

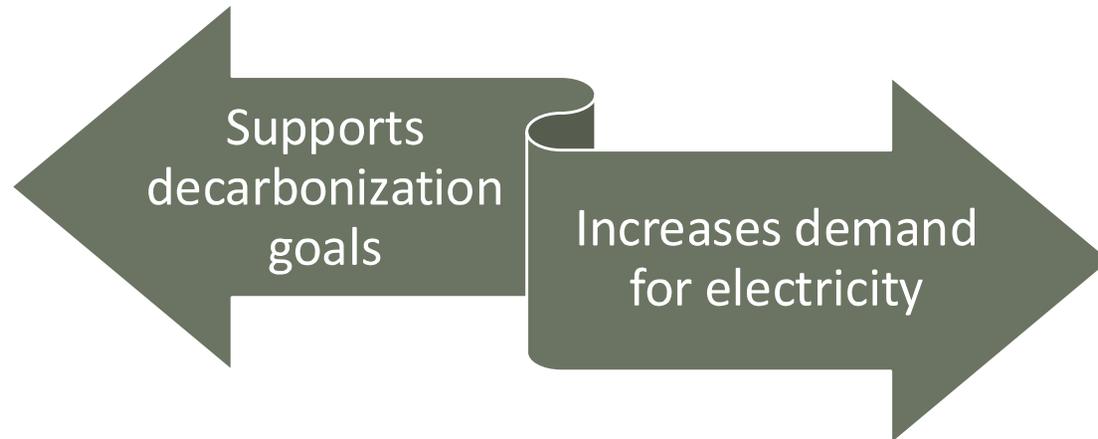


Climate, Grid, and Customer: Three Dimensions of Heat Pump Impacts

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Why Should We Care?

Residential energy use contributes to about 20% of total greenhouse gas (GHG) emissions in the United States, so residential building electrification is key to meeting climate goals.



Goldstein, B., D. Gounaridis, and J.P. Newell. 2020. "The Carbon Footprint of Household Energy Use in the United States." *Sustainability Science* 117 (32): 19122-19130.

Program Overview

 Projects completed in California's TECH Initiative between July 2021 and July 2023

 Participants receive heat pump HVACs or heat pump water heaters (HPWHs)

 Vast majority of homes (n~10k) were single family with natural gas heat

 Over 1 in 4 participating homes were net metered due to solar PV

 Key outcomes include energy, peak demand, GHG, and bill impacts

Methods: Data and Sample Selection

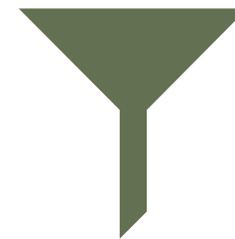


Data Review and Preparation

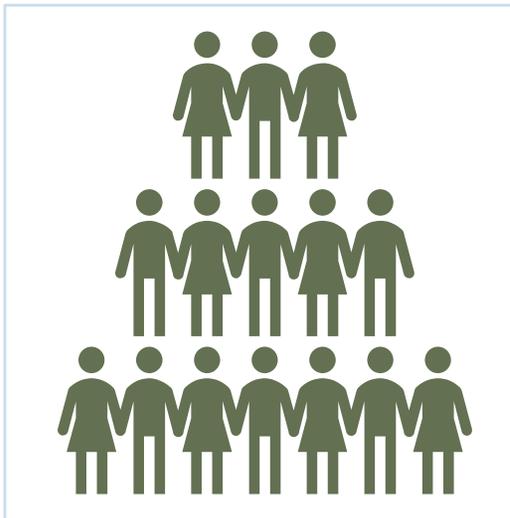
- Hourly electric
- Monthly natural gas
- Program tracking
- Customer and site attributes

Sample Selection

- Key requirements: availability of energy consumption data and ability to link incentive claim to consumption data
- Consideration: Uncertainty about gas account closures



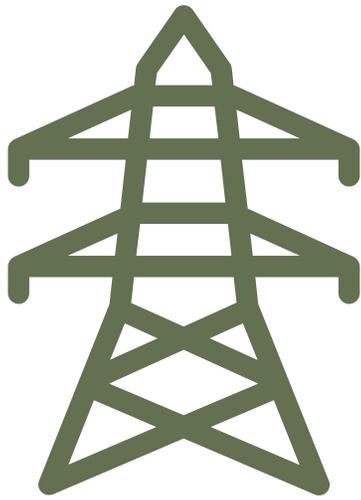
Methods: Comparison Group Design



Matched nonparticipant comparison group

- Separate comparison groups for electric and natural gas analyses
- Exact matching based on key customer attributes > probabilistic matches based on consumption
- Considerations: Non-program impacts on consumption, rolling program enrollment

Methods: Energy Impact Estimation



Gas and Electric Impacts

- Fixed-effects difference-in-difference regression modeling
- Weather-normalized impacts
- Seasonal and annual impacts for both fuels
- Hourly impacts for electricity
- Considerations: Rolling program enrollment, weather-sensitive measures, time-varying electric grid impacts

Methods: Non-Energy Impact Estimation

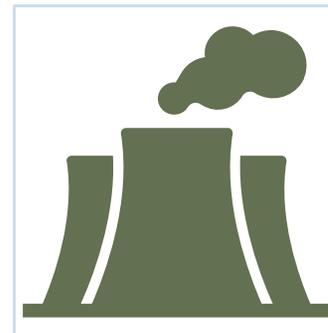


Bill Impacts

- Change in electric and natural gas bills
- Net change in energy bills
- Based on TECH energy impacts and participant energy tariffs at time of participation
- Accounts for time-varying rates, net metering tariff, and low-income discounts

GHG Emissions

- Change in net emissions across fuels
- Based on time-varying marginal emissions factors
- Estimated by climate zone and statewide
- Consideration: Impacts vary by time and space



On average participants **reduced** natural gas consumption by **38%** & **increased** electric consumption by **17%**.

This translates to reductions in overall energy use and GHG emissions.

TECH Initiative Annual Per-Participant Energy & GHG Emissions Impacts

Impact Outcome	Units	Baseline	Impact	Lower CI	Upper CI	% Impact
Electric	kWh	8,421	1,451*	1,315	1,587	17.2%
Natural Gas	Therms	432	-165*	-172	-158	-38.2%
Total Energy	mmBTu	71.9	-11.55*	-12.72	-10.39	-16.1%
Total GHG Emissions	tonnes CO2-e	4.26	-0.73*	-0.77	-0.69	-17.2%

Note: Normal weather estimates based on fixed-effects D-in-D panel regression analysis of TECH Initiative participant and matched nonparticipant electric interval data. (*)Results are statistically significant at 95% confidence level.



TECH Initiative Energy Impacts by Fuel and Season

Season	Electric Impacts		Gas Impacts		Total Energy Impacts	
	Average Impact (kWh)	% Impact	Average Impact (therms)	% Impact	Average Impact (MMBtu)	% Impact
Summer	-100*	-2.9%	-17*	-25.6%	-2.00*	-11.1%
Winter	1,215*	41.6%	-101*	-41.2%	-5.98*	-17.3%
Shoulder	336*	15.9%	-47*	-39.1%	-3.57*	-18.5%

Note: Normal weather estimates based on fixed-effects D-in-D panel regression analysis of TECH Initiative participant and matched nonparticipant electric interval data. Summer is defined as June through September, winter as December through March, and shoulder as April, May, October, and November. (*) Results are statistically significant at 95% confidence level.

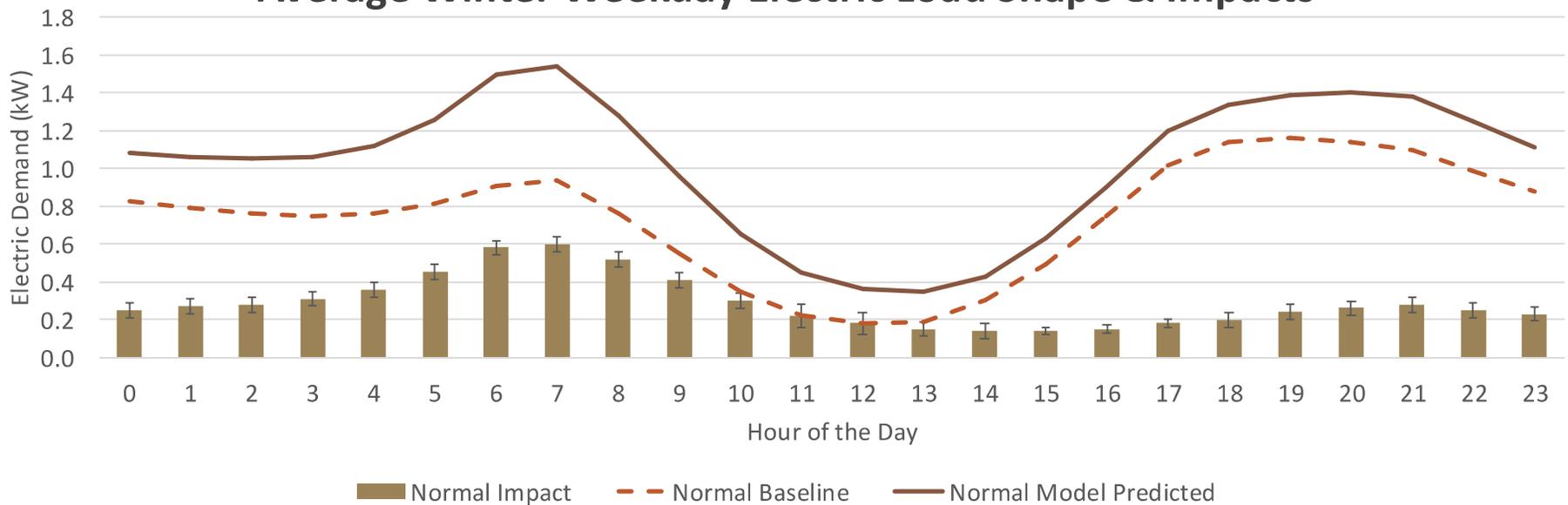
Gas consumption decreases in all seasons.

Electric consumption increases in winter & decreases in summer for the average participant.



Electrification of space heating leads to a significant increase in electric consumption during all hours of the day in winter and creates a new winter morning peak

Average Winter Weekday Electric Load Shape & Impacts

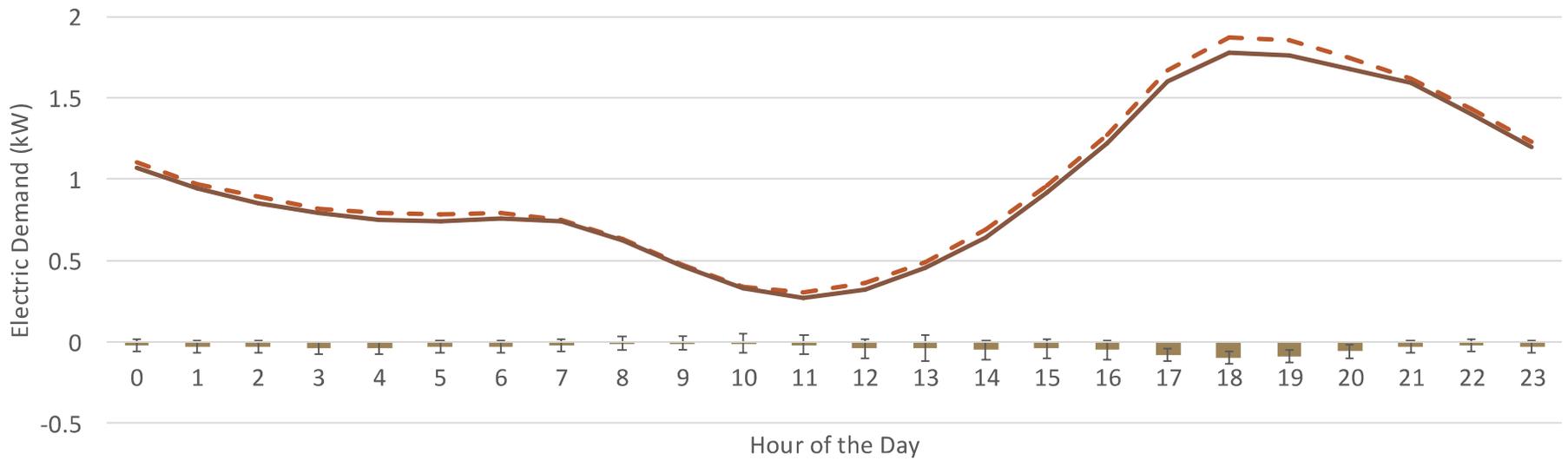


Note: Normal weather estimates based on fixed-effects D-in-D panel regression analysis of TECH participant and matched nonparticipant interval electricity consumption data. Error bars show 95% confidence intervals.



The TECH Initiative had minimal impacts on summer demand but there is substantial variation by climate zone. Among participants, peak consumption generally remains in the summer afternoon period.

Average Summer Weekday Electric Load Shape & Impacts



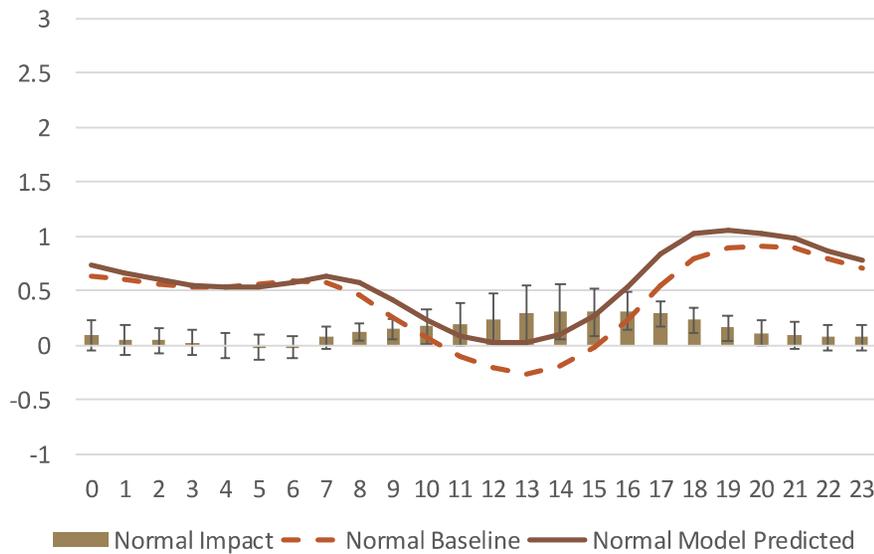
■ Normal Impact - - Normal Baseline — Normal Model Predicted

Note: Normal weather estimates based on fixed-effects D-in-D panel regression analysis of TECH participant and matched nonparticipant interval electricity consumption data. Error bars show 95% confidence intervals.

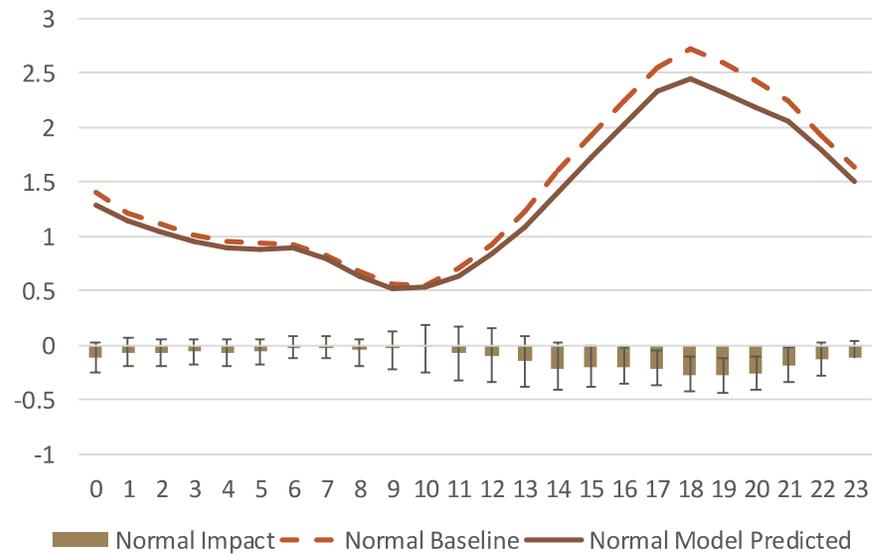


Cooler climate zones tend to experience significant increases in electric demand on summer days, while warmer climate zones may see a small demand reduction in peak hours

AVERAGE SUMMER WEEKDAY:
NORTHERN CALIFORNIA (CLIMATE ZONE 2)



AVERAGE SUMMER WEEKDAY:
SOUTHERN CALIFORNIA (CLIMATE ZONE 10)



Note: Normal weather estimates based on fixed-effects D-in-D panel regression analysis of TECH participant and matched nonparticipant interval electricity consumption data. Error bars show 95% confidence intervals.



The average participant does not experience a statistically significant change in annual energy bills, but there are meaningful seasonal changes

Change in Customer Energy Bills by Fuel & Season

Season	Electric Estimate	Natural Gas Estimate	Net Change		
			Annual Change	Lower CI	Upper CI
Winter	\$316	-\$222	\$94*	\$79	\$108
Summer	-\$33	-\$24	-\$56*	-\$74	-\$39
Shoulder	\$50	-\$99	-\$49*	-\$62	-\$36
Overall	\$333	-\$344	-\$11	-\$37	\$15

Note: Normal weather estimates based on fixed-effects D-in-D panel regression analysis of TECH participant and matched nonparticipant monthly natural gas consumption data and interval electricity consumption data, combined with utility rates. Summer is defined as June through September, winter as December through March, and shoulder as April, May, October, and November. (*) Results are statistically significant at 95% confidence level.



As usual, it does depend...

*An overview of
important and
interesting differences
observed in this study*

Central heat pumps have the smallest electric impacts, even though these sites have the greatest average baseline electric usage

Participants receiving HPWHs tend to experience the largest decrease in energy bills of all subgroups observed

Customers in cooler climate zones experience a much larger increase in electric consumption than those in warmer climate zones

Summer peak period consumption may increase or decrease among participants depending on the climate zone

Low-income customers experience much smaller growth in electric energy consumption compared to market rate customers

Net metered participants experience significant annual energy bill savings nearly three times that of a non-net metered participant

Key Takeaways

Climate

- Consistent reduction in GHG emissions statewide and across climate zones
- Heat pump measures are also more energy efficient than baseline measures

Grid

- Summer peak demand impacts sensitive to cooling needs/baseline prevalence
- Persistent increase in winter demand with a new morning winter peak

Customer

- Negligible change in average energy bills, on average
- Significant changes in seasonal energy bills
- Substantial variation by measure, geography, customer subgroup

Summary

Our project is one of many establishing a framework for how to extend traditional energy efficiency evaluation methods to a decarbonization framework.

- Multi-fuel analysis
- Seasonal impacts
- Hourly electric impacts
- Non-energy impacts are key
- Inclusion of participants with solar/net metered is critical

We can learn a lot from California's TECH Initiative, & there is even more to glean from future research:

- Colder or warmer climates
- Pre-existing air conditioning status
- Different heat pump technologies (cold climate, variable speed compressor)
- Solar + battery (or other DERs)
- Multi-family housing
- "All-electric" participants
- Variation in bill impacts with different rates

We hope you will build on our work!

Check out our IEPEC paper



Read the full evaluation report



Feel free to contact the study team:



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Prabhat Gautam



Dr. Ellen Steiner

