Data Center Demands & Impacts on the Energy System:

An Energy Horizons Special Report

September 26, 2024

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The OL24-NEMS model used in this analysis is a modified version of the U.S. Energy Information Administration's National Energy Modeling System (EIA NEMS) developed by OnLocation for use in this analysis. The OL24-NEMS model and results do not represent the views of EIA. OL24-NEMS is based on the EIA Annual Energy Outlook (AEO) 2023 and includes the same market and technology assumptions unless otherwise noted. For more information about EIA NEMS, visit https://www.eia.gov/outlooks/aeo/.

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Report Outline

Introduction

Current Market: Data Center General Overview

- The Why, What, Where, and How of Data Centers

Data Center Demand: Implications for the U.S. Power Sector

- Demand Distribution and Growth
- National Generation and Capacity
- Regional Generation and Capacity
- CO_2 Emissions

Further Research Opportunities

Caveats, Glossary, and Acknowledgements

Appendix

- Key Assumptions
- End Notes by Slide
- Data Sources

Introduction

Corporate Overview

KeyLogic

Mid-tier firm offering deep domain expertise in our country's most critical undertakings within the energy, federal civilian, and defense sectors

Innovative Integration

Large-scale data management, advanced analytics, enterprise transformation, science & technology advisory services, R&D management, and systems engineering

Thought Leaders in Emerging Technologies

Technology readiness scale: Experience in modeling and assessing range of energy-relevant technologies at low-technology-readiness levels

Critical Materials Expertise

Material and resource analysis, including life-cycle analyses, across the supply chain in support of energy production, generation, and storage technologies

OnLocation

Specialized firm with four decades of experience developing and applying innovative energy system and economic models to address key energy, climate, and environmental regulations and policies

Assess Role of New Energy Technologies

Evaluate system and economic impacts of new energy and climate mitigation technologies such as electric vehicles, biofuels, hydrogen, carbon capture & storage, and direct air capture

Explore Alternative Energy Futures

Design "what-if" scenarios and alternative energy futures for use in uncertainty analyses, including alternative energy prices, technology costs, and macroeconomic forecasts

Inform Energy & Environmental Policy

Perform economic impact assessments of new or proposed energy and environmental regulations and policies such as Inflation Reduction Act and EPA GHG Standards for Vehicles and Power Plants

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Why a Projection

EIA will not release an Annual Energy Outlook (AEO) in 2024.

OnLocation's report provides a projection for the benefit of the energy & climate modeling community.

OnLocation Energy Horizons (OL EH) is not a U.S. Government product.

Purpose of Energy Horizons Report & Data Center Focus

Provide updated reference case projections using OnLocation's version of the National Energy Model System (NEMS)

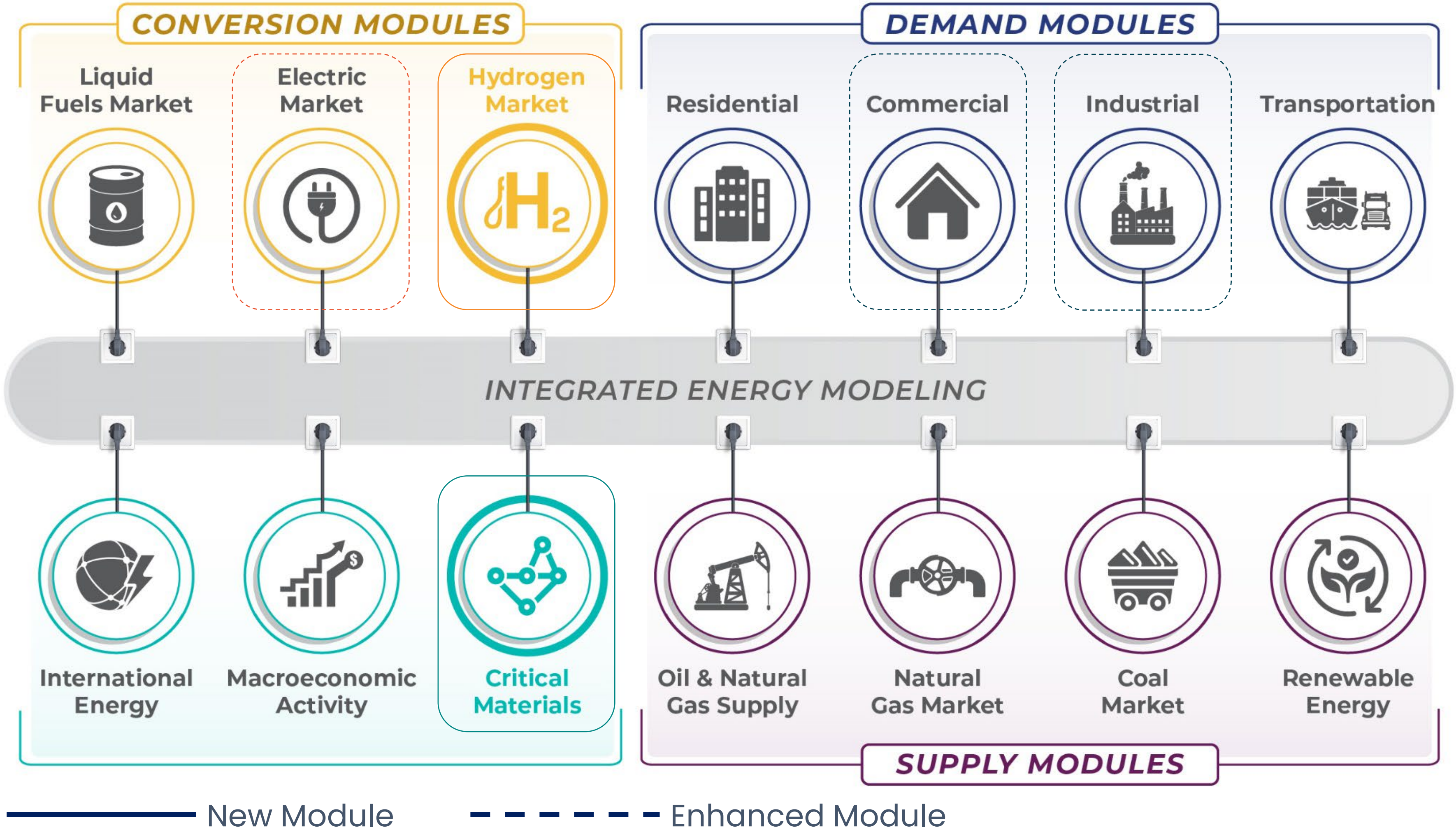
Update model representation of U.S. laws and regulations since EIA's AEO 2023 release in March 2023

Explore CO_2 mitigation strategies for the U.S. energy system

Demonstrate new model capabilities and enhancements

Evaluate key driving forces in the U.S. energy system (e.g., ***data centers***) and challenges to achieve deep decarbonization

OnLocation's Customized Version of the National Energy Modeling System (OL24-NEMS)



Development & Application of Energy System Models

- Analyzing Energy and Climate Policy Impacts
- Assessing New Energy Technologies
- Informing Cost-effective Approaches and Policies

Customization & Analyses

- Inflation Reduction Act
- Renewables and EV Expansion
- Hydrogen Economy
- Regional Data Centers
- Critical Materials Analysis

Official version of NEMS developed by the Energy Information Administration (EIA), U.S. DOE

Selected Drivers and Key Questions

What are the main data center types?

How is electricity consumption distributed across various components of a data center?

How many data centers are in the U.S. now and projected to 2050?

Where are data centers located and what factors drive new placements (price, workforce, permitting)?

What short-term constraints could limit data center expansion (reliable power, grid reliability)?

What are the potential impacts on electric grid reliability?

How can new generation – *traditional & microgrid* - be optimized to meet demand?

What clean alternatives can data centers use as a power-source and for backup?

What are the decarbonization goals of data center providers and their approaches to meeting them?

Insights from Three Scenarios

- **High Growth:** Rapid expansion tapering off after 2035
- **Low Growth:** Steady annual increase in demand
- **No AI Growth:** *Counterfactual* case to allow examination of incremental demand

Data Center Report Highlights

Data center demand growth, while substantial (comprising up to 13% of total demand by 2050), is expected to be met with an accelerated transition to clean energy sources, minimizing long-term emissions impacts.

Clean energy expansion is expected to take over by mid-century while natural gas and existing fossil capacity will continue to support demand growth in most regions in the near-term.

Multiple clean energy sources will be essential for meeting the growing demand for data centers:

- **Renewable generation**, especially solar photovoltaics and wind, which already account for most capacity additions in many regions.
- **Battery storage** extends the availability of renewable generation and enhances grid reliability.
- **Nuclear generation**, especially small modular reactors, could play an increasing role in later years as a stable, low-carbon energy source.

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Current Market: Data Centers General Overview

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Why are data centers important?

Data center power demand currently accounts for more than 4% of total U.S. electricity consumption.[1]

Consumer preferences continue to demand frequent and innovative products from energy-intensive data centers.

Digital transformation, boosted by the COVID-19 pandemic, drives data center energy demand:

- Cloud computing, artificial intelligence (AI) systems, digital services, and cryptocurrency mining operations.

Significant growth in near-term electricity demands in the U.S. with projections indicating a potential growth of 9-12% annually by 2030 and 15-20% by 2035.[1, 2, 3, 4]

- Driven by rapid expansion of AI models and applications, quantum computation by major tech companies, and cloud service providers such as Amazon, Google, and Microsoft.

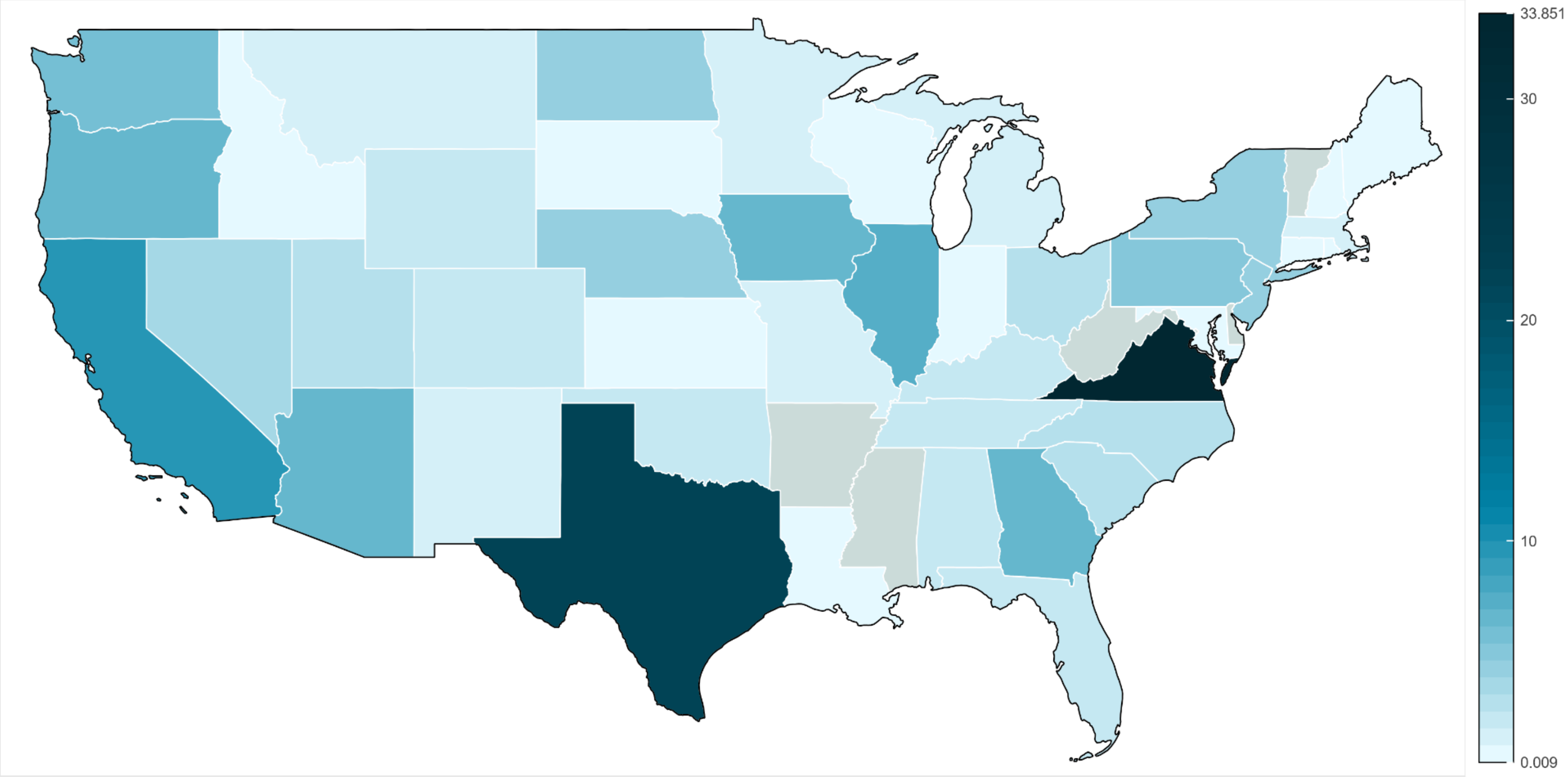
How can AI Benefit the Energy Sectors?

Increasing energy demands of generative AI might raise carbon emissions, however; it could also promote long-term sustainability through:[5]

- **Optimizing the power grid** (load forecasting, dynamic pricing, fault detection).
- **Expanding use of smart energy management** in buildings, transportation, industrial processes, and agriculture.
- **Improving weather forecasts** to better predict renewable energy generation such as wind and solar power.
- **Analyzing climate change impacts** more accurately.
- **Stimulating advancements** in large-scale and distributed clean energy technologies including wind, solar, battery storage, carbon capture and storage, and fuel cells.
- **Advancing technology performance** in data centers such as more efficient Heating, Ventilation, and Air Conditioning (HVAC) and lighting systems, servers, chips, semiconductors, etc.

How many data centers and where are they located in the U.S.?

Data Center Demand by State in 2023 (TWh)



- **5,388 U.S. data centers** as of August 2024.[6]
- **Power consumption** depends on the scale, design, specific use case of the facility, and energy efficiency of the equipment.[7]
- **Data centers are located across the country** with high concentrations in northern Virginia, Georgia, Texas, Arizona, California, Oregon, Washington, Iowa, Illinois, and Pennsylvania.

Source: OnLocation

Using state level data from EPRI 2024: Powering Intelligence, Analyzing Artificial Intelligence and Data Center Energy Consumption

What are the main data center types?

Primary Data Center Types:

- **Small-scale:** Includes server rooms and edge data centers. Serves localized operations such as small businesses, facilities, or individual customers. [8, 9]
- **Large-scale:** Serves extensive operations such as cloud computing, training models, and processing large datasets often for multiple businesses, governmental agencies, or entire industries. [9, 10, 11]
  - **Enterprise data centers**: 20-30% of the U.S. data center load
  - **Hyperscale and co-location data centers**: 60-70% of the U.S. data center load

Type	Size	% Bldg Load	Capacity
Small-scale	<10,000 sq. ft.	10%	500kW – 5MW
Large-scale	>10,000 sq. ft.	90%	>40MW

Types of Large-scale Data Centers: [9, 10, 11]

- **Enterprise data centers** are controlled by one organization for the purpose of storing important IT infrastructure and other elements necessary for processing, storing, and managing the organization's data and applications.
- **Co-location data centers** are facilities that provide server hosting and hardware services for multiple businesses that share infrastructure.
- **Hyperscale data centers (>100,000 Sq. Ft.)** support and service major cloud providers such as Amazon, Google, and Microsoft and can quickly expand to accommodate extensive computing and storage requirements.

How is electricity consumption distributed across various components of a data center?

The electricity use within a data center is mainly driven by three key areas and their consumption range can differ by data center size: [12, 13, 14]

% Data Center Total Energy Consumption

IT Equipment	Cooling Systems	Auxiliary Components
40%-65% (80%-90% for large centers)	30% - 40%	10% - 30%

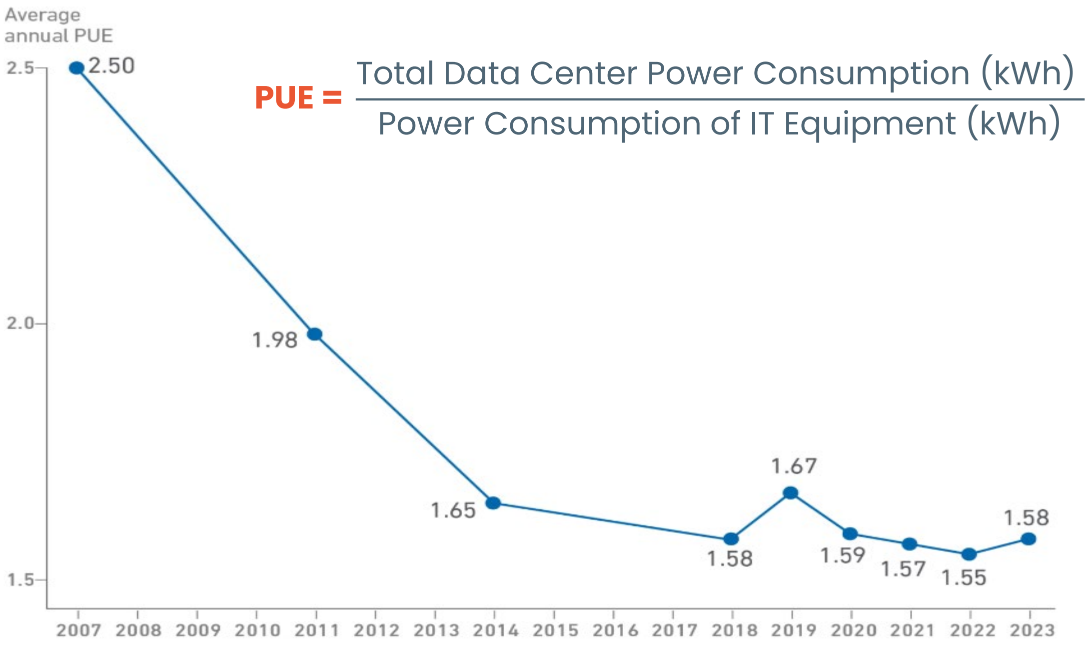
- **Servers:** The largest energy consumers, handling most data processing and computational tasks.
- **Storage Systems:** Include both conventional hard disk drives and more energy efficient solid-state drives for data storage.
- **Network Infrastructure:** Comprises switches, routers, and other essential components for effective data transfer and connectivity.

- **Essential for maintaining optimal temperatures** to prevent overheating and prolong the lifespan of hardware.
- **Cooling methods range from traditional HVAC systems to more advanced technologies** like liquid cooling, immersion cooling, and economizers.

- **Uninterruptible Power Supply (UPS):** Provides emergency power during power outages to ensure constant operation.
- **Security Systems:** Consist of cameras, sensors, and access control systems for safeguarding data centers.
- **Lighting:** Accounts for a small percentage of the total energy consumption.

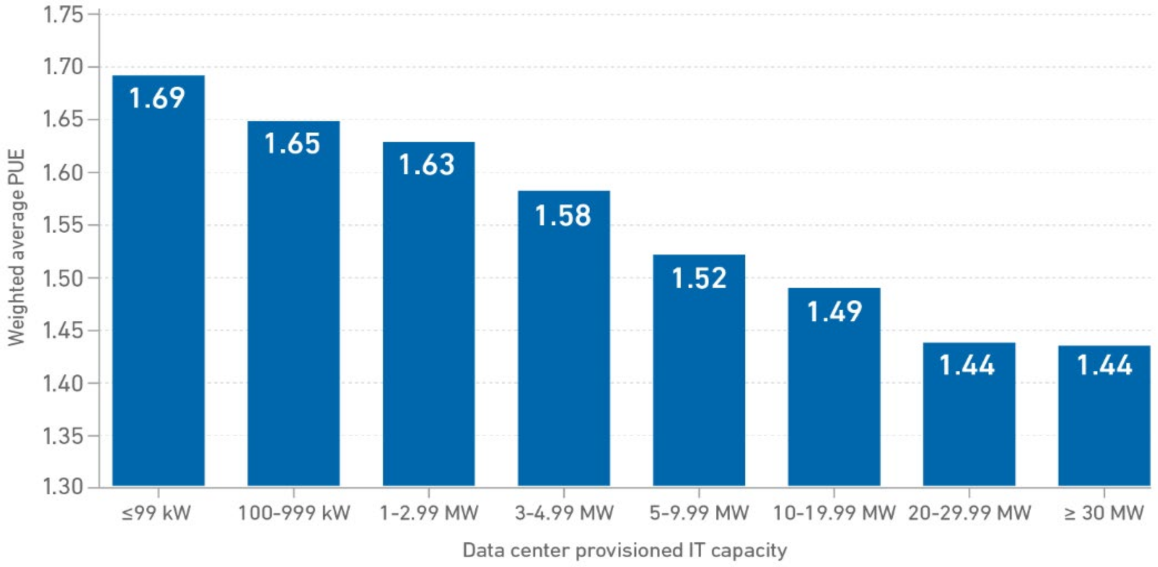
What is Power Usage Effectiveness (PUE) of a data center?

$$PUE = \frac{\text{Total Data Center Power Consumption (kWh)}}{\text{Power Consumption of IT Equipment (kWh)}}$$



UPTIME INSTITUTE GLOBAL SURVEY OF IT AND DATA CENTER MANAGERS 2023

Figure 1. Weighted average PUE by data center IT capacity



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UPTIME INSTITUTE GLOBAL SURVEY OF IT AND DATA CENTER MANAGERS 2023

- Per Uptime Institute, the global industry average PUE across all data centers is 1.58 in 2023.[15]
- Hyperscale and large cloud providers (Google, Amazon Web Services) claim PUE values of ≤1.2 at some sites.[15]
- Larger data centers tend to have lower PUE values compared to smaller centers due to newer, more efficient equipment and optimized designs and control systems.[16]

What short-term constraints could limit data center expansion?

Power infrastructure and backup systems

- Average construction timeline before 2020 was 1-3 years. Limited access to power means it can now take 2-6 years.
- Large data centers needing >100 MW of electricity wait up to 7 years to connect to the grid.[17]

Infrastructure and technological requirements

- Impacted by supply chain for servers, chips, semiconductors, HVAC systems, security and data protection.

Highly specialized and skilled workforce needs

- Increasing demands for expertise in network engineering, cybersecurity, hardware maintenance, automation, and systems architecture.

Site selection and land acquisition

- Highly impacted by power and internet connection availability, community resistance, restrictive permitting, and compliance with regulations and policies.[18, 19]

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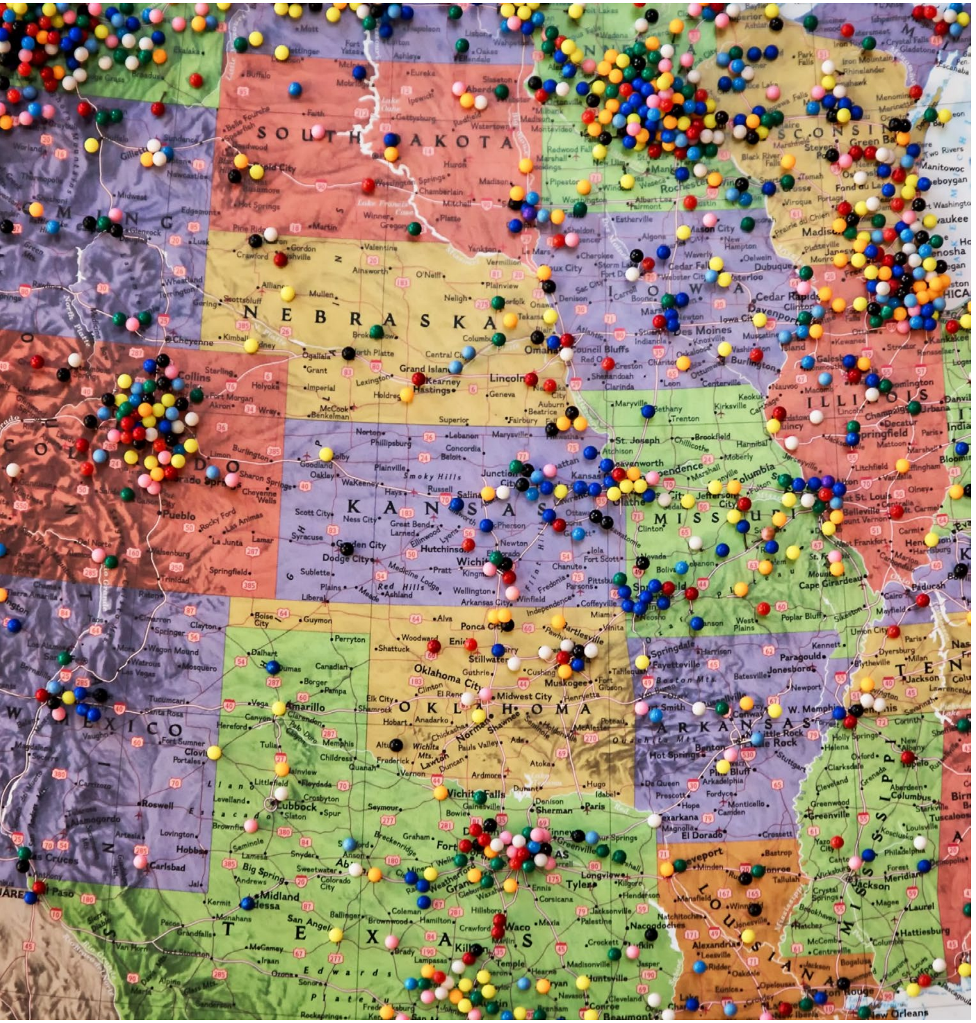
What short-term constraints could limit data center expansion?



Permitting and regulatory hurdles

- Zoning approvals
- Environmental impact assessments
- Building permits
- Compliance with different regulations at local, state, and federal level. In states like CA, NY, IL, and VA, new regulations are emerging that can affect data center development:
  - CA Climate Corporate Data Accountability Act (SB 253) and Greenhouse Gases: Climate-Related Financial Risk Act (SB261)[20, 21]
  - NY Senate Bill S987A and S5437 (In Committee Senate)[22, 23]
  - IL Bill HB4268 (Referred to Rules Committee)[24]
  - VA has multiple bills in place related to electricity costs impact (SB 191), environmental pressures (SB 285, HB 338), non-carbon-emitting power sources (SB 192), location restrictions (SB 284, SB 286), and even noise control (SB 288).[25, 26, 27]

What are the decarbonization goals of data center providers and their approach to meeting them?

Data center operators require energy sources that can be rapidly deployed and are economically viable, environmentally friendly, and dependable. While it is expected that data centers will become more efficient over time, they are also expanding considerably in both capacity and land requirements.

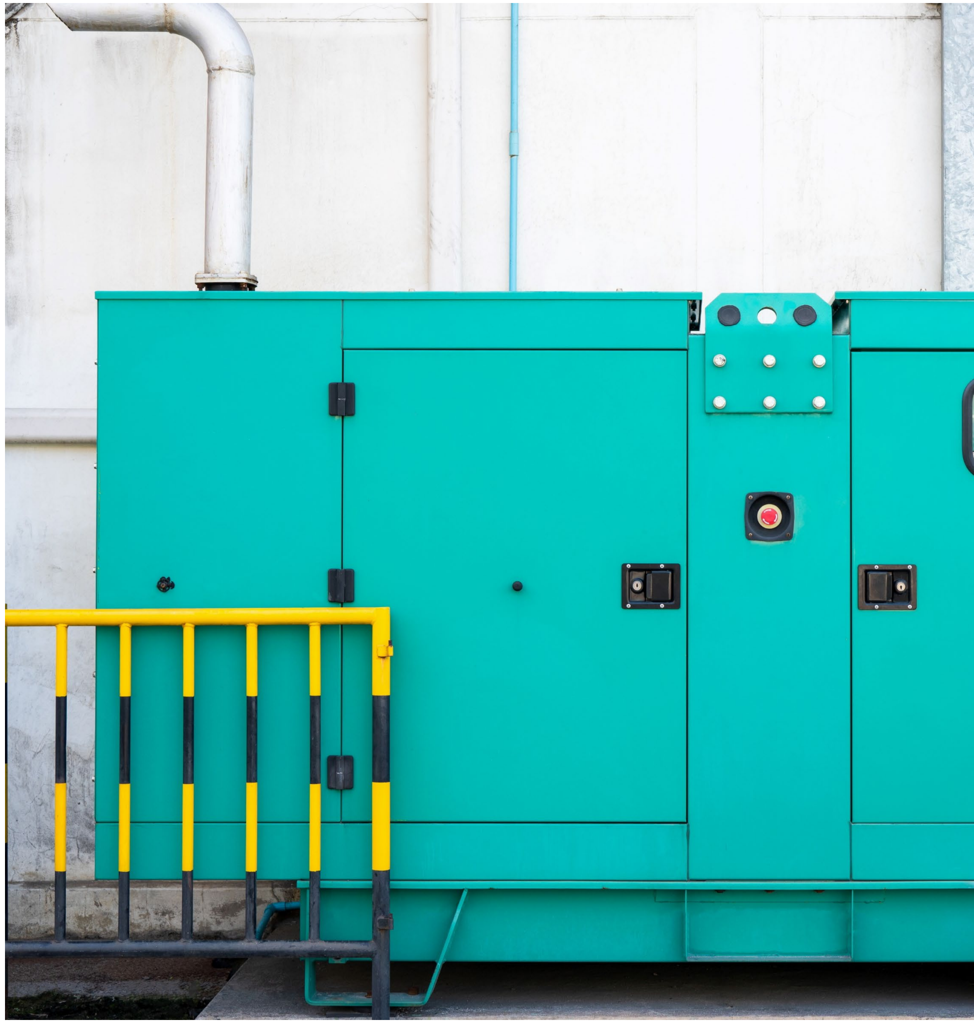
This growth in scale presents new challenges alongside the fact that major technology companies often set ambitious targets for reducing their carbon footprints:[28, 29]

- **Amazon:** net-zero carbon emissions across its entire business by 2040 and powering its operations with 100% renewable energy by 2025 including data centers, warehouses, and delivery networks.[30]
- **Google and Meta:** net-zero emissions across operations and value chain by 2030, operating Google's data centers and office campuses on 24/7 carbon-free energy, such as solar and wind.[31, 32]
- **Microsoft:** carbon negative by 2030 and remove all historical carbon emissions by 2050, shift to 100% supply of renewable energy by 2025, water positive (replenishing more water than they consume) by 2030.[33]

Hyperscale providers face challenges in implementation of their ambitious sustainability goals with increasing energy demands of AI technologies, particularly regarding their indirect emissions (Scope 3). Including traditional power generation technologies that result in high air emissions could lead to extended permitting timelines and increased expenses for emission control technologies.[29]

What clean alternatives can data centers use as power-source and for backup?

With the growing importance of renewable energy integration, climate impacts, extreme weather events, and concerns over grid reliability, a robust and clean primary source of electricity and backup power is critical for data center operations.[34, 35, 36, 37, 38, 39]



Clean electricity generation:

- Geothermal
- Modular nuclear reactor
- Hydropower
- Fossil with carbon capture and storage
- Solar and wind with storage

Most U.S. data centers currently rely on diesel generators for backup power, typically sized to match the facility's load capacity.[40, 41, 42, 43, 44, 45, 46, 47]

Reliable, low environmental impact backup power:

- Batteries
- Fuel cells
- Solar and wind power with battery storage
- Compressed air energy storage
- Alternative fuel generators

What are recent investments in clean power for data centers?

- **Meta**, partnering with Sage Geosystems, aims to power its data centers with geothermal energy, with implementation expected by 2027.[48, 49]
- **Microsoft** plans to use small modular reactors and microreactors to power its data centers.[50, 51] Microsoft is also working with Constellation Energy to reopen Three Mile Island nuclear plant to provide 835 MW power for its data centers for the next 20 years.[52]
- **Google** partnered with Fervo to run a geothermal energy project in NV to power Las Vegas and Reno data centers.[53]
- **Iron Mountain** purchases power from Rye Development (hydropower developer) to support data center projects in PA and WV. The purchase is for up to 150 MW of geothermal power over the next 10 years.[54, 55]
- **Amazon Web Services** will purchase electricity from Talen Energy's existing nuclear plant to power its newly-acquired data center campus in PA.[56]

What are the strategies for data center providers to pursue their decarbonization goals?

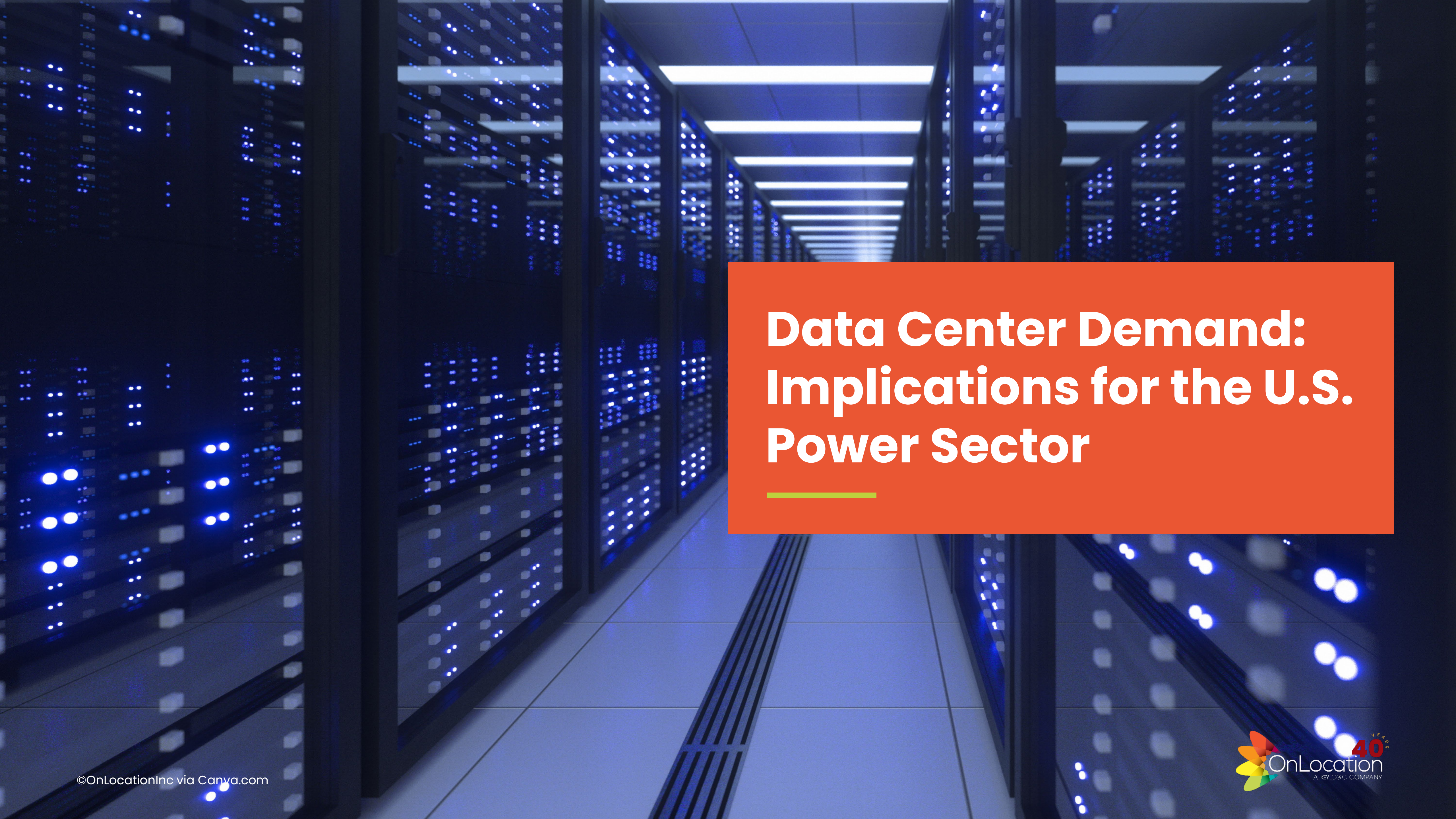
Data center providers can pursue sustainability goals by combining technological innovations, operational improvements, and broader industry collaborations:[57, 58, 59, 60, 61]

- **Investing in renewable energy projects**, green hydrogen, energy storage, advanced geothermal, nuclear power, and carbon removal technologies.
- **Improving energy and water efficiency** in data centers and facilities (air-cooled systems to reduce water consumption).
- **Exploring possibilities to re-use waste heat** from data centers (heat recovery and circular energy systems).
- **Repairing and recycling servers** to reduce e-waste, energy use, and associated environmental impacts (circular economy).
- **Utilizing AI, machine learning, and optimization** to account for factors such as seasonality, weather, IT capacity, lower maintenance costs, risk of human errors, equipment failure, and power outages.

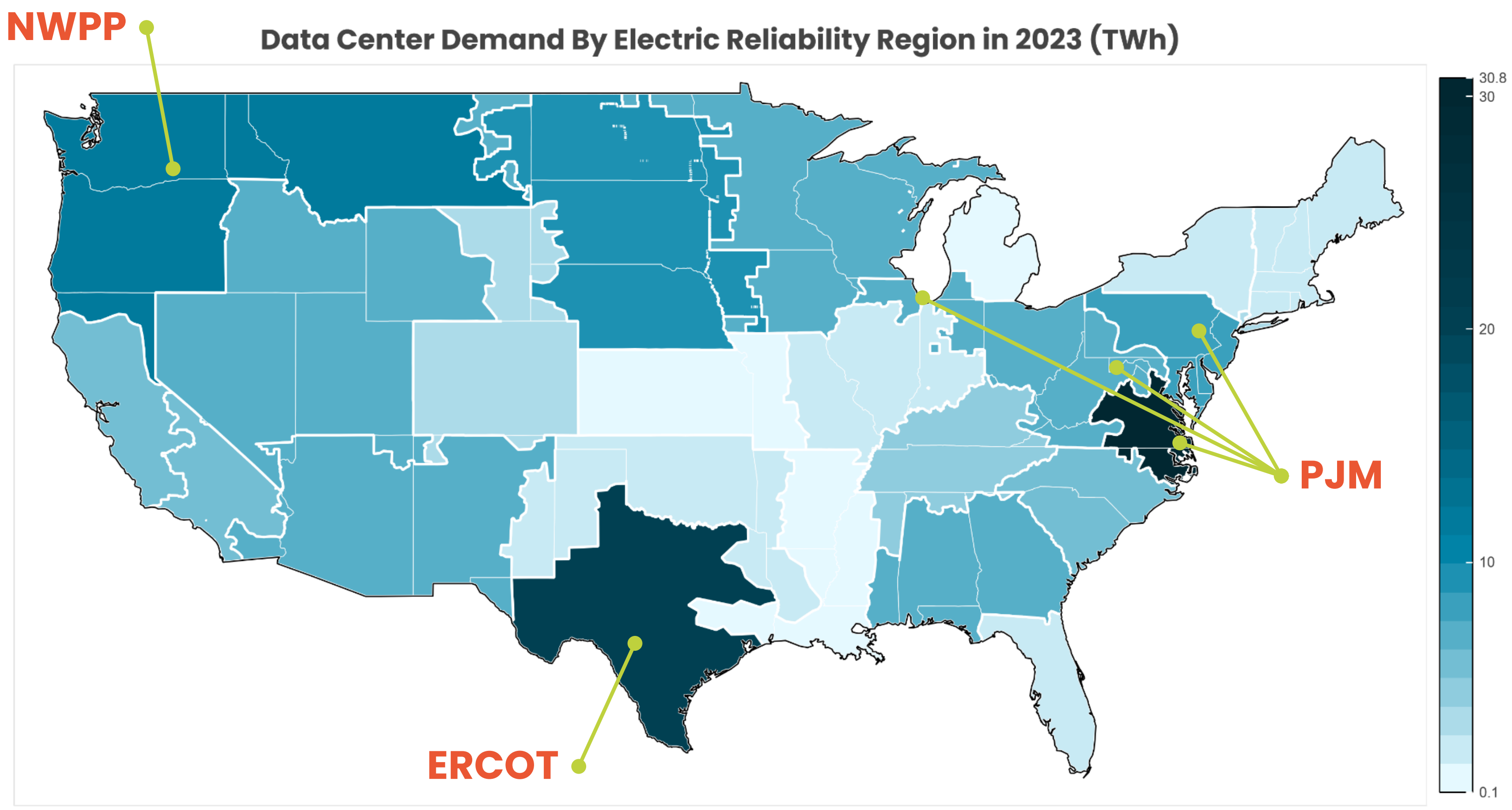
What are the strategies for data center providers to pursue decarbonization goals?

- **Developing decentralized (modular) data centers**, compaction, and better facility design to reduce land usage and ecosystem damage.
- **Building data centers** in locations with naturally cooler climates or access to renewable energy sources to minimize cooling costs and emissions.
- **Utilizing smart grid technologies** and engaging in demand response programs to match energy supply with demand more effectively.
- **Getting suppliers involved** in cutting emissions in their supply chains.
- **Investing in tools and procedures** to track power usage, equipment efficiency, and carbon emissions from various components of a data center and report their findings.
- **Purchasing carbon offsets** to neutralize remaining emissions (reforestation, methane capture).
- **Collaborating** with utilities, governments, and NGOs to share best practices, technologies, and strategies for reducing carbon footprints.

Data Center Demand: Implications for the U.S. Power Sector



Highly Concentrated Demand Is Reshaping Regional Power Systems



Source: OnLocation

Using state level data from EPRI 2024: Powering Intelligence, Analyzing Artificial Intelligence and Data Center Energy Consumption

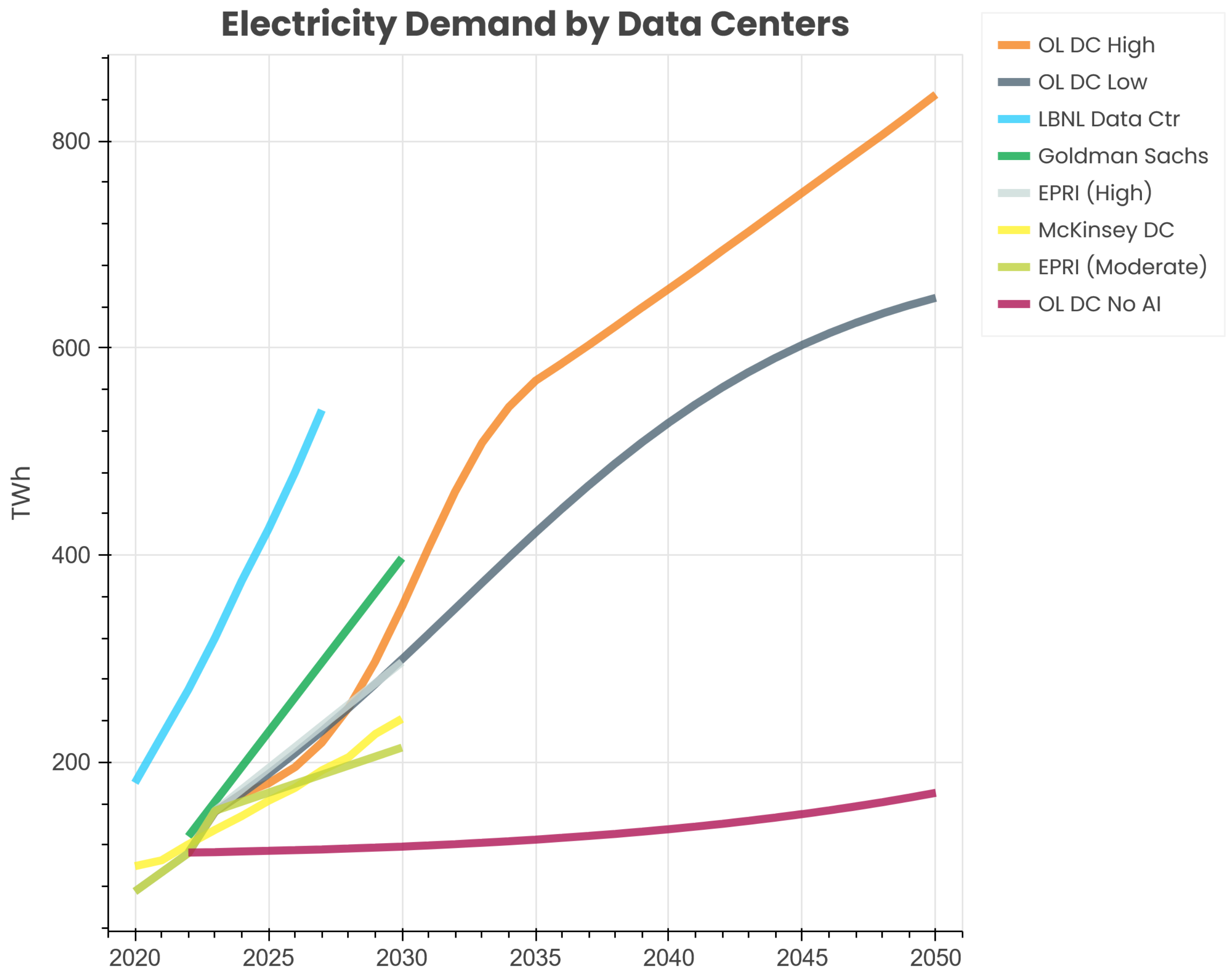
- Our analysis allocates data center electricity demand across 25 electric reliability regions.
- Regional differences in generation mix mean location of additional demand directly impacts capacity expansion, emissions, and grid reliability.
- Key considerations:
  - How does continued regional clustering affect power systems?
  - How does growth in fossil fuel-dominated regions compare to clean energy regions?

Growth is Significant but Highly Uncertain

- Three scenarios to assess the range of potential data center demand growth:
  - **High Growth:** Rapid expansion tapering off after 2035.
  - **Low Growth:** Steady annual increase.
  - **No AI Growth:** A counterfactual case to allow examination of incremental demand.

- Scenarios are based on our **Energy Horizons** *Reference* case which includes current energy policies such as Inflation Reduction Act incentives and EPA greenhouse gas regulations.

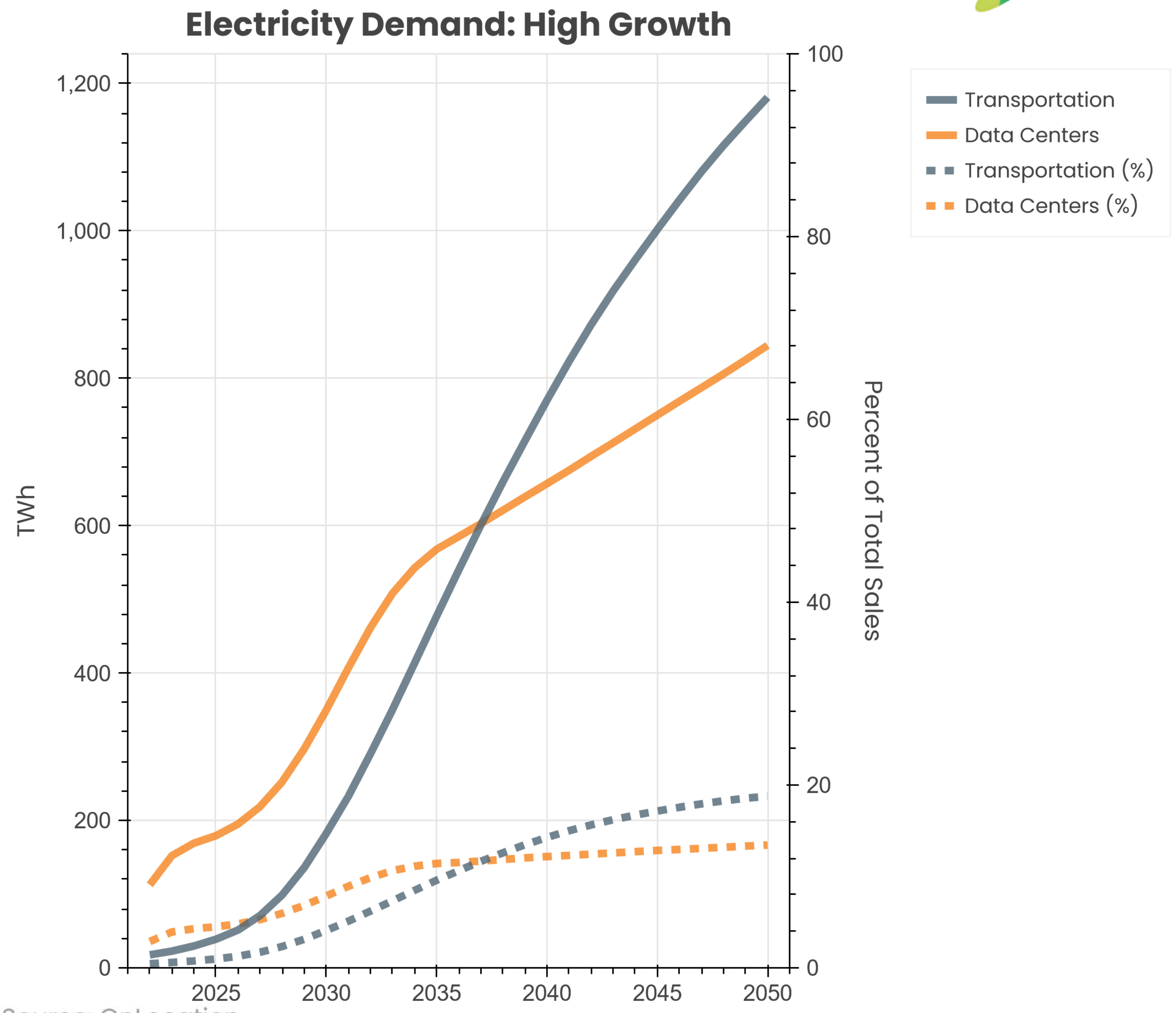
- Growth is assumed to be uniform across regions with demand fully met by grid-based electricity.



Source: OnLocation

Data Center Growth May Exceed EVs in Near-Term

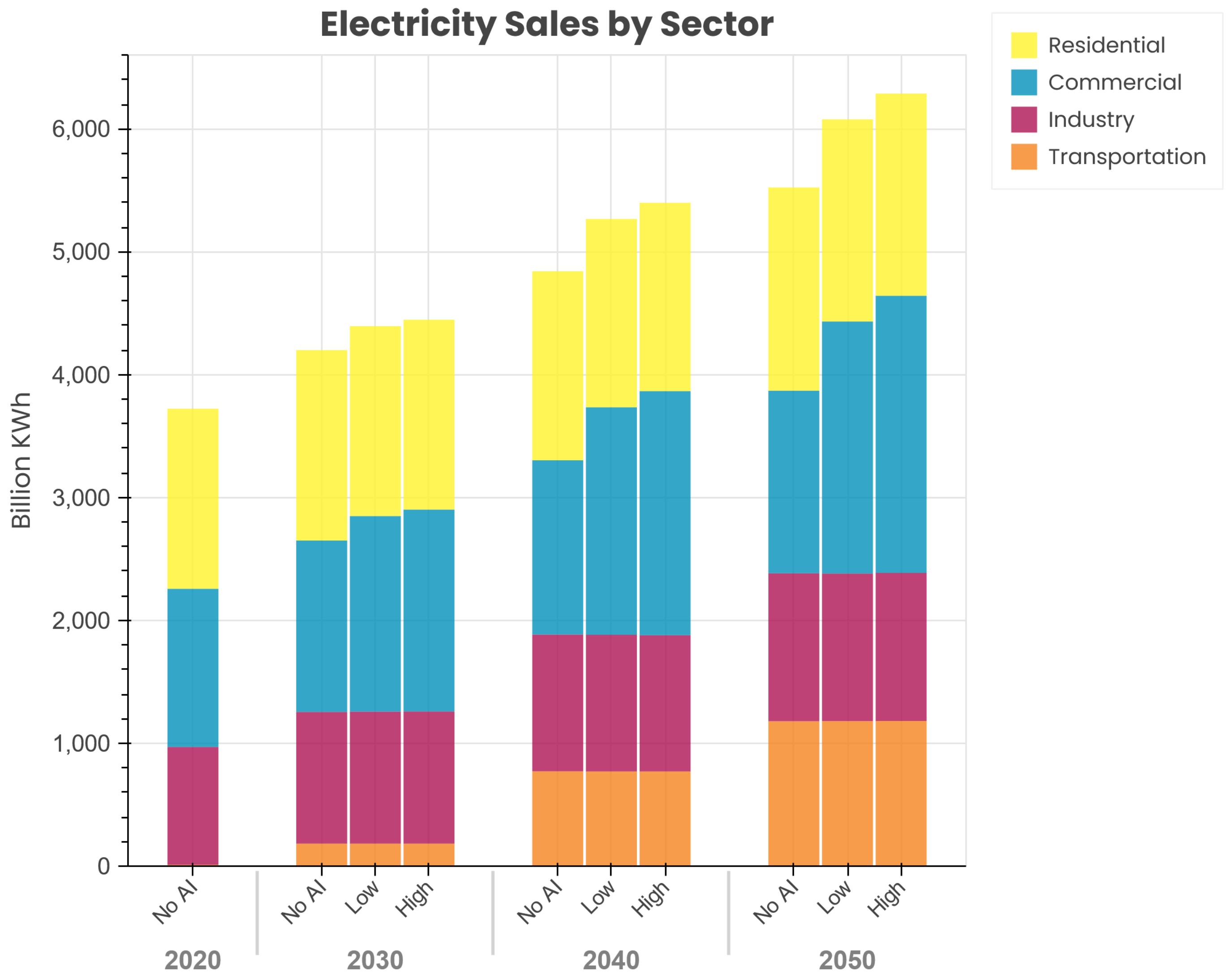
- Scenarios include over 600 TWh of growth in data center demand over the next 30 years, making up nearly one-third of commercial electricity demand by 2050.
  - Equivalent to ~130 GW of new natural gas power plants.
- Data center electricity demand is growing rapidly and is likely to outpace demand growth in electric vehicles (EVs) in the near term.
- Both data center and EV demand growth are highly uncertain, but both will play a critical role in shaping the decarbonization of the U.S. economy.
- From late 2030s to 2050, combined load could range from 30% - 35% of total demand.



Source: OnLocation

National Electricity Demand

- Data centers add significant demand to overall load growth, building on the broader economy-wide electrification trend.
- National electricity demand is projected to grow by 48% from 2020 to 2050, due primarily to increased electricity use in vehicles, even without AI-driven data center growth.
- In the High Growth scenario, demand could rise up to 69% by 2050, factoring in significant data center expansion.
- Across all scenarios, load growth in other energy sectors remains consistent.



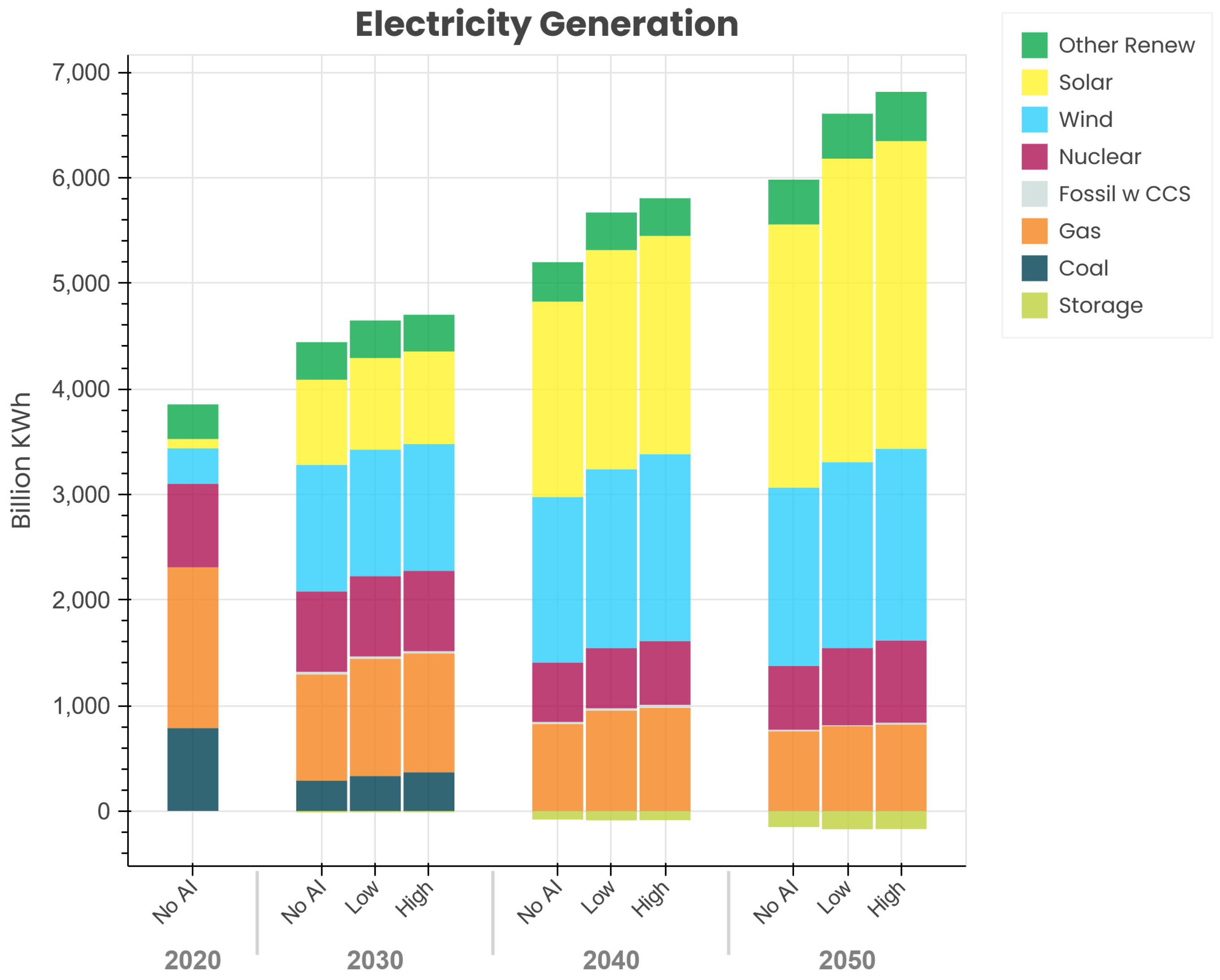
Source: OnLocation OL24-NEMS

National Electricity Generation

- Data center demand leads to increased generation of all types:
  - Initially met by existing natural gas plants.
  - Expansion of renewables accelerates, driven by decreasing costs and IRA incentives.
  - Nuclear increases in later years with new facilities and delayed retirement of existing units.

- In the High Growth case (relative to No AI case), clean generation comprises roughly 23% of incremental generation in 2030, rising to 75% by 2040 and 92% by 2050.

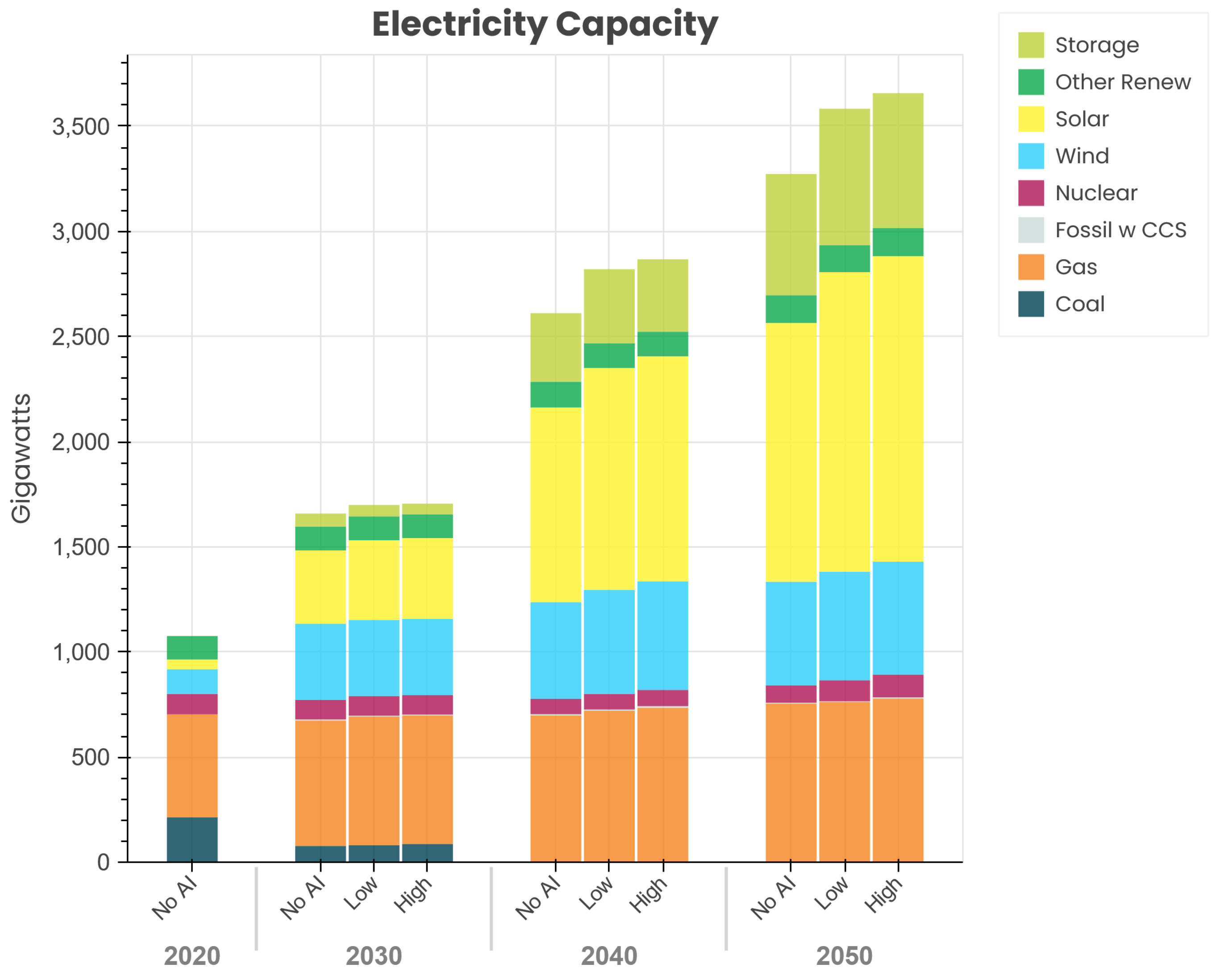
- Through 2050, new clean energy generation outpaces the additional demand from data centers.



Source: OnLocation OL24-NEMS

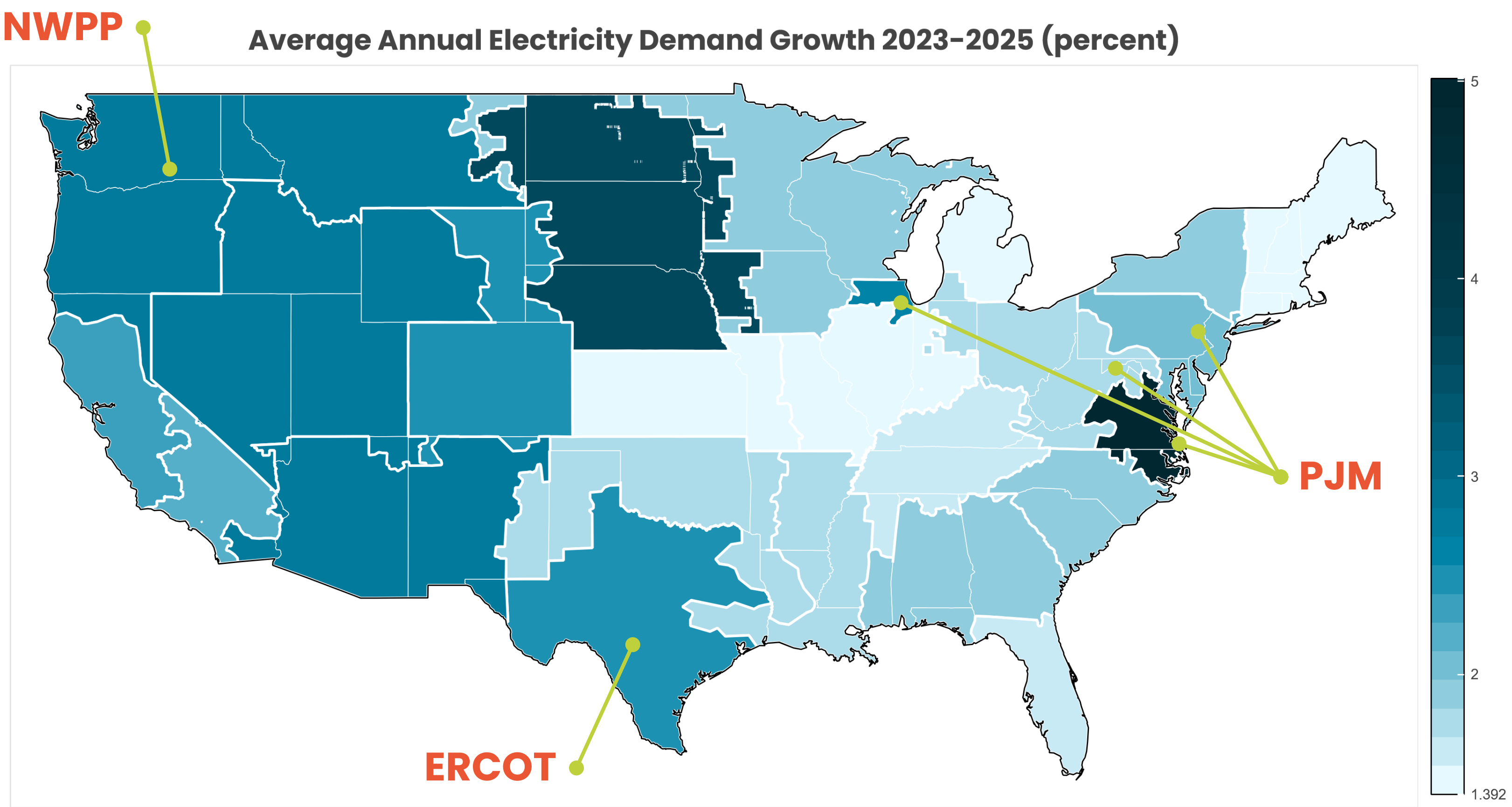
National Electricity Capacity

- Initial capacity increases to meet data center demand are largely driven by natural gas, solar, and battery storage.
- Wind and solar dominate capacity additions with batteries providing essential grid support.
- Additional gas capacity, primarily from combustion turbines, is added to enhance grid reliability.
- In the longer term, nuclear capacity rises due to retention of existing facilities (which retire in the No AI case when the IRA support expires) and new construction of small modular reactors.



Source: OnLocation OL24-NEMS

Data Centers with Other Factors Lead to High Electricity Demand Growth in Many Regions

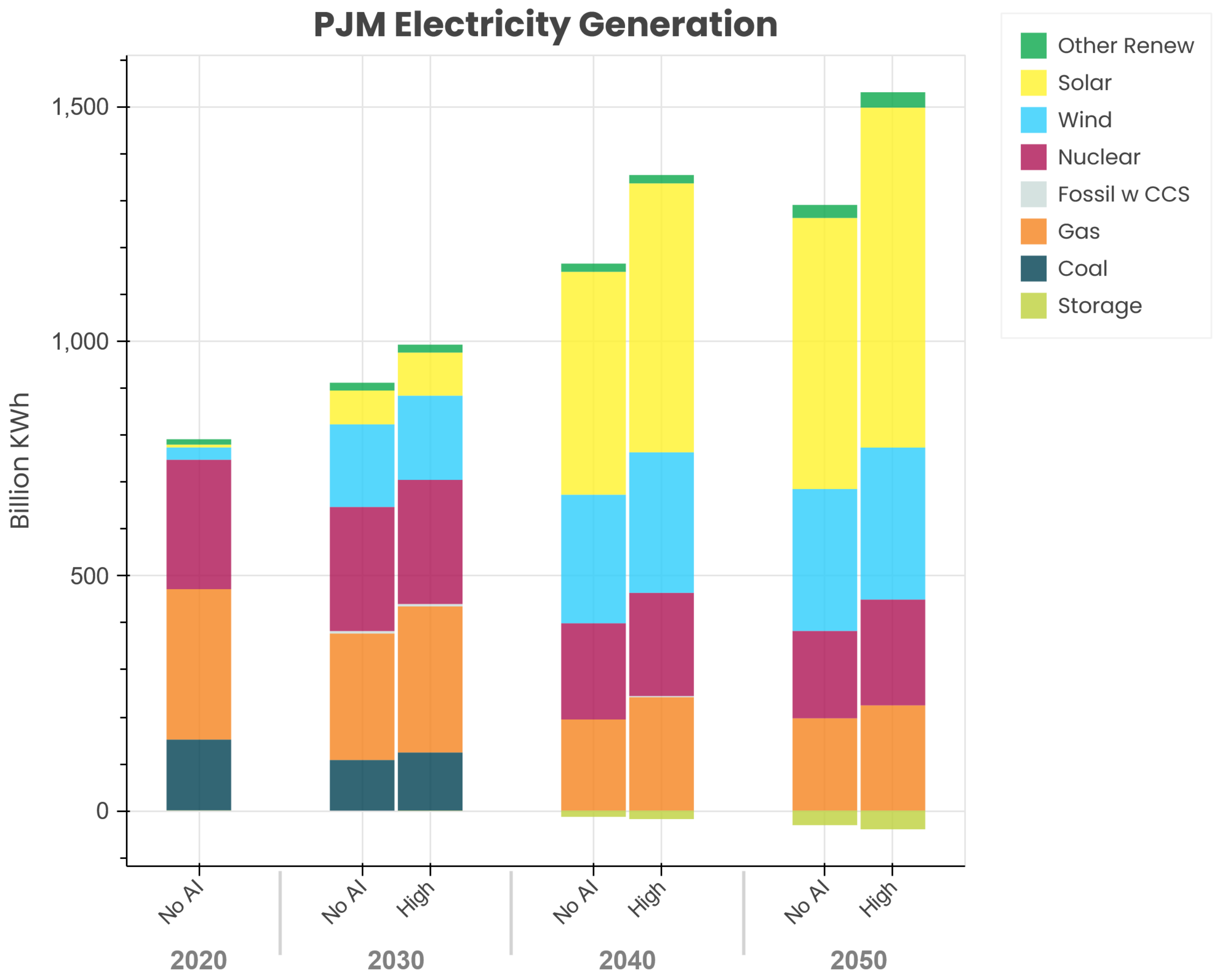


Source: OnLocation

- Projected average annual electricity growth rates for 2023 to 2035 range from a low of 1.4% per year in parts of the Mid-Continent region and New England to a high of 5% per year in PJM-Dominion.
- Data centers contribute to higher than historical growth rates in ERCOT (Texas), SPP-North (Northern Great Plains), and NWPP (Northwest) in addition to PJM-Dominion.

Electricity Generation in PJM Region

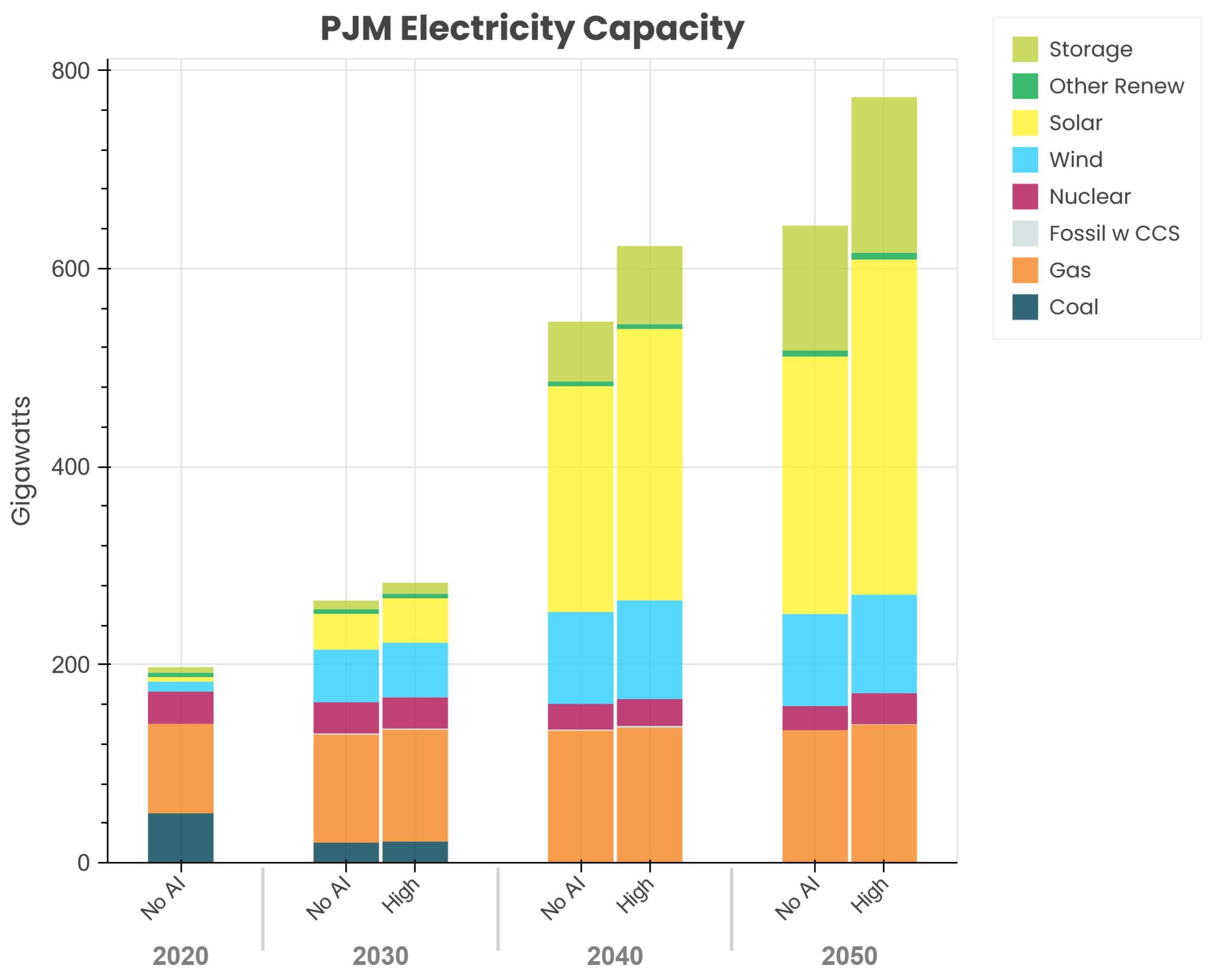
- In 2023, PJM accounts for 34% of national electricity demand from data centers.
- The highest data center demands are in PJM/Dominion, but impacts extend across the region due to intra-PJM trade and exchanges with neighboring regions.
- By 2050, solar and wind significantly expand their share of PJM's generation mix in both scenarios.
- After 2045, nuclear generation increases in the High Growth case as new construction costs decline, and existing plants delay retirement.



Source: OnLocation OL24-NEMS

Electric Capacity in PJM Region

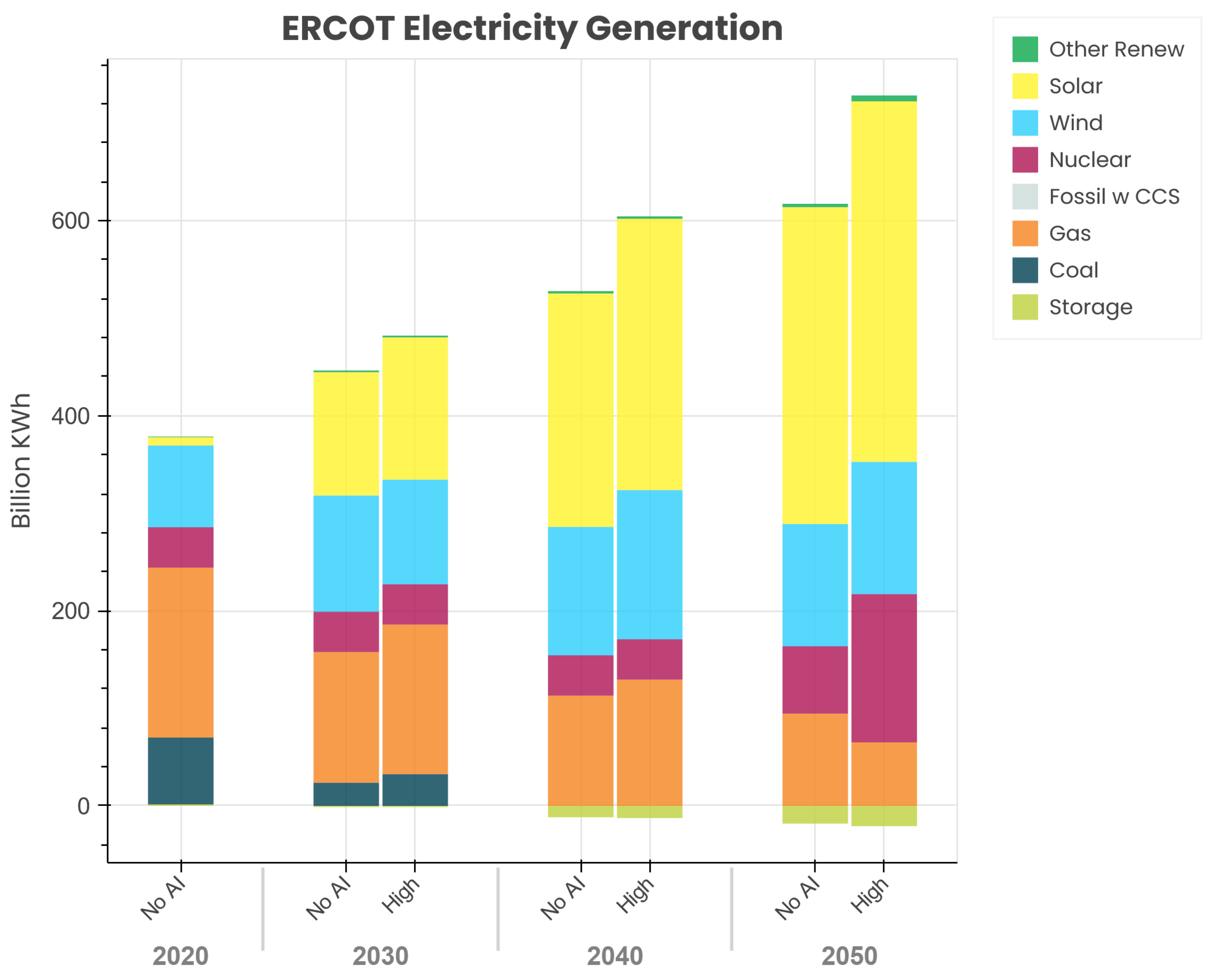
- Total electricity capacity in PJM more than triples from 2020 to 2050, with solar, wind, and storage making up most new capacity additions.
- Incremental capacity to meet data center demand is primarily composed of solar and battery storage.
- In the High Growth case (relative to No AI case), clean generation comprises roughly 54% of incremental capacity in 2030, rising to 89% by 2040 and 100% by 2050.
- Coal plants retire by 2040 in both scenarios due to the new EPA greenhouse gas regulations under CAAA Section 111.



Source: OnLocation OL24-NEMS

Electricity Generation in ERCOT Region

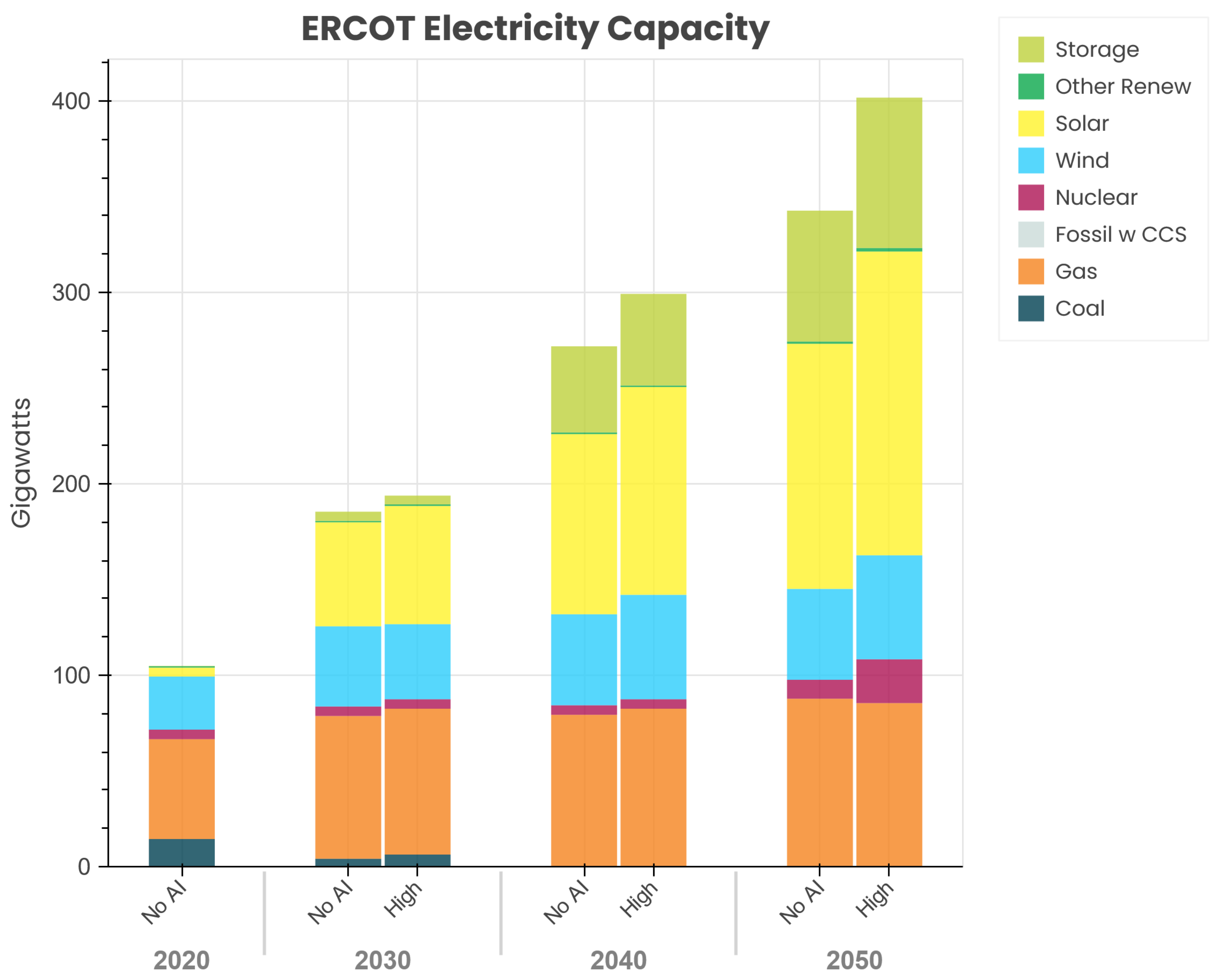
- In 2023, ERCOT (Texas) accounts for 14% of national data center electricity demand.
- ERCOT has limited ability to trade with neighboring regions, so building new capacity is critical for meeting increasing demand.
- Wind generation continues to expand through 2050 while solar becomes a significant part of the generation mix.
- In the High Growth scenario, nuclear generation more than doubles after 2045 due to falling construction costs and IRA clean electricity credits, displacing some natural gas generation.



Source: OnLocation OL24-NEMS

Electric Capacity in ERCOT Region

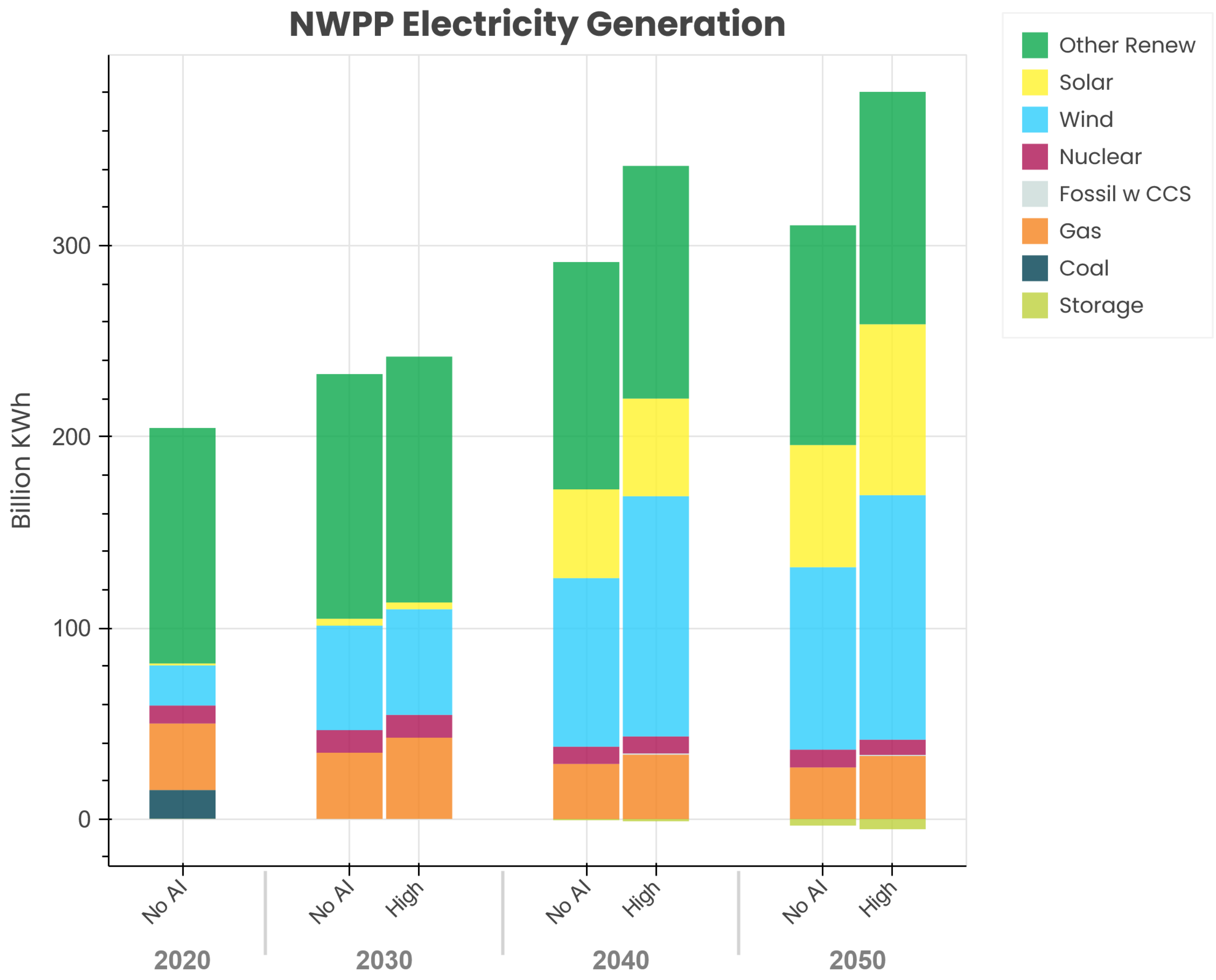
- Total capacity in ERCOT more than triples between 2020 and 2050 in both scenarios, and quadruples by 2050 in the High Growth scenario.
- Solar, wind, and storage make up most capacity additions alongside new nuclear capacity, particularly in the High Growth scenario.
- The cost of new nuclear and other generating capacity in ERCOT is projected to be lower than the national average due to relatively lower construction costs.



Source: OnLocation OL24-NEMS

Electricity Generation in NWPP Region

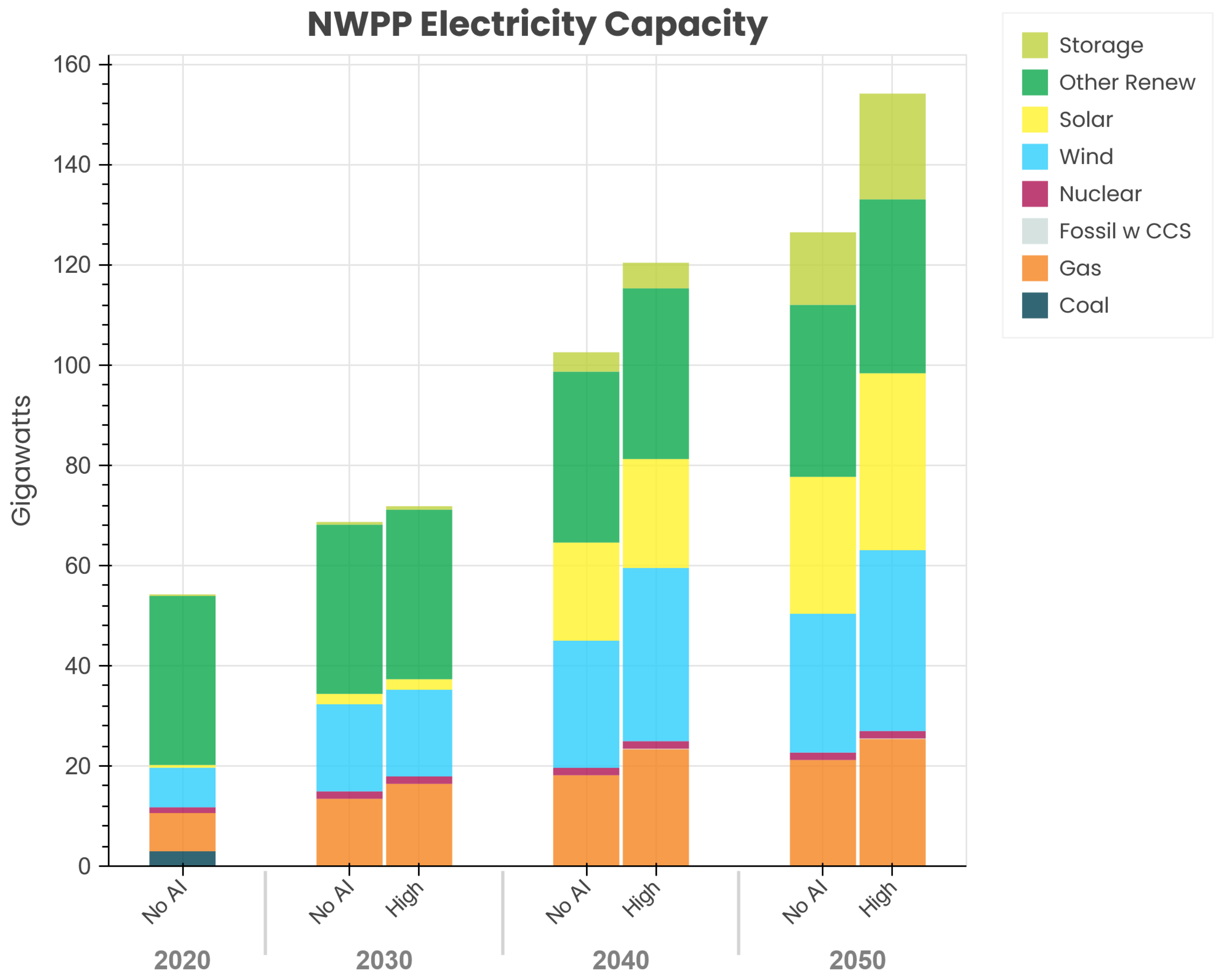
- The NWPP (Northwest) region has good wind resources, so a large share of incremental generation is from wind.
- Nuclear is not as attractive in this region due to available wind and existing hydropower.
- Most of incremental generation due to data center growth is clean, though 86% of incremental generation is provided by natural gas without CCS in 2030, dropping to only 9% by 2050.



Source: OnLocation OL24-NEMS

Electricity Capacity in NWPP Region

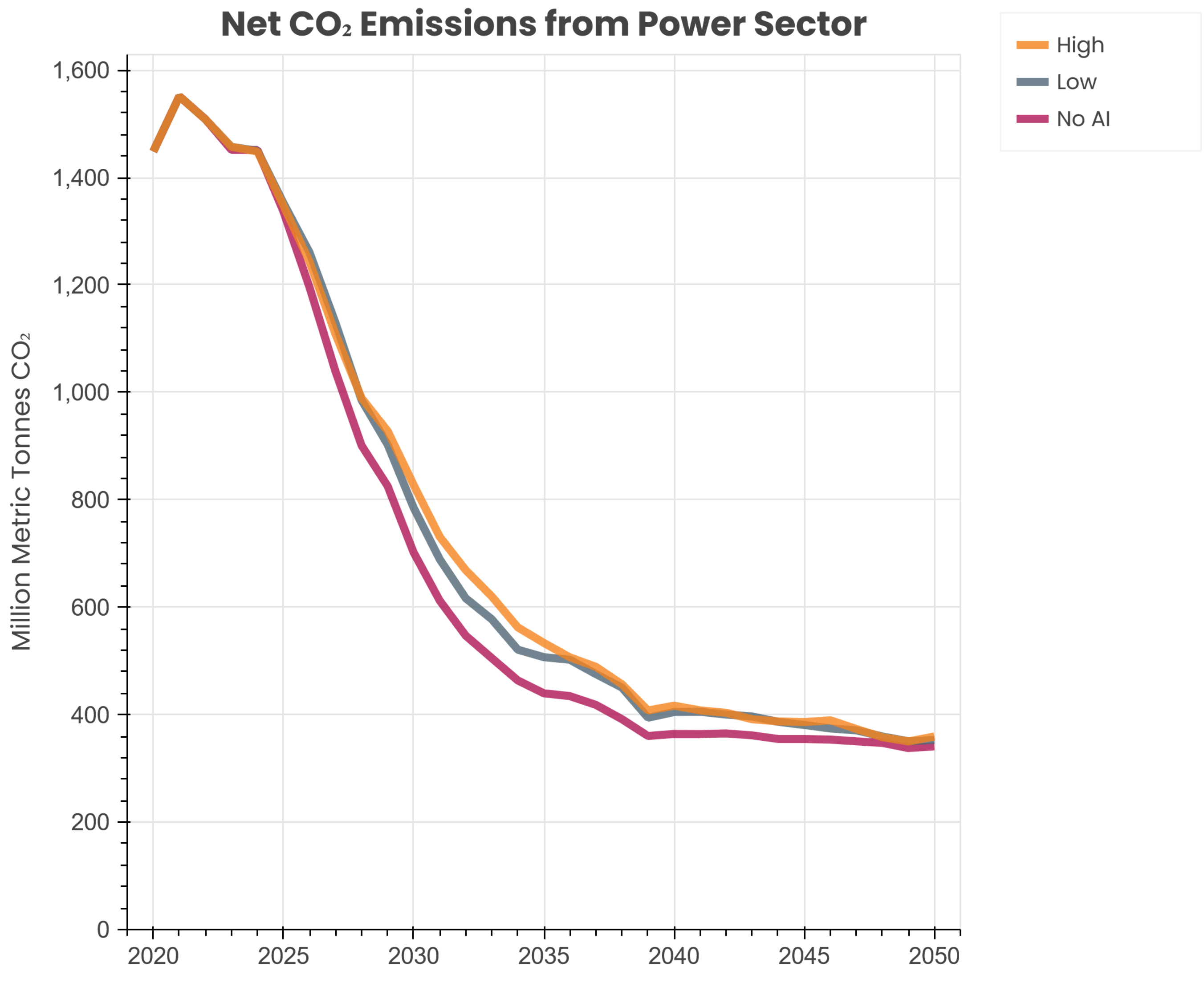
- Wind, solar, and battery storage provide most of the capacity growth over time and incrementally to meet data center demands.
- This region also sees some expansion of natural gas capacity, primarily combustion turbines.



Source: OnLocation OL24-NEMS

Implications for CO_2 Emissions

- In all three scenarios, annual CO_2 emissions drop significantly over time as fossil generation is replaced by cleaner sources, particularly renewable energy.
- Long term, increased demand stimulates more clean generation, leading to similar emission levels across scenarios by 2050.
- In the near term (2025-2035), emissions are about 90 MMT higher per year in the High Growth scenario due to increased generation from baseload fossil plants, mostly natural gas.



Source: OnLocation OL24-NEMS

Key Takeaways

Data center demand growth, while substantial (comprising up to 13% of total demand by 2050), is expected to be met with an accelerated transition to clean energy sources, minimizing long-term emissions impacts.

Clean energy expansion is expected to take over by mid-century, while natural gas and existing fossil capacity will continue to support demand growth in most regions in the near term.

Multiple clean energy sources will be essential for meeting the growing demand for data centers:

- **Renewable generation**, especially solar photovoltaics and wind, which already account for most capacity additions in many regions.
- **Battery storage** extends the availability of renewable generation and enhances grid reliability.
- **Nuclear generation**, especially small modular reactors, could play an increasing role in later years as a stable, low-carbon energy source.

Priority Questions and Further Research Needs
(Thank you to webinar attendees!)

- Will clean energy sources be supplied by electric power industry or be behind-the-meter?
- How will various criteria impact location choice of data centers – low cost, clean electricity, workforce requirements, internet infrastructure, etc.?
- How large a premium will data center operators be willing to pay for clean generation and to what degree will they be concerned with additionality?
- What future environmental regulations and local energy policies will affect data center development and how will centers comply?

Priority Questions and Further Research Needs
(Thank you to webinar attendees!)

- What are the primary costs associated with building and maintaining various types of data centers, as well as equipment efficiencies, to incorporate them in energy modeling?
- How could the impact of other technologies such as geothermal or quantum computing change the energy demand generated by AI Data Centers?
- If the U.S. were to reach a goal Net-Zero GHGs emissions by 2050, what impact will the increased energy demand from Data Centers have on reaching that target?

Many, Many more.........................

Modeling and Analysis Caveats

Scope of Analysis

1. **Time Horizon**: The projections extend to 2050, and longer-term implications beyond this period are not considered.
2. **Spatial Coverage**: This analysis is focused on U.S. energy markets and assumes business-as-usual policies in the rest of the world.
3. **Technological Development**: While the model is comprehensive, not all emerging technologies are fully represented. Assumptions about future technological advancements and their adoption rates are speculative and subject to significant uncertainty.
4. **Modeling Challenges**: As with all models, OL24-NEMS is an economic abstraction of the energy industry and may not fully reflect the complexities associated with significant energy transitions including electric grid reliability and infrastructure buildout.

Modeling Framework

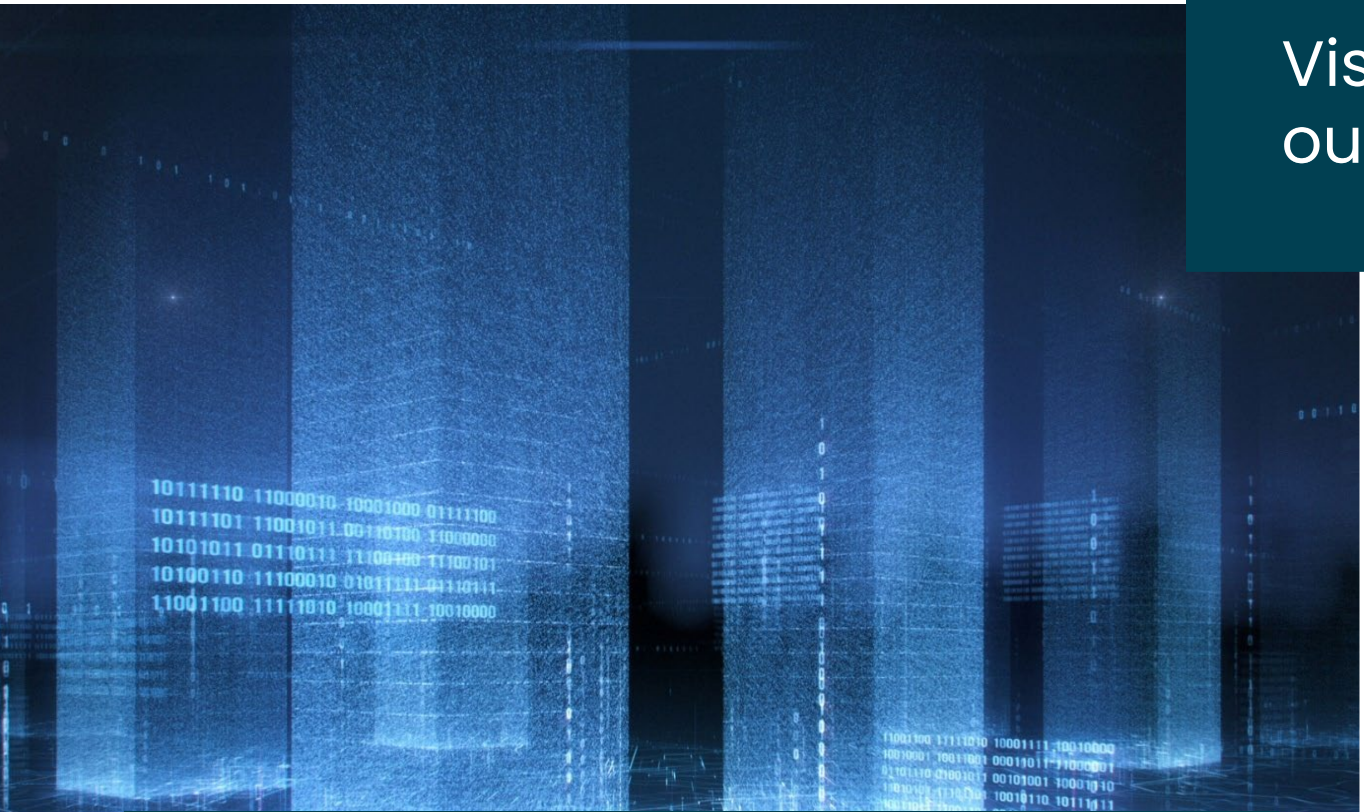
1. **Model Enhancements and Updates:** The model includes several enhancements over the AEO 2023 baseline, such as improved CCS, DAC, and hydrogen market representations. These enhancements are based on current knowledge and might need revision as new data becomes available.
2. **Policy Assumptions:** Assumes continuation and full implementation of current laws and regulations. Any changes in policy direction could significantly alter projected outcomes.
3. **Economic Assumptions:** Macroeconomic growth rates, crude oil prices, and other economic projections could vary with economic fluctuations. Macroeconomic Implications in the Advanced Technologies Case were not considered.
4. **Consumer Behavior**: Assumptions about consumer acceptance of new technologies, such as electric vehicles, are uncertain and may not materialize as projected.

Data Center Assumptions

1. **Current Data Center Demands**: Even current demands are uncertain with an almost 2-fold estimated range.
2. **Projected Regional Growth**: For simplicity, growth in data centers is assumed to occur evenly, and demand remains concentrated in several regions. Infrastructure limitations, clean generation resources, and electricity prices may lead to future shifts in data center locations.
3. **Central vs. On-site Generation**: Grid-based power sources are assumed. While critical for reliability, backup generation is likely to be infrequently used and is not explicitly modeled.
4. **Data Center Operations and Electricity Loads**: Data center loads are assumed to be fairly constant throughout the day and year as the most cost-effective method of operations given their capital intensity. Alternative patterns of operations, including participation in utility demand side management programs, could affect their grid impact and emissions.

Glossary of Key Abbreviations

ACT	Advanced Clean Trucks Regulation
AEO	Annual Energy Outlook
AI	Artificial Intelligence
ANL	Argonne National Laboratory
ATB	Annual Technology Baseline
AWS	Amazon Web Services
BECCS	Bioenergy with Carbon Capture and Storage
BEV	Battery Electric Vehicle
BIL	Bipartisan Infrastructure Law
CAAA	Clean Air Act Amendments
CARB	California Air Resource Board
CCS	Carbon Capture and Storage
CSAPR	Cross-State Air Pollution Rule
DAC	Direct Air Capture
DC	Data Centers
DOE	Department of Energy
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute, Inc
ERCOT	Electric Reliability Council of Texas
EVs	Electric Vehicles
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air Conditioning
ICCT	International Council on Clean Transportation
IRA	Inflation Reduction Act
IT	Information Technology
LBNL	Lawrence Berkeley National Laboratory
LDV	Light-Duty Vehicle
MHDV	Medium- and Heavy-Duty Vehicles
MPG	Miles per Gallon
NEEDS	National Electric Energy Data System
NEMS	National Energy Modeling System
NETL	National Energy Technology Laboratory
NGOs	Non-Governmental Organizations
NG	Natural Gas
NOx	Nitrogen Oxides
NREL	National Renewable Energy Laboratory
NWPP	Northwest Power Pool Area
OL EH	OnLocation Energy Horizons
PEM	Proton Exchange Membrane
PJM	PJM Interconnection LLC
PUE	Power Usage Effectiveness
PV	Photovoltaics
R&D	Research and Development
SAF	Sustainable Aviation Fuel
SMR	Small Modular Reactors
SPP	Southwest Power Pool
UPS	Uninterruptible Power Supply
ZEV	Zero Emission Vehicle



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Energy Horizons Reports, 2024

Energy Horizons Report, June 2024

Critical Materials Demands on the U.S. Energy Sector (*Update to our Sept 2023 Report*), Winter 2024

Employment Impacts of the U.S. Energy Transition, Winter 2024

Appendix

OLEH Reference – Technology and Data Assumptions*

	Description	Source
Power		
Technology costs and characteristics	Utility solar PV and wind, rooftop solar PV	NREL ATB 2023 Moderate Technology case
	Coal and natural gas CO_2 capture technologies (assumes 95% capture rate)	NREL ATB 2023 Moderate Technology case
	Coal-fired power plants retrofit with 95% CO_2 capture and up to 49% biomass cofiring	NETL BECCS Baseline
Capacity retirements and additions	Announced coal and nuclear plant retirements and solar PV additions through December 2023	EPA NEEDS Database version 01-04-2024
Electric vehicle charging load shape	More daytime charging than AEO 2023	EV Project Electric Vehicle Charging Infrastructure Summary Report
Transportation		
Electric vehicles	Light-duty electric vehicle prices	Modified ANL 2023 Low Case
	Heavy-duty electric truck prices and base MPG	CARB Advanced Clean Fleets Total Cost of Ownership
Charging stations	Home and DC public fast charger costs	ATLAS public policy report

**Note: All EH scenario assumptions reflect those in the EIA Annual Energy Outlook 2023 unless otherwise noted here and in the following slides. For more information about the AEO 2023, visit https://www.eia.gov/outlooks/aeo/.*

OLEH Reference – Technology and Data Assumptions

	Description	Source
Liquid Fuels		
CO_2 capture	CCS retrofits for ethanol and hydrogen production at refineries	NETL Industrial CCRD 2022
Biofuel technologies	Biomass-to-Liquids with CCS	Published article (Geleynse, et al.)
	Cellulosic ethanol with CCS, and SAF technologies	Published article (Kreutz, et al.)
Industry		
Industrial CCS	Cost of CCS in Cement, Natural Gas Processing	NETL Industrial CCRD 2022
	Cost of CCS in Steel	NETL Capturing CO_2 from Industrial Sources
Hydrogen technologies	Steam Methane Reforming with and without CCS; Autothermal Reforming with CCS; Biomass Gasification without CCS; Electrolysis technologies: Proton Exchange Membrane (PEM), Alkaline, Solid Oxide	NREL H2A Models
	Biomass Gasification with CCS	NETL Hydrogen Production Technologies
Direct Air Capture		
DAC technologies	Natural gas technology using liquid solvent	NETL DAC Case Studies: Solvent System
	Electric technology using solid sorbent	NETL DAC Case Studies: Sorbent System

OLEH Reference – BIL & IRA Policy Assumptions

	Description
Infrastructure Investment and Jobs Act (Bipartisan Infrastructure Law – BIL)	
CCS demos (industry & power sectors)	Includes CCS demonstration plants that have been awarded funding as of February 2024; industrial demo funding split between steel and cement CCS
Advanced nuclear demos	Two 330MW small modular reactors by 2028, one in Washington state and one in Wyoming
CO_2 pipeline and saline storage subsidies	Subsidies applied as reduced CO_2 transport and storage costs
Inflation Reduction Act (IRA)	
45Q tax credits (EOR / saline / DAC)	$60 / $85 / $180 per tonne CO_2; credits available for first 12 years of operation
Clean Electricity Credits	5X + 10% bonus credits assumed for all clean power sector technologies and commercial solar PV; credits available through 2050
Electric vehicle tax credits	BEV cost reductions applied for 30D new clean vehicle credits, and 45X battery manufacturing credits based on ICCT Moderate case; commercial clean vehicle credit (45W) for MHDV
45Z Clean Fuel Production tax credits	Credits extended for years 2025 through 2027 based on AEO 2023 lifecycle carbon intensities
45V credits for hydrogen production	Electrolysis-based technologies get the maximum credit and 5X multiplier. CCS-based technologies are eligible for a lower tier of credit but use the higher 45Q tax credit instead
Residential incentives	Tax credits for high efficiency equipment (25C), solar and geothermal credits (25D), efficient new construction credits (45L), and high-efficiency electric home rebates from section 50122
Commercial building tax credits	179D energy efficiency credits approximated as cost reductions for high efficiency HVAC equipment
Regional Direct Air Capture Hubs	$3.5B allocated for four hubs; 2 hubs announced by DOE (Liquid solvent + NG and Solid sorbent + Electric), and 2 hubs determined by model

OLEH Reference – Other Policy Updates

	Description
Power Sector	
EPA GHG Standards for power plants	Final EPA Clean Air Act Section 111 standards for coal and new natural gas plants
EPA Good Neighbor NOx Rule	Updated CSAPR state NOx budgets for years 2023-2029
State battery storage and offshore wind capacity mandates	Updated mandates included as planned capacity additions (60 GW through 2040)
Other Sectors	
Renewable Fuels Standard	Final rule issued for years 2023, 2024, and 2025
EPA GHG standards for vehicles	Final EPA GHG standards (2027 to 2032) for light- medium- and heavy-duty trucks
Zero Emission Vehicle (ZEV) and Advanced Clean Truck (ACT) state policies	EPA-approved ZEV waiver for CA and section 177 states in LDVs (same as in the AEO2023), ACT adopted by 11 states
Appliance standards	New standards for natural gas furnaces, natural gas boilers, electric water heaters, natural gas water heaters, and refrigerators in the final rule stage

End Notes by Slide

Slide 11

1. Electric Power Research Institute, Inc (EPRI). "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption", EPRI, May 28, 2024. EPRI.com - Powering Intelligence
2. S&P Global Market Intelligence. "2024 US Datacenters and Energy Report", S&P Global Inc, 2024. S&P.com - US Datacenters Report
3. Department of Energy (DOE). "Clean Energy Resources to Meet Data Center Electricity Demand", DOE, August 12, 2024. DOE.gov - Meet DC Electricity
4. The Goldman Sachs Group, Inc. "Generational Growth: AI, data centers and the coming US power demand surge", The Goldman Sachs Group, Inc., April 28, 2024. GoldmanSachs.com - Generational Growth

Slide 12

5. Morgan Stanley. "Powering the AI Revolution", Morgan Stanley, March 8, 2024. MorganStanley.com - AI Energy Demand

Slide 13

5. Cloudscene. United States of America Market Profile. Cloudscene.com - US Data Center Market
6. Zhang, Mary. "Data Center Power: A Comprehensive Overview of Energy", Dgtl Infra, March 25, 2024. DgtlInfra.com - Data Center Power

Slide 14

8. Zhang, Mary. "Data Center Power: A Comprehensive Overview of Energy"
9. EPRI. "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption"
10. Bannerman, Natalie. "The future of hyperscale data centres", Capacity Media, March 08, 2024. CapacityMedia.com - Future of Hyperscalers
11. Dgtl Infra. "Cities and regions with the highest concentration of data centers", IREI, February 01, 2023. IREI.com - Data Centers Locations

End Notes by Slide

Slide 15

12. EPRI. “Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption”
13. Nuoa Lei, Eric Masanet. “Climate- and technology-specific PUE and WUE estimations for U.S. data centers using a hybrid statistical and thermodynamics-based approach”, Resources, Conservation and Recycling, Volume 182, 2022, 106323. ScienceDirect.com - PUE and WUE estimations for DC
14. Davis, Jacqueline. “Large data centers are mostly more efficient, analysis confirms”, Uptime Institute, February 07, 2024. UptimeInstitute.com - Large DC are more efficient

Slide 16

15. Davis, Jacqueline. “Large data centers are mostly more efficient, analysis confirms”
16. Bizo, Daniel. “Global PUEs — are they going anywhere?”, Uptime Institute, December 04, 2023. UptimeInstitute.com - Global PUEs

Slide 17

17. Bloomberg. “Data centers face 7-year wait for Dominion Power hookups“, PoliticoPRO, September 03, 2024. PoliticoPRO.com - DCs & Dominion Power
18. Obando, Sebastian. “Data center building boom shows cracks”, Construction Dive. November 10, 2023. ConstructionDive.com - PSMJ DC Construction
19. Mahan, Josh. “Data Center Construction Challenges: Complexities and Solutions”, C&C Technology Group. February 12, 2021=4. C&CTechGroup.com - DC Construction

Slide 18

20. Patrizio, Andy. “California’s Climate Disclosure Laws Could Have Adverse Effects on Data Centers”, DataCenter Knowledge, October 25, 2023. DataCenterKnowledge.com - California's Climate Laws

End Notes by Slide

21. Kaplan, Beth, Katie Glynn, and Brian Jobe. "California goes first: Responding to state-led ESG regulations", Deloitte Perspectives, May 15, 2024. Deloitte.com – California Goes First
22. Hoylman-Sigal. "Climate Corporate Data Accountability Act, Senate Bill S897A", The New York State Senate, January 9, 2023. NYStateSenate.gov - Senate Bill S897A
23. Harckham. "Climate-related Financial Risk Report, Senate Bill S5437", The New York State Senate, March 3, 2023. NYStateSenate.gov - Senate Bill S5437
24. Du Buclet. "Corporate Emissions Reporting, Bill Status of HB4268", Illinois General Assembly, December 13, 2023. IllinoisGeneralAssembly.gov - Bill HB4268
25. Marcilla, Max. "Fairfax County passes measure to regulate where data centers can be built", DC News Now, September 10, 2024. DCNewsNow.com - Where DC can be built in Fairfax County
26. Swinhoe, Dan. "Virginia lawmakers propose new bills limiting data center development", Data Center Dynamics, January 15, 2024. DCD.com - New Virginia Bills for DC Development
27. Paullin, Charlie. "As data centers continue spreading across Virginia, state lawmakers propose new development rules", Virginia Mercury, January 15, 2024. VirginiaMercury.com - DC New Development Rules

Slide 19

28. Saul, Josh, Leonardo Nicoletti, Saritha Rai, Dina Bass, Ian King, Jennifer Duggan. "AI Is Already Wreaking Havoc on Global Power Systems", Bloomberg Technology, June 21, 2024. Bloomberg.com - AI wreaking Havoc
29. HDR, Inc. "Rethinking Data Center Power", HDR Inc., May 08, 2023. HDR.com - Rethinking DC Power
30. Amazon. "2023 Amazon Sustainability Report", Amazon, 2023. Amazon.com - Sustainability Report
31. Meta. "2024 Sustainability Report", Meta Sustainability, 2024. Meta.com - Sustainability Report
32. Google. "Sustainable Innovation & Technology", Google Sustainability, 2024. Google.com - Sustainability Report

End Notes by Slide

33. Smith, Brad. "Microsoft will be carbon negative by 2030", Microsoft, January 16, 2020. Microsoft.com - Carbon Negative by 2030

Slide 20

34. Hughes, Tim. "The Future of Backup Energy Storage is a Mixed Bag of Challenges and Opportunities for Data Centers", Stack Infrastructure. StackInfrastructure.com - Backup Energy Storage for DC
35. DOE. "The Future of Resource Adequacy: Solutions for clean, reliable, secure, and affordable electricity". DOE, April 2024. DOE.gov - The Future of Resource Adequacy
36. Switch, "Switch and Capital Dynamics Break Ground on Massive Solar and Battery Storage Developments, Advancing Rob Roy's Gigawatt Nevada". Switch.com - Solar and Battery Storage
37. DOE. "Clean Energy Resources to Meet Data Center Electricity Demand". DOE, August 12, 2024. DOE.gov - Clean Energy Resources
38. Research and Markets. "Global Data Center Generator Market Outlook 2024-2029: Adoption of Innovative Generators, Automation & Remote Monitoring, Deployment of Modular Data Centers & Gensets", Global Newswire, July 24, 2024. GlobalNewswire.com - Modular DC & Gensets
39. Miller, Rich. "ECL Advances its Vision for Hydrogen-Powered Data Centers", Data Center Frontier, June 25, 2024. DataCenterFrontier.com - ECL Hydrogen DC
40. HDR, Inc. "Rethinking Data Center Power"
41. Bigelow, Stephen J. "How to design and build a data center", TechTarget, February 21, 2024. TechTarget.com - Build and Design a DC
42. FuelCell Energy. "Data Centers". FuelCell Energy. FuelCellEnergy.com – DC
43. Hann, Chris, AH Jain, Trisha Sieh. "Battery Energy Storage Systems: The Future of Sustainable Energy for Data Centers", Kimley-Horn and Associates, Inc. May 03, 2024. Kimley-Horn.com - Battery Energy Storage Systems
44. Equinix, Inc. "Tech Consortium to Lead Low-Carbon Fuel Cell Development for Data Centres", Equinix, Inc. December 14, 2021. Equinix.com - Low-carbon Fuel Cell for DC
45. U.S. Energy Information Administration (EIA). "Electricity Explained: Energy Storage for Electricity Generation", EIA, August 28, 2023. EIA.gov - Electricity Explained

End Notes by Slide

46. BOSCH, “Fuel cells as a flexible and modular energy source for data centers”. Bosch. BOSCH.com - Fuel Cells for DC
47. Proctor, Darrel. “Hydrogen Fuel Cell Provides Backup Power for Microsoft Data Center”, Power Magazine, January 21, 2024. Power.com - Power Microsoft DC

Slide 21

48. Gent, Edd. “Meta Looks to Next-Gen Geothermal to Fuel Ravenous Data Centers”, Singularity Hub, September 9, 2024. SingularityHub.com - Meta Next-Gen Geothermal to DC
49. Johnson, Lamar. “Meta inks geothermal deal with Sage Geosystems to power data centers”, Utility Dive, August 29, 2024. UtilityDive.com - Meta Geothermal Deal to DC
50. Williams, Wayne. “Microsoft goes atomic — World's most valuable company just hired a director of nuclear development acceleration to help power its very own AI revolution”, Techradar Pro, January 22, 2024. Techradar.com - Microsoft Goes Atomic
51. Moss, Sebastian. “Microsoft trains generative AI to handle SMR nuclear regulatory process”, Data Center Dynamics, December 18, 2023. DCD.com - Microsoft AI to SMR Regulatory Process
52. Halper, Evan. “Microsoft deal would reopen Three Mile Island nuclear plant to power AI”, The Washington Post, September 20, 2024. WP.com - Three Mile Island to Microsoft AI ambitions
53. Calma, Justine. “Google’s new geothermal energy project is up and running”, The Verge, November 28, 2023. TheVerge.com - Google's Geothermal Energy Project
54. Brun, Becky. “Rye Development Signs Groundbreaking 100% Hydropower Deal to Power Data Centers”, PittsburgHydro, June 13, 2023 . Pittsburghydro.com - Rye Development Hydropower to DC
55. Judge, Peter. “Iron Mountain signs 24/7 PPA to draw hydroelectric power from existing US dams”, Data Center Dynamics, June 13, 2023. DCD.com - Iron Mountain PPA to Hydroelectric
56. Nuclear News. “Amazon buys nuclear-powered data center from Talen”, Nuclear Newswire, March 7, 2024. ANS.org - Amazon nuclear-powered DC

End Notes by Slide

Slide 22

57. Sunbird. “World’s Leading Data Center and Cloud Operators with Zero Carbon Goals”. Sunbird DCIM. Sunbird.com - DC and Cloud Operators Zero Carbon Goals
58. Baynes, Matthew. “How data center operators can strike a balance with sustainability and rising demand”, Schneider Electric Blog, May 07, 2024. SchneiderElectric.com - DC: Balance Sustainability and Demand
59. RPS Group. “Sustainable Data Centre: Meeting Net Zero Carbon”. RPS. RPS.com - Sustainable DC
60. Brown, Forrest. “Data Center Sustainability: Making the Internet Green”, Nerd Rabbit, December 13, 2022. NerdRabbit.com - DC Sustainability
61. Climate Neutral Data Center. “Climate Neutral Data Centre Pact”. ClimateNeutralDataCenter.com - Neutral DC Pact

Data Sources

Amazon. “2023 Amazon Sustainability Report”, Amazon, 2023. Amazon.com - Sustainability Report

Bannerman, Natalie. “The future of hyperscale data centres”, Capacity Media, March 08, 2024. CapacityMedia.com - Future of Hyperscalers

Baynes, Matthew. “How data center operators can strike a balance with sustainability and rising demand”, Schneider Electric Blog, May 07, 2024. SchneiderElectric.com - DC: Balance Sustainability and Demand

Bigelow, Stephen J. “How to design and build a data center”, TechTarget, February 21, 2024. TechTarget.com - Build and Design a DC

Bizo, Daniel. “Global PUEs — are they going anywhere?”, Uptime Institute, December 04, 2023. UptimeInstitute.com - Global PUEs

Bloomberg. “Data centers face 7-year wait for Dominion Power hookups“, PoliticoPRO, September 03, 2024. PoliticoPRO.com - DCs & Dominion Power

BOSCH, “Fuel cells as a flexible and modular energy source for data centers”. Bosch. BOSCH.com - Fuel Cells for DC

Brown, Forrest. “Data Center Sustainability: Making the Internet Green”, Nerd Rabbit, December 13, 2022. NerdRabbit.com - DC Sustainability

Brun, Becky. “Rye Development Signs Groundbreaking 100% Hydropower Deal to Power Data Centers”, PittsburgHydro, June 13, 2023 . Pittsburghydro.com - Rye Development Hydropower to DC

Calma, Justine. “Google’s new geothermal energy project is up and running”, The Verge, November 28, 2023. TheVerge.com - Google's Geothermal Energy Project

Climate Neutral Data Center. “Climate Neutral Data Centre Pact”. ClimateNeutralDataCenter.com - Neutral DC Pact

Cloudscene. United States of America Market Profile. Cloudscene.com - US Data Center Market

Data Center Journal. “Data Centers in the United States”, DCJ, 2024. DCJ.com - Find Data Centers and Fiber Cables

Davis, Jacqueline. “Large data centers are mostly more efficient, analysis confirms”, Uptime Institute, February 07, 2024. UptimeInstitute.com - Large DC are more efficient

Department of Energy (DOE). “Clean Energy Resources to Meet Data Center Electricity Demand”, DOE, August 12, 2024. DOE.gov - Meet DC Electricity

Dgtl Infra. “Cities and regions with the highest concentration of data centers”, IREI, February 01, 2023. IREI.com - Data Centers Locations

DOE. “Clean Energy Resources to Meet Data Center Electricity Demand”. DOE, August 12, 2024. DOE.gov - Clean Energy Resources

Data Sources

DOE. "The Future of Resource Adequacy: Solutions for clean, reliable, secure, and affordable electricity". DOE, April 2024. DOE.gov - The Future of Resource Adequacy

Du Buclet. "Corporate Emissions Reporting, Bill Status of HB4268", Illinois General Assembly, December 13, 2023. IllinoisGeneralAssembly.gov - Bill HB4268

Electric Power Research Institute, Inc (EPRI). "Powering Intelligence: Analyzing Artificial Intelligence and Data Center Energy Consumption", EPRI, May 28, 2024. EPRI.com - Powering Intelligence

Equinix, Inc. "Tech Consortium to Lead Low-Carbon Fuel Cell Development for Data Centres", Equinix, Inc. December 14, 2021. Equinix.com - Low-carbon Fuel Cell for DC

FuelCell Energy. "Data Centers". FuelCell Energy. FuelCellEnergy.com – DC

Gent, Edd. "Meta Looks to Next-Gen Geothermal to Fuel Ravenous Data Centers", Singularity Hub, September 9, 2024. SingularityHub.com - Meta Next-Gen Geothermal to DC

Ghatikar, Girish, M.A. Piette, S. Fujita, A. T. McKane, J.Q Han, A. Radspieler, K.C. Mares, D. Shroyer. "Demand Response and Open Automated Demand Response Opportunities for Data Centers. California Energy Commission, PIER Program and Pacific Gas and Electric Company (PG&E)", Lawrence Berkeley National Laboratory. 2010. LBNL.gov - Demand Response for DC

Google. "Sustainable Innovation & Technology", Google Sustainability, 2024. Google.com - Sustainability Report

Google Maps. "Data Center Locations in the United States." Accessed from July to September 2024. from Google.com - Maps

Halper, Evan. "Microsoft deal would reopen Three Mile Island nuclear plant to power AI", The Washington Post, September 20, 2024. WP.com - Three Mile Island to Microsoft AI ambitions

Hann, Chris, AH Jain, Trisha Sieh. "Battery Energy Storage Systems: The Future of Sustainable Energy for Data Centers", Kimley-Horn and Associates, Inc. May 03, 2024. Kimley-Horn.com - Battery Energy Storage Systems

Harckham. "Climate-related Financial Risk Report, Senate Bill S5437", The New York State Senate, March 3, 2023. NYStateSenate.gov - Senate Bill S5437

HDR, Inc. "Rethinking Data Center Power", HDR Inc., May 08, 2023. HDR.com - Rethinking DC Power

Data Sources

Hoylman-Sigal. “Climate Corporate Data Accountability Act, Senate Bill S897A”, The New York State Senate, January 9, 2023. NYStateSenate.gov - Senate Bill S897A

Hughes, Tim. “The Future of Backup Energy Storage is a Mixed Bag of Challenges and Opportunities for Data Centers”, Stack Infrastructure. StackInfrastructure.com - Backup Energy Storage for DC

Johnson, Lamar. “Meta inks geothermal deal with Sage Geosystems to power data centers”, Utility Dive, August 29, 2024. UtilityDive.com - Meta Geothermal Deal to DC

Judge, Peter. “Iron Mountain signs 24/7 PPA to draw hydroelectric power from existing US dams”, Data Center Dynamics, June 13, 2023. DCD.com - Iron Mountain PPA to Hydroelectric.

Kaplan, Beth, Katie Glynn, and Brian Jobe. “California goes first: Responding to state-led ESG regulations”, Deloitte Perspectives, May 15, 2024. Deloitte.com – California Goes First

Mahan, Josh. “Data Center Construction Challenges: Complexities and Solutions”, C&C Technology Group. February 12, 2021. C&CTechGroup.com - DC Construction

Marcilla, Max. “Fairfax County passes measure to regulate where data centers can be built”, DC News Now, September 10, 2024. DCNewsNow.com - Where DC can be built in Fairfax County

Meta. “2024 Sustainability Report”, Meta Sustainability, 2024. Meta.com - Sustainability Report

Miller, Rich. “ECL Advances its Vision for Hydrogen-Powered Data Centers”, Data Center Frontier, June 25, 2024. DataCenterFrontier.com - ECL Hydrogen DC

Morgan Stanley. “Powering the AI Revolution”, Morgan Stanley, March 8, 2024. MorganStanley.com - AI Energy Demand

Moss, Sebastian. “Microsoft trains generative AI to handle SMR nuclear regulatory process”, Data Center Dynamics, December 18, 2023. DCD.com - Microsoft AI to SMR Regulatory Process

Nuclear News. “Amazon buys nuclear-powered data center from Talen”, Nuclear Newswire, March 7, 2024. ANS.org - Amazon nuclear-powered DC

Data Sources

Nuoa Lei, Eric Masanet. “Climate- and technology-specific PUE and WUE estimations for U.S. data centers using a hybrid statistical and thermodynamics-based approach”, Resources, Conservation and Recycling, Volume 182, 2022, 106323. ScienceDirect.com - PUE and WUE estimations for DC

Obando, Sebastian. “Data center building boom shows cracks”, Construction Dive. November 10, 2023. ConstructionDive.com - PSMJ DC Construction

Parker, Andrew, Henry Horsey, Matthew Dahlhausen, Marlena Praprost, Christopher CaraDonna, Amy LeBar, Janghyun Kim, and Lauren Klun. “ComStock Reference Documentation: 2024 Release 1”, National Renewable Energy Laboratory (NREL), 2024. NREL.github.io - ComStock

Patrizio, Andy. “California’s Climate Disclosure Laws Could Have Adverse Effects on Data Centers”, DataCenter Knowledge, October 25, 2023. DataCenterKnowledge.com - California's Climate Laws

Paullin, Charlie. “As data centers continue spreading across Virginia, state lawmakers propose new development rules”, Virginia Mercury, January 15, 2024. VirginiaMercury.com - DC New Development Rules

Proctor, Darrel. “Hydrogen Fuel Cell Provides Backup Power for Microsoft Data Center”, Power Magazine, January 21, 2024. Power.com - Power Microsoft DC

Research and Markets. “Global Data Center Generator Market Outlook 2024-2029: Adoption of Innovative Generators, Automation & Remote Monitoring, Deployment of Modular Data Centers & Gensets”, Global Newswire, July 24, 2024. GlobalNewswire.com - Modular DC & Gensets

Riu, Isabelle, Dieter Smiley, Stephen Bessasparis, and Kushal Patel. “Load Growth Is Here to Stay, but Are Data Centers?: Strategically Managing the Challenges and Opportunities of Load Growth,” Energy and Environmental Economics, Inc., July 2024. E3.com - Load Growth is Here to Stay but are DC

RPS Group. “Sustainable Data Centre: Meeting Net Zero Carbon”. RPS. RPS.com - Sustainable DC

S&P Global Market Intelligence. “2024 US Datacenters and Energy Report”, S&P Global Inc, 2024. S&P.com - US Datacenters Report

Saul, Josh, Leonardo Nicoletti, Saritha Rai, Dina Bass, Ian King, Jennifer Duggan. “AI Is Already Wreaking Havoc on Global Power Systems“, Bloomberg Technology, June 21, 2024. Bloomberg.com - AI wreaking Havoc

Smith, Brad. “Microsoft will be carbon negative by 2030”, Microsoft, January 16, 2020. Microsoft.com - Carbon Negative by 2030

Data Sources

Sunbird. “World’s Leading Data Center and Cloud Operators with Zero Carbon Goals”. Sunbird DCIM. Sunbird.com - DC and Cloud Operators Zero Carbon Goals

Swinhoe, Dan. “Virginia lawmakers propose new bills limiting data center development”, Data Center Dynamics, January 15, 2024. DCD.com - New Virginia Bills for DC Development

Switch, “Switch and Capital Dynamics Break Ground on Massive Solar and Battery Storage Developments, Advancing Rob Roy’s Gigawatt Nevada”. Switch.com - Solar and Battery Storage

“Texas Electric Grids: Demand and Supply”, Texas Almanac, 2024. Txalmanac.com - TX Electric Grids

The Goldman Sachs Group, Inc. “Generational Growth: AI, data centers and the coming US power demand surge”, The Goldman Sachs Group, Inc., April 28, 2024. GoldmanSachs.com - Generational Growth

U.S. Energy Information Administration (EIA). “Electricity Explained: Energy Storage for Electricity Generation”, EIA, August 28, 2023. EIA.gov - Electricity Explained

“United States Data Centers Locations”, Data Centers, 2024. Datacenters.com - Providers Map in United States

“USA Data Centers”, Data Center Map, 2024. Datacentermap.com - USA Data Centers

Williams, Wayne. “Microsoft goes atomic — World's most valuable company just hired a director of nuclear development acceleration to help power its very own AI revolution”, Techradar Pro, January 22, 2024. Techradar.com - Microsoft Goes Atomic

Zhang, Mary. “Data Center Power: A Comprehensive Overview of Energy”, Dgtl Infra, March 25, 2024. DgtlInfra.com - Data Center Power

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