Debugging Data Center Demand

2025 Midwest Energy Solutions

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Agenda

- "The Era of Flat Power Demand is Behind Us"

- Demand growth drivers: cloud, crypto mining, & AI

- Energy use & load profile

- Regional growth concentration

- Demand response / flexibility opportunities

- Data centers a resource for the clean energy transition

"The Era of Flat Power Demand is Behind Us"
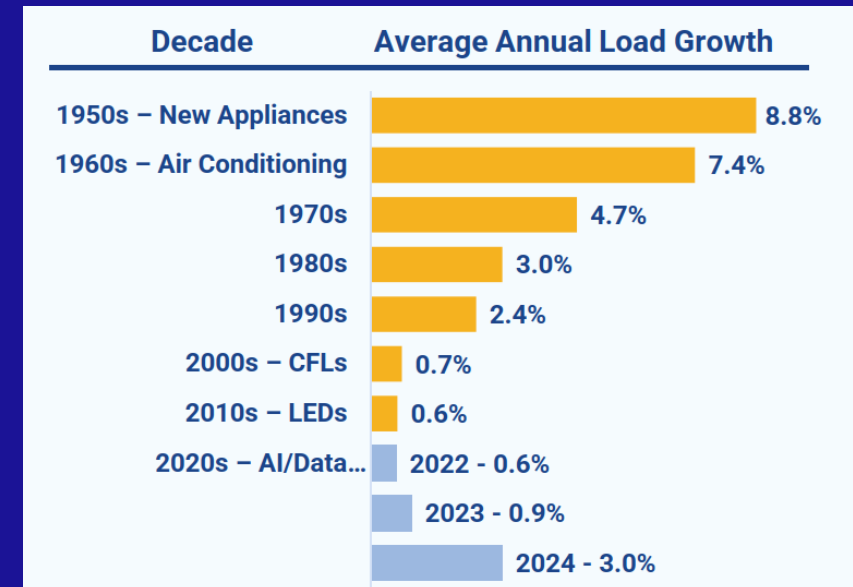## - Grid Strategies, Dec 2024

Load growth to add 128 GW peak demand by 2029
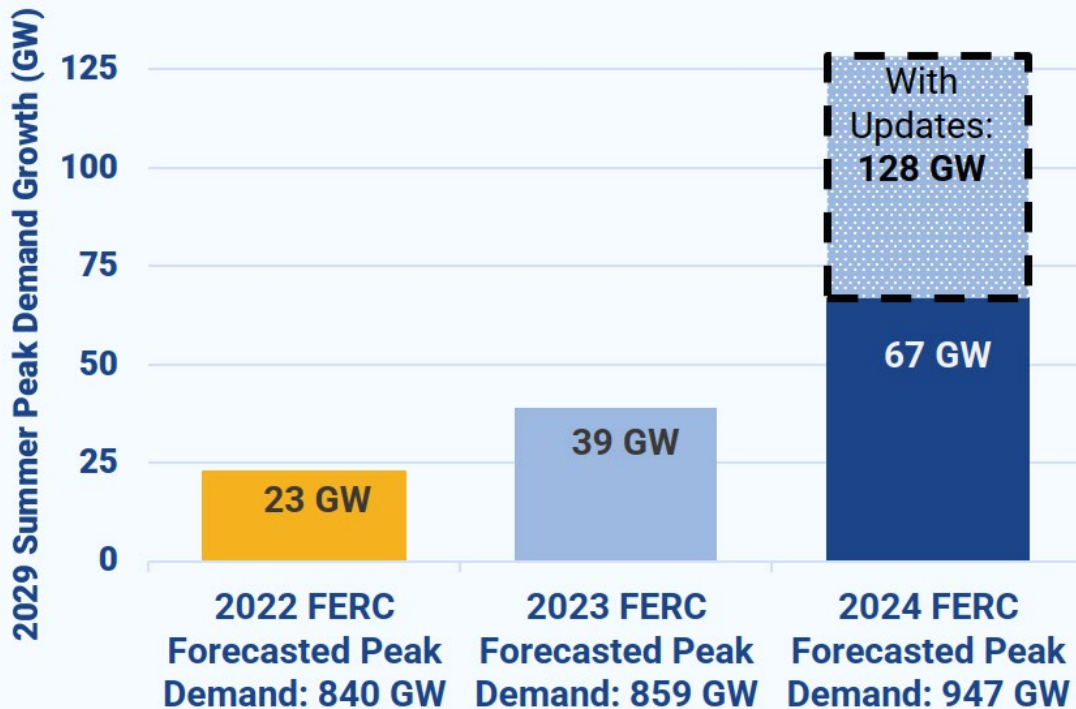
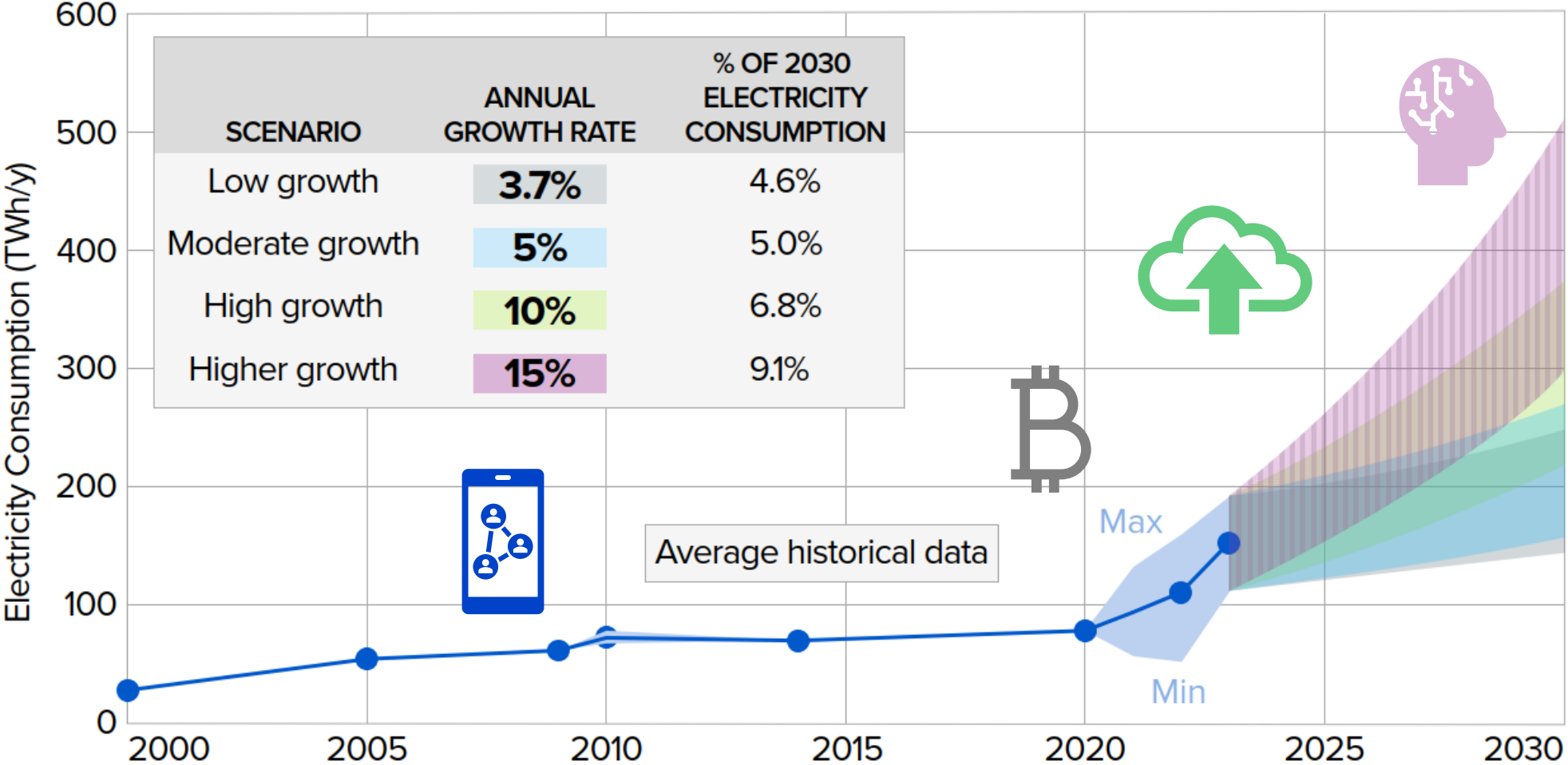*Source: Grid Strategies National Load Growth Report 2024*

"Electricity is a bull market for the first time in decades"
- Semafor, Mar 2024

Decade	Average Annual Load Growth
1950s – New Appliances	8.8%
1960s – Air Conditioning	7.4%
1970s	4.7%
1980s	3.0%
1990s	2.4%
2000s – CFLs	0.7%
2010s – LEDs	0.6%
2020s – AI/Data...	2022 - 0.6%
	2023 - 0.9%
	2024 - 3.0%

Grid Strategies 2024

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Data Centers Driving US Load Growth

SCENARIO	ANNUAL GROWTH RATE	% OF 2030 ELECTRICITY CONSUMPTION
Low growth	3.7%	4.6%
Moderate growth	5%	5.0%
High growth	10%	6.8%
Higher growth	15%	9.1%

EPRI paper _Powering Intelligence: Analyzing AI and Data Center Energy Consumption_

Generative AI Energy Use

- **Large language models rely on massive matrix multiplication**

- **Estimates of ChatGPT energy:**
  - <u>Model training:</u> roughly 50-60,000 MWh
  - <u>Application / inference:</u> 500+ MWh to serve 200M requests per day

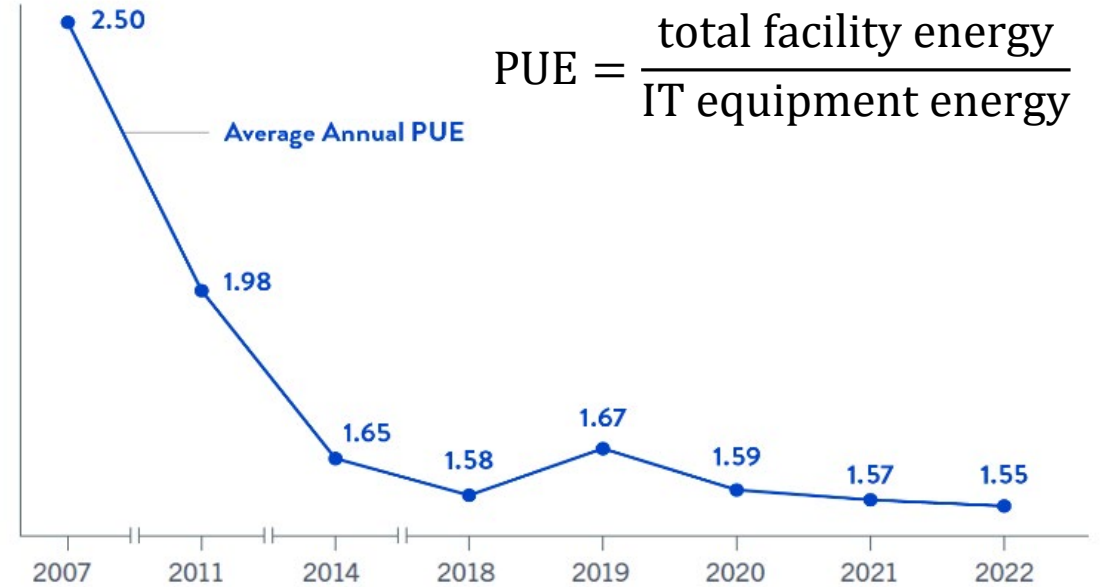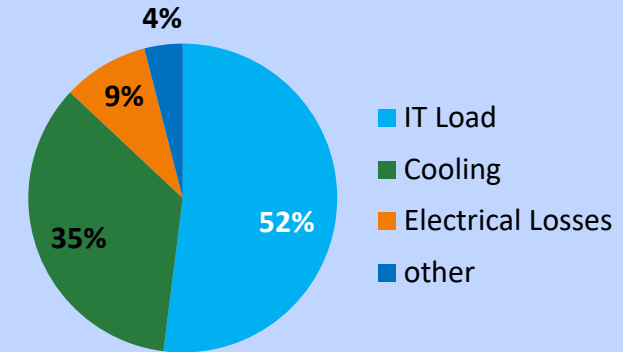- **High energy density driving adoption of liquid cooling**
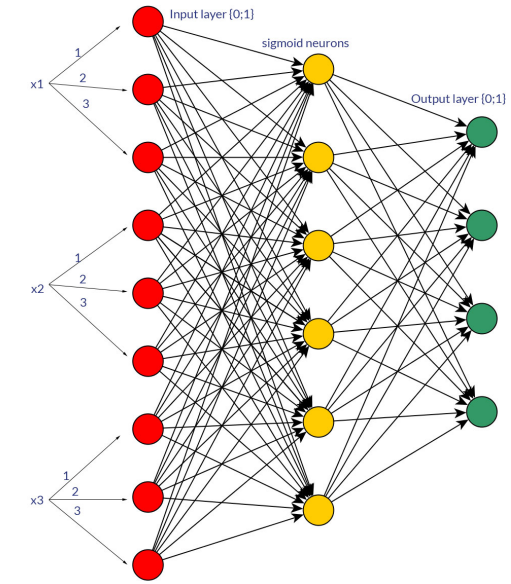
**Nvidia GB200 NVL72
with 72x GPUs (700W each)**

Energy Use Breakdown

- **IT load**
  - servers, storage, networking
- **Cooling**
  - driven by 24x7x365 IT load
  - Chiller efficiency impacted by outdoor air
  - Limited humidification load
- **Power Conditioning**
  - Uninterruptible power supply (UPS) & battery loss
  - Backup generator may use block heater
- **Support**
  - Lighting, office equipment, space conditioning
- **Metric:** PUE (Power Usage Effectiveness)

Typical Data Center Energy Use

- IT Load — 52%
- Cooling — 35%
- Electrical Losses — 9%
- other — 4%

$$PUE = \frac{\text{total facility energy}}{\text{IT equipment energy}}$$

Average Annual PUE: 2007: 2.50; 2011: 1.98; 2014: 1.65; 2018: 1.58; 2019: 1.67; 2020: 1.59; 2021: 1.57; 2022: 1.55

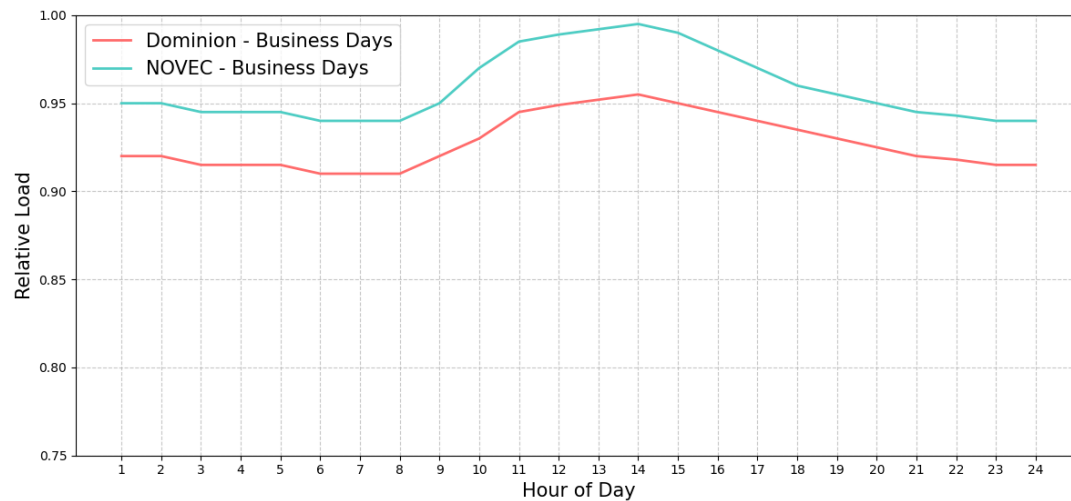*Uptime Institute (2022)*

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Data Center Load Profiles

- "Flat" electrical demand profile
  - High load factor
- Small diurnal and seasonal changes
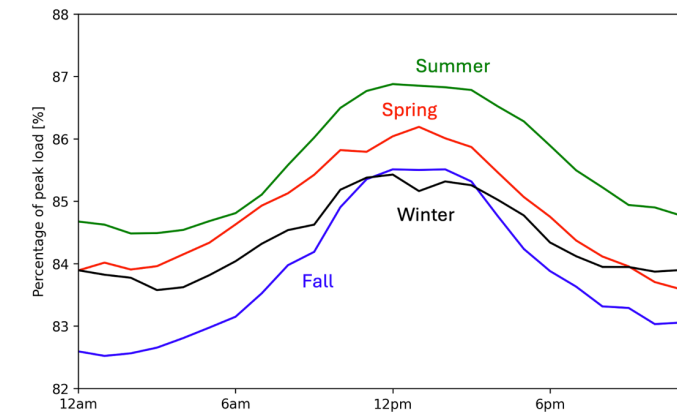 - Variation in cooling system efficiency

Weekly generator test
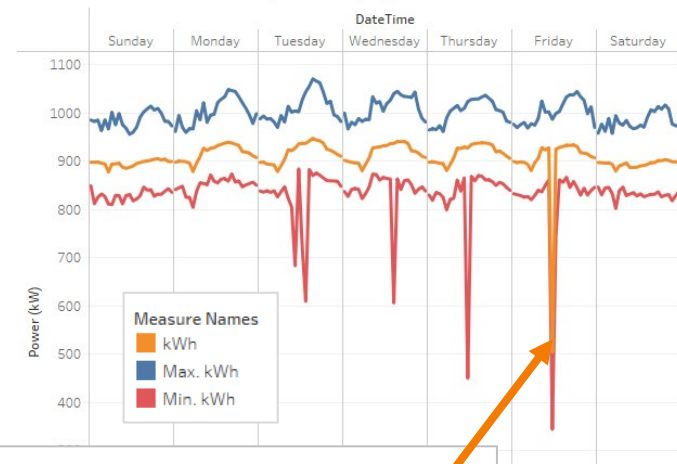
Source: 2024 PJM Load Forecast Supplement


EPRI analysis of Standard demand profiles used by UK Power Network (2019)

Emerging Issue: Load Transients

- Conventional data centers support a diverse mix of applications
  - Overall data center load shows little variation due to stochastic nature of various workloads (CPU based)

- Emerging AI data centers rely heavily on GPUs
  - Short bursts of 2-4x power observed (on the order of 100 ms to seconds)
  - Similar behavior measured at HPC (supercomputers)
  - Can cause local voltage (flicker), imbalance, and frequency issues
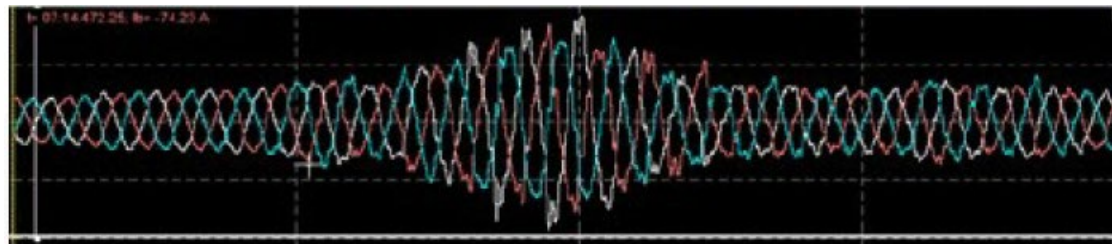
Short (~100 ms) load burst from HPC supercomputer

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Data Center Growth is Straining Grid Capacity in Certain Regions

Top Data Center Markets by Operational Load

Load (MW): 5,000 / 4,500 / 4,000 / 3,500 / 3,000 / 2,500 / 2,000 / 1,500 / 1,000 / 500 / -

Markets: Virginia, Beijing, Oregon, Phoenix, Shanghai, Dallas, Columbus, Atlanta, Tokyo, London, Chicago, Singapore, Amsterdam, SF Bay Area, Iowa, Dublin

Source: Cushman & Wakefield Data Center Market Comparison (2024)
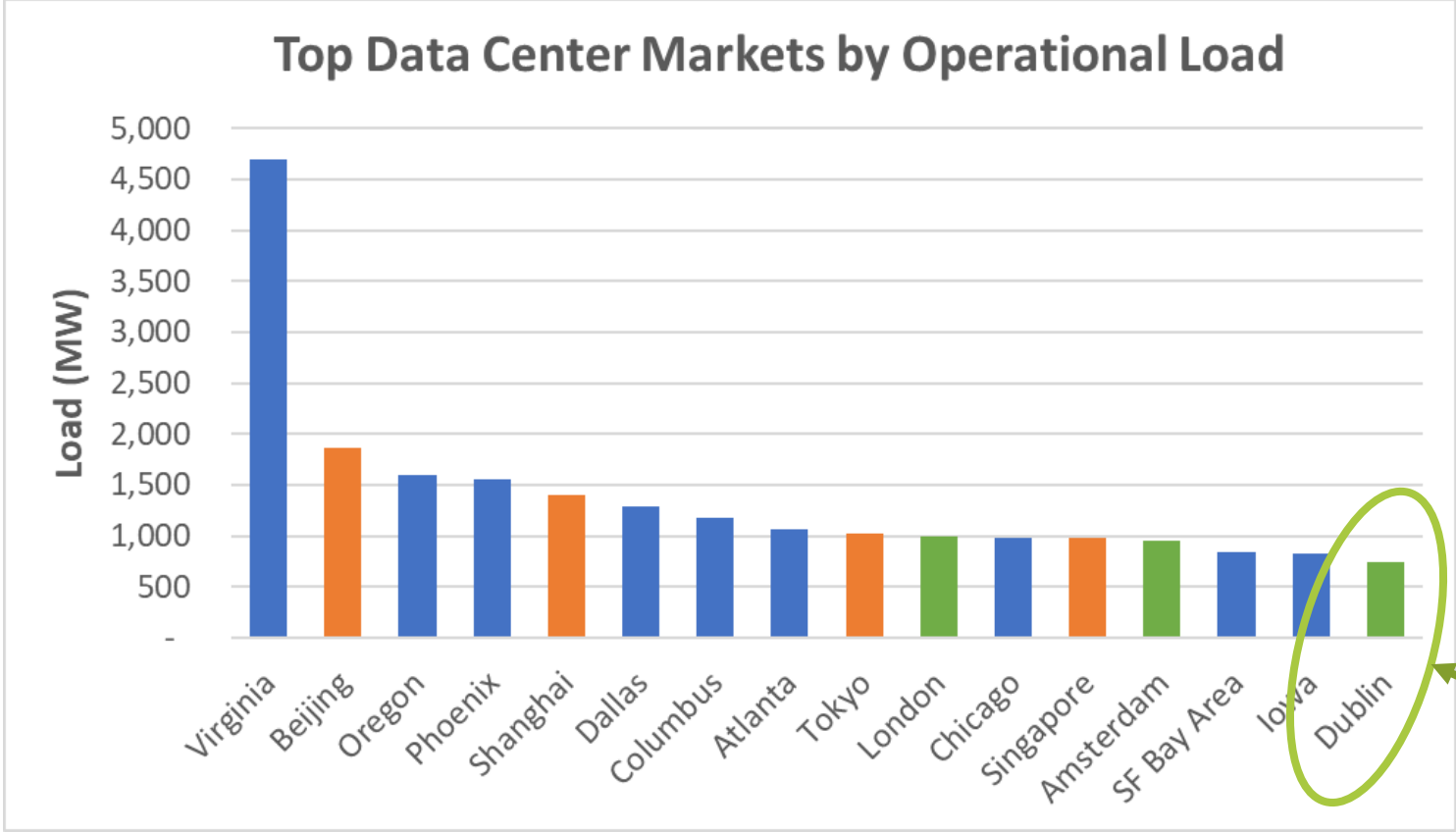
Site selection criteria:
- Power availability
- Local tech market
- Fiber connectivity
- Costs (land, taxes, power)
- Renewable energy options

18% of Ireland's electricity in 2022, could rise to 32% by 2026

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Powering Data Centers the Face of Climate Goals

Today

- Power purchase agreements (PPA)
- 24/7 carbon-free energy (CFE)
- Bring-your-own-power:
  - Several vendors offering microgrids solutions
- Fuel cells, low-carbon fuels (HVO, H_2)

Google announces 3.5 MW geothermal plant is powering 2 data centers in NV (Nov '23)

Future

- Battery storage
- Load flexibility
- Geothermal
- Nuclear?
  - Small modular reactors (SMR)

Three Mile Island to reopen to power Microsoft data center (Sept '24)

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Demand Response/Flexibility

Backup generators
- Limited by local emissions regulations in some jurisdictions

UPS / batteries
- Limited number of discharge cycles with lead acid
- Li-ion UPS can provide grid services (frequency response)

Load flexibility
- Some processes can be scheduled for off-peak hours (backups, updates, etc.)
- Dynamic load transfer to another data center

Opportunity in AI?
- How much flexibility offered by AI model training?

Microsoft's Dublin DC uses Li-ion batteries to support growth of renewables on the grid

Texas crypto miner Riot Platforms made $32M from DR participation in August 2023 *(~3.5x the bitcoin mined)*

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Data Center DR Examples

- **Google** shifting non-urgent workloads to non-peak times & locations
  - E.g., video processing, adding new words to translate
  - **Europe:** Winter 2022-23 in Europe (Netherlands, Belgium, Ireland, Finland, Denmark)
  - **Taiwan:** summer peak reduction in (2022-23)
  - **USA:** extreme weather events in Oregon, Nebraska, and Southeast
- **ERCOT** Large Flexible Load Task Force focused on integrating crypto mining
  - Improve load forecasting, reduce interconnection times
  - Establish voltage ride-through standards to avoid unplanned disconnections
  - Define DR ramp rate limits to mitigate need for frequency regulation

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WS1: Flexible Data Center Designs

Enabling future data centers to become grid resources through flexible & efficient designs and operational practices

WS2: Transformational Utility Programs

Explore market & program structures that advance data center flexibility

WS3: Grid Planning for Operational Flexibility

Equip the utility industry planning practices to embrace large flexible loads

Objective: Demonstrate how data centers can support and stabilize the grid while improving interconnection and efficiency.

Data centers can be a key resource for the clean transition!

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Questions?

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