

On Large Loads in ERCOT and Future Work on Connections & Impact to Mexico

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ISTC, Sustainable Systems Seminar (Online)
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We are a multi-disciplinary group using data science to support community-centered & inspired energy transitions

We care deeply about how technology impacts society, and work to mitigate potential disparities from it.



Growing trend to electrify... everything!

The New York Times

A key part of America's plan to slash carbon emissions:

Plug in (almost) everything.

YaleEnvironment 360

Published at the Yale School of the Environment

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From Homes to Cars, It's Now

INNOVATION > SUSTAINABILITY

Electrify Everything Everywhere All At Once For The Climate And Economy

Forbes

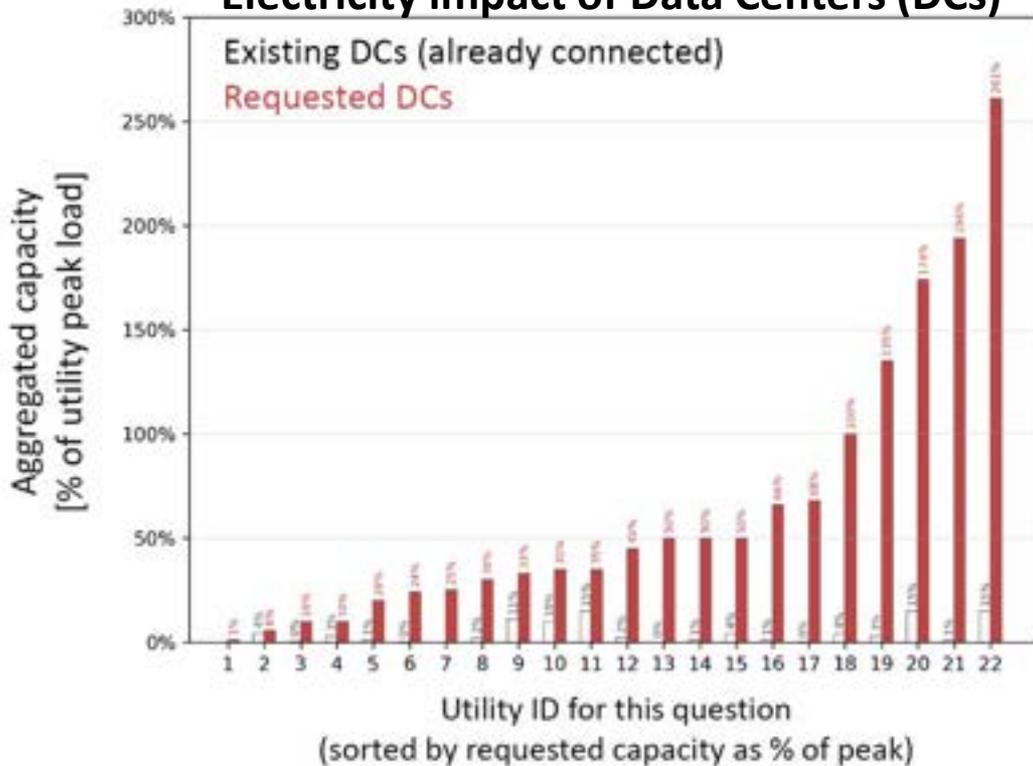
Electricity demand growth also from AI

Bloomberg

Markets Magazine | Green

Power-Hungry Data Centers Are Gobbling Up Texas Amid AI Boom

Electricity impact of Data Centers (DCs)



Out of 22 utility responses:

- 23% reported total aggregate DC requests $\geq 100\%$ of their present peak load
- Most utilities with requests $\geq 100\%$ of system peak range from ~ 10 – 25 GW currently

<https://www.epri.com/research/products/000000003002030643>

Research Questions

What is the potential for **generation technologies** to meet **large load growth**?
What are the **impacts** of these technologies on a system's **cost** and **emissions**?

What are some ways to reflect **opposition, people**, and the impacts of the power sector on people's **well-being**?

Beyond the border: How might these large load growth dynamics impact Mexico's power sector?

Research Questions

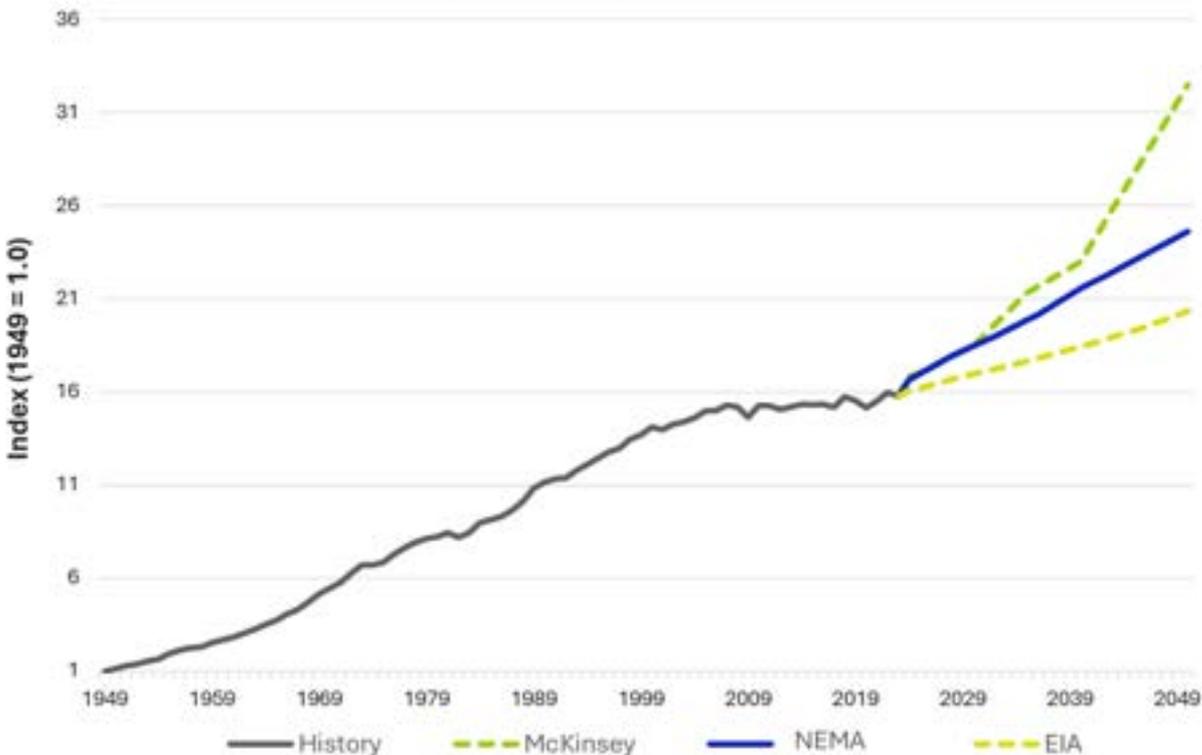
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The US is entering a period of unprecedented load growth

U.S. Electricity Consumption Index 1949–2050



End-use electrification

- Electric vehicles
- Residential and commercial buildings

Alternative fuels and industrial processes

- Hydrogen

Energy-intensive computing

- Artificial intelligence
- Data centers
- Cryptocurrency mining

Source: NEMA (2025)

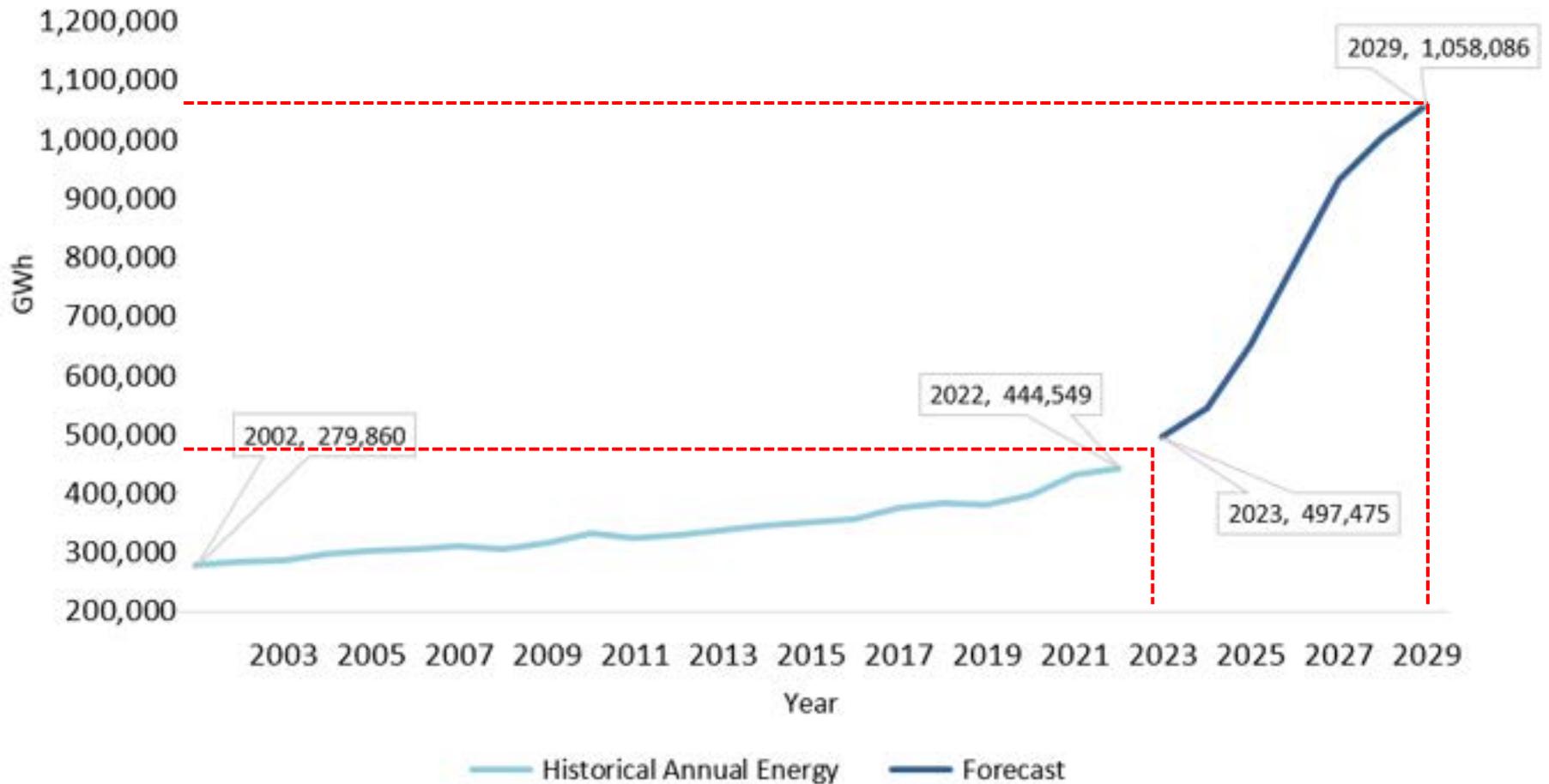
Long-term planning is crucial



~\$75B in Generation & Transmission (2023)

https://gridarchitecture.pnnl.gov/media/Modern-Distribution-Grid_Volume_IV_v1_0_draft.pdf
https://eta-publications.lbl.gov/sites/default/files/frick-schwartz_idsp_overview_20240124.pdf

Electricity demand in ERCOT is poised to grow substantially!



Potts, J., Castellanos, S. (2025) Grid planning insights from near-optimal generation portfolios amidst large-load growth. (*Under Review*)

SWITCH-ERCOT: capacity expansion model used to optimize the power sector

$$\min \sum_{p \in \mathcal{P}} d_p \left\{ \sum_{c^f \in \mathcal{C}^{\text{fixed}}} c_p^f + \sum_{t \in \mathcal{T}_p} w_t^{\text{year}} \sum_{c^v \in \mathcal{C}^{\text{var}}} c_t^v \right\}$$

Power balance: $\sum_{p^i \in \mathcal{P}^{\text{inject}}} p_{z,t}^i = \sum_{p^w \in \mathcal{P}^{\text{withdraw}}} p_{z,t}^w$

Operational: $0 \leq P_{g,t} \leq \eta_{g,t} K_{g,p}^G$

Investment:

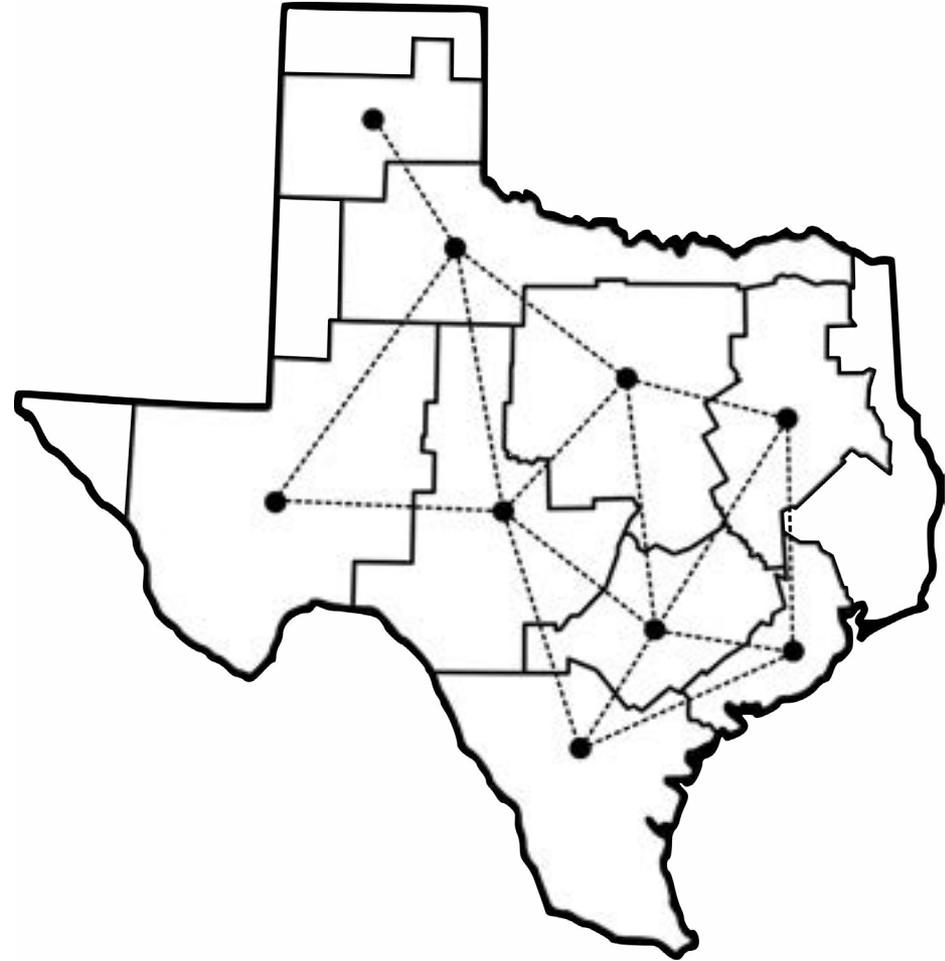
$$K_{g,p}^G = \sum_{p' \in \mathcal{P}_{g,p}^{\text{on}}} B_{g,p'}^G,$$

$$B_{g,p}^G = b_{g,p}^G,$$

$$K_{\ell,p}^L = \sum_{p' \in \mathcal{P} \cup \{p_0\}: p' \leq p} B_{p',k}^L,$$

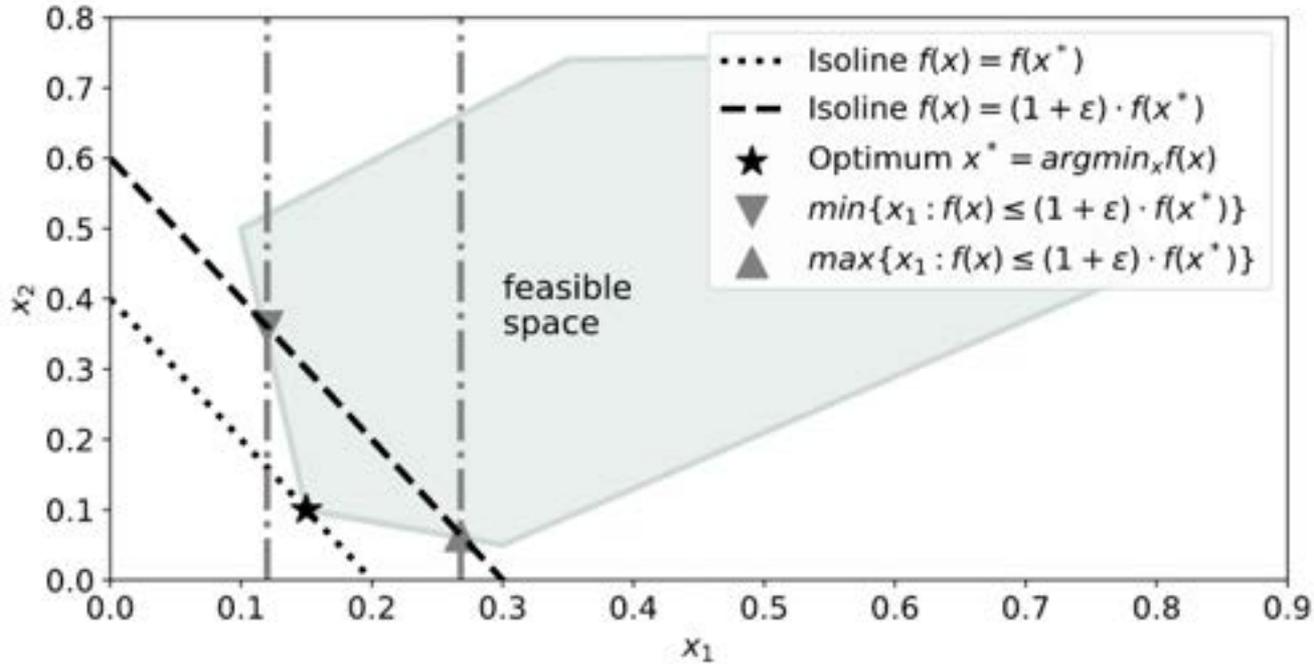
$$B_{\ell,p}^L = b_{\ell,p}^L,$$

$$0 \leq K_{g,p}^G \leq \overline{k}_g^G$$



Johnston, Josiah, et al. "Switch 2.0: A modern platform for planning high-renewable power systems." *SoftwareX* 10 (2019): 100251

Modeling to generate alternatives (MGA) allows us to explore the near-optimal solution space of a model

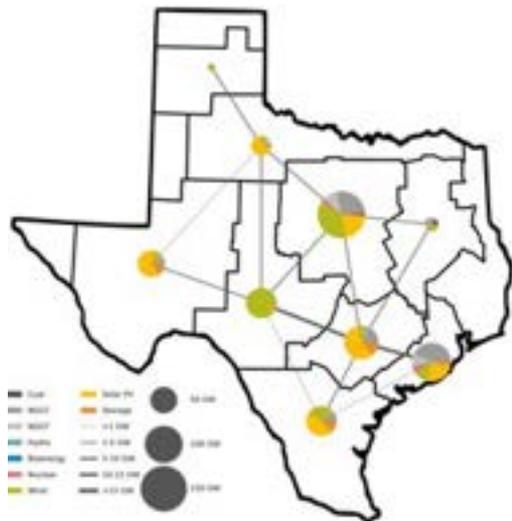


Source: Neumann and Brown (2021)

$$\min \sum_{p \in \mathcal{P}} d_p \left\{ \sum_{c^f \in \mathcal{C}^{\text{fixed}}} c_p^f + \sum_{t \in \mathcal{T}_p} w_t^{\text{year}} \sum_{c^v \in \mathcal{C}^{\text{var}}} c_t^v \right\} \quad \min/\max \sum_{g \in \mathcal{G}_{\text{mga}}} \sum_{p \in \mathcal{P}} B_{g,p}^G$$

$$\text{s. t. } \sum_{p \in \mathcal{P}} d_p \left\{ \sum_{c^f \in \mathcal{C}^{\text{fixed}}} c_p^f + \sum_{t \in \mathcal{T}_p} w_t^{\text{year}} + \sum_{c^v \in \mathcal{C}^{\text{var}}} c_t^v \right\} < (1 + \epsilon) OSC$$

Modeling to generate alternatives (MGA) allows us to explore the near-optimal solution space of a model



Recent SB proposals

Texas Senate passes anti-solar, wind bill

The bill exclusively places permit restrictions, fees and new regulatory requirements for solar and wind projects.

APRIL 16, 2025 RYAN KENNEDY

SB819

INSTALLATIONS MARKETS & POLICY POLICY UTILITY SCALE PV TEXAS



Image: Basla Latawiec

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The Texas Senate voted 22-9 to pass Senate Bill 819. The bill places restrictions on solar and wind power projects, requiring new permits, assessing fees, adding new regulatory requirements and placing new taxes on the projects.

The legislation "adds onerous requirements to new solar projects that would not apply to other energy sources except wind," said the Solar Energy Industry Association (SEIA).

Texas Senate passes bill to establish 'dispatchable' power credits trading program

The scheme would incentivize new gas and other "dispatchable" generation at the expense of renewables and batteries, which constitute the vast majority of recent capacity additions in ERCOT.

Published March 24, 2025

SB388

By Brian Martucci



A worker watches as flared natural gas burns off into the air at an Apache Corp. facility in the Permian Basin in Texas. The state could adopt a "dispatchable" power credits trading program under a bill approved by the Texas Senate on March 19, 2025. *Source: Flare via Getty Images*

Dive Brief:

- The Texas Senate on Wednesday passed a bill to create a new "dispatchable" power credits trading program that would effectively require utilities, generation companies and electric cooperatives in Electric Reliability Council of Texas territory to offset new renewables and battery capacity — with an equal amount of new dispatchable capacity beginning as early as next year.
- The bill's definition of "dispatchable" excludes batteries while also exempting power generation companies that exclusively operate battery energy storage systems from the dispatchable power generation requirement.
- The bill is "the most heavy-handed, anti-market kind of legislation ... [that] would bring economic growth in Texas to a screeching halt" amid supply chain issues that have pushed gas turbine deliveries out to 2020 or beyond. Texas-based power-sector analyst Doug Leshin wrote

Electricity demand in ERCOT is modeled under seven growth scenarios

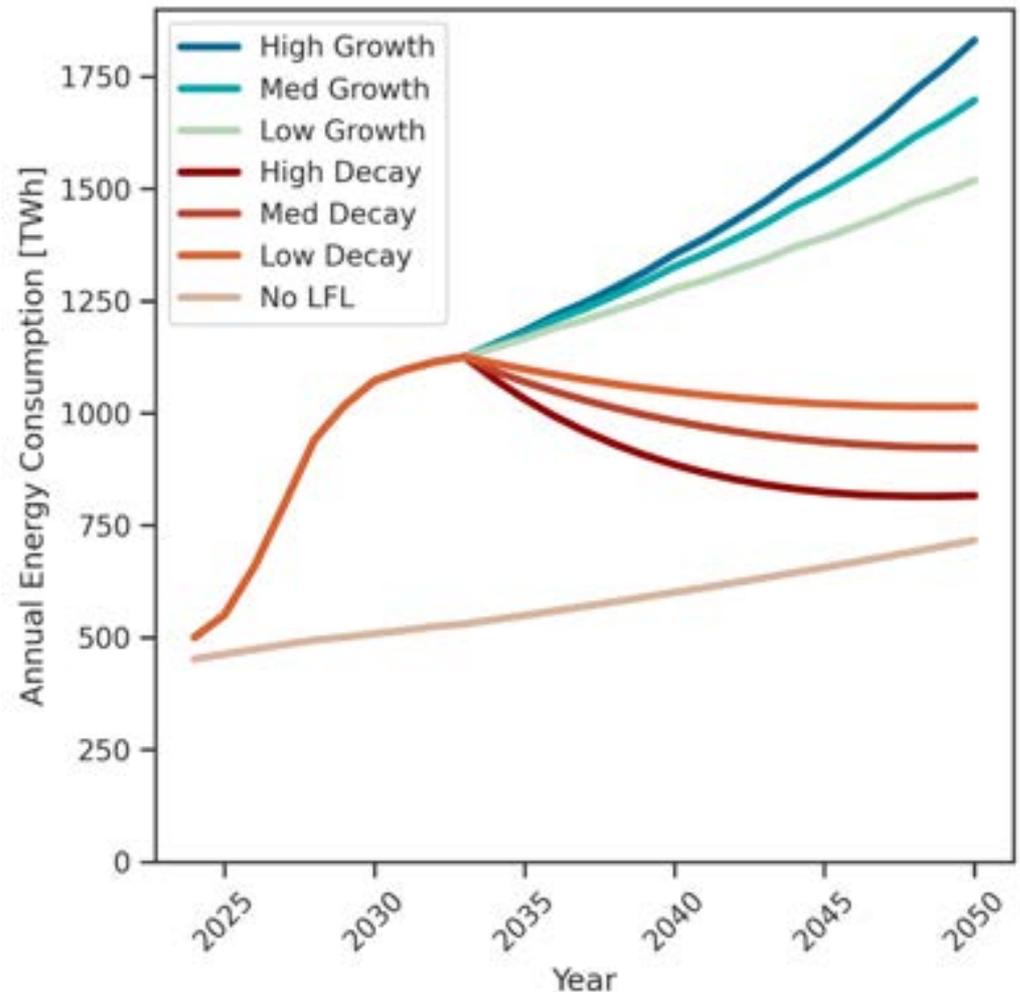
Maximizing and minimizing nine different technologies:

1. Coal
2. Natural Gas
3. Bioenergy
4. Nuclear
5. Geothermal
6. Onshore Wind
7. Offshore Wind
8. Solar PV
9. Battery Storage

- **Dispatchable:** (nuclear, geothermal, bioenergy, coal, gas)
- **Renewables:** (solar, O/OS Wind)

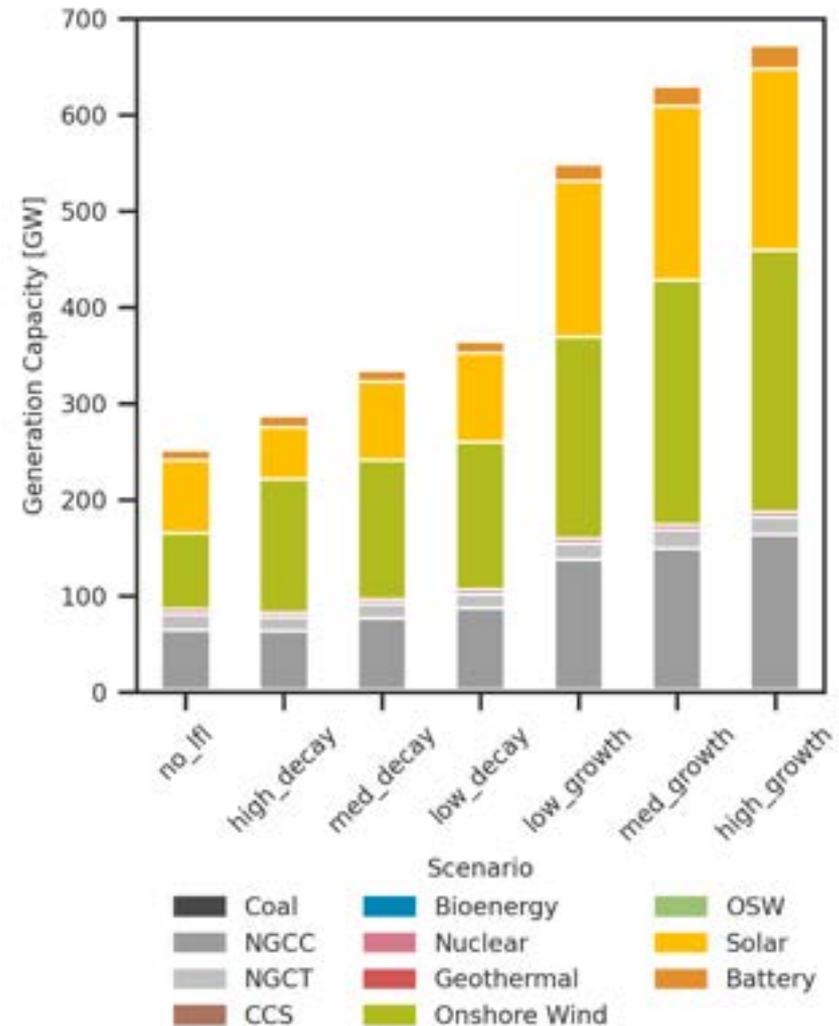
Slack values from 1–15%:

2,112 near-optimal solutions

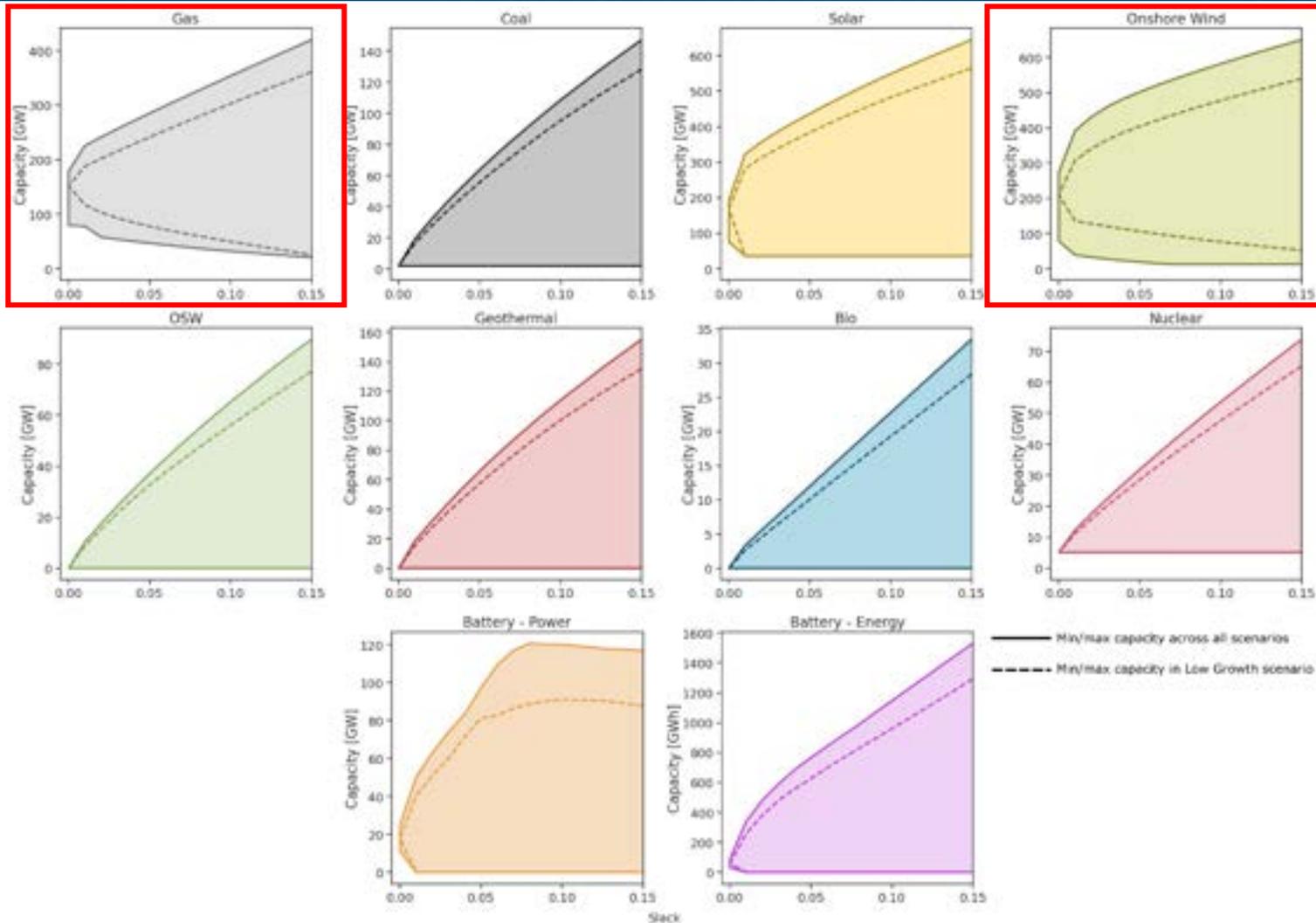


Cost-optimal capacities

- Solar, wind, and natural gas are consistently dominant in 2050
- Higher demand scenarios tend to use more wind energy
- Small amounts of nuclear and CCS technologies, and modest storage
- Demand decay scenarios have similar grid configurations to No LFL case by 2050

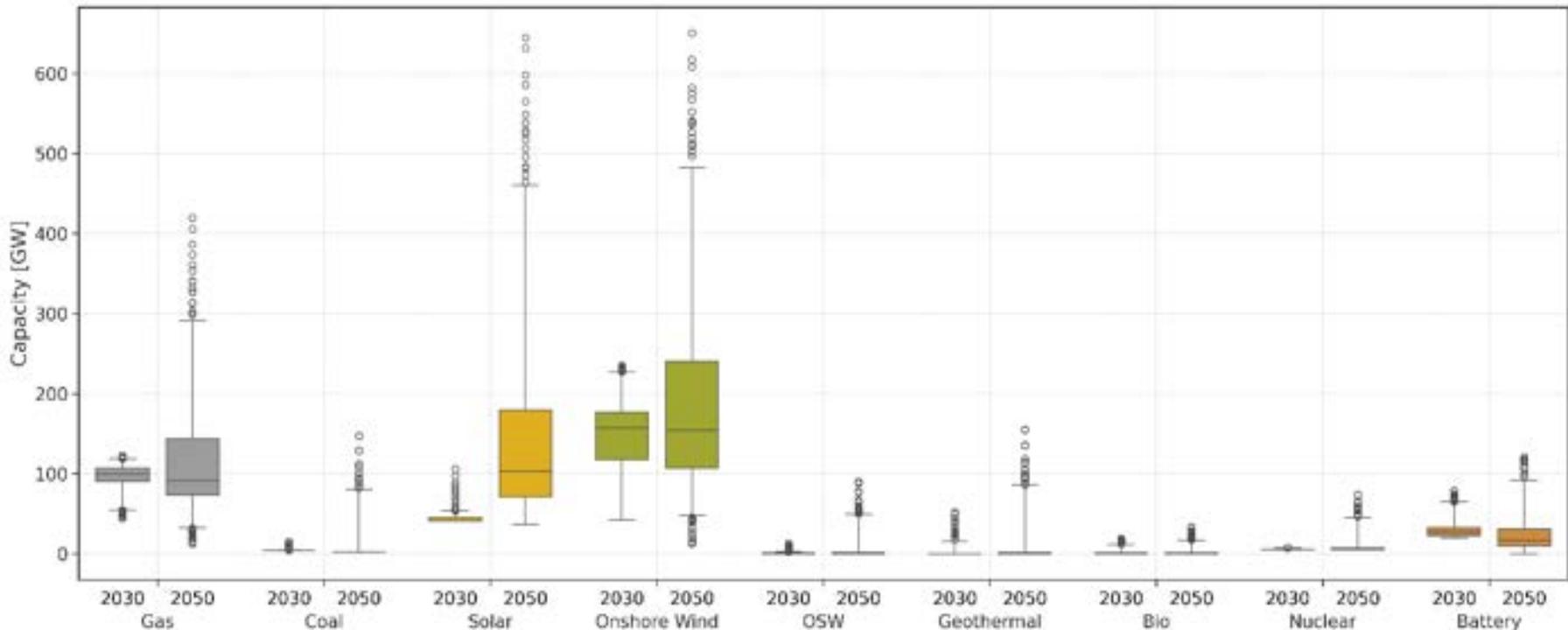


Wind, solar, and gas dominate even in near-optimal scenarios



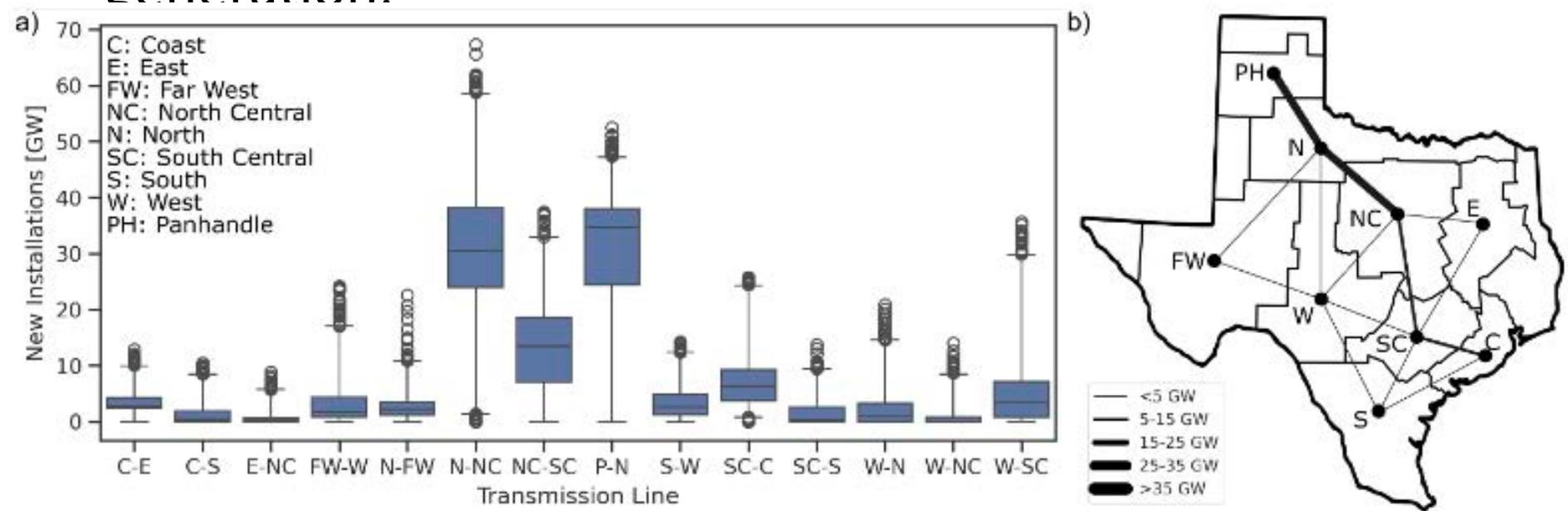
Only wind, solar, and gas are used to meet near-term demand growth

- Alternative technologies (nuclear, geothermal, etc.) are too expensive in the short-term to build, even when their capacity is maximized
- By 2050, some alternative technologies have comparable capacities to dominant technologies in some scenarios



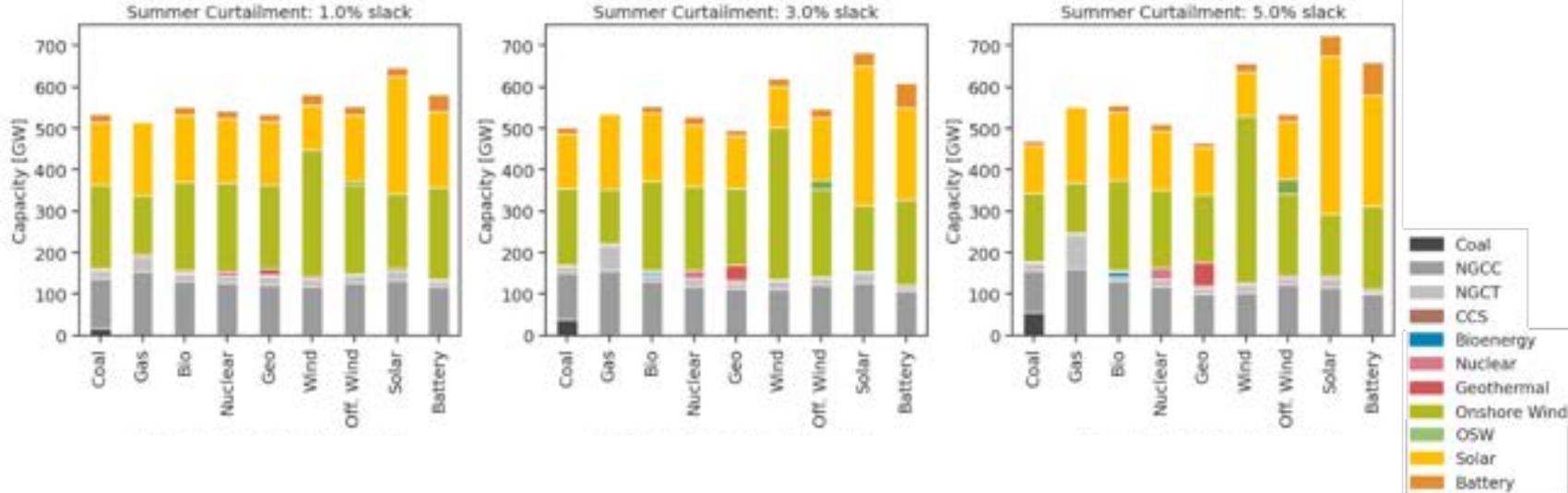
Interregional transmission needs

- Cost-optimal: North Tx → Demand centers (S, C)
- Expansion depends on spatial distribution of new generation.



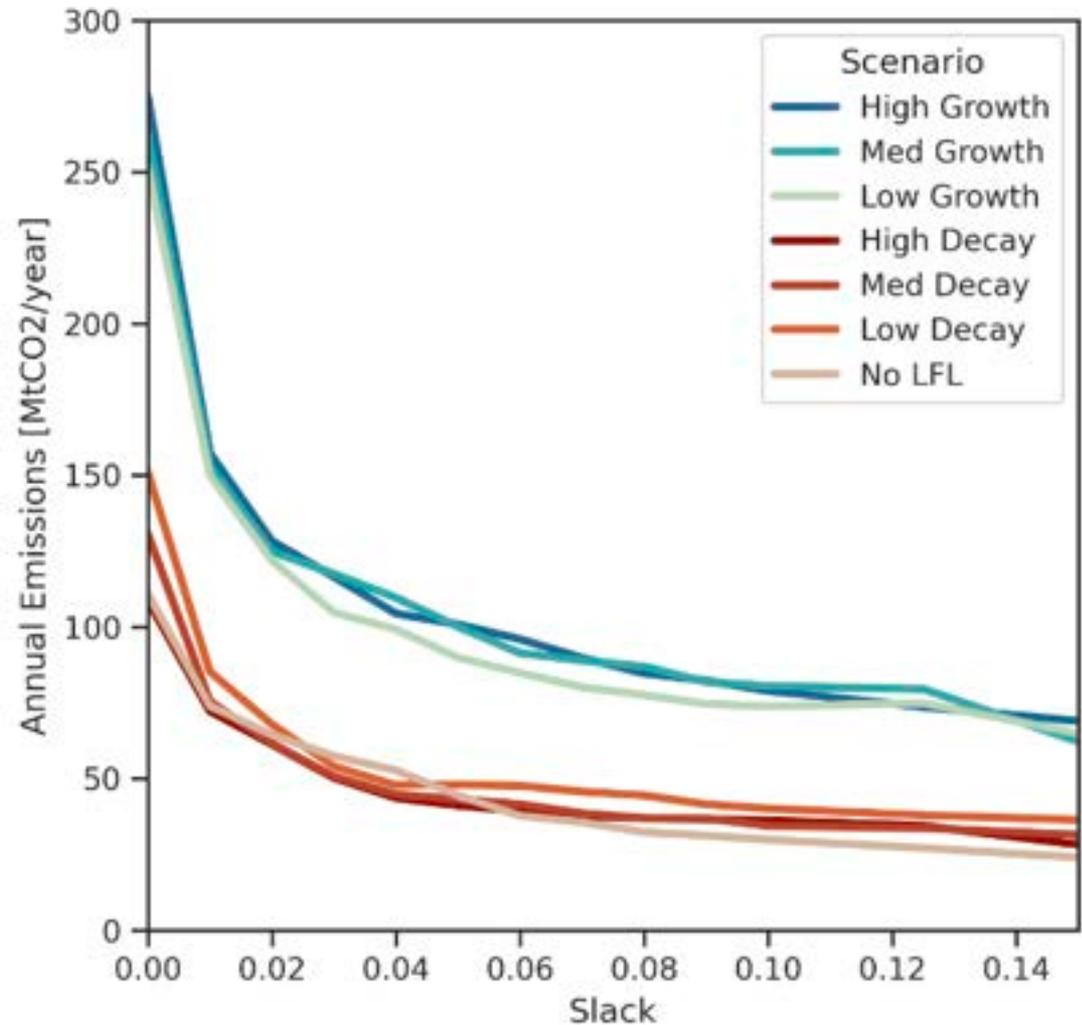
Flexible LFL operations reduced capacity requirements and favors firms generation

Complementarity & Competition



Significant emission reductions can be achieved even with near-optimal solutions

- LFL growth can increase annual emissions by 147% by 2050
- A 1% increase in system cost can reduce emissions by 33-44%
- Diminishing returns at high slack values; particularly in low-demand scenarios



Key takeaways

- Cost-optimal solutions favor wind, solar, and gas.
- Phasing out wind or natural gas results in significant system cost increases
 - Important implications for bills like SB388
- Increased flexibility reduces capacity across near-optimal scenarios; leads to increased firm generation capacity.
- Significant emission reductions can be achieved even with minimal increases to system cost.

Research Questions

What is the potential for generation technologies to meet large load growth?
What are the impacts of these technologies on a system's cost and emissions?

What are some ways to reflect **opposition, people**, and the impacts of the power sector on people's **well-being**?

Beyond the border: How might these large load growth dynamics impact Mexico's power sector?

Nearly all 50 states face local opposition to renewable projects, report finds

June 17, 2024 Sean Walls



Photo by iStock

Local opposition has proven to be a significant barrier to the rapid expansion

A new edition of Columbia Law School's Sabin Center's *Opposition to Renewable Energy Projects* across 47 states that have encountered significant opposition state-level restrictions that could have the effect of blocking a renewable energy

This is the fourth edition of the Sabin Center's report on *Opposition to Renewable Energy Projects*, 2023. Previous editions of the report were published in *Spring* 2022, 2021, and 2020. The May 2023 edition (from 228 to 386), 111% more state-level projects than the May 2022 edition (from 283 to 316). This edition also includes Defense Council and Blue Water LLC.

Focus on Demand

Citation Leah Temper et al 2023 *Environ. Res. Lett.* 18: 123001

DOI 10.1088/1748-9326/abc197

Clean Energy

Community Opposition and Slow the Pace of Renewable Energy Survey of Developers Shows

"The newest bottleneck has been social acceptance."

By Emma Foehringer Merchant
February 23, 2024



Sources of opposition to renewable energy projects in the United States

Lawrence Susskind ^a, Jungwoo Chun ^b, Alexander Gant ^c, Chelsea Hodgkins ^d, Jessica Cohen ^e, Sarah Lahmar ^f

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<https://doi.org/10.1016/j.enpol.2022.112922>

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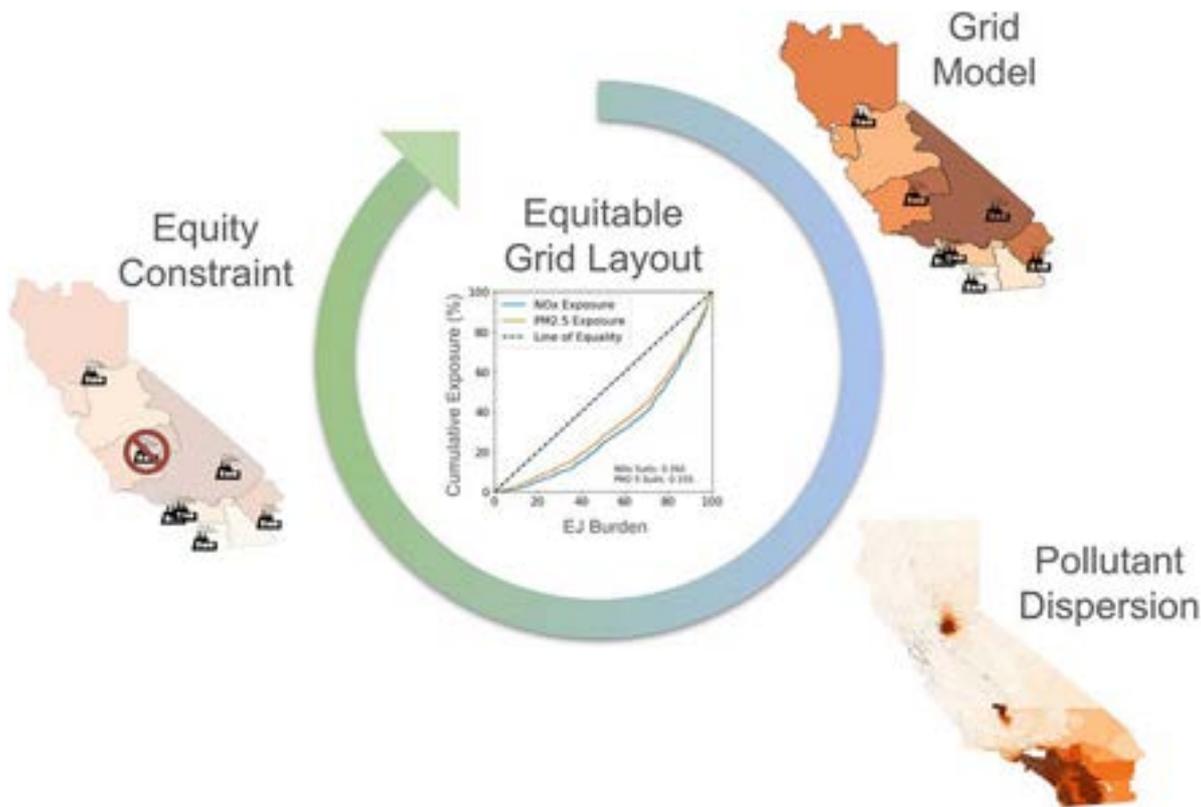
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Highlights

- A surprising number of utility-scale renewable energy projects face multiple sources of local opposition.
- Some sources of local opposition are value-based; that is, they do not relate to financial gains or losses.
- Institutional and procedural complexities deepen the conflicts that emerge between project proponents and opponents.
- Disputes between the US government and Tribal nations need to be addressed separately from efforts at public participation.
- Early engagement with potential local opponents can avoid extended delays or project cancellations.

Reflect Challenges and Opportunities in Capacity Expansion Pathways



Measuring impact of PM2.5

- PM_{2.5} Population-Weighted Exposure Level

- $PWEL = \frac{\sum(P_i \times C_i)}{\sum P_i}$

2025-2050 Average Facility Contributions to PM_{2.5} (µg/m³)

