Planning for the Infrastructure of the Digital Age

Julie Bolthouse, AICP

Director of Land Use, Piedmont Environmental Council

The Digital Age

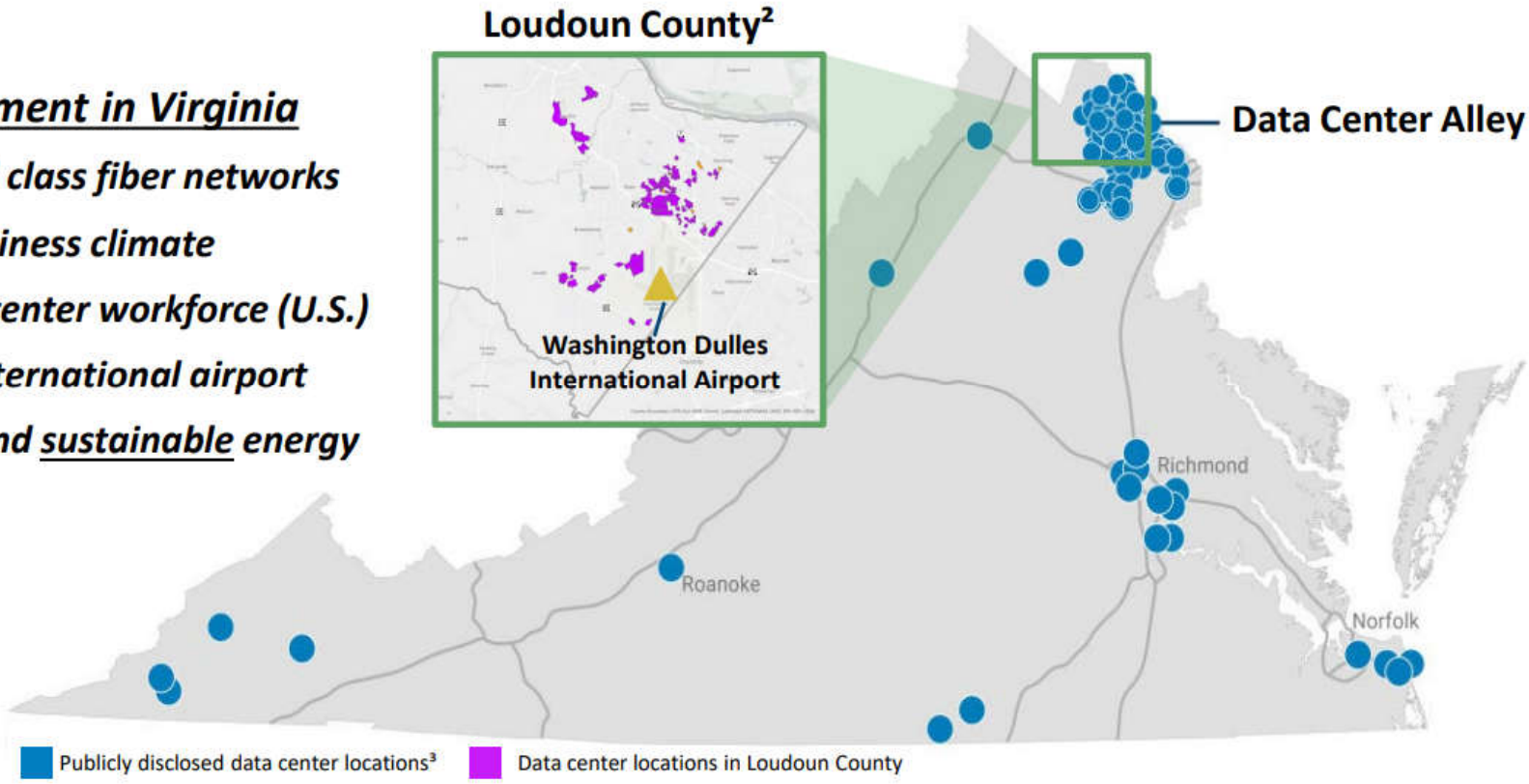
- Outsourcing of information technology functions
- Advancing smartphone technology and apps (5G)
- Roll out of rural broadband
- Digitalization and data storage
- Internet of things
- Self driving vehicles
- Artificial intelligence and machine learning

Dominion Energy Virginia

Northern Virginia boasts the largest data center market in the world[1]

Data center development in Virginia

- ✓ *Connectivity to world class fiber networks*
- ✓ *Attractive business climate*
- ✓ *Access to largest data center workforce (U.S.)*
- ✓ *Access to nearby international airport*
- ✓ *Access to affordable and sustainable energy*



Committed to deliver safe, reliable, affordable and sustainable energy to our customers

[1] https://www.vedp.org/industry/data-centers [2] February 2022 Loudoun County Data Center Land Study [3] Data Center locations provided by Data Center Hawk

Data Centers: Connected by Fiber and Powered by Electricity

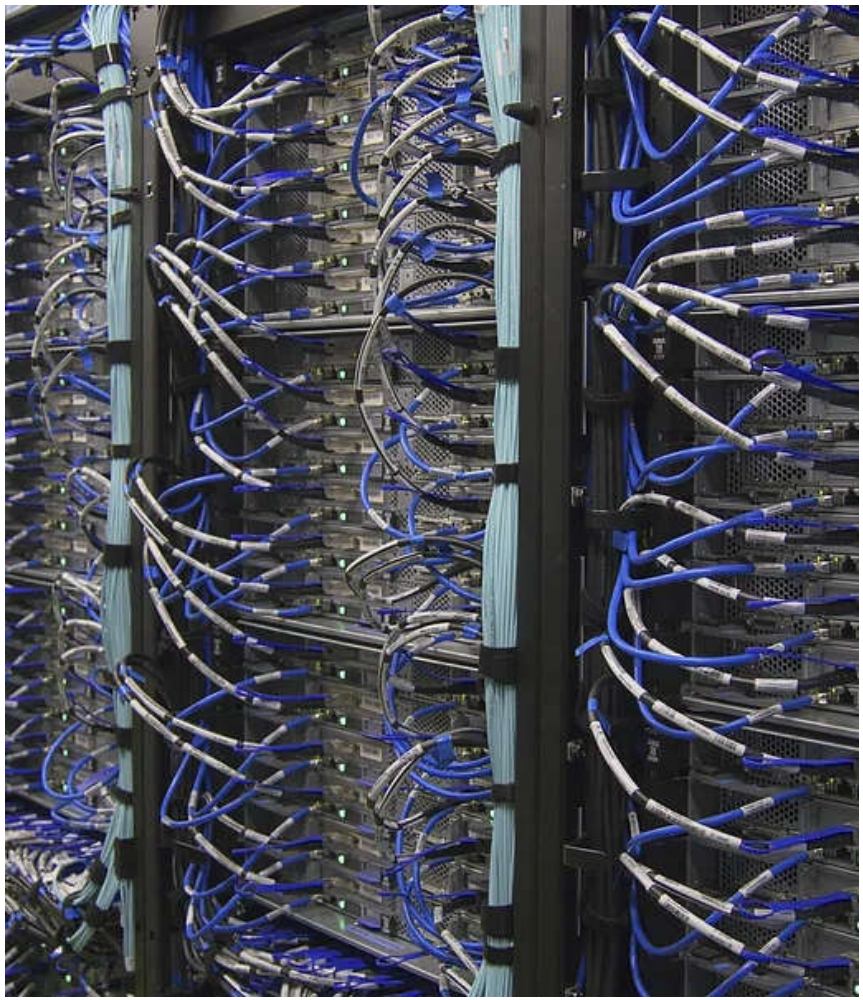
Loudoun Now - August 17, 2023

Outgoing Deputy County Administrator Charles Yudd said he thinks Loudoun's next big planning challenge won't be land use, as it has been for the past three decades, but infrastructure, especially energy infrastructure.

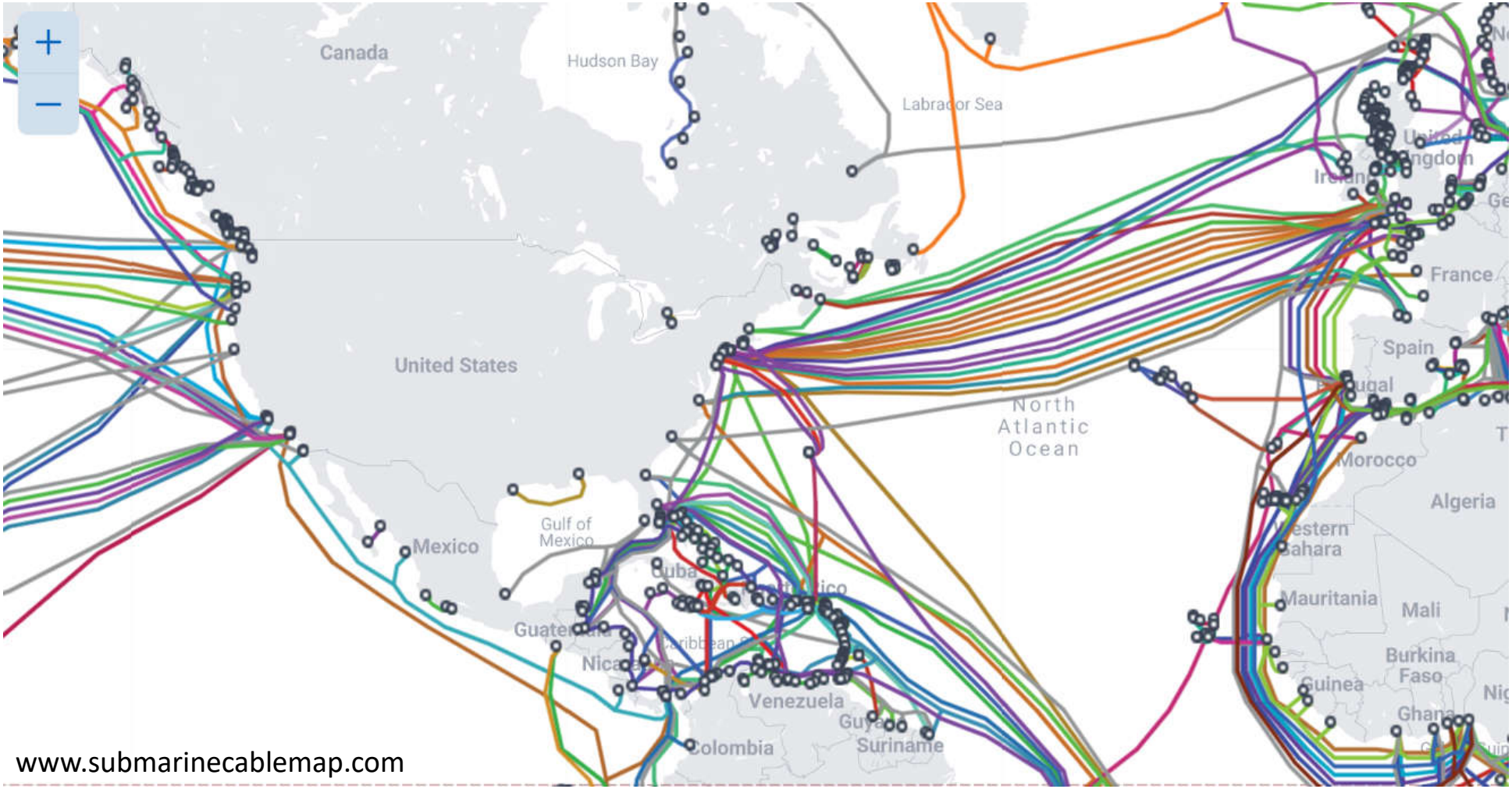
Fiber Connects Everything

Dark/Lit Terrestrial Fiber:

- **Internet Content Providers** (e.g. Google, Facebook, Microsoft, Akami and Alibaba)
- **Service Providers** – Typically telecommunications or cable companies (e.g. Verizon, AT&T, Cox, or Comcast)
- **Dark Fiber Providers** – Fiber available for lease from owners (e.g. Crown and Castle, Lumen, and Zayo)



Submarine Cable Map:

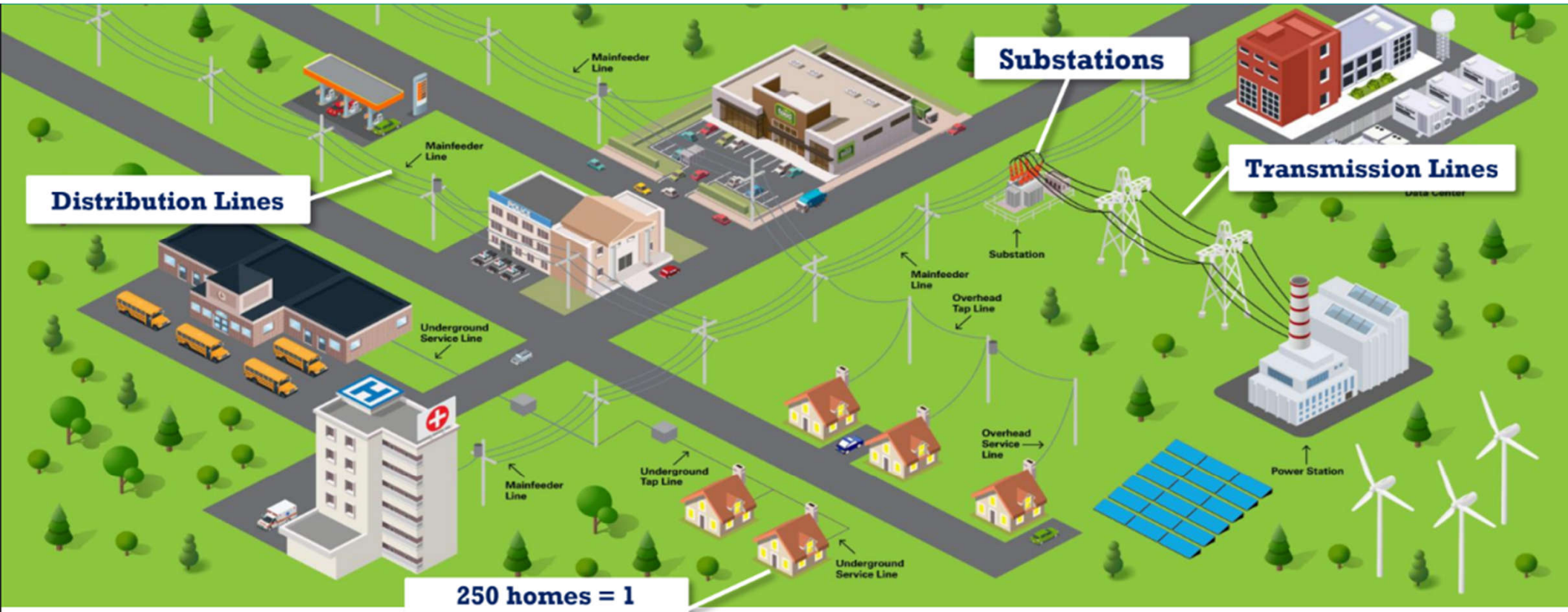


Virginia Beach is the landing point for four transoceanic fiber connection cables.

Source: www.vedp.org/industry/data-centers

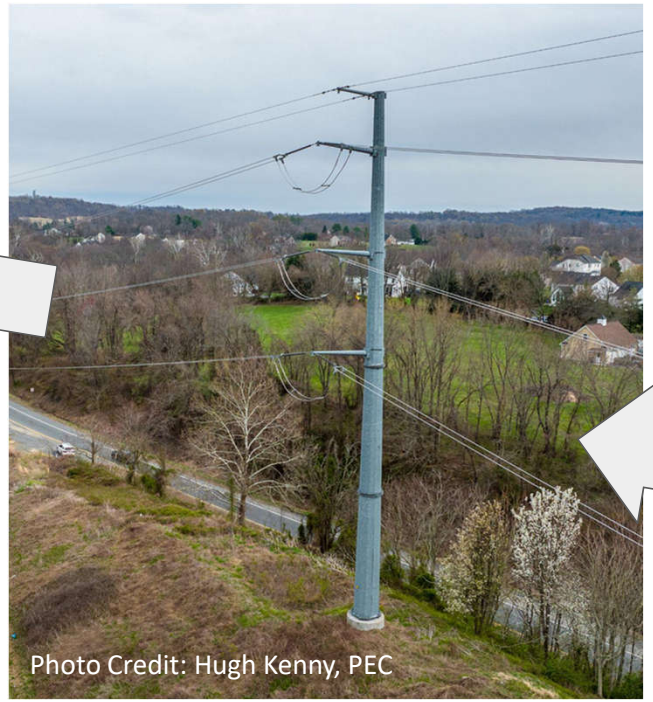
The Electric Grid

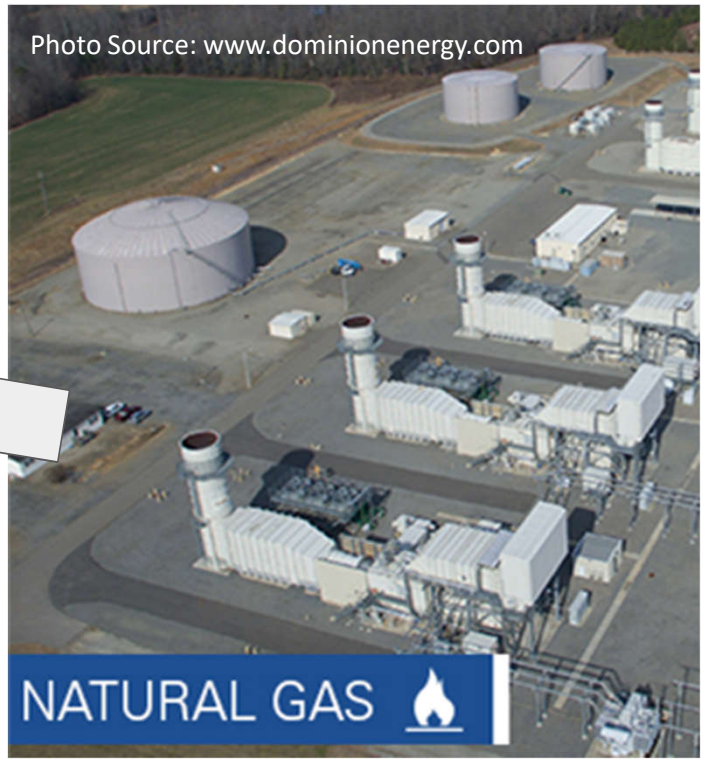
1000 watts = 1 kilowatt
1000 kW = 1 megawatt
1000 MW = 1 gigawatt



Dominion Energy

Data Centers Consume a Huge Amount of Electricity





PENN TODAY

The hidden costs of AI: Impending energy and resource strain

Deep Jariwala and Benjamin C. Lee on the energy and resource problems AI computing could bring.

By Nathi Magubane

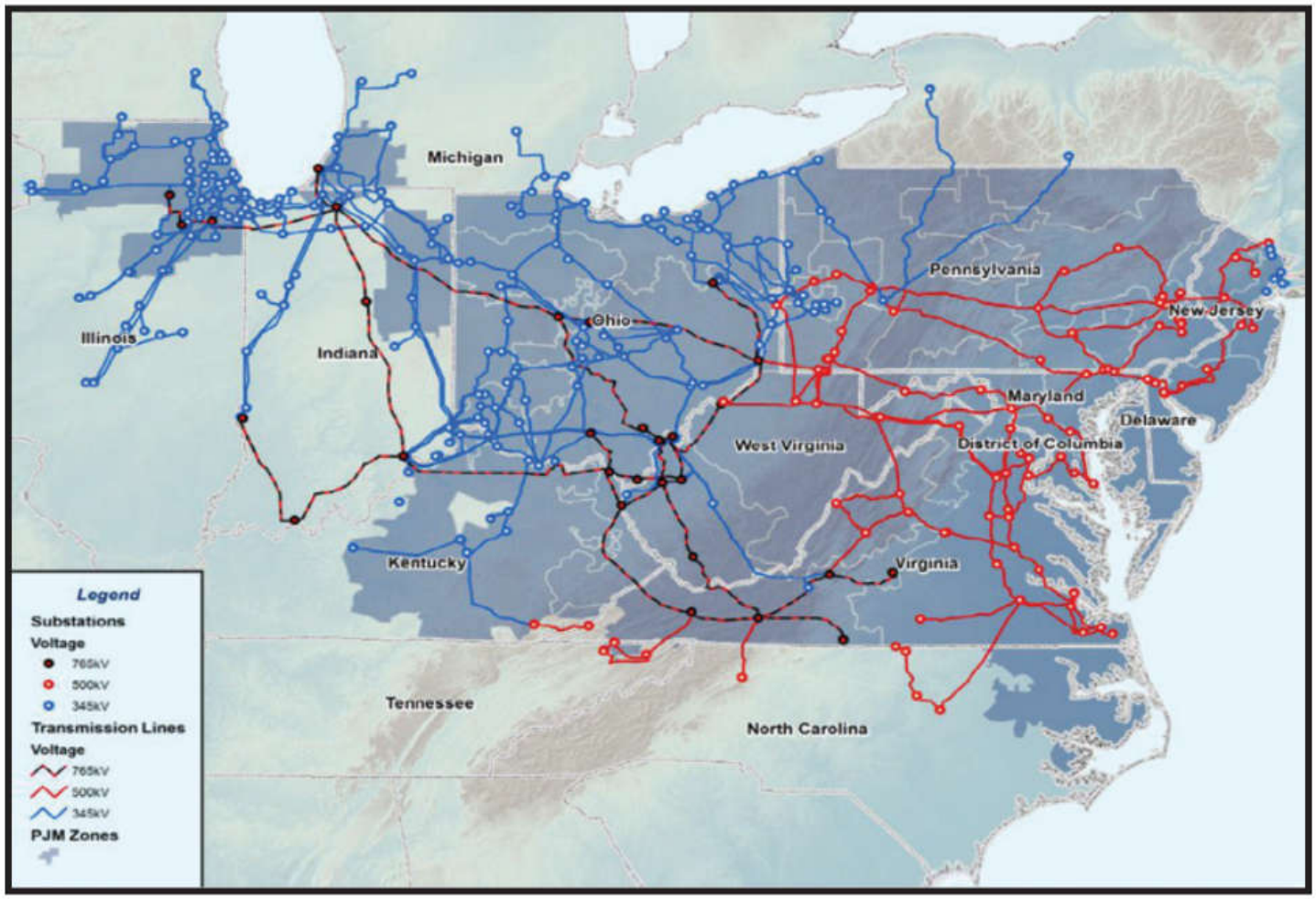
March 08, 2023

https://environment.upenn.edu/events-insights/news/hidden-costs-ai-impending-energy-and-resource-strain

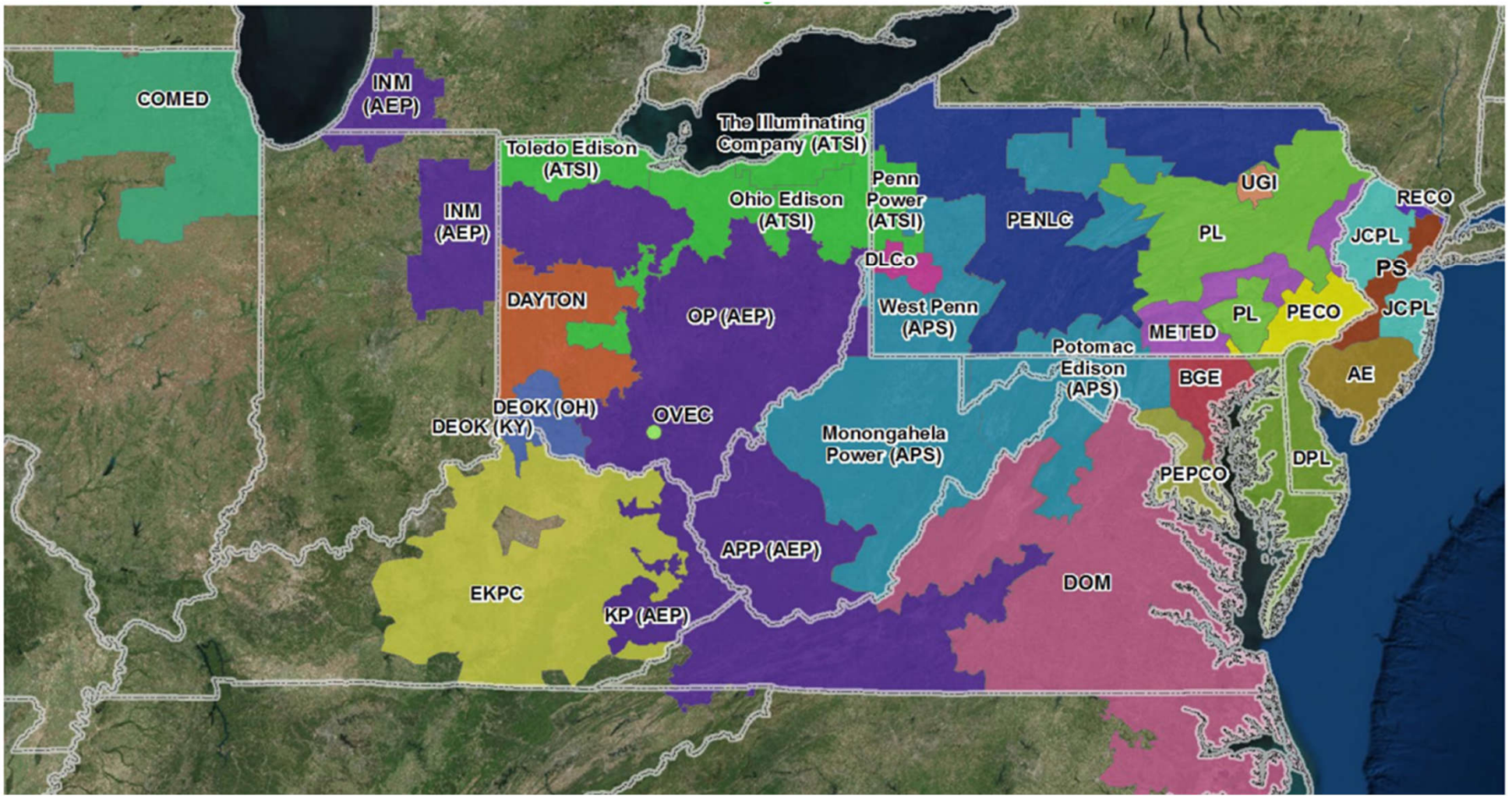
“We take it for granted, but all the tasks our machines perform are transactions between memory and processors, and each of these transactions requires energy. As these tasks become more elaborate and data-intensive, two things begin to scale up exponentially: the need for more memory storage and the need for more energy… in 2018 our computers consumed roughly 1-2% of the global electricity supply… If we continue at this rate, by 2030, it's projected to rise between 8-21%, further exacerbating the current energy crisis.” – Jariwala

Role of RTO

Acting as a neutral, independent party, PJM operates a competitive wholesale electricity market and manages the high-voltage electricity grid to ensure reliability for more than 65 million people.



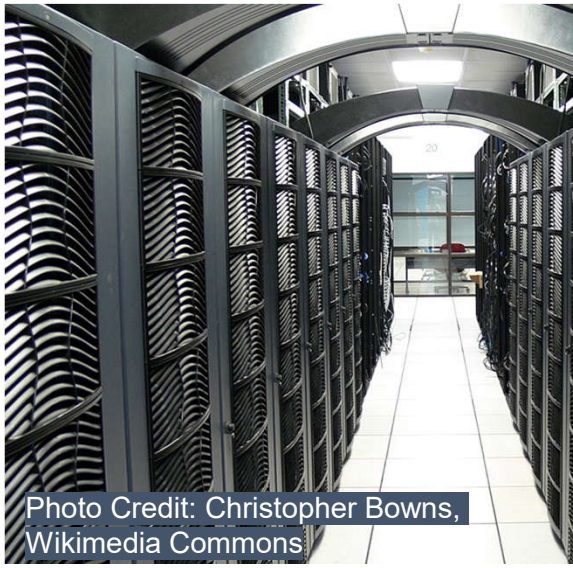
PJM Interconnection


COMED
INM (AEP)
The Illuminating Company (ATSI)
Toledo Edison (ATSI)
Ohio Edison (ATSI)
Penn Power (ATSI)
INM (AEP)
PENLC
UGI
RECO
PL
JCPL
PS
DLCo
DAYTON
OP (AEP)
West Penn (APS)
PL
PECO
JCPL
METED
Potomac Edison (APS)
BGE
AE
DEOK (OH)
DEOK (KY)
OVEC
Monongahela Power (APS)
DPL
PEPCO
APP (AEP)
DOM
EKPC
KP (AEP)

Transmission Planning Standards (varies by utility, this is Dominion Energy Standards)

- Direct-connect load at any substation is limited to 300 MW (due to reliability criteria)
- Generally only 230kV and below are used to serve local load requests. Tapping into 500kV with a new substation is typically only done to resolve system level issues.
- The State Corporation Commission provides regulation of electric facilities; however, it requires a CPCN (certificate of convenience and public necessity) for most lines over 138kV or those placed underground or including structures in a navigable waterway.
- Local government regulates permitting (siting, zoning, and site plan) of substations.
- Rough estimates of what lines can carry (varies based on conductor and conditions):
  - 230 kV line around 1 to 1.6 GW
  - 500 kV line around 4.3 to 5.2 GW
- Single source radial transmission line load is generally limited to 100MW
- Dominion requires reinforcements when load exceeds 300MW (N-1-1 contingency; simultaneous loss of 2 major units); applies to both line loss and substation loss

What is a Data Center?



Types of Data Centers

- **Cloud** - hosted off-premises (ex: Amazon (AWS), Microsoft (Azure), Google
- **Colocation -** companies rent space (ex: Digital Realty and QTS)
- **Enterprise -** built, owned, and operated by companies (ex: Meta)
- **Bitcoin Miner -** dedicated to cryptocurrency (ex: TeraWulf)

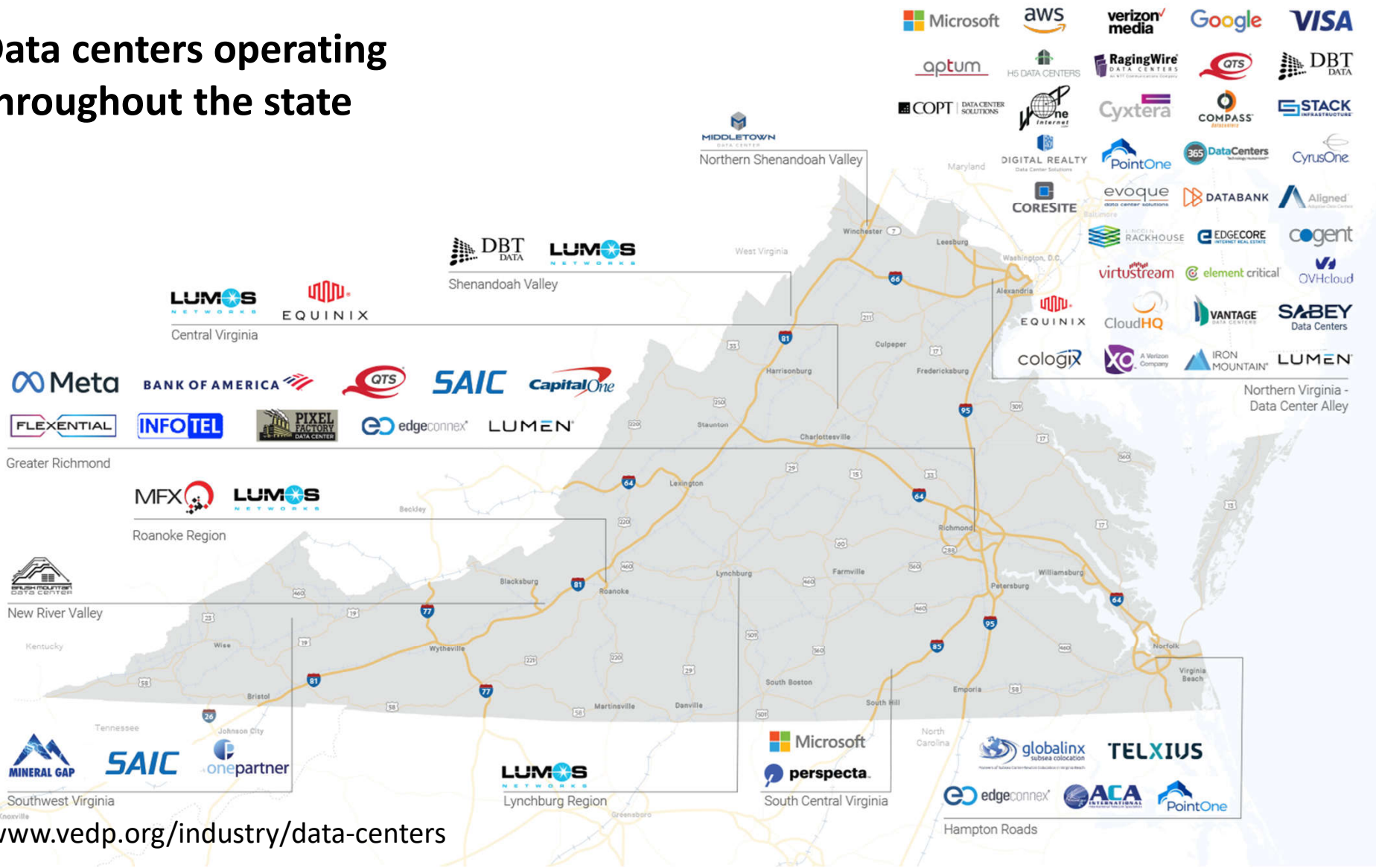
What is a Hyperscale data center?

What about Edge data centers?

An edge data center is a small data center that is located close to the edge of a network, closer to end users and devices. They deliver cached content and cloud computing closer to consumers so that the applications and services they use perform faster and are more secure. They are usually tied into a large network of data centers with a large core data center campus.

Edge data centers are all the buzz but not that much of the market yet…

Data centers operating throughout the state



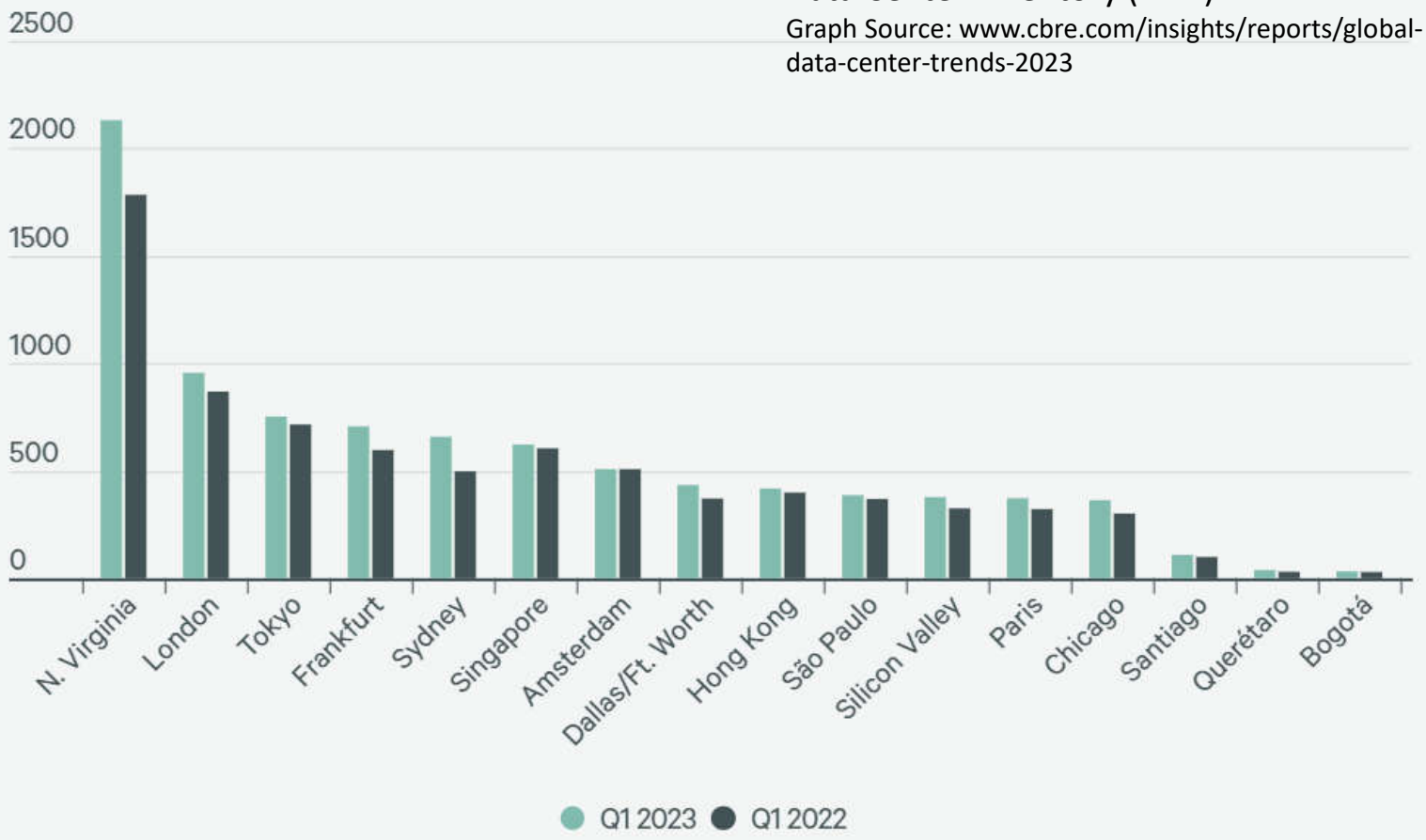
Source: www.vedp.org/industry/data-centers

Major Data Center Markets

Image Source: www.cbre.com/insights/reports/global-data-center-trends-2023

Data Center Inventory (MW)

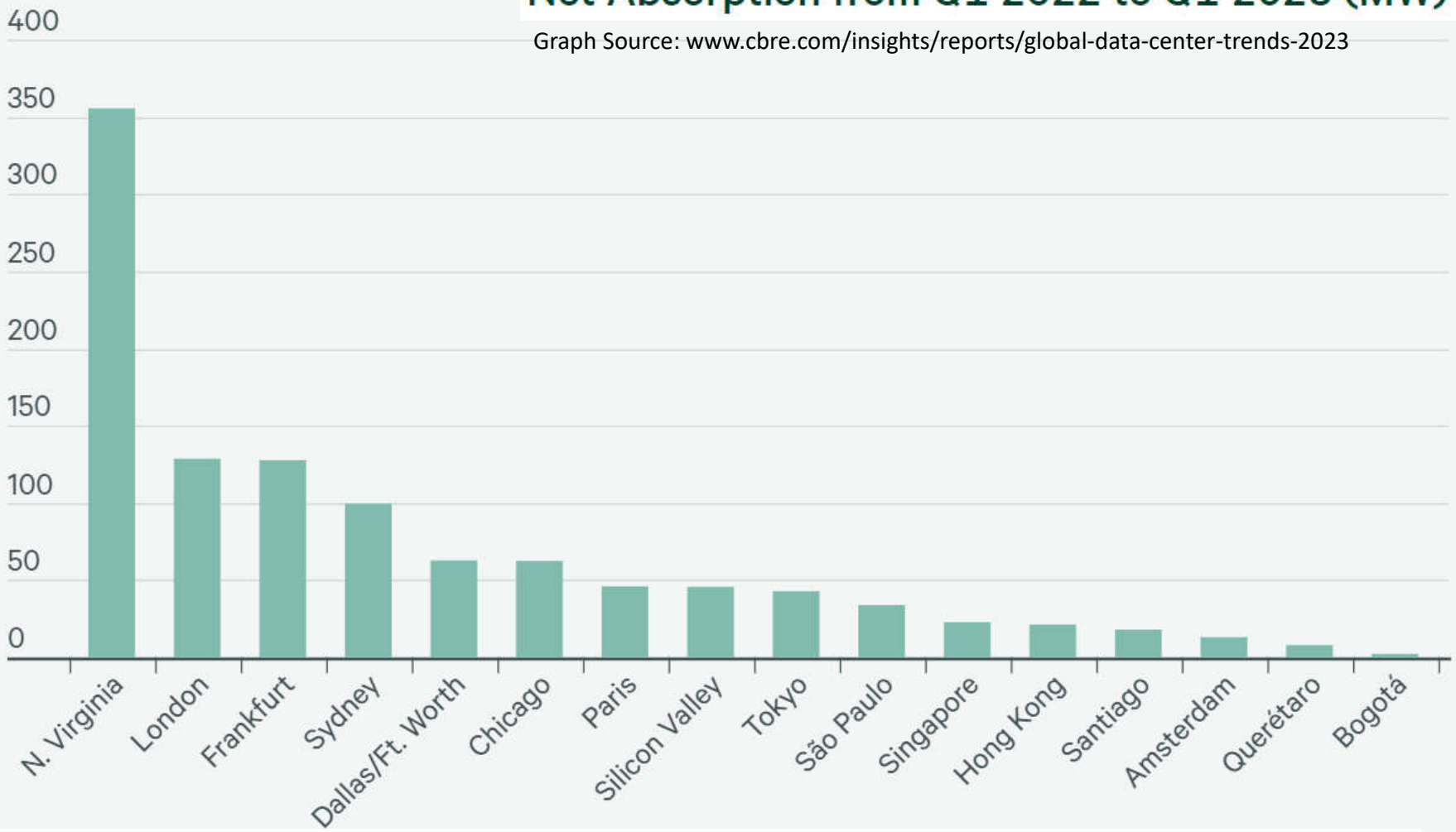
Graph Source: www.cbre.com/insights/reports/global-data-center-trends-2023



Source: CBRE Research, Q1 2022 & Q1 2023. Figures and data for North American markets include only wholesale colocation facilities. In Europe, Latin America, and Asia-Pacific, total inventory includes both wholesale and retail colocation facilities.

Net Absorption from Q1 2022 to Q1 2023 (MW)

Graph Source: www.cbre.com/insights/reports/global-data-center-trends-2023



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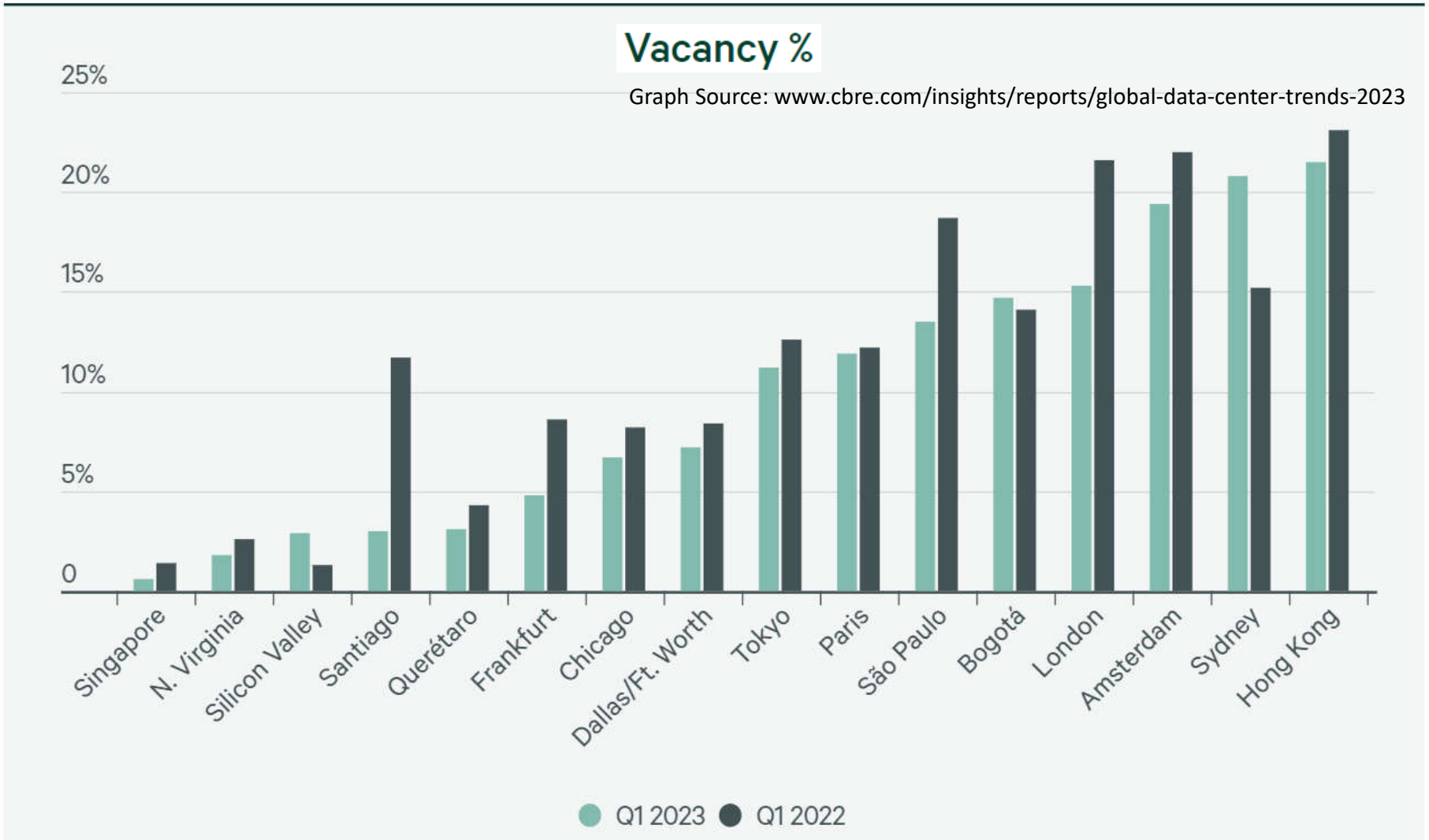
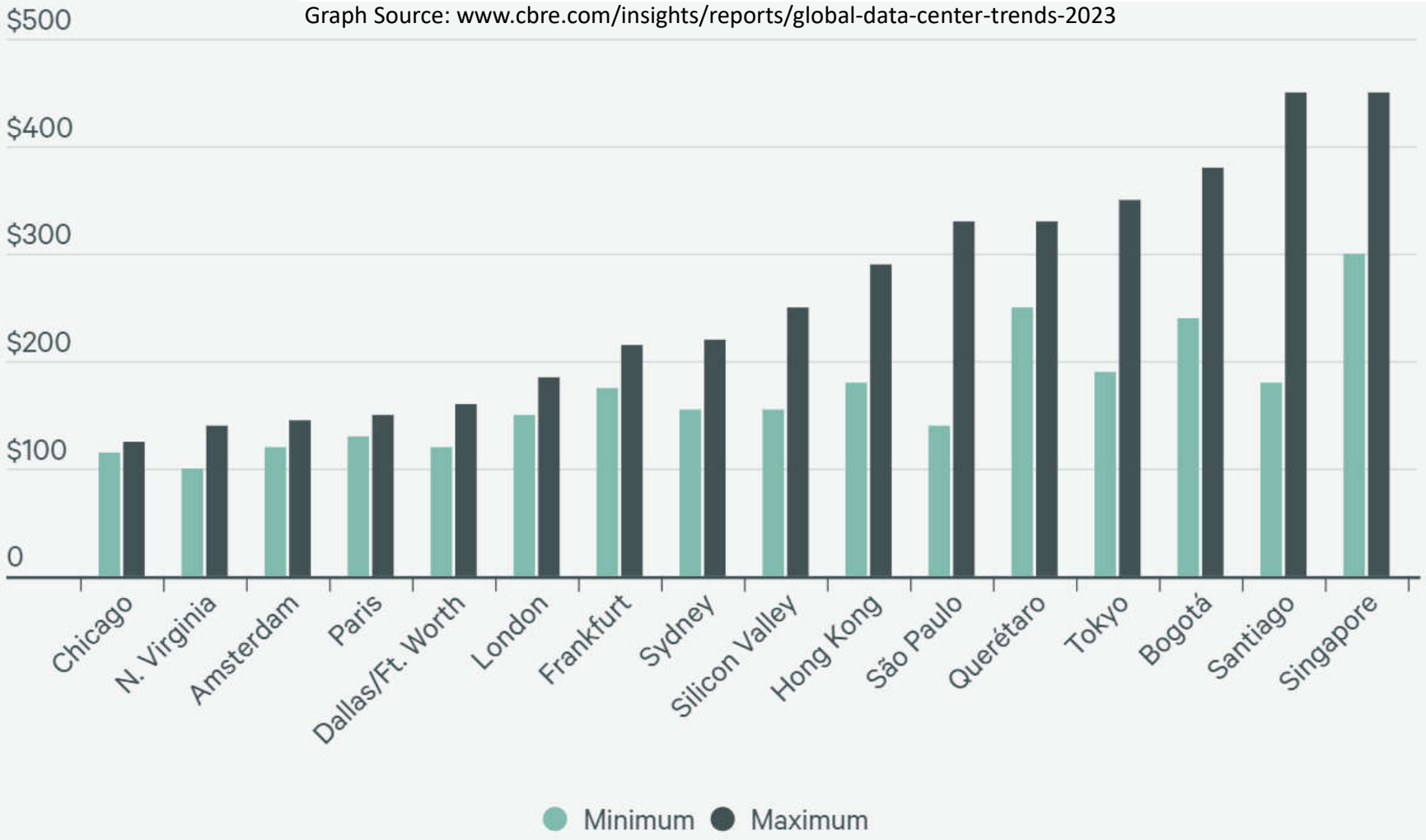


Graph Source: www.cbre.com/insights/reports/global-data-center-trends-2023

Source: CBRE Research, Q1 2022 & Q1 2023. Figures and data for North American markets include only wholesale colocation facilities. In Europe, Latin America, and Asia-Pacific, total inventory includes both wholesale and retail colocation facilities.

Monthly Pricing Range for 250-500kW (Min-Max) $USD Without Electricity Cost

Graph Source: www.cbre.com/insights/reports/global-data-center-trends-2023



Source: CBRE Research, Q1 2022 & Q1 2023. Figures and data for North American markets include only wholesale colocation facilities. In Europe, Latin America, and Asia-Pacific, total inventory includes both wholesale and retail colocation facilities.

Approved and Applications Filed with Localities…

County	Status	Development Sqft	Estimated Power Range
Loudoun	Approved	12,286,529	1,843MW – 5,529MW
	Applications	10,938,449	1,641MW – 4,922MW
Prince William	Approved	10,719,984	1,608MW – 4,824MW
	Applications	42,510,328	6,377MW – 19,130MW
Fauquier	Approved	2,901,000	435MW – 1,305MW
Culpeper	Approved	4,630,000	695MW – 2,083MW
	Applications	1,990,000	299MW - 896MW
Stafford	Applications	6,010,000	902MW – 2,705MW
Spotsylvania/Caroline	Applications	6,600,000	990MW – 2,970MW
King George	Applications	7,500,000	1,125MW – 3,375MW

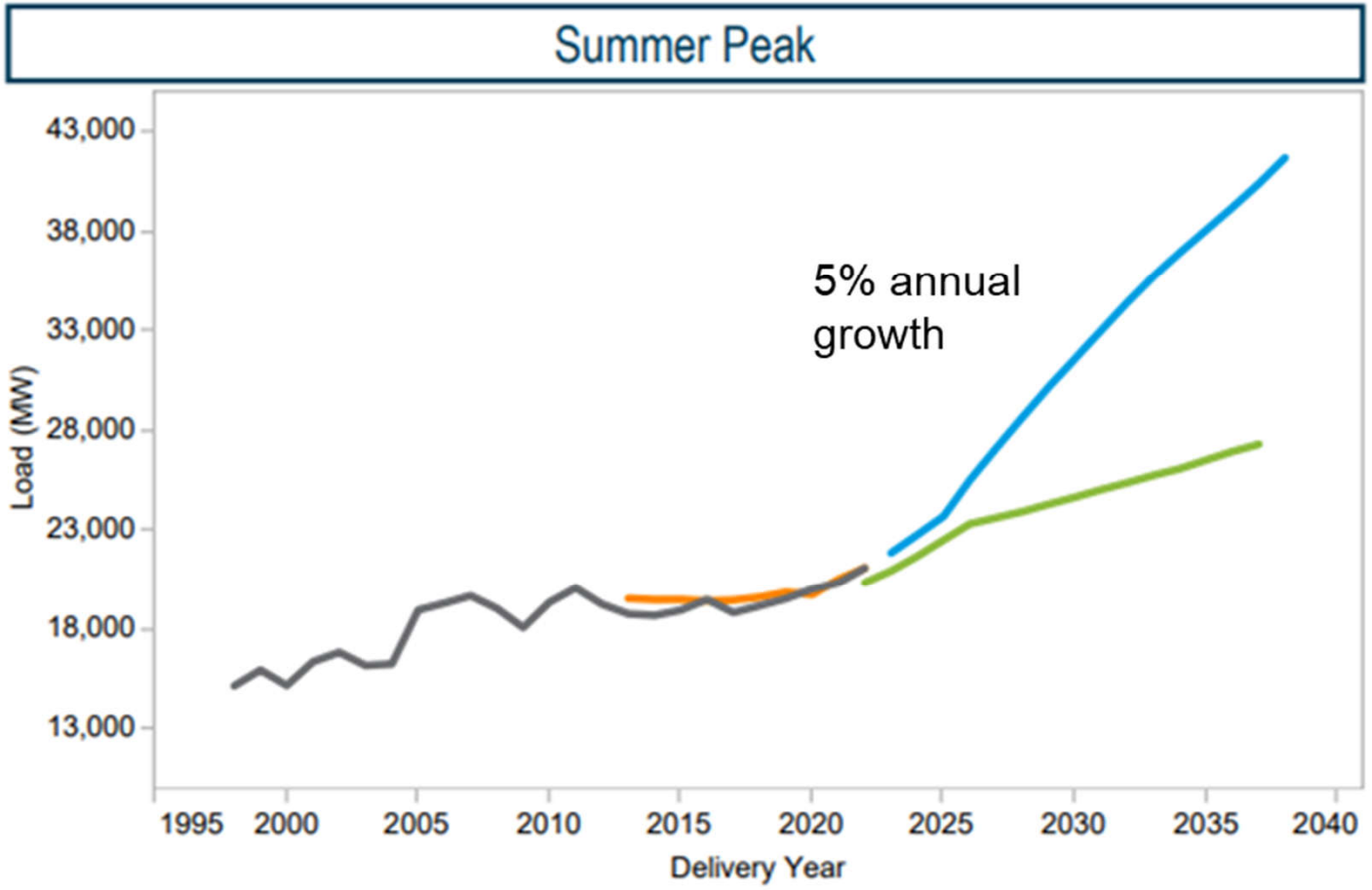
Approved and Applications Filed with Localities…

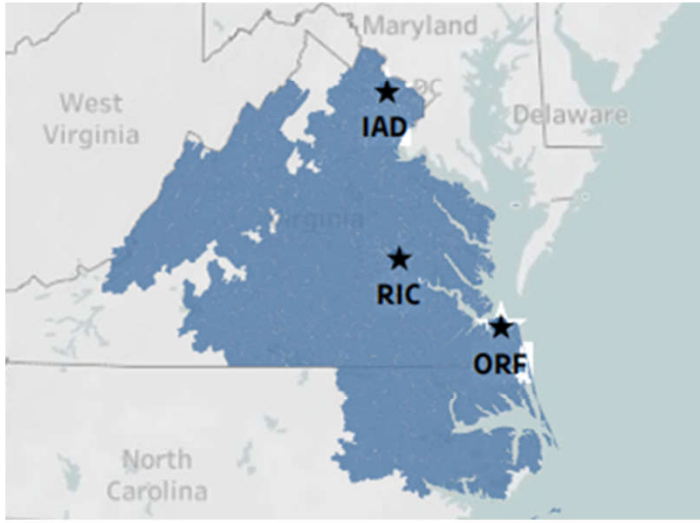
County	Status	Development square feet	Estimated Power Range
			1,843MW – 5,529MW
			1,641MW – 4,922MW
			1,608MW – 4,824MW
			6,377MW – 19,130MW
			435MW – 1,305MW
Culpeper	Approved		
	Applications		
Stafford	Applications		
Spotsylvania/Caroline	Applications		
King George	Applications		

Total Approved:
30,537,513 square feet
4,611MW – 13,742MW

Total With Applications:
106,086,290 square feet
15,915MW – 47,739MW

Dominion Area Explosive Growth Trends





Why do Localities Find Data Center Attractive?

- They generally don't usually create a lot of traffic
- They don't require school seats
- They create some jobs (although not as much as many other forms of economic development)
- **They offer a lot of tax revenue**
  - **Personal Property Tax (IT Equipment)**
  - **Real Estate Tax**

Loudoun Now August 15, 2023
Town Vice Mayor of Leesburg Neil Steinberg said on Leesburg's recent decision on data centers, *"in the end, it is all about the money, and it is a lot of money..."*

Local Land Use Impacts of Data Centers Vary…

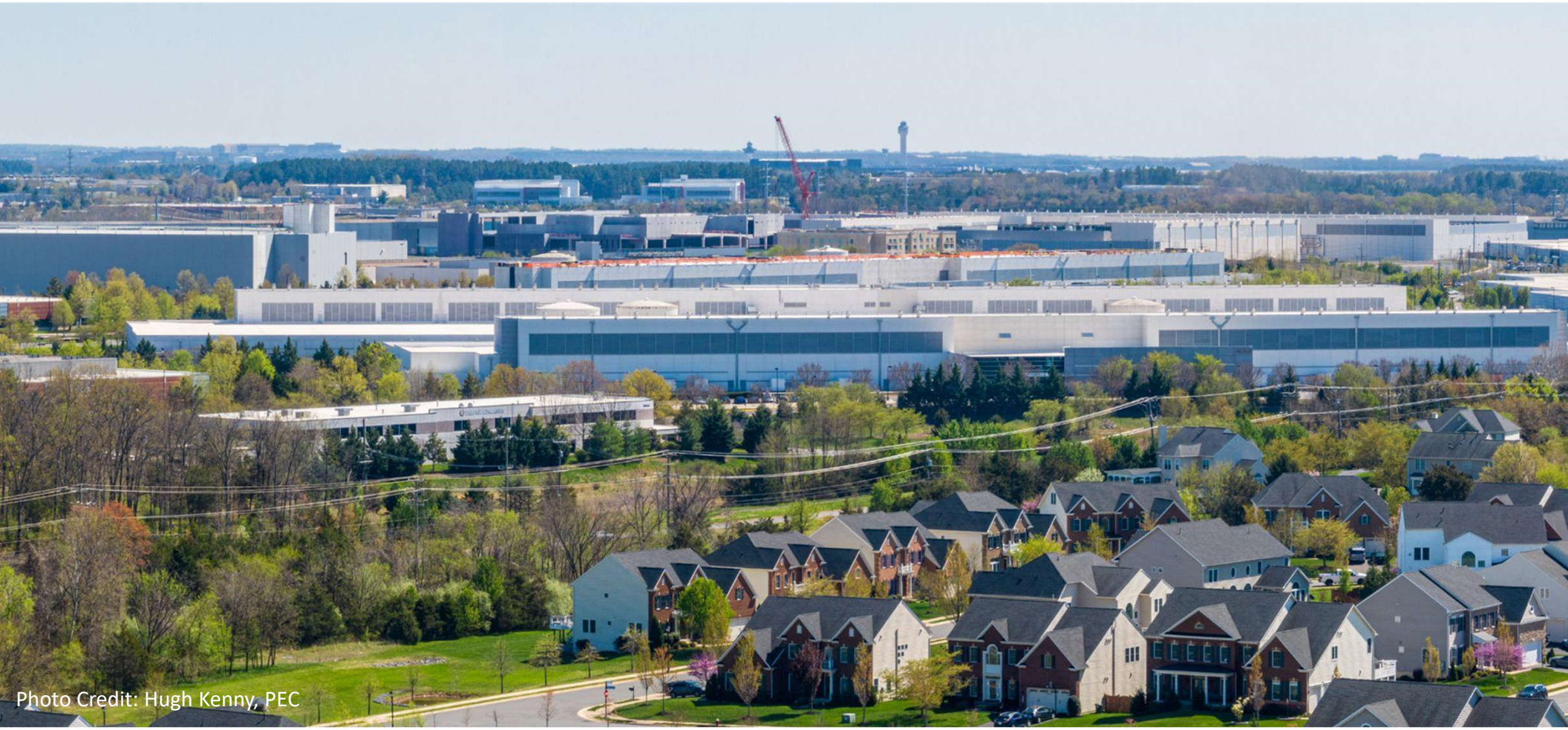
- Traffic
- Effect on Adjacent Uses
- Lighting
- Building Design
- Energy Usage
- Air Quality
- Noise
- Water Usage and Wastewater
- Water Vapor Plumes
- Fire Protection and Fuel Storage

Traffic

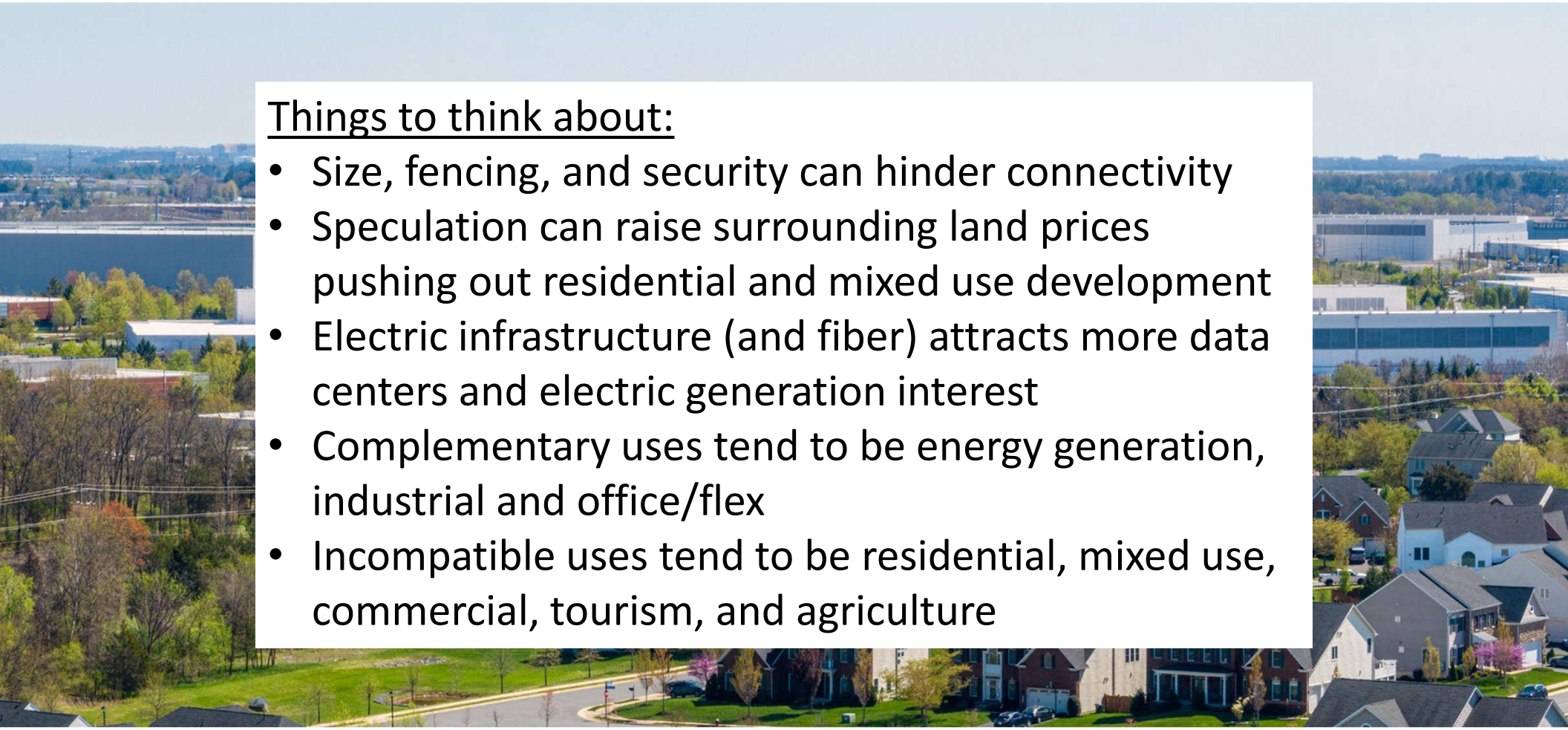
Digital Reality colocation data center with conference and work space

Amazon cloud data center

Effect on Adjacent Uses



Effect on Adjacent Uses



Things to think about:

- Size, fencing, and security can hinder connectivity
- Speculation can raise surrounding land prices pushing out residential and mixed use development
- Electric infrastructure (and fiber) attracts more data centers and electric generation interest
- Complementary uses tend to be energy generation, industrial and office/flex
- Incompatible uses tend to be residential, mixed use, commercial, tourism, and agriculture

Lighting

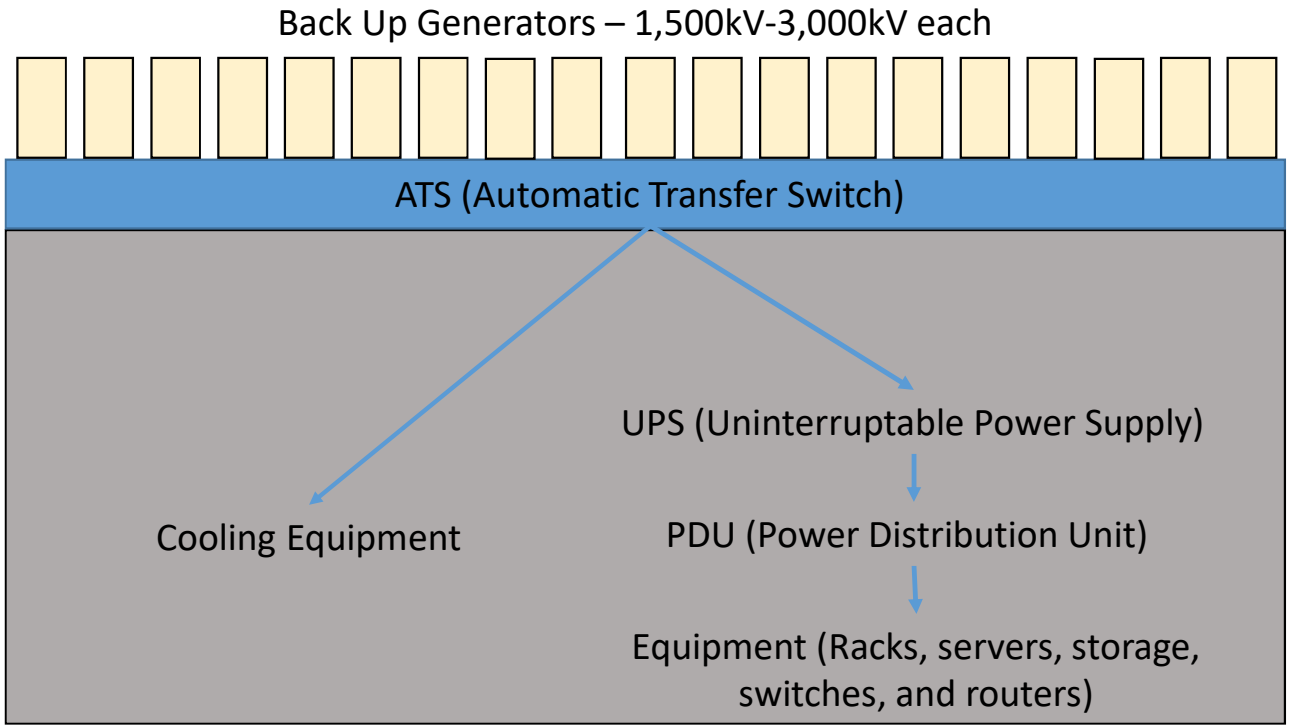
Good data center lighting example; Amazon data centers in Ashburn

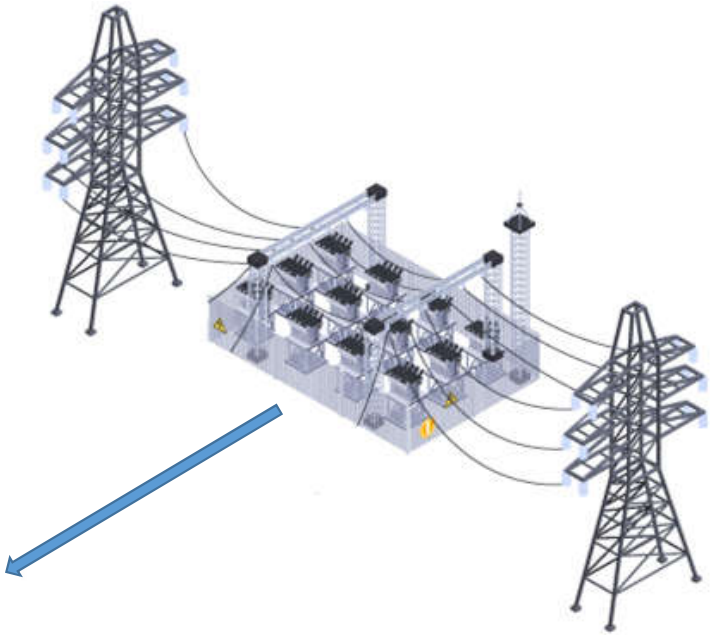
Building Design and Massing

Things to think about:

- Height limits/FAR/building footprint limits (affects power usage as well)
- Encourage different architectural treatments to break up the monolithic appearance of the primary façade (such as building step-backs, projections, recesses, fenestration (or simulated windows), differentiated surfaces and materials)
- Use screening and site layout to ensure mechanical and storage facilities are not visible from the primary façade.
- Roof parapets, equipment penthouse, or other visually solid screen should be used to screen roof top equipment (this may help some with noise as well).

Power Path for Typical Data Center

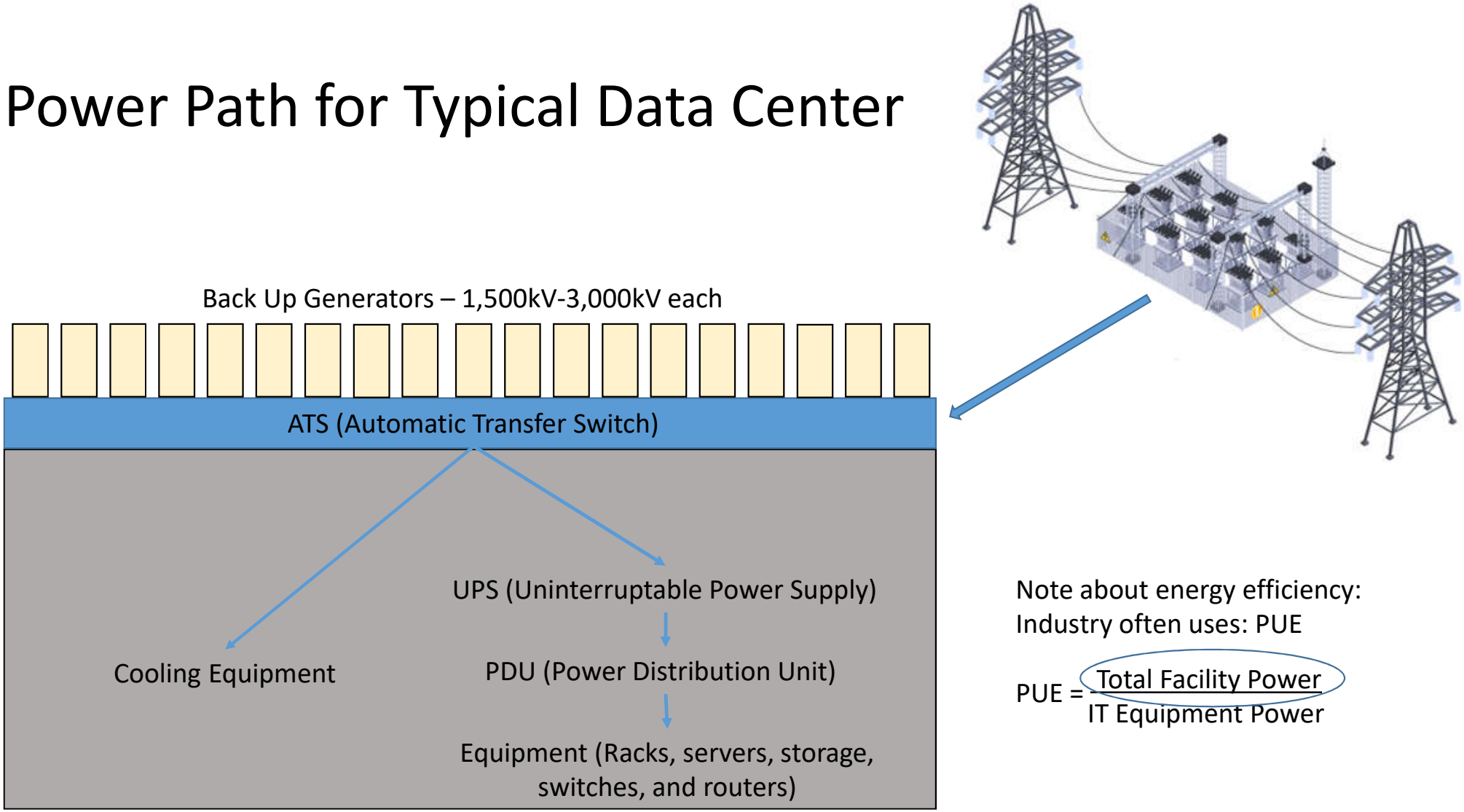




Note about energy efficiency:
Industry often uses: PUE

$$PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

Power Path for Typical Data Center



Note about energy efficiency:
Industry often uses: PUE

$$PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}}$$

Backup Generators

Whole House Generators are from 7.5 to 26kW


Photo credit: www.homedepot.com

Commercial Generators run from 1500kW to 3500kW


Photo credit: peo-acwa-flickr-cc

Generator Regulations

EPA Generator Tiers:

Tier I - first set of emission standards covering all new non-road mobile diesel engines

Tier II - Adopted 1999. Addressed NOx, carbon monoxide, unburned hydrocarbons and particulate matter (PM)

Tier III - Implemented between 2006 and 2008. Restricting exhaust emissions further.

Tier IV – Implemented 2008 to 2015. Mandated reduction of sulfur content and 90 percent reduction of PM and NOx emissions. Uses the best emissions-reduction technology available

Virginia DEQ Emergency vs. Non Emergency Standards

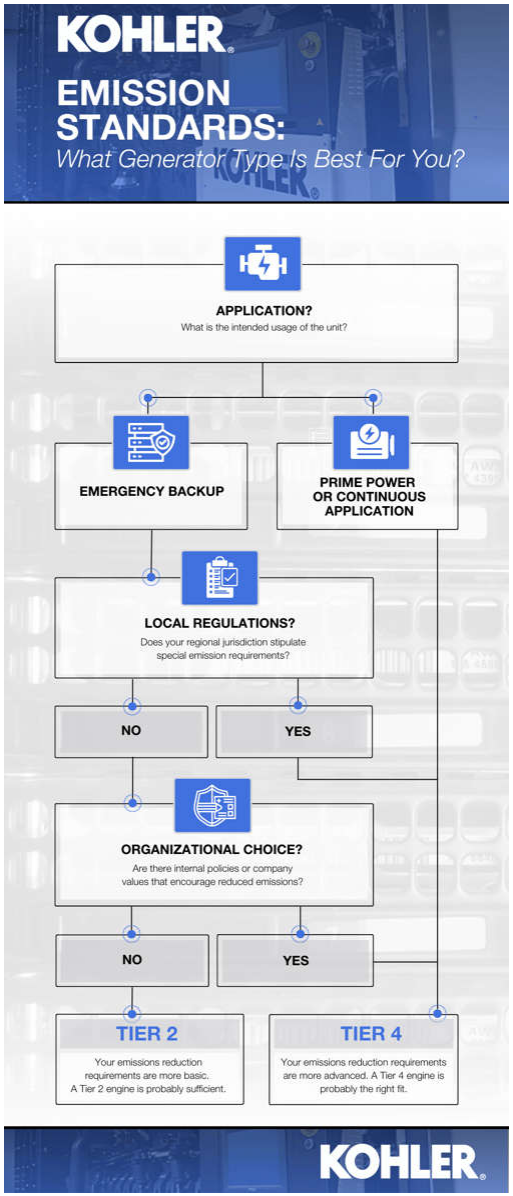
Emergency Generators (Tiers 1-3, most are 2)

- Use of low sulfur diesel fuel oil
- Must use good operating practices and perform appropriate maintenance
- Emission limit = 6.0 g/hp-hr

Non-Emergency Generators (Tier 4)

- Use of low sulfur diesel fuel oil
- Emission limit = 0.60 g/hp-hr
- Requires diesel particulate filters (DPF)
- Requires diesel oxidation catalyst (DOC)
- Requires open or closed loop SCR (Selective Catalytic Reduction) systems

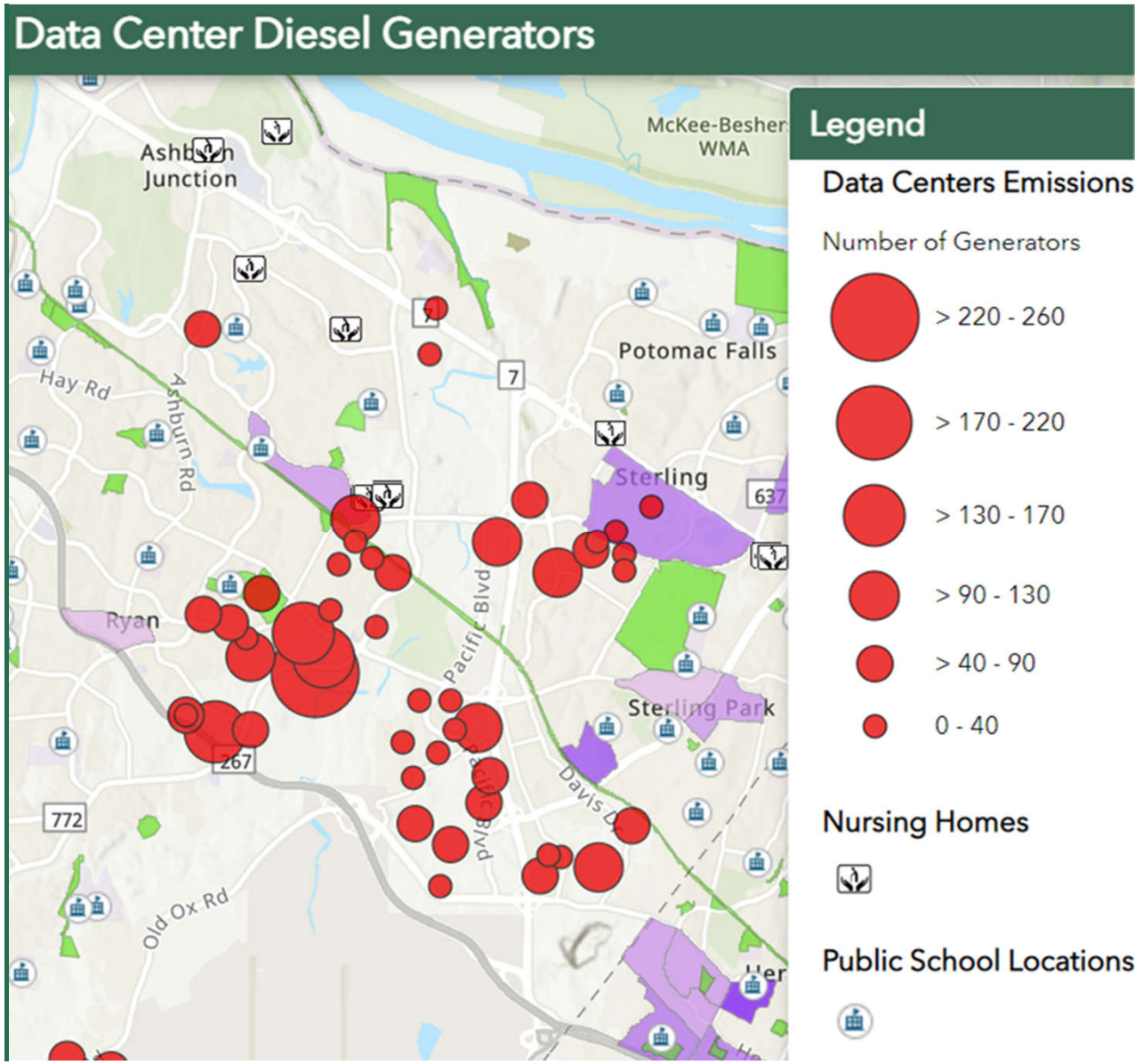
How companies decide what generator type to use:



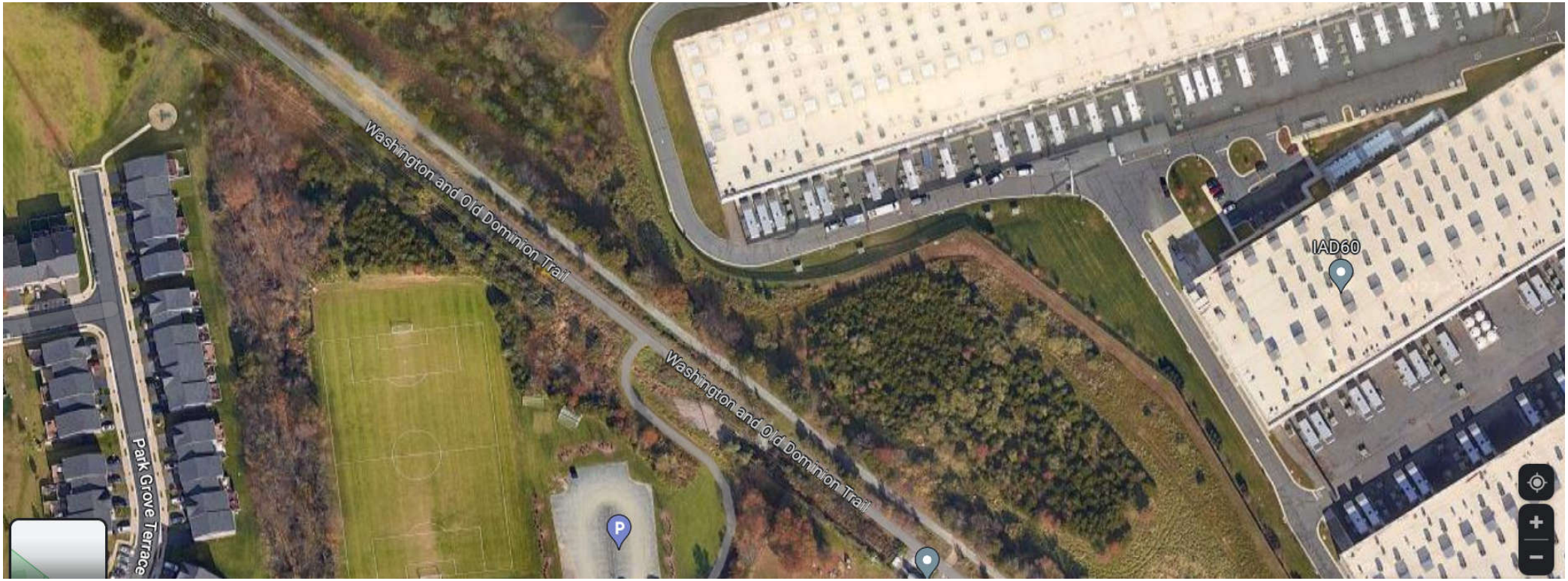
Source: https://insights-datacenters.kohlerpower.com/emission-standards-for-data-centers-a-decision-making-guide

There are over 4000 data center diesel generators permitted in Loudoun, the vast majority are Tier II

www.pecva.org/work/energy-work/data-centers-diesel-generators-and-air-quality-pec-web-map/



Amazon Datacenters in Ashburn, VA



Google Map Clipped Image 2023

Noise Issues

- Cooling (air conditioning compressors and chiller fans)
- Generators (run for maintenance and emergencies)
- Cyptocurrency (noisier than other data centers but don’t need to run 24/7 the same way as other data centers, may be able to cut them off…)

Roof of 2-story data center in Ashburn, VA

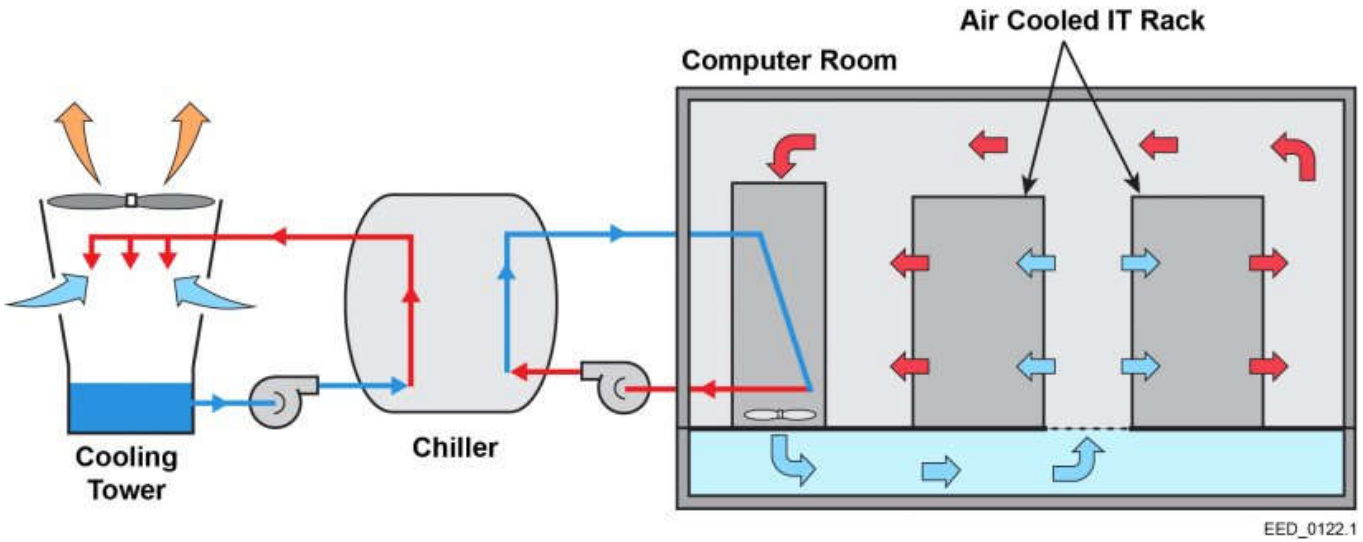
Photo Credit: Hugh Kenny, PEC

Bitfury Mines, Georgia

Thoughts for addressing noise issues

- Avoid allowing data centers in close proximity to residential development
- Require noise study upfront rather than going through costly battle to enforce noise ordinance after construction
- Some cooling systems are quieter than others. Liquid cooling is not only more energy efficient it is also much quieter because it eliminates fans.
- Require generator maintenance to be done during waking hours and not on weekends.
- Consider only allowing cryptocurrency data centers to run during daytime hours

Typical cooling at data center



This is a simplified schematic of a typical data center that relies on evaporation from a cooling tower as the last stage of heat removal from the facility.

Source: www.energy.gov/femp/cooling-water-efficiency-opportunities-federal-data-centers

Cooling Techniques (often combination of several)

Air Cooling - CRAC systems (computer room air conditioner) which provides traditional air cooling or CRAH (computer room air handler) systems which use cooling coils and a chiller system to remove heat.

Closed loop cooling design:

- Air-cooled chiller (no water loss)
- Adiabatic cooling has no cooling tower (much less water loss)

Liquid Cooling - liquid Immersion or direct-to-chip (uses less energy and less water)

Hybrid Cooling – In row cooling unit or rear-door heat exchangers (uses less energy and less water)

Other industry solutions to reduce water consumption:

- Free cooling or air- or water-side economizers (utilizing naturally cool air or water)
- Rainwater harvesting and treatment for use in cooling
- Bleed recovery using reverse osmosis units to treat water blown down from evaporative cooling system
- Trigeneration using absorption chillers (onsite power generations using natural gas)

Design Configurations: Room, Row, Rack, or Hybrid; raised floor; hot/cold aisles; blanking panels

Things to think about

- **Water Usage** – Evaporative cooling towers can use a lot of water and are often only are a sustainable choice when there is gray water available
- **Energy Usage** – Air cooling without evaporative cooling uses more energy
- **Noise** – Use and location of HVAC equipment (fans, condensers, compressors, and cooling towers); require noise study up front
- **Blowdown** – The capacity of wastewater treatment facility to handle amount and concentration of projected blowdown from evaporative cooling systems
- **Water Vapor Plumes** – Cooling tower plumes are harmless but can be unsightly and create public concern
- **Trigeneration** - Additional Community Impact of a Trigeneration facility (basically an onsite natural gas power plant)

Fire Protection

- Locality will likely need additional training for first responders to fires at data centers (see Loudoun's ER manual)
  - Lithium-ion batteries thermal runaway
  - Physical access can be challenge
  - Entry gates (may restrict longer vehicles)
  - Security policies can delay response
  - Facility size and lack of markings
- Locality may need additional equipment such as trucks with taller ladders
- Local inspectors may need additional training if first data center in locality
- Ensure proper fire protection and fighting system in place for data center and fuel storage yard

Fuel Storage

- Above ground storage is safer than underground storage tanks for preventing leaks
- Bulk fuel storage should be separated from generators and buildings
- Fuel storage containers must have secondary containment and overfill protections
- Insure there are no storm drains near fueling stations that could end up polluting nearby wells, rivers, ponds and water reservoirs if there was an overflow

Onsite Power Generation

Loudoun Now - August 17, 2023
Outgoing Deputy County Administrator Charles Yudd said he thinks Loudoun's next big planning challenge won't be land use, as it has been for the past three decades, but infrastructure, especially energy infrastructure.

"We see high-demand users contemplating small nuclear reactors, things that might need to be incorporated into business systems," he said.

SMR Nuclear to Hydrogen On-Site Power Generation Plan Proceeds In Surry County, Virginia

An illustration of Green Energy Partners' and IP3's jointly planned data center and energy campus near the Surry Nuclear Power Station in Southeastern Virginia.

Source: Onsite Energy Plans for New Data Center Projects, August 23, 2023. Matt Vincent: www.datacenterfrontier.com

Natural Gas to Hydrogen Plan Emerges for On-Site Data Center Power Generation In West Virginia

Rendering of the proposed Mountaineer GigaSystem by Fidelis New Energy, LLC, including hyperscale, carbon neutral data centers providing for both production and consumption of lifecycle net zero hydrogen. Credit: Fidelis New Energy, LLC

DuPont Fabros NJ1 data center in Piscataway, New Jersey (now owned by QTS)

Final Thoughts

- Define data centers/cryptocurrency (possibly separately) and any type of onsite power generation allowed
- Adopt use-specific standards (require basic information on data center type and cooling system, projected energy and water usage, building design, site layout with substation, generators, fuel storage and containment area, noise study, etc)
- No perfect model ordinance to point to but take a look at:
  - Loudoun County, VA (building design standards, screening of mechanical equipment, etc.)
  - Prince William County, VA (Data Center Opportunity Zone Overlay District)
  - Prince George County, VA (building design standards, require noise study, etc)
  - Town of Leesburg, VA (building design standards, sustainability recommendations, etc)
  - Niagara Falls, NY (High Energy Usage Overlay District)
  - Frederick County, MD (building design, landscaping, screening, noise standards, etc)
  - Pitt County, NC (separation from sensitive uses, requires noise study and underground wiring)
  - Chandler, AZ (preconstruction noise baseline study, annual noise study during peak operation, requires sound mitigation measures, establishes generator maintenance time limitations, etc)

Final Thoughts

- Don’t sign NDA’s and review FOIA regulations and what is considered proprietary information (a general concept plan with building locations, anticipated power usage, generator yard, fuel storage, substation, etc and basic description of type of data center and cooling is not proprietary info)
- Meet with your utility to discuss electrical infrastructure required during review not after approval! This requires full information such as projected MW of data center and planned location of substation.
- DEQ oversees the air permitting of generators but to protect the public health safety and welfare localities could adopt local regulations on the number or location of diesel generators in proximity to sensitive uses such as schools, parks, trails, elderly living facilities, hospitals, etc.

More information

- UpTime Institute - IT advisory organization tracking industry trends and providing guidance
- CBRE – commercial real estate services and investments research and provide insights
- Data Center Dynamics (DCD) - Articles, white papers, training, webinars, magazine
- Data Center Frontier – Articles, white papers, projections/trends, webinars, videos
- Podcasts – The Data Center Frontier Show, DCD Zero Downtime, Not Your Father's Data Center Podcast (less technical and more local focus)
- APA Illinois Chapter On-Demand Education Course on Crypto Mining & Data Centers (David Morley, AICP, Stewart Weiss, and Tom Thunder) CM 1.25
- PJM Transmission Expansion Advisory Committee (TEAC) – determining transmission line routes to deliver power to northern Virginia and other small data center hubs in the state
- Take a tour of Loudoun's Data Center Alley and schedule tour of inside of colocation data center with Iron Mountain or QTS
- **Visit PEC's website**

www.pecva.org/our-work/energy-matters/data-centers-energy-demand/

Questions?