

# How Data Centers Shape Virginia's Energy Capability

- Github Link for Project: <https://github.com/JedDataScience/VA-Energy-Capability---DataCenter-EDA>

## HOW DATA CENTERS SHAPE VIRGINIA'S ENERGY CAPABILITY

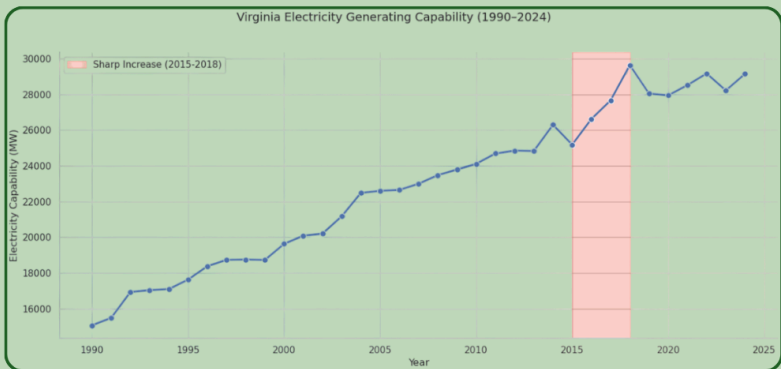
### ABOUT THE DATA

- THIS PROJECT USES VIRGINIA'S ELECTRICITY CAPABILITY DATA FROM THE U.S. ENERGY INFORMATION ADMINISTRATION (EIA). ELECTRICITY CAPABILITY REPRESENTS THE MAXIMUM POWER A GENERATING UNIT CAN RELIABLY PRODUCE DURING PEAK SUMMER CONDITIONS WHEN ALL RESOURCES ARE AVAILABLE. IT'S A KEY METRIC FOR UNDERSTANDING HOW MUCH ELECTRICITY THE STATE CAN ACTUALLY SUPPLY DURING HIGH-DEMAND PERIODS.
- THE DATA COMES FROM A FORM CALLED EIA-860, A FEDERAL SURVEY WHERE POWER PLANT OPERATORS REPORT DETAILS ON GENERATORS OF 1 MW OR LARGER (FUEL TYPE, OWNERSHIP, TECHNOLOGY, LOCATION, AND CAPACITY). WE WILL BE EXPLORING THE CAPABILITY!

26%

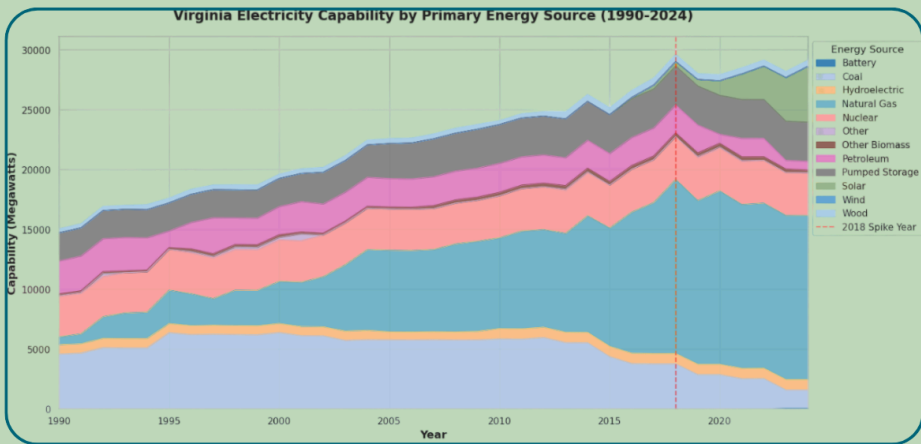
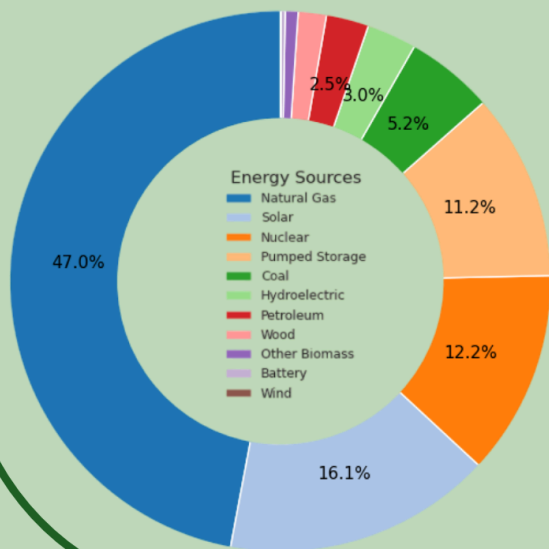
OF TOTAL ELECTRIC CAPABILITY GOES DIRECTLY TO DATACENTERS

TOTAL VA CAPABILITY (2024)  
29.25 GIGAWATTS



THIS GRAPH SHOWS TOTAL ELECTRIC CAPABILITY FROM 1990 TO 2024. WE CAN SEE A CLEAR POSITIVE RELATIONSHIP, WITH STEADY GROWTH THROUGHOUT THE YEARS. HOWEVER, IF WE TURN OUR ATTENTION TO THE RED SHADED REGION WE SEE THIS SHARPER GROWTH FROM 2015-2018. THIS IS INTERESTING LETS EXPLORE THIS MORE!

### 2024 ENERGY SOURCE CAPABILITY BREAKDOWN



VIRGINIA'S ENERGY MIX HAS TRANSFORMED SINCE 1990, WITH NATURAL GAS EMERGING AS THE DOMINANT SOURCE IN RECENT YEARS. ITS PEAKED SHARPLY AROUND 2018 AS DATA-CENTER GROWTH ACCELERATED. THE DECLINE OF COAL AND THE RISE OF SOLAR FURTHER SHOW HOW THE STATE SHIFTED ITS RELIABLE POWER SUPPLY TO SUPPORT NOVA'S MASSIVE DIGITAL DEMAND.



### THE NATURAL GAS DOMINANCE

NORTHERN VIRGINIA'S DATA CENTERS RELY HEAVILY ON ELECTRICITY GENERATED FROM NATURAL-GAS PLANTS, MAKING NATURAL GAS THE BACKBONE OF THEIR ROUND-THE-CLOCK POWER SUPPLY. REGIONAL REPORTS SHOW THAT MANY NOVA FACILITIES ARE EFFECTIVELY POWERED BY METHANE-GAS GENERATION (SOUTHERN ENVIRONMENTAL LAW CENTER, 2024) , AND UTILITIES ARE EXPANDING OR PRESERVING GAS CAPACITY SPECIFICALLY TO SUPPORT THE SURGE IN DATA-CENTER DEMAND (PIEDMONT ENVIRONMENTAL COUNCIL, 2024).

THIS IS WHY NATURAL-GAS CAPABILITY IS A CENTRAL FOCUS OF OUR ANALYSIS.

### YOY PERCENT CHANGE OF CAPABILITY BY SOURCE NORMALIZED BY YEAR

	Battery	Coal	Hydroelectric	Natural Gas	Nuclear	Other	Other Biomass	Petroleum	Pumped Storage	Solar	Wind	Wood
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.00	1.61	0.51	26.02	0.00	0.00	0.00	5.81	0.00	0.00	0.00	2.65
1992	0.00	9.80	-0.13	117.29	-0.98	314.52	2.00	-5.25	0.00	0.00	0.00	0.00
1993	0.00	-0.37	0.77	18.18	0.00	0.00	0.00	3.82	1.45	0.00	0.00	0.00
1994	0.00	0.00	-0.13	3.09	0.00	0.00	0.00	2.52	-3.36	0.00	0.00	24.07
1995	0.00	24.75	-2.93	26.98	1.28	0.00	0.00	-48.61	0.00	0.00	0.00	-7.85
1996	0.00	-2.48	-0.13	-4.64	0.00	-49.81	33.74	58.99	0.00	0.00	0.00	7.52
1997	0.00	0.50	-0.13	-18.63	0.00	0.00	0.00	36.47	0.00	0.00	0.00	-7.68
1998	0.00	-0.45	0.39	32.75	0.00	59.69	-2.75	-26.03	0.00	0.00	0.00	7.07
1999	0.00	-0.26	-0.65	0.00	0.00	0.00	-0.94	0.00	0.00	0.00	0.00	0.00
2000	0.00	2.80	0.40	19.32	2.21	0.00	4.29	5.87	0.00	0.00	0.00	-16.51
2001	0.00	-3.88	-0.52	5.13	0.00	172.33	-23.29	7.58	0.00	0.00	0.00	13.55
2002	0.00	-0.33	-0.13	13.06	0.00	0.00	0.00	-3.80	12.79	0.00	0.00	2.99
2003	0.00	-6.28	-0.94	32.62	0.00	0.00	0.00	-0.82	-0.26	0.00	0.00	2.42
2004	0.00	1.08	0.26	21.52	-0.78	0.00	0.00	0.62	2.35	0.00	0.00	0.00
2005	0.00	-0.21	-14.07	1.10	-0.23	0.00	0.00	-1.93	8.04	0.00	0.00	1.24
2006	0.00	-0.16	-0.15	-0.28	0.00	0.00	1.19	-0.17	2.74	0.00	0.00	0.24
2007	0.00	0.35	0.60	0.88	-0.82	0.00	49.41	1.34	5.47	0.00	0.00	1.95
2008	0.00	-0.36	0.25	7.01	0.00	0.00	6.02	0.01	0.00	0.00	0.00	0.98
2009	0.00	0.07	5.79	2.52	0.00	0.00	3.12	0.37	2.53	0.00	0.00	-3.08
2010	0.00	1.57	20.99	0.59	2.85	0.00	4.32	0.18	0.00	0.00	0.00	-19.12
2011	0.00	-0.34	0.00	7.65	1.09	0.00	1.69	-2.54	0.00	0.00	0.00	9.82
2012	0.00	2.19	0.00	0.06	0.65	0.00	2.99	-0.05	0.00	0.00	0.00	0.00
2013	0.00	-7.06	-0.02	1.26	0.54	-62.89	0.00	-1.33	0.00	0.00	0.00	59.08
2014	0.00	-0.22	0.00	17.95	-0.37	0.00	0.89	0.13	0.00	0.00	0.00	0.00
2015	0.00	-20.98	0.00	1.42	0.00	0.00	2.16	0.13	0.00	0.00	0.00	0.00
2016	0.00	-13.22	0.00	19.23	0.00	0.00	0.51	0.29	0.00	0.00	0.00	0.00
2017	0.00	-0.99	0.00	6.96	0.00	0.00	0.00	-0.14	0.00	234.65	0.00	0.00
2018	0.00	0.05	0.00	15.30	0.00	0.00	0.00	-0.16	0.00	13.21	0.00	0.00
2019	0.00	-23.84	0.00	-5.90	0.00	0.00	-1.59	-0.09	0.00	41.68	0.00	-14.27
2020	0.00	-0.01	0.00	5.84	0.00	0.00	0.00	-67.49	0.00	122.08	0.00	0.00
2021	0.00	-11.90	0.00	-5.42	0.00	0.00	-0.45	103.64	0.00	73.04	0.00	0.00
2022	0.00	0.00	0.07	0.71	0.00	0.00	-0.78	-0.85	0.00	30.69	0.00	0.22
2023	571.43	-39.66	0.00	-0.56	0.00	0.00	2.16	-52.02	0.37	31.00	0.00	0.00
2024	0.00	0.00	0.00	-0.10	0.00	0.00	-25.19	0.60	0.00	27.87	0.00	-1.41

YEAR-TO-YEAR PERCENT CHANGE IN VIRGINIA'S ELECTRICITY CAPABILITY SHOWS A CLEAR PATTERN THAT NATURAL GAS (HIGHLIGHTED IN RED BOX) CONSISTENTLY POSTS SOME OF THE LARGEST GROWTH RATES ACROSS THE 2010S. THIS SHOWS ITS DOMINANT ROLE IN POWERING VIRGINIA'S GRID. ESPECIALLY AS DATA-CENTER DEMAND ACCELERATES. ANOTHER INTERESTING TREND IS THE 1998-2004 VOLATILITY, WHICH MOST LIKEY COMES FROM NEW GAS UNITS COMING ONLINE WHEN VIRGINIA'S NATURAL GAS CAPACITY WAS SMALLER SO THIS COULD INDICATE YEARS LARGE NATURAL GAS PLANTS BECAME OPERATIONAL.

ROUGHLY 25% OF VIRGINIA'S ENERGY CAPABILITY IS BEING BUILT TO SERVE DATA-CENTER DEMAND, NOT COMMUNITY CONSUMPTION.

#### UNCERTAINTY IN THE DATA

- THE DATASET RELIES ON SELF-REPORTED INFORMATION FROM POWER PLANT OPERATORS, WHICH CAN VARY IN ACCURACY.
- SOME YEARS HAVE INCOMPLETE OR INCONSISTENT REPORTING, ESPECIALLY IN EARLIER PERIODS.
- PERCENT CHANGES ESPECIALLY IN THE HEAT MAP CAN BE MISLEADING WHEN BASELINE CAPABILITY IS VERY SMALL.
- RAPID DATA-CENTER GROWTH IN NOVA ISN'T DIRECTLY MEASURED HERE, SO ITS TRUE DEMAND IMPACT MUST BE INFERRED, NOT OBSERVED.

This project explores the relationship between data centers and Virginia's energy capability. Through comprehensive exploratory data analysis, we examine trends in electricity generation capabilities, producer types, and the impact of data center growth on Virginia's energy infrastructure. The final infographic visualizes key insights about how data centers are shaping Virginia's energy landscape, highlighting natural gas and other energy capability growth to allow for the ever evolving energy landscape.

## Why This Topic?

I chose to investigate the intersection of data centers and Virginia's energy capability because NOVA is the largest data center market in the world, constituting 13 percent of all reported data center operational capacity globally. This rapid growth has created a critical need to understand how the state's energy infrastructure is adapting to meet this demand. The topic is highly relevant as data centers consume substantially more energy than other commercial or industrial operations, and their expansion is forecast to drive lots of increases in energy demand across the state. This analysis provides valuable insights into how Virginia's energy generation capabilities are evolving to support this data center infrastructure boom.

## Project Details

The project employs exploratory data analysis techniques to examine Virginia's electricity generation data, focusing on:

- **Temporal Trends:** How energy capabilities have changed over time, particularly in response to growing data center demand
- **Producer Type Analysis:** Understanding which energy sources (natural gas, renewable, nuclear, etc.) are being developed to meet increasing needs by different producers.
- **Percentage Change Metrics:** Quantifying the rate of growth and transformation in Virginia's energy landscape

The analysis reveals shifts in Virginia's energy generation mix, with particular emphasis on natural gas and other energy sources that provide the reliability and capacity needed to support data center operations. The findings highlight both the opportunities and challenges facing Virginia's power grid as we need to consider the impacts that the data center growth can have on the rest of the State.

## Manifest of Resources

### Data Files

Name	Description	Link
va_electricity_capability.csv	Virginia electricity generation capability data	<a href="#">Data/va_electricity_capability.csv</a>

### Notebooks

Name	Description	Link
Understanding_the_data.ipynb	Initial data exploration and understanding	<a href="#">Data/Understanding_the_data.ipynb</a>
CapabilitiesOverTime.ipynb	Analysis of energy capabilities over time	<a href="#">EDA/CapabilitiesOverTime.ipynb</a>
PercentChangeAnalysis.ipynb	Percentage change analysis of energy metrics	<a href="#">EDA/PercentChangeAnalysis.ipynb</a>
ProducerTypeTrends.ipynb	Trends analysis by producer type	<a href="#">EDA/ProducerTypeTrends.ipynb</a>

### Scripts

Name	Description	Link
NationalWeatherApiDataPull.py	Python script for pulling National Weather API data	<a href="#">Data/NationalWeatherApiDataPull.py</a>

## External Resources

Name	Description	Link
PECVA - Data Centers Energy Demand	Article on data centers' energy demand in Virginia	<a href="https://www.pecva.org/our-work/energy-matters/data-centers-energy-demand/">https://www.pecva.org/our-work/energy-matters/data-centers-energy-demand/</a>
SELC - Data Center Growth	Article on overhyped data center growth shaping energy future	<a href="https://www.selc.org/news/overhyped-data-center-growth-is-shaping-our-energy-future/">https://www.selc.org/news/overhyped-data-center-growth-is-shaping-our-energy-future/</a>
Mordor Intelligence - Northern Virginia Data Center Market	Market report on Northern Virginia data center industry	<a href="https://www.mordorintelligence.com/industry-reports/northern-virginia-data-center-market">https://www.mordorintelligence.com/industry-reports/northern-virginia-data-center-market</a>
JLARC - Data Centers in Virginia	Comprehensive study on the impacts of data centers in Virginia, including economic benefits, energy demand, infrastructure needs, and policy recommendations	<a href="https://jlarc.virginia.gov/landing-2024-data-centers-in-virginia.asp">https://jlarc.virginia.gov/landing-2024-data-centers-in-virginia.asp</a>