Data Center Load, Smart Code

Tackling Virginia's Energy Demand from Data Centers

Virginia Clean Energy Summit 2025

Meta's Henrico Data Center in Sandston, Virginia. *Source: vpm.org*

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Future-Proof AI Data Centers: Grid Reliability and Energy Affordability

Nora Esram, Ph.D.

Virgina Clean Energy Summit / Richmond, VA / October 01, 2025

About NBI

- 501(c)(3) nonprofit
- Founded in 1997 to advance zero-energy-buildings through policies and market leadership.
- Our vision is a built environment that equitably delivers community benefits and climate solutions.

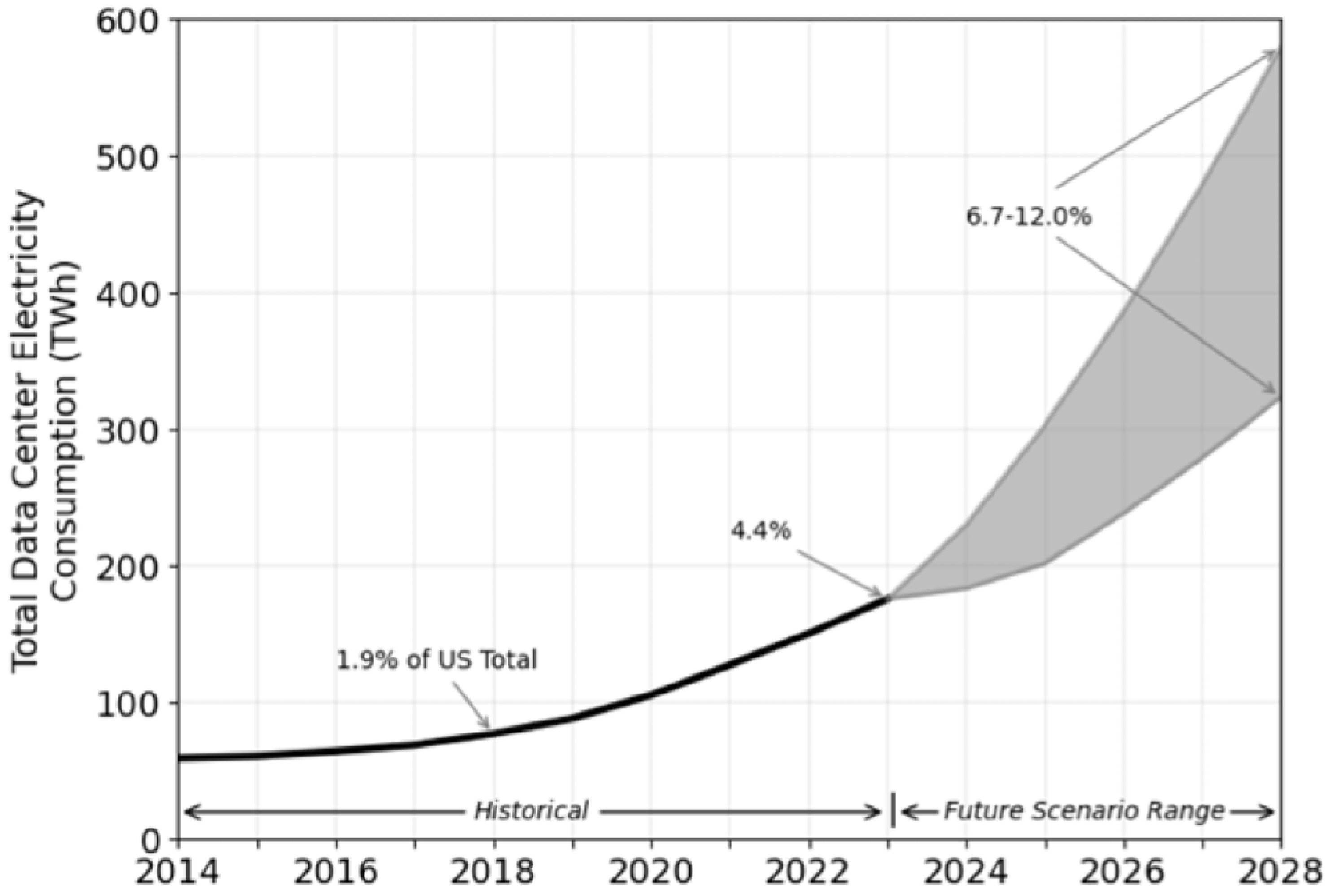
www.newbuildings.org

NBI headquarters office at PAE Living Building, Portland, OR *Photo by Portland Drone*

Recent projections suggest that AI-driven data centers could consume up to **9%** of U.S. electricity by 2030.

Equivalent to the electricity needed to power 20–40% of today's vehicles if they were EVs.

Total U.S. data center electricity usage from 2014 through 2028



Source: Lawrence Berkeley National Lab (https://eta.lbl.gov/publications/2024-lbnl-data-center-energy-usage-report)

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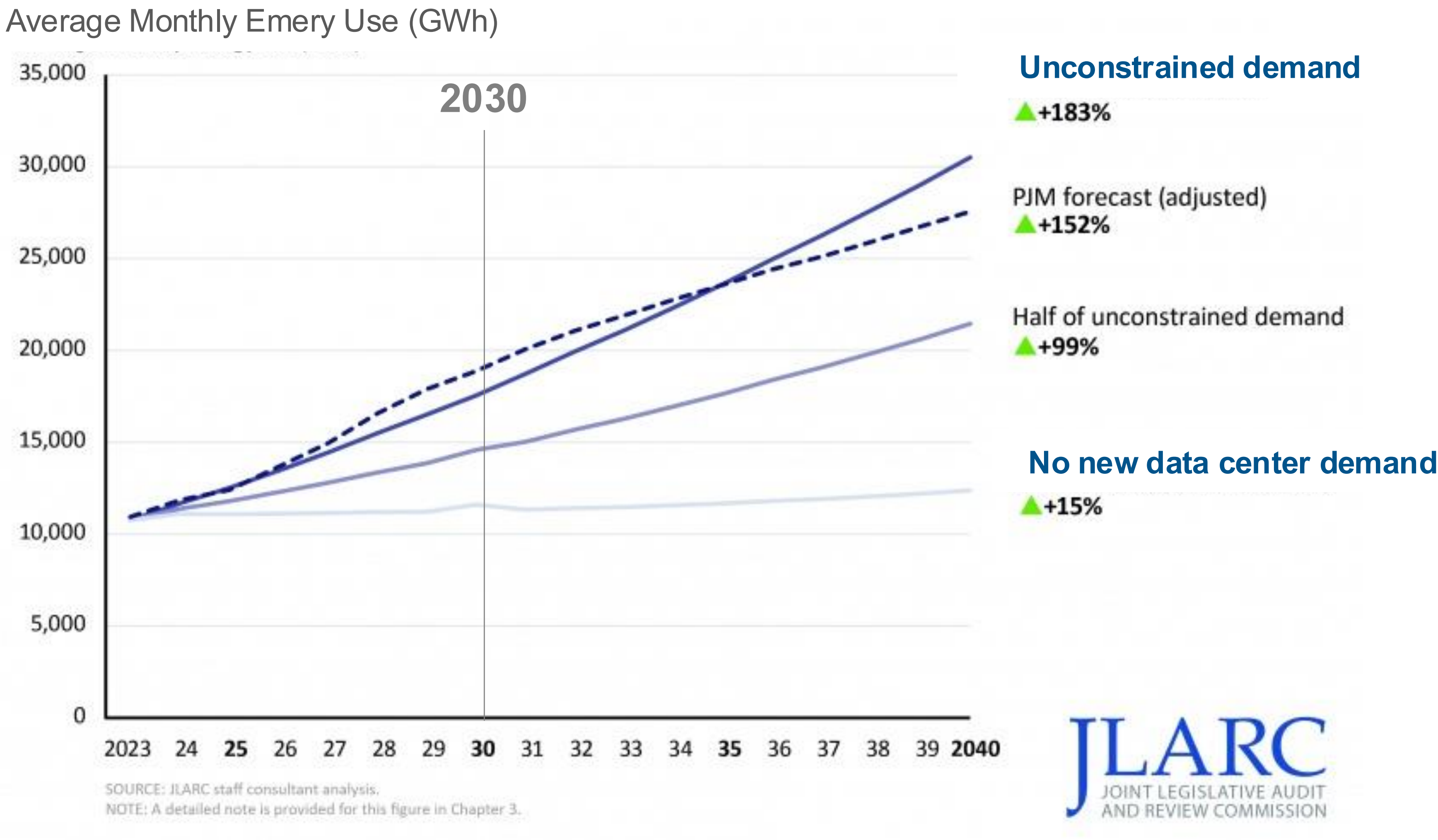
Virgina electricity growth (driven by data centers) from 2023 through 2040

Unconstrained demand for power in Virginia would **double within the next 10 years**, with the data center industry being the main driver.



Source: JLARC (https://jlarc.virginia.gov/landing-2024-data-centers-in-virginia.asp)

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Data centers: One Name, Different Forms

Hyperscale cloud computing infrastructure is operated by large technology companies (e.g., AWS, Google, Microsoft) and hosts customers' software (from small businesses to large companies like Netflix). It helps customers optimize workloads and emissions.

Co-location services provide connectivity, power, cooling, and facilities for customer servers, but where the operators (e.g., Iron Mountain) have limited control of their customers' server utilization and energy use.

Crypto mining seeks locations with cheap electricity rates to improve profitability. Many Bitcoin mining companies participate in formal demand response programs.

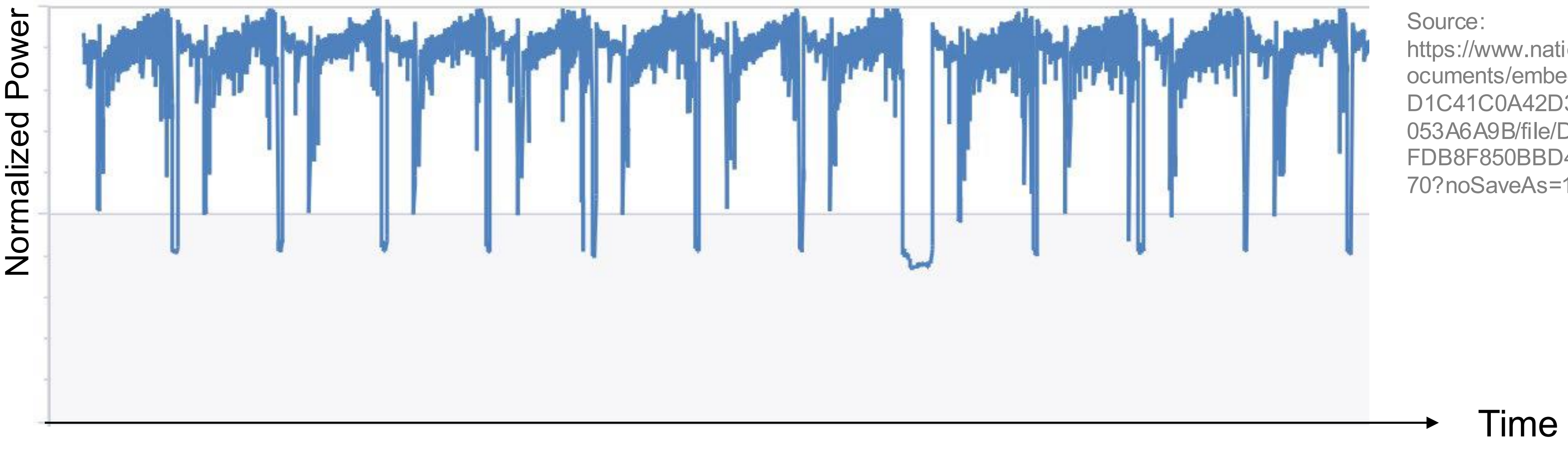
AI data centers as an emerging category that typically use arrays of GPU-based servers to train large language models and respond to queries using these models (known as inference). Training large models often results in high load factors, while inference workloads may have more variable load factors.

Traditional data centers consume around **7.5kW** per rack of servers.

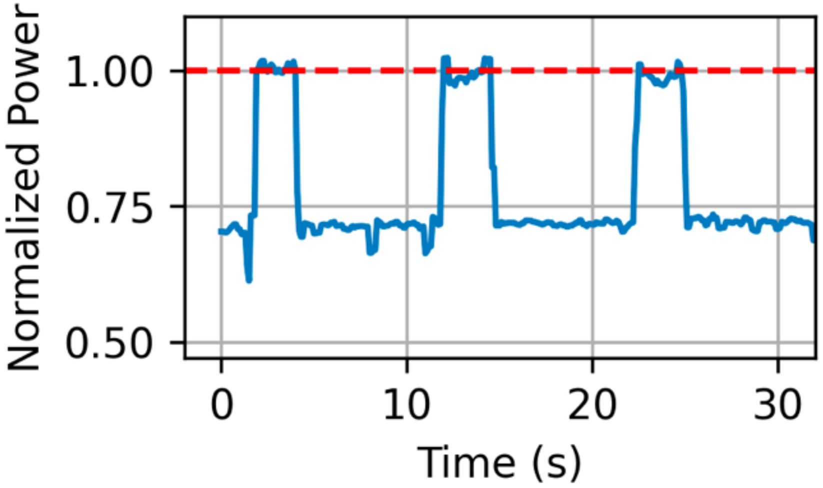
AI data centers operate above **30kW** per rack, and emerging designs will require **100kW** per rack.

Appliances	Low (W)	High (W)
AC	3500	5000
Dryer	1800	5000
Water Heater	3000	4500
Pool Pump	500	2500
Dish Washer	1200	2400
Electric Grill	1200	1800
Hair Dryer	1200	1800
Vacuum Cleaner	500	1500
Microwave	600	1200
Coffee Maker	800	1200
Toaster	800	1000
Blender	300	1000
Washing Machine	300	500
TV	150	400
Computer	100	400
Refrigerator	100	400
Total	**16.05 kW**	**30.6 kW**

AI Training vs Inference



Source: https://www.nationalacademies.org/documents/embed/link/LF2255DA3DD1C41C0A42D3BEF0989ACAECE3053A6A9B/file/D0589B040D44ED15FDB8F850BBD42463DA4CF1AC7270?noSaveAs=1

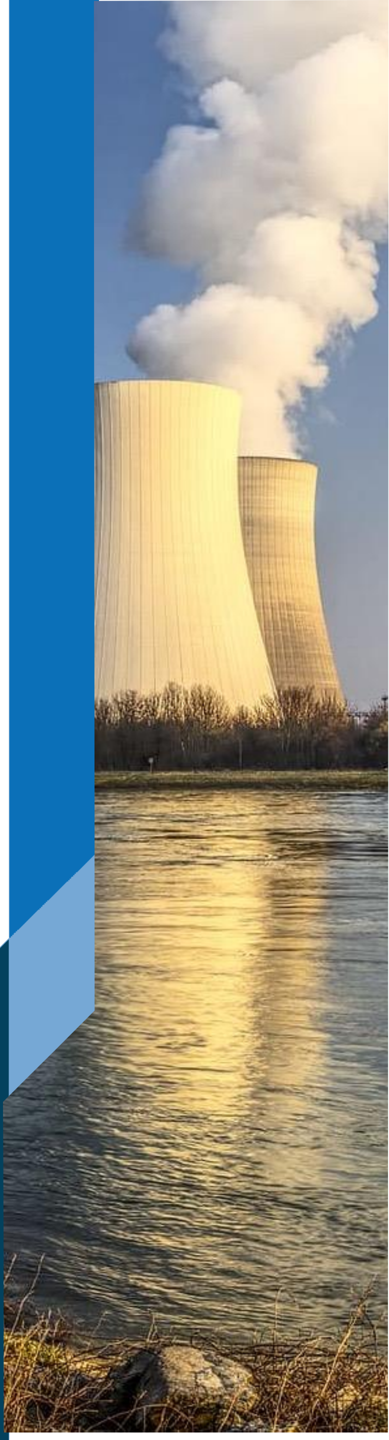


AI Training (above) involves batch jobs with high power utilization and dramatic power fluctuations. It requires massive synchronous computation, with effective utilization decreasing due to component failures.

AI Inference (left) is an interactive service with lower utilization (like cloud services). Phases behave differently depending on applications.

Rapid electrical load growth results in substantial consumption of water

- In 2018 (two years before ChatGPT was publicly released), data centers were estimated to consume **135 billion gallons** of water (~0.4% of the total annual water withdrawals in the U.S.)
  - Microsoft's water consumption increased by **34%** from fiscal year 2021 to fiscal year 2022.
  - Google's water consumption was **5.6 billion gallons** in 2022, projected to increase due to the generative AI revolution.
  - Meta's water withdrawal was ~**1.29 billion gallons** in 2022.
- In some regions, data centers can account for **a quarter of** a town's annual water consumption.
  - Data centers in certain areas consume up to **57%** of cooling water from potable sources.



A typical hyperscale data center can use **3–7 million** gallons of water per day for cooling purposes.

An Olympic sized pool holds ~0.5 million gallons of water.

Dimensions: 165 feet long by 56 feet wide; 8 lap lane,; each 7 feet wide.

Rapid electrical load growth affects environmental quality

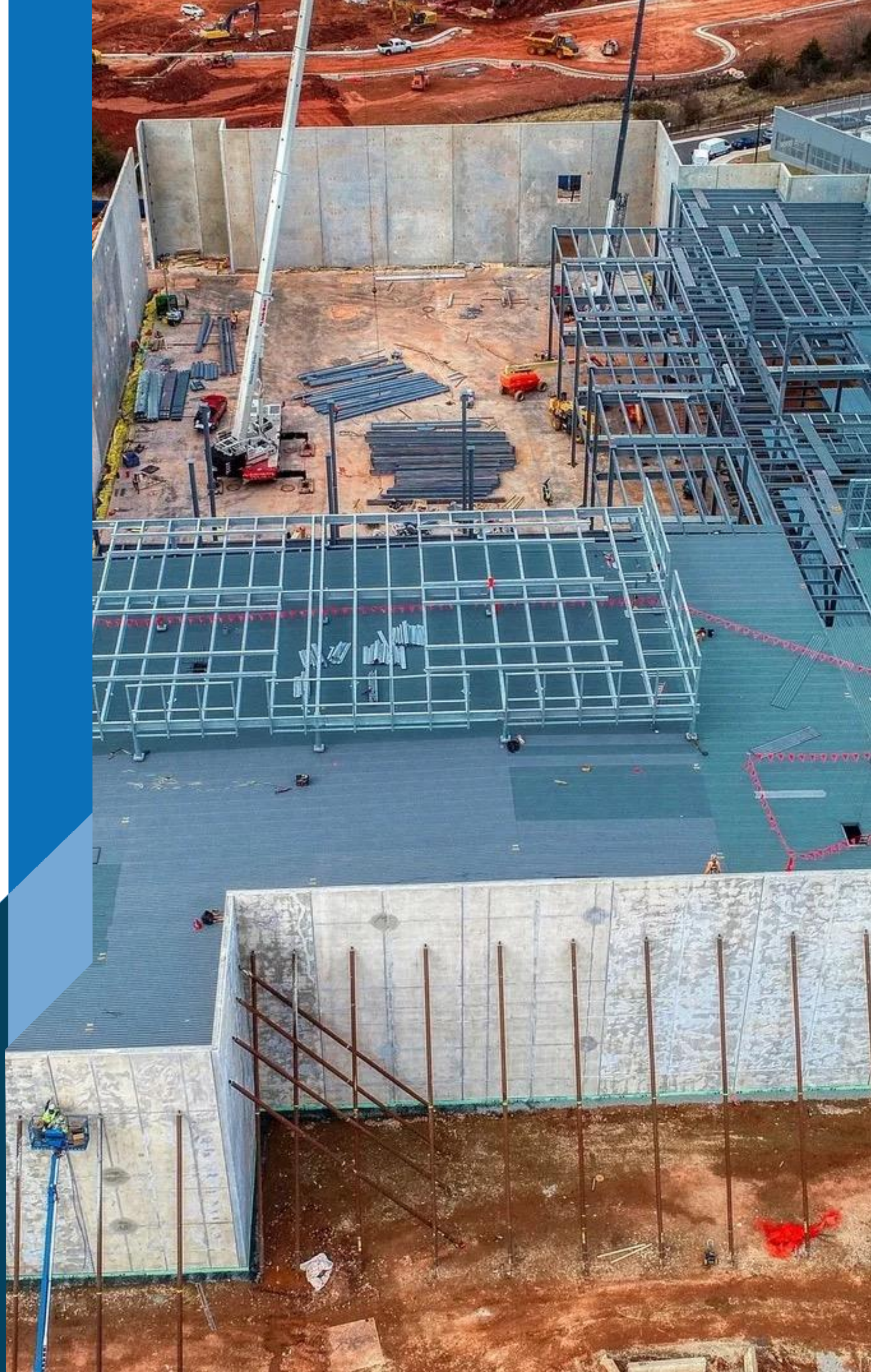
- The health costs of training an AI model could be **30-120%** of the electricity costs.
  - Fossil-fueled power plants and diesel backup generators that power data centers emit hazardous pollutants (NOx, PM).
  - U. S. data centers in 2030 could contribute to nearly 1,300 deaths annually, resulting in a public health burden of more than **$20 billion**.
- The health impact of data centers in the U.S. is projected to exceed that of on-road emissions in California by 2030.
- The health costs are often felt most by low-income communities.

Data centers bring tax revenue

- Data centers have been a significant source of tax revenue, making them attractive to state and local policymakers.
- The data center industry is estimated to bring **$1.2 billion** in tax revenue into the Virginia economy annually, including $1 billion to local municipalities and $174 million to the state.
- However, this revenue boost has not been adequately assessed in the context of increasing electricity demand and its broader impact.

Data centers generate limited long-term local jobs

- A typical data center employs significantly fewer people on site (5-30) than headquarters and manufacturing (200-1,000 jobs).
- Data center construction added **1%** point to U.S. GDP growth in the first quarter of 2025.
- The Virginia Joint Legislative Audit and Review Commission (JLARC), estimates data centers generate 74,000 jobs, mostly during construction, $5.5 billion in labor income, and $9.1 billion in GDP to Virginia's economy annually (1.5% VA's real GDP in 2024).
  - Construction of a data center takes 12 to 18 months; ~1,500 workers are on site at the height of construction.
  - A typical 250,000 sq.ft. data center hires ~**50** full-time workers (half of which are contract workers).



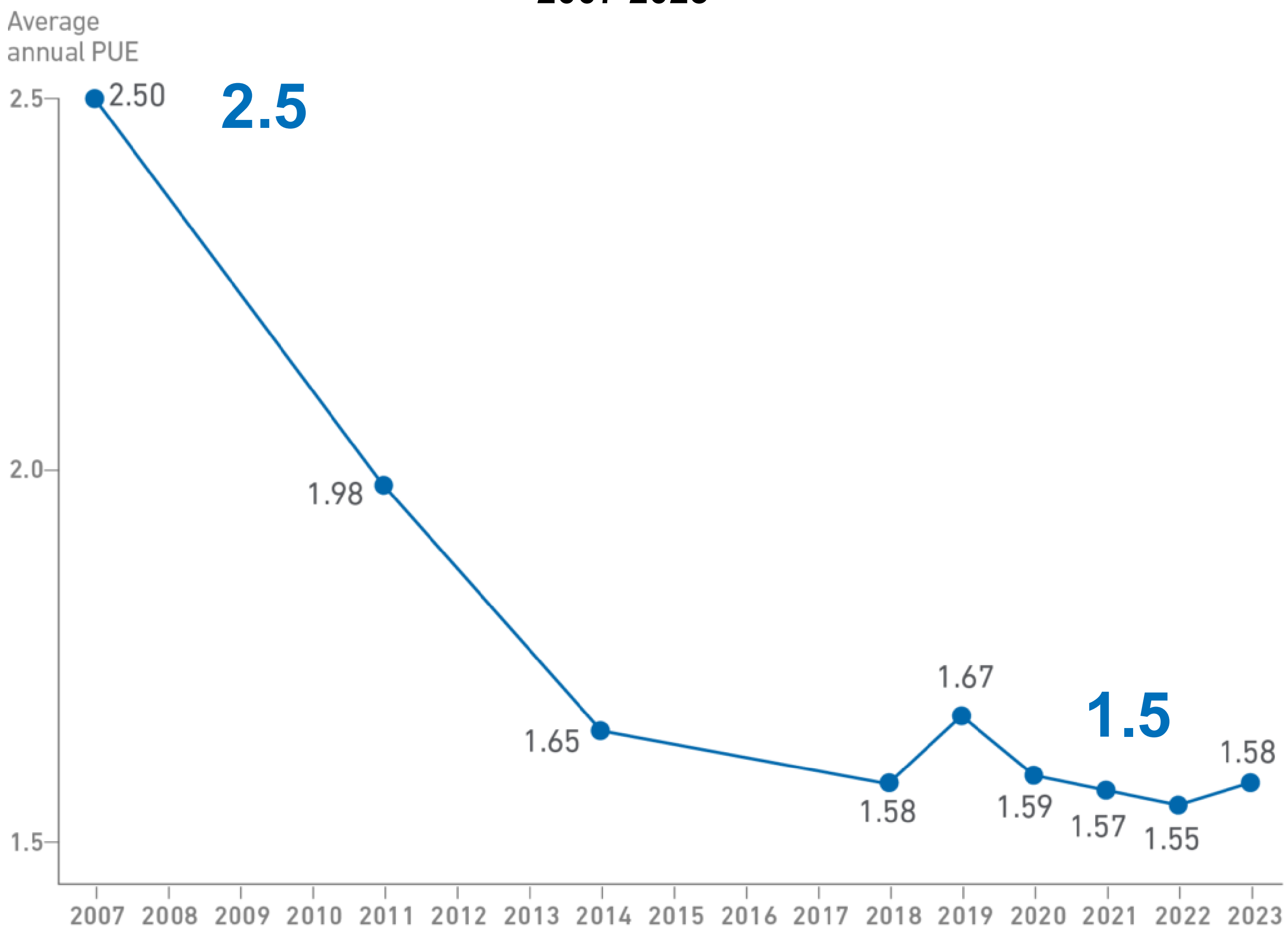
Call to Action: Fill data and knowledge gaps and develop appropriate metrics

- **Data transparency and comprehensive data gathering** (e.g., power dynamics in AI model training and inference, spatial and temporal concentration of energy loads) are essential for integrating AI data centers with the power grid.
- **New metrics are needed** to evaluate data center efficiency, flexibility, and productivity.
  - Productivity metrics such as tasks completed per kWh, or AI efficiency index.
  - Flexibility metrics such as peak-time load reduction (time and speed), grid score.

Power Usage Effectiveness

- PUE is defined as the ratio of total facility power to IT equipment power
- A lower PUE (closer to 1.0) means less overhead energy is wasted on cooling, fans, lighting, and so on.
- The most efficient cloud data centers boast PUE in the 1.1–1.3 range while the industry average has been around 1.5 since 2020.

What is the average annual PUE for your data center? (N=567) 2007-2023



Source: Uptime (https://journal.uptimeinstitute.com/global-pues-are-they-going-anywhere/)

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Thank you!

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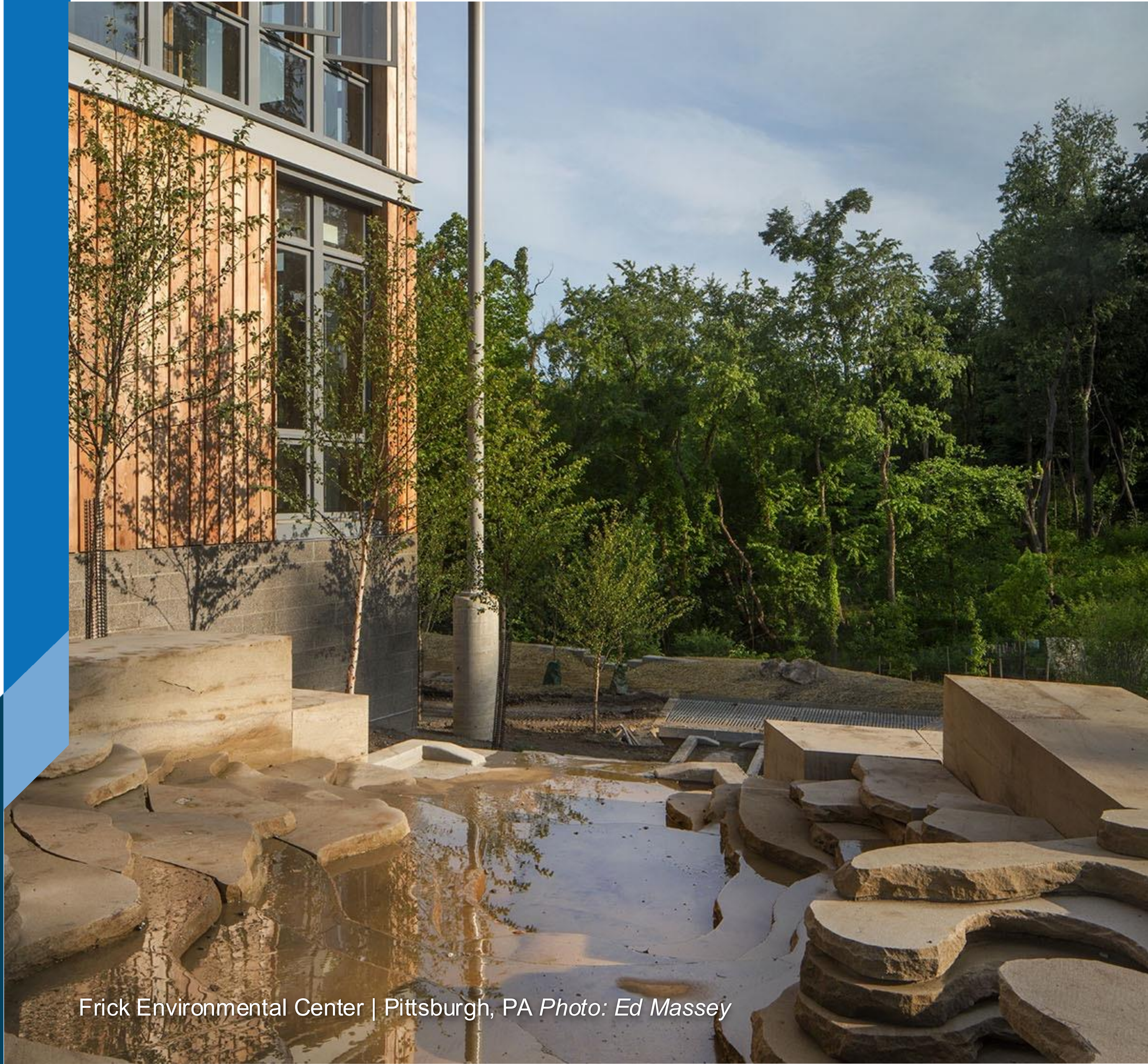

Frick Environmental Center | Pittsburgh, PA *Photo: Ed Massey*

The Loud and Clear Reality Today: Data Centers & Energy Demand Growth

Virginia Clean Energy Summit – Richmond, VA
October 1, 2025

Rich Bralley | Siemens Data Center Solutions

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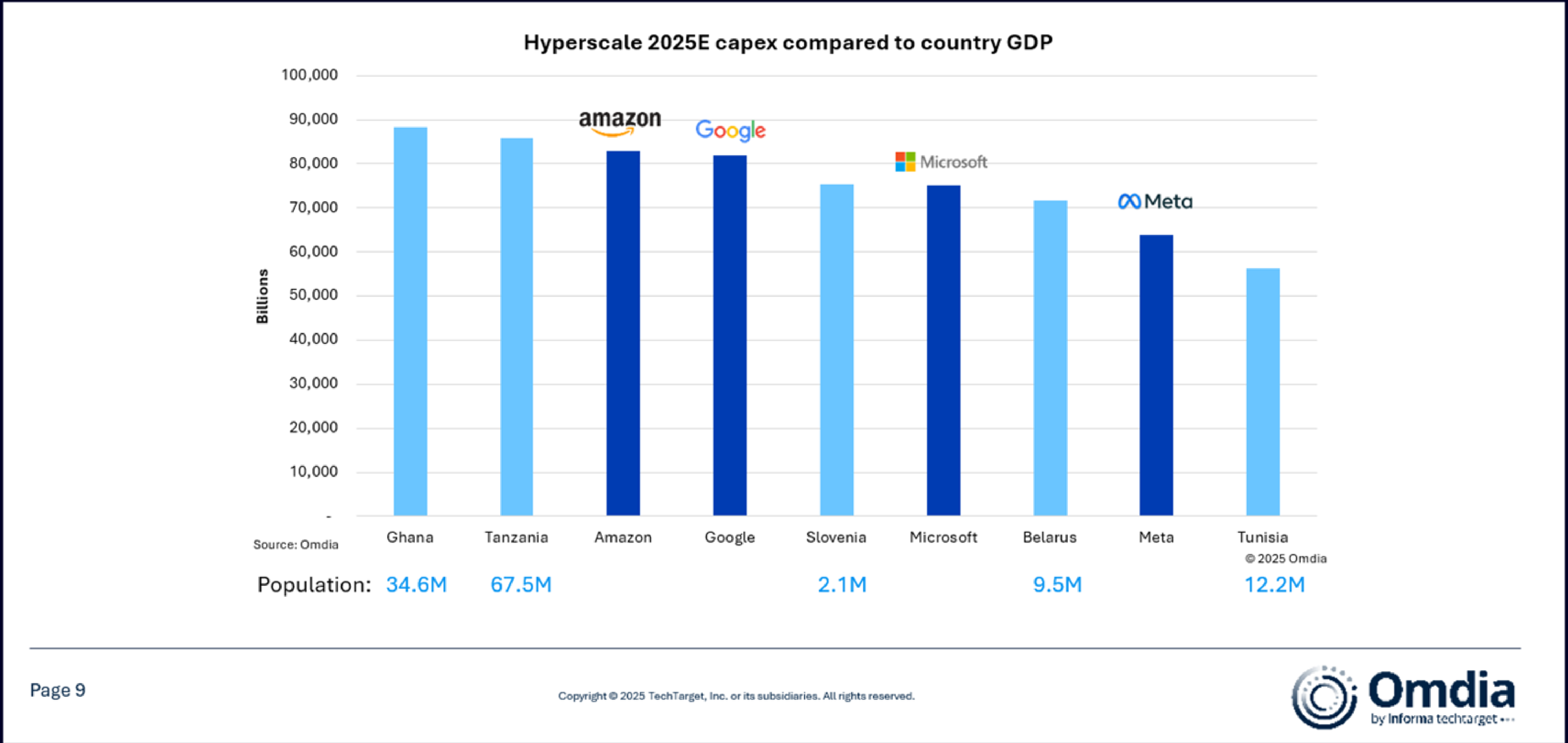
From Ripples → Ocean → Tsunami

Three Loud & Clear Reality Takeaways from Today:

1. Energy demand is accelerating
2. Supply is constrained & complex
3. Efficiency & innovation are levers now

Hyperscale CapEx Vs. Country GDP



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September 2025 Headlines: $46B Investment Committed Globally in One Month

North America

- 📍 Montana: EnCap-backed Quantica unveils "Big Sky", a 5,000-acre platform targeting 500MW → 1GW with new fibre conduits
- 📍 Louisiana: Regulators clear Entergy's plan to power Meta's Hyperion multi-plant build to support a $10bn AI campus (scaling to 5GW)
- 📍 New Jersey: CoreWeave buys the NEST site for $322m; 36 acres reserved for future AI expansion
- 📍 Texas: Vantage "Frontier" $25bn, 1.4GW, 10-building campus on 1,200 acres
- 📍 Dallas area: Yondr secures a 163-acre site for a new 550MW campus
- 📍 ND/IL/GA: Applied Digital adds 150MW leased to CoreWeave (Polaris Forge 1)
- 📍 EdgeConneX / Lambda plan 30MW+ AI sites in Chicago & Atlanta
- 📍 M&A: Apollo to acquire a majority stake in Stream Data Centers to scale a multi-GW pipeline

Europe

- 📍 UK: Google opens Waltham Cross, its first UK DC, within a £5bn UK package; heat-recovery ready, high CFE share
- 📍 London: Vantage LHR2 (Park Royal) goes live at 20MW
- 📍 Paris: Digital Realty completes north-Paris campus build-out at ~76MW
- 📍 Berlin metro: Maincubes wins zoning; 200MW grid deal for a new campus (up to 400MW)
- 📍 Finland: Skanska signs a €95m DC build; completion due 2026

Asia-Pacific

- 📍 Western Australia: CDC plans a 200MW Perth campus with zero-water primary cooling
- 📍 Malaysia: Vantage secures $1.6bn (GIC/ADIA); moves to acquire Yondr's Johor campus (72.5MW → 300MW)
- 📍 Thailand: Digital Edge / B.Grimm break ground on a 100MW green hyperscale site
- 📍 India: OpenAI scoping a ≥1GW "Stargate" DC; evaluating local partners

Middle East & Africa

- 📍 Saudi Arabia (NEOM Oxagon): LG / DataVolt sign MoU to supply advanced cooling for a flagship AI DC
- 📍 Kenya: Nxtra by Airtel breaks ground on 44MW at Tatu City; RFS Q1 2027.
- 📍 Nigeria: Digital Realty opens LKK2 in Lagos (~2MW), interconnected to 2Africa CLS

CALA

- 📍 Chile: Ascenty inaugurates its third Santiago DC (~$114m)
- 📍 Mexico: ODATA launches QR04 near San Miguel de Allende; 12MW live (24MW in total)
- 📍 Brazil: Govt rolls out "Redata" renewables tax incentive to attract hyperscalers

Reveal trends: mega AI campuses, off-grid power, nuclear, zero-water cooling and sovereign cloud rollouts.

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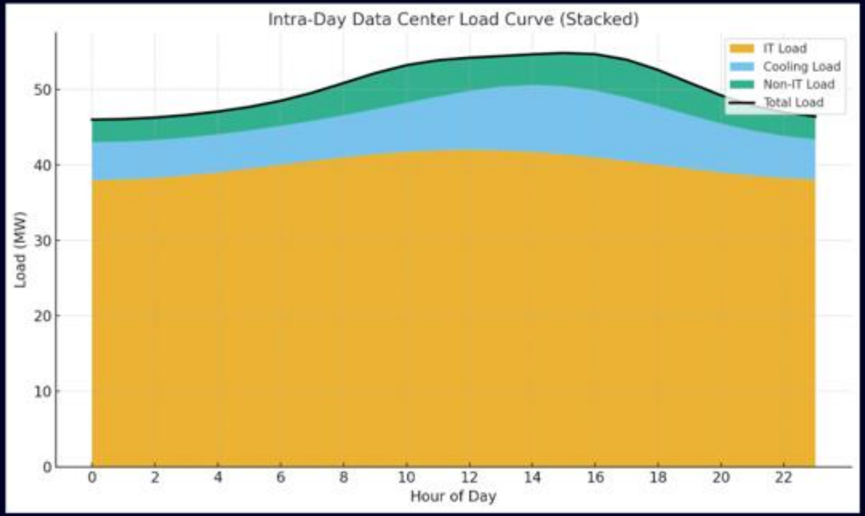
Why 'Steady Load' is a Myth in the AI Era

- Cloud - Traditional IT = flat baseload



- AI inference = volatile, second-by-second spikes

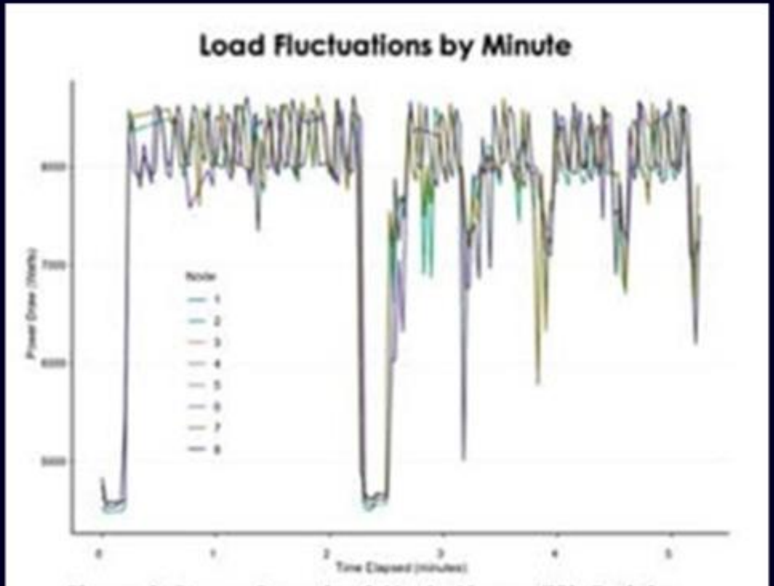
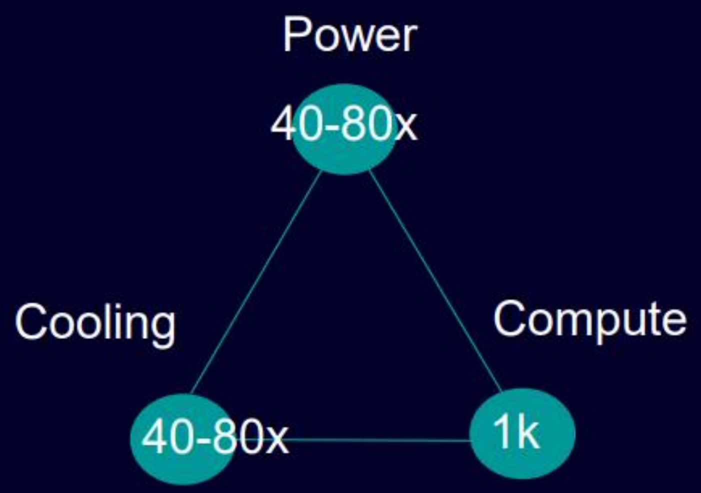


Figure 3. Power Draw by 8 Node Llama-70b Training

AI is reshaping load profiles - Reliability planning must adapt to volatility

What's Fueling Energy Demand Growth at the Data Center Level – Compute Driven Disruption



Market Change @ 3 Levels

GPU Rack

- 50 kW → MW+ Rack
- Air → Liquid Cooling
- CPU → GPU

Building

- Cable → Busway
- LV AC → 800-1500V DC
- UPS → battery

Campus

- 100MW → 3 GW
- Fiber → Power
- Load → Co-gen

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Three Zones that Impact Supply

1. The Grid (Utilities, ISOs & Policy Makers) – Bottlenecks & Progress
- Transmission & approvals lagging demand – "We have data centers that won't have power until 2032." – Buddy Rizer, Loudoun County, Economic Development
- VA Policy: New "large-load / data center tariff rate class under consideration
- PJM has launched a "Critical Issue Fast Path" process to keep reliability intact as large loads pile in
- PPL & Blackstone JV with QTS Data Centers
- Louisiana & Entergy: Regulatory approval of construction & power supply plan to support Meta

2. Behind-the-Meter = Local Fuel Solutions
- Solar: valuable, but profile mismatch
- Wind:
  - Dominion's 2.6 GW Wind project—powering 660,000 homes by 2026
  - Soluna – 1 GW+
- Natural gas: still the bridge with coal retired
  - Corscale: proud partner here in NOVA using E2 Companies' R3Di system for resiliency

Challenges with intermittency and grid integration

3. Emerging Baseloads
  - Nuclear upgrades: Constellation investing $100M at Calvert Cliffs to boost ~10% output
  - SMRs: potential, but skepticism (N.O.P.E.)
  - Green hydrogen & geothermal: promising, still scaling

No single fuel source solves it all – Diversified mix required – Regional Solutions Needed - Availability, reliability, scalability, and sustainability must all be weighed

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Smarter, Not Just More -- Efficiency Levers Deployable Today

Conversion, Cooling & Optimization

- AC to DC Conversion
- Siemens White Space Cooling Optimization
- Siemens Demand Flow Chiller Optimization

Storage & Flexibility

- Battery Energy Storage Systems (BESS) peak-shaving:
  - Real-world efficiency: 70–80% - Response time: seconds
  - Global market grew 44% last year, 69 GW installed
  - Virginia JLARC study: up to 5.5 GW of storage feasible
- Magnetic flywheels: 95% efficiency – balancing AI loads in seconds

AI-Driven Operations Embedded in All

- Predictive analytics
- Forecasting consumption
- Fault detection & prevention

Combined, total up to 30% efficiency gains!

"If supply is constrained, efficiency is where ground is gained."

In Summary – The Loud & Clear Reality Today

Demand Acceleration
AI has fundamentally changed data center energy profiles from steady to volatile, requiring new approaches to power planning and reliability.

Supply Constraints
Power infrastructure development timelines (7-10 years) are misaligned with data center construction (18-24 months), creating critical bottlenecks.

Efficiency Deployable Today
Technological innovations in efficiency, storage, and smart operations can provide immediate relief while longer-term solutions develop.

What are main pros & cons?

PROS	CONS
• Storage solutions can be deployed within 12-18 months • Efficiency gains of 15-30% achievable with existing technology • Solutions ready for immediate deployment	• Policy changes move slower than market demand • Renewable generation has intermittency challenges • Capital costs for comprehensive solutions are significant

The Tsunami is Here – How can we ride the wave?

Virginia's position as the world's largest data center market makes it the perfect proving ground for balancing digital growth with energy transition goals.

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Thank You

Let's connect!

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Demand Response: Managing Virginia's Load Growth

Haneepha DeGarmo, CEM, CMVP
Director, Project Operations

voltus™

Key takeaways

1. Distributed Energy Resources (DERs) are needed to manage load growth and maintain grid reliability.

1. PJM, Utilities, Commercial and Industrial businesses play a key role in reducing energy costs and keeping the lights on.

1. Virtual Power Plants (VPPs) manage 8 GW of DERs in PJM to maintain grid reliability and can scale quickly.

1. Call to action: What role can you play?

Virtual power plants (VPPs)

VPP / Grid Connector

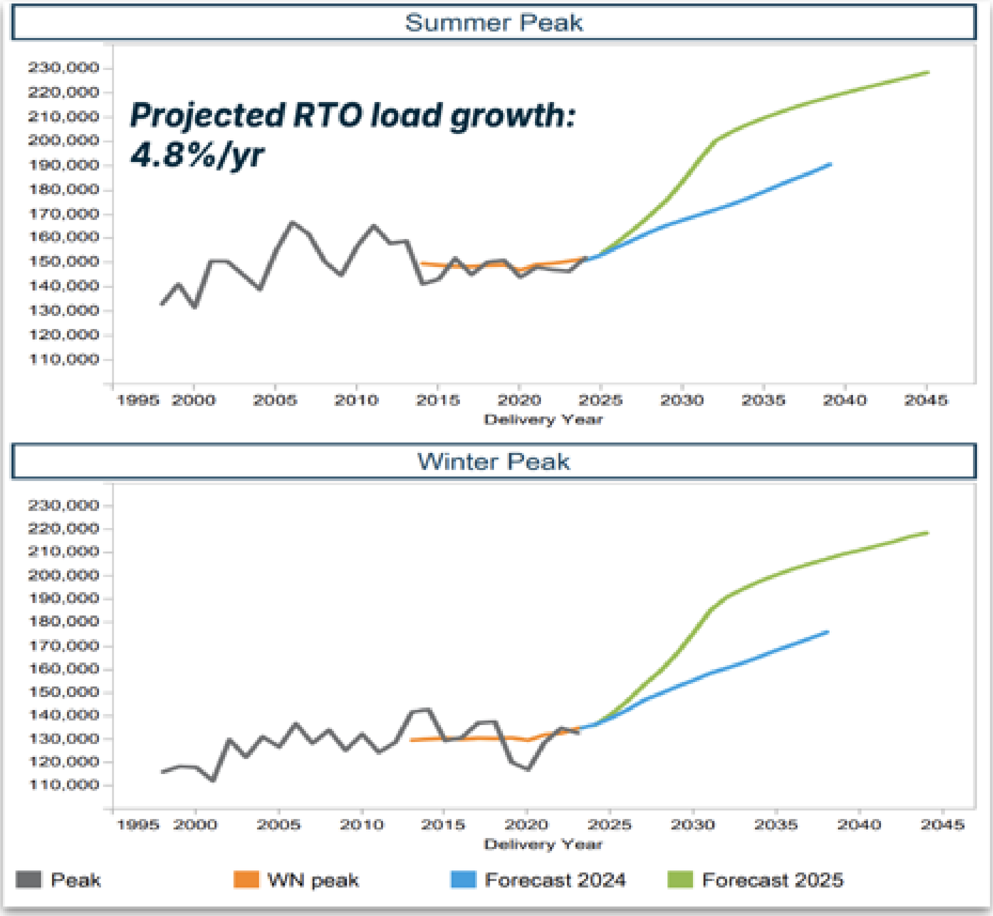
- Grid Resilience
- Capacity
- Emission Reduction
- Cleaner Energy (Renewables)
- Affordability (reduces electricity bills)

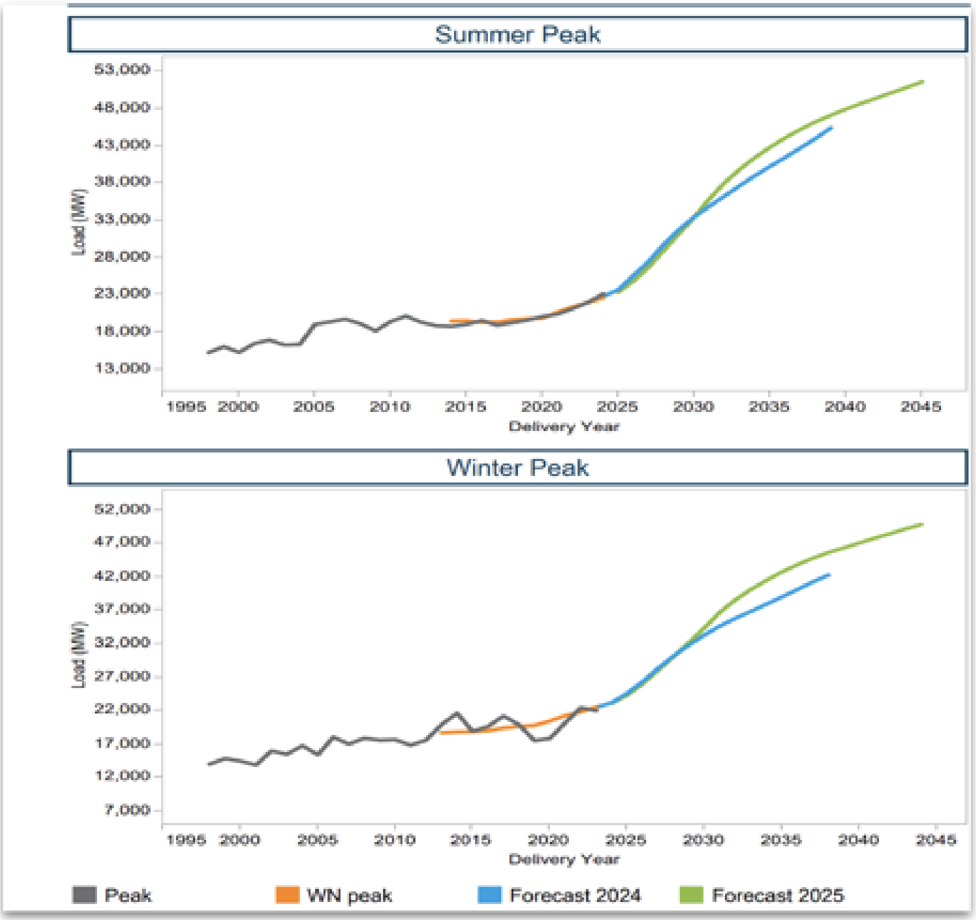
Distributed Energy Resources (DERs)

- Demand Response
- Price Response
- Carbon Reduction

30 GW of forecasted load growth by 2030 due to data center energy demand.

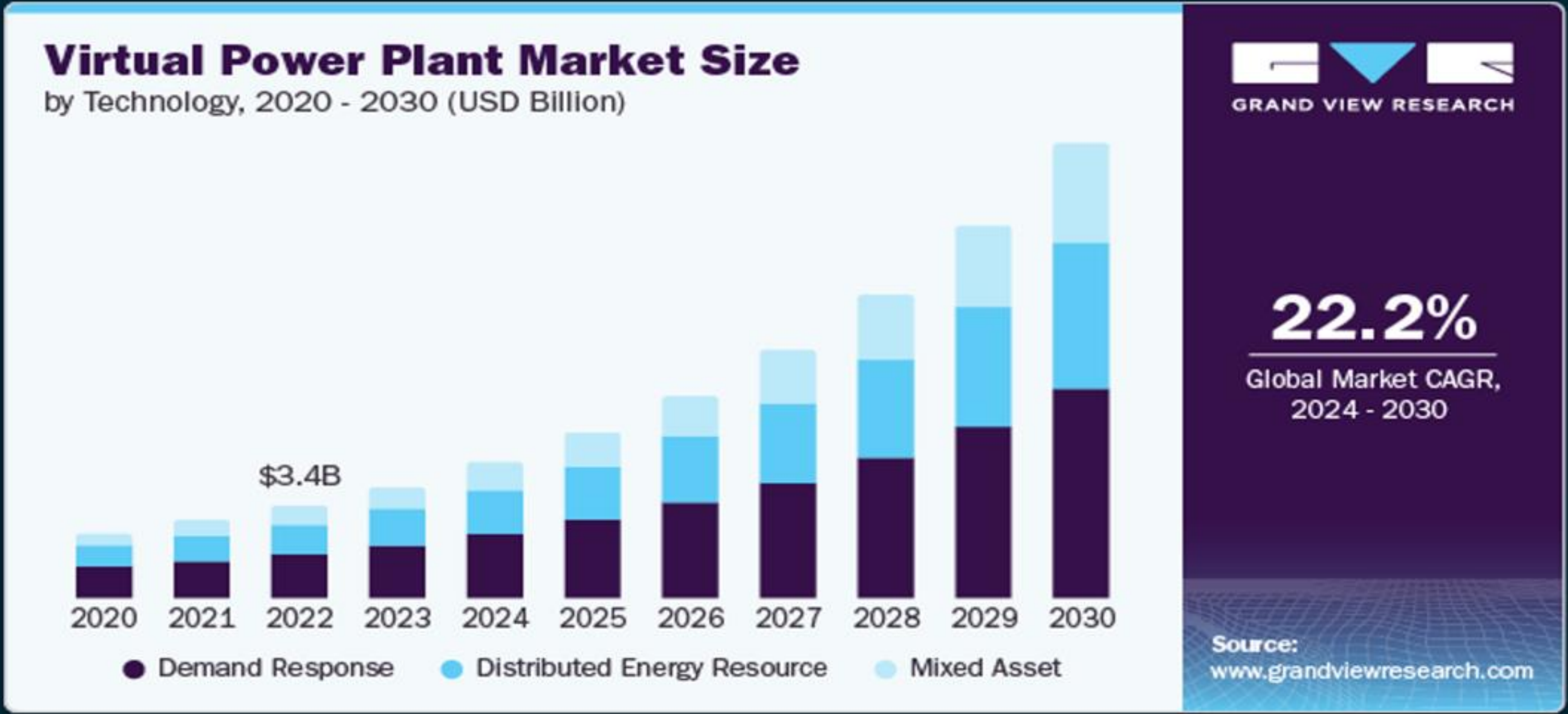
RTO vs Dominion Energy





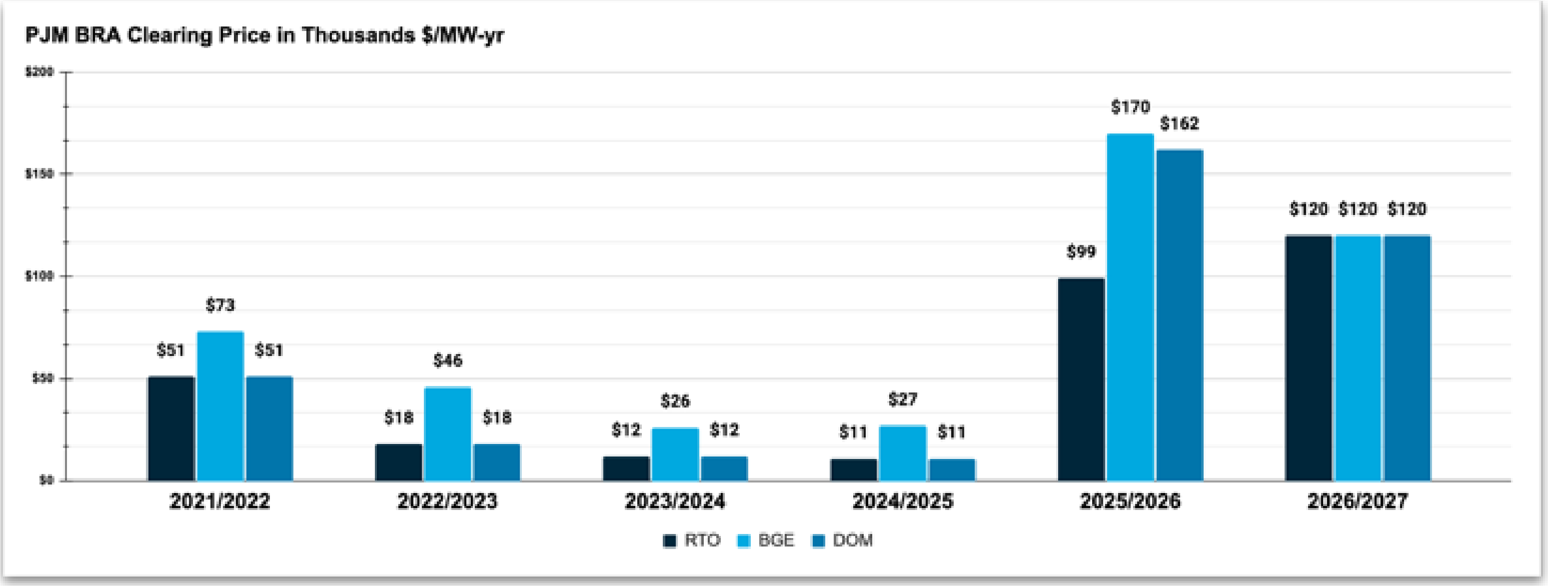
Heatwave in June caused 160 GW grid peak and four days of grid balancing dispatches.

Growth of virtual power plants is inevitable...



Energy Markets: PJM

DR Pricing & New Programs



PJM's Solutions:

1. Capacity Auction RTO cleared at the highest of all time for Demand Response

1. Proposed Non-Capacity-Backed-Load (NCBL)
    a. Curtailment
    b. Diesel Back up
    c. Bring-Your-Own-Gen (BYOG)

Utilities

Community Energy Act- HB 2346/SB 1100

The Virginia Community Energy Act (HB 2346/SB 1100) was signed into law in May 2025, directing major utilities, including Dominion Energy and Appalachian Power (APCo), to launch pilot virtual power plant (VPP) programs. These VPPs will aggregate distributed energy resources like rooftop solar, battery storage, smart devices, and electric vehicle chargers to help manage peak electricity demand, improve grid reliability, and potentially lower costs for customers. The program aims to be a cost-effective alternative to traditional power plants, while also providing incentives for low-income customers.

iStockphoto

Curtailment Service Provider (CSP): Voltus

Customer Participation in DR

Residential:

- Third-party Partnership
- Thermostat controls
- EV charging, Solar, Battery

Commercial:

- Asset Curtailment (HVAC, Lighting,others)
- Peak Shaving
- EV, Solar, Battery
- Thermal Energy Storage
- Backup Generator & UPS

Industrial/Manufacturing :

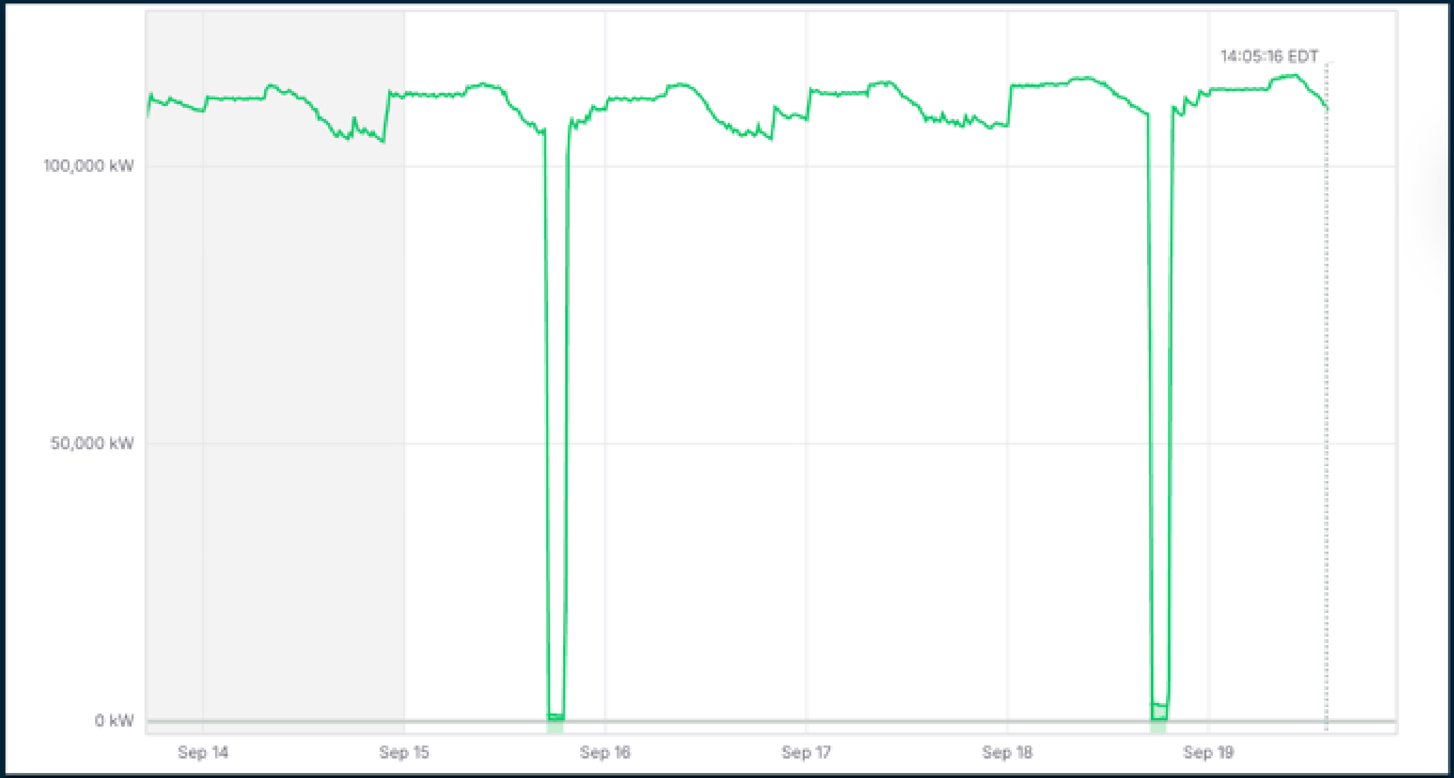
- Asset and Process Curtailment
- Load Shifting & Leveling
- Thermal Energy Storage
- EV, Solar, Battery
- Backup Generator

Data center demand response participation

- Supports grid emergencies with flexible capacity
- Reduce electricity pricing by adding more resources

Data Center Customers

- Curtailment type: Backup gen, load shifting via automation, Voltus AI Adjuster
- Estimated Earnings and savings for 100MW: $24M for a 24/7 resource participating in Price Response, ELRP, Sync-Reserves and Voltus Peak Saver



New Voltus Product: Bring Your Own Capacity (BYOC)

This new solution builds virtual power plants (VPPs) to enable hyperscalers and developers to secure additional, local, sustainable capacity - accelerating timelines for data centers.

BYOC Product:

- Leverage existing flexibility on the grid
- Aggregates DERs to bring market accredited capacity
- Allows Data Centers to not just be power consumer but also power producers
- Data Center can bring economic benefits to the community by funding VPPs

PJM program summary

	ELRP Emergency Load Response Program	SRM Synchronized Reserves	PR Price Response	PS Peak Saver for TransCap and GenCap
Earning Potential	$120,000/ MW-yr	$25,000-$45,000/MW-yr for a 24/7 resource	You set the price and parameters	Gen Cap: $98,500-170,000/MW-yr depending on zone. TransCap can add $25,000-$175,000/MW-yr
Season(s)	Year-Round or Seasonal	Year-Round	Year-Round	GenCap: June-September. TransCap: November-October
Days & Hours	Summer: May - Oct 10am-10pm ET / Winter: Nov - Apr 6am-9pm ET	24/7	24/7	TransCap: 24/7/365. GenCap:Jun- to Sept.
Dispatch Notification	30-minute lead time. Some sites may qualify for 60 or 120-minute lead times based on exemptions.	10 minutes	Day Ahead: 2 pm the day prior / Real Time: 30 min - 2 hours prior	Monday prediction with official dispatch notification by 10am
Dispatch Duration	Average of 3 hours	11 min average; 30 min maximum	Customizable	Typical 3 hours
Number of Dispatches	Last dispatches: 2022, 2014	3-6 per year	Customizable	Full: 10-15 dispatches/summer and 3-5 per winter for peaking TransCap zones / Reduced: Target 5-6/summer, and ~2/winter for peaking TransCap zones.

Questions?

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