Data Center Demands & Impacts on the Energy System:

An Energy Horizons Special Report

September 26, 2024

Disclaimers

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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/.

Outline

- Introduction
- Current Market: Overview of Data Centers
- Data Center Demand: Implications for the U.S. Power Sector
- Key Takeaways and Q&A

Presenters & Respondents

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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

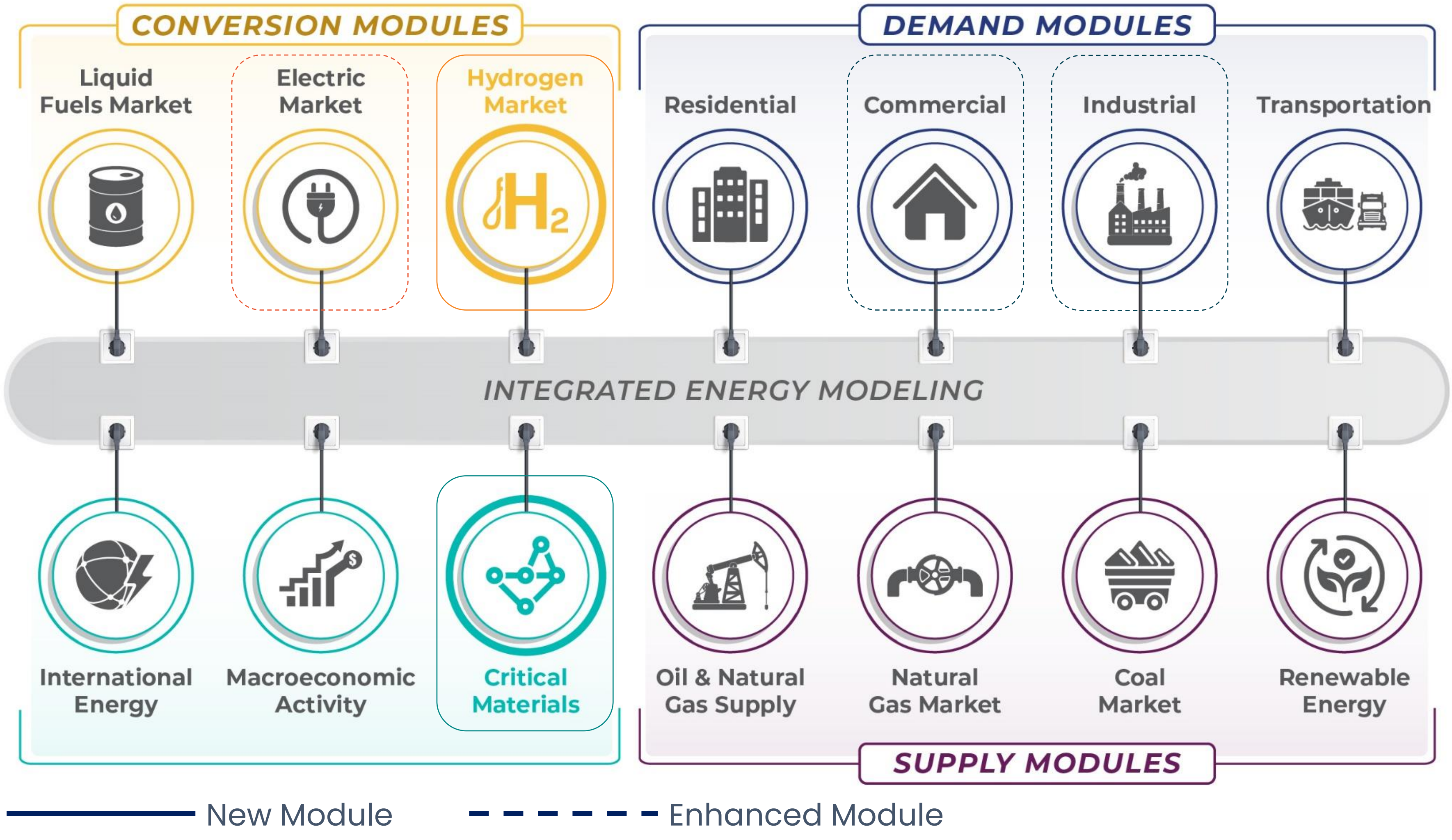
Explore CO_2 mitigation strategies for the U.S. energy system

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

See the Full Report to this webinar at: www.onlocationinc.com

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

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Data Center Report Highlights

Data center demand growth, while substantial (up to 13% 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: Overview of Data Centers

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:

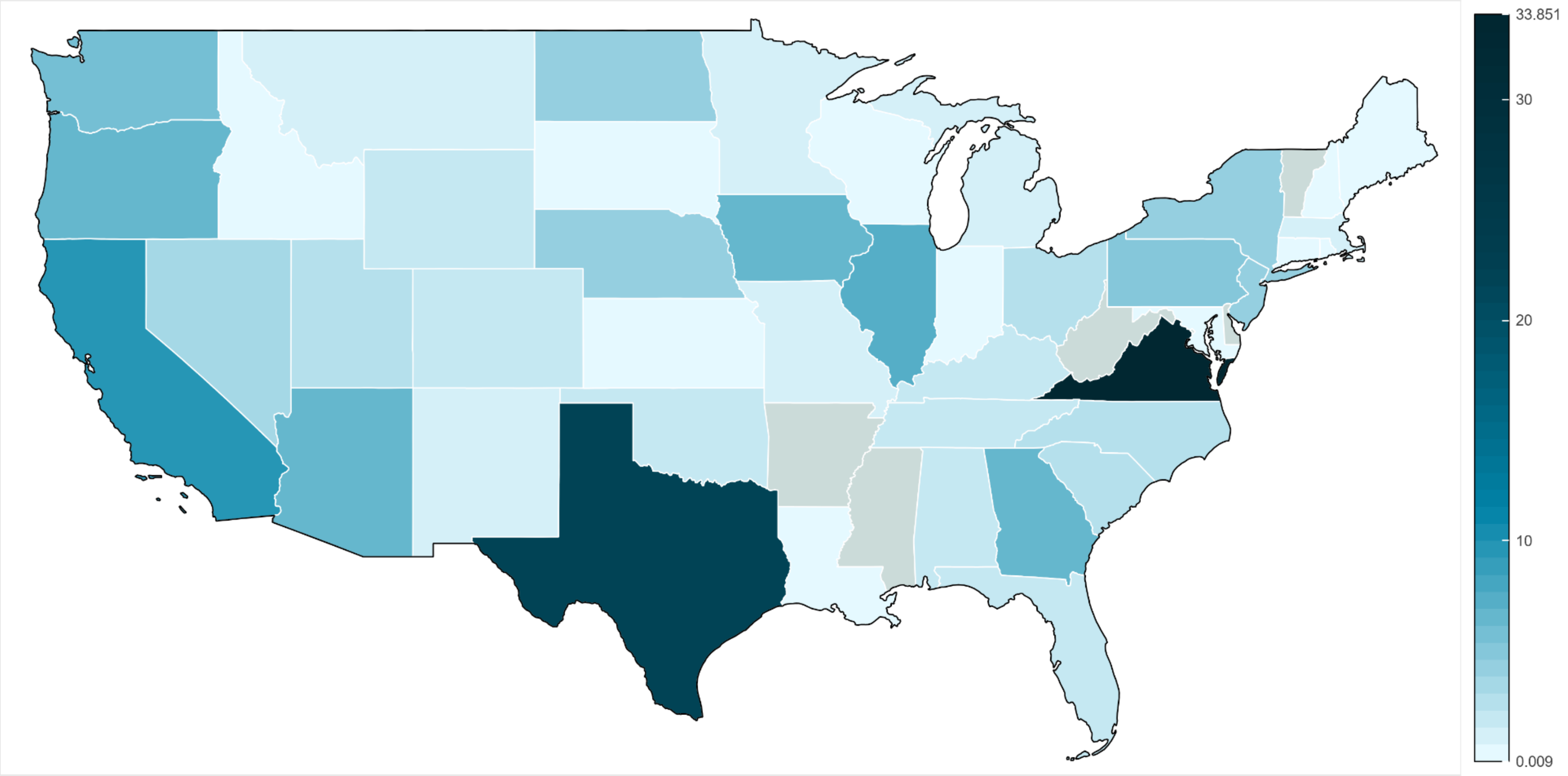
- Cloud computing, artificial intelligence (AI) systems, digital services, and cryptocurrency mining operations.

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.

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?

Main Data Center Types:

- **Small-scale:** Includes server rooms and edge data centers. Serve localized operations such as small businesses, facilities, or individual customers. [8, 9]
- **Large-scale:** Serve extensive operations such as cloud computing, 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 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]

% Data Center Total Energy Consumption

IT Equipment	Cooling Systems	Auxiliary Components
40% - 50%	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 short-term constraints could limit data center expansion?

Some key aspects to consider when building a new data center include:[14, 15]

- **Site selection and land acquisition**
  - Highly impacted by power and internet connection availability, restrictive permitting, community resistance, and compliance with regulations and policies.
- **Power infrastructure and backup systems**
  - Average construction timeline before 2020 was 1-3 years. Limited access to power means the process now can take 2-6 years.
  - Large data centers that need more than 100 MW of electricity wait up to 7 years to connect to the grid.[16]
- **Infrastructure and technological requirements**
  - Impacted by supply chain.
- **Highly specialized and skilled workforce needs**

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

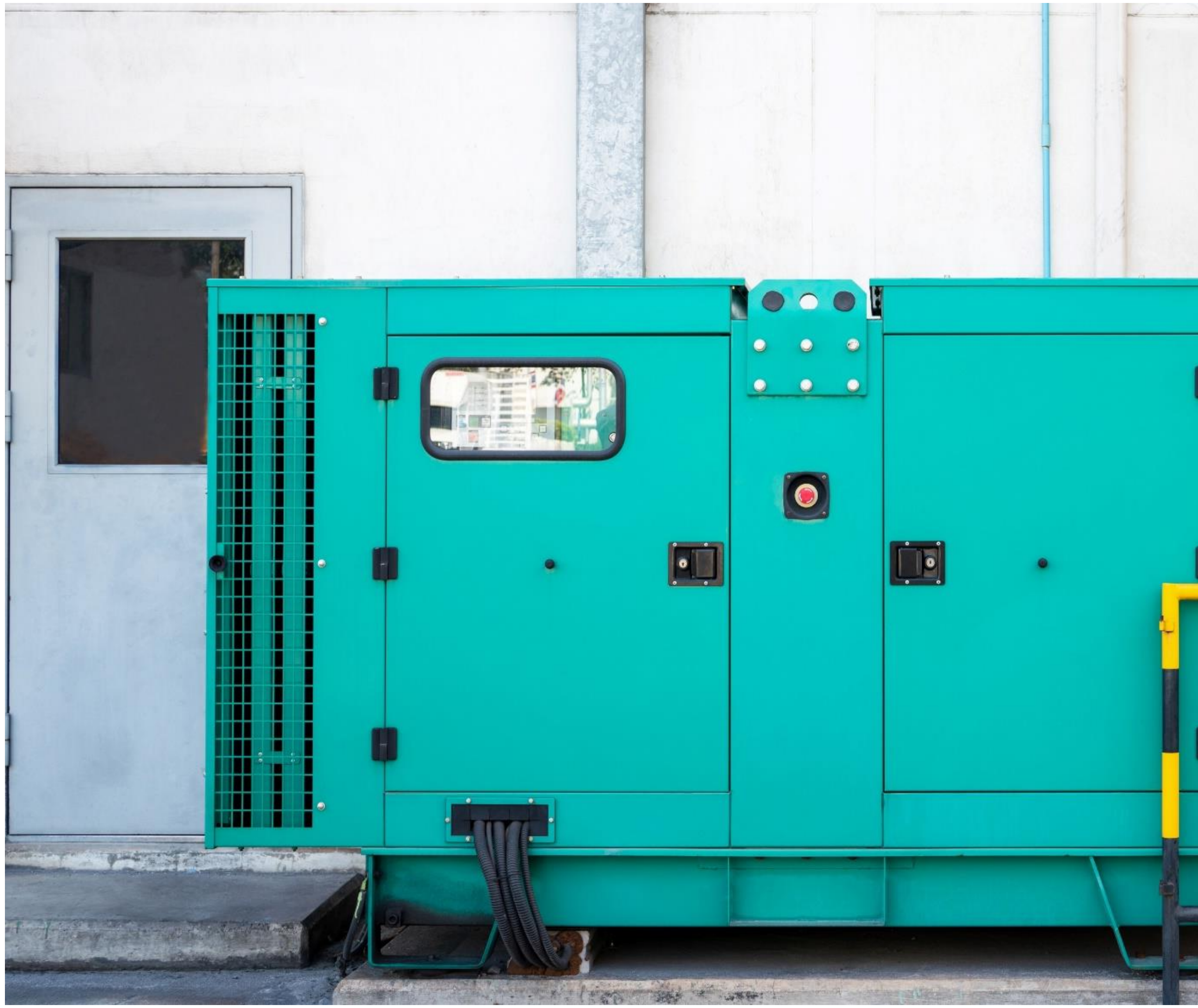
- Most U.S. data centers currently rely on diesel generators for backup power.[17, 18]
- Considerations of primary and backup power include grid reliability, renewable energy integration, climate change goals and impacts, and extreme weather events [19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29]

Clean electricity generation:

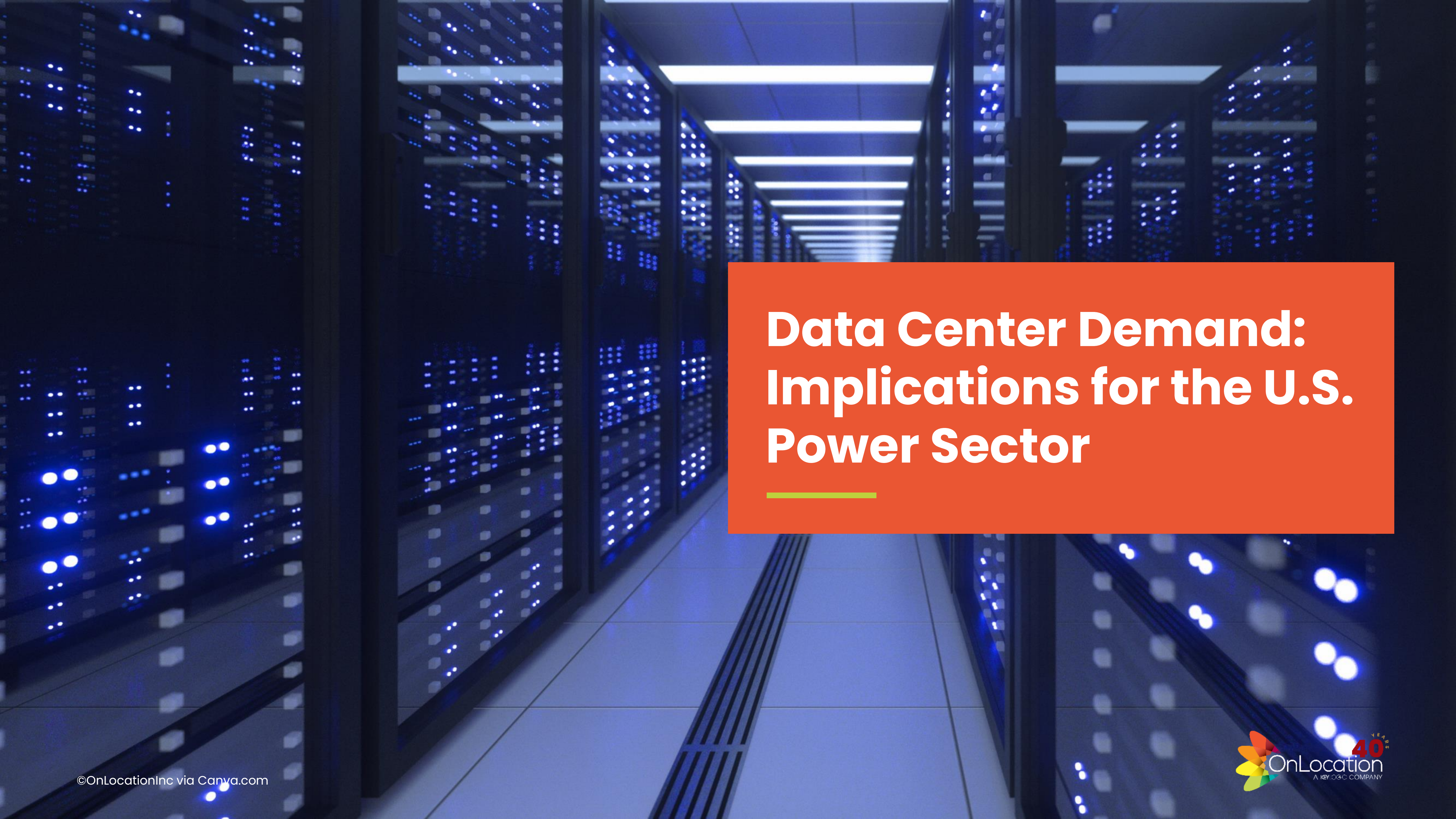
- Geothermal
- Modular nuclear reactor
- Hydropower
- Fossil with carbon capture and storage
- Solar and wind with storage

Reliable, low environmental impact backup power:

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



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



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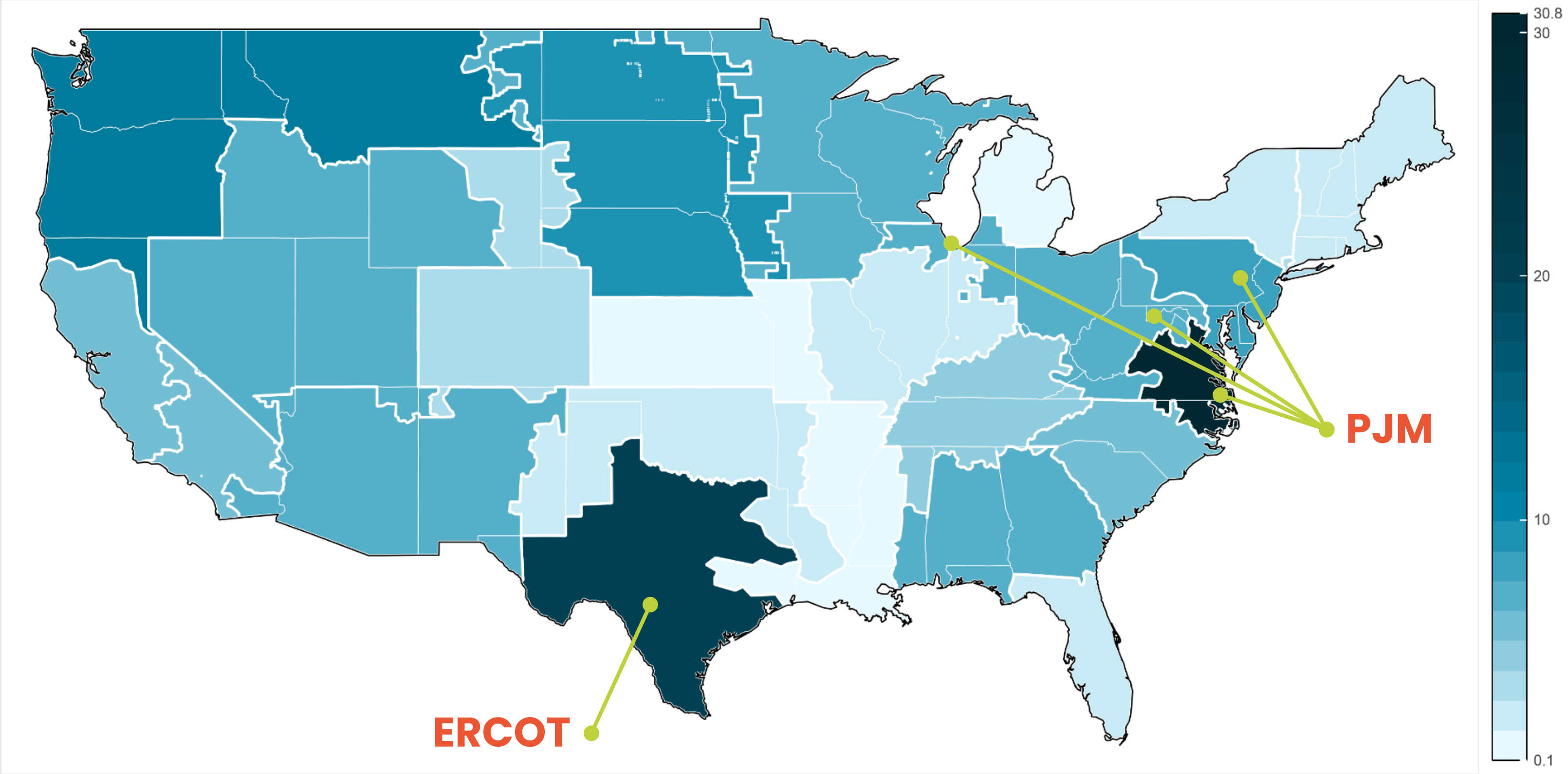
Highly Concentrated Demand Shaping Regional Power Systems

Data Center Demand By Electric Reliability Region in 2023 (TWh)



Source: OnLocation

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

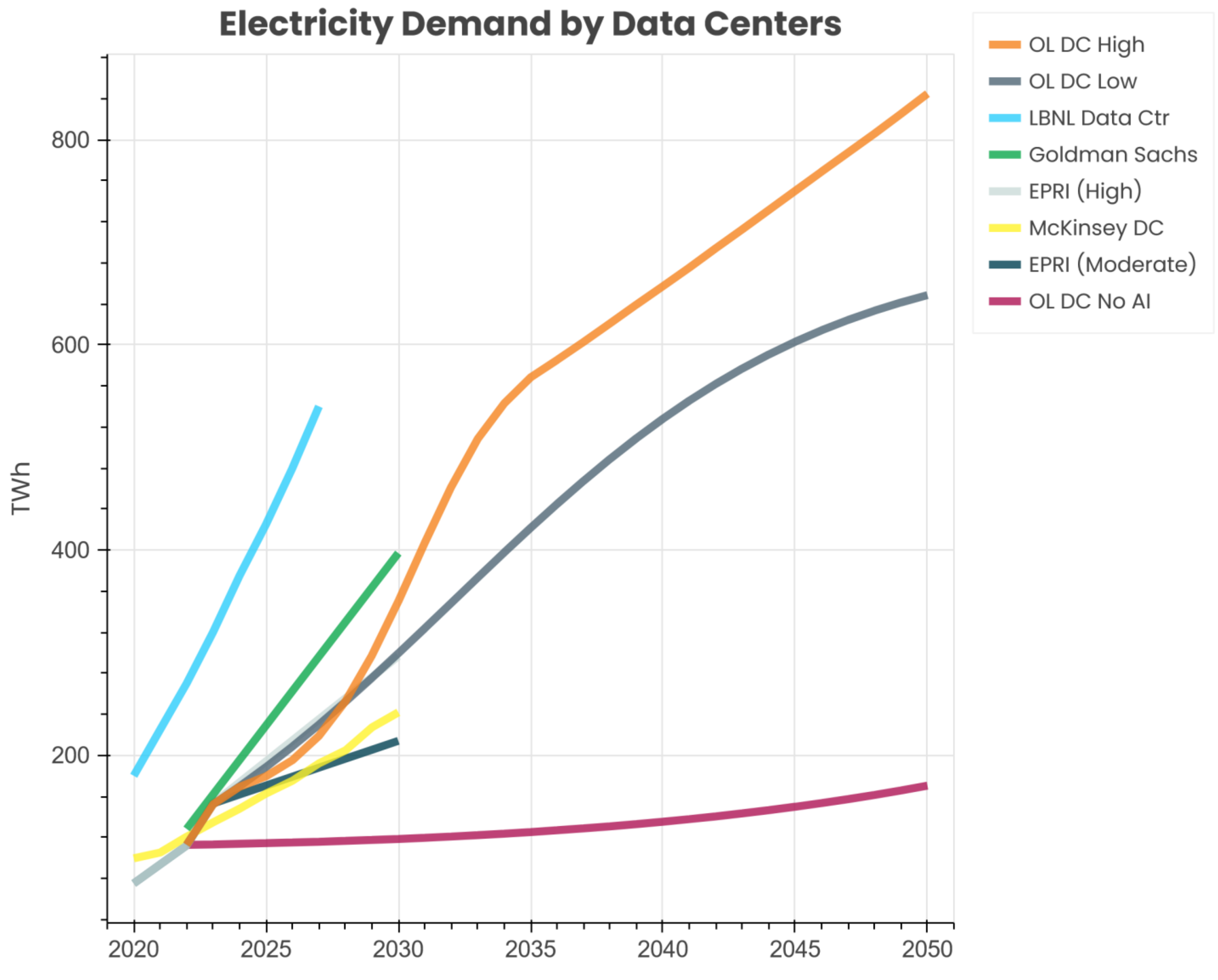
- Our analysis allocates data center electricity demand across 25 electric reliability regions.
- Regional differences in generation mix mean location of additional demand directly impacts capacity expansion, emissions, and grid reliability.
- Key considerations:
  - How does continued regional clustering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

Growth is Significant but Highly Uncertain

- We modeled 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 IRA incentives and EPA GHG regulations.

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



Source: OnLocation

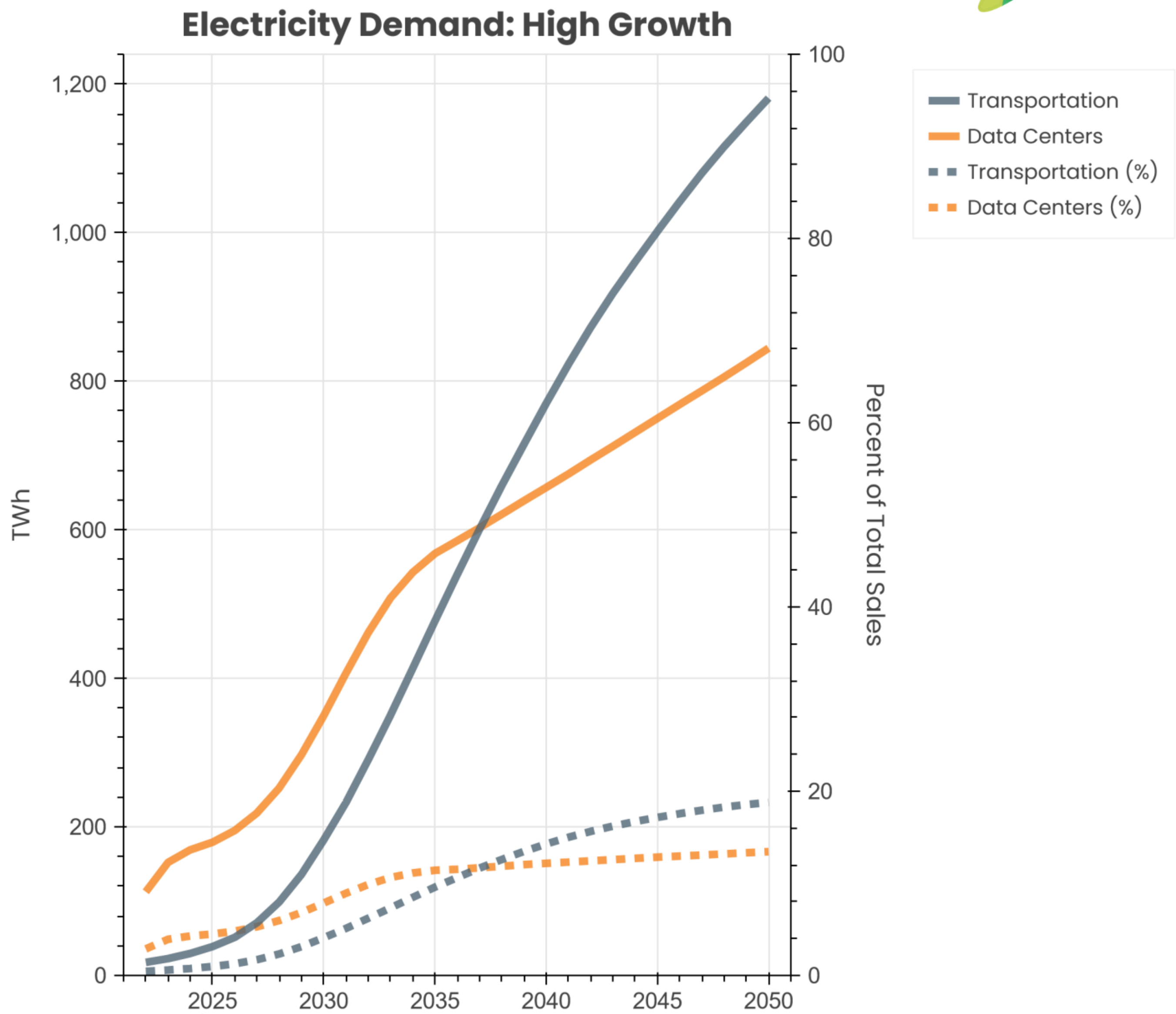
Data Center Growth May Exceed EVs in Near-Term

- Our 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.

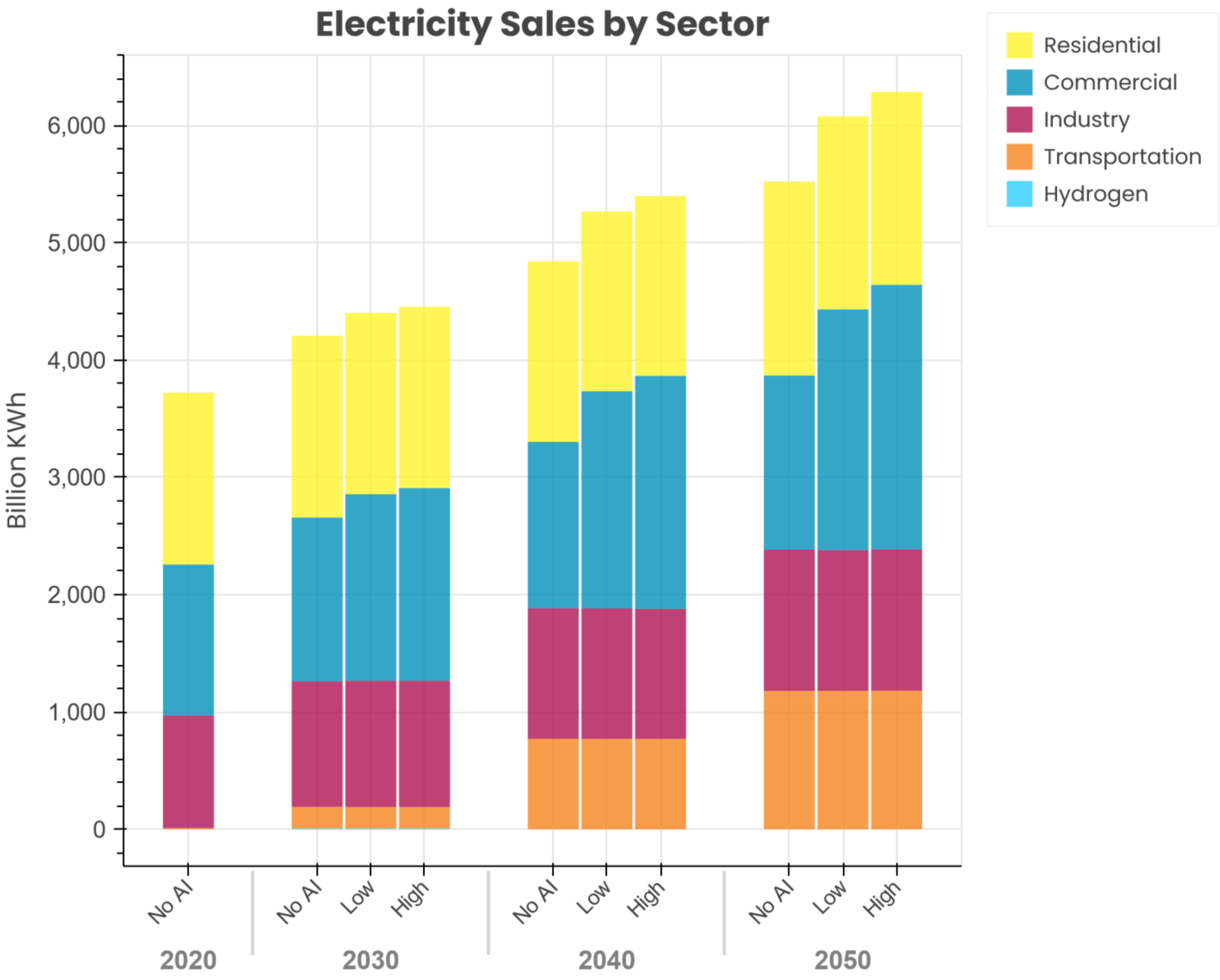
- From late 2030s to 2050 combined load could range from 30% - 35%.



Source: OnLocation

Total 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, primarily due to increased electricity use in vehicles, even without AI-driven data center growth.
- In the High Growth scenario, demand could rise by up to 69% by 2050, factoring in significant data center expansion.
- Across all scenarios, load growth in other energy sectors remains consistent.



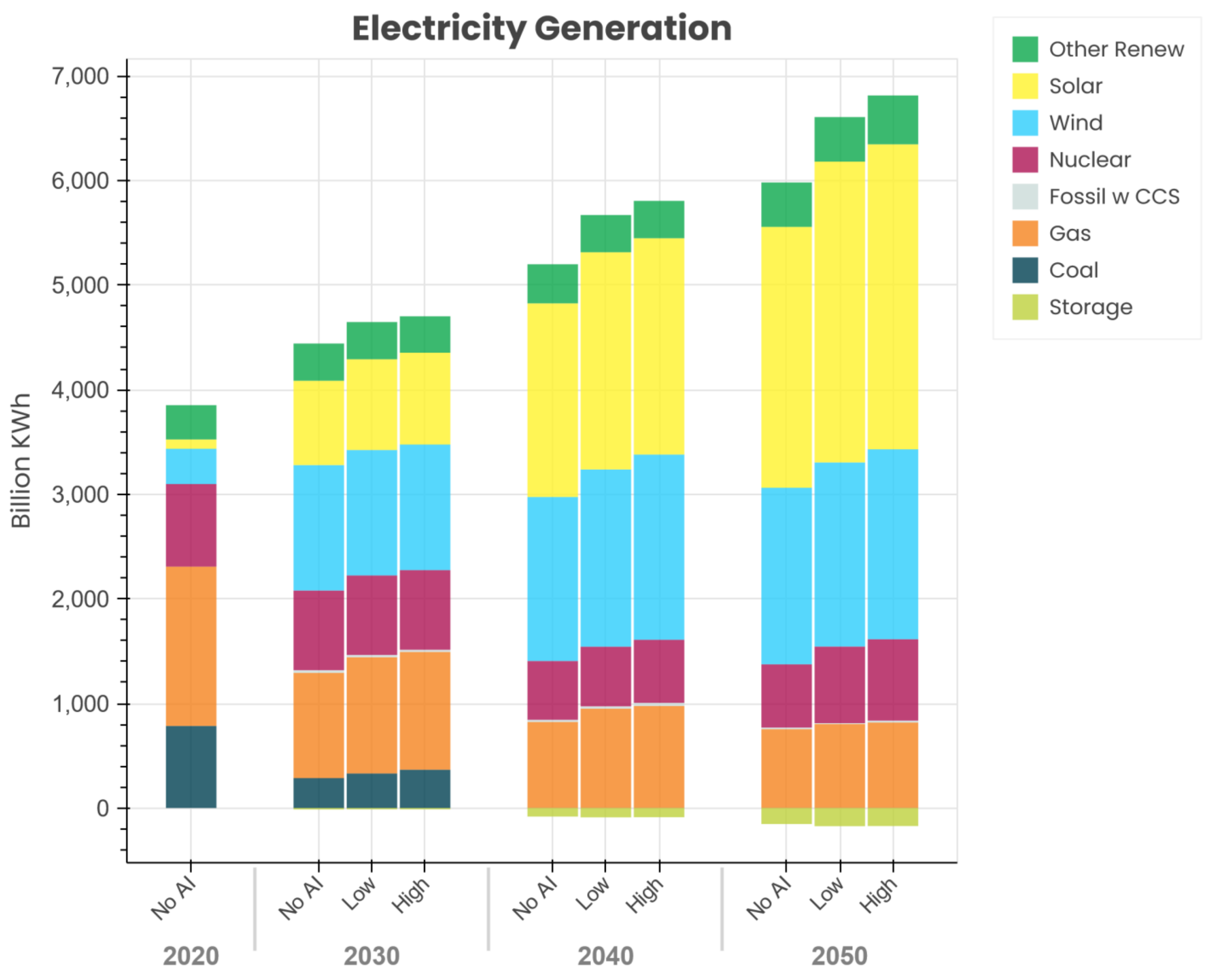
Source: OnLocation OL24-NEMS

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 preservation of existing units.

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

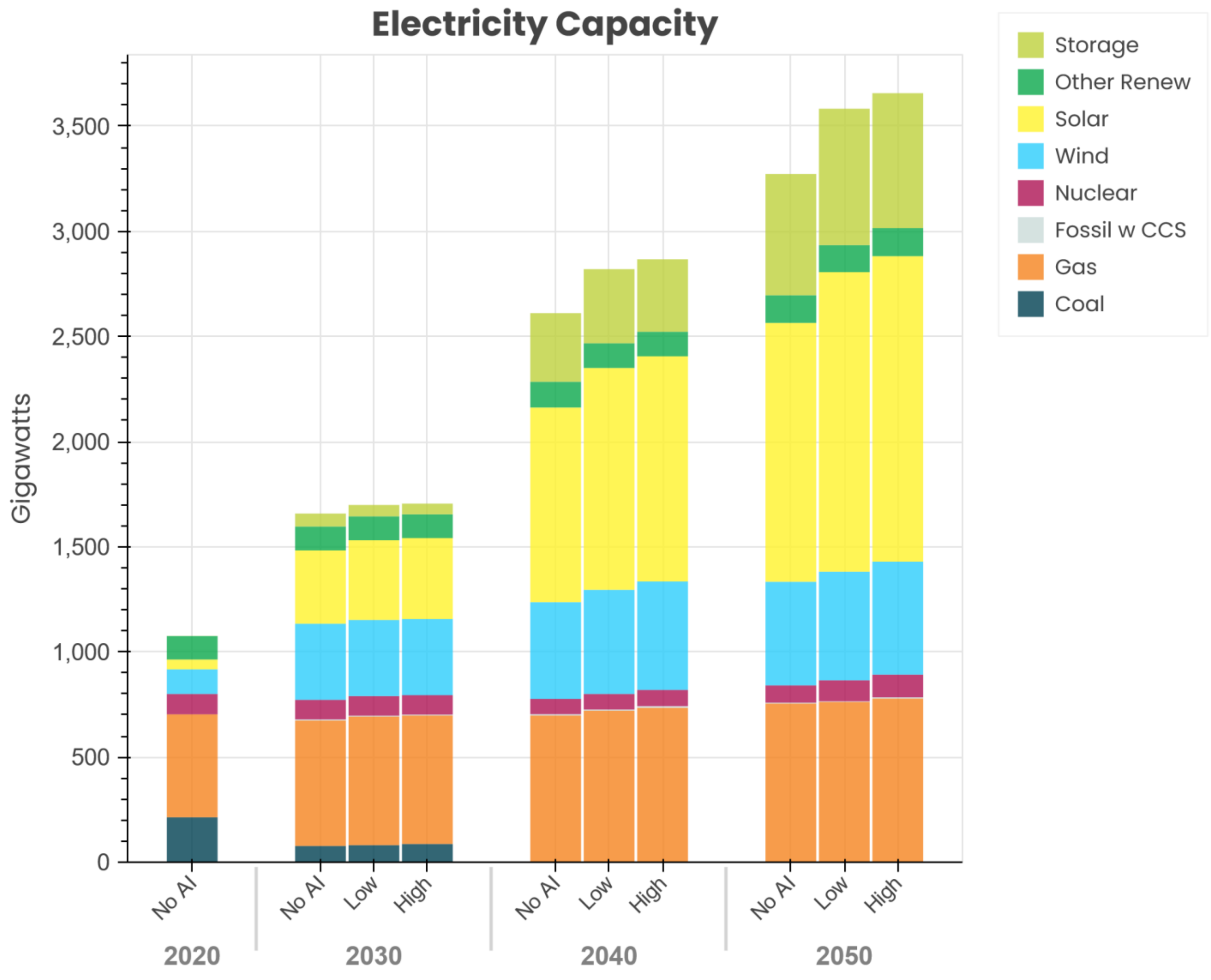
- Through 2050, new clean energy generation outpaces the additional demand from data centers compared to 2020 levels.



Source: OnLocation OL24-NEMS

National Electricity Capacity

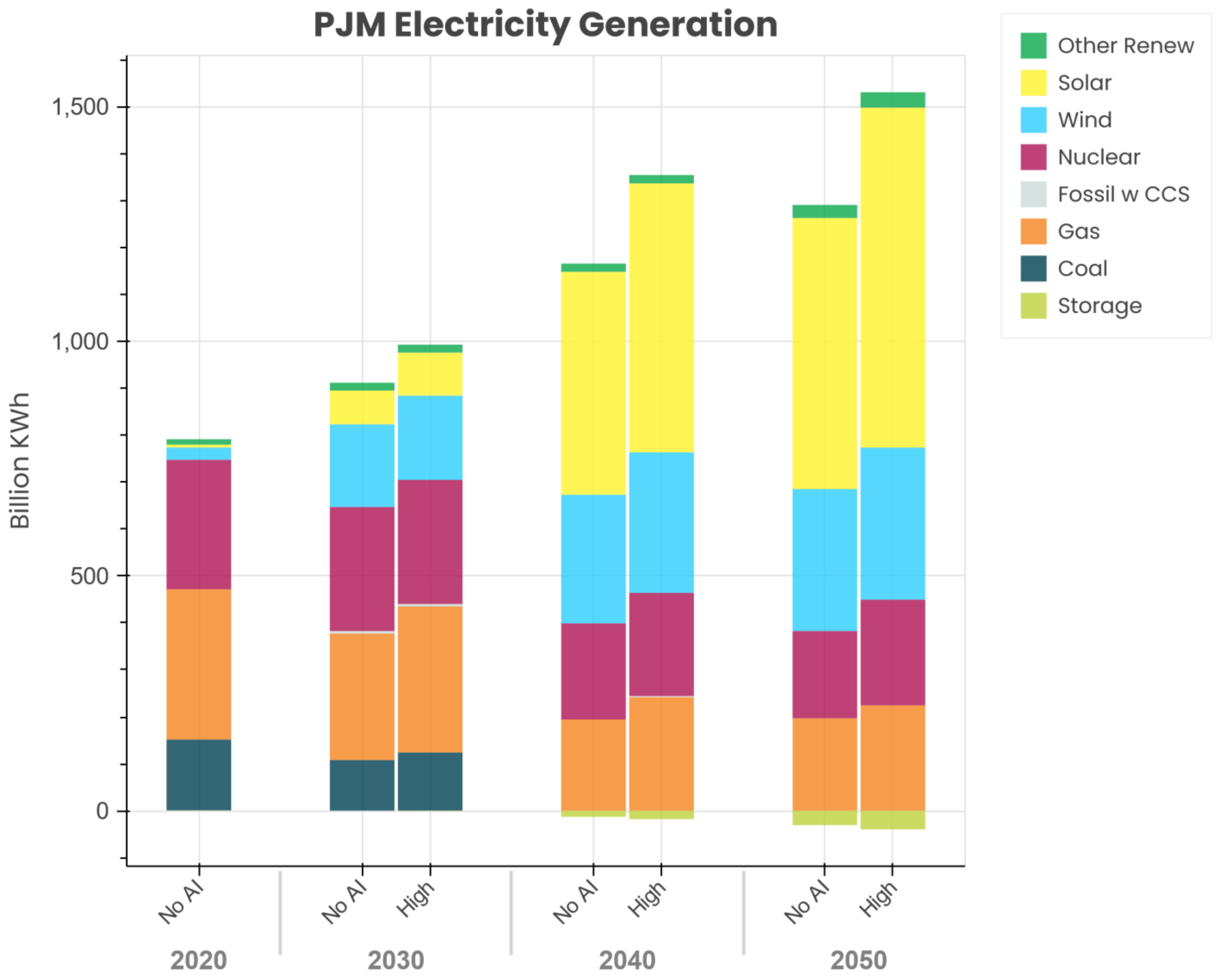
- Initial capacity increases to meet data center demand are largely driven by natural gas, solar, and battery storage.
- Wind and solar dominate capacity additions, with batteries providing essential grid support.
- Additional gas capacity, primarily from combustion turbines, is added to enhance grid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



Source: OnLocation OL24-NEMS

Electricity Generation in PJM

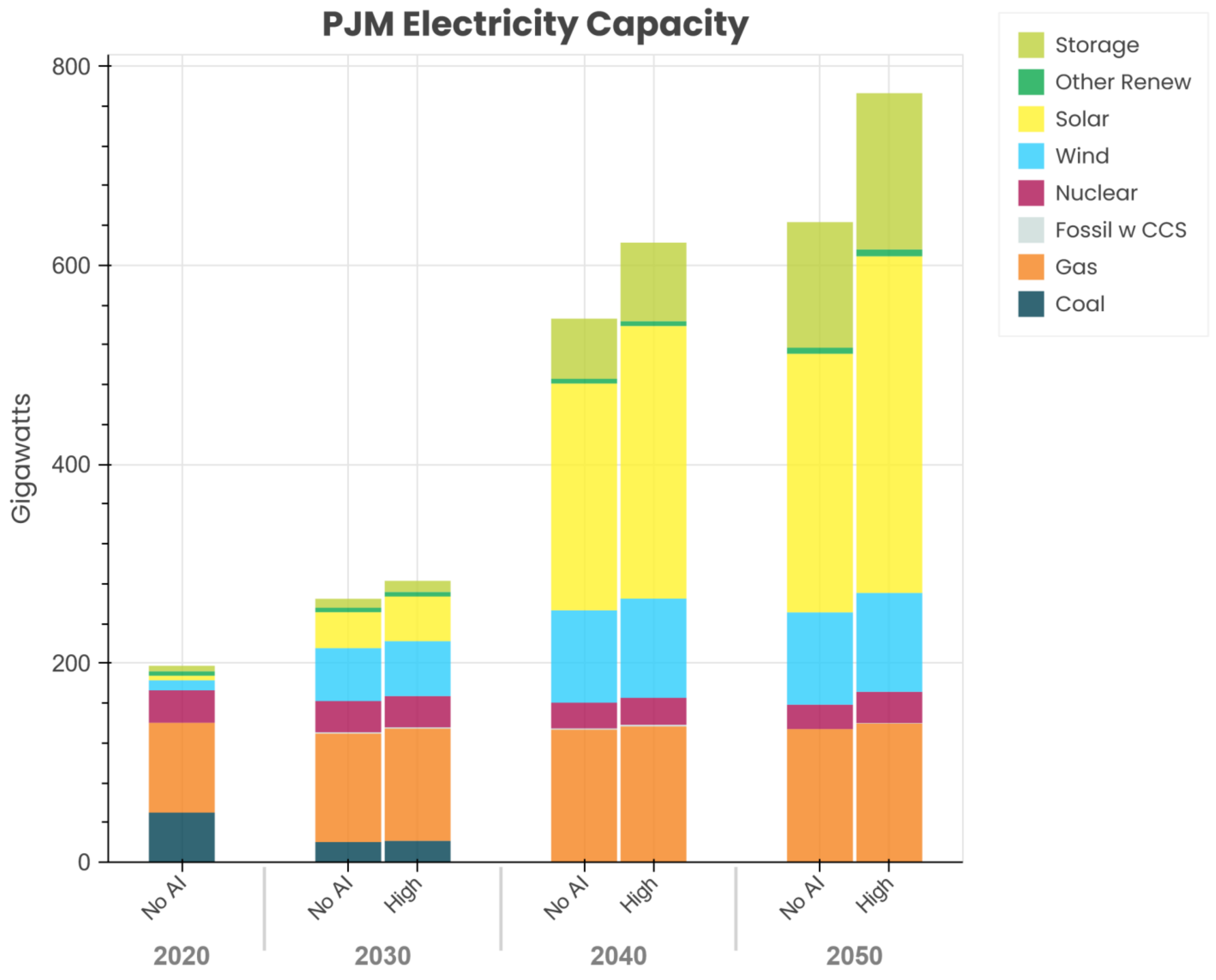
- In 2023, PJM accounts for 34% of national electricity demand from data centers.
- The highest data center demands are in PJM/Dominion, but impacts extend across the region due to intra-PJM trade and exchanges with neighboring regions.
- By 2050, solar and wind significantly expand their share of PJM's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



Source: OnLocation OL24-NEMS

Electric Capacity in PJM

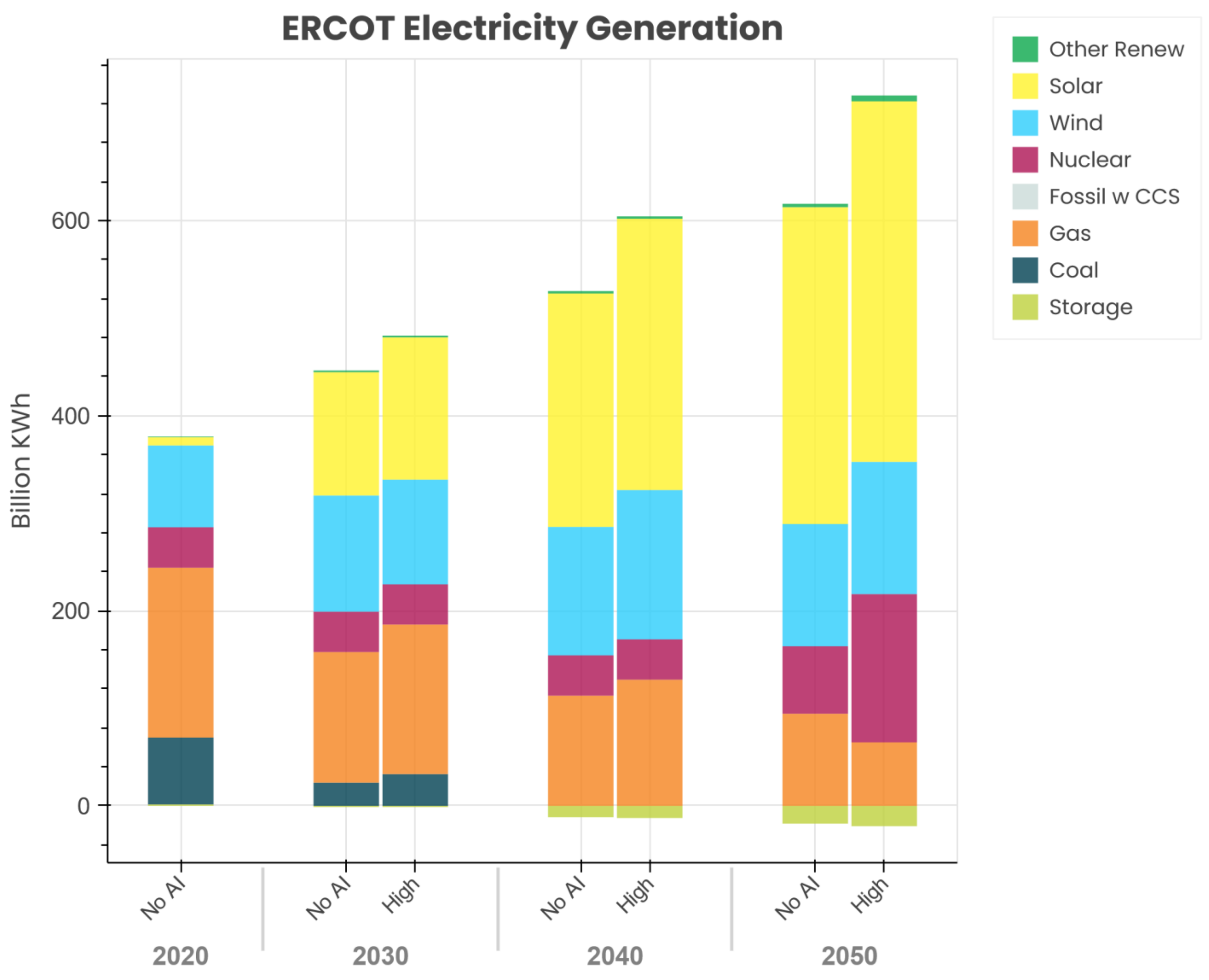
- Total electricity capacity in PJM more than triples from 2020 to 2050, with solar, wind, and storage making up most new capacity additions.
- Incremental capacity to meet data center demand is primarily composed of solar and battery storage.
- In the High Growth case (relative to No AI), clean generation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



Source: OnLocation OL24-NEMS

Electricity Generation in ERCOT (Texas)

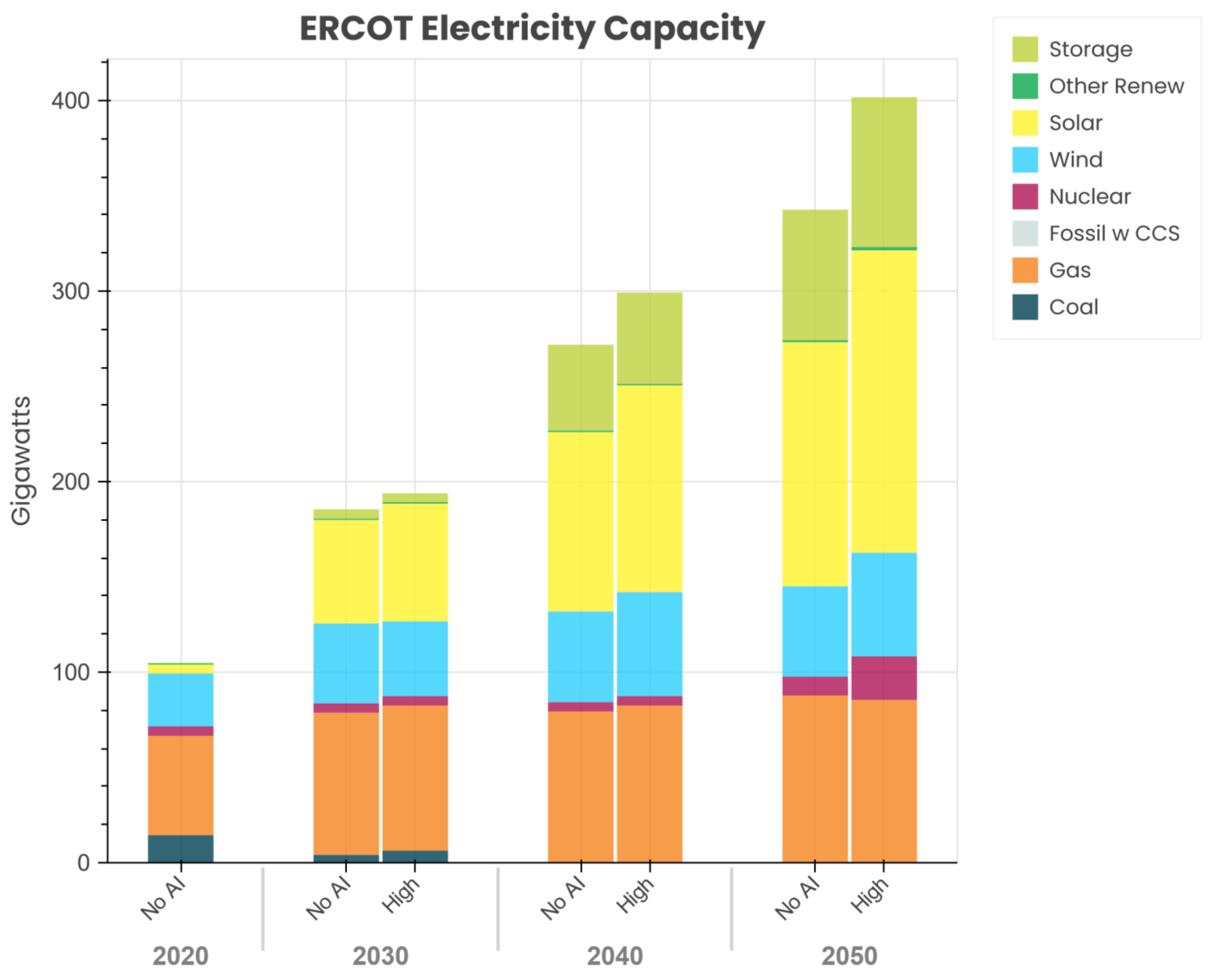
- In 2023, ERCOT accounts for 14% of national electricity demand from data centers.
- ERCOT has limited ability to trade with neighboring regions so building new capacity is critical for meeting increasing demand.
- Wind generation continues to expand through 2050 while solar becomes a significant portion 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 (Texas)

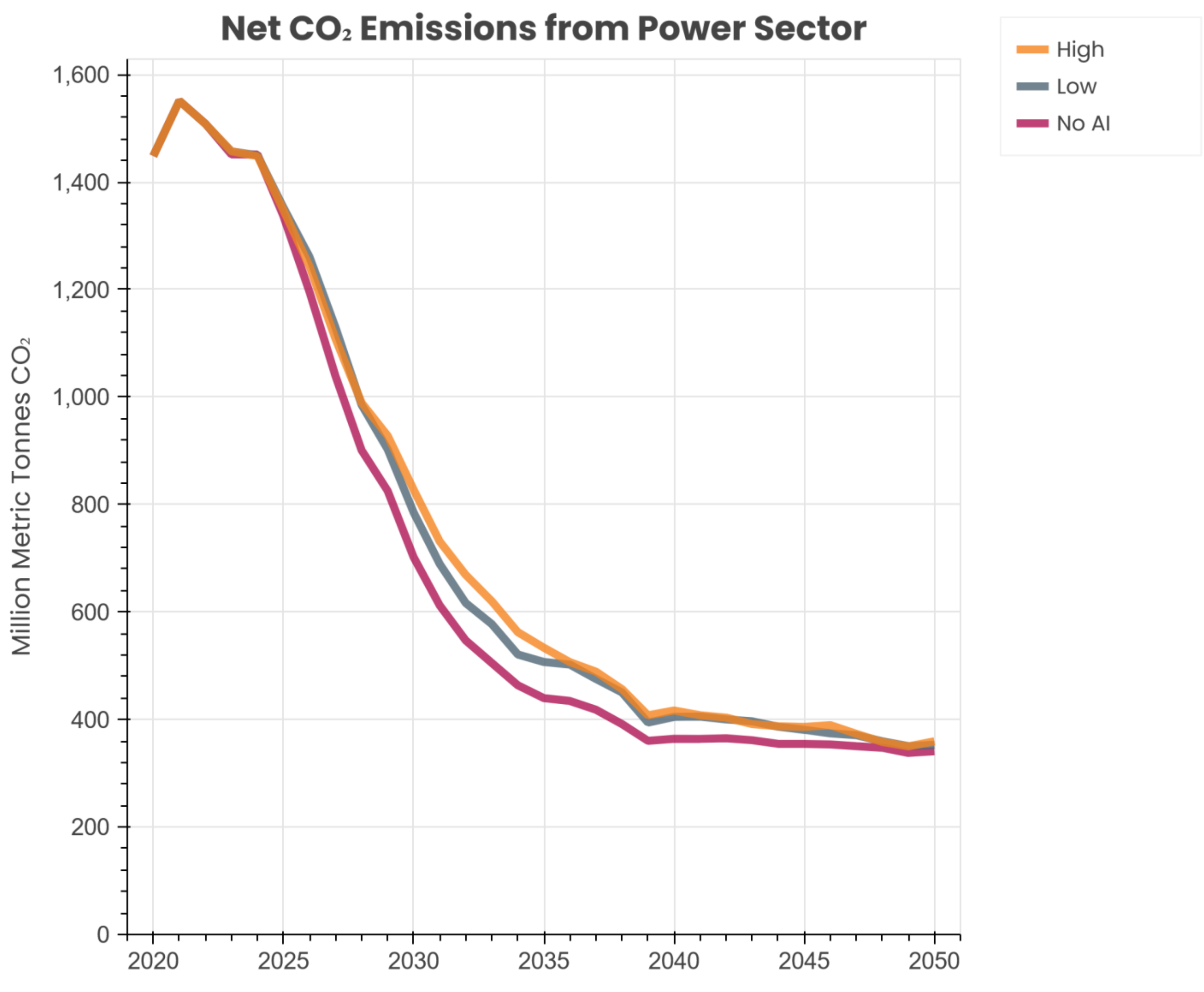
- Total capacity more than triples between 2020 and 2050 in both scenarios, and quadruples by 2050 in the High Growth scenario.
- Solar, wind, and storage make up most capacity additions, alongside new nuclear capacity, particularly in the High Growth scenario.
- The cost of new nuclear and other generating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



Source: OnLocation OL24-NEMS

Implications for CO_2 Emissions

- In **Energy Horizons** *Reference Case,* Annual CO_2 emissions drop significantly over time in all scenarios 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.



Source: OnLocation OL24-NEMS

Key Takeaways

Data center demand growth, while substantial (up to 13% 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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Special Thanks to TeamPeople for Report, Video, and Web Production

- Jessica Winter, Head Of Creative Production & Virtual Services
- Sarah Doyle, Technical Director

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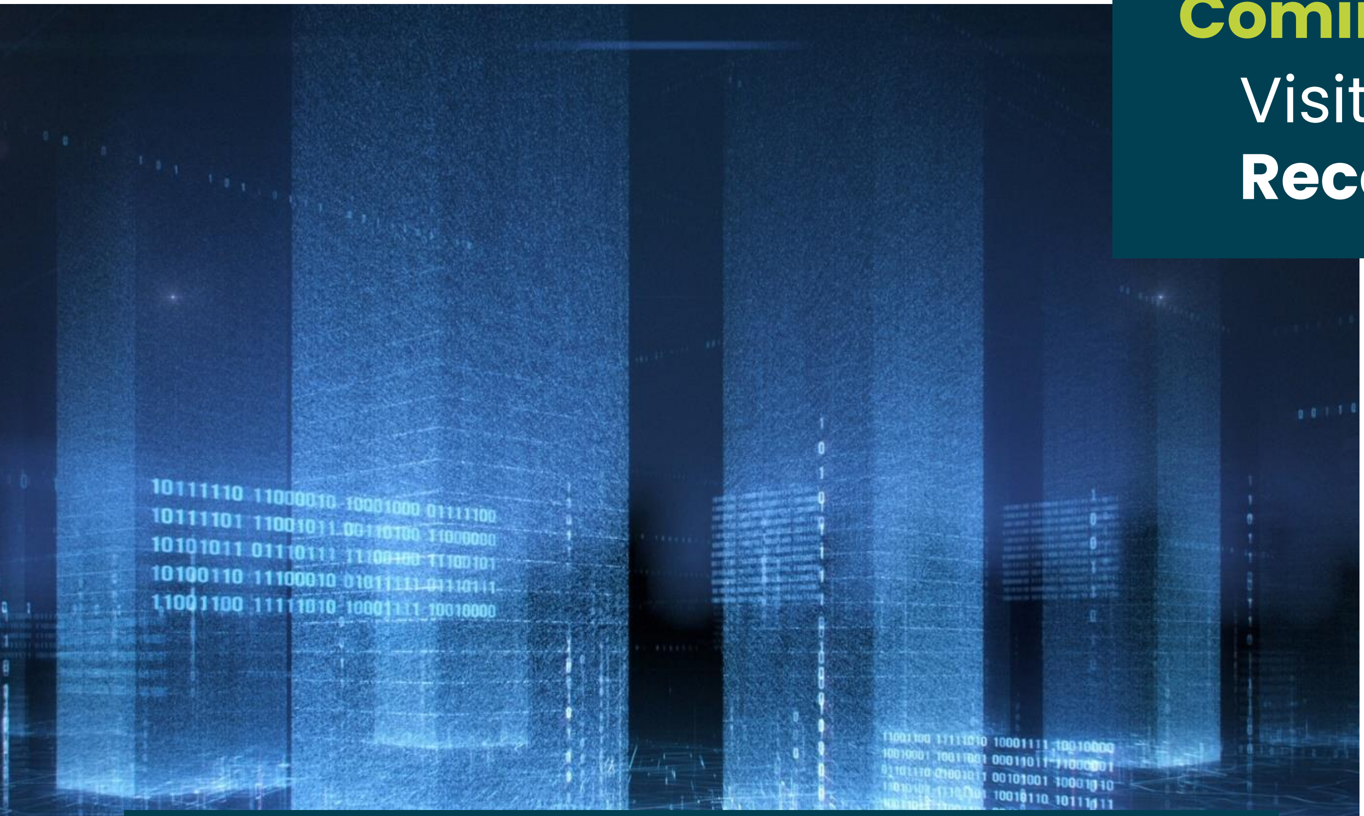

Coming Soon…

Visit our Website to see the **Webinar Recording & Full Report**

Energy Horizons Reports, 2024

Energy Horizons Report, 2024 June 2024

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

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

Contact OnLocation for a free consultation on customized analysis of the U.S. energy system

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Q&A Session

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…………………………