Environmental Costs of the AI Boom

Data Center Power Play

Union of Concerned Scientists

HOW MUCH ENERGY IS CONSUMED BY A SINGLE AI QUERY?

Sonnet 4.6

Step 1: Power draw

$$I = \boldsymbol{P_{GPU}} \times \boldsymbol{N_{GPU}}$$

$P_{GPU} = \textbf{GPU power draw}\ [\boldsymbol{W}] \approx 400\ W$
$N_{GPU} = \#\ \boldsymbol{GPUs}\ [-] = 8$

Step 2: Efficiency

$$I = P_{GPU} \times N_{GPU} \times \boldsymbol{PUE}$$

P_{GPU} = GPU power draw $[W] \approx 400\ W$
$N_{GPU} = \#\ GPUs\ [-] = 8$
PUE = **"power use effectiveness"** $[-] \approx 1.2$

Step 3: Throughput

$$I = \frac{P_{GPU} \times N_{GPU} \times PUE}{\boldsymbol{R_q}}$$

$P_{GPU} = \text{GPU power draw } [W] \approx 400\ W$

$N_{GPU} = \#\ GPUs\ [-] = 8$

$PUE = \text{"power use effectiveness" } [-] \approx 1.2$

$\boldsymbol{R_q} = \textbf{throughput } [\boldsymbol{queries/s}]$

Step 4: Energy-per-query

$$I = \frac{400 \times 8 \times 1.2}{10} = 384\, J = \mathbf{0.1Wh}$$

$P_{GPU} \approx 400\, W$

$N_{GPU} = 8$

$PUE \approx 1.2$

$R_q \approx 10\, q/s$

Embodied energy

$$I + \frac{T}{N_q^{(m)}} + \frac{E}{N_q^{(s)}}$$

$T =$ **Energy from model training** $[Wh]$

$E =$ **Embodied energy** $[Wh]$

$N_q^{(s)} =$ Server lifetime queries $[-]$

$N_q^{(m)} =$ Model lifetime queries $[-]$

WHAT DOES AI ENERGY CONSUMPTION LOOK LIKE AT SCALE?

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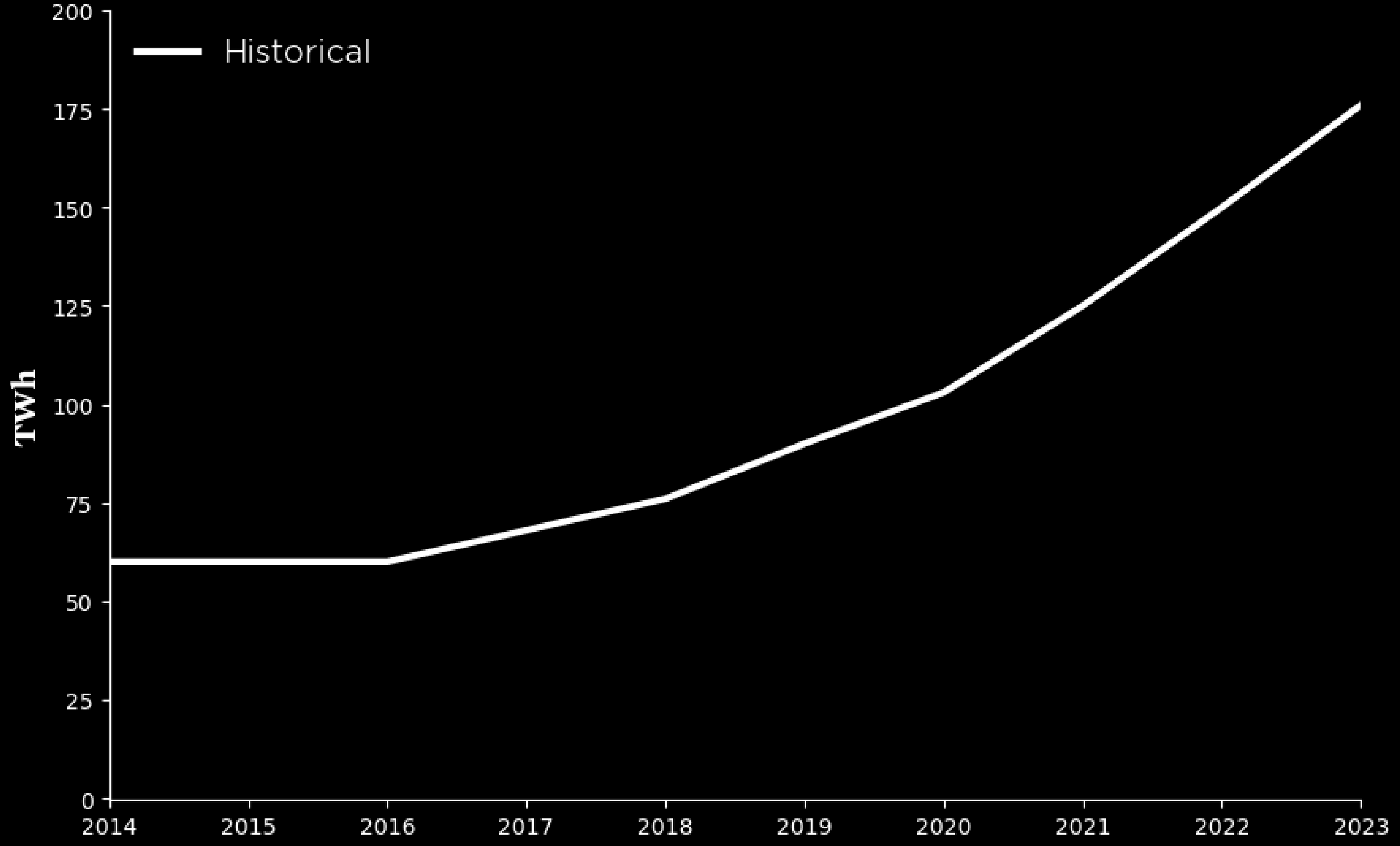
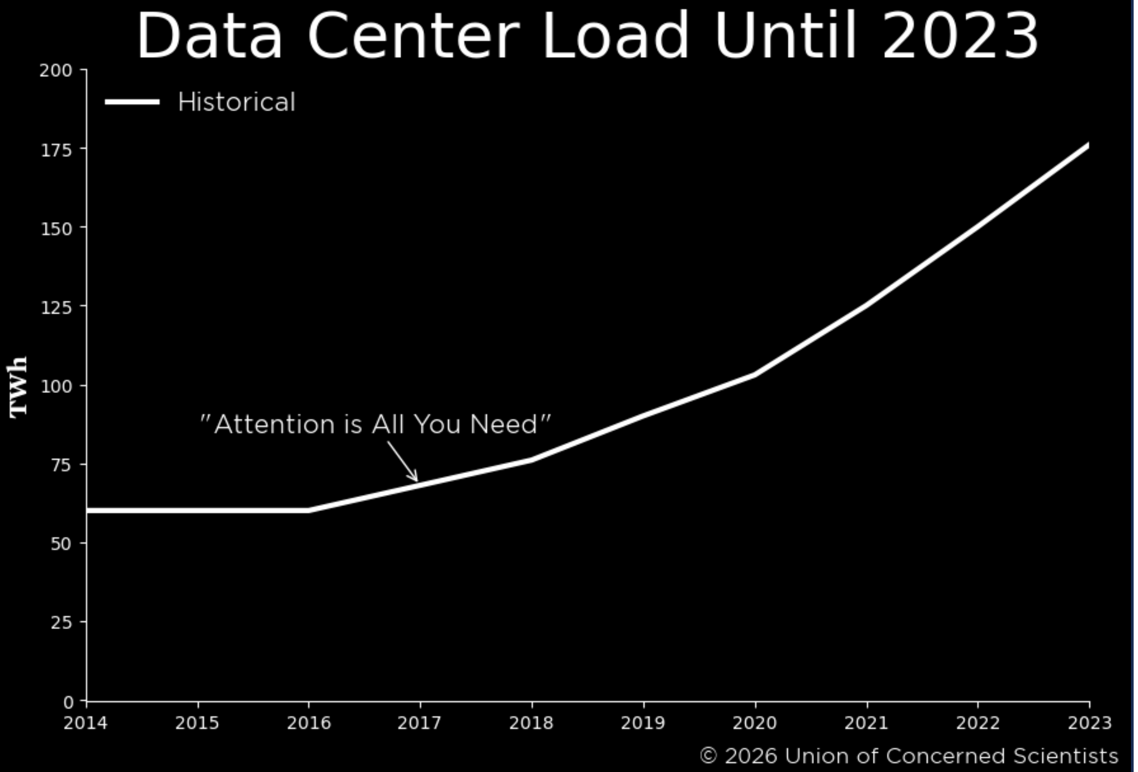
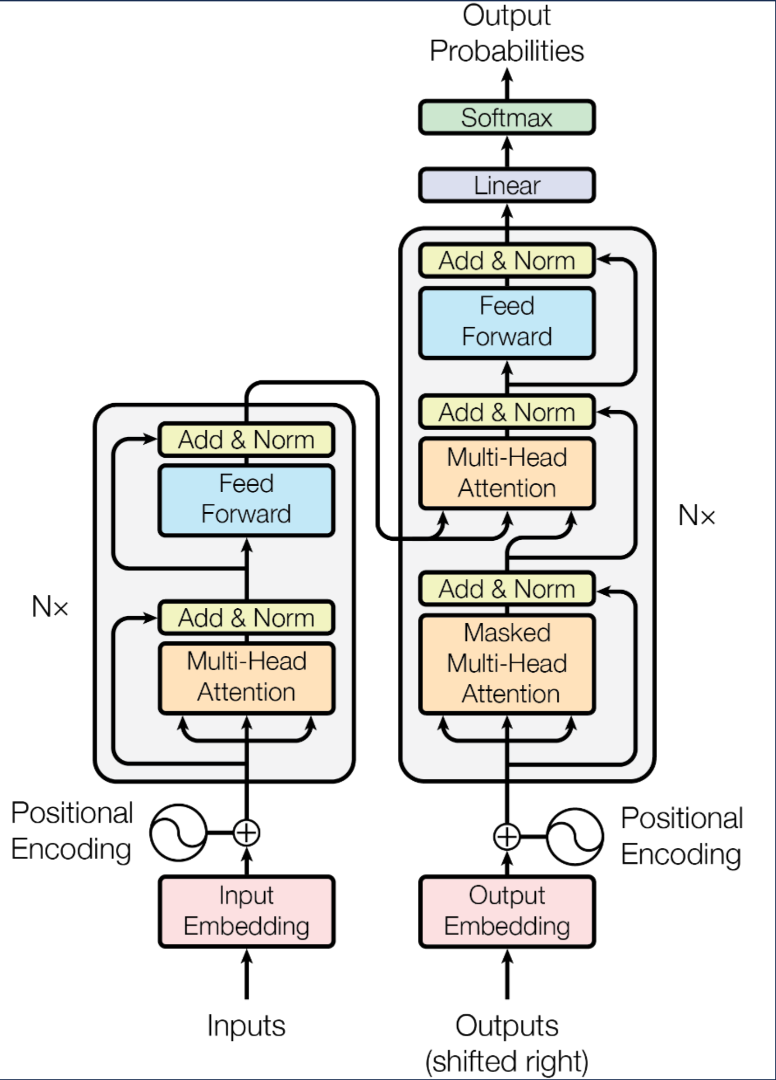
Data Center Load Until 2023



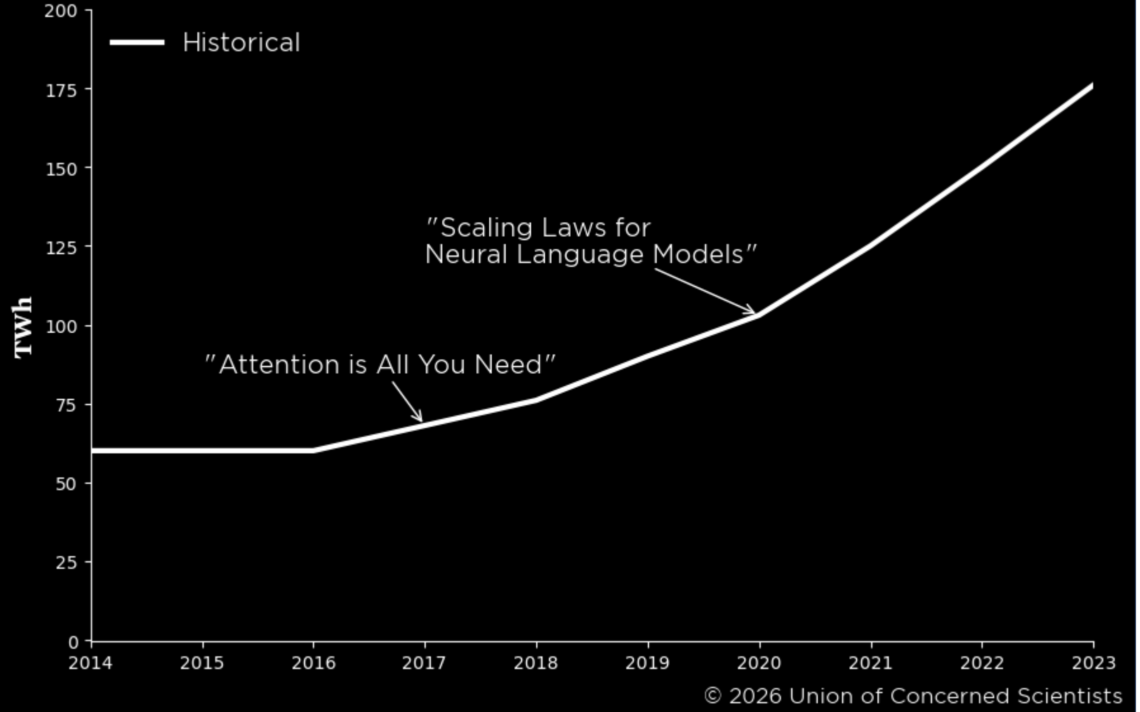
Shehabi, A., Smith, S., Hubbard, A., Newkirk, A., Lei, N., Siddik, M.A.B., Holecek, B., Koomey, J., Masanet, E., Sartor, D., 2024. 2024 United States Data Center Energy Usage Report (No. LBNL-2001637). Lawrence Berkeley National Lab (LBNL), Berkeley, California.

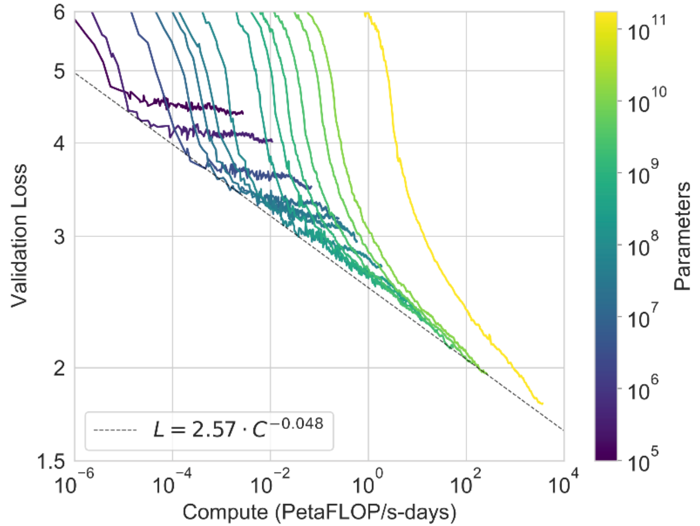




(Right) Encoder-decoder transformer architecture. Figure reproduced from: Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A.N., Kaiser, L., Polosukhin, I., 2017. Attention Is All You Need. https://doi.org/10.48550/arXiv.1706.03762

Data Center Load Until 2023



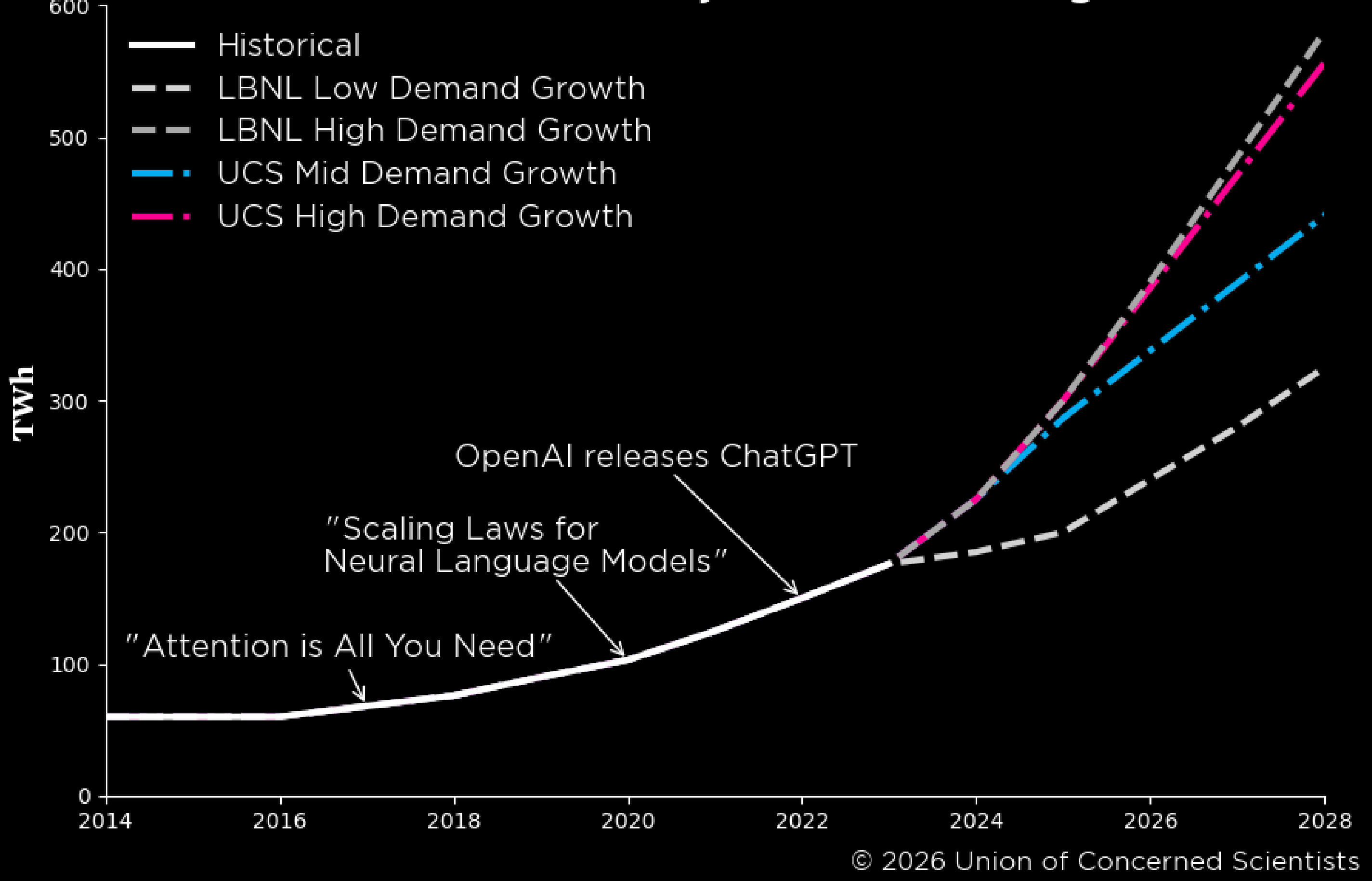


(Right) Loss reduction follows a smooth curve according to compute time and model size.

Kaplan, J., McCandlish, S., Henighan, T., Brown, T.B., Chess, B., Child, R., Gray, S., Radford, A., Wu, J., Amodei, D., 2020. Scaling Laws for Neural Language Models. https://doi.org/10.48550/arXiv.2001.08361

Welch, A., 2025. Neural Scaling Laws, in: Illustrated Guide to AI: A Deep Dive into Modern AI. The Welch Labs, pp. 217–244.

Data Center Load Projections Through 2028



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WHAT ARE THE ENVIRONMENTAL IMPACTS OF DATA CENTER GROWTH?

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Data center impacts modeled with ReEDS

- Regional Energy Deployment System (ReEDS) model
- Open-source power sector capacity expansion model
- Based on 2024 Standard Scenarios
- Included state and regional power sector policies as of August 2024
- Assumed delay in OSW targets

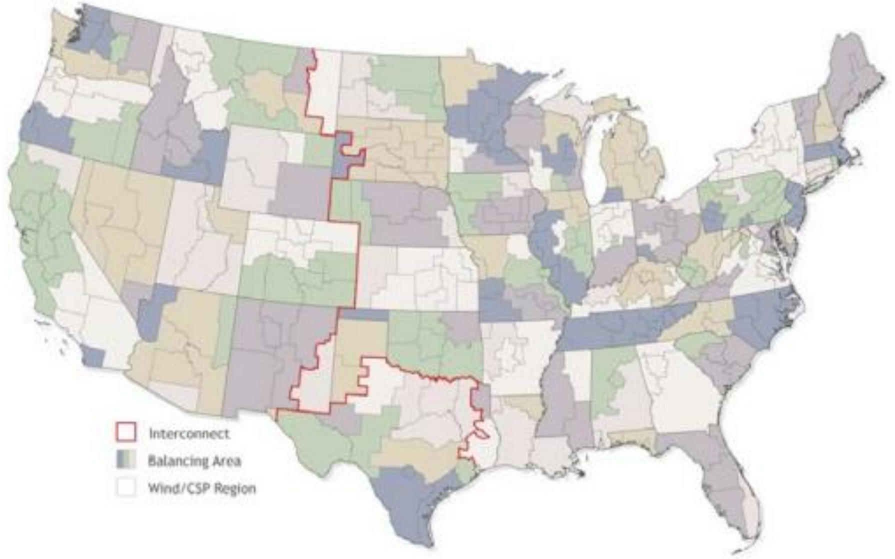


Figure 4. Map showing the ReEDS regional structure

ReEDS includes 3 interconnections, 134 model BAs, and 356 wind and CSP resource regions.

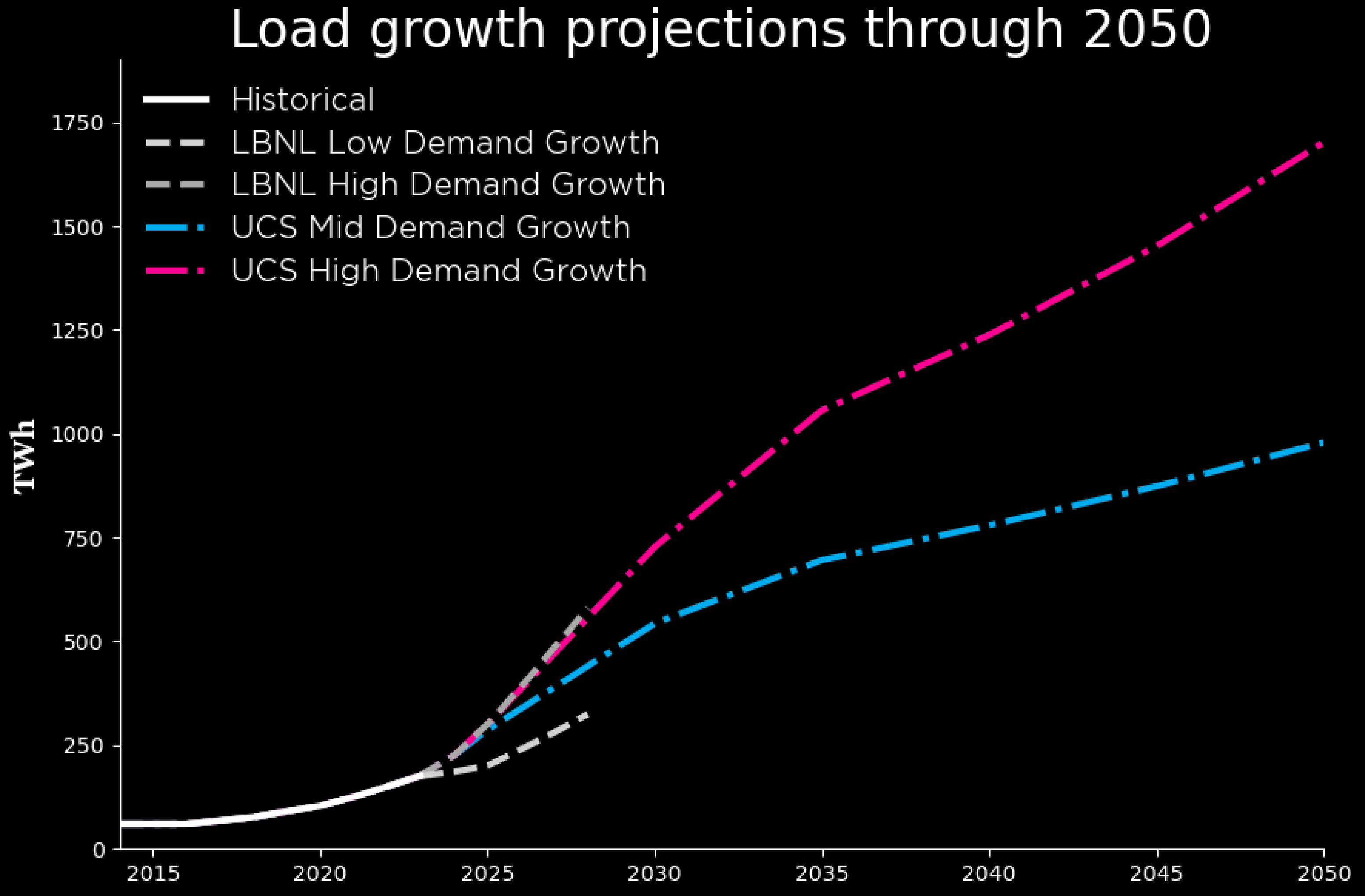
Modeling Scenarios

Policy scenarios

- **Current Policies:** Includes OBBBA; excludes EPA power plant carbon standards
- **Restored Tax Credits:** Extends clean energy credits based on IRA
- **Low-Carbon Policy:** Reduces US power sector CO_2 emissions 70% by 2035 and 95% by 2050, extends tax credits, includes EPA carbon standards, and increases transmission investment

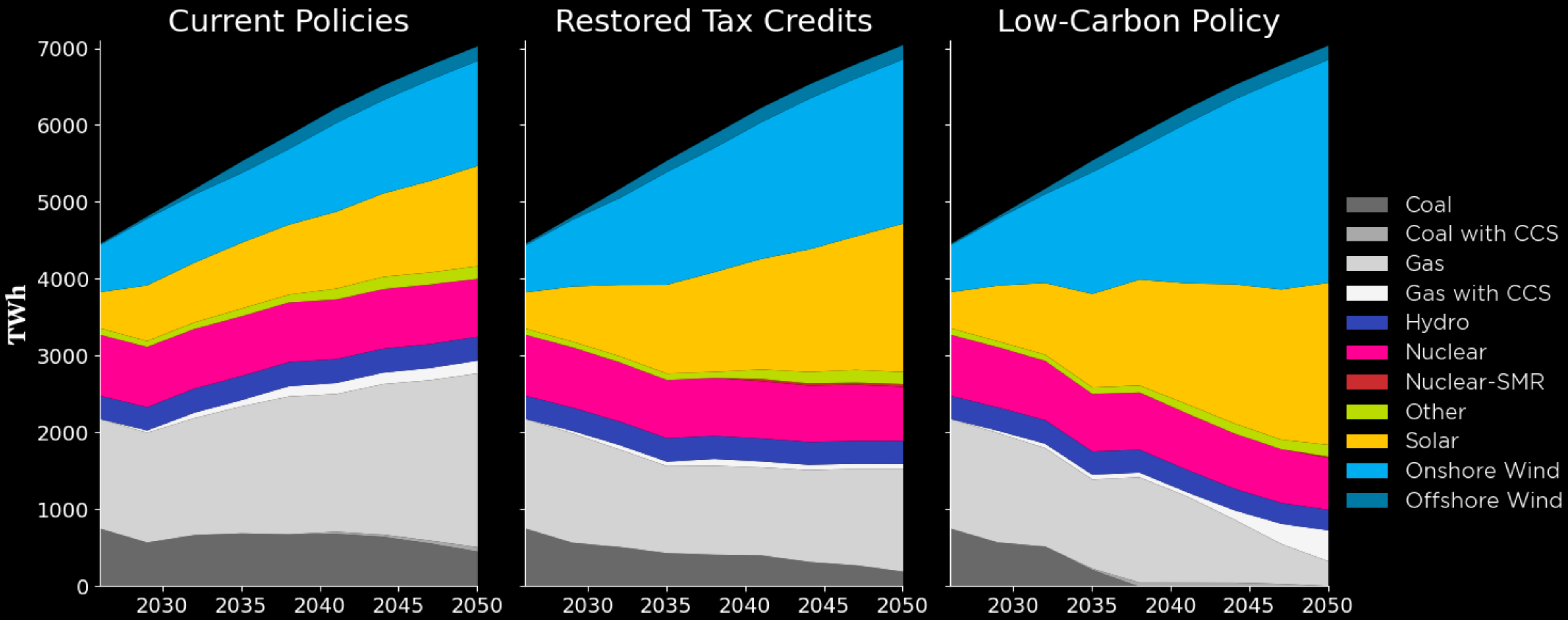
Data center demand growth scenarios

- **Mid Demand Growth**: mid-level assumptions for data center demand
- **No Demand Growth**: counterfactual to isolate data center impacts
- **High Demand Growth**: high data center demand sensitivity

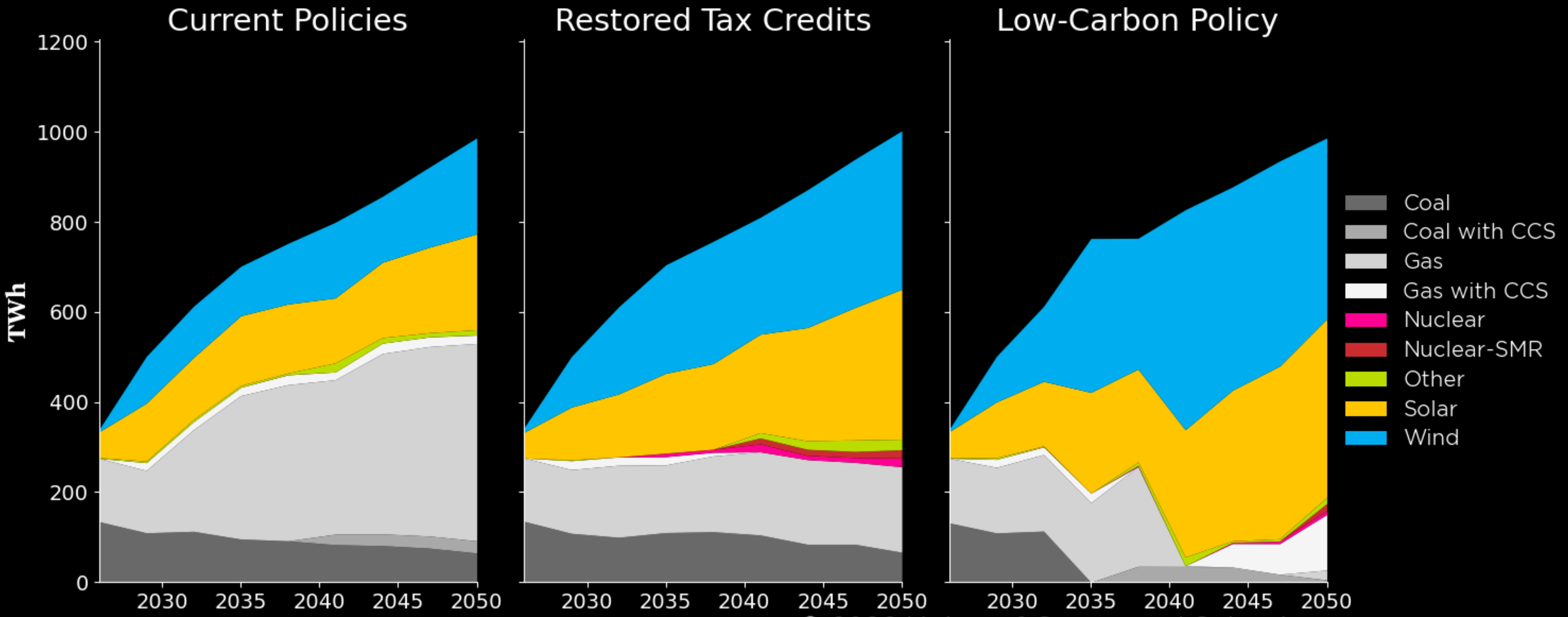


Load growth projections through 2050
Historical
LBNL Low Demand Growth
LBNL High Demand Growth
UCS Mid Demand Growth
UCS High Demand Growth
TWh
0
250
500
750
1000
1250
1500
1750
2015
2020
2025
2030
2035
2040
2045
2050

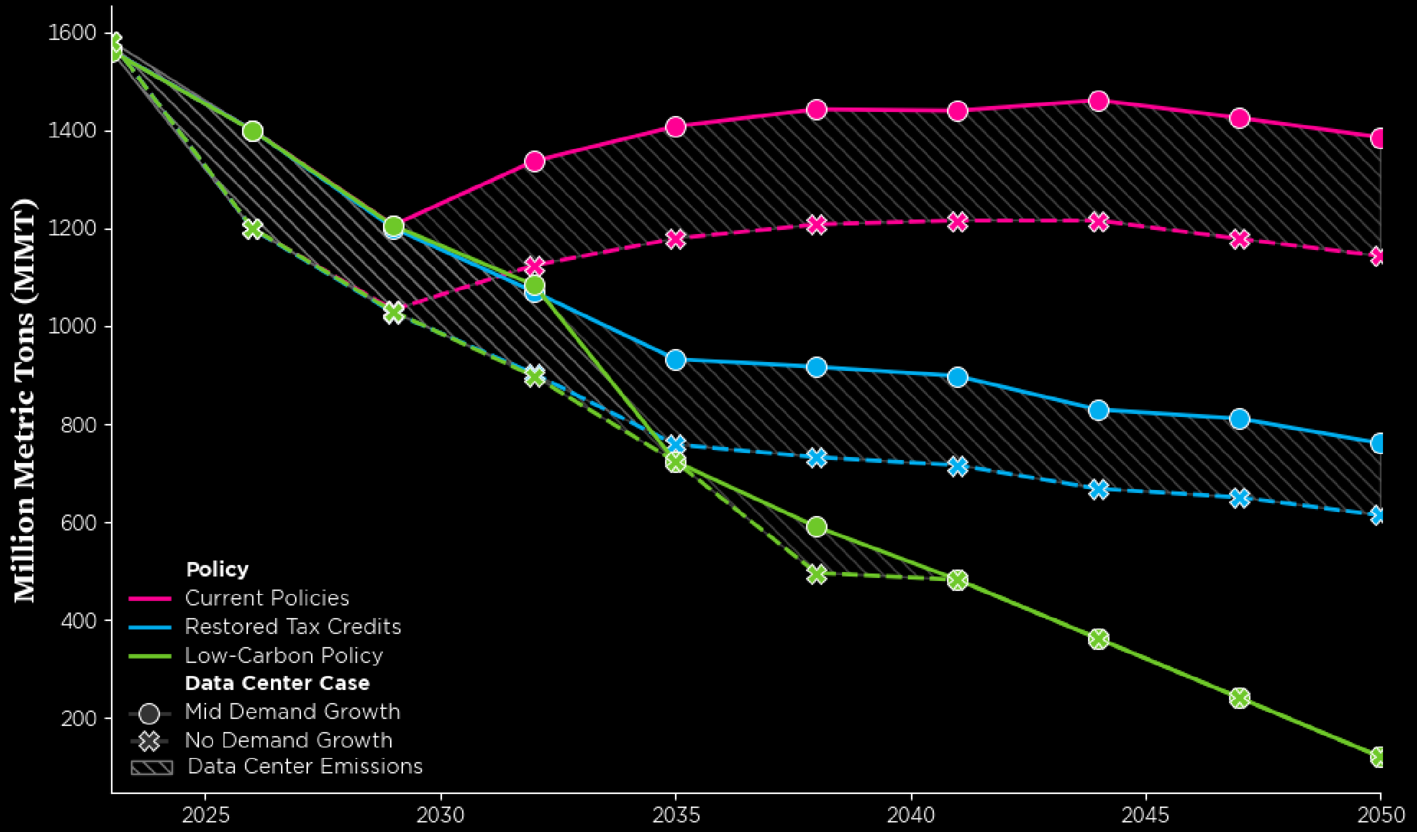
The U.S. can meet data center demand with clean energy



Impact of data centers on US electricity generation

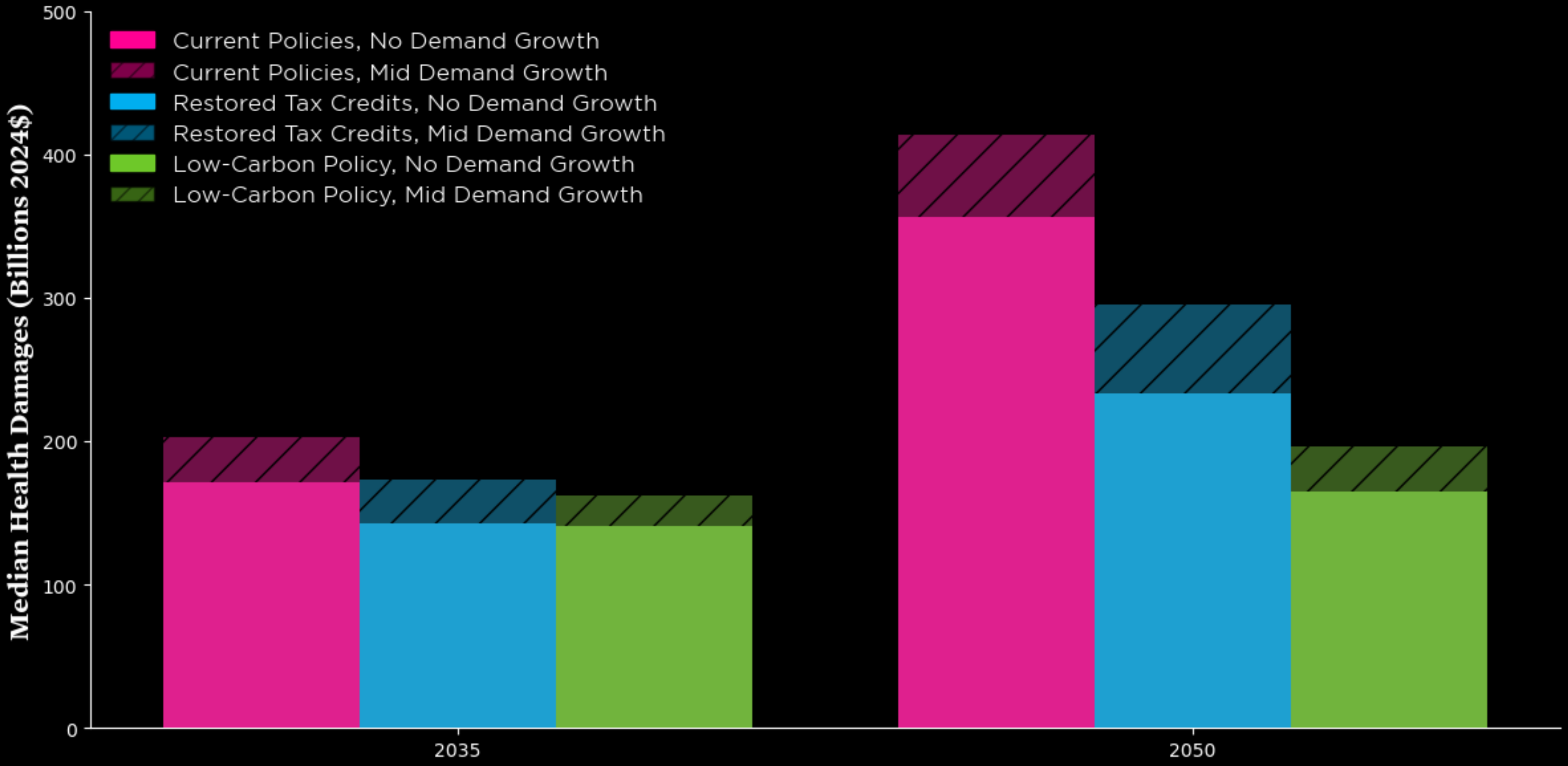


Investing in clean energy reduces power plant CO_2 emissions



Phasing out fossil fuels improves air quality

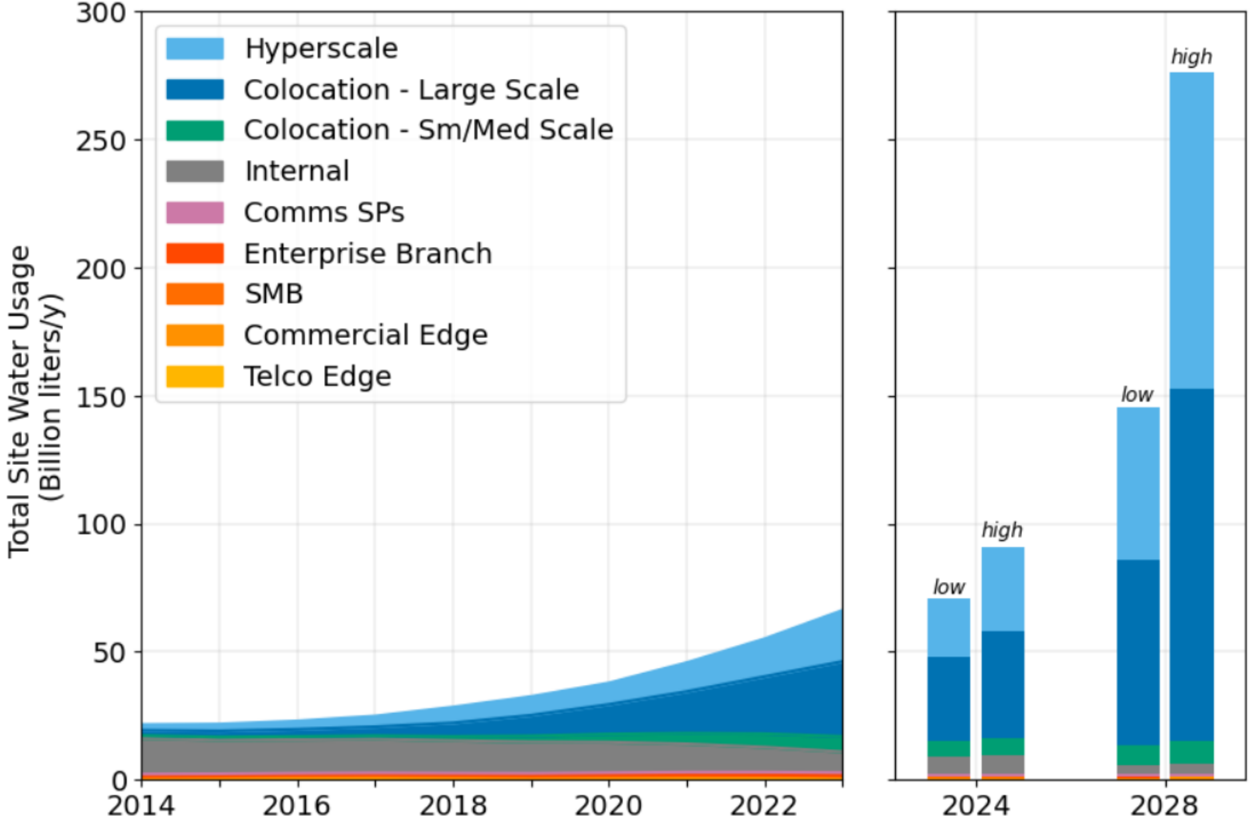
Clean energy policies save lives and lower health costs



Cumulative climate and health damages from data centers

	Current Policies		Low-Carbon Policy	
	2035	2050	2035	2050
Climate Damages (billions 2024$)	$1,547	$4,423	$1,165	$1,754
Median Health Damages (billions 2024$)	$32	$57	$24	$31
Median Additional Mortalities	998	1,777	672	977

Water consumption from data centers



- **66 billion liters** of direct water consumption **in 2023**.
- **800 billion liters** of indirect water consumption.
- Rates:
  - **0.38 L/kWh** (direct)
  - **4.52 L/kWh** (indirect)

Reproduced from: Shehabi, A., Smith, S., Hubbard, A., Newkirk, A., Lei, N., Siddik, M.A.B., Holecek, B., Koomey, J., Masanet, E., Sartor, D., 2024. 2024 United States Data Center Energy Usage Report (No. LBNL-2001637). Lawrence Berkeley National Lab (LBNL), Berkeley, California.

Key Findings

1. With stronger policies, **US can meet electricity demand** from data centers **primarily with clean energy** while phasing down fossil fuel use.
2. Data center growth puts ratepayers at **risk of large cost increases.**
3. **Clean energy policies reduce air pollution** and heat-trapping emissions from fossil fuels.
4. The climate and health **benefits of reducing fossil fuel use outweigh the costs** of transitioning to clean energy.
5. Forward-looking policies can avoid the health and environmental harms associated with the unmitigated growth of data centers.

Recommendations

1. Protect ratepayers from cost increases
    - Require data centers to pay for additional electricity costs
2. Increase transparency and accountability
    - Require utilities to do long-term planning for data center growth
    - Publicly report power needs, emissions, water use and other impacts
    - Include standards and guardrails to protect public health
3. Adopt stronger clean energy policies
    - Require additional clean energy to meet data center demand
    - Adopt fair interconnection rules that reduce barriers to clean energy

{ Thank You

Coauthors: Steve Clemmer, Maria Chavez, Sam Dotson, James Gignac, Sandra Sattler, and Lee Shaver

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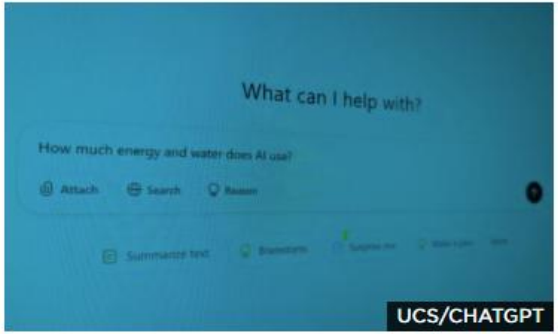
Extras

Want to learn more?



UCS/CHATGPT

June 25, 2025

What Are the Environmental Impacts of Artificial Intelligence?

JOSÉ PABLO ORTIZ PARTIDA

DIRECTOR OF INNOVATION AND COLLABORATION

THE DESERT PHOTO / GETTY IMAGES

January 21, 2026

Powering Data Centers with Clean Energy Could Avoid Trillions in Climate and Health Costs

STEVE CLEMMER

DIRECTOR OF ENERGY RESEARCH & ANALYSIS

WEST END 61 / GETTY IMAGES

March 4, 2026

Data Centers Are Changing the Grid. Our Energy Sources Should Evolve Too.

LEE SHAVER

SENIOR ENERGY ANALYST

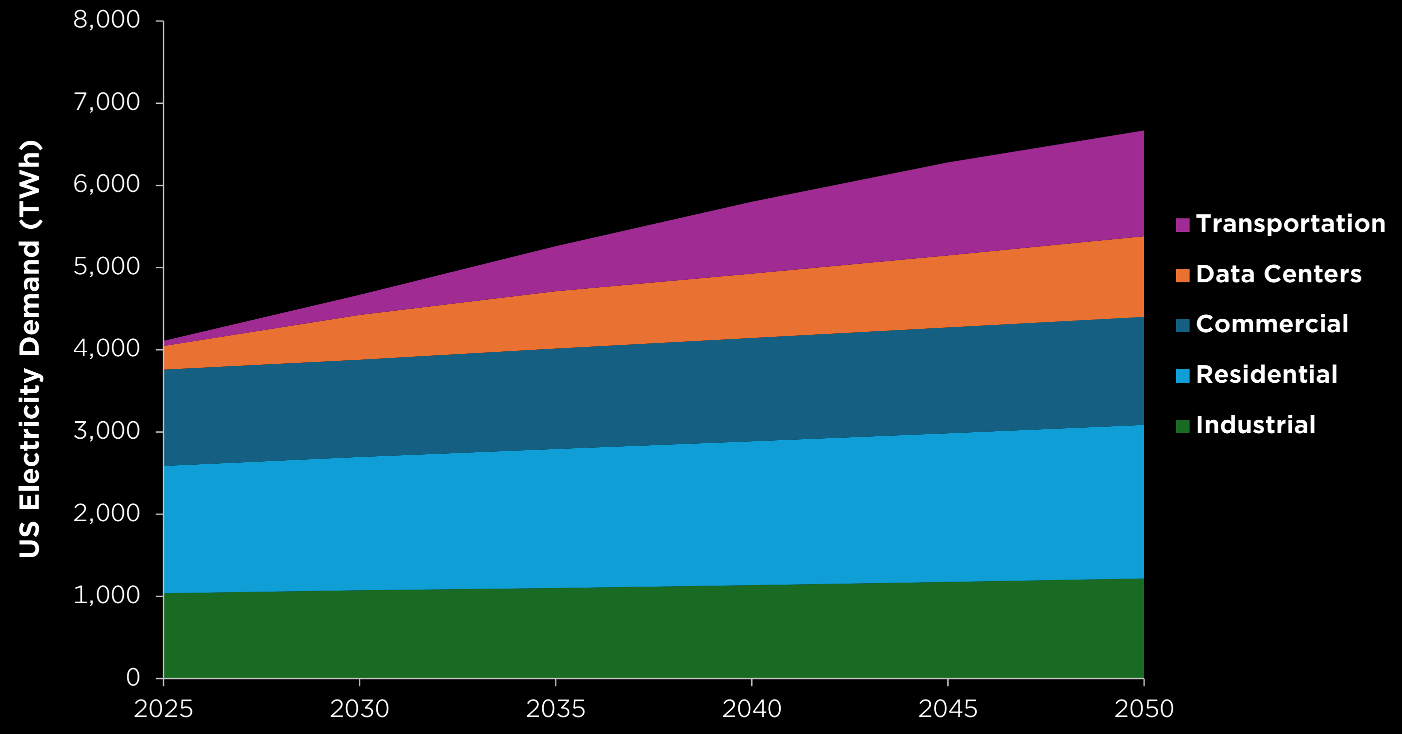
Research Questions

- What impact will AI data centers have on **electricity demand**?
- How much will data centers be **powered with fossil fuels vs. clean energy** under different demand and policy scenarios?
- What **impact** will data centers have **on electricity costs, emissions, public health and climate change**?
- What **policies and guardrails** are needed to ensure responsible growth in electricity demand from data centers while **protecting other customers from cost increases** and health and climate impacts?

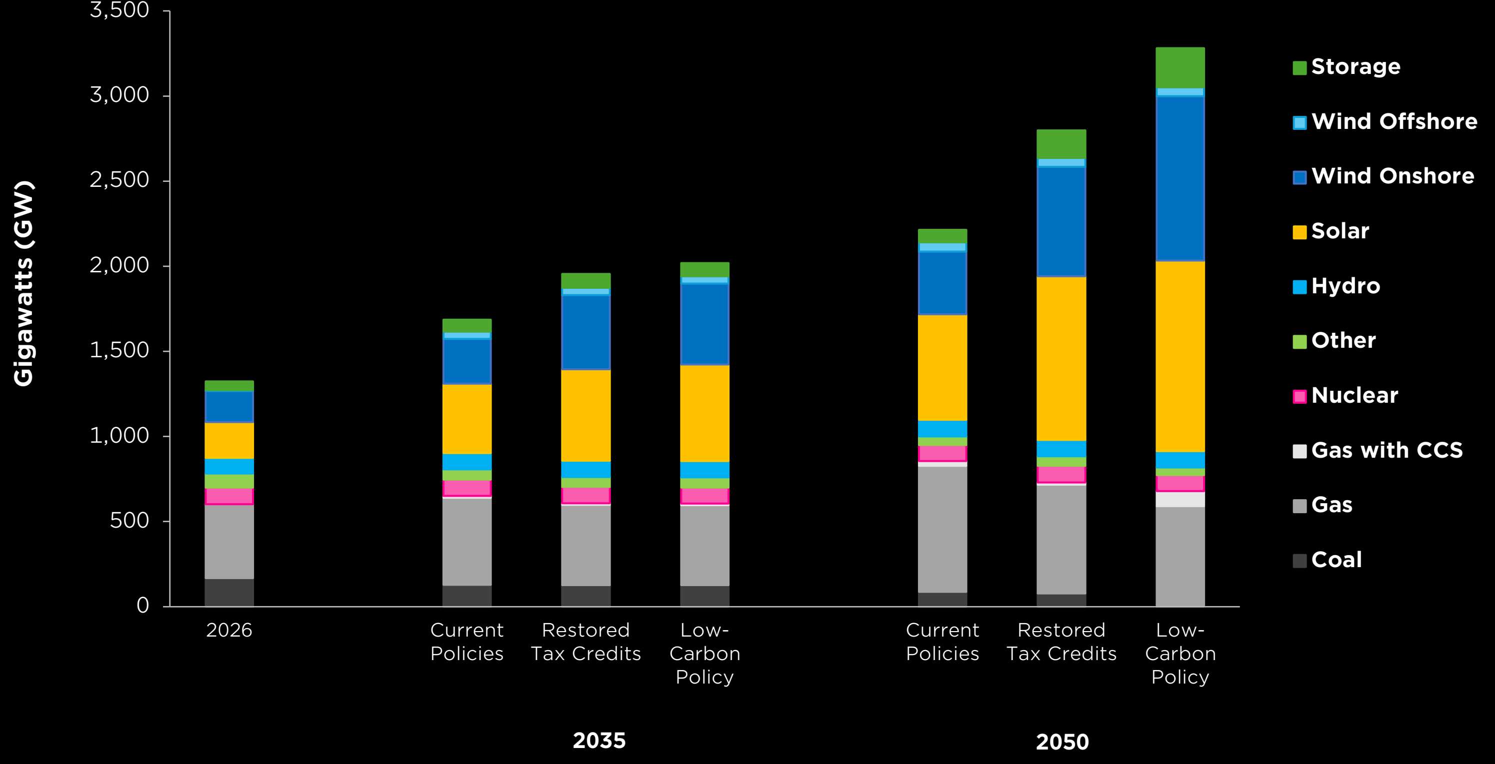
Tech Company Water Pledges

- Google aims to **replenish 120% of freshwater consumption** by 2030
- Microsoft aims to **replenish more water than they consume**.
- Meta wants to be **water positive by 2030**.
    - Replenish 200% of water in high stress regions.
    - Replenish 100% of water in medium stress regions.

US electricity demand by sector
(mid data center demand growth scenario)



US Electric Generating Capacity



Climate and health benefits of clean energy policies

	Restored Tax Credits		Low-Carbon Policy	
	2035	2050	2035	2050
Climate Benefits (billion 2024$)	$1,350	$8,350	$1,610	$13,120
Median Health Benefits (billion 2024$)	$30	$120	$40	$220
Median Avoided Mortalities	940	3,750	1,250	6,875