Distribution Planning for Load Growth: Buildings

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Agenda

- Impact of building load growth on distribution planning - Challenges and solutions
- Energy efficiency and demand flexibility programs to manage building load growth
- Value of efficiency and demand flexibility programs for future grids
- Energy and bill impacts of building electrification investments and efficacy of alternative rate designs

For more information, see Berkeley Lab's Integrated Distribution System Planning website and Efficiency and Load Flexibility website.

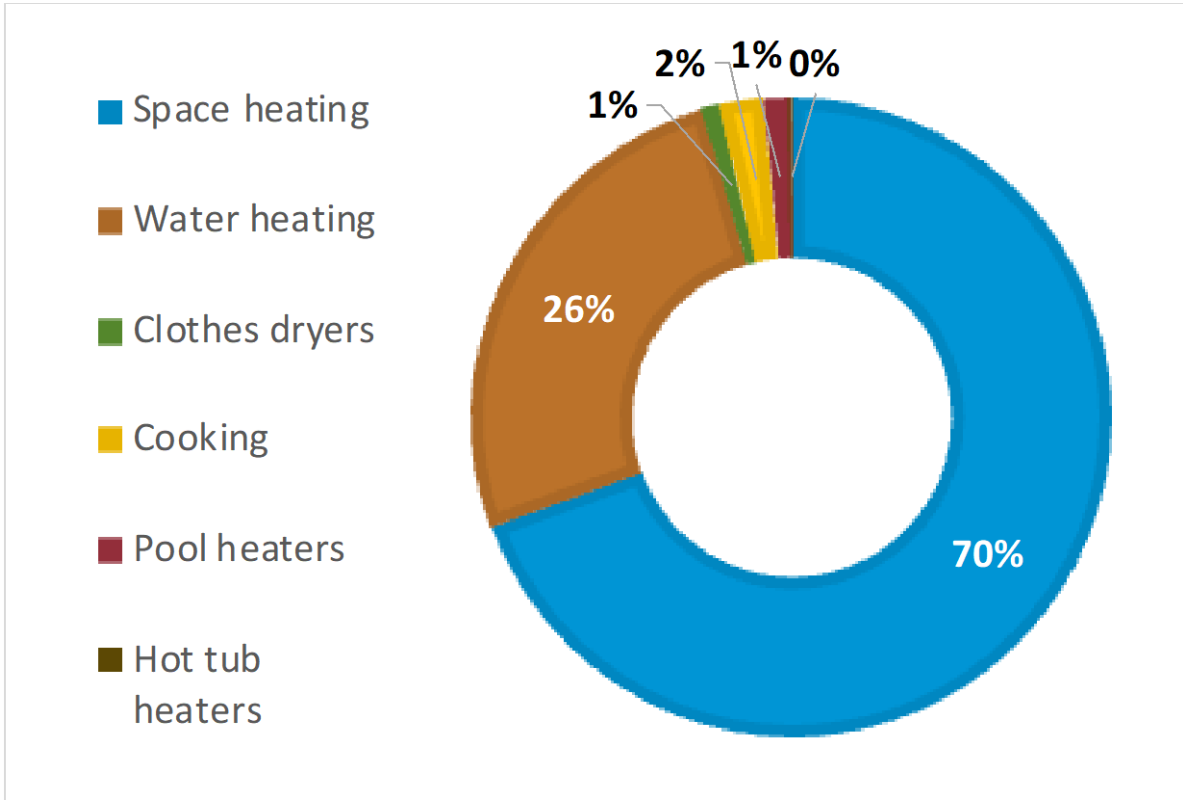
Poll

Is your organization considering the impacts of electricity load growth from (select as many as applicable):

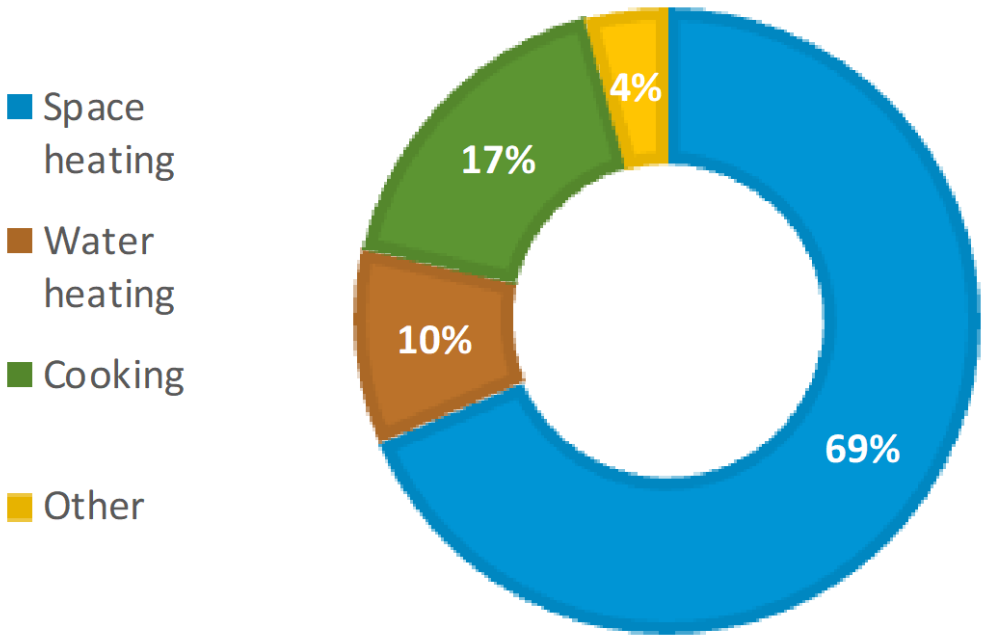
- ☐ Buildings
- ☐ Electric Vehicles
- ☐ Data Centers
- ☐ Crypto Mining
- ☐ Manufacturing

Building load growth impacts the distribution system

Residential Natural Gas Consumption by End Use, 2020 (EIA 2023)

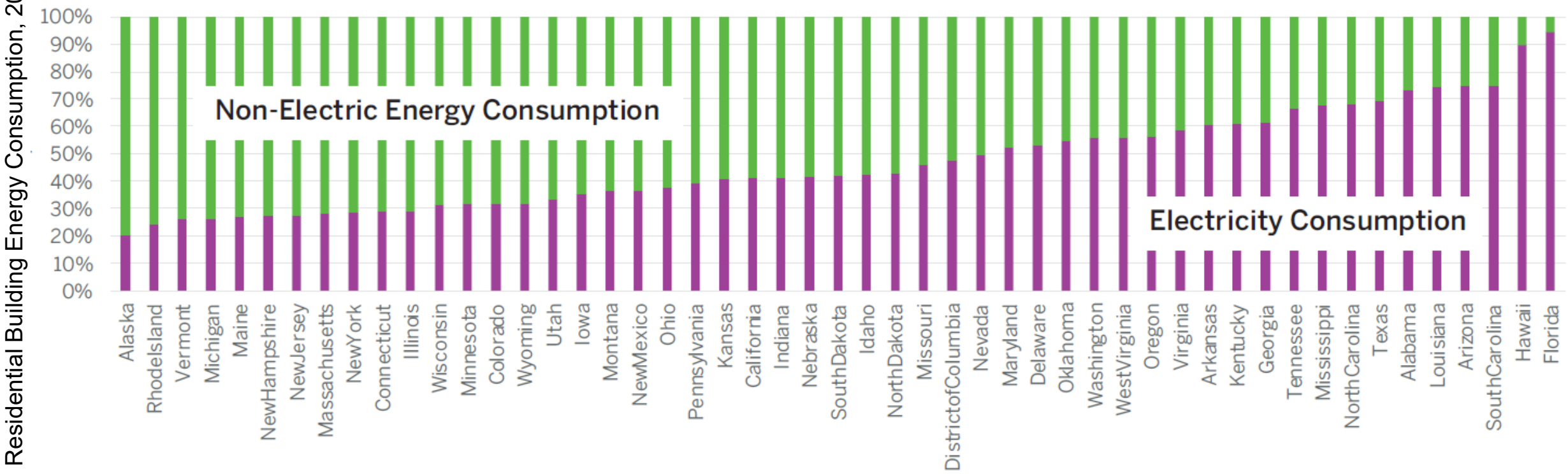


Commercial Natural Gas Consumption by End Use, 2018 (EIA 2023)



Building load growth can affect all regions

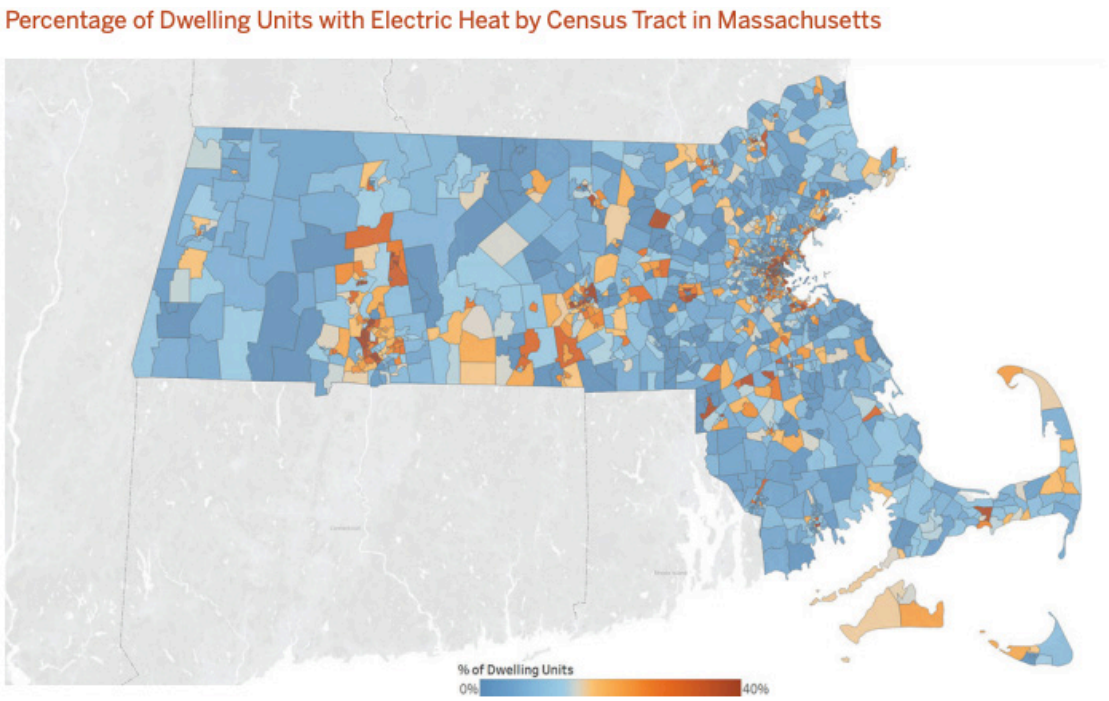
Different regions across the country are at different levels of electrification. Changing non-electric energy consumption to electricity could have significant effects on the electricity sector.



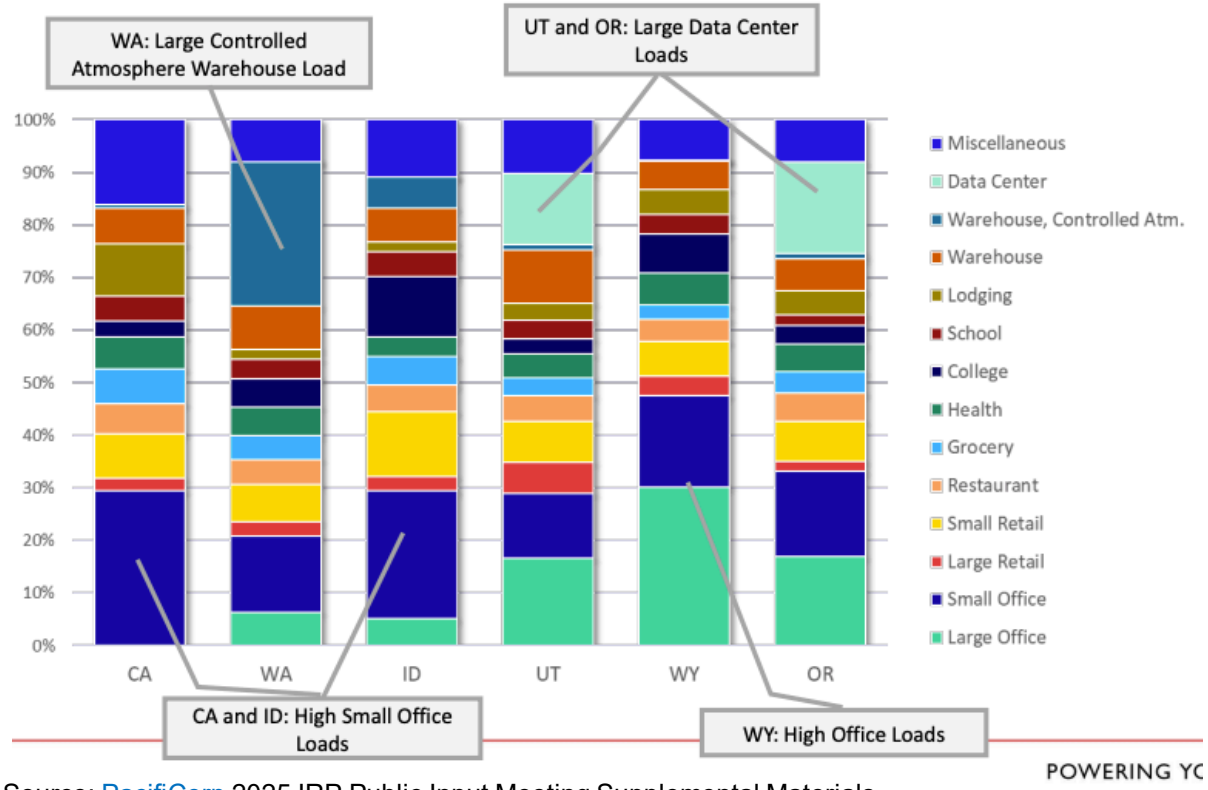
Slide credit: ESIG, Grid Planning for Building Electrication (2024)

But the impacts will not be uniform

Electricity sector impact will vary based on existing fuel for space and water heating and cooling



Source: ESIG, Grid Planning for Building Electrication (2024)

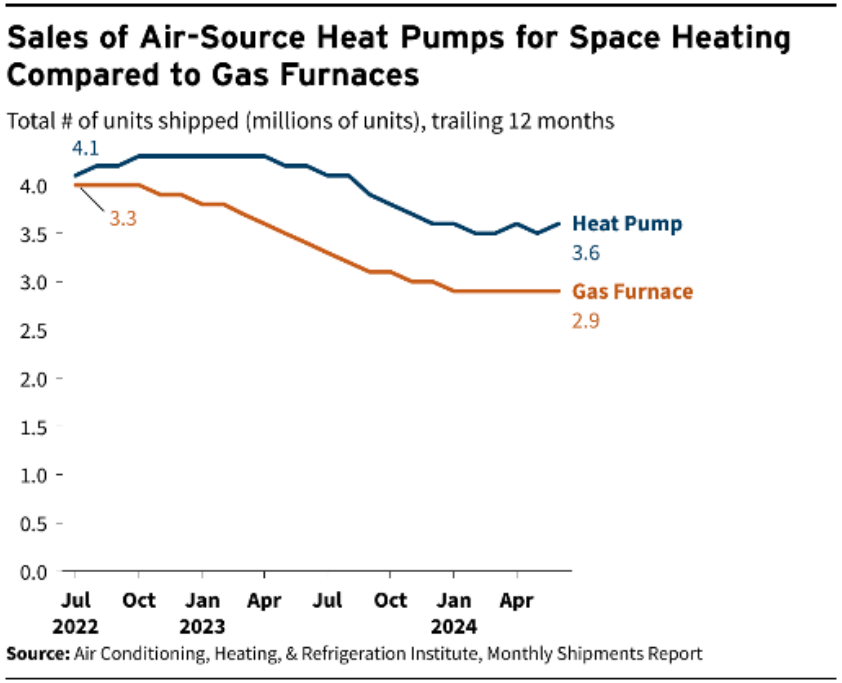


Source: PacifiCorp 2025 IRP Public Input Meeting Supplemental Materials

Impact of load growth from buildings, and opportunities for energy efficiency, will vary based on building stock

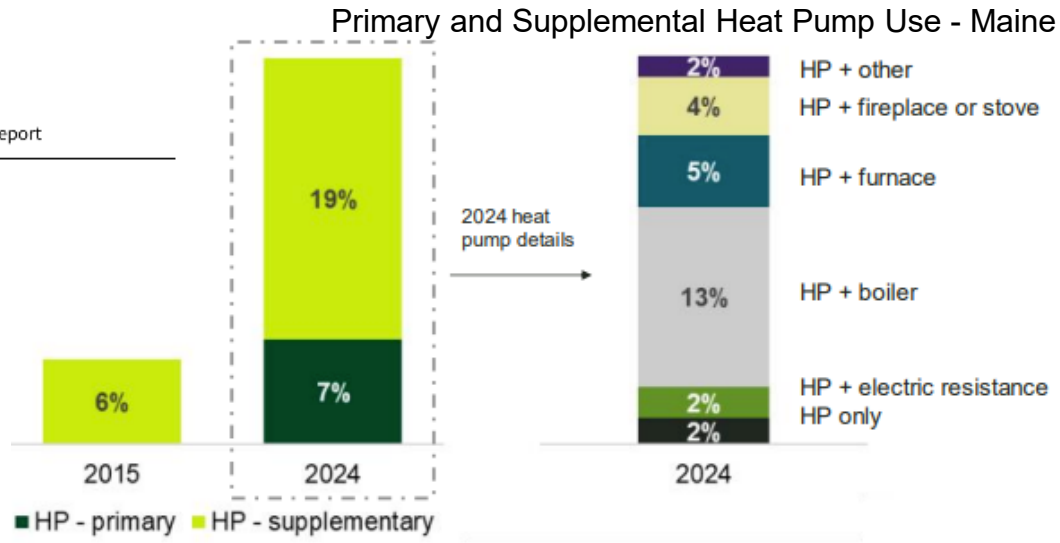
Building load growth impacts on distribution system planning - Challenges

- Changing weather patterns are hard to plan for
  - Heat pumps operate differently during extreme cold temperature
  - Longer events stress equipment and the grid



Source: RMI (2024)

- Areas with high heat pump adoption will see distribution system impacts sooner



Source: Efficiency Maine (2024)

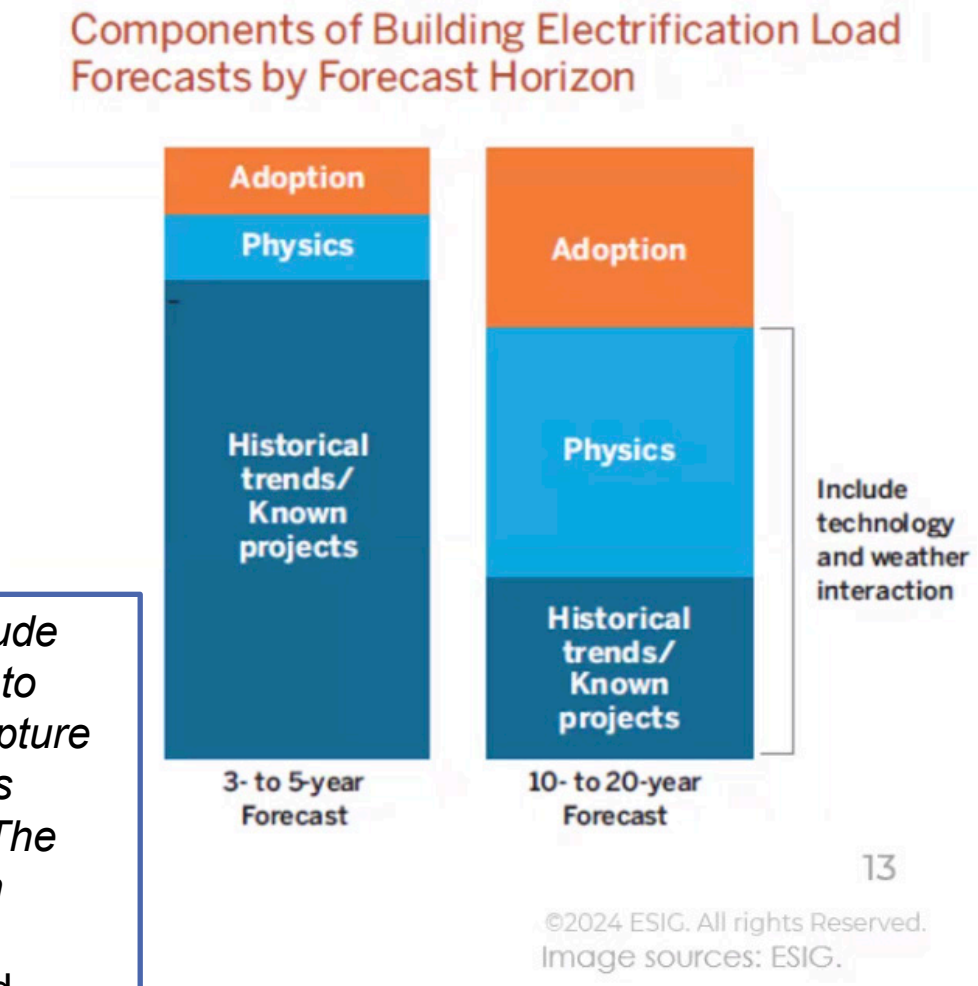
Source: ESIG, Grid Planning for Building Electrication (2024)

Strategies to improve consideration of building load growth in distribution system planning

Building electrification impacts on distribution system planning – Solutions
Improve load forecasting

- Expand the forecast horizon and broaden the factors considered
- Consider how buildings are used to establish a clear baseline
- Consider weather effects – the weather-sensitivity factors that historically captured building response will change with increased electrification
- Use multiple sources for forecasts to understand trade-offs, variables and key assumptions driving forecasts

"In addition to refining its residential beneficial electrification forecasts to include low, medium, and high adoption scenarios, the Commission will require Xcel to submit a Commercial & Industrial beneficial electrification forecast to help capture the significant changes in electricity demand occurring in this sector. If Xcel is unable to complete such a forecast for its next IDP, it must explain why not. The Commission will also require Xcel to utilize IDP forecast scenarios to perform sensitivities on grid capacity or capital expense plans to create a more well-rounded forecast." (Sept. 16, 2024, MN PUC order on Xcel Energy Integrated Distribution Plan, Docket E-002/M-23-452)



Source: ESIG, Grid Planning for Building Electrication (2024)

Building electrification impacts on distribution system planning – Solutions
Modernize planning approach

- Reconsider core planning assumptions, including equipment standards
- Move beyond a singular peak hour
- Improve reliability and resilience metrics for an electrified future
- Share information across natural gas and electricity

Design conditions
by which standards and plans are made, such as outdoor temperature

Thresholds
that trigger further analysis

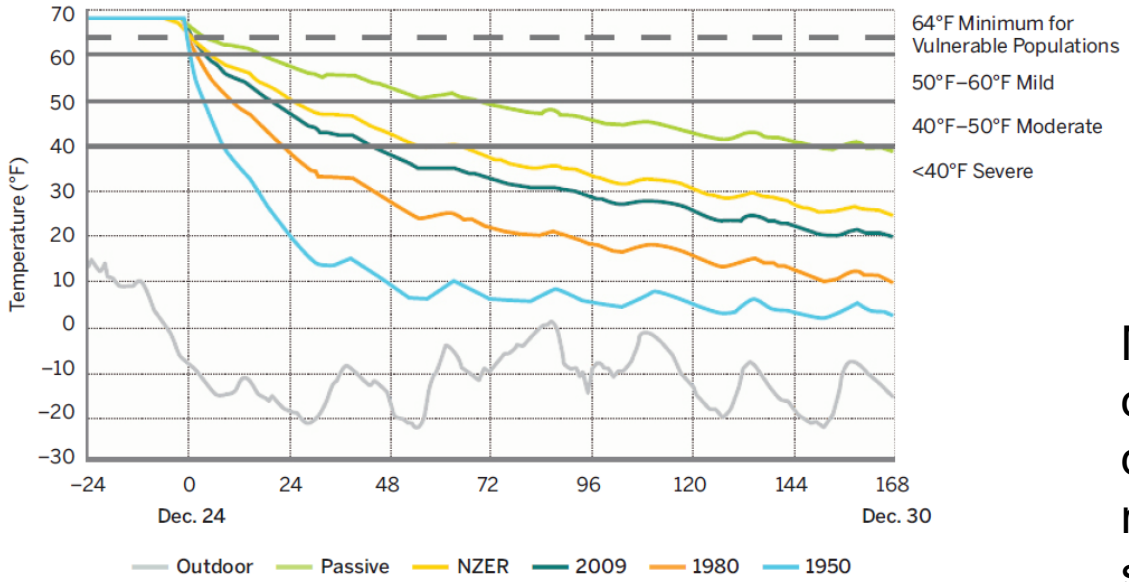
Headroom
margin planned for new equipment

Load Diversity
Heterogeneity of load impacts equipment sizing

Source: ESIG, Grid Planning for Building Electrication (2024)

Improve reliability and resilience metrics

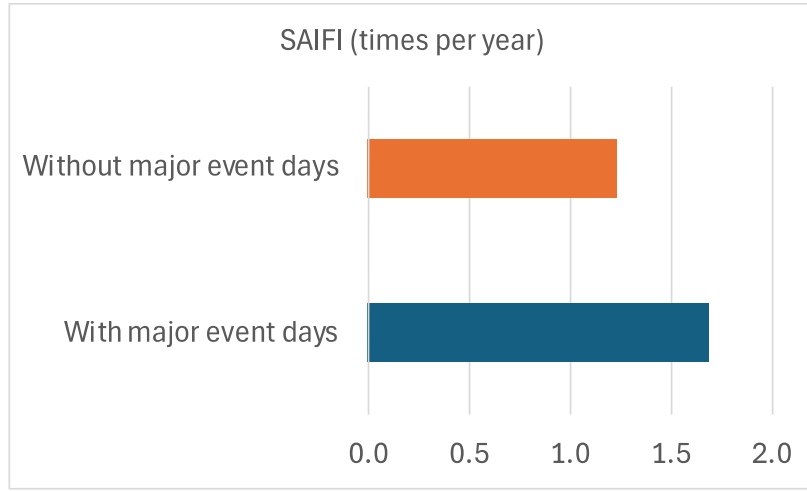
Indoor Temperature Degradation of Different Types of Buildings in Power Outages During Winter Storms



Source: RMI

Older, more inefficient homes lose heat more quickly during power outages.

Major event days are often excluded from distribution reliability metrics. There is significantly more outage time when they are included. The impacts in an all-electric building are amplified.



Source data: EIA

Example: Consolidated Edison Benefit-Cost Analysis Handbook

- Consolidated Edison files a benefit-cost analysis handbook with its distribution system implementation plan.
- The current version included two reliability/resiliency benefits.
  - **Net avoided restoration costs** account for avoided costs of restoring power during outages.
  - **Net avoided outage costs** account for customer outage costs due to a reduction in frequency and duration of outages.

Source: Freepik

Source: Consolidated Edison (2023)

Share information across natural gas and electricity

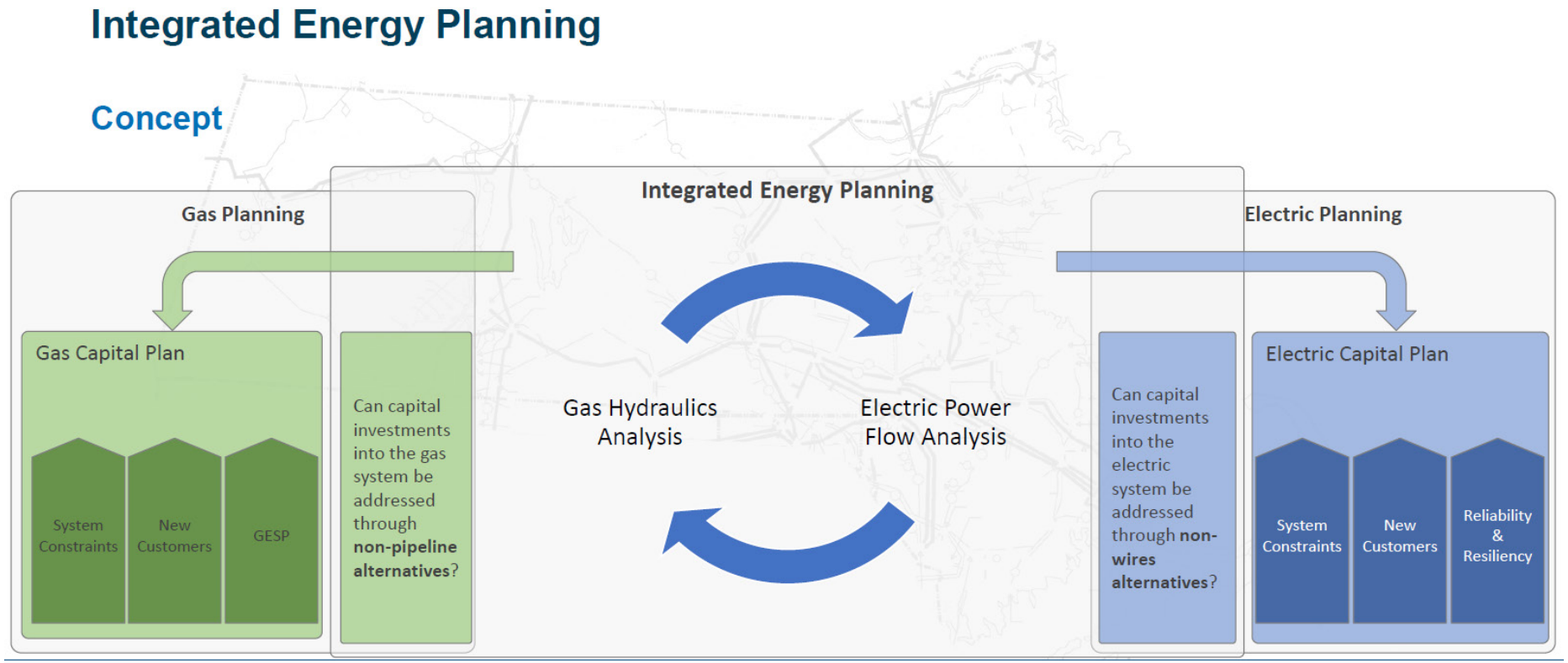
Indicator	Benefit					
	Lower costs	Reliability	Greater confidence	Equitable cost allocation	Streamlined processes	Least-cost compliance with environment and health
Consistent and aligned forecasts and inputs across proceedings	●	●	●	◔	◕	◕
Best available data inputs and up-to-date modeling techniques	●	●	●	◔	◕	◕

○ = None ◔ = Low ◑ = Moderate ◕ = High ● = Full

Source: LeBel et al (2024)

- Recent research from Regulatory Assistance Project and Berkeley Lab identifies integrated electric-gas distribution planning characteristics, indicators and benefits.
- Aligning inputs for forecasting and planning can produce multiple benefits including lower costs, increased reliability, and improving the confidence of regulators and stakeholders in utility investment decisions.

Example: Eversource

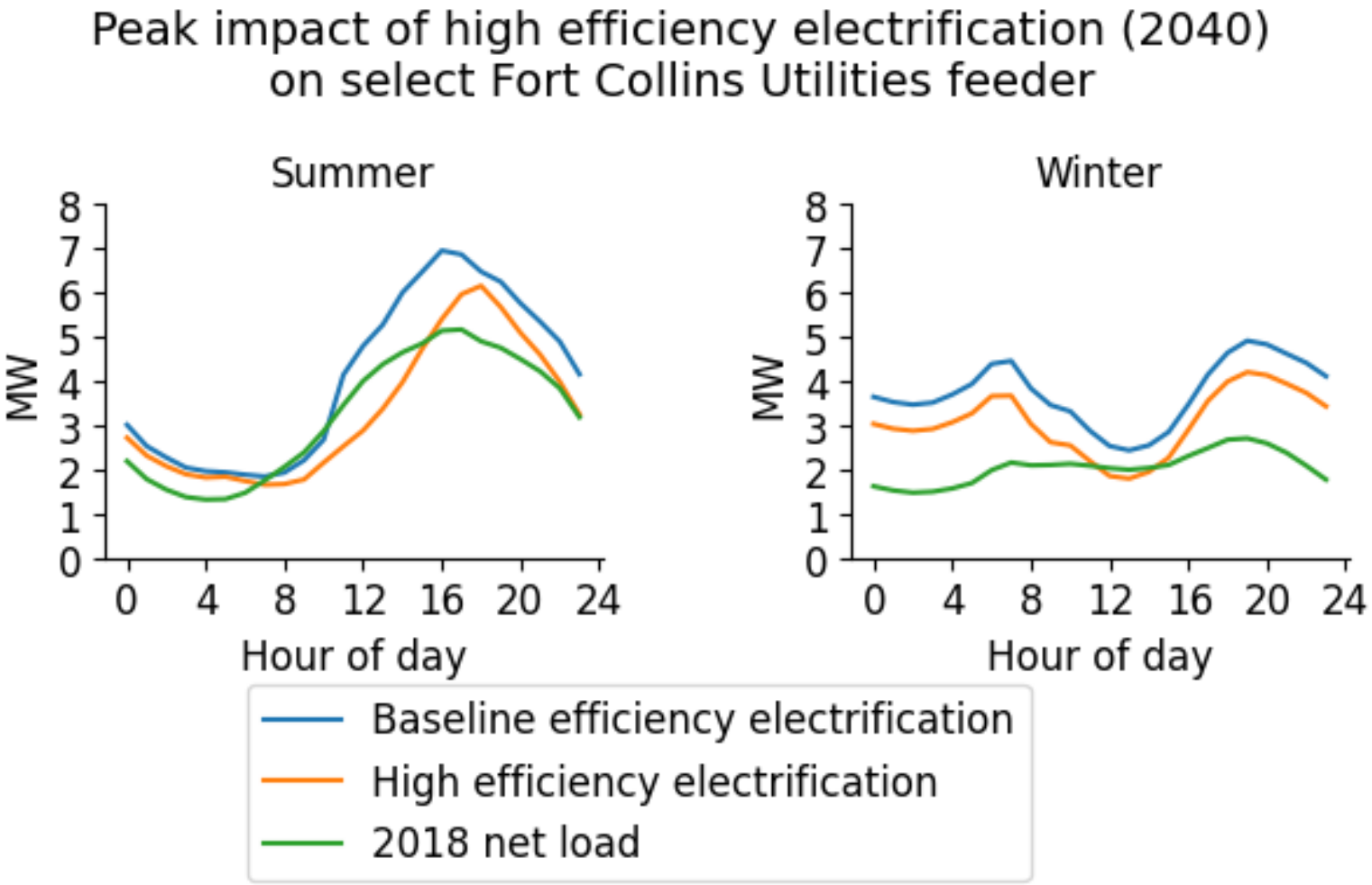


Source: Eversource

In the Future of Gas Proceeding, the Massachusetts Department of Public Utilities required electric distribution utilities to participate in planning with local gas distribution companies. Integrated Energy Plans are due April 2025.

Strategies to reduce the impact of building load growth on the distribution system

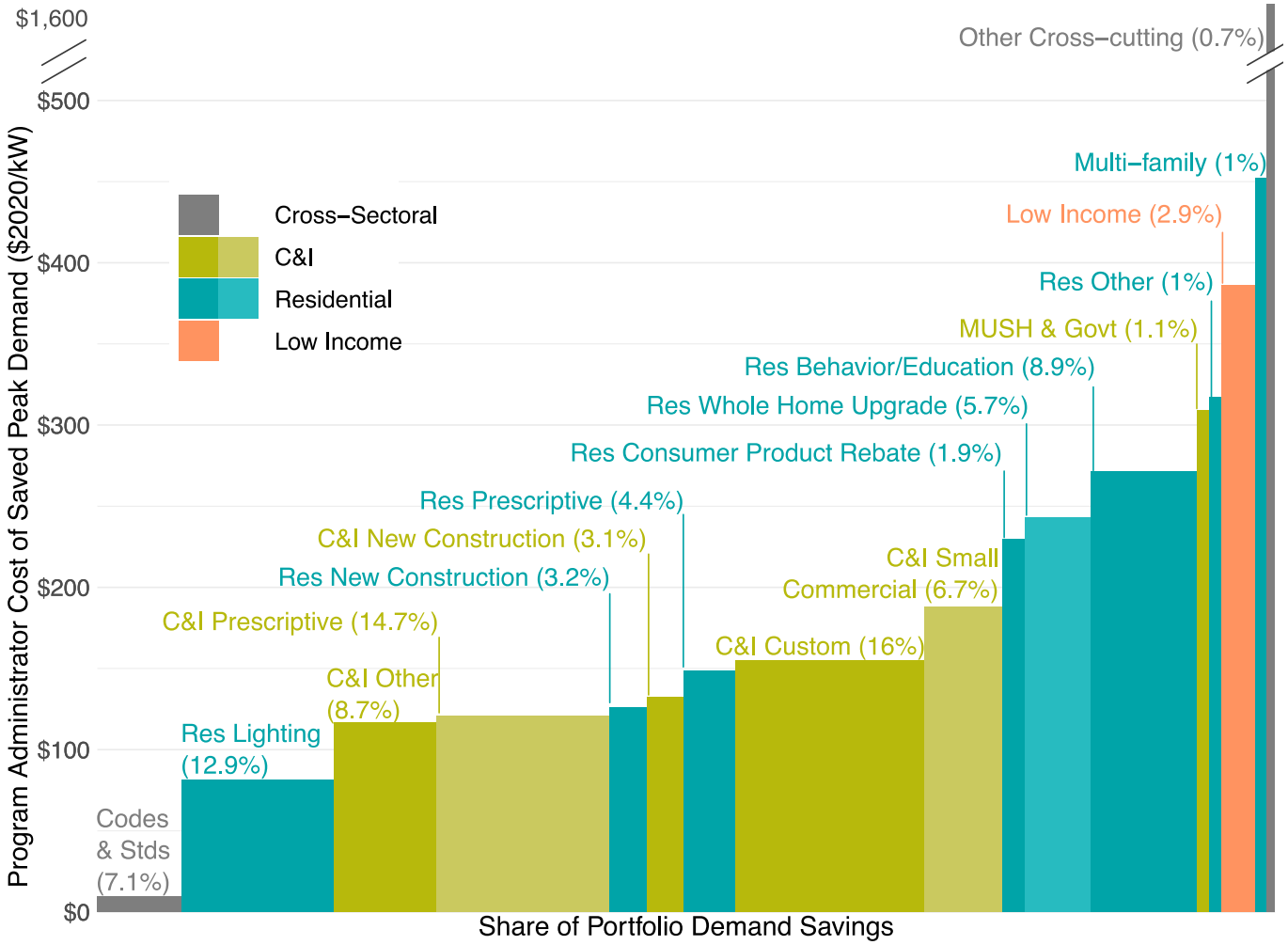
Promote *efficient* electrification



Berkeley Lab analysis for Fort Collins Utilities found efficient electrification reduced summer and winter peak demand on a representative feeder.

Source: Sean Murphy, Berkeley Lab

Design energy efficiency programs to reduce peak demand



- Cost of Saving Peak Demand research gathers data on energy efficiency program savings for residential, commercial, and industrial sectors — energy and demand savings and costs.
- Analysis found that most savings are <$200/kW.

Source: Frick et al. (2021)

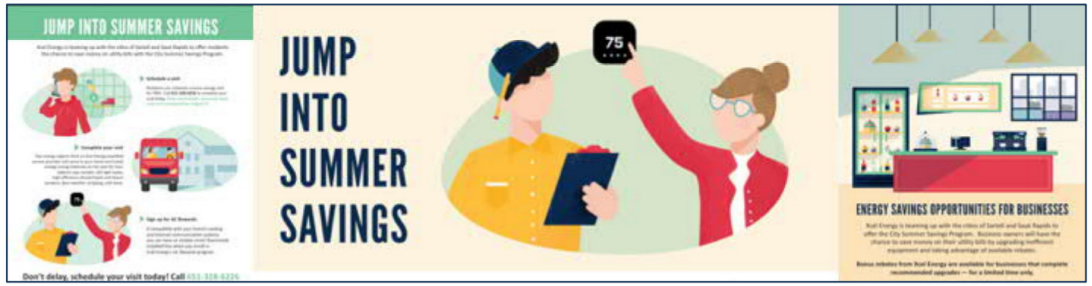
Program example: Xcel Energy geotargeted pilot

Grid need: New transformer, feeder, and feeder configuration, needed in 5 years

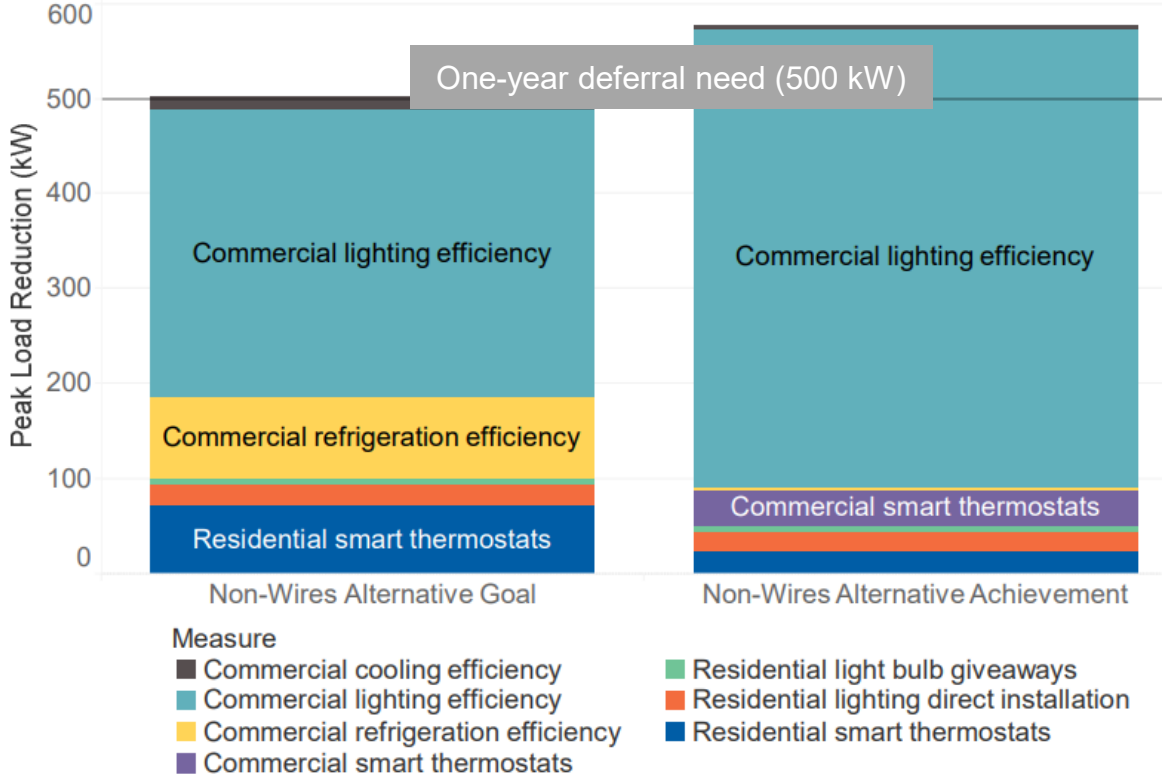
Solution: Targeted energy efficiency and load management to reduce peak demand by 500 kW

Goal: Defer $4.1M estimated distribution system capacity upgrades

Results: 576 kW of peak demand savings, exceeding the goal



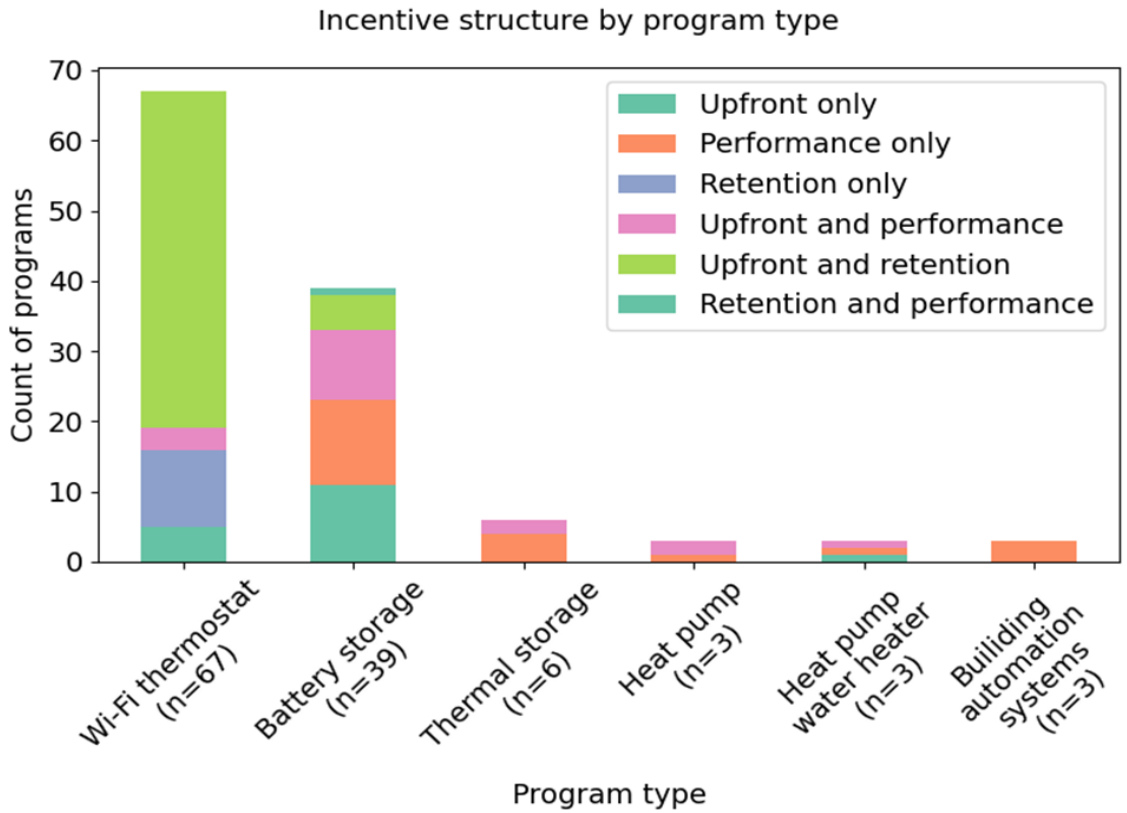
Source: Guillermo Pereira, Berkeley Lab, "Using Energy Efficiency to Help Meet Distribution System Capacity Needs," 2023 ACEEE Energy Efficiency as a Resource conference, Oct. 18, 2023

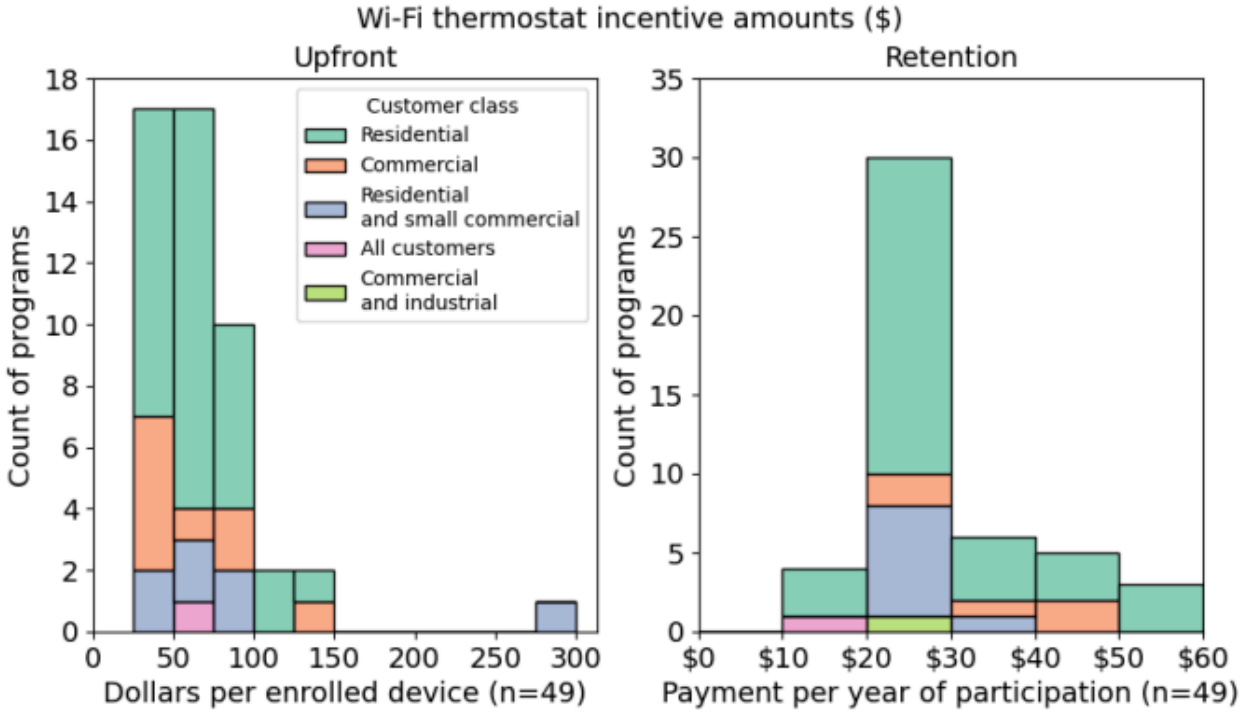


Source:
CEE 2021, Non-wires Alternatives as a Path to Local Clean Energy: Results of a Minnesota Pilot
Geotargeted Distributed Clean Energy Initiative Update Report

Incentivize demand flexibility in buildings – Program types and customer incentive levels

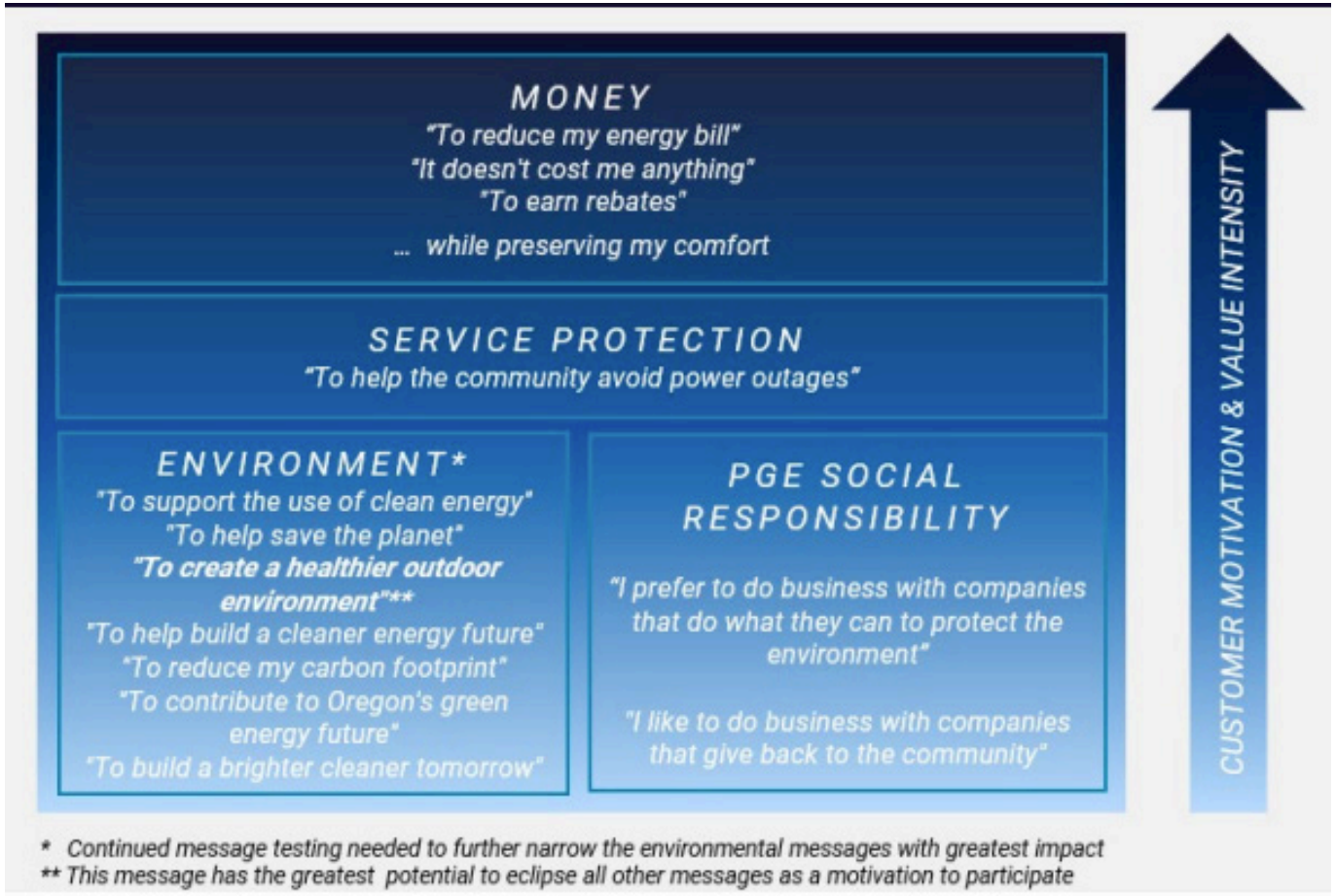
Recent Berkeley Lab research identified demand flexibility incentive structures and levels by program type.





Source: Murphy et al. (2024)

Incentivize demand flexibility in buildings - Participation



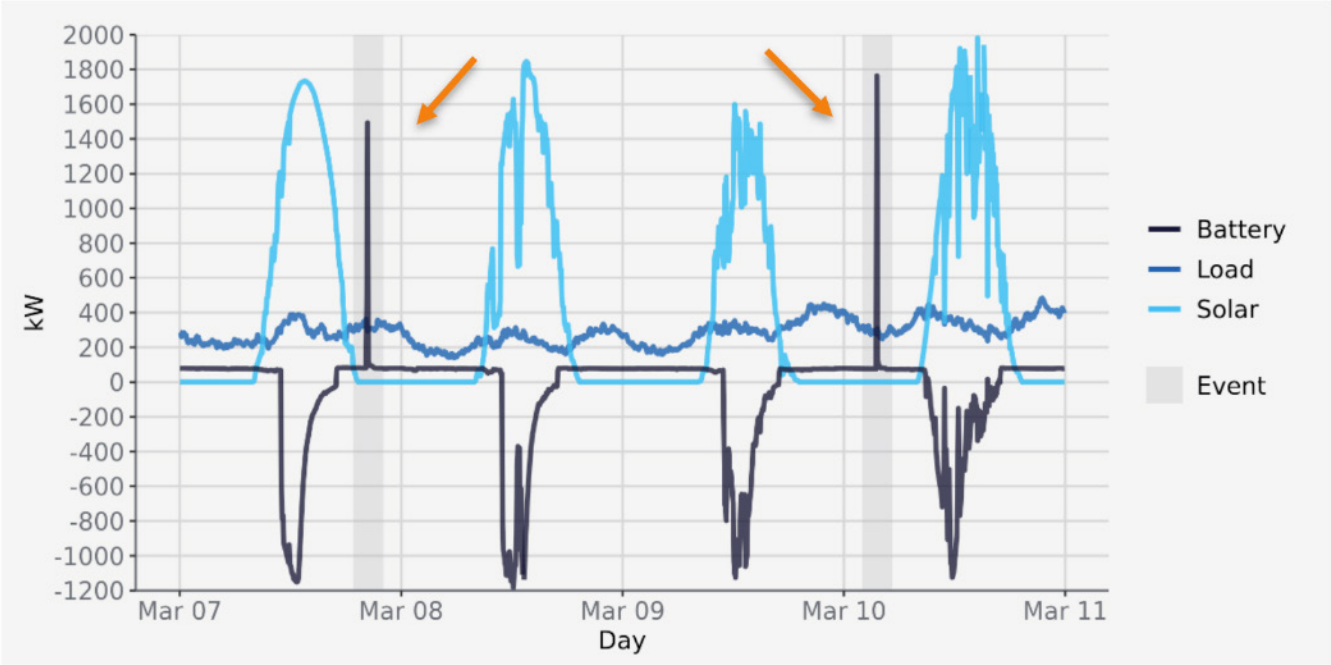
Portland General Electric explored what motivated customers to participate in their demand flexibility pilot, clustered in neighborhoods around three distribution substations.

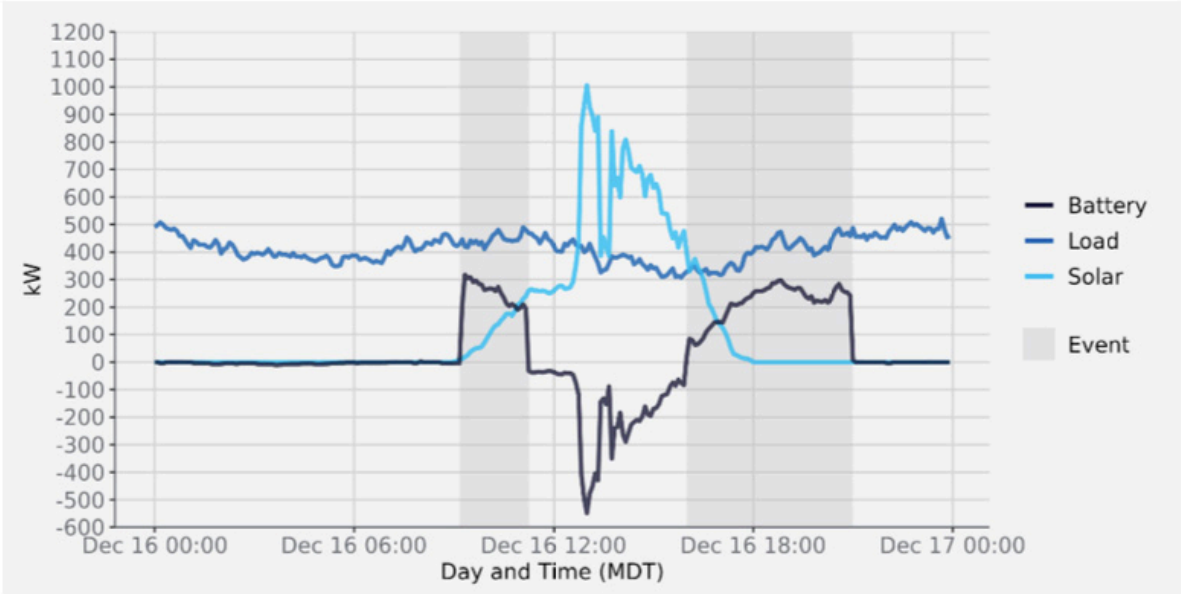
Source: PGE (2021)

Program example: Rocky Mountain Power pilot

Rocky Mountain Power tested demand flexibility from residential batteries in homes as part of a pilot program.

March 2020 Frequency Regulation Events





Peak Management Operations, December 16, 2020

The pilot for 600 homes with batteries tested their ability to:

- Provide frequency regulation services
- Manage peak demand
- Provide circuit level congestion relief

Source: Rocky Mountain Power (2021)

Consider targeted electrification

- California passed legislation in 2024 requiring the California Public Utilities Commission (CPUC) to create a pilot that designates up to 30 neighborhood decarbonization zones to transition buildings from gas to electricity and thermal energy networks.
- Albany, California, was awarded a federal grant to electrify one city block and decommission the gas system. Lessons learned and best practices will be published at the conclusion of the project.

Targeted Electrification – A Cost-Based Approach to Electrification

Targeted electrification success story: ~2,000 ft Aldyl-A replacement project

	Status quo gas replacement	Electrification alternative
Pipe replacement/retirement	$1.2M	$20K
Customer electrification	-	$130K
Service retirement	-	$6K
TOTAL	**$1.2M**	**$156K**

Progress to Date

- PG&E's Gas Investment for the Future (GIF) team evaluates alternatives to gas investments and engaged customers on alternatives to gas service.
- Small-scale projects conducted to date have electrified 102 customers, avoided 80 high-pressure regulator rebuilds and 4.2 miles of distribution main, while enabling the retirement of 22 miles of line.
- On August 10th 2022, PG&E filed an application with the CPUC that asks for up to $17.2 million to pursue targeted electrification at CSU Monterey Bay. Costs of the project would be fully offset by the savings of not having to repair the gas line.

Scaling Early Success

- Scale is dependent on changes to "obligation to serve", external funding, and ability to capitalize behind-the-meter electrification costs.
- Utilities need a streamlined application process for targeted electrification projects to ensure that they can be conducted on a timeline consistent with critical gas safety and/or reliability needs.

Source: PG&E

- Prior to the legislation, PG&E proposed a zonal electrification pilot at California State University Monterey Bay in 2022 that is currently being considered at the CPUC (Docket 22-08-003).
- Massachusetts Department of Public Utilities required the local gas distribution companies to deploy targeted electrification pilots and file their project proposals by March 1, 2026.
- Eight states (CA, CO, MA, MD, MN, NY, VT, WA) enacted legislation advancing or promoting thermal energy networks (neighborhood-scale shared network of water pipes that can transfer heat in and out of buildings).

Consider front of the meter efficiency programs

- Conservation voltage reduction (CVR) is the "intentional operation of the transmission and distribution system to provide customer voltages in the lower end of the acceptable range, with the goal of achieving energy and demand reductions for customers."
- Volt-VAR optimization (VVO) occurs when utilities "manage and optimize voltage and reactive power simultaneously."
- Both of these strategies are efficiency measures that utilities can implement directly on their distribution systems.
- Common distribution system planning tools such as CYMDIST and Synergi can simulate CVR/VVO and estimate the energy efficiency savings.
- Recent measurement and verification from a CVR/VVO program in Illinois saved almost 87,000 MWh and more than 13 MW of peak demand savings in 2022.

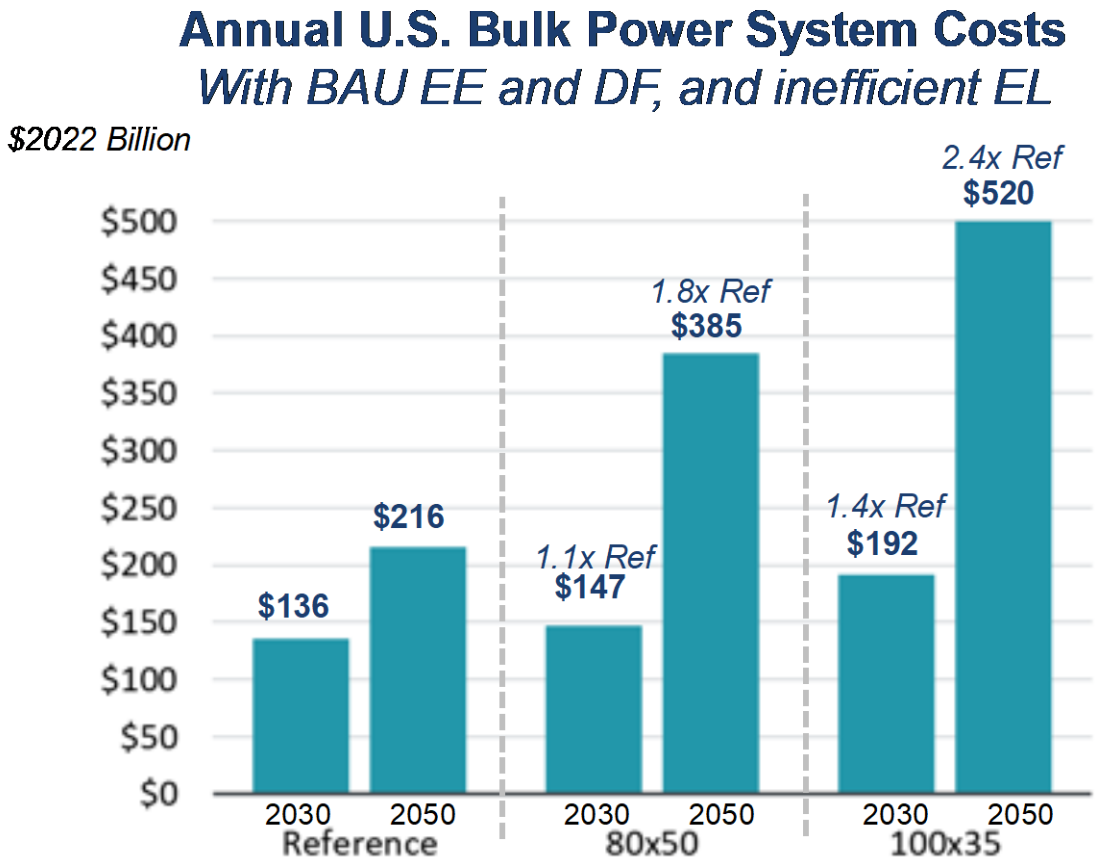
Equipment		Grid Locations	Grid Functions
Load tap changers		Substation transformers	Adjusts feeder voltages at the substation
Voltage regulators		Distribution feeders or substations	Adjusts voltages at the substation or along the feeder
Capacitor banks		Distribution feeders or substations	Compensates for reactive power and provides voltage support

Equipment for voltage support and reactive power control
Source: DOE

Value of efficiency and demand flexibility programs for future grids

High load growth will require significant investments in bulk power system generation and transmission

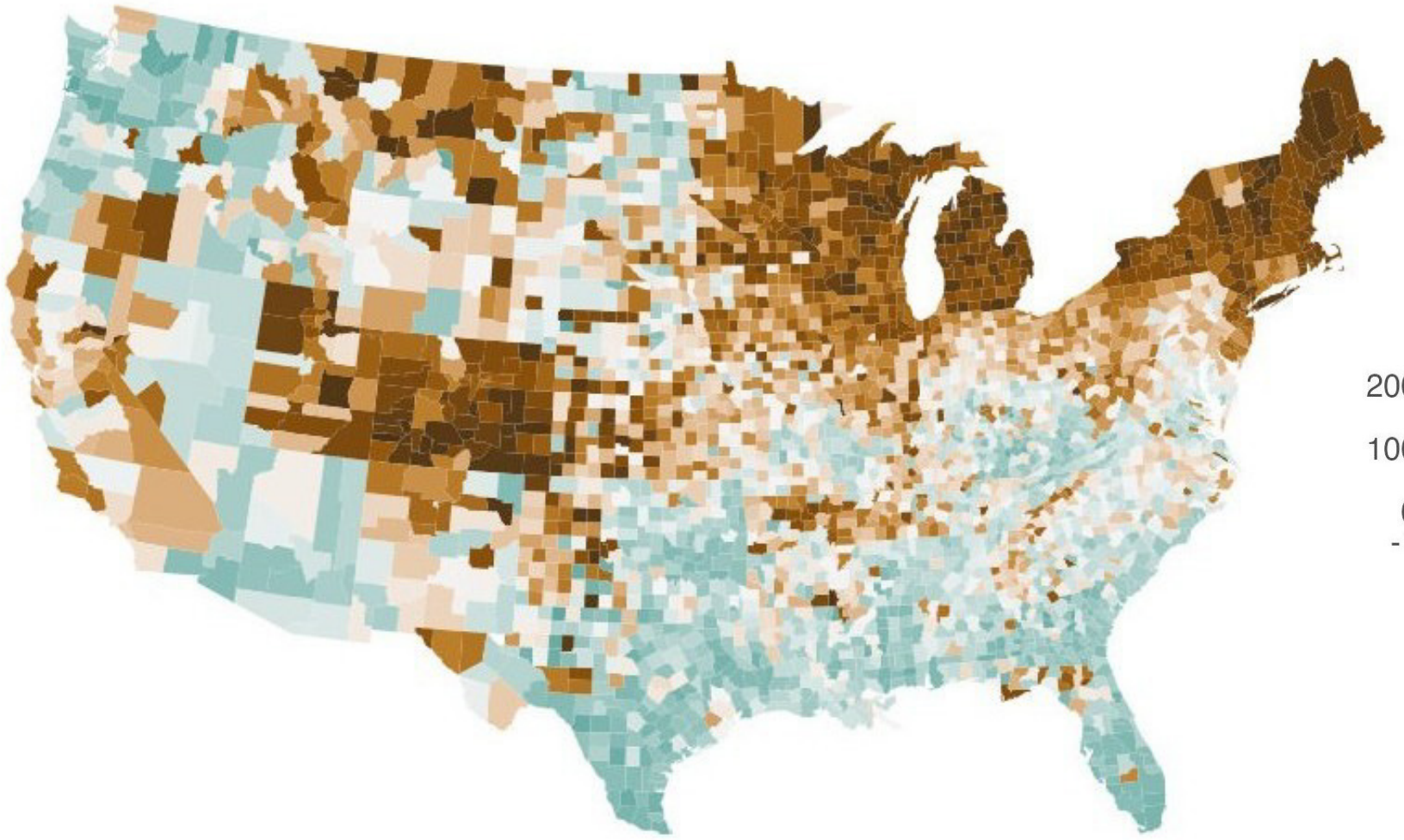
- *Inefficient* electrification (e.g., electric resistance space and water heating) adds significant load.
- New generation supply to meet demand growth requires capital generation and transmission investments.
- Grid systems may switch from summer to winter peaking driven by building heating electrification. Summer peaks will shift later in the day with new electrified water heating and cooking loads.

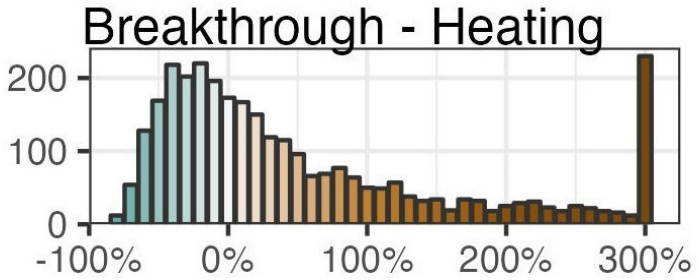


Source: Langevin et al. (2023)

Bulk power system costs include new generation and transmission capacity, fuel and variable operations, and maintenance expenses.

Load growth will have important locational impacts for residential and commercial customers

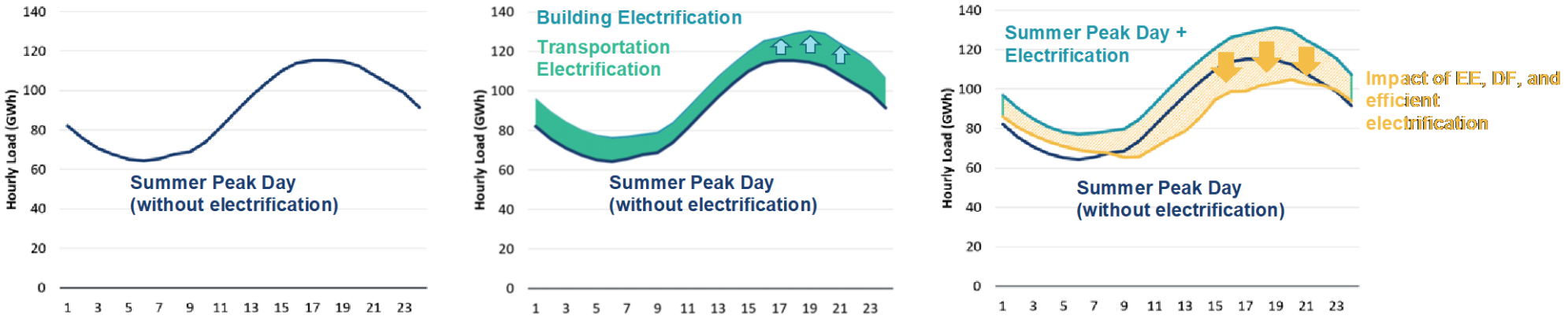




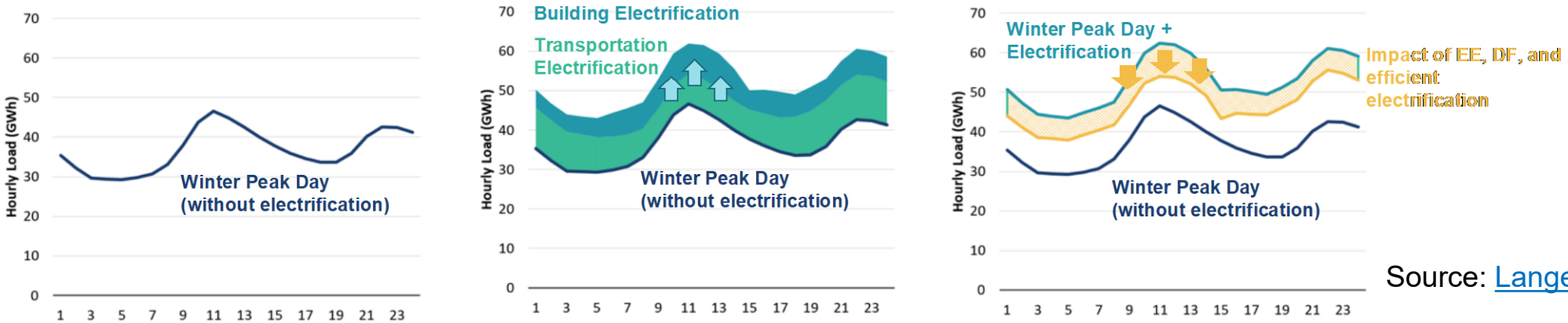
Source: Berkeley Lab, Building Standard Scenarios (forthcoming). Percentage change is change in annual residential heating electricity consumption.

Efficiency and flexibility can mitigate electrification load increases

Texas 2050: Summer peak day with electrification and energy efficiency/demand response impacts



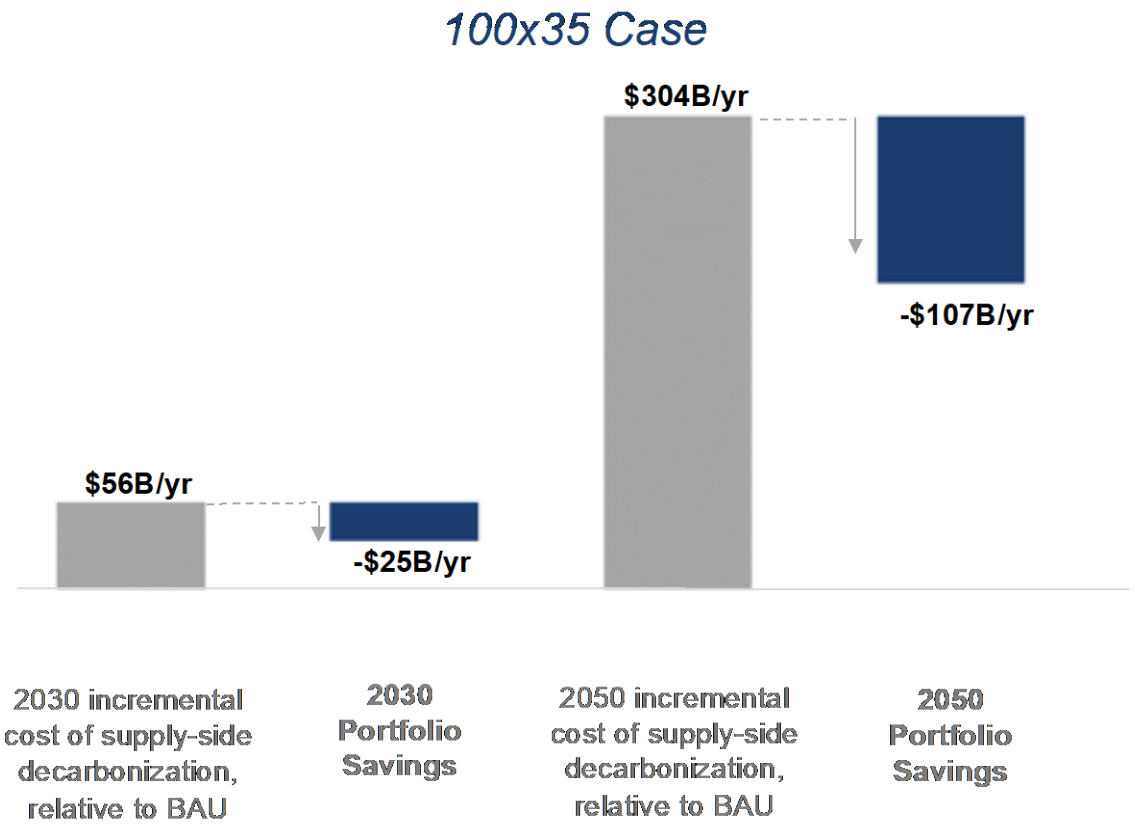
Northwest 2050: Winter peak day with electrification and energy efficiency/demand response impacts



Source: [Langevin et al. (2023)]

Efficiency and flexibility avoid incremental bulk power system costs

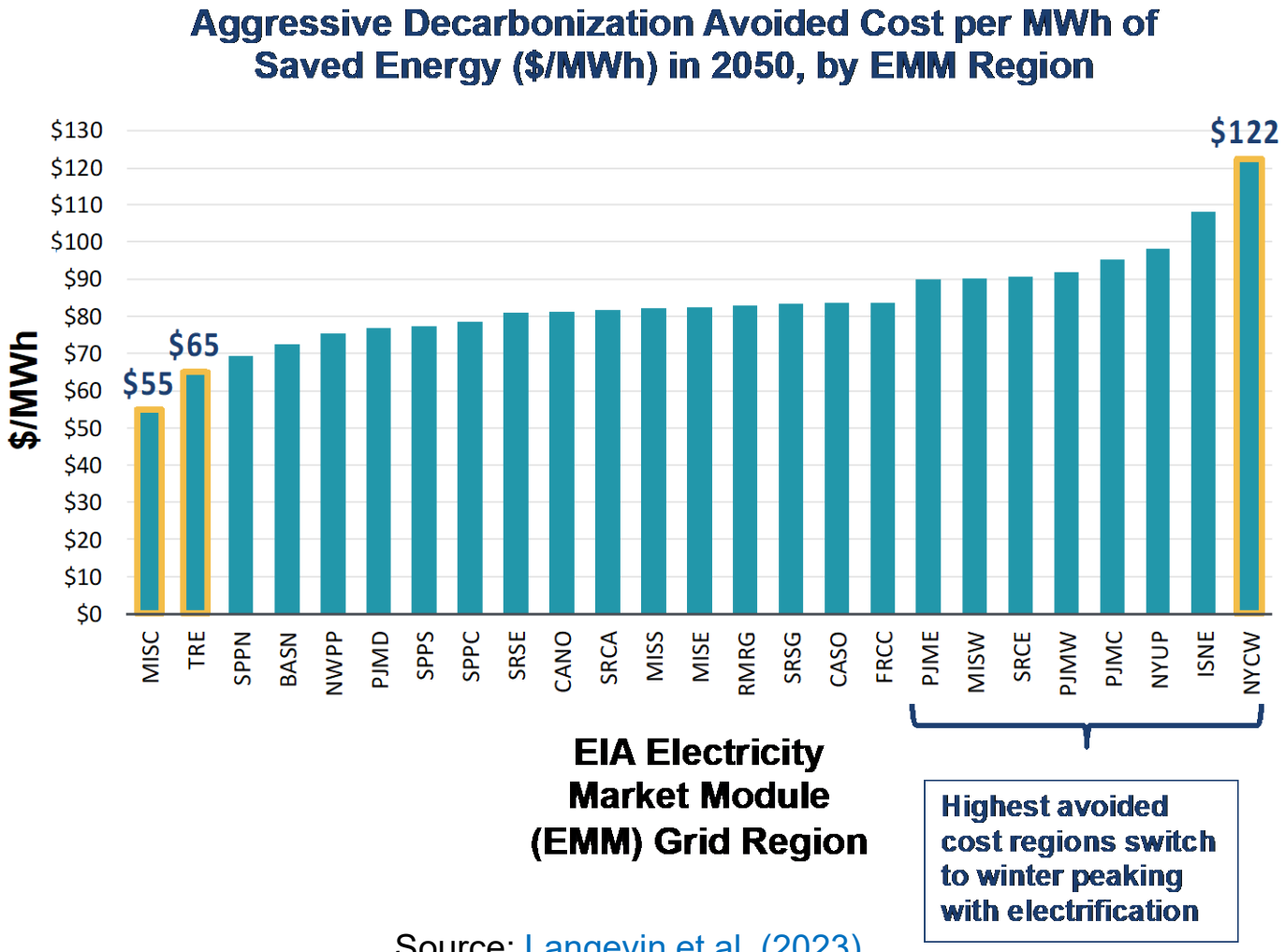
- Significant value for energy efficiency (including the efficiency gains from heat pumps) and demand flexibility to reduce fixed and variable power system costs
- Value is higher in power systems with more aggressive load growth and state goals related to renewable and clean energy sources



Source: Langevin et al. (2023)

There are important regional differences in the impacts of building electrification

- Incremental system costs vary geographically across the US with different regional grid conditions and constraints, with implications for energy efficiency and flexibility value
  - Especially pronounced in systems with winter peak capacity needs
  - Systems with heavily constrained transmission and limited ability to rely on lower cost wind and solar resources also see high efficiency and flexibility value by avoiding more expensive generation

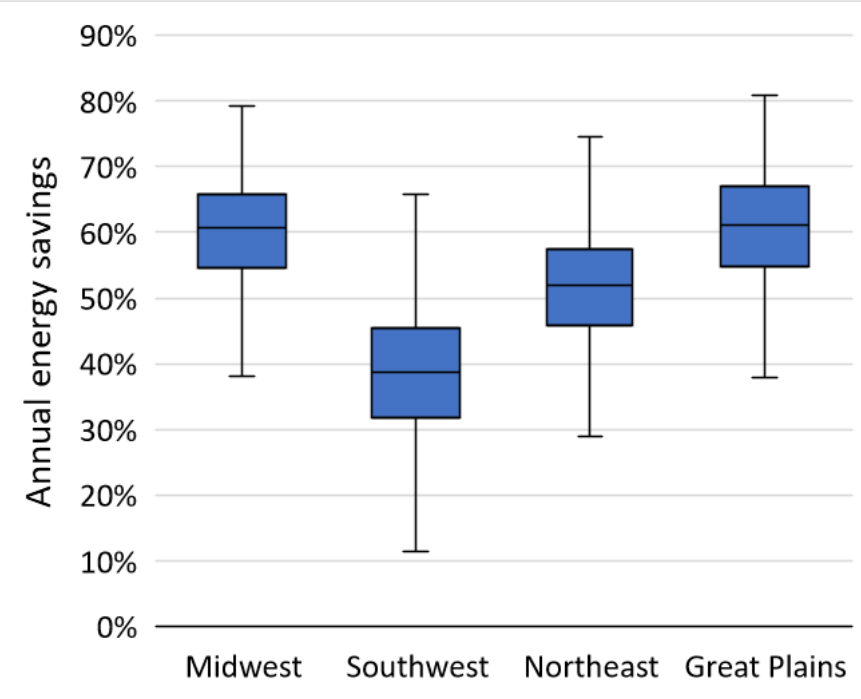


Source: Langevin et al. (2023)

ENERGY MARKETS & POLICY

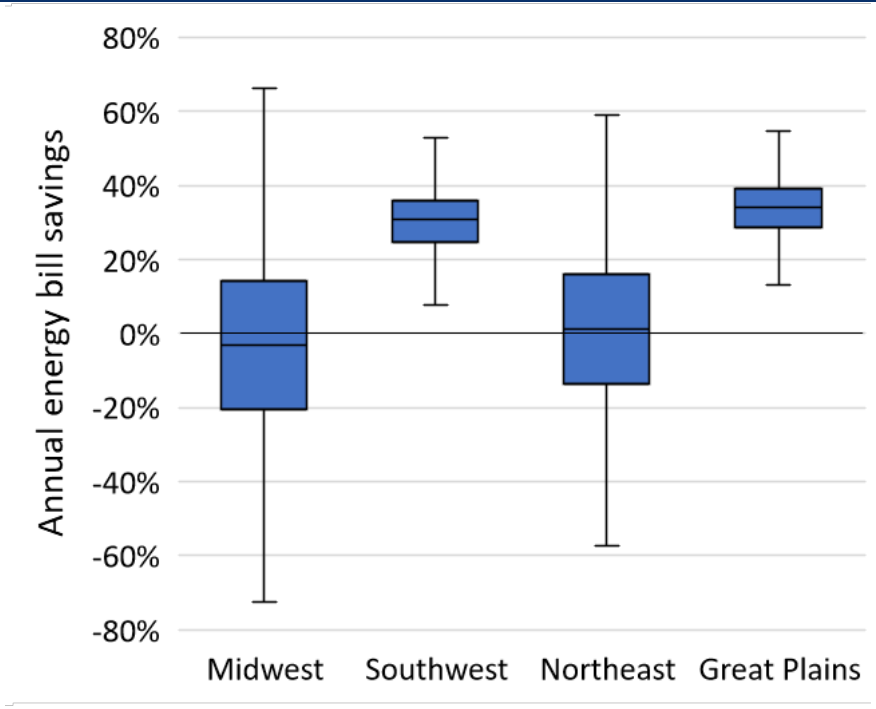
Energy and bill impacts of building electrification investments and efficacy of alternative rate designs

From the customer perspective, building electrification can result in bill increases or decreases



Electrification reduces building *energy* consumption

however…

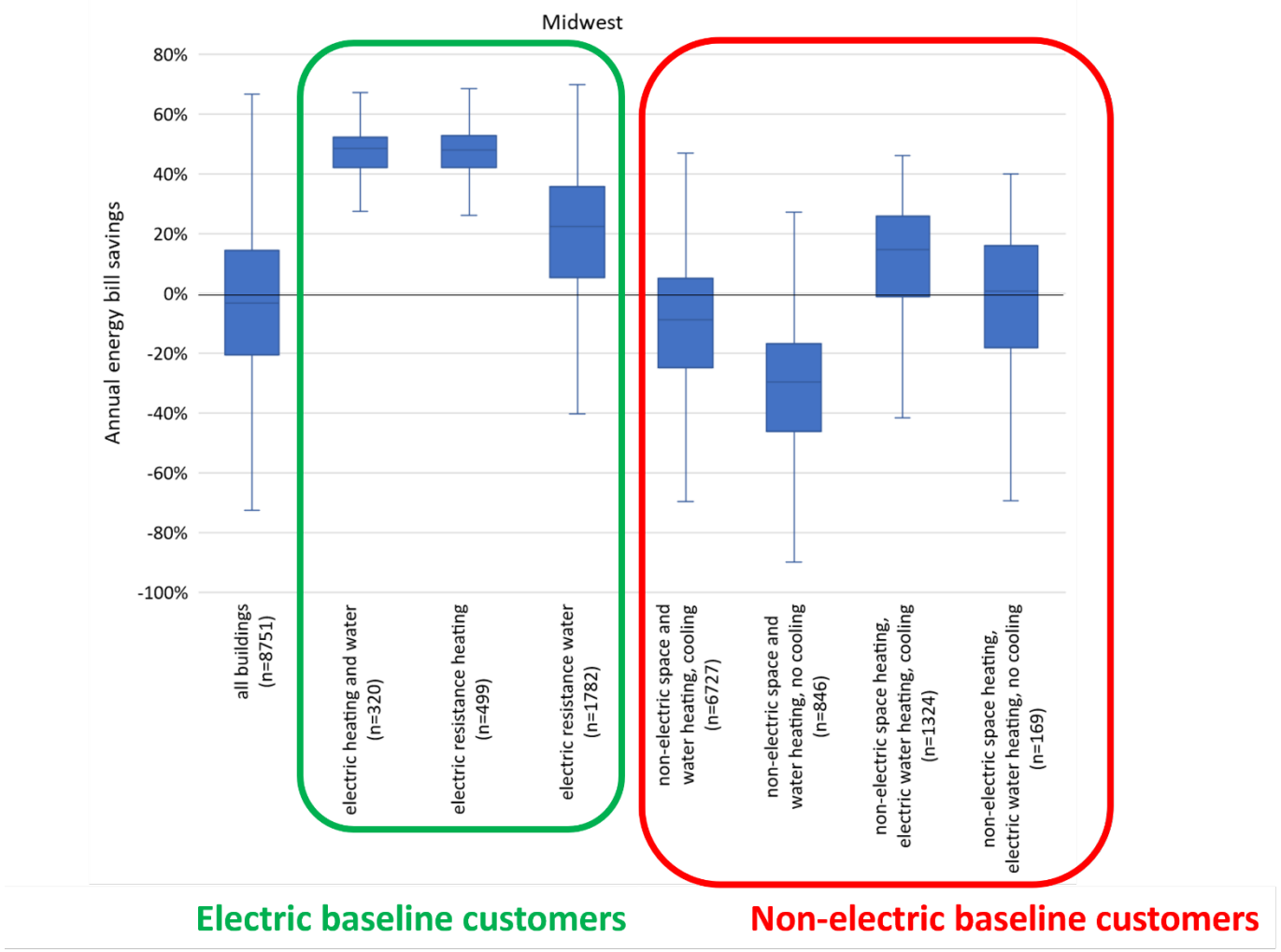


Some customer bills increase largely because of the differential between electricity and fossil fuel prices

Source: Miller et al. (2024)

Customer baseline technologies are a strong determinant of bill changes with electrification

- The distribution of customer bills with electrification is wide
- Climate and baseline building efficiency are important factors
- Whether a customer is replacing electric vs. non-electric technologies is a very strong determinant in bill outcomes



Source: Miller et al. (2024)

Electrification rate design can shift revenue collection from volumetric to fixed charges

- Increasing the fixed component of customer bills (e.g., monthly customer fee) lowers the volumetric energy rate, all else being equal
- A lower volumetric energy rate may mitigate the impacts of increased electricity demand from heat pumps and other electrification technologies (including EVs) on customer bills
- At the same time, reducing the volumetric energy rate may mute customer economic incentives to invest in energy efficiency and distributed solar PV

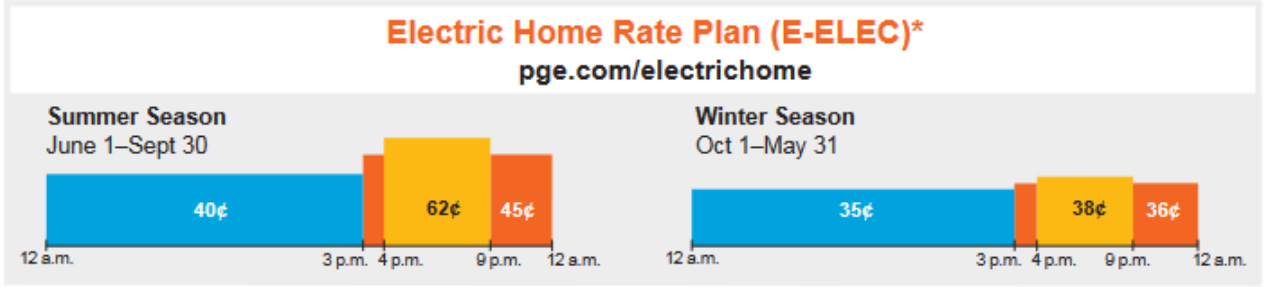
Electric Home (E-ELEC)

A new rate plan to support home electrification

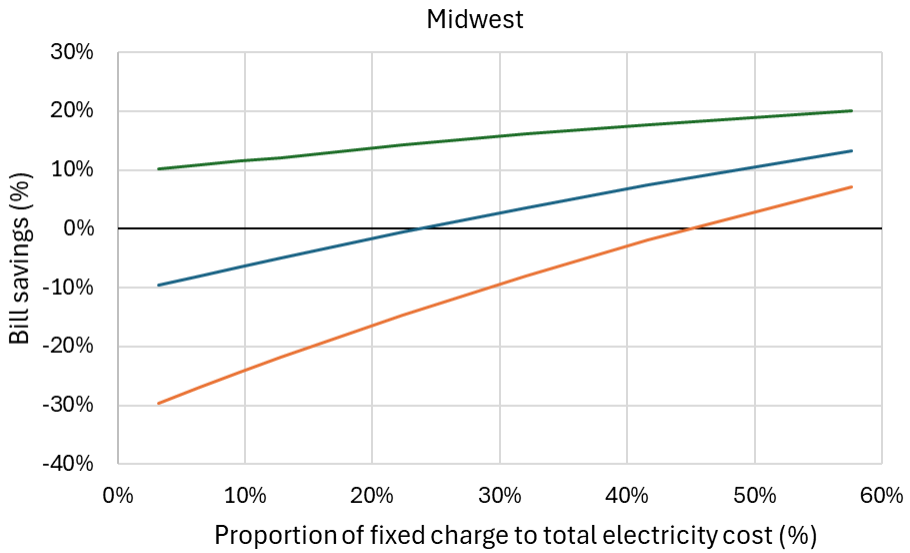
Rate plan highlights

Electric Home is a Time-of-Use rate plan for those that have begun to electrify their home.

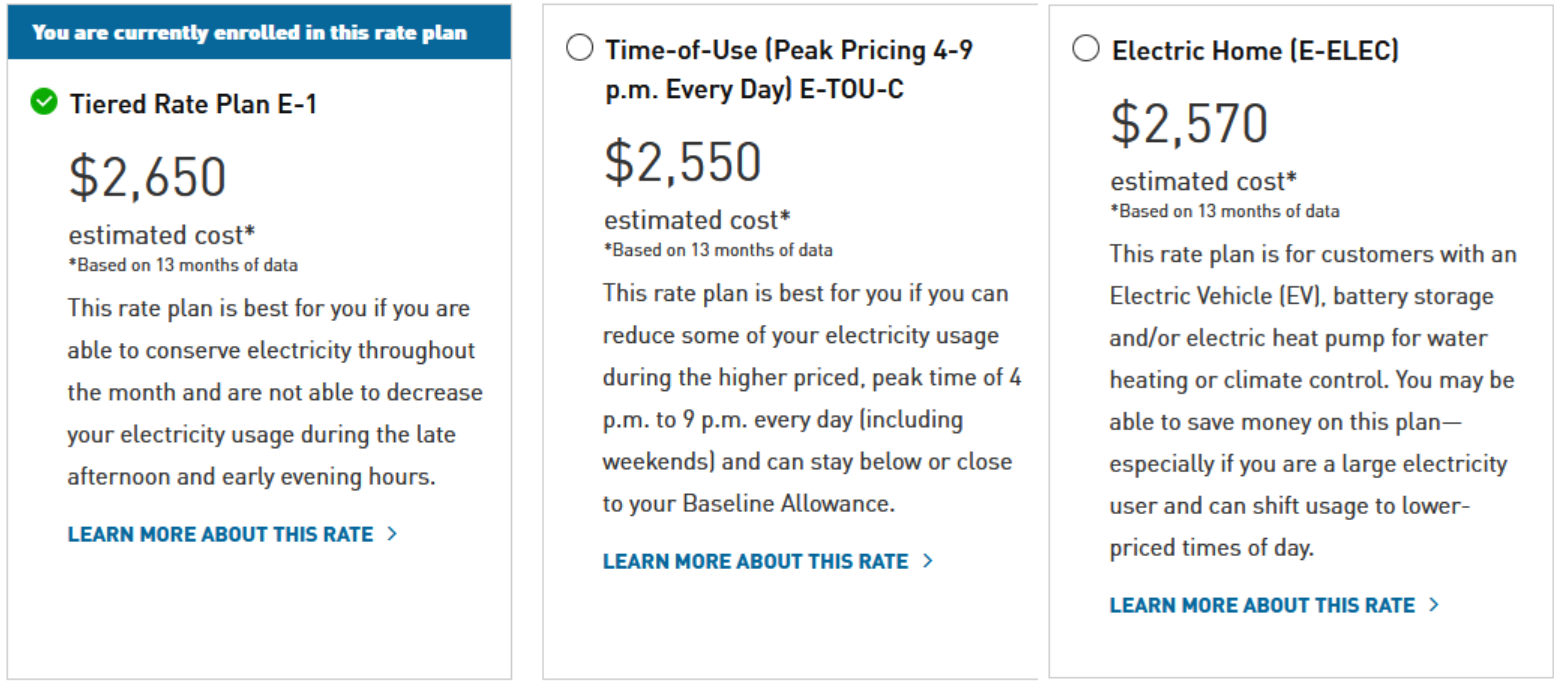
- It includes a $15 per month Base Services Charge which lowers the charges per unit of energy (kWh), on average, compared to other rate plans.
- **You may be able to save money on this rate plan, especially if you are a large electricity user who can shift usage to lower-priced times of day.**
- Your home does not need to be all electric to qualify for this rate plan.



Do electrification rates work as intended?



Source: Miller et al. (2024)



Source: PG&E bill for customer with single-family home, 2 heat pumps, moderate building efficiency

Higher fixed charges

- The distribution of energy bill savings convergences as fixed charges increase
- Fixed charges reduce extreme bill increases due to electrification

Time-varying rates

- May achieve the same intent to reduce bill increases due to electrification and preserve incentives for load shedding and shifting

Individual customer bill impacts vary significantly.

Poll

Which of the following rate design strategies do you think is most likely to balance the needs of utilities, customers, and the grid in the context of load growth?

1. Time-varying rates that reflect temporal variation in electricity costs
2. Increasing fixed charges to reduce the volumetric energy rate
3. Rates for specific electric-load growth technologies (e.g., heat pumps, EVs)
4. Other (please share your ideas in chat)

Customer bill drivers have important implications for building electrification program design and implementation

Electrify buildings in locations with low electricity rates

Target marketing to customers with electric resistance technologies who are likely to experience bill savings and favorable payback times

Educate customers with fossil-fuel baseline technologies (e.g., natural gas heating) or without pre-existing space cooling about the potential financial costs and health and comfort benefits of electrification

Consider additional, non-rate incentives to incentivize heat pump adoption among some customer populations

Balance lowering the volumetric energy rate, either by increasing the fixed charge or other ratemaking decisions, with the incentive to invest in energy efficiency

Resources for more information

- Berkeley Lab's Integrated Distribution System Planning website, including slides and recordings for previous trainings
- Energy Systems Integration Group, Grid Planning for Building Electrication 2024
- S. Murphy, L. Schwartz, C. Reed, M. Gold, and K. Verclas, *State Energy Offices' Engagement in Electric Distribution Planning to Meet State Policy Goals*, National Association of State Energy Officials, 2023
- J. Carvallo and L. Schwartz, *The use of price-based demand response as a resource in electricity system planning*, Berkeley Lab, 2023
- J. Keen, E. Pohl, N. Mims Frick, J.P. Carvallo and L. Schwartz, *Duke Energy's Integrated System and Operations Planning: A comparative analysis of integrated planning practices*, Grid Modernization Laboratory Consortium, 2023
- Berkeley Lab, Pacific Northwest National Lab and NARUC, Peer-Sharing Webinars for Public Utility Commissions on Integrated Distribution System Planning, 2023
- N. Frick, S. Price, L. Schwartz, N. Hanus and B. Shapiro, *Locational Value of Distributed Energy Resources*, Berkeley Lab, 2021
- Langevin, J. et al. 2023. U.S. Building Sector Decarbonization Scenarios to 2050.
- Miller, C., A. Satchwell, and J. Kahn-Lang. 2024. The Customer Bill Impacts of Efficient Building Electrification.
- Wilson, et al. 2024. Heat pumps for all? Distributions of the costs and benefits of residential air-source heat pumps in the United States.

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