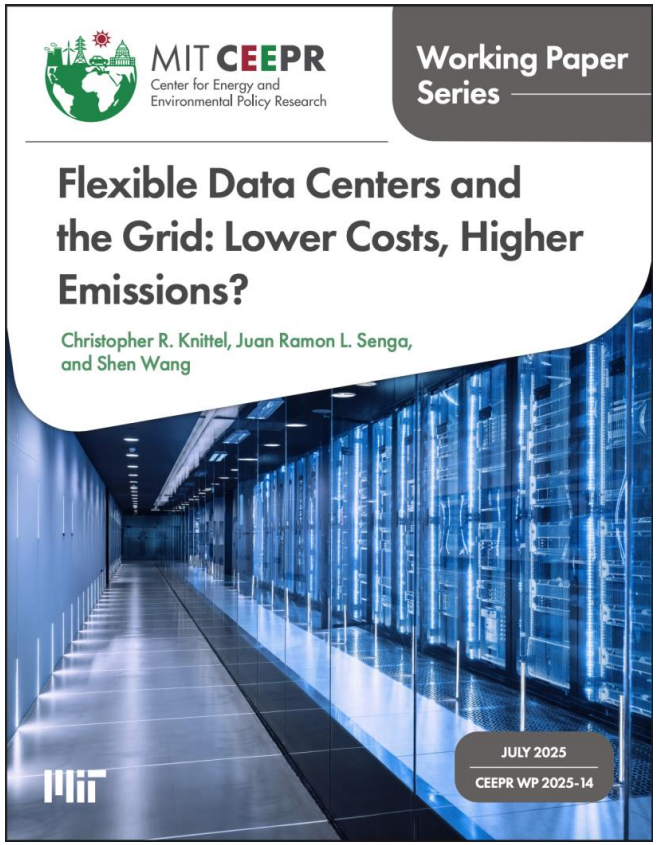
Flexible Data Centers and the Grid: Lower Costs, Higher Emissions?



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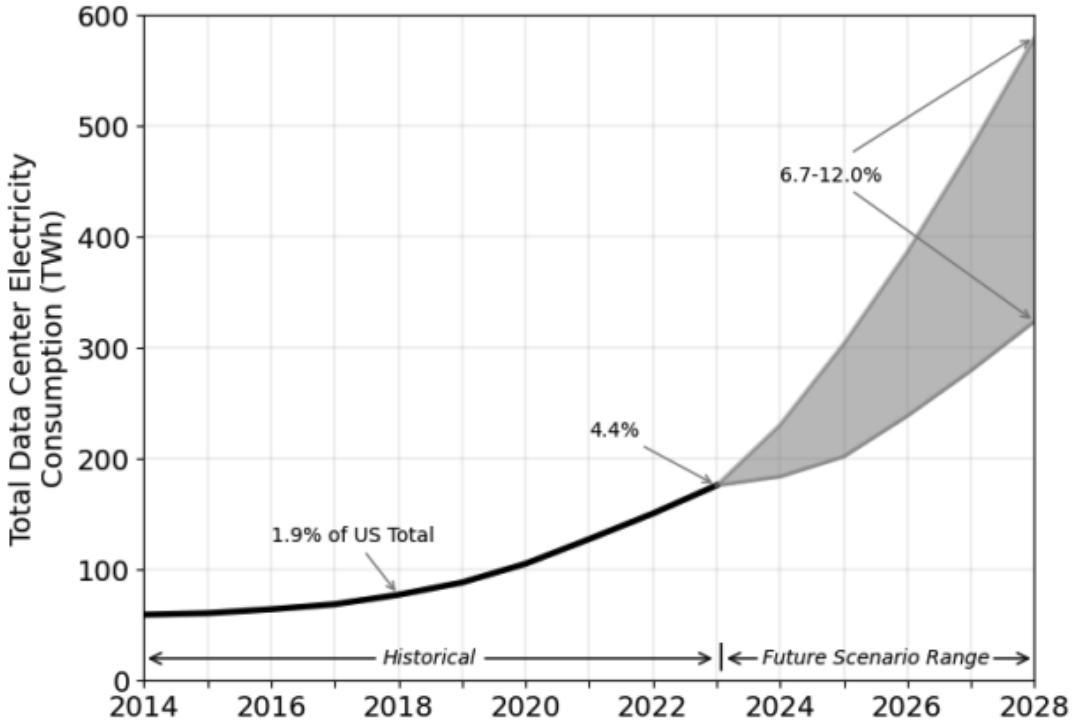
Data Center Growth

- Data Center Load is projected to be between 6.7% to 12% of total U.S. electricity demand by 2028-2030
- Growth is driven by Hyperscalers, which is projected to increase data center load share to 60% by 2030 vs 41% as of 2024
- U.S. is projected to contribute ~36% of global Data Center market.

Historical and Projected U.S. Data Center Load



Taken from LBNL (2024); DOE (2024)

There is a case for moving DC compute loads across time and space to take advantage of cheaper power

General consensus: Data Center (DC) Flexibility reduces cost and has co-benefits of emissions reduction

Summary

- **The cost and emissions benefit of DC Temporal Flexibility depends on the existing generation portfolio.**

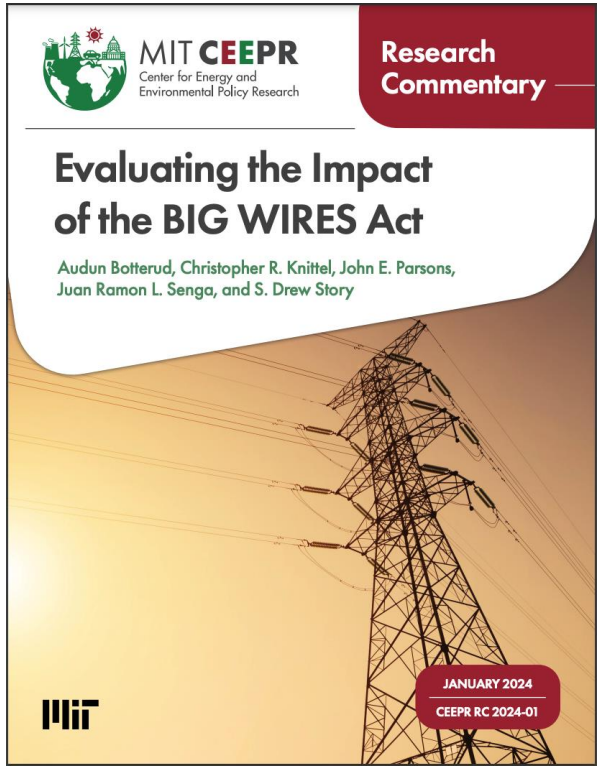
- **DC Temporal Flexibility always reduces cost relative to having no flexibility but does not necessarily reduce emissions**

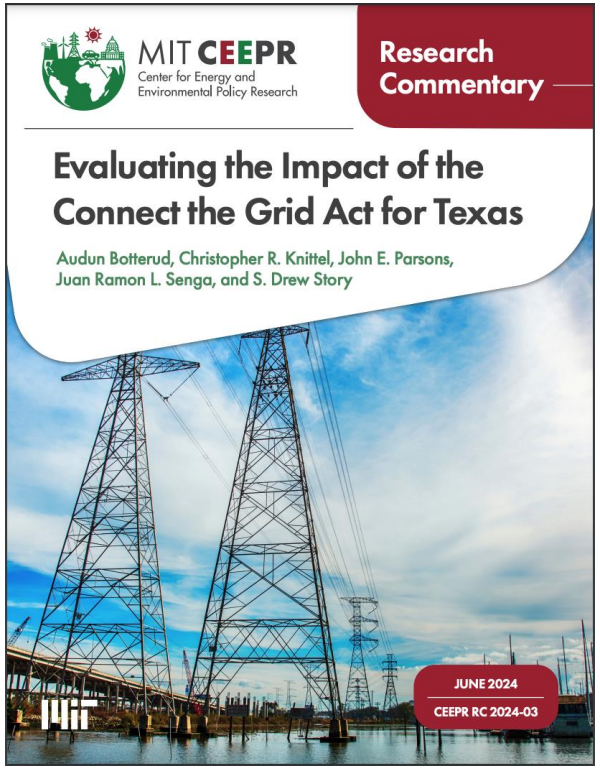
1. **Flexible DCs favor the installation of renewables but it may also increase fossil fuel and thermal generation**
   - Flexible DCs + Renewables mean that DC load can be shifted to hours with high availability and reduces the need for investments in new thermal generation
   - In systems with high shares of renewable generation, data center flexibility reduces emissions compared to having no flexibility
   - In systems with low shares of renewable generation, data center flexibility increases emissions compared to having no flexibility
2. **Temporal DC Flexibility changes system operations as DCs enable more stable operation of thermal plants**
   - DC Load is shifted from evening hours to early morning and the middle of the day. Early morning is when non-DC load is relatively low and middle of the day is when solar generation is high
   - Operation of Thermal generation flattens compared to the case without DC Flexibility

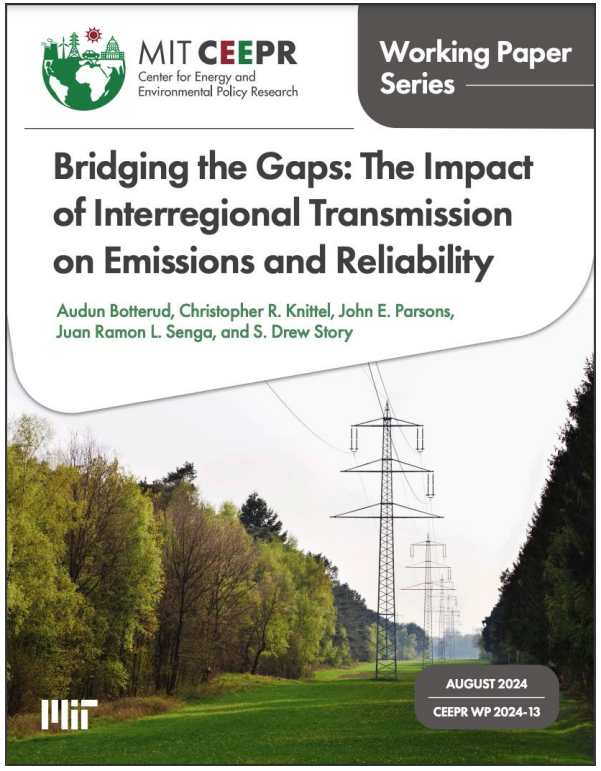
MIT GenX Model

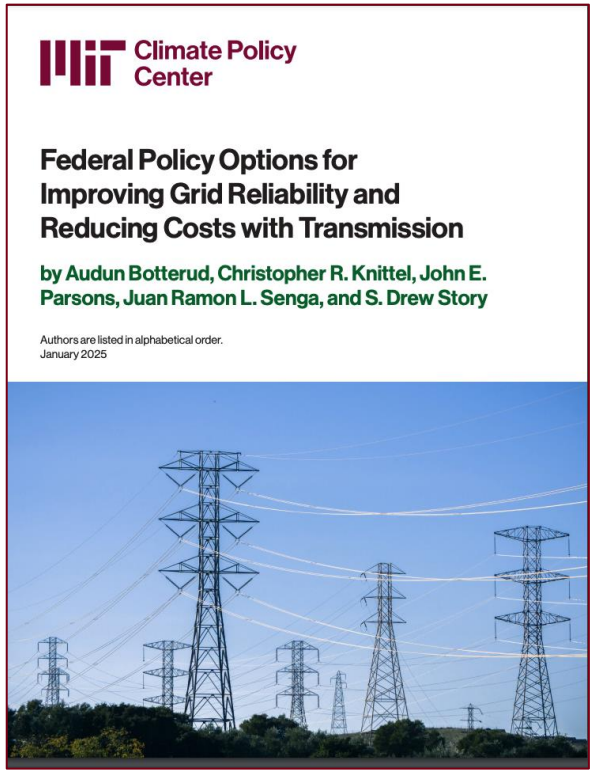
Electricity Resource capacity expansion and cost optimization model (Jenkins and Sepulveda, 2017)

- Models the US electricity grid and lets us experiment with adding and removing power generation and/or building/upgrading local, regional, and interregional transmission to meet certain policy objectives at the lowest cost
- Used in numerous peer-reviewed publications and technical reports within and outside MIT
- Some recent examples of **Policy Analysis** and **research papers** using GenX:





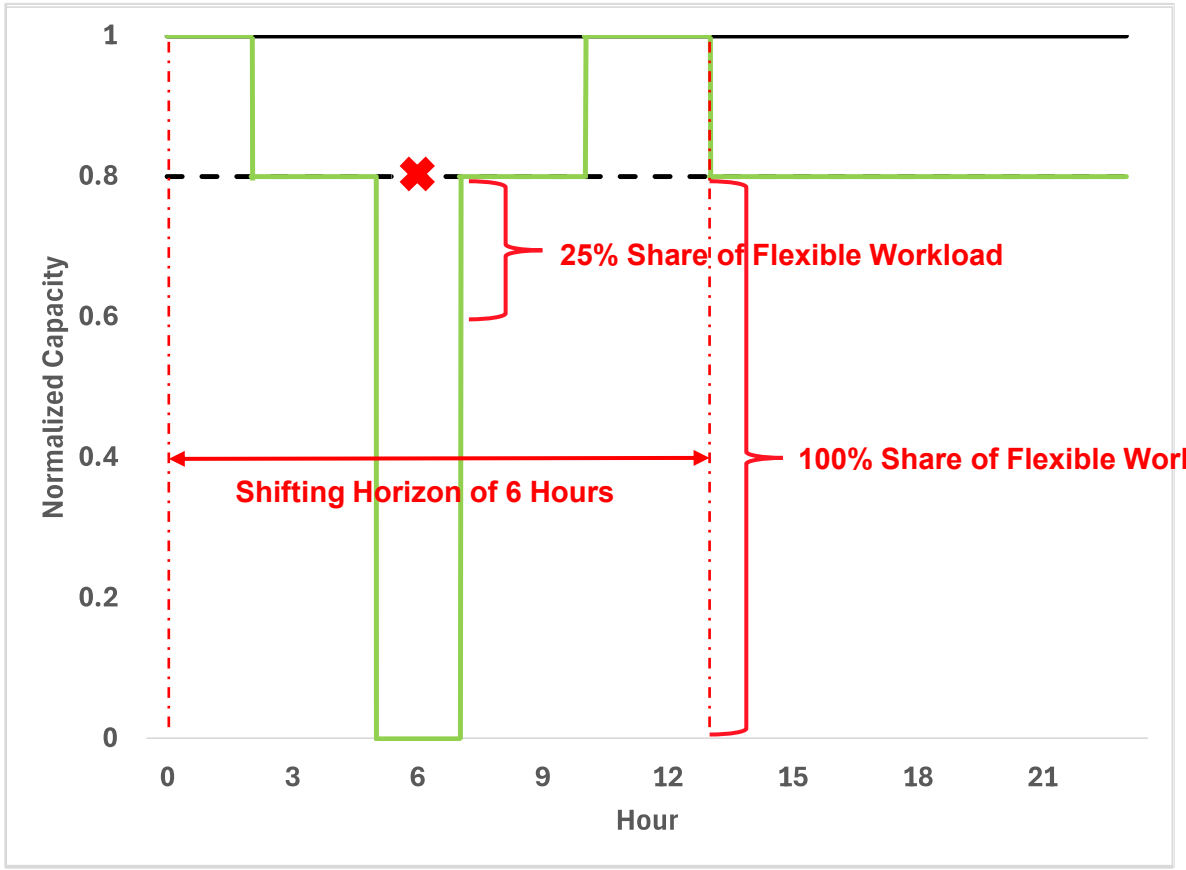




Dimensions of Temporal Flexibility

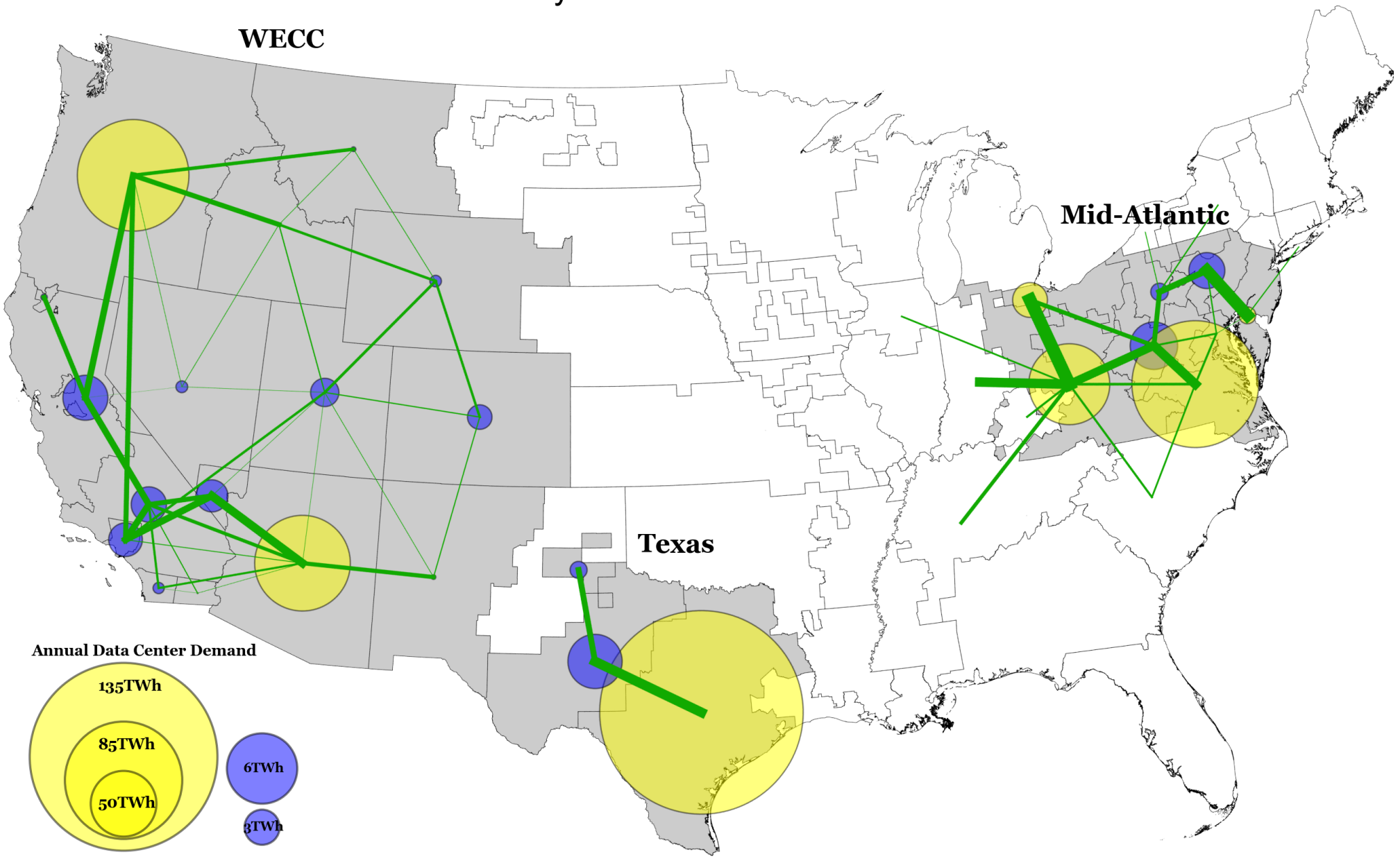
- There are two dimensions to temporal data center load flexibility:
  1. Shifting Horizon – the amount of time that data center load can be delayed or advanced (0 to 24 hours)
  2. Share of Flexible Workload – the percentage of data center load that can be shifted to another hour (1 to 100%)

- We assume that 80% of data center capacity is used per zone such that an additional 20% of load can be shifted to each hour



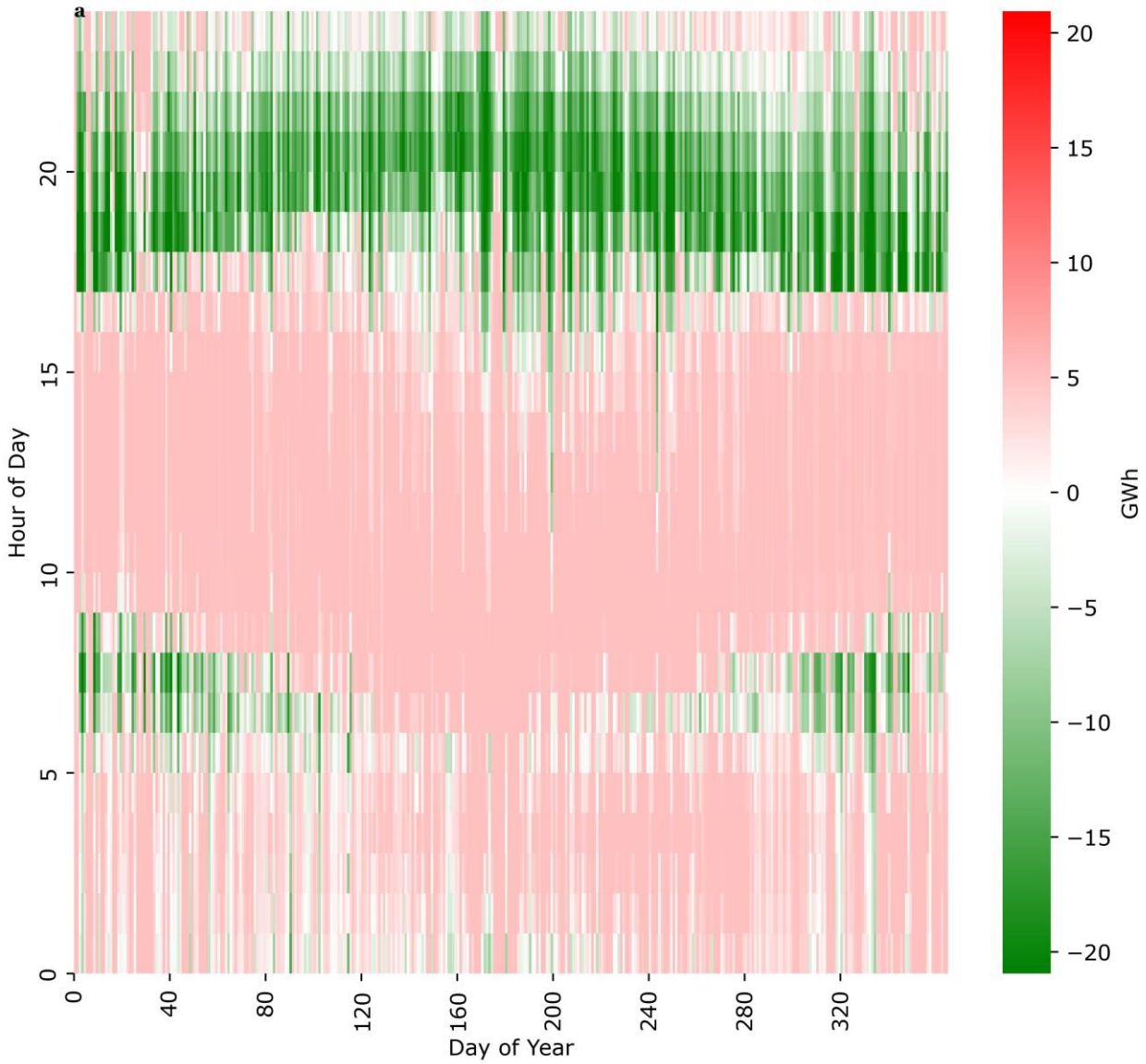
Scenario Map with 2030 Projections of Data Center Load and Transmission Infrastructure

This represents 82% of total Data Center Load by 2030



Data Center Shifting Operations

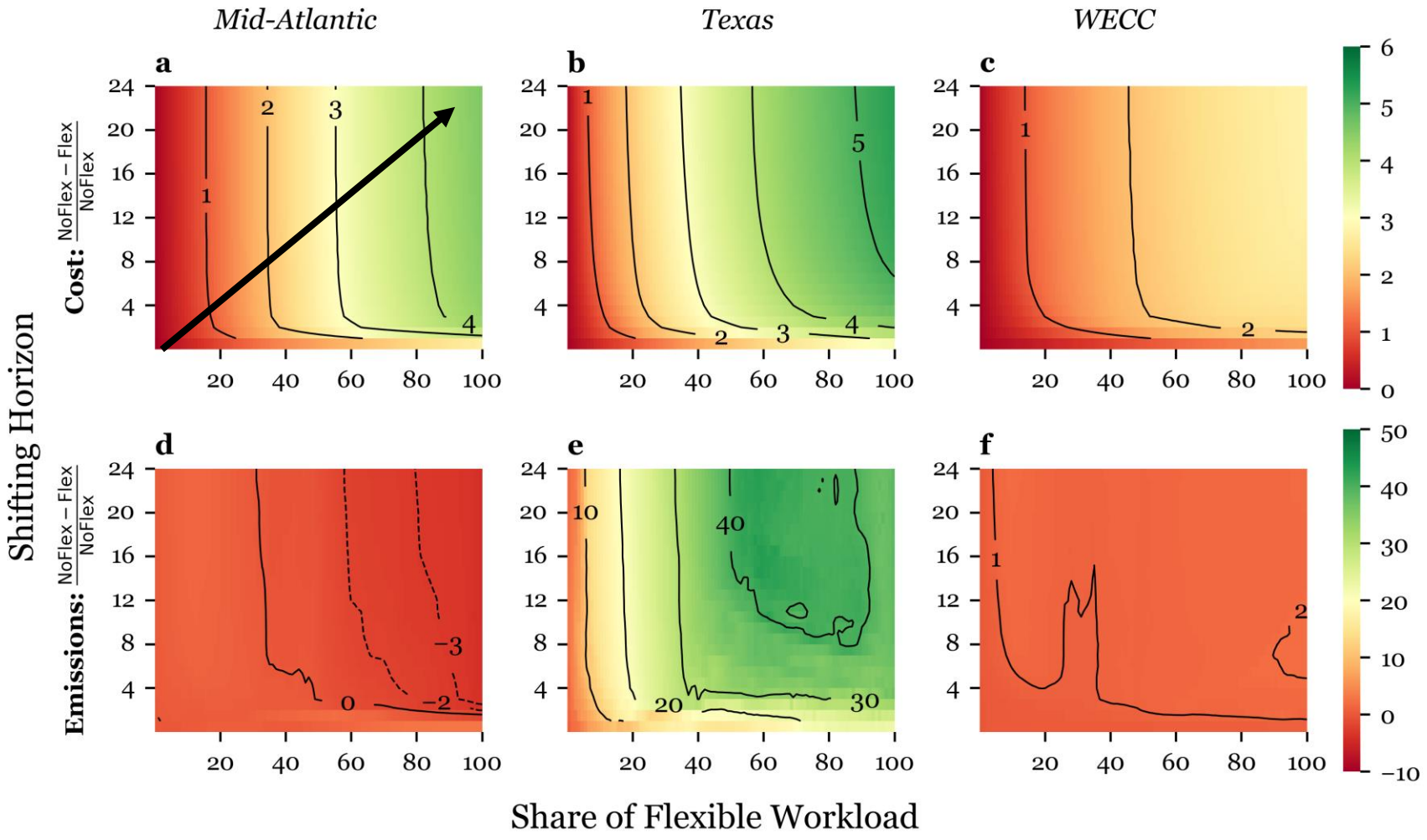
Data Center Load Shifting in the Mid-Atlantic



- Data Center Load is shifted to flatten the Net Load Curve
- Load is shifted out of high net load hours in the evening to low net load hours in the midday

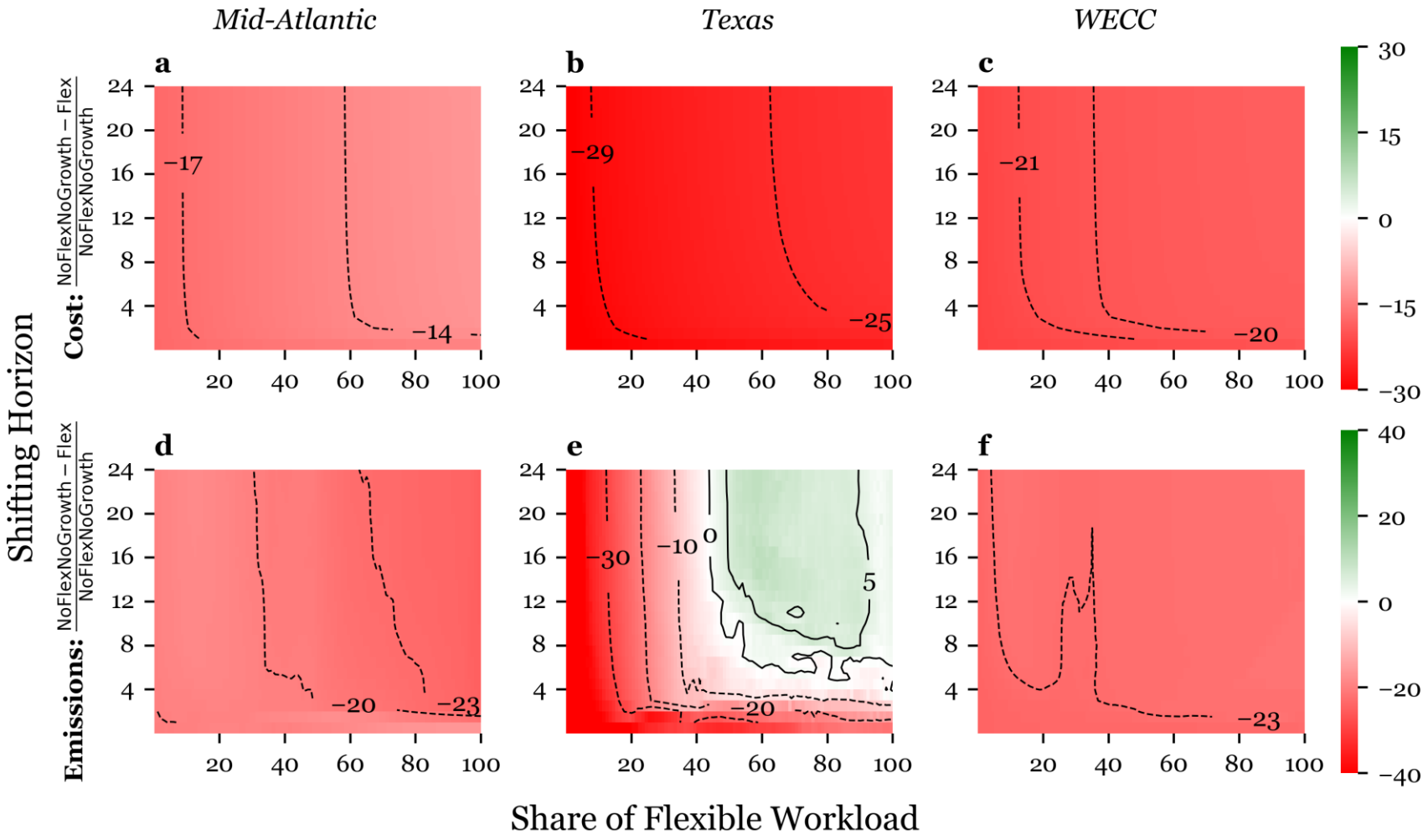
Cost and Emissions benefits of DC Flexibility are not always aligned

There is always a system cost benefit to DC Flexibility, but not necessarily an emissions benefit



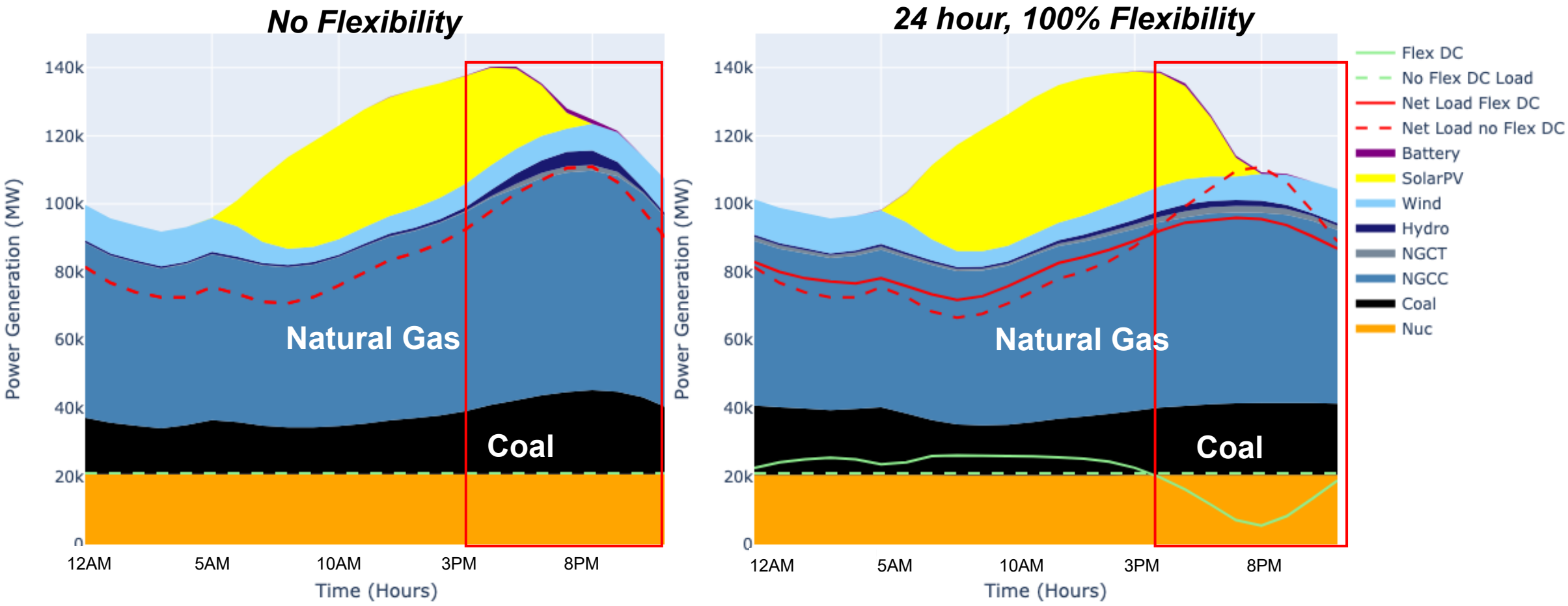
- **Texas** sees both large cost and emissions benefits from Flexibility
- The **Mid-Atlantic** sees large cost benefits but may see emissions increase
- The **Western Interconnect (WECC)** sees modest cost and emissions benefits

The increase in Data Center Demand increases cost, but flexibility mitigates the increase



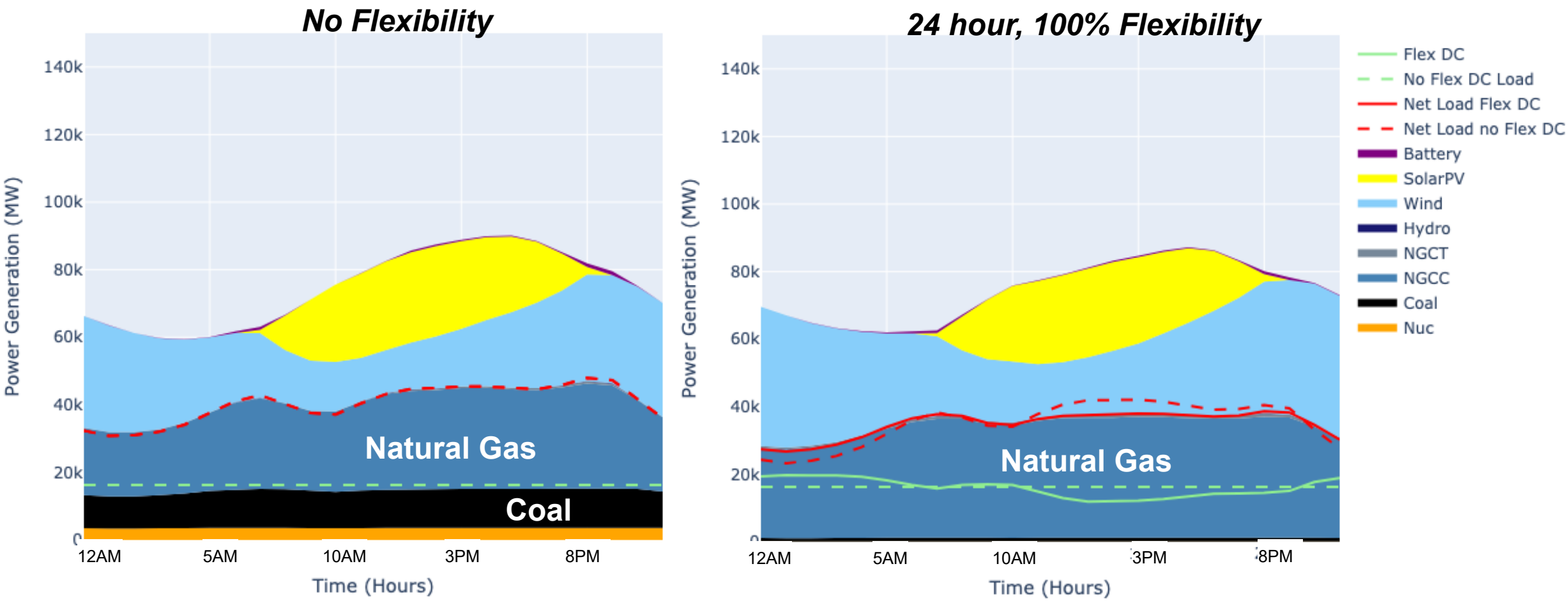
- In **Texas,** Data Center Flexibility can lead to emissions that are lower than the no load growth scenario

Mid-Atlantic Average Summer Operations



- Net Load becomes flatter throughout the day as DC load gets shifted from the evening to early morning and midday
- We observe less ramping in Coal and Natural Gas with DC Flexibility

Texas Average Summer Operations



With DC Flexibility, there is…

- A reduction in Coal and Nuclear generation
- DC Load gets shifted from morning and afternoon to the early morning where Net Load is the lowest

Summary

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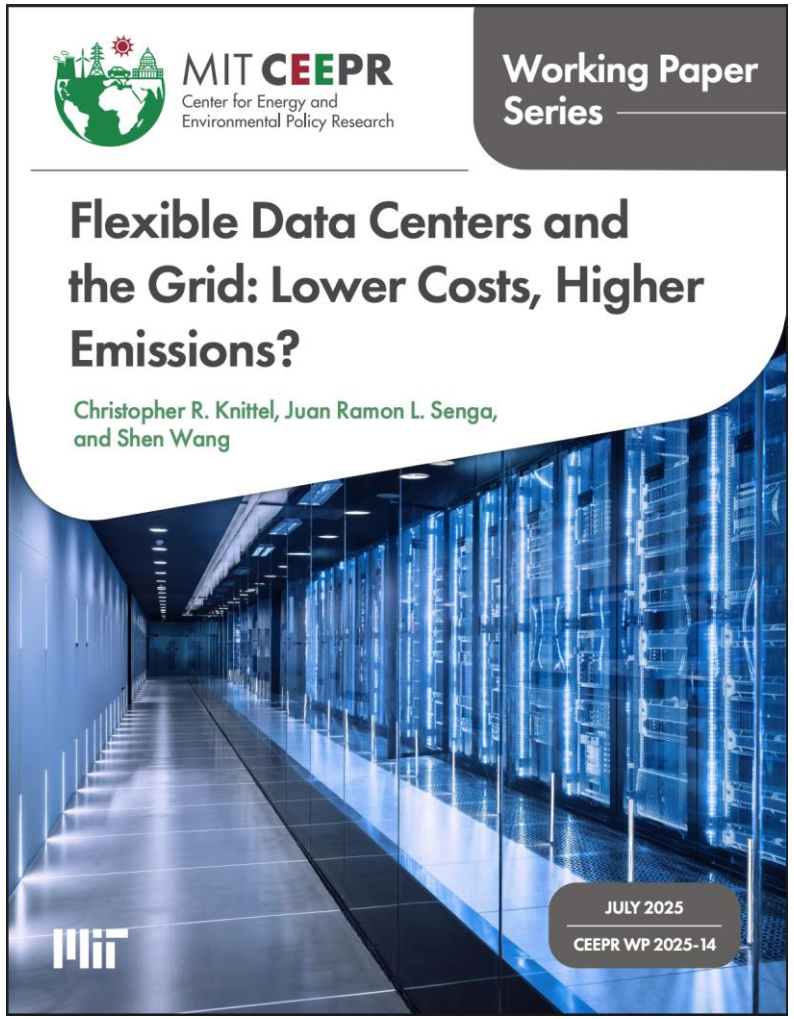
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Thank you!

Appendix

Data Center Demand Assumptions

- Base hourly demand per IPM zone for 2030 is obtained from NREL EFS through PowerGenome (Schivley, 2024)

- Data Center Load Forecasts are obtained from EPRI's "Powering Data Centers" Report
  - The report indicates what % of each state's 2023 electricity demand is for Data Centers
  - We assume the Base Case to have the same % share of Data Center load in 2030.
  - Data Center growth cases have additional Data Center load on top of the % share in the base case.

For example:

- 4.59% of Texas' load in 2023 is for Data Centers

- 2030 NREL EFS Demand for Texas Zone 1 is 418TWh

  - 418TWh x 4.59% = 19.18TWh of Base Data Center load in 2030
  - 418TWh – 19.8TWh = 398.2TWh of non-Data Center load in 2030

- There is a High Growth Forecast that 25.28% of Texas 2030 load will come from Data Centers
  - 398.2TWh / (100% – 25.28%) = 532.93TWh total Texas Zone 1 Load
  - 532.93TWh x 25.28% = 134.72TWh of Data Center load in 2030

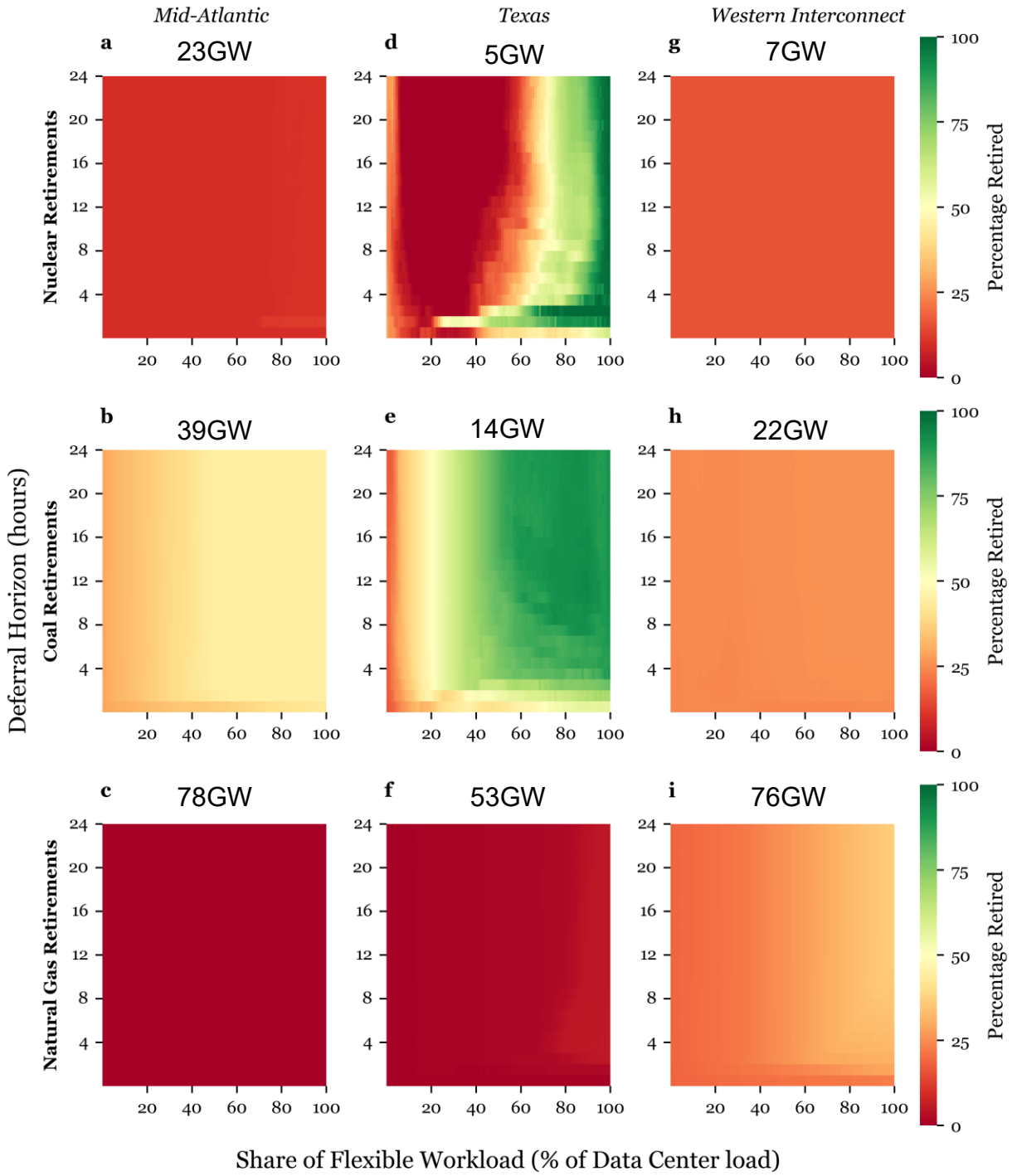
- We assume a constant Data Center load per hour. That is, total Data Center load is divided by 8760 hours

Change in Retirements

Mid-Atlantic…
- Nuclear: DC flexibility does not affect the amount of Nuclear retirements
- Coal: Only retires ~50% of its Coal fleet
- Natural Gas: DC flexibility does not affect the amount of Natural Gas retirements

Texas…
- Nuclear: Retires more Nuclear as flexibility increases
- Coal: Retires more Coal as flexibility increases
- Natural Gas: Only retires a small portion of Natural Gas at high DC Flexibility

Western Interconnect…
- Nuclear: DC flexibility does not affect the amount of Nuclear retirements
- Coal: DC flexibility does not affect the amount of Coal retirements
- Natural Gas: Retires more Natural Gas as DC Flexibility Increases



Change in Capacity Investments

Mid Atlantic…

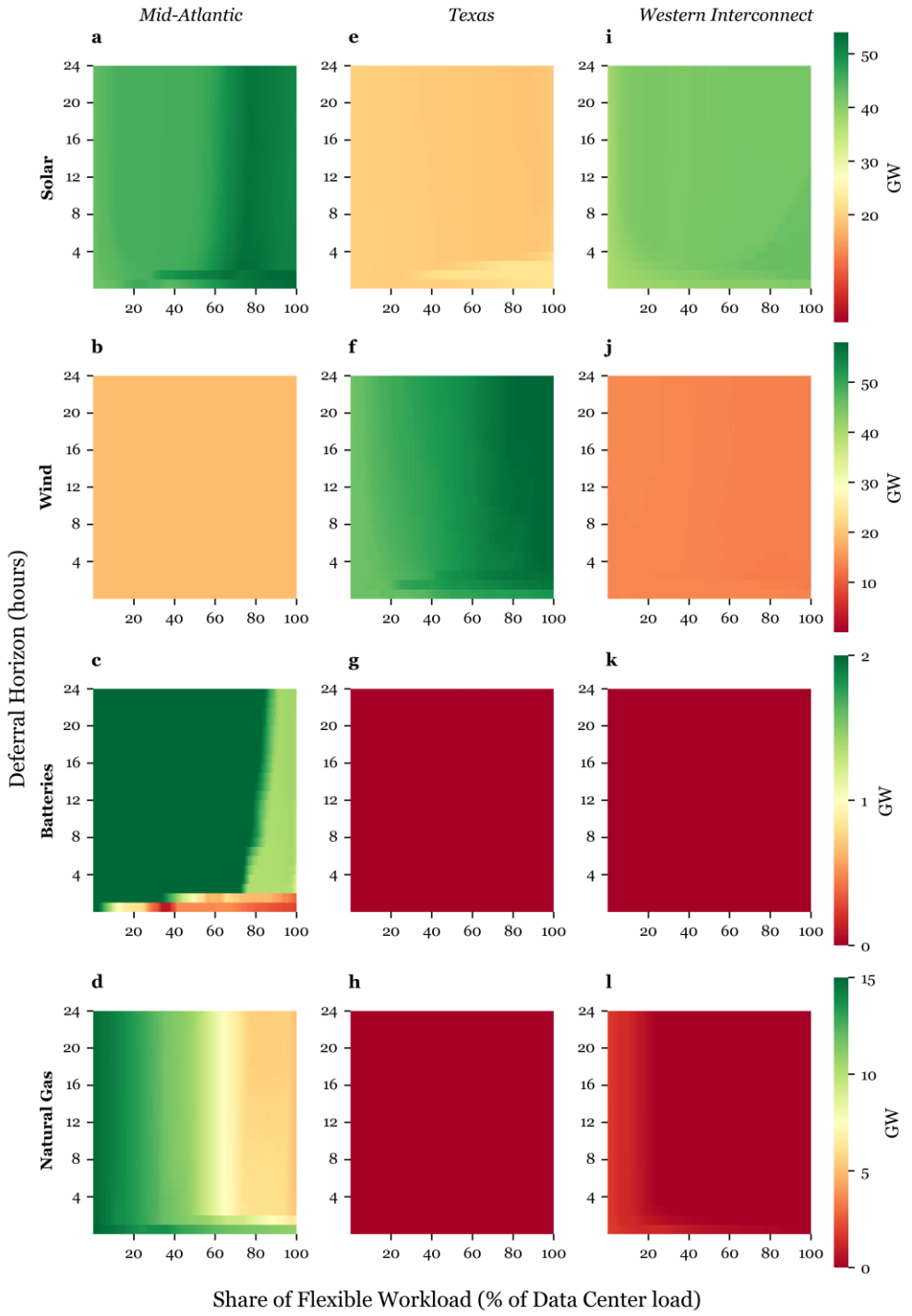
- Solar: Builds more Solar as Flexibility increases
- Wind: DC Flexibility does not affect Investments in Wind
- Natural Gas: Builds new Natural Gas but investments decrease as DC flexibility increases

Texas…

- Solar: Builds more solar at lower deferral horizons as Flexibility increases
- Wind: Builds more Wind as Flexibility increases
- Natural Gas: DC Flexibility does not affect investments in Natural Gas

Western Interconnect…

- Solar: DC Flexibility does not affect Investments in Solar at high levels of flexibility
- Wind: DC Flexibility does not affect Investments in Wind
- Natural Gas: Builds some natural gas but eventually does not invest as DC flexibility increases



Change in Capacity Investments

- **First row:** Coal Operations become more stable in the Mid-Atlantic with higher data center flexibility, which results in higher utilization and emissions
- **Second Row:** In Texas, increasing the cost of VRE resources by 1.4x its base cost lowers the investment in wind and solar, which leads to an increase in coal utilization.
- **Third Row:** A higher VRE cost in Texas leads to higher emissions with data center flexibility compared to having no flexibility

Coal utilization and emissions under varying VRE costs and data center flexibility.