Rural Community Action Assembly:
Planning for Data Center Development

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Agenda

2:00 p.m. **Planning for Data Center Development**

- Jim Ladlee, State Program Leader, Emerging and Advanced Technology, Pennsylvania State University
- Mike Turner, Ashburn District Supervisor, Loudoun County Board of Supervisors
- **Moderator:** Matt Dunne, Founder and Executive Director, Center on Rural Innovation

3:05 p.m. **Panel Q&A**

3:30 p.m. **Closing Remarks**

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DATA CENTERS AND RURAL COMMUNITIES

Overview

- Foundations of AI & Data Centers
- Energy and Jobs
- Data Centers: A Guide to Common Questions

Background and Checkmarks by AdobeStock Image 267303060 and ChatGPT

Purpose

- We aim to support informed, contextual, & fact-based community conversations.
- Our goal is to share current, fact/research-based information on data centers.

Neutrality & Transparency

- We are not advocating for or against data center projects
- Opinions and perspectives will differ, and that's expected.
- The program is not funded by any data center company, developer, or any other group.

Change

- This is a fast-moving topic, and information changes almost daily.
- Sadly, we cannot cover everything in a short presentation.

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Data Centers in Everyday Life

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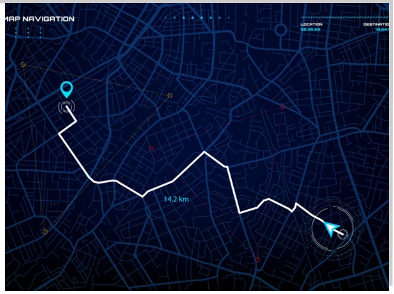
Household

Banking

Messages

Navigation



NETFLIX

Streaming Video

Online Shopping

Social Media

Health

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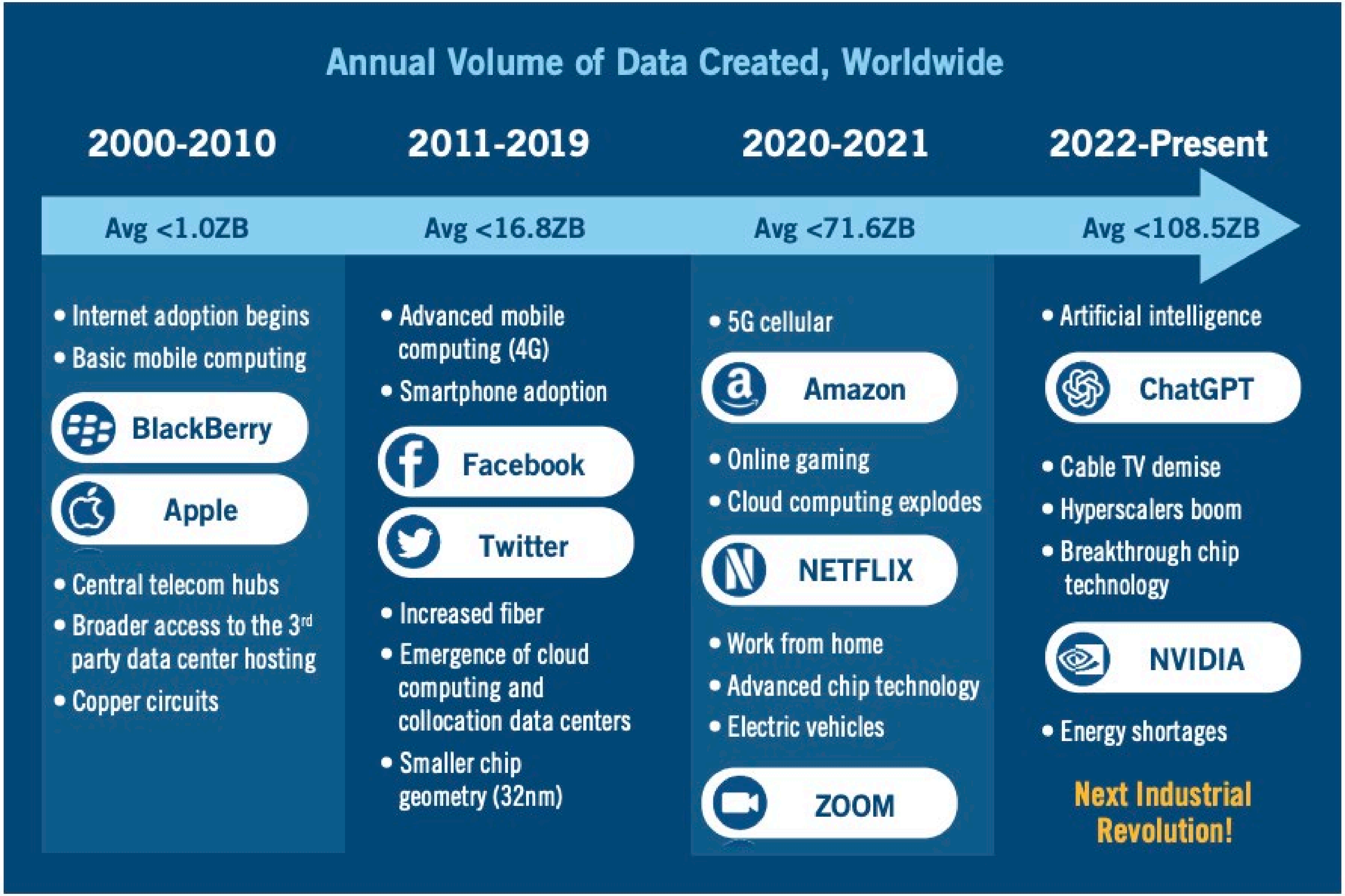
Reference Scale

- Kilo-1,000 bytes
- Mega-1,000 kilobytes
- Giga-1,000 megabytes
- Tera-1,000 gigabytes
- Peta-1,000 terabytes
- Exa-1,000 petabytes
- Zetta-1,000 exabytes
- Yotta-1,000 zetta bytes



Source: CoBank and Statista **ZB = Zettabyte or 1,000,000,000,000,000,000,000 Bytes**

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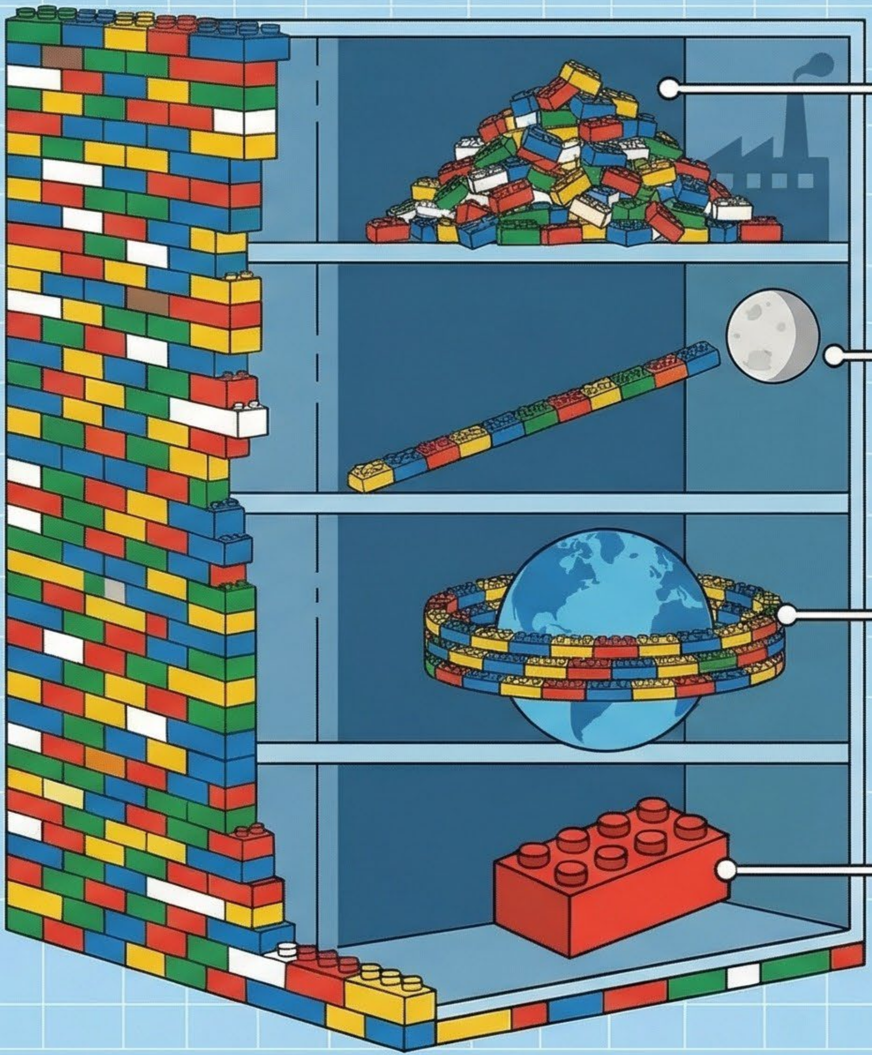
Data at a Zettabyte Scale

By 2025, global data generation will reach 181 Zettabytes (ZB)



45% of All LEGO Bricks Produced

Visualizing 181 ZB would require nearly half of every LEGO brick ever manufactured in history.

Reaching the Moon 14 Times

A chain of bricks representing 181 ZB would span the distance to the moon over 14 times.

135 Full Orbits Around Earth

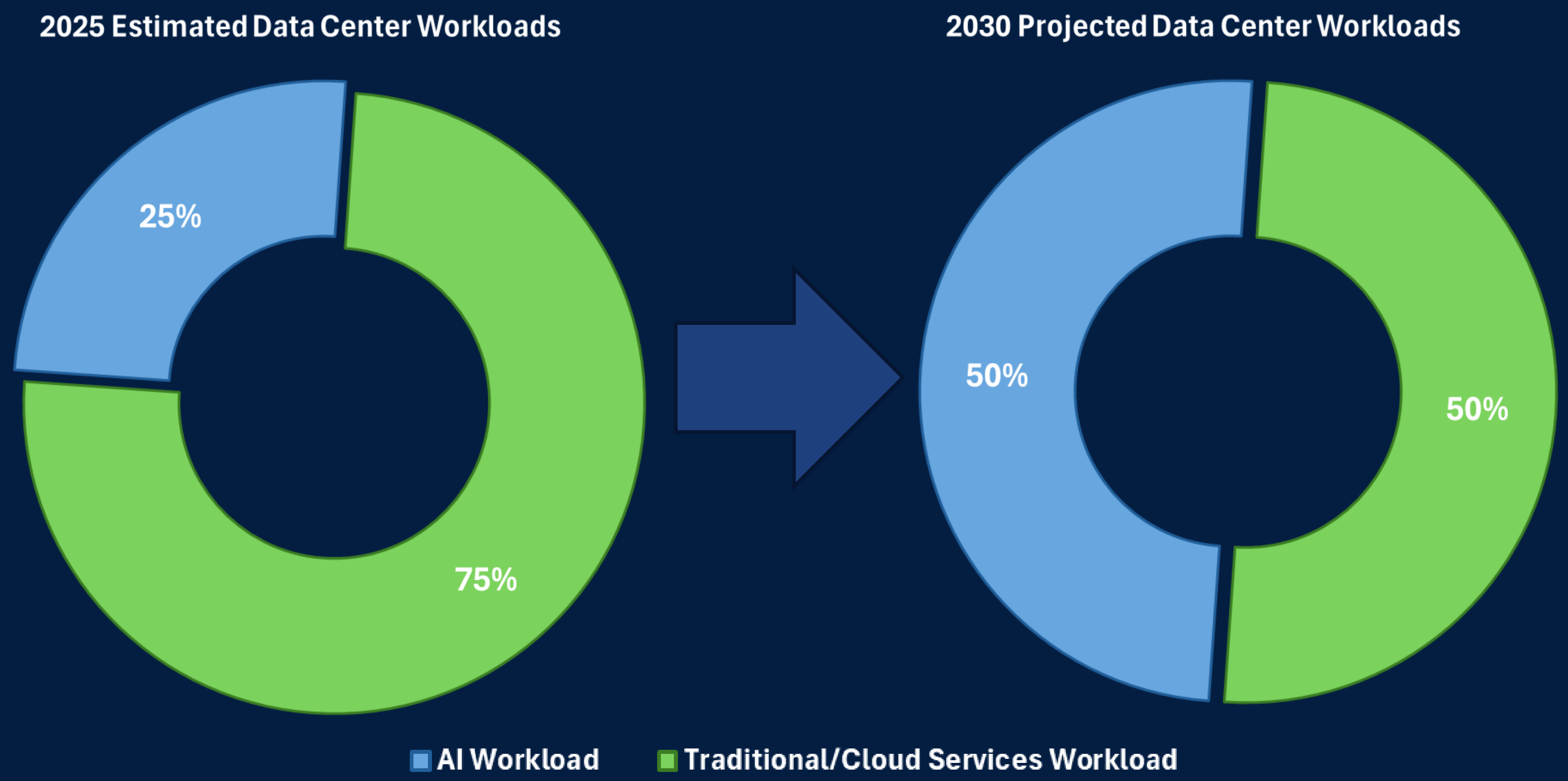
The 2025 data supply would circle the globe 135.5 times in a single brick chain.

1 LEGO Brick equals 1 Terabyte

Every individual 3cm brick represents 1 TB of data.

181 Zettabytes is equal to 181 Billion LEGO bricks.

The Global AI Pivot



Hyperscale

- Extremely large facilities - usually a campus of multiple buildings
- Supporting global-scale cloud, AI, and data services
- Reference scale
  - 100,000+ sq ft
  - 100-1000+ acres
  - 100+ Megawatts
  - 10,000+ servers
  - 10,000-5,000,000+ gallons per day

Note: Definitions are provided as a rule-of-thumb. Actual project specifications may vary based on design, location, technology, and operational goals.

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Cloud Data

- Large facilities
- National or regional cloud & enterprise services
- Reference scale
  - 50,000-200,000 sq ft
  - 10-40+ acres
  - 10-99 Megawatts
  - 1,000+ servers
  - 1,000+ gallons per day

Note: Definitions are provided as a rule-of-thumb. Actual project specifications may vary based on design, location, technology, and operational goals.

Enterprise or Regional Centers

- Serving specific organizations, institutions, or agencies
- Reference scale
  - 10,000-50,000 sq ft
  - 5-15+ acres
  - 1-10 Megawatts
  - 100s - 1,000+ servers
  - 100s - 1,000+ gallons per day

Note: Definitions are provided as a rule-of-thumb. Actual project specifications may vary based on design, location, technology, and operational goals.

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Edge or Micro Data Centers

- Small, localized
- Designed for super low latency and real-time service
- Reference scale
  - <10,000 sq ft
  - <1 acre
  - <1 Megawatt
  - <100 server racks
  - Little to no water needs

Note: Definitions are provided as a rule-of-thumb. Actual project specifications may vary based on design, location, technology, and operational goals.

Cryptocurrency Mining Centers

- Usually small and localized
- Dedicated to blockchain transaction validation only
- Typically use high-density Application-Specific Integrated Circuits (ASIC) or Graphics Processing Units (GPU) hardware
- Reference scale
  - Modular, containerized, or warehouse-based
  - <5 acres
  - 10-100 Megawatts
  - <100 Server racks
  - Little to no water needs

Note: Definitions are provided as a rule-of-thumb. Actual project specifications may vary based on design, location, technology, and operational goals.

Jobs

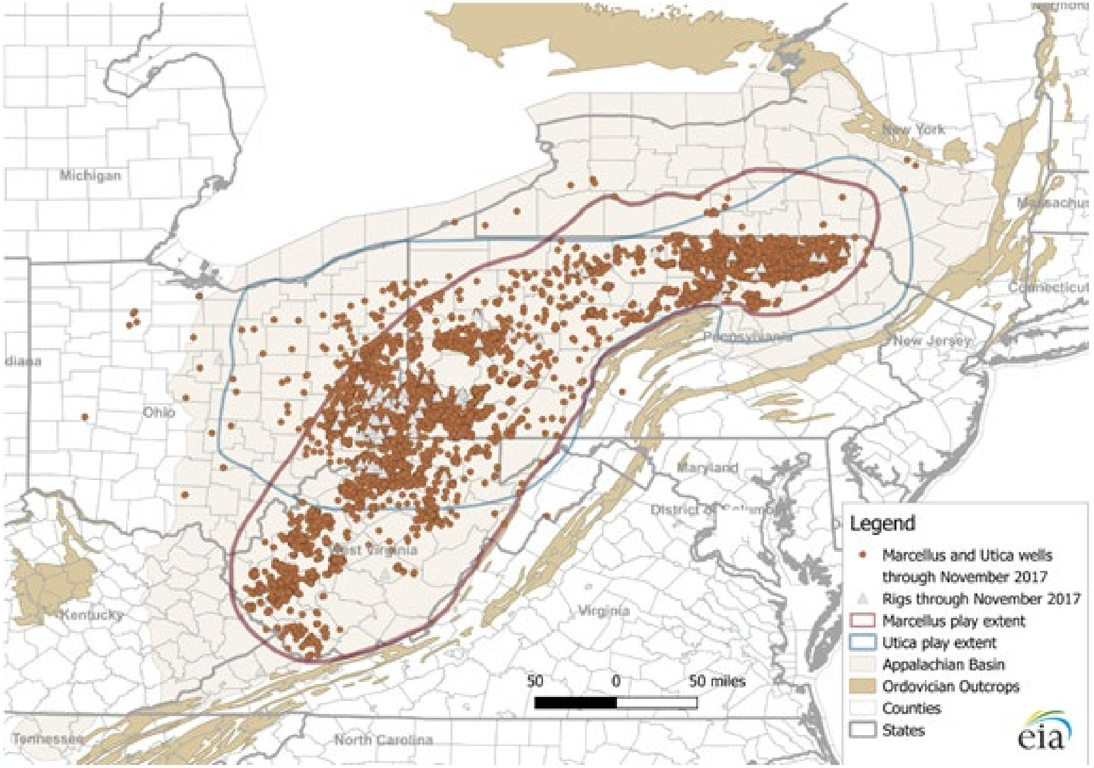
- All Jobs Depend on Data Center Scale
- Construction
  - 100s – 1,000s (total FTE equivalent)
    - Note: may include direct, indirect, and induced jobs
  - ~0.7–2.0 workers per MW (est. peak on-site)
  - Location dependent
  - Move from site to site
  - Likely specialized

Operational Jobs Rule-of-Thumb

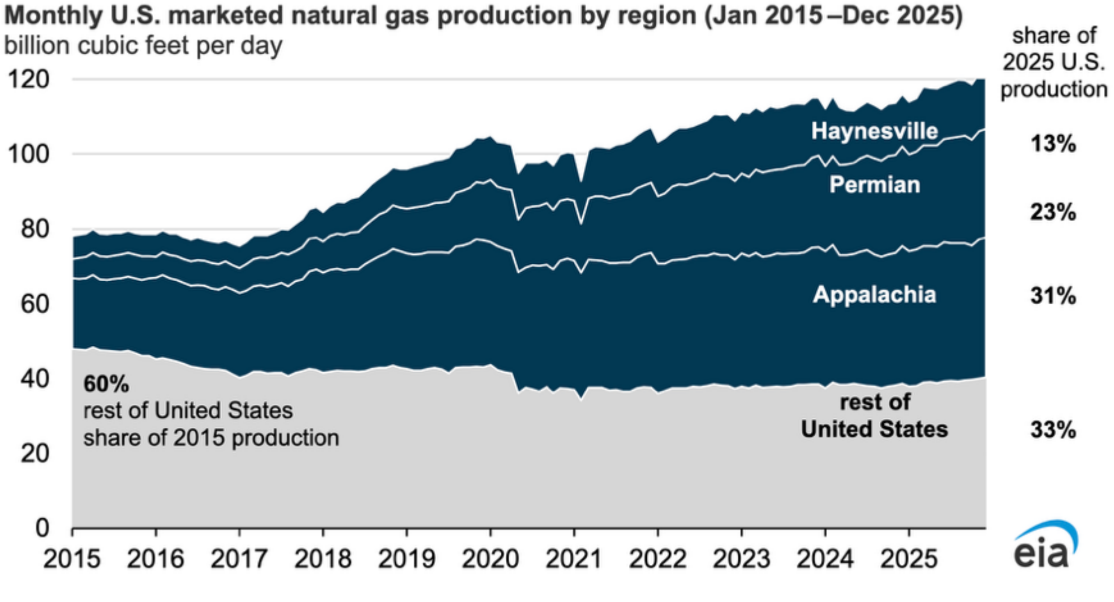
- Location-based jobs
  - ~15-35 per 100 MW
  - 0.15–0.35 full-time employees per MW
- Regional-based jobs
  - ~15-35 per 100 MW

Appalachian Basin: Massive Gas Resources

Marcellus and Utica producing wells (Jan 2003 – Nov 2017)



U.S. natural gas production reached a new record in 2025



Data source: U.S. Energy Information Administration, *Short-Term Energy Outlook* (STEO), March 2026

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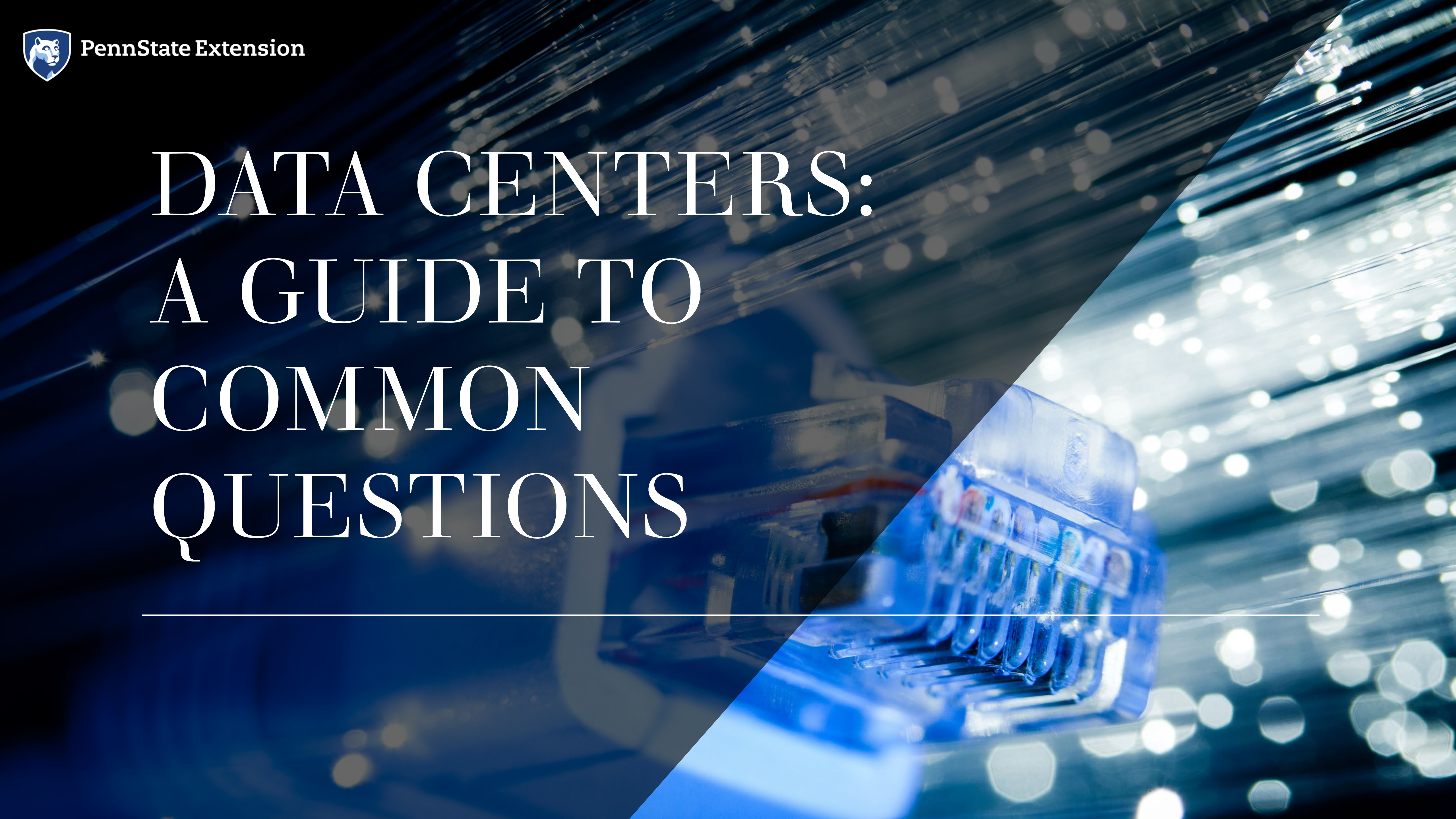
DATA CENTERS: A GUIDE TO COMMON QUESTIONS



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Data Centers: A Guide to Common Questions

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The Data Center Guide to Common Questions is designed to help communities engage in informed, transparent, and respectful conversations about proposed data center development.

should adapt or expand these questions to reflect local conditions, policies, and priorities.

Power/Electricity

Power Demand and Source

1. What is the total estimated power demand (MW or GW) per year (0-5 years, 6-10 years, 11-20 years, and 21 years and beyond)?
2. Where will the power come from: grid, onsite generation, or both at 0-5 years, 6-10 years, 11-20 years, and 21 years and beyond?
3. If onsite generation is used:
   - What source will be used (e.g., natural gas, diesel/oil, renewables, jet turbines, small modular nuclear [currently projected by 2035], etc.)?
   - Is it planned for initial development or future phases?
4. How does this project's estimated energy demand compare to other large regional loads (existing or planned)?

Goals of the Guide

Help engage in informed, transparent, and respectful conversations

Not intended to advocate for or oppose any specific project

Evaluate proposals in the context of local priorities, land-use planning, infrastructure capacity, and long-term goals

Encourage thoughtful evaluation and fact-based discussion

A starting point, not the final word. It is a living & working document.

Data Centers: A Guide to Common Questions

- Power/Electricity
- Water
- Broadband Infrastructure and Capacity
- Land Use
- Workforce/Jobs
- Zoning and Permitting
- Policy, Taxes, and Incentives
- Environment and Climate
- Additional Considerations
- Community Readiness for Data Center Conversations
- Help Strengthen This Guide

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Data Centers: A Guide to Common Questions

Power/Electricity

Power Demand and Source

Infrastructure and Capacity

Power Reliability and Operations

Cost and Rate Impacts

What is the projected Power Usage Effectiveness (PUE)

Data Centers: A Guide to Common Questions

Workforce/Jobs

Preconstruction

Construction

Post Construction/Operations

Data Centers: A Guide to Common Questions

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Thank You!

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Resource Page

Loudoun County

VIRGINIA

WHERE TRADITION MEETS INNOVATION

Ashburn, Loudoun County, VA
Data Center Growth and Energy Constraints

Ashburn Supervisor, Mike Turner

April 6, 2026

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Loudoun County, VA Key Milestones

- Overview: Loudoun County, VA
  - Highest concentration of data centers in the world
  - Home to “Data Center Alley”; construction every single day for 16 years
  - 250+ data centers built; NOVA has 600+; TX 440; CA: 290
  - 53 million sq. ft. built; 60 million in the pipeline

Data Centers: Key Milestones

- 2000: Zoning Administrator determination: Data Centers are considered "office buildings" in the 1993 Zoning Ordinance; (6) types of parcels allow "by right" data centers w/o BOS approval
- 2003: Zoning Ordinance aligned with 2001 Comprehensive Plan; first Mention of Data Centers in Zoning Ordinance
- 2008: Loudoun Economic Development initiates marketing strategy to recruit data centers on land designated for data centers
- 2014: Zoning Ordinance Amendment (ZOAM) addressing data center sight, setback, sound
- 2019*: General Plan (Comprehensive Plan) Updated (*4-yr. plan/ordinance mismatch)
- 2022: Pivotal year! PJM informs Dominion its infrastructure plan is insufficient; "constrained power grid" is announced; 20% power cap on large consumers
- 2023*: Zoning ordinance updated to match Comprehensive Plan; Dominion announces plan to build (6) new Loudoun transmission lines
- 2024: JLARC study states it will be "very difficult" for Dominion to meet unconstrained demand
- 2025: On March 18th, Loudoun BOS ends all "by right" data center development in Loudoun

Data Centers: Benefits

- Revenue: FY2027 Projected $2.9 billion in Local Tax Funding
  - Lowest Real Property Tax Rate in NOVA; About 25% Lower Than Neighbors[7]
- Expense: A Data Center Costs the County $0.04 per $1 of Tax Revenue[8]
  - Most Businesses Cost About $0.25 per $1; Homes About Even[8]
- Infrastructure:
  - Put Few Cars on the Road
  - Very Few Kids in Schools

Exponential Growth in Data Demand

- Growth of Permitted data center floor space:[10]
  - 2016: 8.8 mil. sq. ft.
  - 2017: 10.1 mil. sq. ft. (14.7% increase)
  - 2018: 13.1 mil. sq. ft. (29.7% increase)
  - 2019: 18.3 mil. sq. ft. (39.7% increase)
  - 2020: 21.5 mil. sq. ft. (17.5% increase)
  - 2021: 26.4 mil. sq. ft. (22.8% increase)
  - 2022: 28.1 mil. sq. ft. (6.4% increase)
  - 2023: 31.9 mil. sq. ft. (13.5% increase)
  - 2024: 41.2 mil. sq. ft. (29.2% increase)
  - 2025: 53.0 mil. sq. ft. (14.0% increase)

2016-2020 =144% Increase

2021-2025 =100% Increase

Exponential Growth in Power Demand:

- Power Consumption in Loudoun County:[11]
  - 2018: 1 Gw (chart interpolation)
  - 2019: 1.5 Gw (chart interpolation)
  - 2020: 1.6 Gw (chart interpolation)
  - 2021: 2.0 Gw (chart interpolation)
  - 2022: 2.8 Gw (chart interpolation)
  - 2023: 3.4 Gw (chart interpolation)
  - 2024: 4.14 Gw (actual)
  - 2025: 5.33 Gw (actual)

2020-2025 = 233%

- Same Linear Progression Over the Next 5 Years = 17.75 Gw by 2030
- BUT…Artificial Intelligence (AI) Will Increase Existing Data Rack Power Consumption from 10-14 Kw/rack to 100+ Kw/rack = 30+ Gw by 2030

Five Converging, Co-dependent, Conflicting Trends

Exponential increase in demand for data…

Means more data centers; denser racks within existing data centers;

Leads to…

Exponential increase in demand for power

Reduced periodically by increased efficiency…

Means more transmission lines/generation plants; higher bills;

Leads to…

Much higher water use as data centers try to lower power usage by switching to more efficient water cooling…

And Leads to…

Delay or cancellation of plans to decommission fossil fuel plants; new fossil fuel plants built…

Leads to…

Rapid increase in community resistance to data centers due to higher power/water use and noise…

Means more pressure on local elected officials to curtail growth, impose stricter performance standards, stop power lines

Loudoun County Current and Planned Transmission Lines[15]

1. In VA, utility companies are required, by law, to provide power to all customers
2. 500 Kv line = 2.1 Gw; 230 Kv line = 750 Mw (distance dependent; est.)[16]

Current transmission lines bringing power into Loudoun County:

- From the north: (1) 500 Kv line = 2.1 Gw; (2) 230 Kv lines = 1.5 Gw
- From the south: (2) 500 Kv lines = 4.2 Gw; (2) 230 Kv lines = 1.5 Gw
- Total currently coming into Loudoun: 9.3 Gw, but not to the "Data Center Alley" loop

(3) Planned new lines bringing more power into Loudoun by 2028 (earliest):

- From the north: (2) 500 Kv lines = 4.2 Gw
- From the south: (1) 500 Kv line = 2.1 Gw
- Total existing plus planned: 15.6 Gw by 2028

(3) Added lines to take 3.6 Gw to Data Center Alley; (2) Transit; (1) HVDC

Total needed power is 17.75 Gigawatts by 2030

Existing:

Blue = single 230Kv lines countywide

North combination lines:

Red = (1) 500Kv & (2) 230Kv

South combination lines

Red = (2) 500Kv & (2) 230Kv

New:

North Black Lines = (2) 500Kv

South Black Line = (1) 500 Kv

Red Dashed = 500/230Kv combined (3 segments)

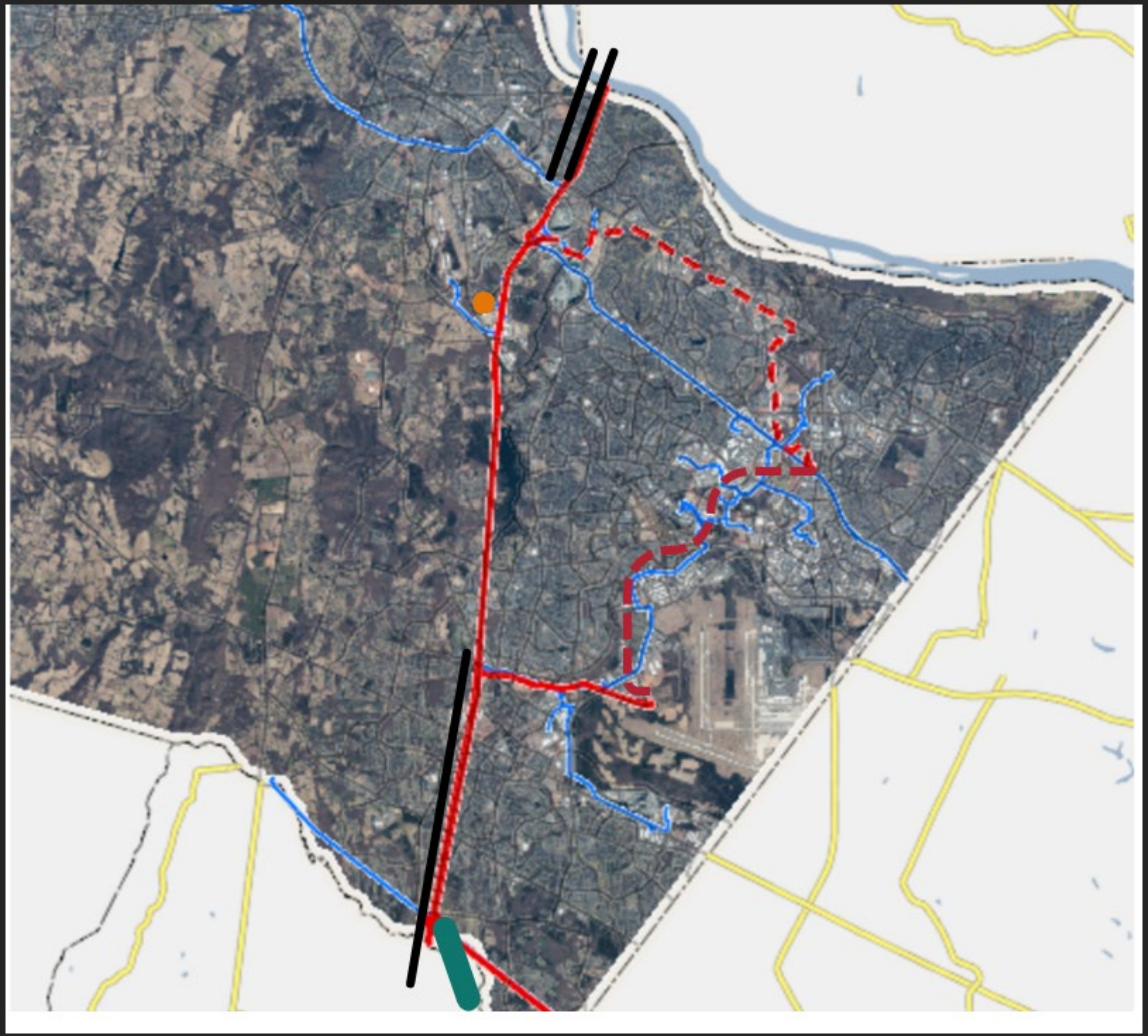
Green = 525 HVDC undergrounded (1)

Orange dot = 770 Mw Gas power plant

Not included are the new 230Kv lines

Across the northern portion (not pictured)

- Existing: (1) 500 Kv line
- New: (1) 500 Kv & (1) 765 Kv



If Unconstrained Power Grid Buildout is "Very Difficult," We Must Lower/Stabilize Demand

Only Three Possible Scenarios:

1. Scenario #1: Artificially Constrain Demand
   A. Utilities "delay but don't deny" applications based on generation/transmission capacity limits (currently happening de facto)
   B. Localities impose efficiency performance standards
   C. State uses sales tax exemption to incentivize efficiency
2. Scenario #2: Technological Breakthrough
   A. New Nvidia chip uses 1000x less energy to process AI; 2,300% savings
   B. Jevon's paradox; more efficient use of a resource leads to more resource used
3. Scenario #3: Onsite Power Through Microgrids
   A. Happening now; less demand on grid due to onsite power
   B. Lays the foundation for demand response/distributed energy network

What Is a Microgrid?

Five Elements[24]

- Large Power Consumer
- Power Grid Connection with Demand Response System
- Baseload Power Source (24/7/365 maximum power source)
- Backup Power Source
- Energy Storage System

Baseload Power Sources:

- Gas Turbines (Natural Gas; Biomass Gas)[25]
  - Should always include Selective Catalytic Reduction (reduces NOX emissions by 95%; CO emissions by 85% (with ammonia); still produces PM2.5 and CO2
- Small Modular Reactors (micro: 0-20 Mw; SMR: 20-100 Mw)
  - NuScale is the only one currently licensed; Light water
  - X Energy/Oklo sodium fast reactors near licensing

What Is a Microgrid?

Backup Power Sources

- Diesel Generators
  - Should be Tier IV; most are now Tier II
- Energy Storage Systems
  - Battery Energy Storage Systems (BESS; lithium ion; fire hazard; 4-hr. storage)
  - Long Duration Energy Storage Systems (LDES; 10+ hrs of storage)
- Hydrogen Fuel Cells
  - Green: Solar power strips Hydrogen and Oxygen from H_2O; combined at a catalyst; no noise/emissions; 10′ x 10′ cell produces about 2.5 Mw
  - Blue: Natural gas is reformed before fuel cell to obtain Hydrogen and Oxygen; fuel cell has no noise/emissions, but reforming upstream leaks methane and CO_2 into the air

Choosing a Microgrid Power Source

Power Source Type	Baseload Capacity	Carbon Net Zero	NOX, CO, CO_2, PM2.5
Diesel Backup Generators w/SCR; PM Filter			Tier IV
Energy Storage Systems (BESS; LDES)		✓	✓
Natural Gas Turbines (SCR; PM Filter)	✓		Tier IV
Green Hydrogen Fuel Cells		✓	✓
Blue Hydrogen Fuel Cells			
Small Modular Reactor	✓	✓	✓

Capacity Factor: Choosing a Microgrid Power Source

- Capacity Factor Definition[30]
  - Annual hours operated at max. capacity / (8,670 annual hours)
  - Examples:
    - 1 MW max. capacity averaging .5 MW every hour for a year / 8,670 hrs. = 50%
    - 1 MW max. capacity averaging 1 MW over 4,380 hours for a year / 8,670 hrs. = 50%
- Actual Capacity Factors in 2024 of Various Power Sources[31]

2024	Geothermal	Hydroelectric	Nuclear	Biomass	Gas	Solar	Wind
Capacity Factor	65%	34.5%	92.3%	59.0%	59.7%	23.4%	34.3%

15 Best Practices for Communities

Six Factors Communities Must Address When Considering Data Centers:

1. Sound 2. Setback 3. Sight (appearance) 4. Power 5. Water 6. Emissions

Basic Rules:

- Make sure your Comprehensive Plan lists performance standards and your Zoning Ordinance aligns with the plan; make sure both are current.
- Never allow "by right" data center development; require local jurisdiction approval.
- Never sign a Non-Disclosure Agreement.

Sound

1. Conduct a pre- and post-construction noise study (dBA and dBC). dBA is audible noise; dBC is Tonal/Narrow band low-frequency humming. dBC has the worst health effects and usually occurs in a single, narrow band.

15 Best Practices for Communities (cont.)

Sound (cont.)

2. Pass a noise ordinance/zoning ordinance that limits noise to a maximum of 50 dBA (audible sound) perceived noise at the sending property line and reduces dBC to background noise levels. (Option: Limit post-construction to a % of pre-constr.)

Setback

3. 500’ minimum setback from residential; 1,000’ preferred.

Sight (appearance)

4. Require natural screening, berms, fenestration (windows) on principal facades.
5. Limit building height, Floor Area Ratio (FAR) to ensure compatibility with surrounding structures.
6. Encourage microgrid design within the data center campus for future use (Microgrid: large power consumer, baseload power source, backup power source, long-duration storage, grid connection).

15 Best Practices for Communities (cont.)

Power

7. Require utilities to specify, in writing, the maximum power requested by the data center, how the utility plans to deliver power (routing, overhead, substations, etc.)(500 Kv = 2.1 Gw; 230 Kv = 750 Mw), and require Board approval to exceed.

8. Build data centers near existing power lines but no closer than 2x the ROW

9. Require substations to be onsite or adjacent and included in the application and never allow "by right" separate substation development or list them as "accessory use" to a data center.

10. For energy storage, use long duration storage systems (10 hours of storage minimum), not lithium-ion batteries which are not long duration systems.

15 Best Practices for Communities (cont.)

Water

11. Require the data center and water utility to specify in writing how much water the data center will use annually.
12. Determine whether the data center will use air cooling, open loop water cooling or closed loop water cooling.
13. Determine whether the data center will use potable water or reclaimed water
14. Determine how the data center will purify its wastewater and whether or not the local water treatment facility can adequately process the wastewater.

Emissions

15. Require Tier IV backup generators or Tier II generators with Selective Catalytic Conversion (SCR) attached. If using natural gas turbines, require SCR using ammonia as the catalyst

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Resource Page

Questions?

Endnotes

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Thank You!

- Please complete the survey
- Save the date - Our next rural engagement is scheduled for **June 23, 2026**
  - Rural Economic Development Summit: Data Center Development and Digital Infrastructure
- Suggestions or questions about the series?
  - Contact Philip Jones at **Philip.Jones@phil.frb.org**

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