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Loudoun County
VIRGINIA
WHERE TRADITION MEETS INNOVATION

White Paper

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

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The opinions and recommendations in this presentation represent those of the author alone and in no way represent those of any other Board member, the Loudoun County Board of Supervisors or Loudoun County Staff. Furthermore, these opinions and recommendations have no legal authority nor are they in any way legally binding on any Loudoun County employee.

Data Centers: Key Milestones

- 1993 Update of 1972 Zoning Ordinance: No mention of data centers
- 1990's (latter half): Metro Area Exchange-East established in Loudoun County; AOL HQ fiber laid
- 2000 Zoning Administrator determination: Data Centers are viewed similar as office buildings in the 1993 Zoning Ordinance. Office parks hot trend.
- 2001: General Plan (land use) updated
- 2003: Revised 1993 Zoning Ordinance aligns with General 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: ZOAM addressing data center sight, setback, sound
- 2019: General Plan (Comprehensive Plan) Updated

- 2022 May-Aug: Loudoun TLUC holds meetings to map/manage data center growth through CPAM/ZOAM; Dominion announces Wishing Star/Mars
- 2022 Jul: PJM informs Dominion it has underestimated power need; Dominion constrains "data center alley until new lines in 2027[1, 2]
- 2023: Dominion announces new 500/230 Kv line along Rte. 7 in Loudoun[3] and a new 500 KV line from Doubs-Aspen.[4]
- 2023 Dec: Zoning Ordinance updated to 2019 Comp Plan; SPEX for RDP and OP parcels, remove permission for Town Center
- 2023 Dec: PJM accepts NextEra proposal to build 500Kv line as part of the Mid Atlantic Resiliency Link (portion through western Loudoun); significant public resistance[5]
- 2024: Loudoun BOS denies a 2.9 mil. sq. ft./600 Mw data center; finally agrees to the "by right" size of 1.3 mil. sq. ft. and about 100 Mw; JLARC issues data center study stating unconstrained power buildout "very difficult"
- 2025: On March 18th, the BOS votes to permanently end "by right" data centers

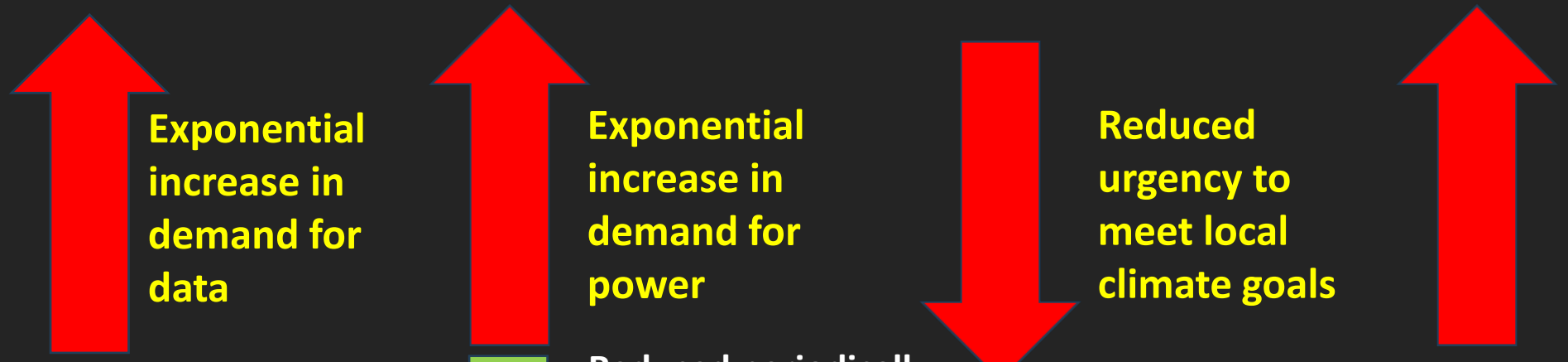
Data Centers: Benefits

- FY2025 Estimated $895M in Data Center Real and Personal Property Tax Revenue; Projected $940M Operating Budget[6]
- Lowest Real Property Tax Rate in NOVA; About 25% Lower Than Neighbors[7]
- 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 (CIF Dependent)[8]
- Put Few Cars on the Road
- Very Few Kids in Schools

Data Center Alley: Land Use Challenges

- They are experiencing explosive sector growth
  - This creates a voracious appetite for land and a willingness to pay top dollar
  - Data center zoned land: $2-3M per acre; Other: $200-300K per acre
- Zoning permits them in the eastern part of the county
- They are concentrated in Ashburn around the internet's first interconnection point, now known as "Data Center Alley."
- In addition to data center growth, Loudoun County has more than doubled its population over the last 20 years – mostly in the east
- Coupled together; data center and residential land uses are now next door to each other
- Burgeoning trend: buy office, tear down, build data centers

Four 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…

Reduced urgency to meet local climate goals

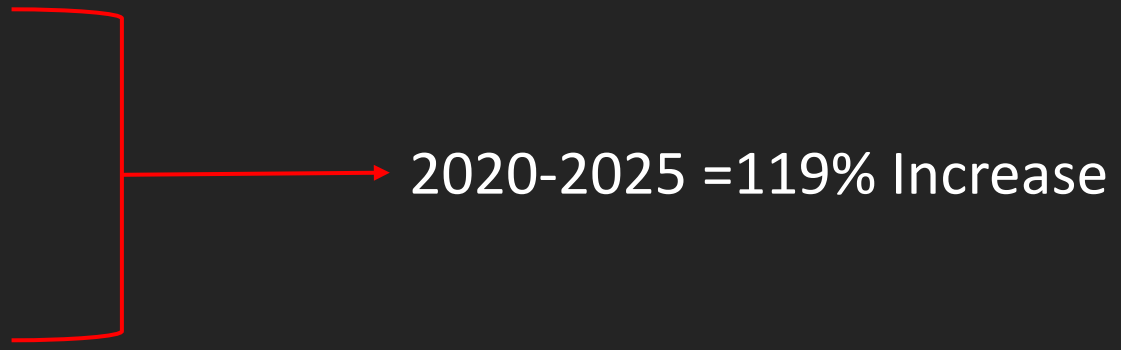
Means plans to decommission fossil fuel plants are delayed or cancelled; new fossil fuel plants built; Leads to…

Rapid increase in Community resistance to data centers and power infrastructure

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

Exponential Growth in Data Demand

- There has not been a single day in the past 15 years when a data center was not under construction in Loudoun County
- Approximately 200 data centers in 30 square miles, more than anywhere on Earth; NOVA has three times more than the second biggest market in U.S.[9]
- 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: 47.0 mil. sq. ft. (14.0% 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)[12]

2019-2024 =176%
(or almost a
threefold increase)

- Same Linear Progression Over the Next 5 Years = 11.43 Gw by 2029
- BUT…Artificial Intelligence (AI) Will Increase Existing Data Rack Power Consumption from 10-14 Kw/rack to 100+ Kw/rack = 30+ Gw by 2029

July 12, 2022 PJM Assessment About "Data Center Alley" (cont.)

- Post the planned supplemental and baseline upgrades planned in the area (2024 and 2025);
  - There are remaining violations that require immediate transmission reinforcement. These needs are driven by the load growth in the Dulles airport load area.
- There is an immediate need to address remaining reliability violations anticipated in 2025.
  - *Dominion has an obligation to serve load and there is high risk of load loss without additional immediate transmission reinforcement in the area*." (emphasis added)

Climate Change Impact

- 2024 World Meteorological Update[33]:
  - Global temperatures increased by 1.55 degrees Celsius in 2024
  - "The year 2024 was the warmest year in the 175-year observational record…
  - For global mean temperature, each of the past ten years, 2015–2024, were individually the ten warmest years on record."
- JLARC Study[32]:
  - "Building enough infrastructure to meet half of unconstrained energy demand would also be difficult…"
  - Disregarding the Virginia Clean Economy Act, we would need to build a 1.5 Gw gas plant every two years for 15 consecutive years.
  - Equal to the busiest period of the last decade for 15 straight years

Loudoun County Current and Planned Transmission Lines[15]

- Utility companies are required, by law, to provide power to all customers
- Transmission lines require 100'-180' of easement
- *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 line = 4.2 Gw; (2) 230 Kv line = 1.5 Gw
  - Total currently coming into Loudoun: 9.3 Gw, but not to "Data Center Alley"
  - Data center loop (Aspen/Golden/Mars/Wishing Star)
- Planned new lines bringing more power by 2028 (earliest):
  - New Doubs-Aspen line: (1) 500 Kv line = 2.1 Gw
  - Mid-Atlantic Resiliency Link: (1) 500 Kv line = 2.1 Gw
  - New Morrisville-Wishing Star line: (1) 500 Kv line = 2.1 Gw
  - Total planned: 15.6 Gw by 2028 (but only 2.85 Gw thru loop added to current 3.4 Gw = 6.25 Gw to

*Peak capacity about double avg. load

Data Center Alley: What About Solar Power?

- 5 Acres of Solar Panels Create 1 Mw of Electricity (nameplate)
- Solar power has a 24% capacity factor (avg. hourly power delivered)[17, 18]
- Example #1:
  - Peak load: 100 Mw per data center (illustrative)
  - Delivering nameplate power, data center would require 500 acres of solar panels
  - Delivering average power (24%), data center would require 2,000 acres of solar panels
  - 200 data centers at 100 Mw per data center = 400,000 acres of solar panels
  - Total Loudoun County landmass = 333,000 acres
- Example #2:
  - Actual average load: 21 Mw per data center (2024: 4.14 Gw/200 data centers)
  - 105 acres/data center (nameplate); 420 acres/data center (avg.) = 84,000 acres (pre-AI)

Data Center Alley: What About Wind?

Vineyard Wind Project in MA:[19]

- 62 Wind Turbines Off the Coast of Martha's Vineyard, 13 Mw (nameplate) per turbine
- Will Generate 806 Mw of Electricity (nameplate)
- Wind Capacity Factor is 34.3%
- Average Generation Per Hour: 276 Mw
- Enough to Power 400,000 Homes (nameplate)…
- …And Two Small Loudoun County Data Centers (actual)

Loudoun County: Current Assessment

Our Realities

1. Loudoun power grid is oversubscribed and will likely worsen; PJM/Dominion's planned infrastructure buildout will not keep up with demand; confirmed by JLARC study[32]
2. Halting new data center construction will slow but not solve our problem
3. Rapid increase in power demand for "data center alley" will slow decommissioning of fossil fuel plants and development of "green" power options throughout PJM service area[20]
4. Community resistance to power infrastructure expansion will grow rapidly
5. Solar and wind are not viable Loudoun County alternatives
6. The 135-yr. old paradigm of power generated by large remote power plants and transmitted across hundreds of miles of transmission lines will not work for Loudoun County

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 (BAD IDEA!)
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

Near-Term Infrastructure Improvements

- PJM/Dominion Energy Actions:
  - Reconductor All Lines in Loudoun County[21]
    - Several options; Dominion using ACSS
    - Increases capacity by 1.5x to 2.0x
  - BHAG: Create New Loudoun County HVDC Grid[22]
    - National pilot project: DoE, NREL, Commonwealth, Loudoun County
    - Data centers convert to all DC power
    - All new lines use advanced conductors, HVDC exclusively to data centers
    - Increases line capacity and efficiency
    - Allows lines to be buried
    - Allows multiple types of renewables to connect to the grid
    - Creates two parallel grids: AC for residential/small commercial, DC for data centers
    - Stabilizes the AC grid; allow separate billing to data centers

A New Power Paradigm for Loudoun County Data Centers

- Onsite, Carbon-Net-Zero Power Production Through Microgrids is the New Data Center Paradigm
- Recent DoD Changes to Title 10: SECDEF may…[23]
  - "…in selecting facility energy projects that will use renewable energy sources, pursue energy security and energy resilience by giving favorable consideration to projects that provide power directly to a military facility or into the installation electrical distribution network."
- To Implement, Loudoun Board of Supervisors Should Establish Requirements (New Data Centers), or Incentives (Existing Data Centers) to Rely on Microgrids for Power

What Is a Microgrid?

- Functional Definition[24]
  - Consists of a large power consumer, an onsite power source, a backup system, regional grid connection, long-duration energy storage or BESS
  - Current examples: large industrial plants; data centers with diesel back up
- Possible Power Sources:
  - Diesel Backup Generators (should be Tier IV; Loudoun currently Tier II)
  - Natural Gas (pipeline)/Renewable Natural Gas (BioMass)[25]
  - Turbines powered by natural gas
  - Prudent gas turbine use must include Selective Catalytic Reduction
  - Reduces NOX emissions by 95%; CO emissions by 85%; still produces PM2.5 and CO2; still below Tier IV generator standards
  - Energy Storage Systems (BESS; Graphene Long Duration Energy Storage)[26]
  - Can replace diesel engines as backup
  - Can also be the primary, independent source of energy

What Is a Microgrid? (cont.)

- Micro/Small Modular Nuclear Reactors (SMR)[27]
- Micro: 0-20 Mw; Small: 20-100 Mw; Large: 100-1,000 Mw
- There are 75 different variations, some are active since the 1960s
- Light water or sodium fast-reactor
- Hydrogen Fuel Cells[28]
- Strips H2 atoms from energy source molecules through "reforming" process
- 95% of hydrogen in U.S. is produced from reformed natural gas
- Source can be Renewable ("green"), Decarbonized ("blue"), Traditional ("gray")
- Carbon-net-zero energy if energy source is not fossil fuel or gas is decarbonized
- Hydrogen fuel cells exist now, just need to go to scale[29]
- Depending on manufacturer, each cell is a 10 ft. cube; generates 2.5 Mw
- Probably best for colocation data centers

Choosing a Microgrid Power Source

Power Source Type	Baseload Capacity	Carbon Net Zero	NOX, PM2.5 Free
Diesel Backup Generators w/SCR		Tier IV	Tier IV
Energy Storage Systems		✓	✓
Natural Gas Turbines w/SCR	✓	Tier IV	Tier IV
Green Hydrogen		✓	✓
Blue Hydrogen			
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%

Local Best Practices

Six Factors Communities Must Address When Considering Data Centers:

1. Sight, 2. Setback, 3. Sound, 4. Emissions, 5. Power, 6. Water

- 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.
- Require Tier IV backup generators.
- Max of 55 Db at the sending property line.
- Conduct a pre- and post-construction professional noise study
- Include both perceived noise (dBA) and low/high frequency noise (dBC; vibration).
- If natural gas turbines are used, require Selective Catalytic Reduction (SCR) and the use of ammonia rather than urea as the catalyst. Ensure Tier IV emission standards met.

Local Best Practices (cont.)

- Long Duration Energy Storage (LDES) backup other than lithium-ion batteries.
- 500’ minimum setback from residential; 1,000’ preferred.
- Consider waste heat recapture (district energy) to heat nearby buildings.
- Require accommodation in site design to enable future incorporation of microgrid elements (baseload power source, backup power source, BESS, demand response system, etc.).
- Work with utilities to encourage them to use advanced conductors to connect the site (Aluminum Conductor Steel Supported [ACSS] at least).
- Talk to utilities about a separate, underground HVDC grid for data centers
- Incorporate Green Building Initiative “Green Globe” ratings into buildings
- Ensure utilities state, in writing, where power will come from and where substations will be located.

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Questions?

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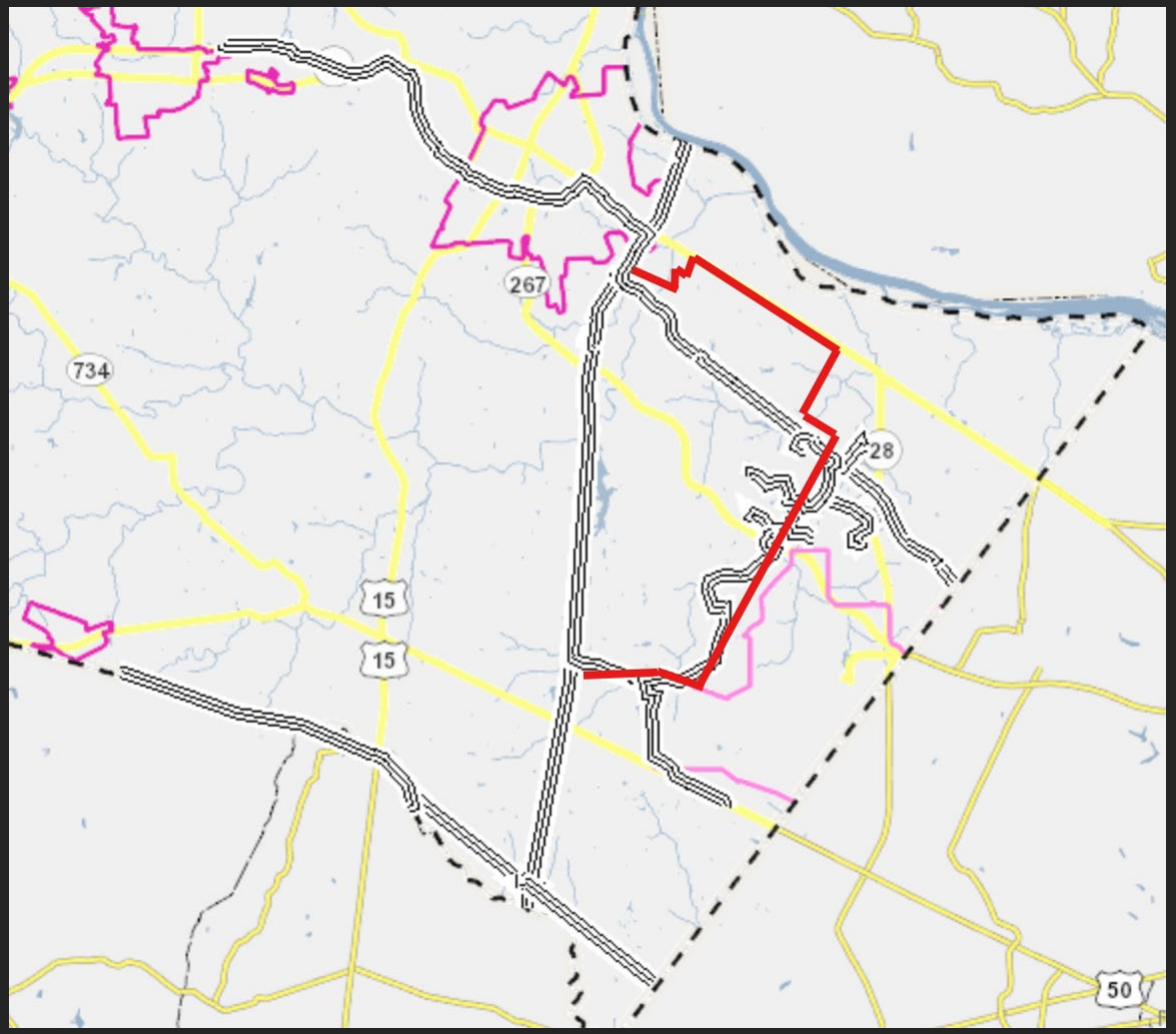
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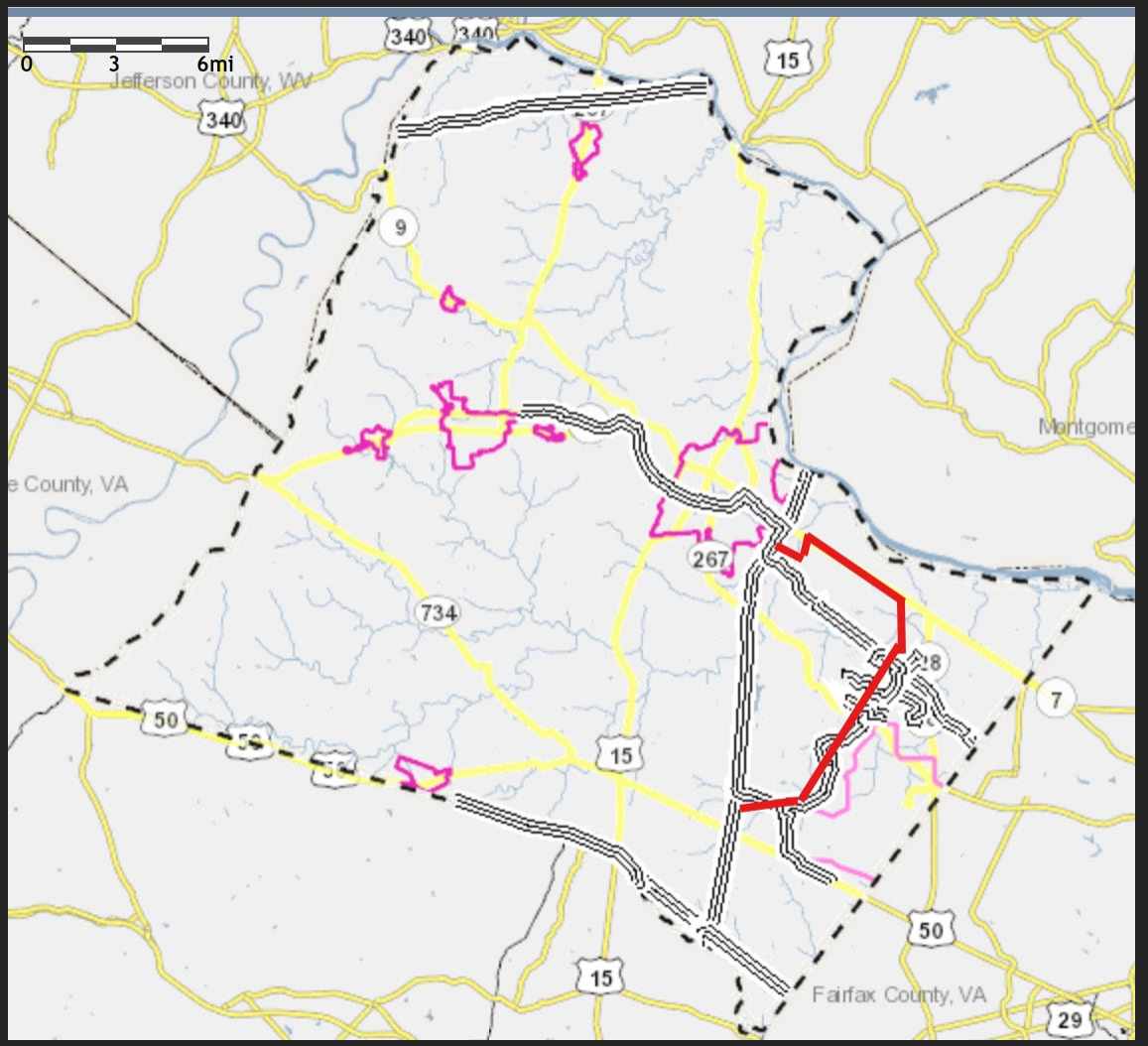
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