# Risks of Rapid Data Center Growth in PJM

Prepared for Sierra Club

12/17/24

Sabine Chavin, Pat Knight, Devi Glick, Tenzin Gyalmo, Ida Weiss

# Project motivation, aims and approach

## Project motivation

- Across the country, data centers are driving a significant acceleration in load growth projections.
- Absent proactive planning and thoughtful policy intervention, this level of projected load growth has the potential to greatly increase emissions and raise energy costs for other ratepayers.

## Aims

- To demonstrate the scale of the potential impacts, we analyze the impacts of projected data center load growth in PJM through 2040.
- We examine the impacts of data center load growth on PJM system costs, $CO_2$ emissions, resource builds and dispatch, and average residential bills.

## Approach

- We used capacity expansion modeling to conduct scenario analysis.
- We examined prospective future scenarios with and without data center load growth, absent any emissions mitigation strategies.

# Modeled scenarios

<table>
<tr><th>Scenario Name</th><th>Goal</th><th>Description</th><th>Non-data center loads</th><th>Data center load</th><th>Clean energy costs</th><th>Environmental regulations</th></tr>
<tr><td>Base case</td><td>Provide a benchmark against which to assess the impacts of data center load growth.</td><td>This scenario examines a future without any new data center load growth.</td><td rowspan="2">Ambitious electrification assumptions for EVs and buildings are held constant across both scenarios.</td><td>No new data center load beyond what exists in 2024.</td><td rowspan="2">Based on NREL 2024 ATB Moderate case. A +25% cost adder is applied throughout the model period to reflect supply chain constraints.</td><td rowspan="2">Environmental control costs associated with finalized EPA air pollution regulations are included in both scenarios.</td></tr>
<tr><td>Data Centers case</td><td>Understand impact of data center load growth, absent emissions mitigation interventions.</td><td>This scenario examines a future that includes projected data center load growth.</td><td>Projections for new data center load are based on data from PJM and EPRI.</td></tr>
</table>

# Summary results

- PJM data center load is projected to increase from 50 TWh in 2023 to 350 TWh by 2040.
  - This represents an increase from 6% of PJM's total load to 24% of PJM's total load.
  - We assume that this increases occurs in the context of ambitious building and transportation electrification trajectories in non-data center sectors.
- Across the PJM region, this amount of data center load causes:
  - Cumulative $CO_2$ emissions over the model period (2025-2040) to increase by 1,014 million short tons, representing a 36% increase relative to the Base case.
  - Average PJM residential bills to increase by +10% in the near-term and +4% in the long-term.
    - *Geographic distribution of data centers, resource availability and cost allocation approaches will drive state level bill impacts.*
  - Net present value of PJM electric system costs to increase by $163 billion, a 33% increase relative to the Base case.
  - 42 GW of additional gas capacity to be built by 2040.
  - Near and mid-term coal generation to increase by 34% (an average of 16 TWh per year) through 2035.

***These results are reported at the RTO level and reflect impacts on the PJM region as a whole. Impacts will vary by state based on several factors, including the distribution of data center load growth.***

# Data centers are projected to cause PJM annual energy consumption and peak load to increase

**Figure 1. PJM annual load (TWh)**

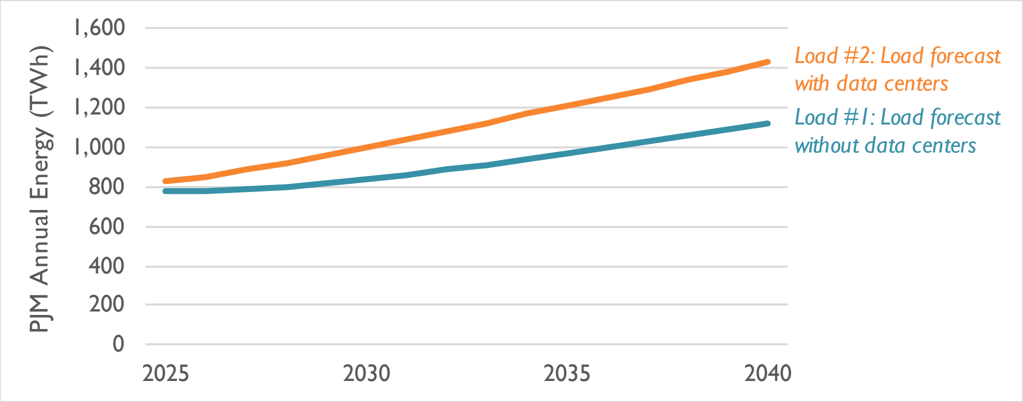
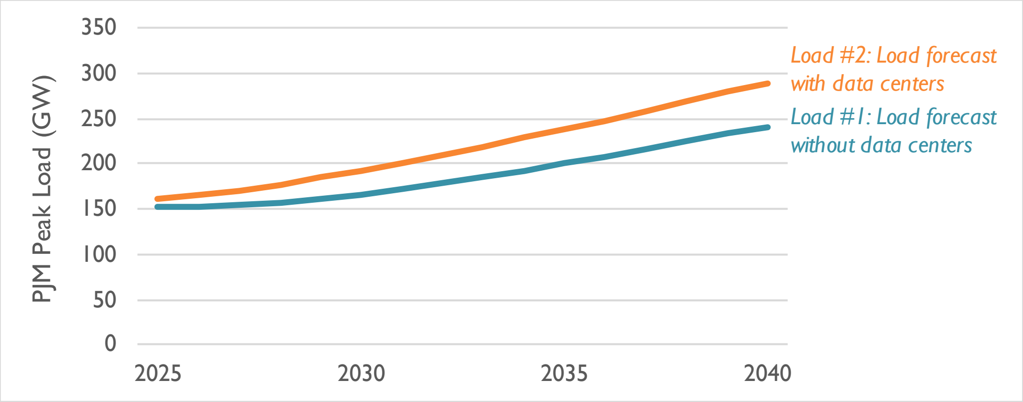



**Figure 2. PJM peak load (GW)**




- Relative to the Base case, by 2040, data centers are projected to cause:
  - Peak load to increase by 49 GW (+20%)
  - Annual energy to increase by 313 TWh (+28%)
- **Conventional loads + electrification:**
  - Both scenarios utilize conventional loads from PJM, and include ambitious heat pump and EV trajectories created by Synapse
- **Data centers:**
  - The data center load forecast is based on current data center usage in PJM states (from EPRI, 2024), escalated using an annual growth rate trajectory that is consistent with Dominion's most recent projections of data center load growth.

# Generation and loads

Figure 1. PJM generation, loads and net imports for Base case

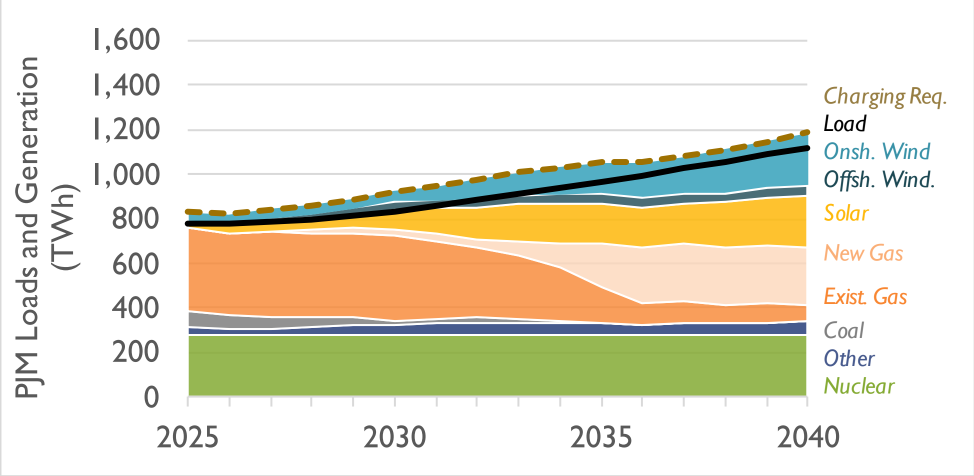
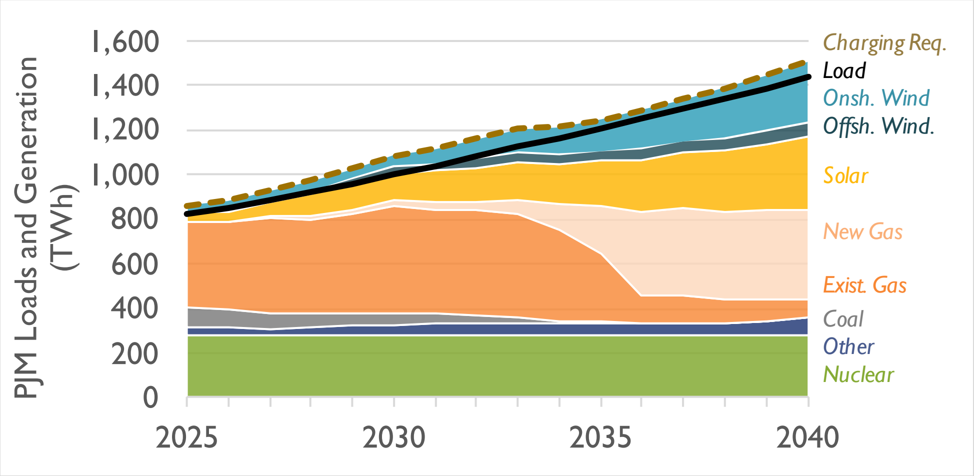
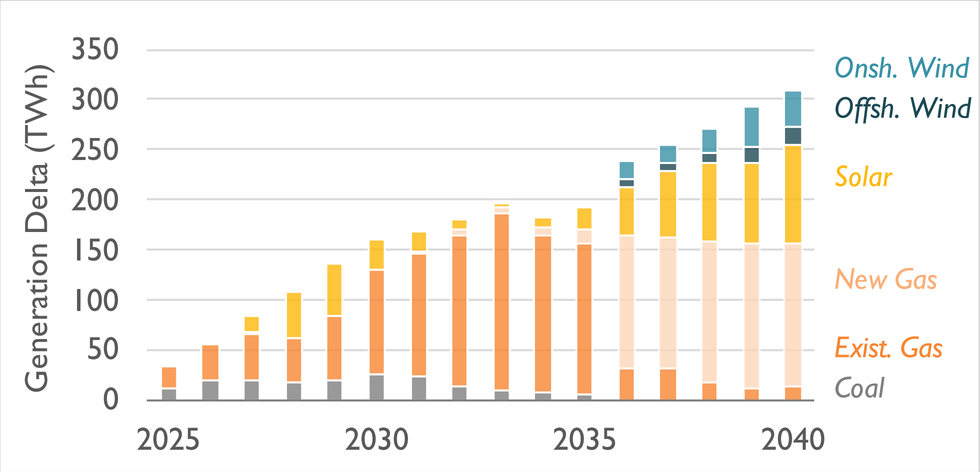



Figure 2. PJM generation, loads and net imports for Data Center case




- By 2040, PJM-wide load is 313 TWh higher in the Data Center case, compared to the Base case (an increase of +28%).
- Of this additional load:
  - 156 TWh is met by additional gas generation.
  - 99 TWh is met by additional solar generation.
  - 54 TWh is met by additional wind generation.
  - The remaining 4 TWh come from other resources (including landfill gas, biomass and demand response).

Figure 3. Incremental PJM generation in Data Center case



# Capacity and new transmission builds

**Capacity:**

- By 2040, data center load drives an increase in resource builds of 114 GW across PJM relative to the Base case.
- Of these incremental builds:
  - 72 GW is incremental new renewable energy.
  - 42 GW is incremental new gas capacity.
- Almost all coal capacity is retired by 2035 in both cases.

**Table 1. Operational capacity of Base case vs Data Center case (GW)**

| | Base case | | | Data Center case | | | Delta | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2030 | 2035 | 2040 | 2030 | 2035 | 2040 | 2030 | 2035 | 2040 |
| Gas CC | 66 | 119 | 136 | 66 | 119 | 175 | 0 | 0 | 39 |
| Other Gas | 37 | 36 | 71 | 37 | 36 | 74 | 0 | 0 | 3 |
| Coal | 23 | 1 | 0 | 24 | 2 | 0 | 1 | 1 | 0 |
| Offshore Wind | 9 | 11 | 11 | 9 | 11 | 16 | 0 | 0 | 0 |
| Onshore Wind | 15 | 42 | 76 | 15 | 42 | 87 | 0 | 0 | 0 |
| Solar | 37 | 78 | 101 | 51 | 88 | 149 | 14 | 10 | 48 |
| Batteries | 10 | 11 | 11 | 10 | 12 | 19 | 0 | 0 | 7 |
| Other* | 22 | 28 | 37 | 22 | 28 | 37 | 0 | 0 | 0 |
| Total | 219 | 327 | 445 | 233 | 338 | 559 | 15 | 11 | 114 |

* *Other contains hydro, landfill gas, and biomass resources.*

**Transmission:**

- Both scenarios build new transmission between COMED and the rest of PJM, as well as between PJM and NYISO.
- In the Data Centers case only, new transmission is built within the rest of PJM (excluding connections to COMED)
- By 2040, the Data Center case builds an additional 400 MW of total transmission capacity.

**Figure 1. 2040 Transmission builds**

# Data center loads increase $CO_2$ emissions

**Figure 1. PJM $CO_2$ emissions**

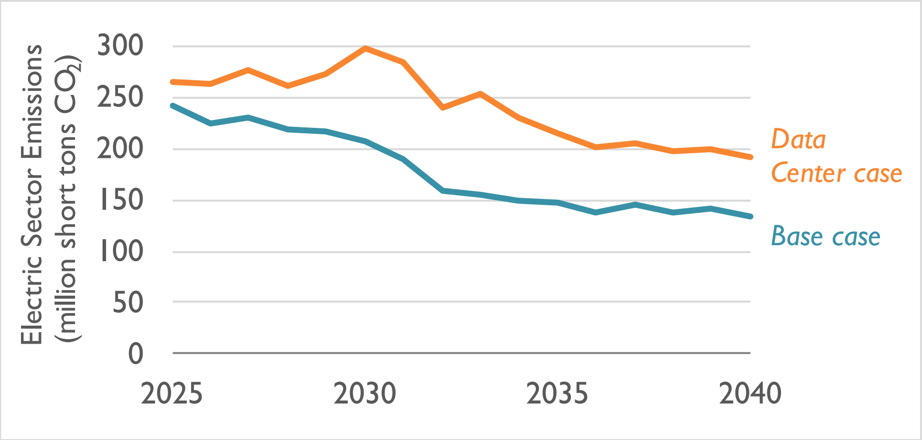
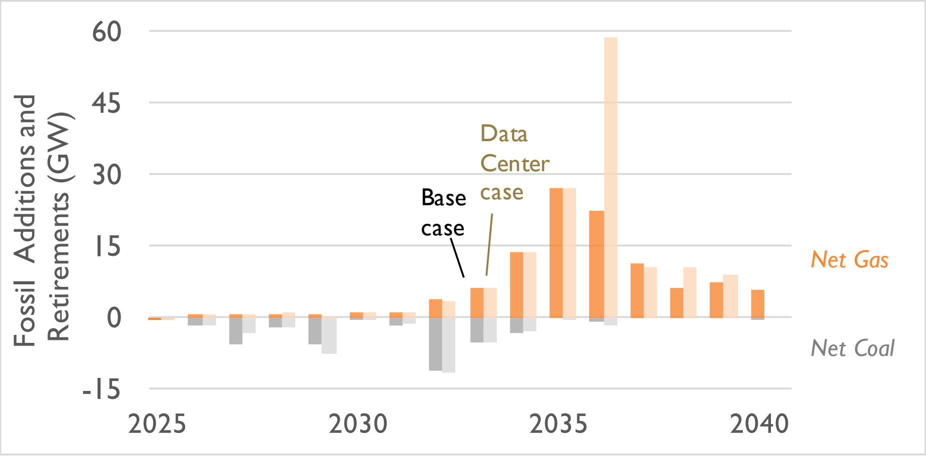



**Figure 2. Fossil retirements and additions**




*Note: this chart includes endogenous and exogenous retirements and additions.*

- Over the entire study period, data center loads cause an increase of 1,014 million short tons of $CO_2$ emissions in PJM.
- **From 2025-2030:**
  - In the near term, data centers drive up coal and gas generation.
  - The costs of EPA environmental regulations drive around 40% of current coal capacity to retire by 2030 in both cases.
  - A few coal plants have delayed retirement dates in the Data Center case.
- **From 2030-2040:**
  - Data center loads drive an increase in gas generation, resulting in increased $CO_2$ emissions .
  - As the model constraints on building new gas start to loosen from 2031-2035, and eventually go away in 2036, substantial amounts of new gas capacity are added, especially in the Data Center case.
  - By 2036, there is only 0.2 GW of coal capacity remaining in both cases.

# Data Center loads increase gas generation

**Figure 1. Total gas generation in each scenario**

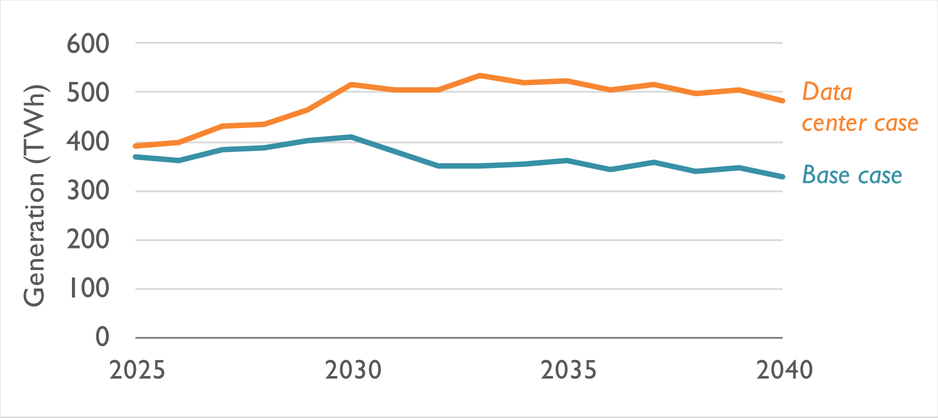
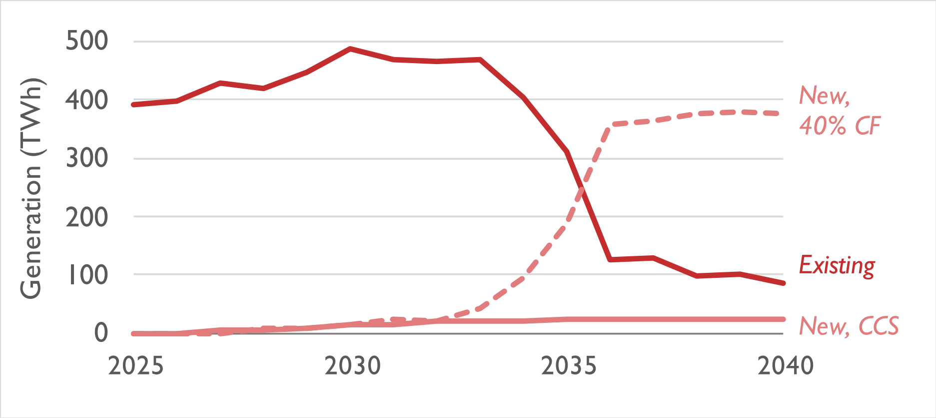



**Figure 2. Data Center case: Gas generation by category**




*Note: 111 restrictions become active in 2032.*

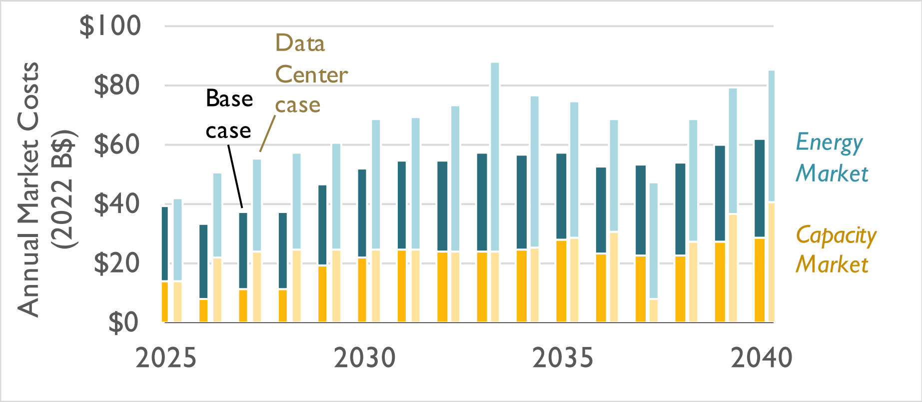
- **From 2025-2030:**
  - Incremental gas generation increases from 4% to 26% relative to the Base case gas generation
  - This is mainly driven by an increase in generation from existing plants, with a smaller contribution from new gas plants.
- **From 2031-2035:**
  - Incremental gas generation is relatively stable, averaging around 150 TWh per year.
  - During this period, new gas plants are built in increasing quantities.
  - New gas generation replaces existing gas generation.
    - New gas plants have lower variable energy costs and better heat rates relative to the existing fleet.
    - These new plants are outcompeting the existing fleet on a dispatch basis.
- **From 2035-2040:**
  - The average capacity factor of existing plants is significantly reduced.
  - The majority of gas generation comes from new plants.

# Data centers substantially increase costs to serve load

**Figure 1. NPV of PJM system costs**


*Notes: These NPV calculations assume a 7% discount rate.*
*"Other" includes REC costs and transmission costs.*

**Figure 2. PJM annual energy and capacity market value**




- Total NPV of PJM system costs are $163 billion higher in the Data Center case compared to the Base case.
- The Data Center case has higher energy costs in the 2028-2035 period. High loads and build constraints result in a higher reliance on inefficient, costly generation.
- The sum of the following value streams represents the total system costs needed to serve load under each scenario.
  - **Energy market costs:** driven by variable resource costs, including O&M and fuel costs.
  - **Capacity market costs:** represent "missing money" needed to pay for fixed costs not recovered in the energy market, clearing price is driven by the relative size of changes in peak loads compared to firm capacity.
  - **Transmission build costs:** cost of building new transmission lines.
  - **REC costs:** costs of complying with state RPS requirements.

# Data centers are expected to drive up average PJM residential bills

**Table 1. Monthly average PJM residential bill impacts (2022$)**

| | 2021-2023 (EIA Historical) | 2025-2030 (Modeled Near-term) | 2031-2040 (Modeled Long-term) |
|---|---|---|---|
| Base case | $126 | $124 | $146 |
| Data Center case | | $136 | $152 |
| Bill impact of data centers | | +$11.9 | +$5.7 |
| % Change in bills due to data centers | | 9.6% | 3.9% |

***Cost Allocation Approach***

- Data centers' capacity market and transmission cost allocations are based on their contribution to system peak load.
- Data centers pay a "round the clock" average energy price, as opposed to the PJM load weighted average energy price, because they have a relatively flat load shape.
- Cost allocation across non-data center loads (including residential, commercial and industrial) are based on historical data from EIA (2021-2023), adjusted to reflect electrification assumptions.
- This analysis assumes that bill components other than energy, capacity, transmission and RECs stay fixed over time and across scenarios.

- Base case bill trends:
  - **2025-2030:** Residential bills are slightly reduced relative to recent historical data, because near-term gas prices are projected to be lower than in recent years.
  - **2031-2040:** Average residential bills are higher due to projected longer-term increases in gas prices and greater average monthly electricity usage associated with rising levels of EV and heat pump adoption.
- Data center bill impacts:
  - **2025-2030:**
    - Data centers are estimated to cause around a +10% increase in residential bills due to higher energy and capacity market prices.
    - Increased energy demand from data centers drives up near-term reliance on inefficient, costly plants. This shifts the energy and capacity clearing prices higher up the supply curves.
  - **2031-2040:**
    - In the longer term, resolving PJM interconnection queue delays allows for the construction of cheap resources (wind and solar), leading to lower energy and capacity prices. This reduces the bill impact of data centers.
  - In 2040, data centers are estimated to pay 18% of PJM-wide system energy costs ($23 billion).

*Projected bill impacts are reported as a PJM average. Bill impacts will vary by state based on several factors, including the distribution of data center load growth across the region.*

# Range of potential rate and bill impacts

*Different approaches to rate design and cost allocation could either increase or decrease the impacts that data centers will have on residential bills.*

**How much would data centers need to pay to offset their projected impacts on residential and industrial sectors?**

- We calculated the rate adders that data centers would need to pay to offset the increases in systemwide costs they are driving, in order keep other customers' rates at the same level as projected in the Base case.
- Average data centers rates would need to increase by 53% in the near-term and 11% in the long-term to avoid increasing costs for other customer classes.

**Table 1. Projected data center rates and cost adders required to mitigate bill increases for other customer classes**

| | | 2025-2030 | 2031-2040 |
|---|---|---|---|
| Projected data center rates | *2022$/kWh* | $0.10 | $0.08 |
| Cost adder | *2022$/kWh* | $0.05 | $0.01 |
| Adjusted data center rates | *2022$/kWh* | $0.15 | $0.09 |
| Percent increase in rates | *%* | 53% | 11% |

**What are the potential impacts on residential customers if data centers receive rate reductions, as many utilities are currently proposing?**

- With a rate reduction of 30% for data center customers, residential customers could see additional bill increases of +$4.4/month in the near-term and +$8.4/month in the long-term. These would be incremental to the expected increases in residential rates due to higher system-wide energy and capacity costs (which are described on the previous slide).
- As the amount of data center load increases over time, the potential magnitude of costs that could be shifted to residential customers also increases.

**Table 2. Projected incremental impacts of discounted data center rates on monthly residential bills (2022$)**

| Level of rate discount given to data centers | Resulting increase in residential bills | |
|---|---|---|
| | 2025-2030 | 2031-2040 |
| 10% Discount | +$1.5 | +$2.8 |
| 20% Discount | +$3.0 | +$5.6 |
| 30% Discount | +$4.4 | +$8.4 |

# Current environmental regulations are a key driver of fossil capacity trajectories

**Figure 1. Coal capacity in PJM**

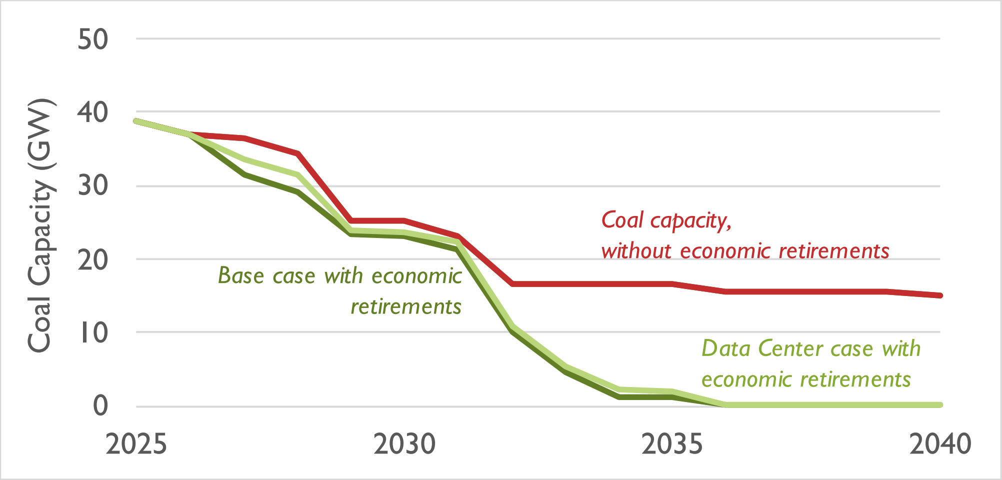
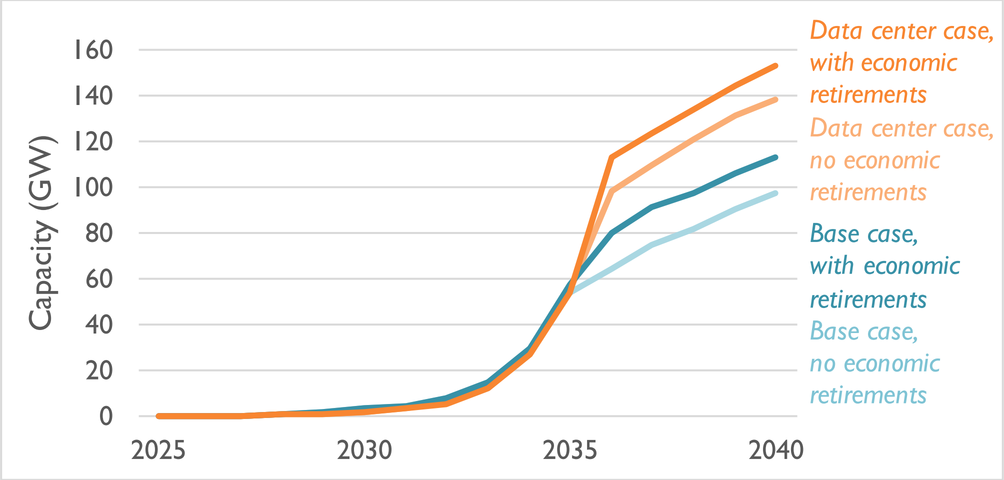



**Figure 2. New gas capacity in PJM**




**With current environmental regulations, most coal plants retire economically in the longer term, regardless of data center loads.**

- We also modeled sensitivities that did not allow fossil plants to economically retire. In these sensitivities, only power plants with currently announced retirement dates retire.
  - *If coal retirement decisions are not economically optimized, around 15 GW of coal remains in 2040.*
- From 2025 to 2035**:** Data centers cause a few coal plants to remain online economically for a few extra years. PJM queue constraints limit the system's ability to retire more coal and instead serve new load with alternative, cheaper resources.
- From 2035 to 2040: Most coal plants retire economically by the mid 2030s, regardless of load. This is due to a combination of environmental regulation costs, cheaper alternative resources and increasingly looser PJM interconnection queue constraints.

**As more coal retires, additional gas capacity comes online.**

- From 2025 to 2035: New gas builds are similar across scenarios due to PJM interconnection queue constraints.
- From 2035 to 2040: In the scenarios where coal is allowed to economically retire, there is a slightly greater amount of new gas capacity added.

# Appendix

# Methods: EnCompass model & topology

***About EnCompass:***

- EnCompass is an optimization-based power systems model for utility-scale generation planning and operations analysis.
- EnCompass covers all facets of power system planning including short- and long-term unit commitment, economic dispatch decisions, environmental compliance, and market price forecasting for energy, capacity, and environmental programs.
- EnCompass provides unit-specific, detailed forecasts of the composition, operations, and costs of the regional generation fleet given the assumptions described in this document.
- Synapse has populated the model using the *EnCompass National Database*, created by Horizons Energy.
- More information on EnCompass and the Horizons dataset can be found at *https://www.yesenergy.com/encompass-power-system-planning-software*.

- **Modeled regions:**
  - PJM is split into 10 subzones.
  - Regions within PJM can dynamically exchange energy with each other.
- **Imported energy:**
  - Energy imports are allowed from MISO, TVA, the Carolinas, Canadian ISOs and NYISO.
- **Existing transmission:**
  - Transmission constraints are modeled using the latest data published by PJM.
- **New transmission:**
  - New transmission can dynamically be built starting in 2027.
  - Costs are based on data from NREL's ReEDS model.

# PJM interconnection queue assumptions

**Start Year: 2025**

Endogenous capacity builds not allowed.

Resources with commercial operation dates are modeled exogenously.

**2027**

Endogenous capacity builds are allowed based on data from PJM's interconnection queue. Selectable resources include solar, onshore wind, lithium-ion batteries, and gas.

**2031**

Queue related constraints are increasingly loosened (representing gradual improvements to the PJM queue and local permitting processes).

**2036**

Interconnection queue-related build constraints are removed, and endogenous capacity builds are driven by economics and resource potentials.

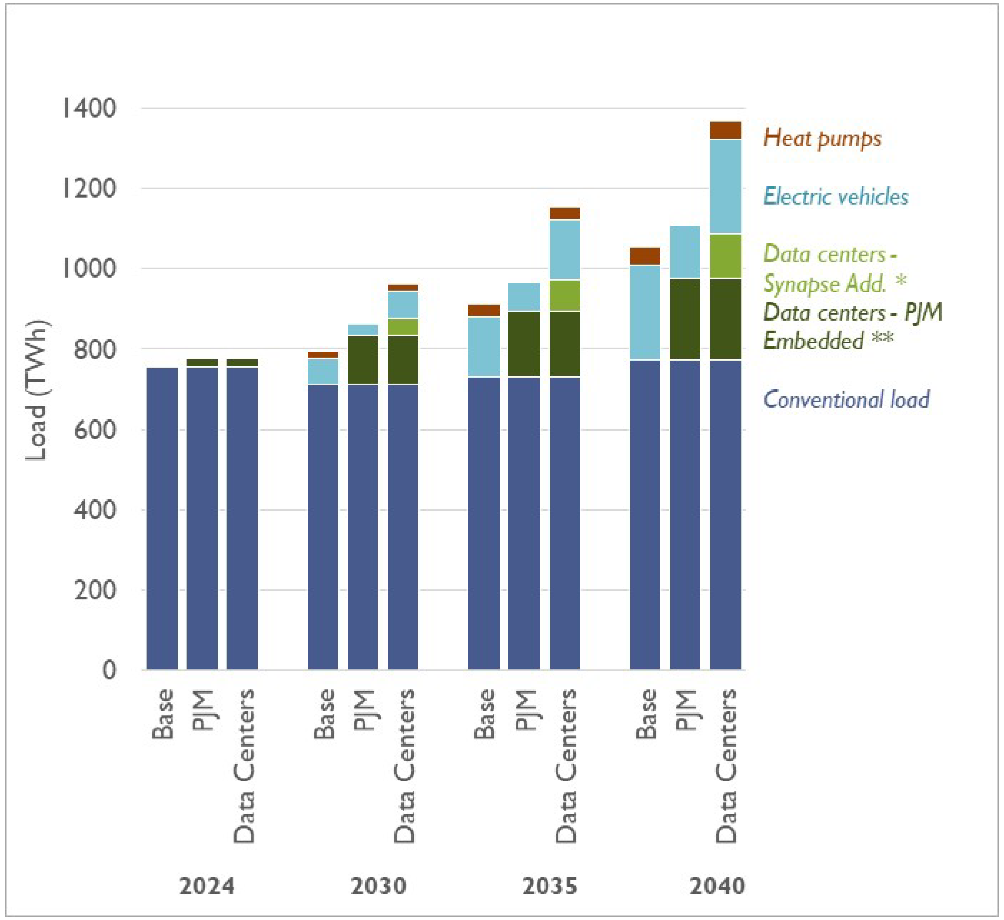
Endogenous offshore wind and long-duration storage resources can now be selected.

**End Year: 2040**

# Load components

**Figure 1. Load Components in Synapse Base case, PJM 2024 Load Forecast, and Synapse Data Centers cases**




** Refers to Synapse's additional projected data center load above PJM's 2024 forecast.*
*** Refers to the data center load adjustments included in PJM's 2024 forecast.*

- **PJM's load forecast** incudes conventional load, electric vehicle projections, and data centers load adjustments from utilities.
  - All PJM data is from *PJM's January 2024 Load Forecast*
- **Synapse's Base case load** uses PJM's conventional load forecast and Synapse's projections for electric vehicles and heat pumps adoption (further details on Synapse's electrification assumptions are on the next slide). The Base case load also includes energy consumption by existing data centers, embedded within the PJM conventional load component.
- **Synapse's Data Centers load** uses the same projections for load components that are shared with the Base case load and described above. In addition, it includes Synapse's projections for new data center load in PJM, based on recent data from EPRI and PJM utilities.
  - This analysis was performed approximately 10 months after the release of *PJM's January 2024 Load Forecast*. Since then, updated information has become available regarding projected data center load growth.
  - Compared to PJM's 2024 forecast, Synapse's Data Center scenario load forecast includes an additional:
    - +44 TWh of data center load in 2030
    - +77 TWh of data centers load in 2035
    - +109 TWh of data centers load in 2040
  - By 2040, total annual energy consumption in Synapse's Data Center load scenario reaches 1,435 TWh, compared to PJM's forecast of 1,176 TWh.

# Key load input assumptions

| Category | Details | Annual energy data source | Load shape data source |
|---|---|---|---|
| Conventional Load | PJM's forecast includes projections for conventional load growth and adjustments for weather and efficiency. PJM does not include heat pump load and only small EV load increases. Existing data center load is included within PJM's conventional load forecast. | PJM January 2024 Load Forecast | Horizon's National Database |
| Building electrification | We assume that all states reach a heat pumps sales market share of 99.9% by 2030 for residential and commercial sectors for both space and water heating. | Building Decarbonization Calculator (BDC) | NREL's ReStock and ComStock |
| Electric vehicles | We assume that MD, NJ, and other northeast states reach 99% light-duty EV sales by 2030; All other PJM states reach 85.5% light-duty EV sales by 2030; All states reach 60% medium- and heavy-duty vehicle sales by 2030. | Electric Vehicle Regional Emissions and Demand Impacts (EV-REDI) | DOE's EVI-Pro Lite tool |
| Distributed solar | Distributed solar resources are modeled on the supply side. | PJM January 2024 Load Forecast | Horizon's National Database |
| Energy efficiency | Not modeled in PJM since energy efficiency efforts have been relatively weak. | N/A | N/A |
| New data centers | New data center load is only included in the Data Centers case. Synapse's data center load forecast is based on current data center usage in PJM states (from EPRI, 2024), escalated using an annual growth rate trajectory that is consistent with Dominion's most recent projections of data center load growth.<br><br>We assume a high utilization factor for data center load, with a relatively flat and inflexible shape. | EPRI's 2024 data center load forecast for PJM states & Dominion's annual data center load growth rate | ComStock hourly annual load for *VA Large Office with Data Center* building type & load type *Electrical Total* |

*All load components, besides new data centers, are held constant across scenarios.*

# Other key input assumptions

- **Fuel prices**
  - Henry Hub prices based on NYMEX data (up-to-date through July 2024) for near-term prices. Long-term prices were based on EIA's 2023 Annual Energy Outlook (AEO).
  - Oil and coal prices based on EIA's 2023 AEO.

- **New resources**
  - The moderate cost trajectory from NREL Annual Technology Baseline 2024 is used for utility-scale solar, battery storage, onshore and offshore wind resources. A cost adder of +25% was also included to represent costs associated with supply chain constraints. All new clean energy resources are eligible for either the IRA Production or Investment Tax Credits.
  - New gas plants must comply with EPA's finalized greenhouse gas emissions regulations under Section 111 of the Clean Air Act. Starting in 2032, new gas CCs can either take the 40% capacity factor cap or install CCS systems with 90 percent $CO_2$ removal rate. CCS capital expenditures, along with fixed and variable operations costs are sourced from Sargent & Lundy's January 2024 report prepared for EIA.
  - Geothermal and SMRs were not included as selectable resource options.

- **Existing resources**
  - All fossil plants are allowed to economically retire beginning in 2027.
  - Coal plants are assumed to follow the 111(d) compliance pathways that are consistent with their currently announced retirement dates. Coal plants with announced retirement dates after January 1st, 2039 must install CCS controls on January 1st, 2032. Coal plants with retirement dates after 2032 but before 2039 must co-fire with gas by 2030.
  - Environmental compliance costs associated with finalized EPA regulations for criteria air pollutants are also included.

- **Policies**
  - Modeled RGGI for 10 participating states. Assume that Virginia re-enters in RGGI and Pennsylvania is not a participating state.
  - We incorporated the Virginia Clean Energy Act's (VCEA) renewable portfolio standard targets.
  - All other existing state RPS policies are also modeled.
  - All RECs consumed in PJM are produced in PJM.

# Total 2040 operational capacity by state, Data Center case

- The distribution of resources across different states is driven by EnCompass's economic optimization algorithm, which considers the geographical spread of load growth, as well as area-specific technical resource potentials and local cost adders from EPA.
- We do not model local siting restrictions and land use constraints.

**Table 1. 2040 operational capacity by state in Data Center case (MW)**

| | Coal | Natural Gas CC | Natural Gas Other | Other* | Battery Storage | Hydro | Nuclear | Solar | Offshore Wind | Onshore Wind |
|---|---|---|---|---|---|---|---|---|---|---|
| Delaware | 0 | 2,766 | 2,008 | 3,504 | 2,573 | 0 | 0 | 10,004 | 0 | 2 |
| District of Columbia | 0 | 6,561 | 711 | 1,533 | 0 | 0 | 0 | 23 | 0 | 0 |
| Illinois | 0 | 7,476 | 13,639 | 748 | 2,225 | 64 | 11,246 | 8,279 | 0 | 15,701 |
| Indiana** | 0 | 1,951 | 421 | 384 | 80 | 5 | 0 | 10,745 | 0 | 6,130 |
| Kentucky | 0 | 0 | 3,452 | 349 | 0 | 175 | 0 | 938 | 0 | 8,700 |
| Maryland | 0 | 6,503 | 6,207 | 1,838 | 1,340 | 554 | 1,769 | 27,343 | 1,094 | 790 |
| Michigan | 0 | 3,149 | 2,000 | 75 | 0 | 14 | 2,271 | 502 | 0 | 100 |
| New Jersey | 0 | 8,130 | 2,054 | 3,675 | 2,079 | 464 | 3,619 | 1,108 | 6,656 | 9 |
| North Carolina | 0 | 5,181 | 2,379 | 208 | 11 | 278 | 0 | 23,528 | 7,500 | 2,708 |
| Ohio | 73 | 73,513 | 20,728 | 1,889 | 117 | 128 | 2,177 | 11,819 | 0 | 8,762 |
| Pennsylvania | 0 | 32,851 | 9,020 | 2,965 | 2,075 | 2,060 | 9,791 | 1,528 | 0 | 26,187 |
| Virginia | 105 | 30,543 | 15,480 | 2,559 | 7,681 | 3,774 | 3,701 | 60,721 | 2,599 | 7,600 |
| West Virginia | 0 | 207 | 1,621 | 2,551 | 48 | 359 | 0 | 117 | 0 | 10,358 |

*Note: This table includes utility scale generation resources only. Demand response and BTM solar are not currently included in these totals. Totals only refer to resources located in PJM.*
**Other includes landfill gas and biomass.*