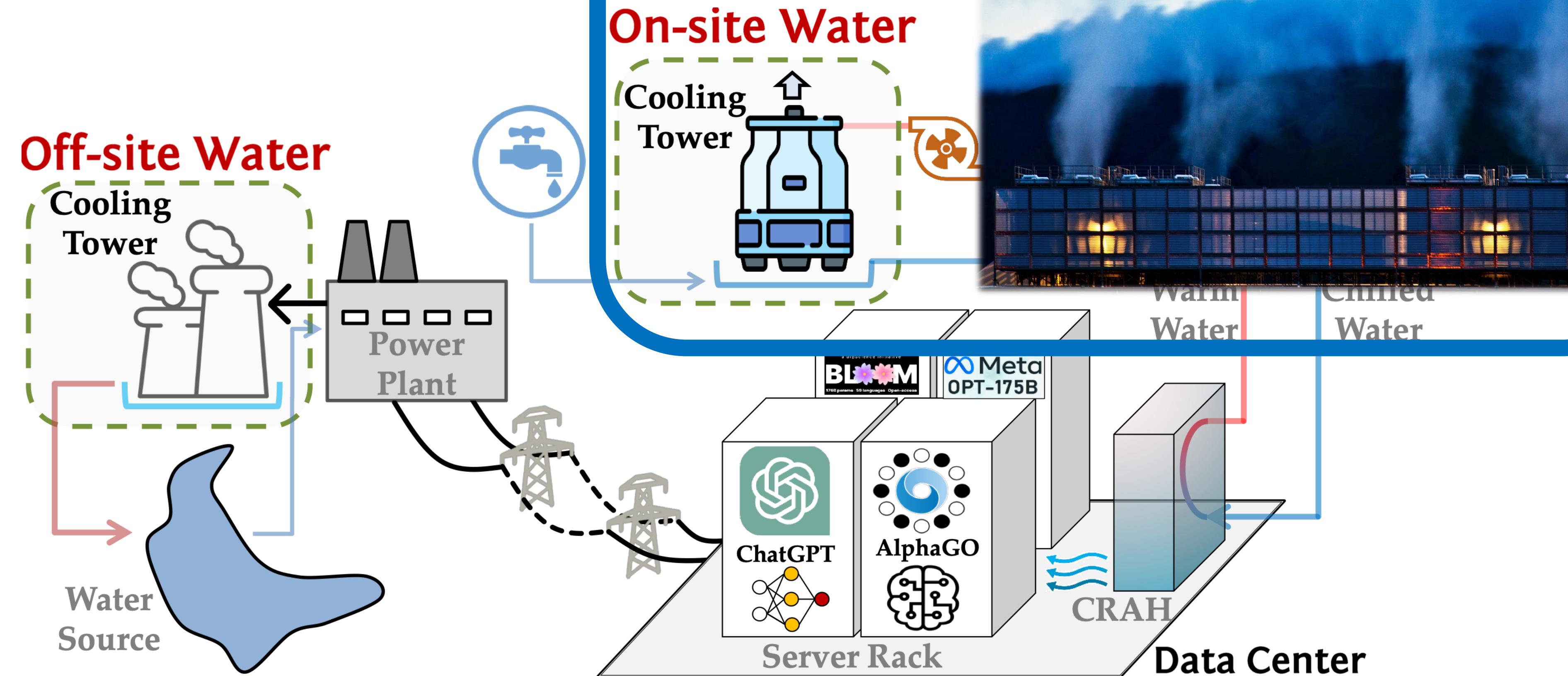


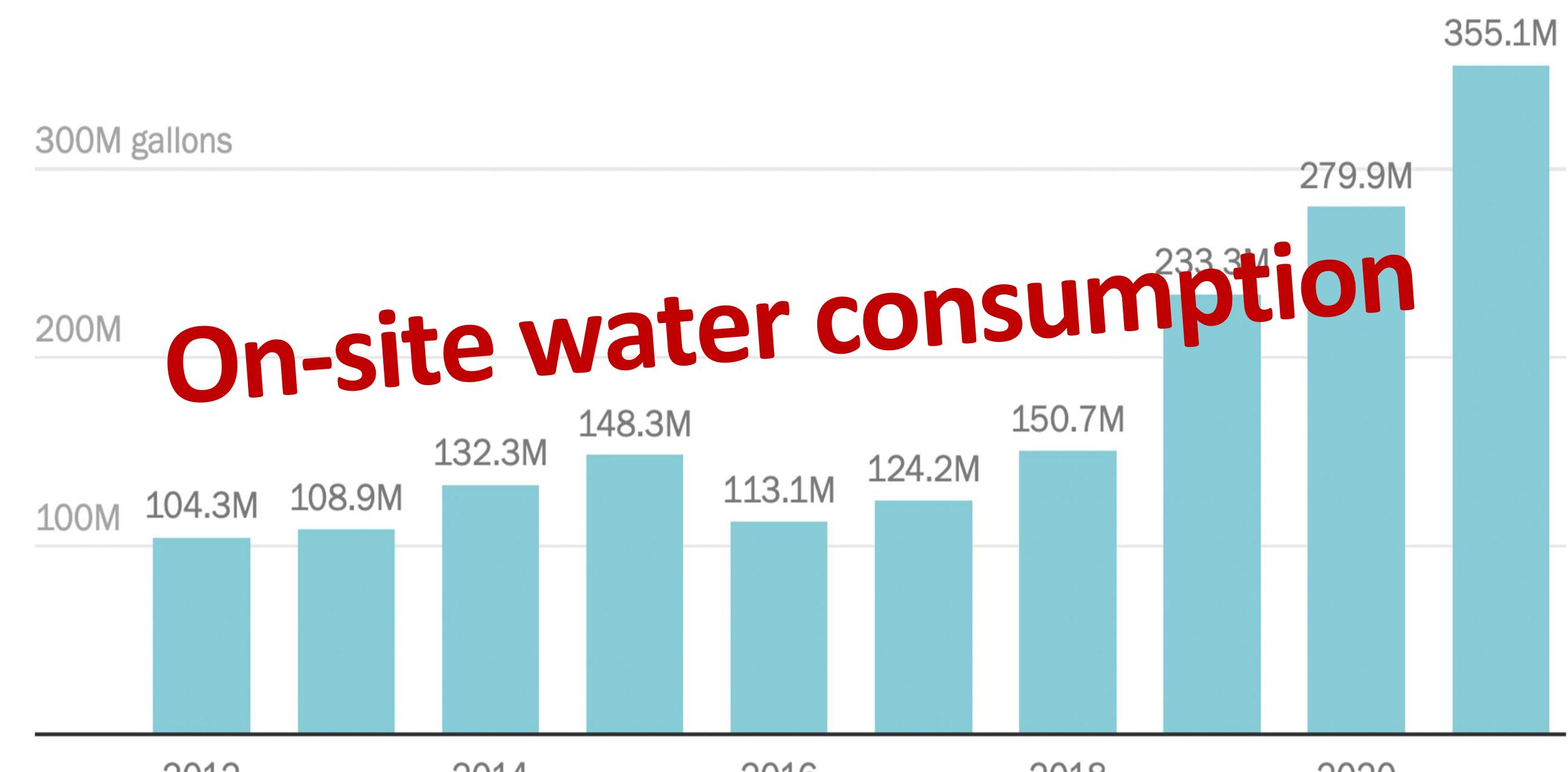
Figure 2. Multiple AI models are trained and/or deployed in the data center. Data center water footprint consists of two parts: on-site water and off-site water consumption

Data centers are guzzling water!

- A large data center can consume millions of gallons of potable water each day for on-site cooling.
- Google's data center used 355 million gallons of water in The Dalles, OR, in 2021, 29% of the city's total water consumption

Google's annual water use in The Dalles, in gallons

Google's data centers in The Dalles use nearly three times more water than they did five years ago and now account for more than a quarter of all the city's water use.



And this trend continues!

What about AI's water usage (withdrawal)?

~6.6 billion cubic meters in 2027

Based on the projected AI GPU energy consumption of up to 134 TWh (de Vries, 2023), US average water withdrawal for electricity generation 44L/kWh, PUE=1.1, on-site water withdrawal 1L/kWh.

What about AI's water usage (**consumption**)?

~0.6 billion cubic meters in 2027

Based on the projected AI GPU energy consumption of up to 134 TWh (de Vries, 2023), US average water consumption for electricity generation 3.14 L/kWh, PUE=1.1, on-site water consumption 0.8L/kWh.

ChatGPT is already “drinking” a lot of water

Table 2: Estimate of GPT-3’s average operational water footprint. “*” denotes data centers under construction as of July 2023, and the PUE and WUE values for these data centers are based on Microsoft’s projection.

Location	PUE	WUE (L/kWh)	Electricity Water Intensity (L/kWh)	Water for Training (million L)			Water for Inference (mL)			# of Inferences for 500ml Water
				Onsite Water	Offsite Water	Total Water	Onsite Water	Offsite Water	Total Water	
US 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

ChatGPT is already “drinking” a lot of water

Table 2: Estimated Water Use for ChatGPT by Region
July 2023, and construction as of

Location	# of Inferences for 500ml Water
US Average	29.6
Wyoming	40.0
Iowa	33.0
Arizona	15.1
Washington	10.4
Virginia	43.1
Texas	35.7
Singapore	33.9
Ireland	69.6
Netherlands	30.7
Sweden	17.3
Mexico*	20.9
Georgia*	47.2
Taiwan*	34.6
Australia*	26.1
India*	25.4
Indonesia*	25.5



**ChatGPT needs about 500 ml of water for answering
10-50 questions.**

Water is a shared public good...

guardian
with \$5 per month

on Sport Culture Lifestyle More ▾
Asia Australia Middle East Africa Inequality Global development

This article is more than 3 months old

'It's pillage': thirsty Uruguayans denounce Google's plan to exploit water supply

Country suffering its worst drought in 74 years, with government even mixing saltwater into drinking supply

People take part in a protest amid a shortage of drinking water reserves in Montevideo, Uruguay, May 2023. Photograph: Eitan Abramovich/AFP/Getty Images

The Guardian

The Washington Post

A new front in the water wars: Your internet use

In the American West, data centers are clashing with local communities that want to preserve water and



By [Shannon Osaka](#)

April 25, 2023 at 6:30 a.m. EDT



Bloomberg

• Live Now Markets Economics Industries Tech AI Politics Wealth Pursuits Opinion [Businessweek](#) US Edition Equality Green
Businessweek Technology

Thirsty Data Centers Are Making Hot Summers Even Scarier

With drought spreading around the globe, battles over water are erupting between AI companies seeking more computing power and communities where their facilities are located.



CNBC MARKETS BUSINESS INVESTING TECH POLITICS CNBC TV INVESTING CLUB PRO

RISING RISKS

Microsoft, Meta and others face rising drought risk to their data centers

PUBLISHED TUE, NOV 15 2022 4:13 PM EST | UPDATED WED, NOV 16 2022 1:21 AM EST

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SHARE f t in e



“Every drop matters.” --- Meta

Water Positive by 2030!



Microsoft



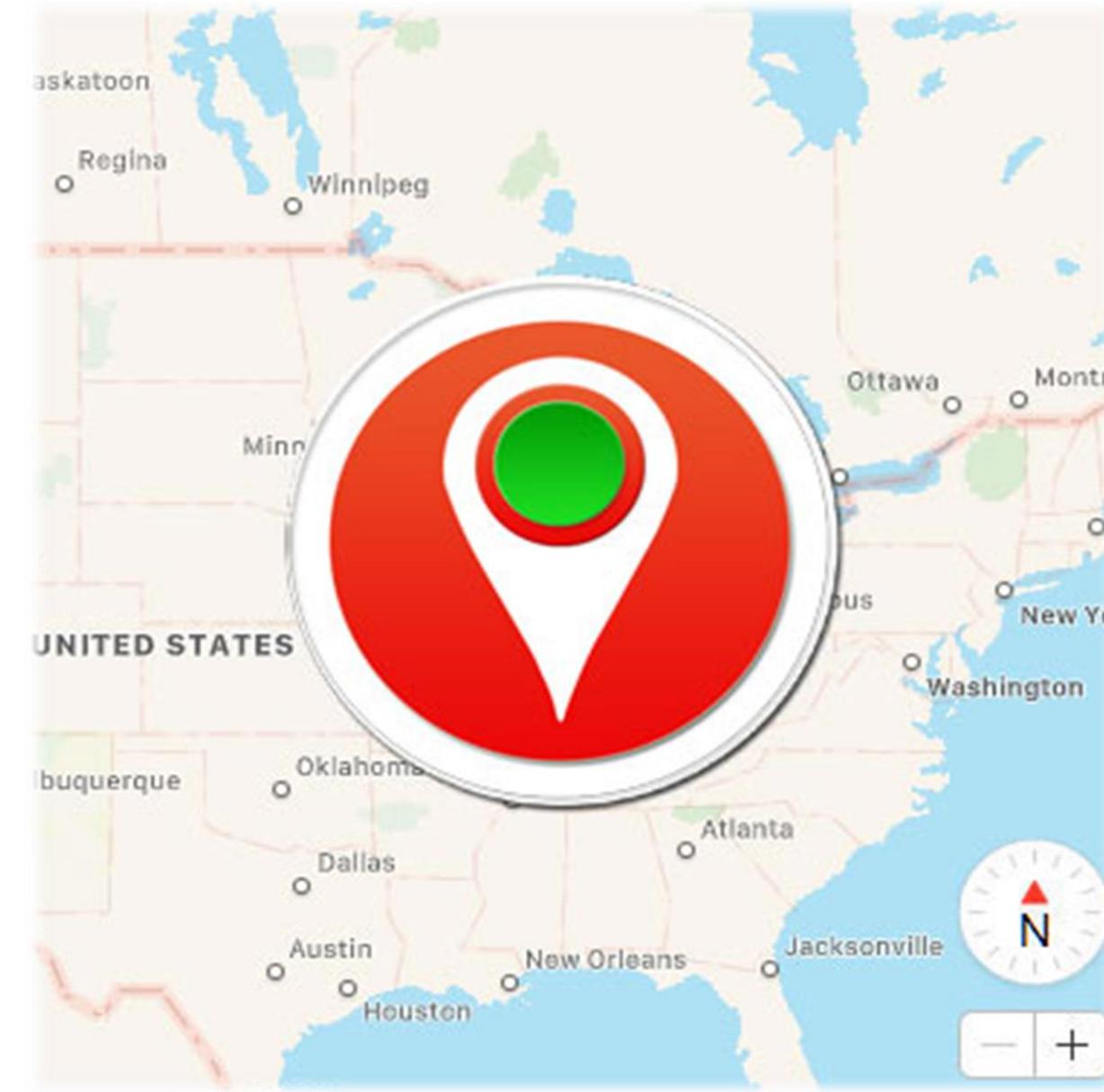
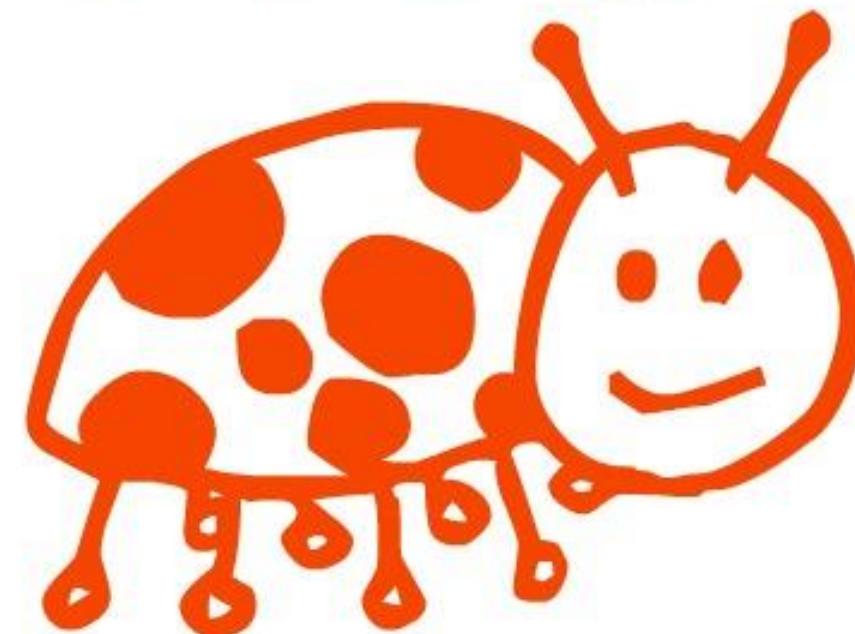
Meta



Algorithmic challenges

“When” and “Where” matter a lot

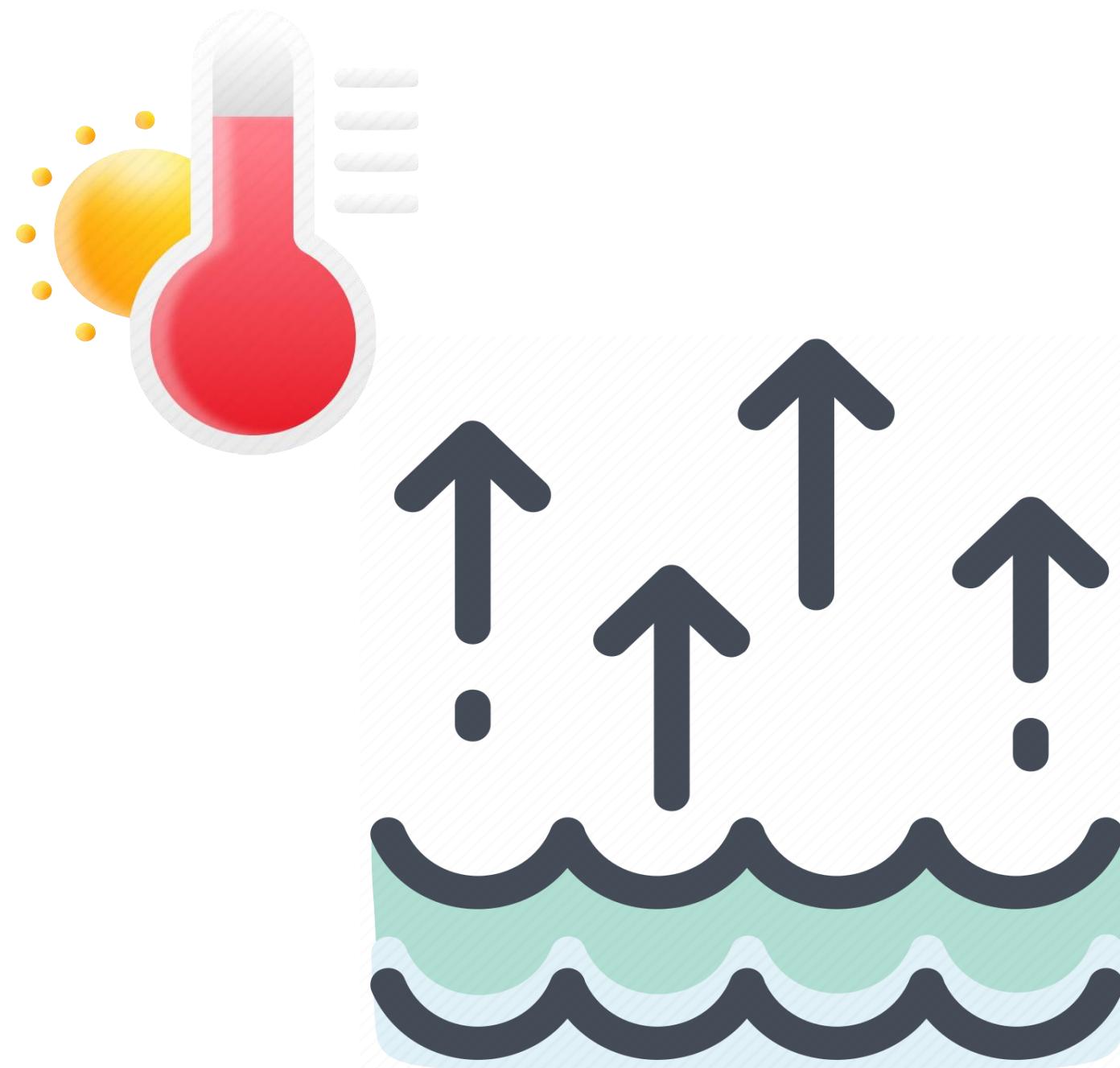
When...



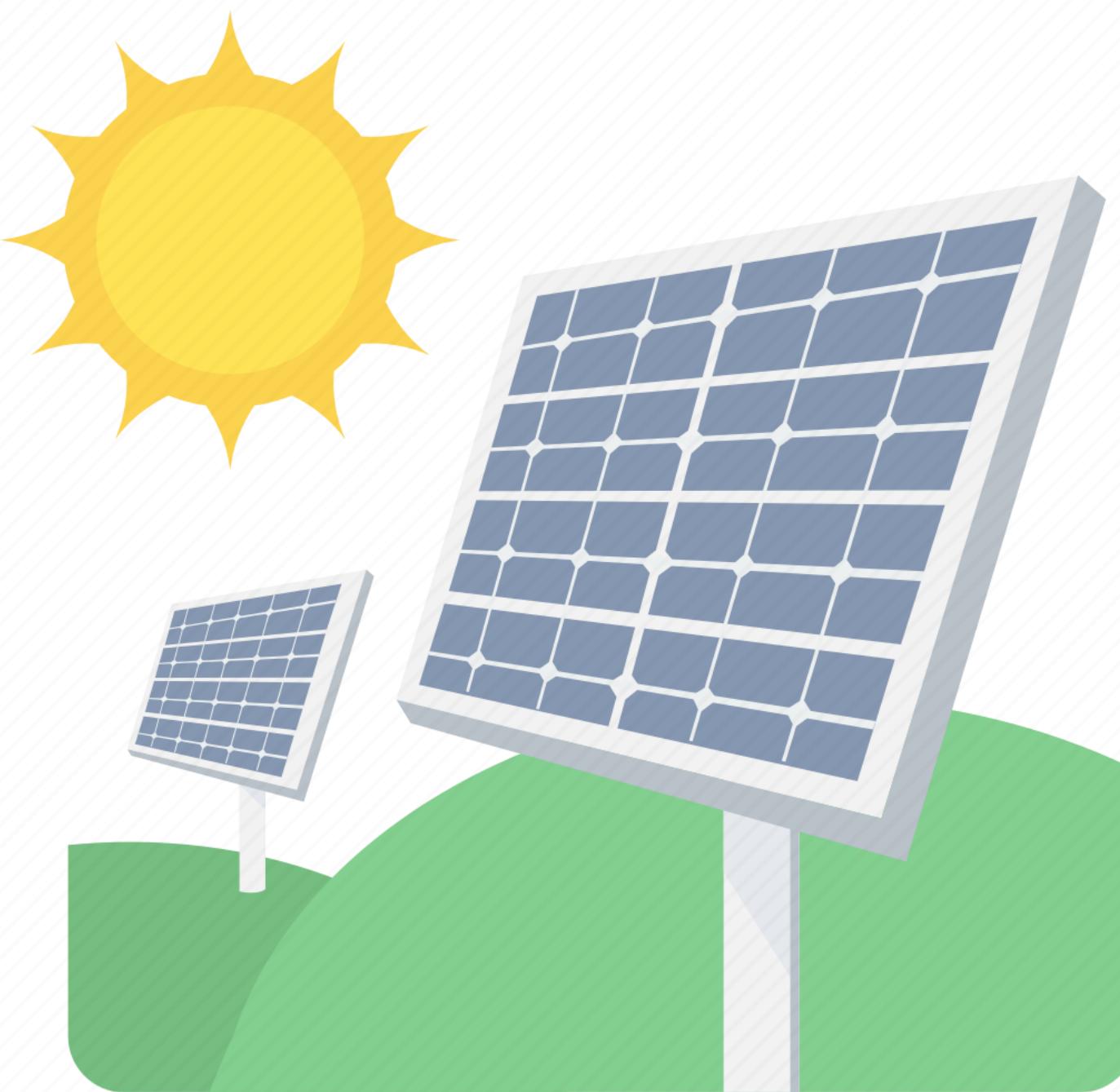
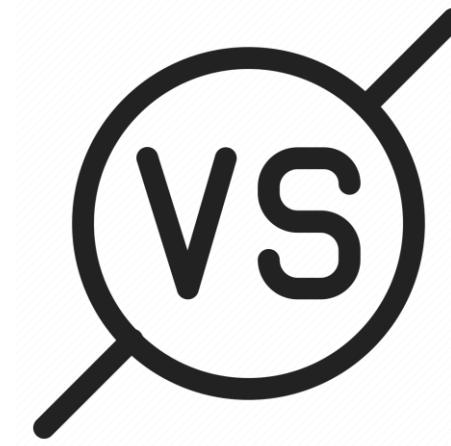
- Outside weather condition
- Time-varying workloads
- Fuel mix for power generation
- Regional climate

Algorithmic challenges

“Follow the Sun” or “Unfollow the Sun”?

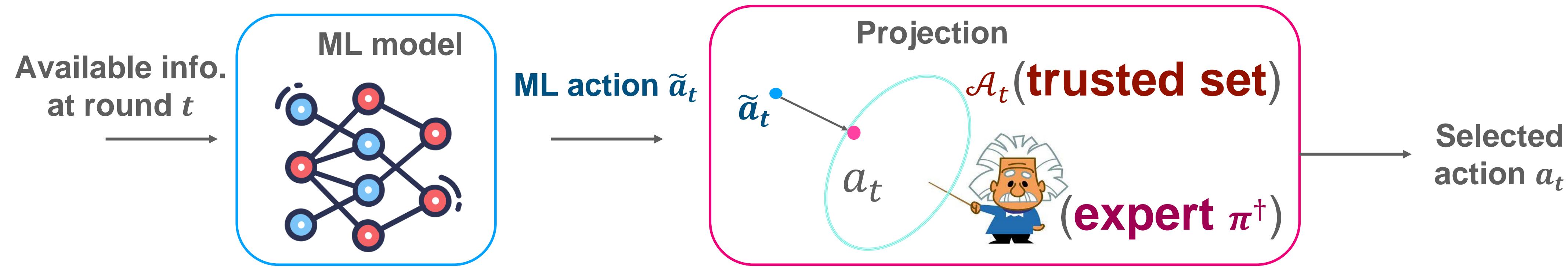


Water Efficient



Carbon Efficient

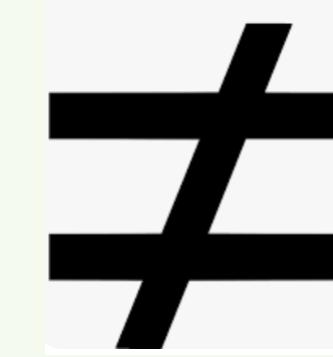
Learning-augmented algorithms



- [NeurIPS'23] Jianyi Yang, Pengfei Li, Tongxin Li, Adam Wierman, and Shaolei Ren, "Anytime-Constrained Reinforcement Learning with Policy Prior," NeurIPS, 2023.
- [NeurIPS'23] Pengfei Li, Jianyi Yang, Adam Wierman, and Shaolei Ren, "Robust Learning for Smoothed Online Convex Optimization with Feedback Delay," NeurIPS, 2023.
- [ICML'23] Pengfei Li, Jianyi Yang, and Shaolei Ren, "Learning for Edge-Weighted Online Bipartite Matching with Robustness Guarantees," ICML, 2023.
- [SIGMETRICS'22] Pengfei Li, Jianyi Yang, and Shaolei Ren, "Expert-Calibrated Learning for Online Optimization with Switching Costs," SIGMETRICS, 2022.

Environmental equity?

minimizing the **total** environmental cost



minimizing **each region's** environmental cost

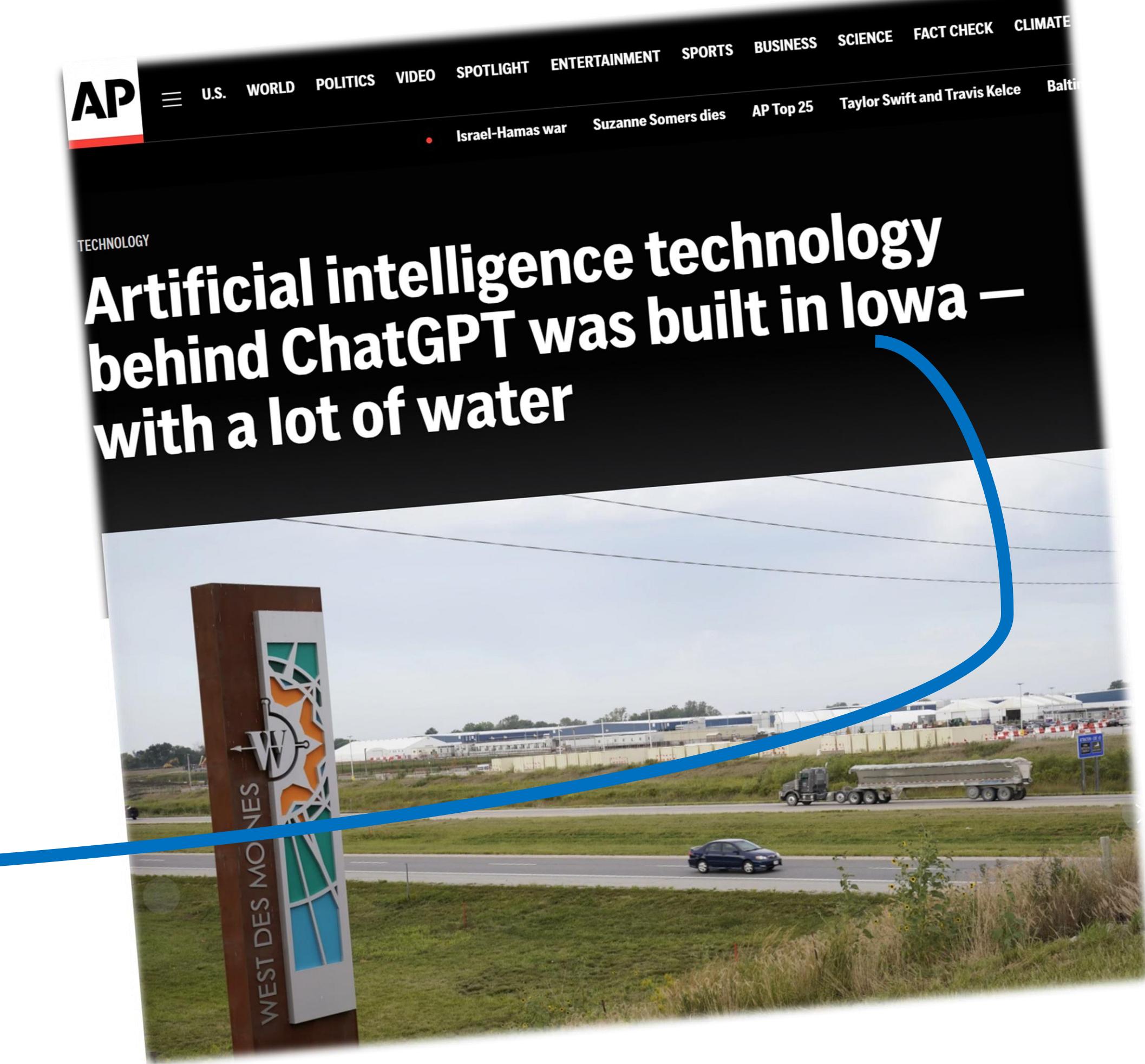
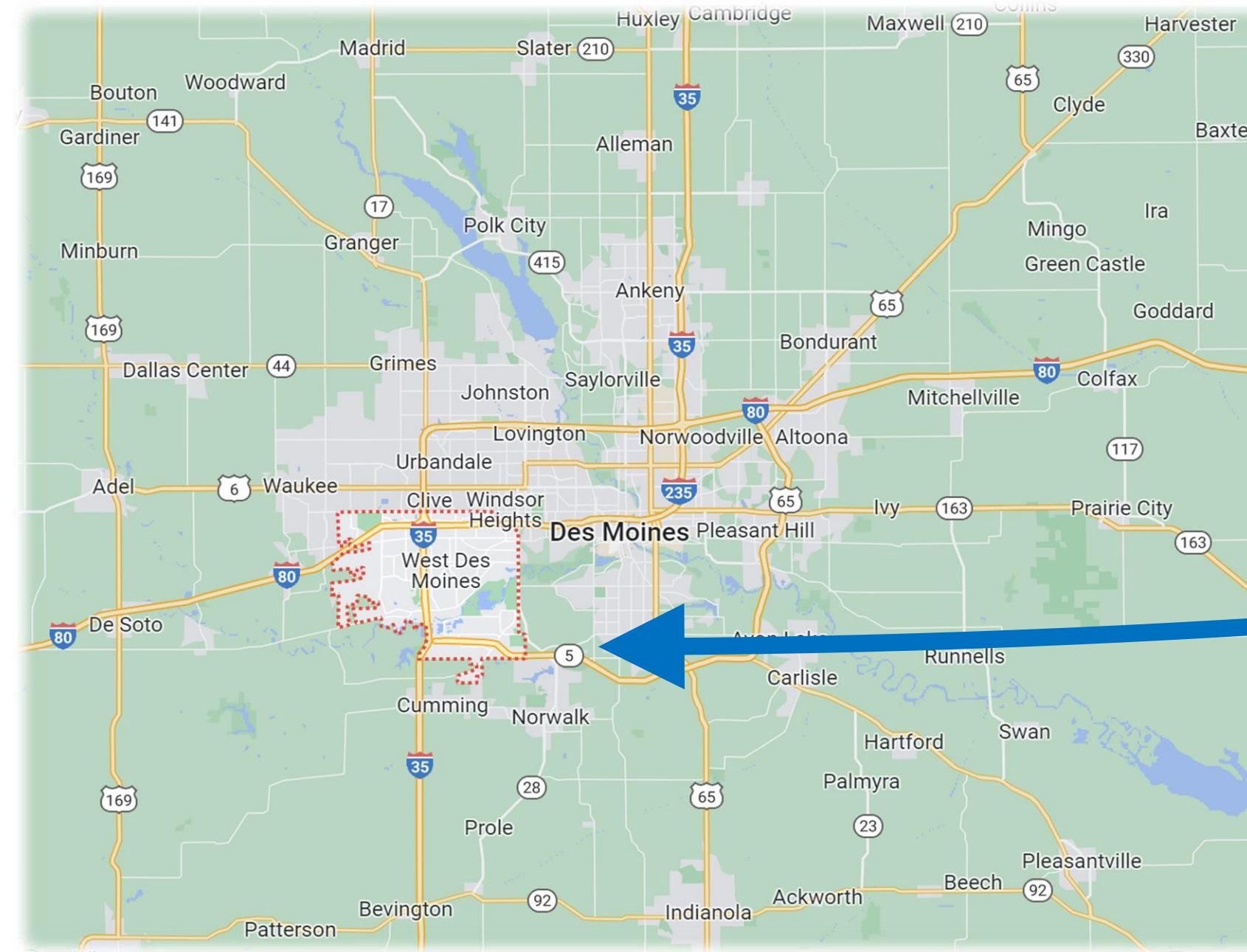
Electricity = Carbon + Water + Air & thermal pollution + ...



Electricity = Carbon + Water + Air & thermal pollution + ...



OpenAI ChatGPT 4.0



Computing's environmental inequity is emerging...

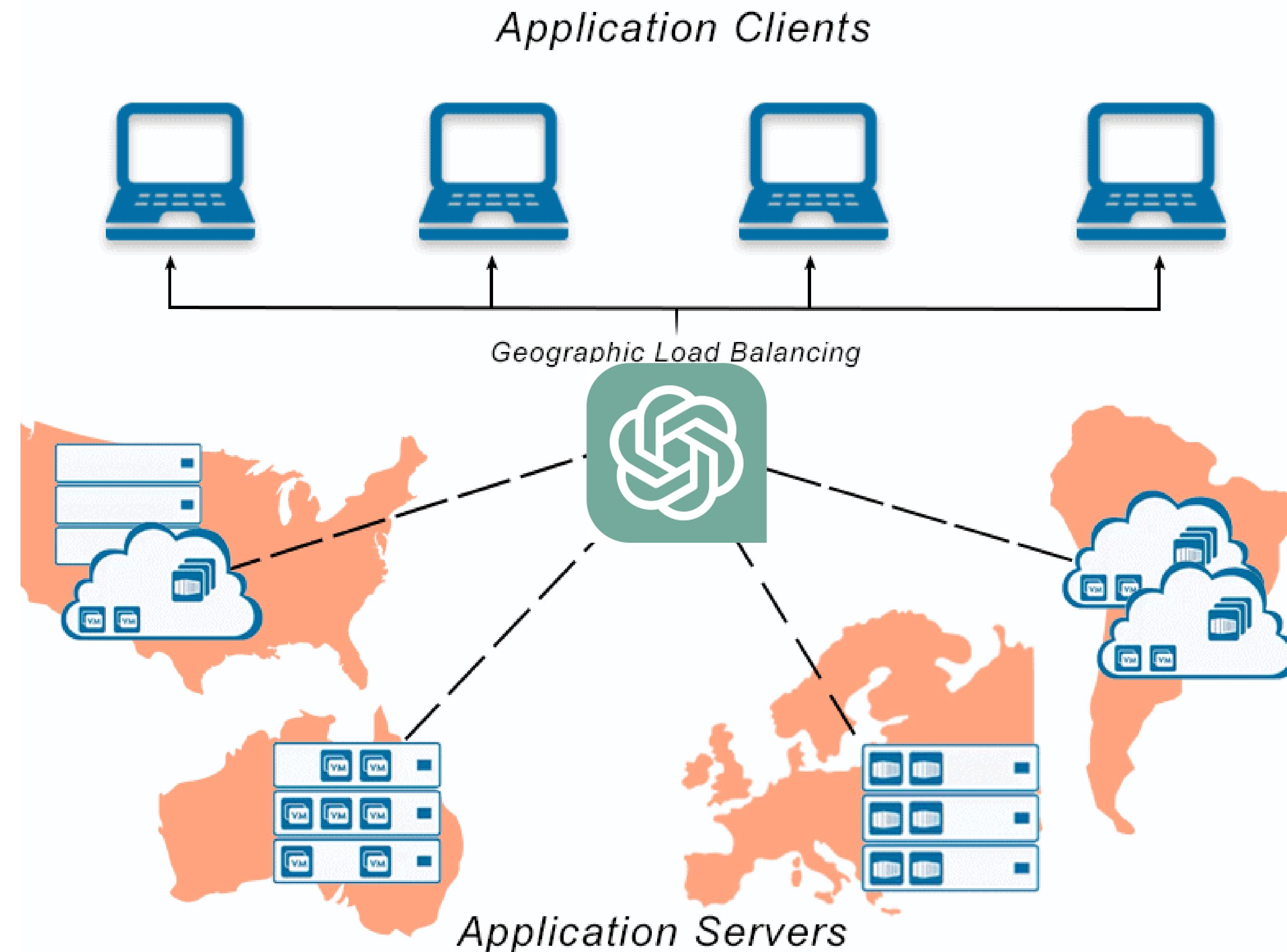
AI NOW

The constant push for scale in artificial intelligence has led Big Tech firms to develop hugely energy-intensive computational models that optimize for “accuracy” – through increasingly large datasets and computationally intensive model training – over more efficient and sustainable alternatives.^① As we increasingly become locked into using Big-Tech infrastructures, we also become locked into their voracious appetite for resources, necessitating a life cycle analysis: the data centers needed for computationally intensive AI have high energy costs and carry a massive carbon footprint.^② Computing technologies rely heavily on minerals that are procured under violent and exploitative conditions.^③ But these environmental harms are not evenly distributed; they disproportionately impact communities that are already marginalized, in a manner that reenacts historical practices of settler colonialism and racial capitalism.^④

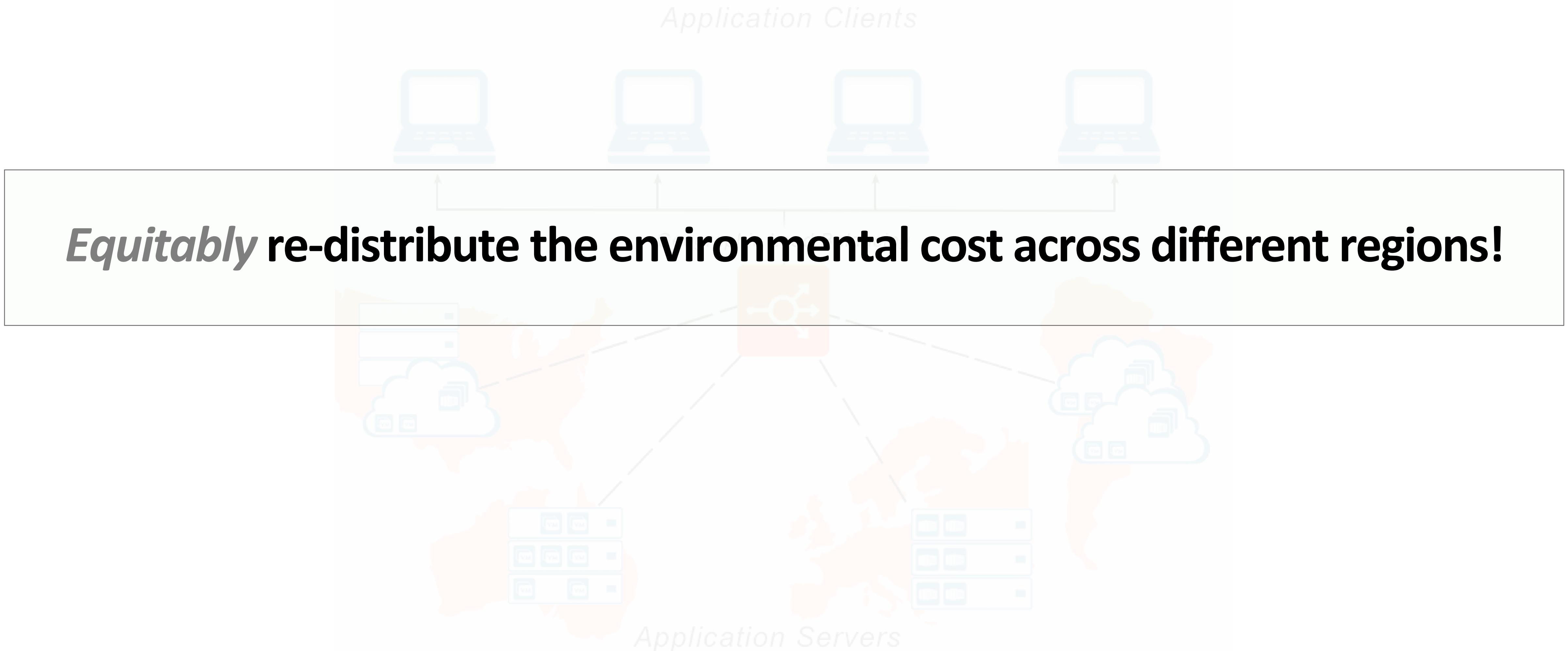
The uneven distribution of AI's environmental cost is “**historical practices of settler colonialism and racial capitalism**”.

In 2022, the **United Nations Educational, Scientific and Cultural Organization (UNESCO)** recommends that “**AI should not be used**” if it creates “**disproportionate negative impacts on the environment**”.

Environmentally *equitable* geographical load balancing (eGLB)



Environmentally *equitable* geographical load balancing (eGLB)



Computing is “thirsty”, just as we are!



ChatGPT needs 500 ml of water for answering 10-50 questions.

The water footprint is coming to the public...

Forbes
AI'S Unsustainable Water Use: How Tech Giants Contribute To Global Water Shortages

Bloomberg
Artificial intelligence technology behind ChatGPT was built in Iowa - with a lot of water

The Guardian
'consume medio litro de agua en cada ción sencilla'

LAVANGUARDIA
700 000 litros de agua, el

Businessweek
Thirsty Data Centers Are Making Hot Summers Even Scarier

AP
With drought spreading around the globe, battles over water are erupting between AI companies seeking more computing power and communities where their facilities are located.

WSJ PRO SUSTAINABLE BUSINESS
Artificial Intelligence Can Make Companies Greener, but It Also Guzzles Energy

euronews.green
ChatGPT 'drinks' a bottle of fresh water for every 20 to 50 questions we ask, study warns

Des Moines
AI's hidden climate costs | About That

OpenAI

Related papers

- [NeurIPS'23] Jianyi Yang, Pengfei Li, Tongxin Li, Adam Wierman, and Shaolei Ren, "Anytime-Constrained Reinforcement Learning with Policy Prior," NeurIPS, 2023.
- [NeurIPS'23] Pengfei Li, Jianyi Yang, Adam Wierman, and Shaolei Ren, "Robust Learning for Smoothed Online Convex Optimization with Feedback Delay," NeurIPS, 2023.
- [ICML'23] Pengfei Li, Jianyi Yang, and Shaolei Ren, "Learning for Edge-Weighted Online Bipartite Matching with Robustness Guarantees," ICML, 2023.
- [SIGMETRICS'22] Pengfei Li, Jianyi Yang, and Shaolei Ren, "Expert-Calibrated Learning for Online Optimization with Switching Costs," SIGMETRICS, 2022.
- [Preprint'23] Pengfei Li, Jianyi Yang, Adam Wierman, and Shaolei Ren, "Towards Environmentally Equitable AI via Geographical Load Balancing," arXiv, 2023.
- [Preprint'23] Pengfei Li, Jianyi Yang, Mohammad A. Islam, Shaolei Ren, "Making AI Less 'Thirsty': Uncovering and Addressing the Secret Water Footprint of AI Models," arXiv, 2023.

Thanks!