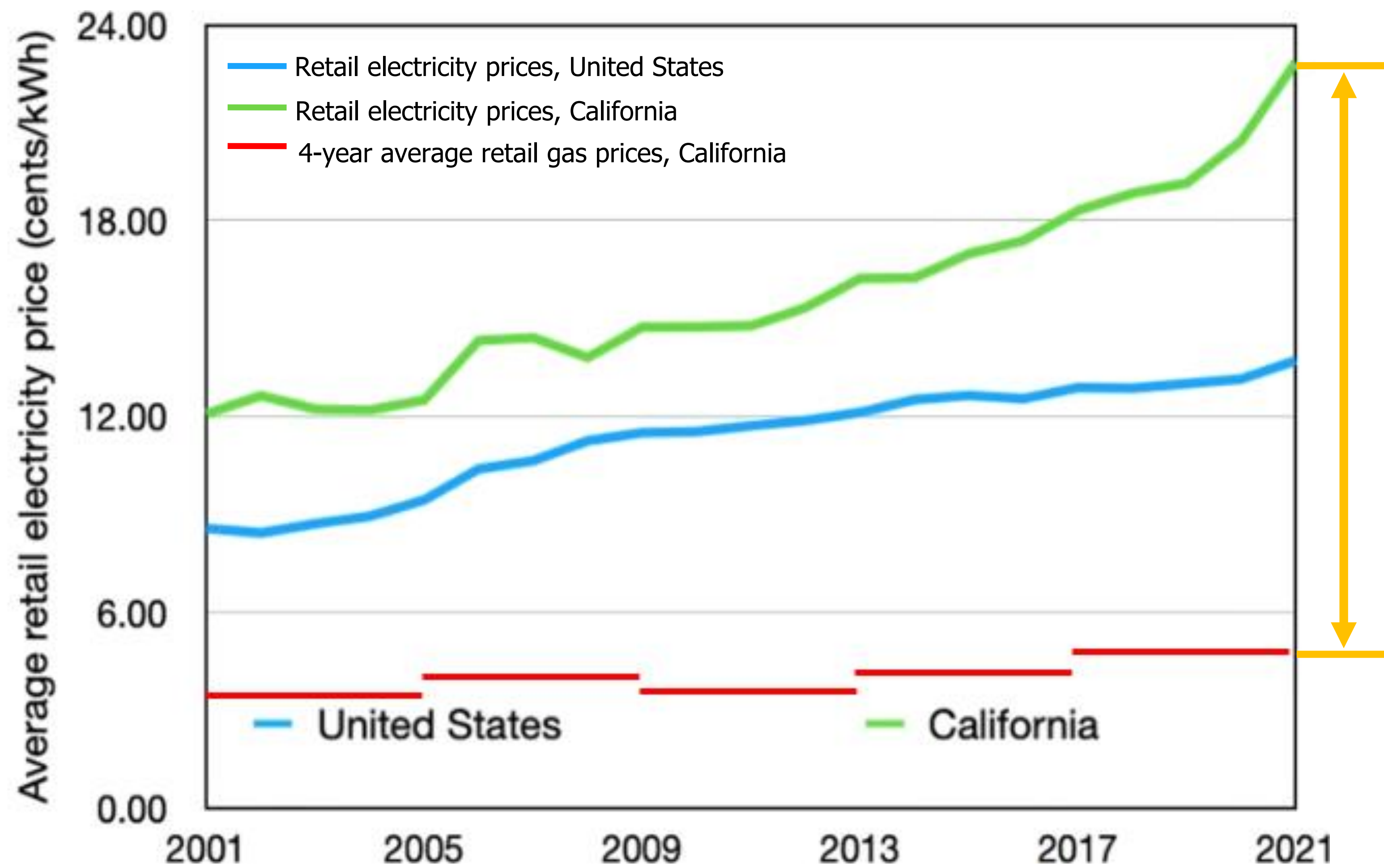# Measuring the Distributional Impacts of Residential Electrification

An empirical analysis from metered data
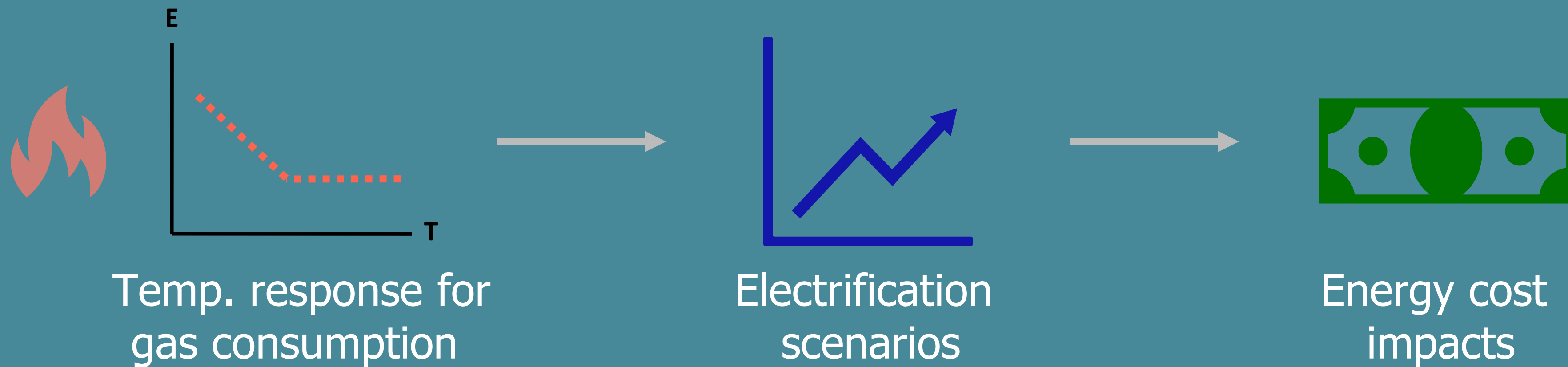in Northern California

Cristina Crespo Montañés | cristina_crespo@berkeley.edu

Source: Adapted from Borenstein et al., "Designing Electricity Rates for An Equitable Energy Transition", Energy institute Working Paper, 2021, and U.S. Energy Information Administration.
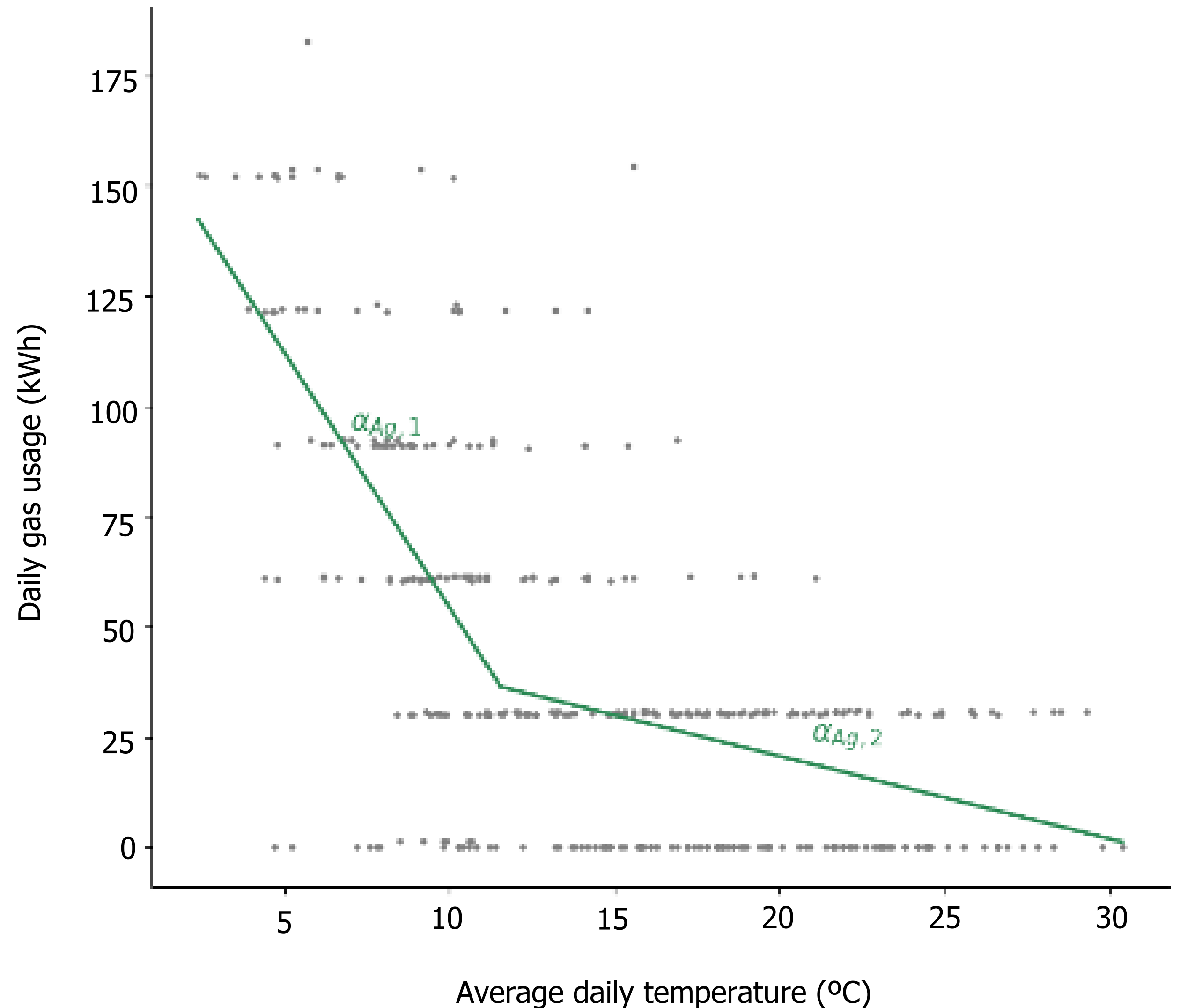
Methods

Temp. response for gas consumption

Electrification scenarios

Energy cost impacts

Identifying gas heating homes

- Use heuristics to determine whether homes are heating with gas.

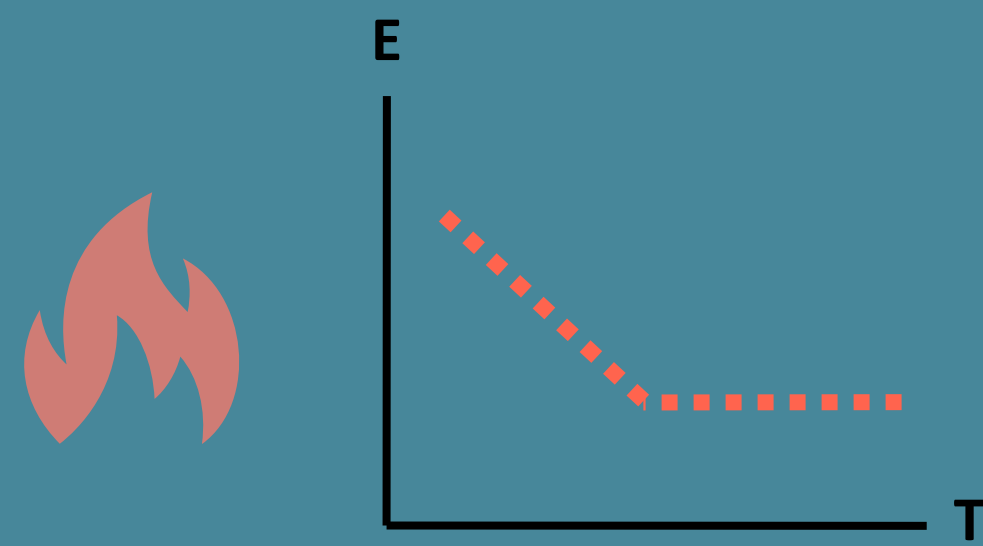- 73% of gas connected homes are using natural gas for heating

Converting gas to electric heating

- Use heating degree days to convert *annual* gas heating demand to *daily*.

- Generate hourly electric heating demand profiles for heat pumps adoption in homes using NREL's End-Use Load Profiles.
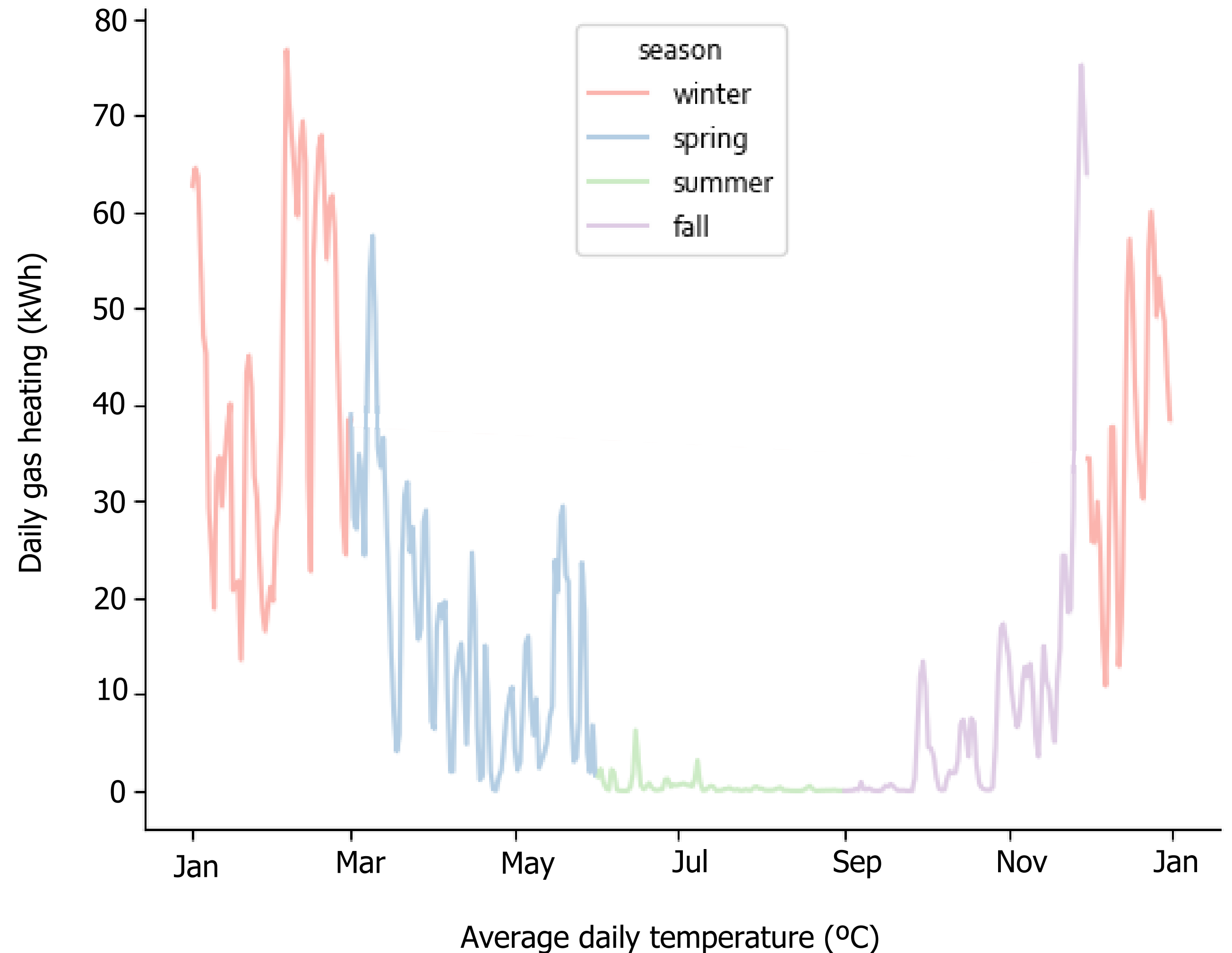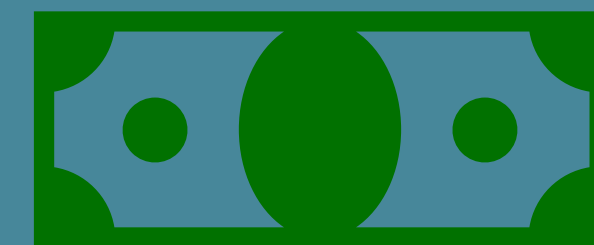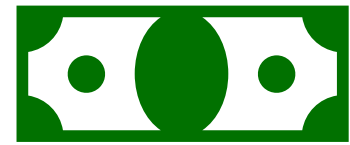
Results

Temp. response for gas consumption

Electrification scenarios

Energy cost impacts

Bill impacts of heat electrification

- Increase in annual energy bills with current default rates and TOU electricity rates, with increasing their energy bills about 6%.

- Current income-based fixed charge rate proposals reduce annual bills by 9% (high income) to 12% (low and moderate income).
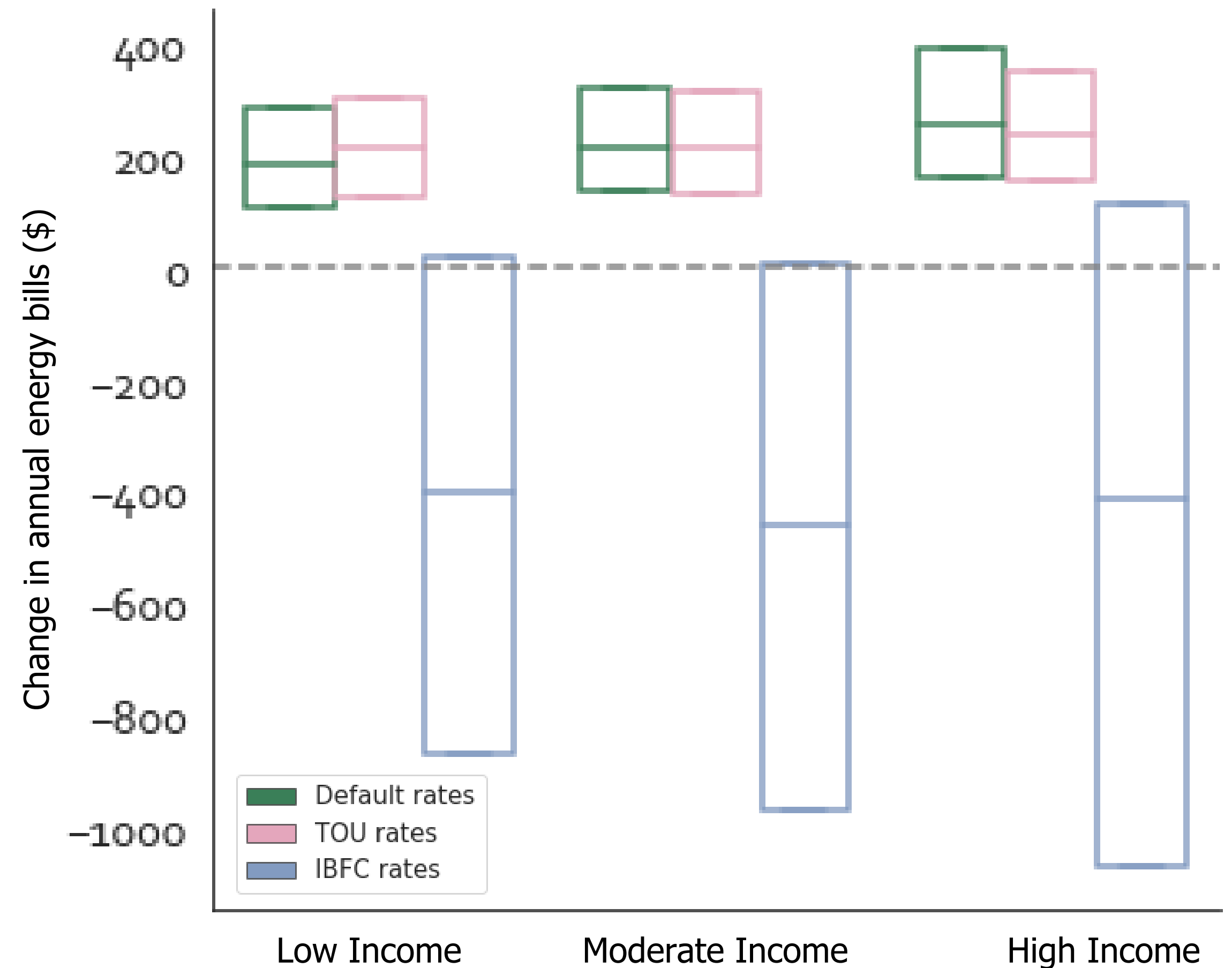
Bill impacts of heat electrification
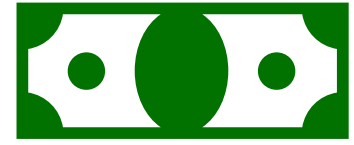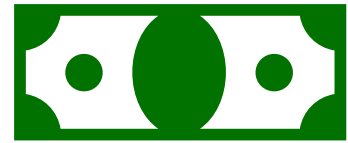
- 10% point reduction in number of homes that are considered energy burdened if IBFC rates used.
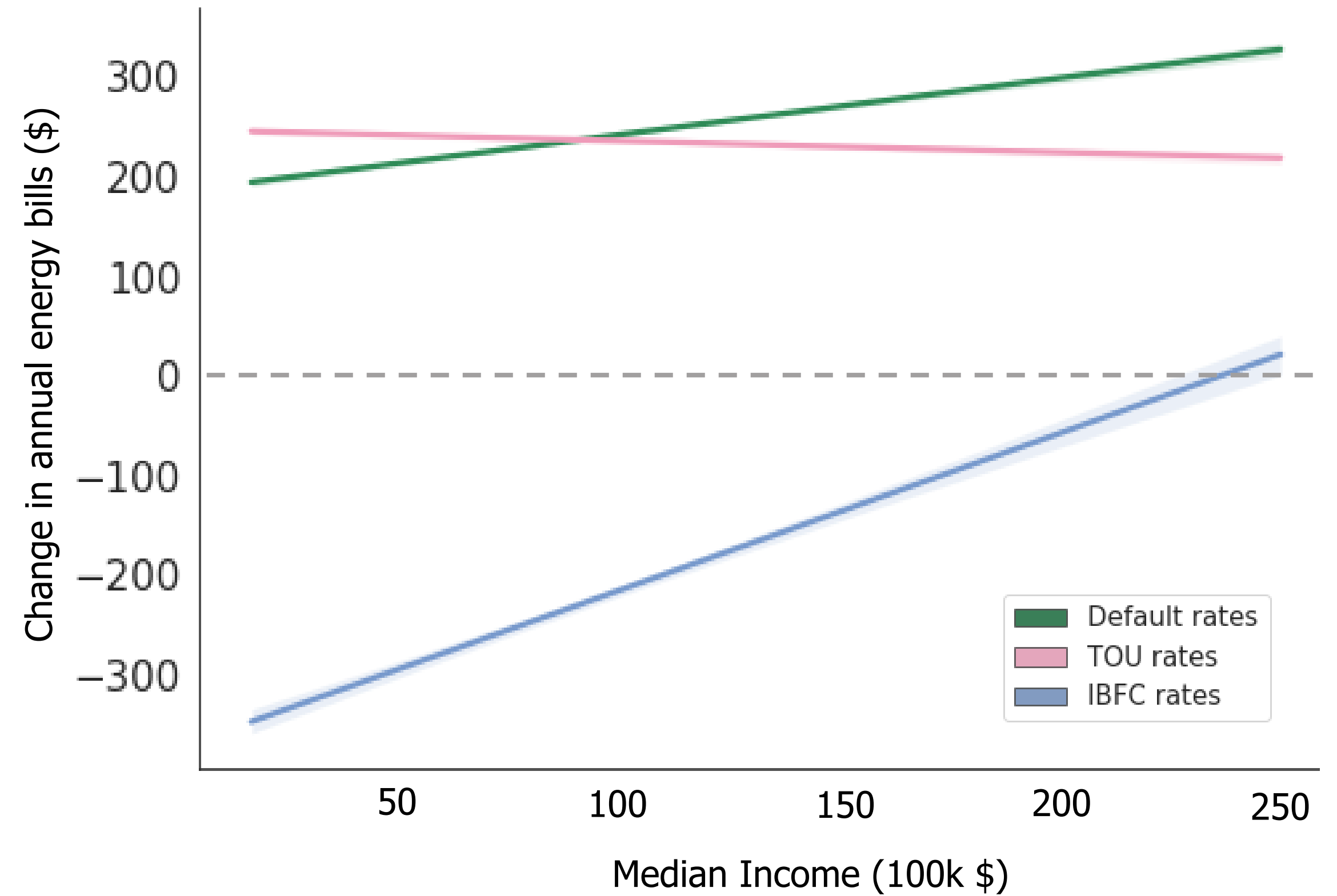
NPV impacts of heat electrification

- **Under current rate structures**, the vast majority of households in the PGE service territory would not find it economic to install a heat pump for space heating.

- Proposed rate reforms that reduce variable electricity costs fully change this picture.
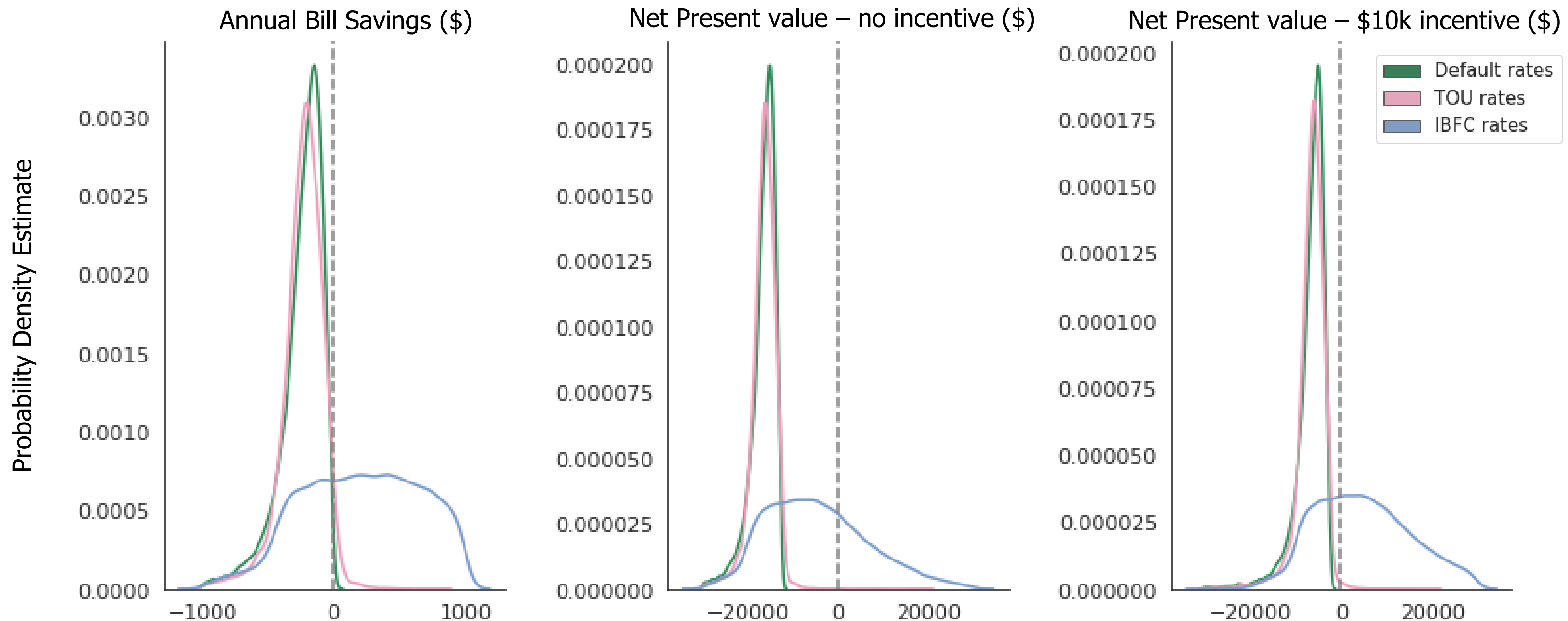
Thank you

Cristina Crespo Montañés | cristina_crespo@berkeley.edu

BECC Conference | Nov 2023

Methods in detail

Electricity consumption analysis

Elec. metered data → Fit piece-wise linear function for elec load
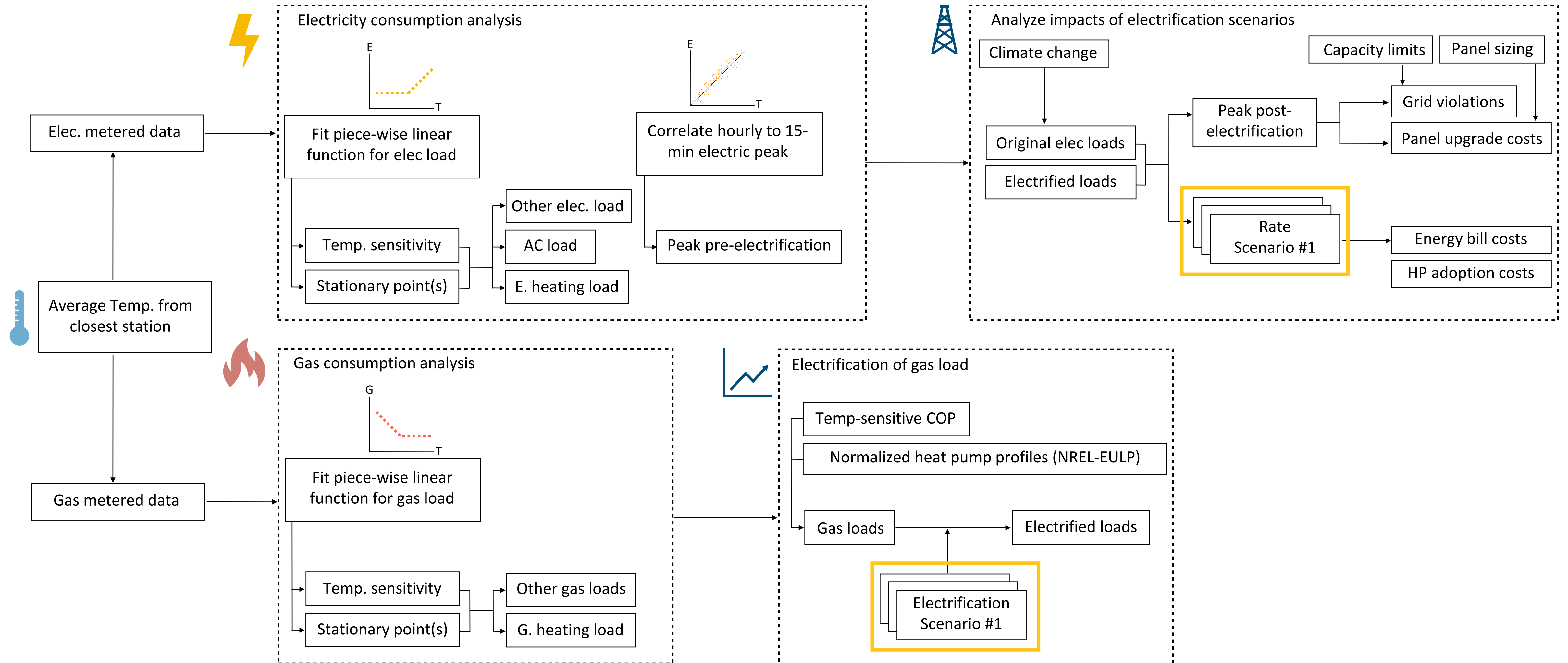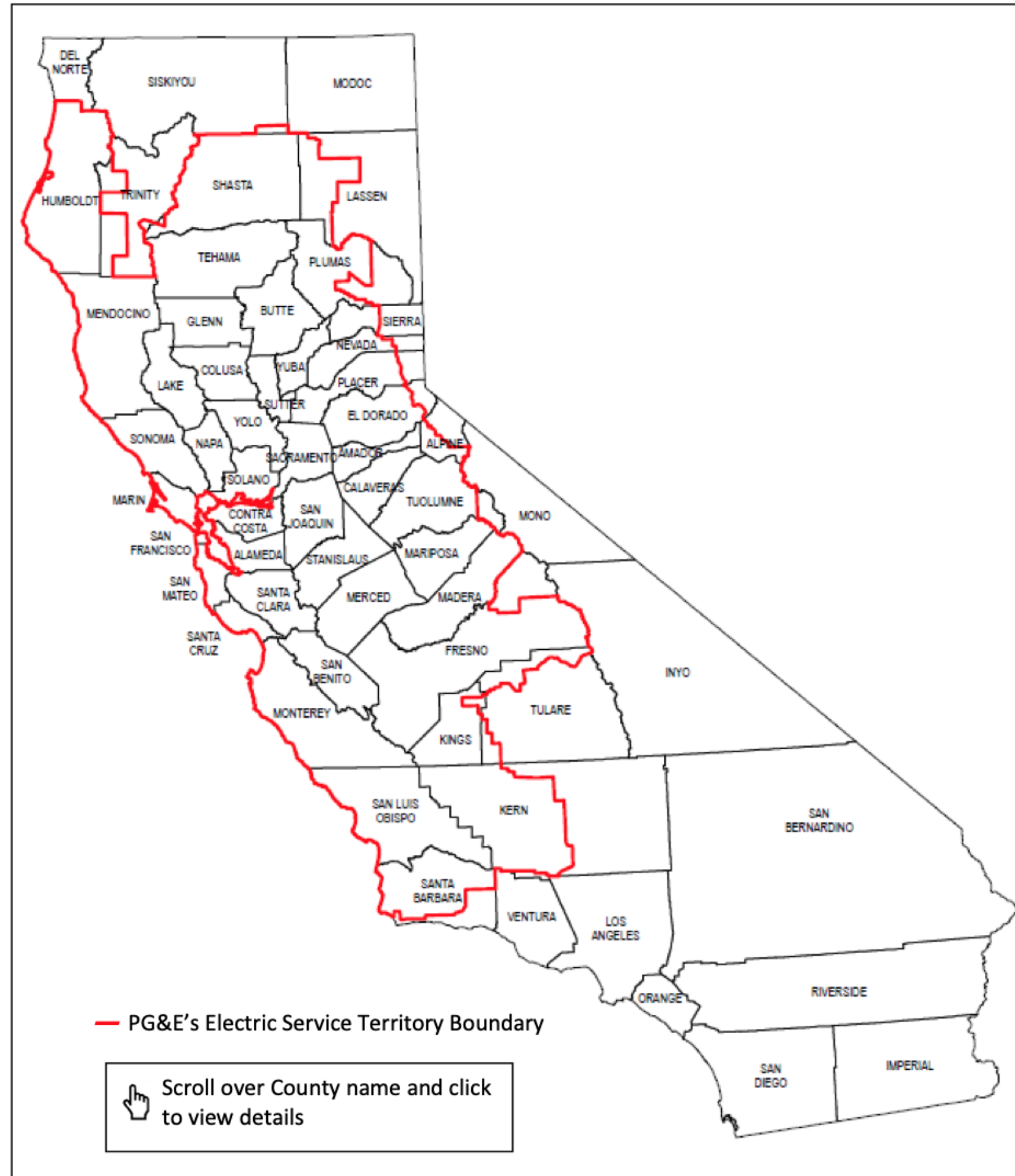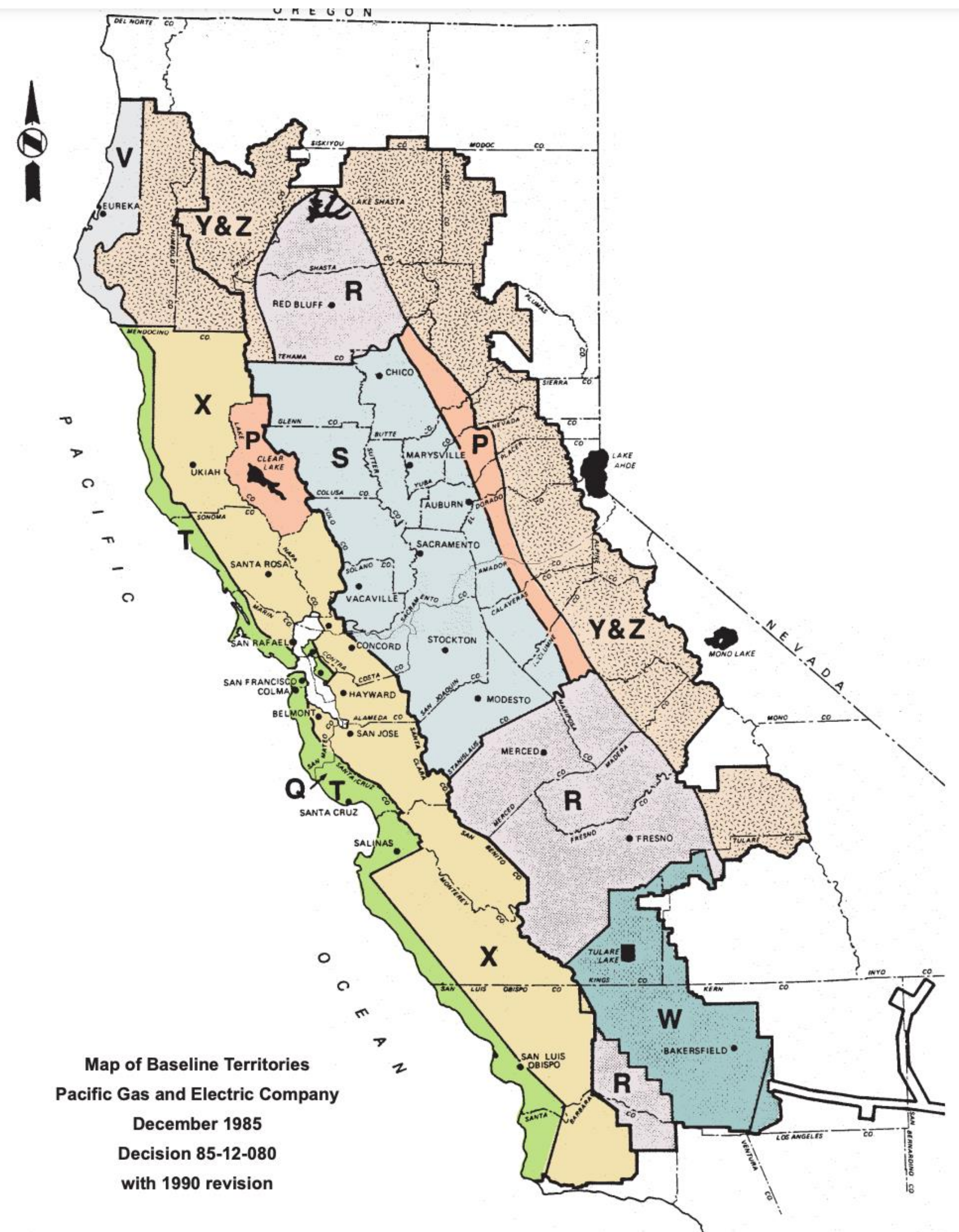
Fit piece-wise linear function for elec load → Temp. sensitivity, Stationary point(s)

Temp. sensitivity / Stationary point(s) → Other elec. load, AC load, E. heating load

Correlate hourly to 15-min electric peak → Peak pre-electrification

Gas consumption analysis

Gas metered data → Fit piece-wise linear function for gas load

Fit piece-wise linear function for gas load → Temp. sensitivity, Stationary point(s)

Temp. sensitivity / Stationary point(s) → Other gas loads, G. heating load

Average Temp. from closest station

Electrification of gas load

Temp-sensitive COP

Normalized heat pump profiles (NREL-EULP)

Gas loads → Electrified loads

Electrification Scenario #1

Analyze impacts of electrification scenarios

Climate change → Original elec loads

Original elec loads / Electrified loads → Peak post-electrification

Capacity limits, Panel sizing → Grid violations, Panel upgrade costs

Peak post-electrification → Grid violations, Panel upgrade costs

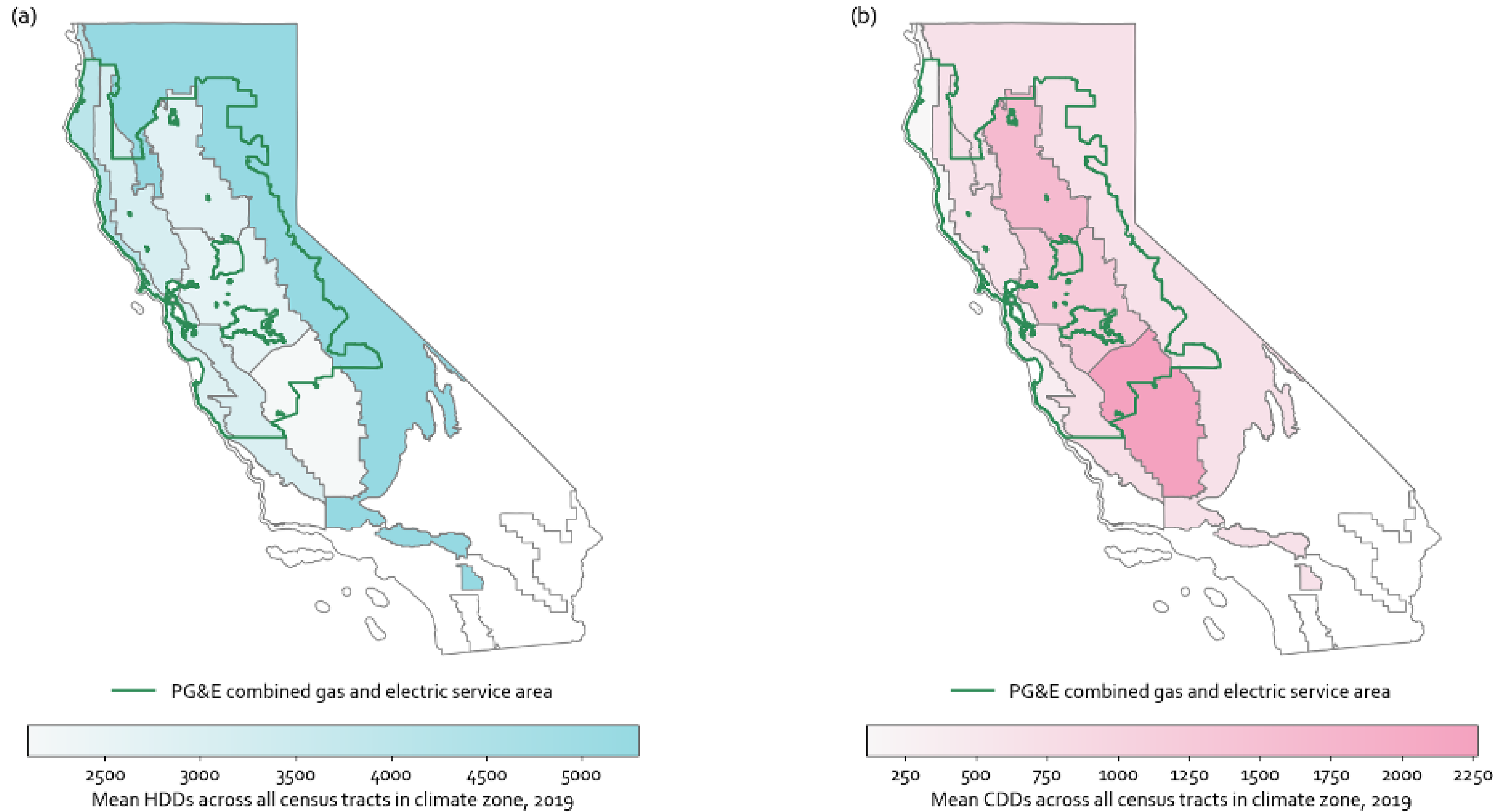Rate Scenario #1 → Energy bill costs, HP adoption costs

Study area

PG&E's Electric Service Territory

PG&E's Gas Service Territory

PGE rate zones

Map of Baseline Territories
Pacific Gas and Electric Company
December 1985
Decision 85-12-080
with 1990 revision

Climate zones, heating and cooling

Map of California showing boundaries of PG&E combined gas and electric service area as well as boundaries of CEC building climate zones, with mean 2019 (a) heating degree days (HDDs) and (b) cooling degree days (CDDs) across all census tracts for each climate zone that overlaps with PG&E's combined service area

Impacts of heat electrification: all climate areas
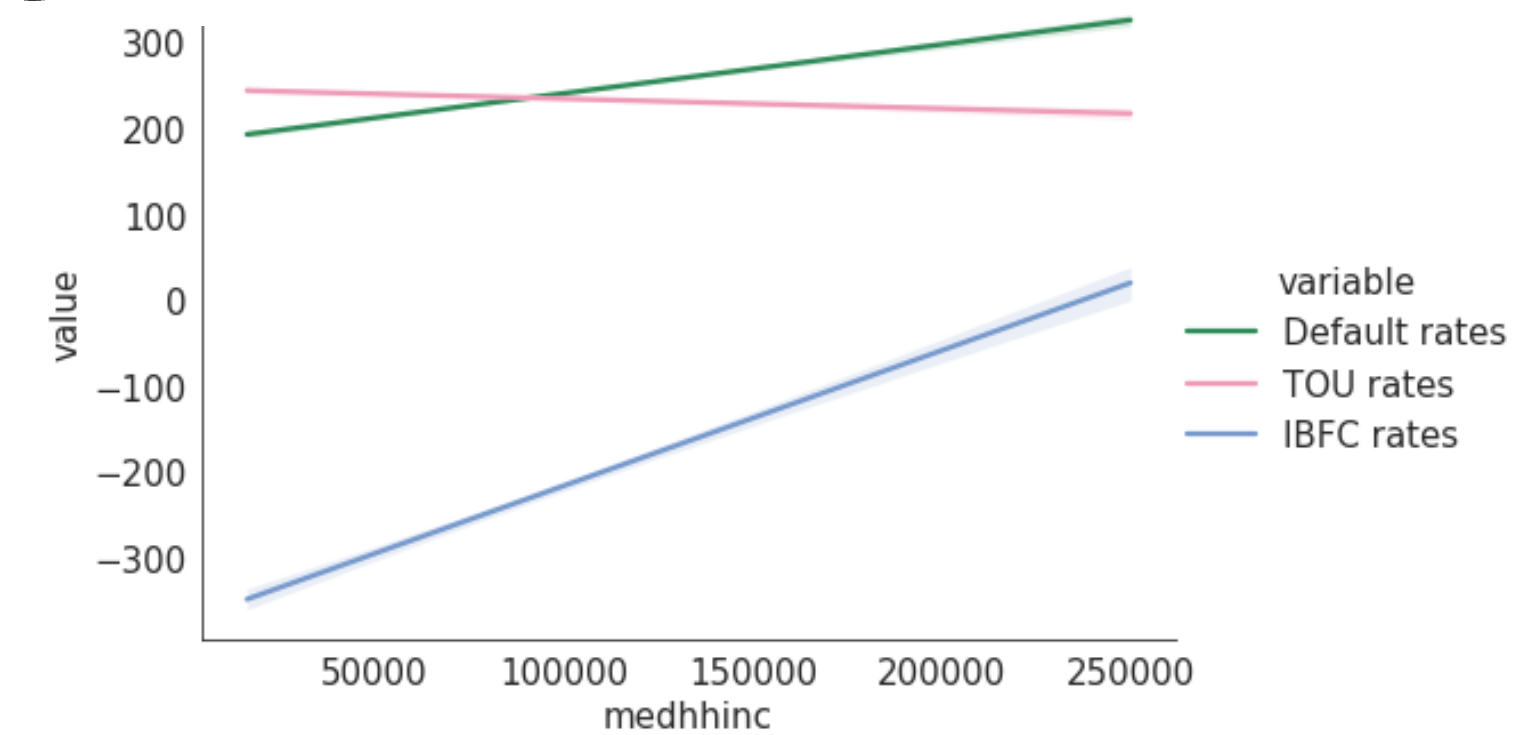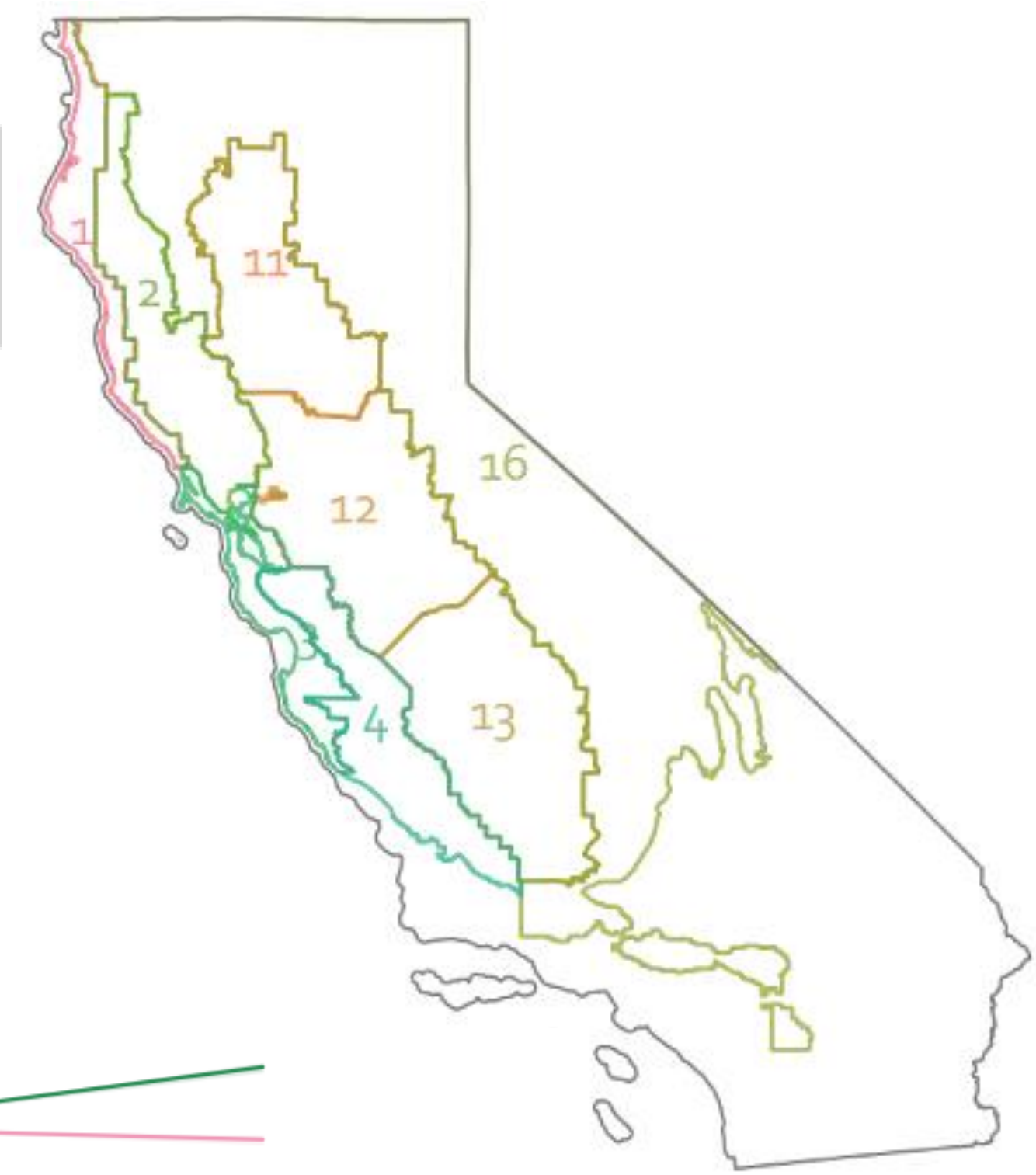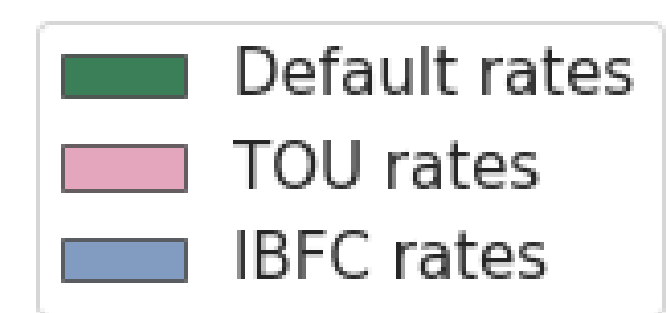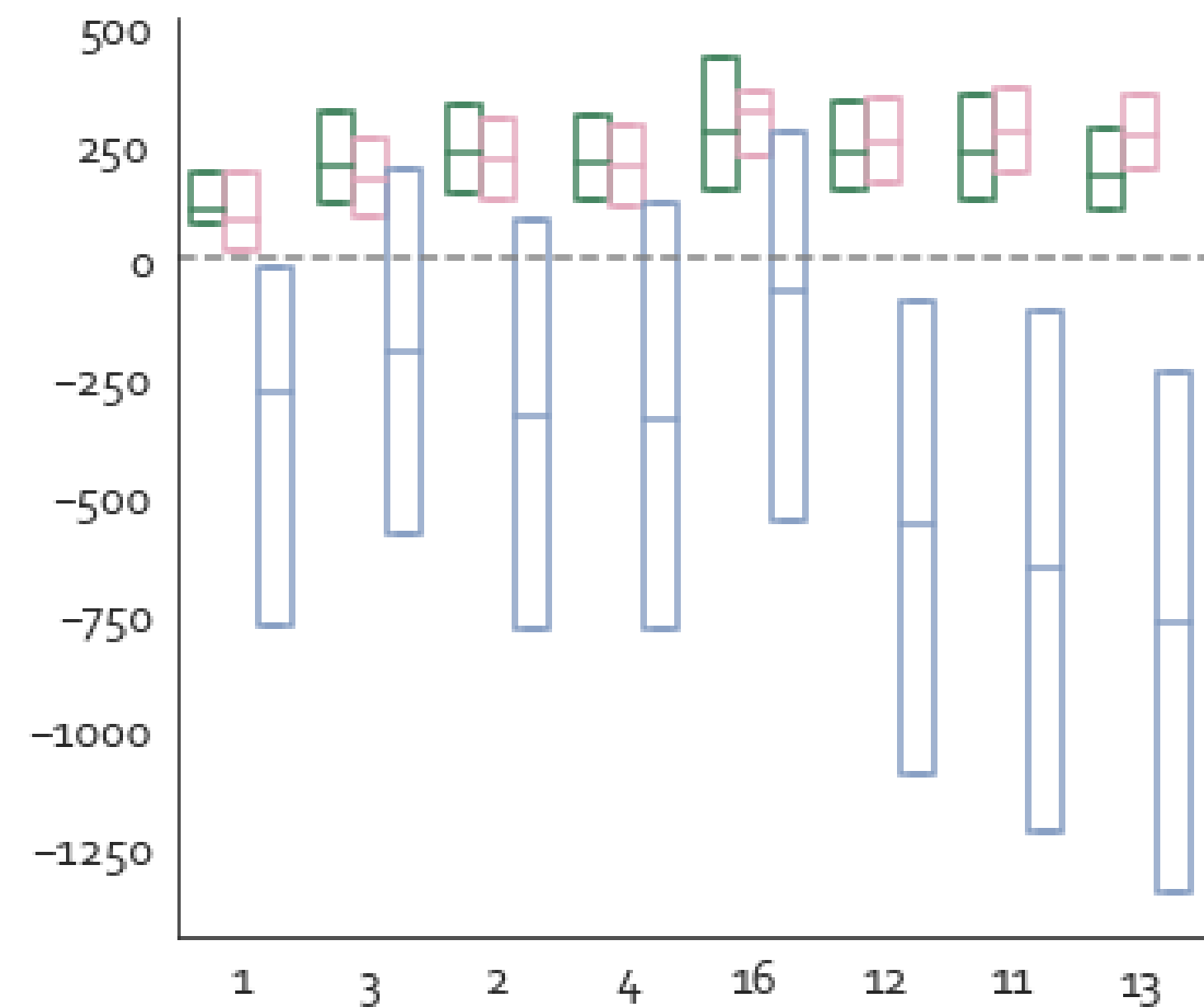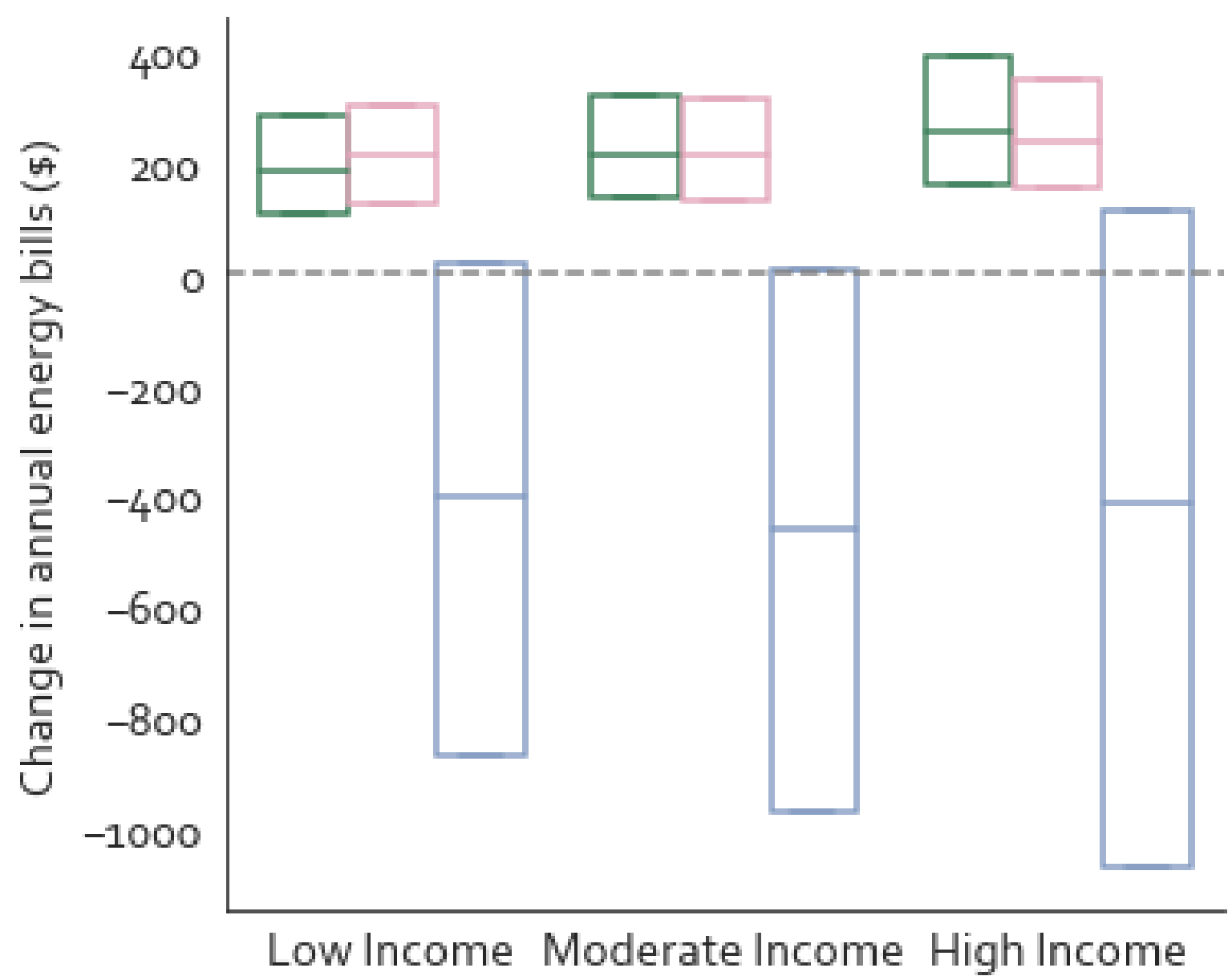
Impacts of heat electrification: temperate climate areas
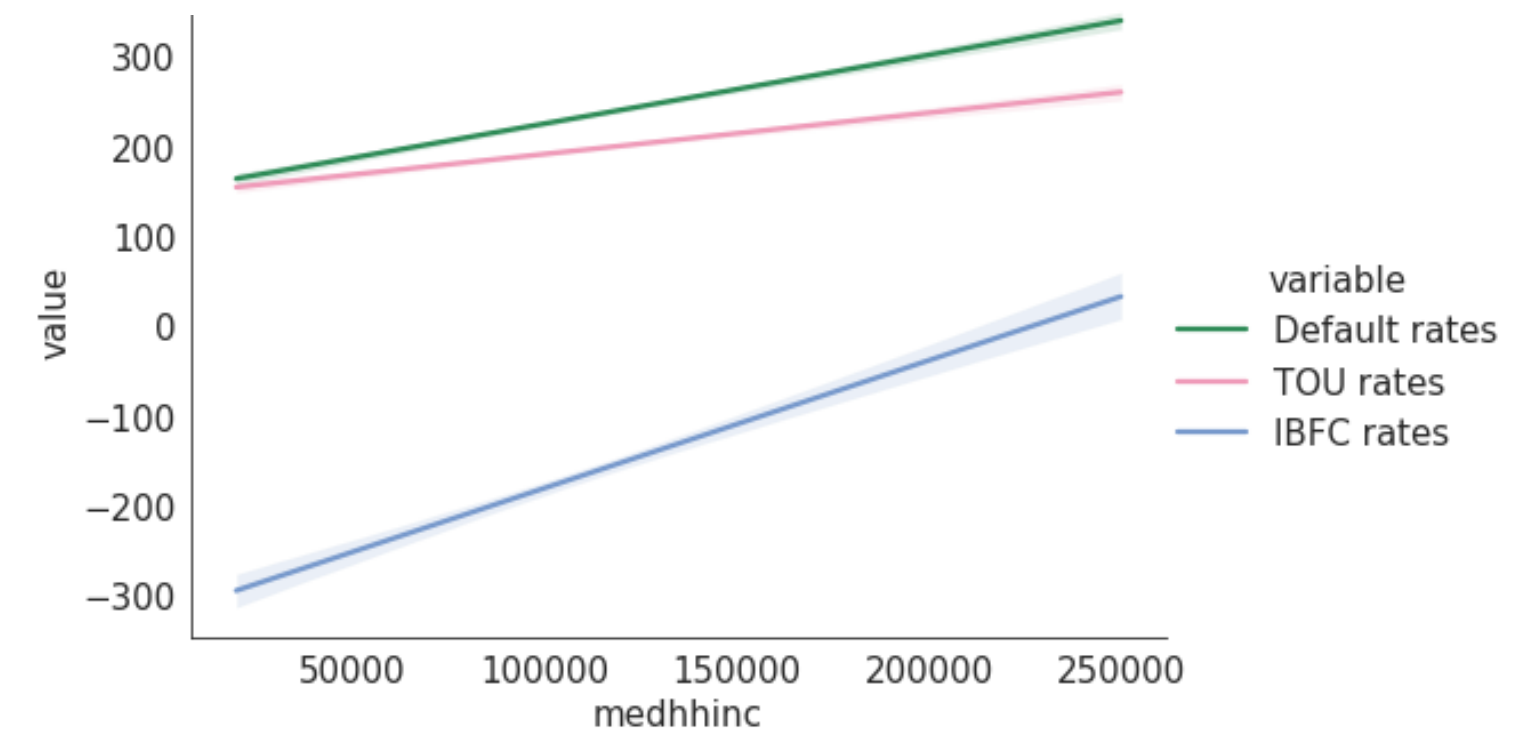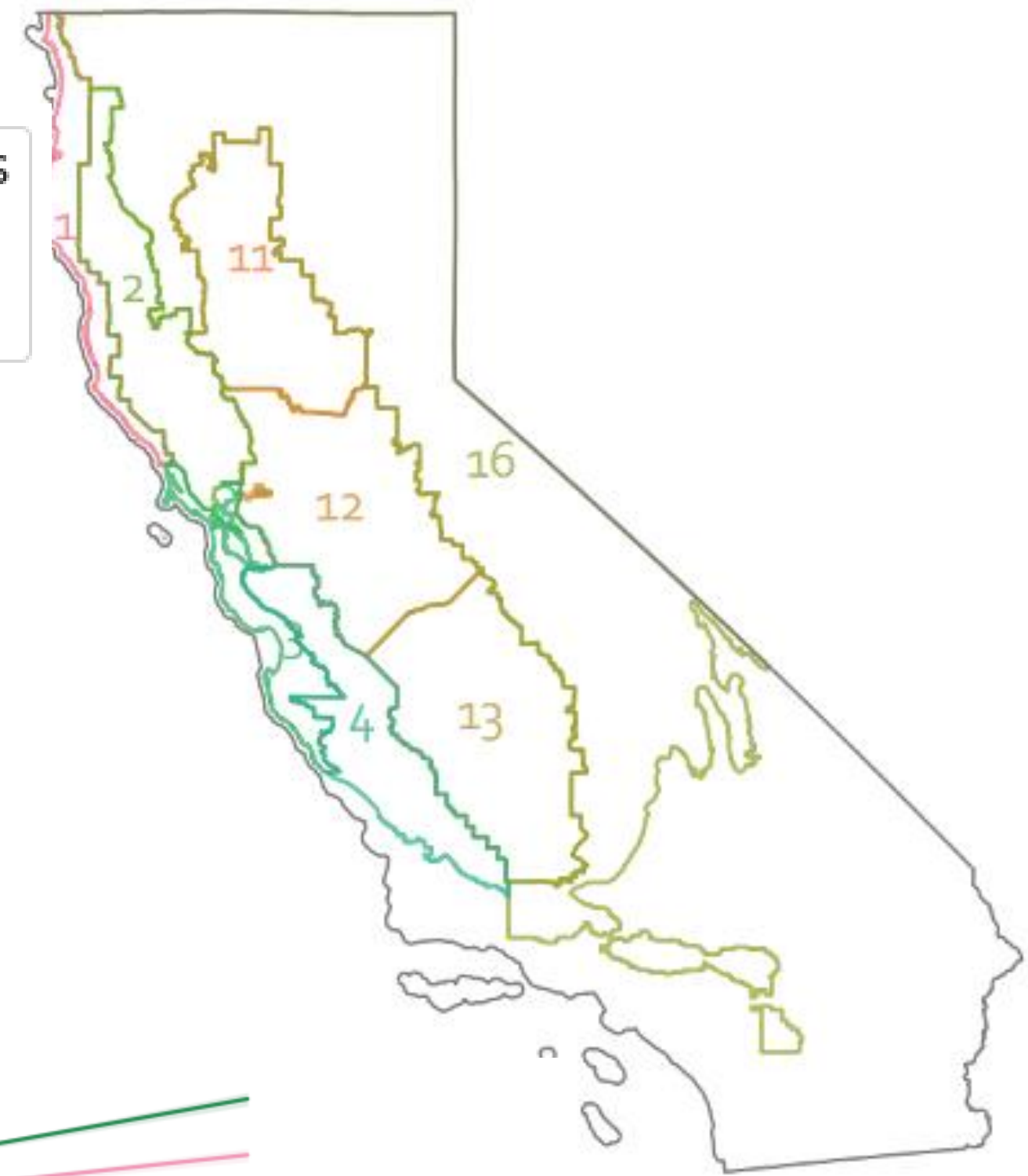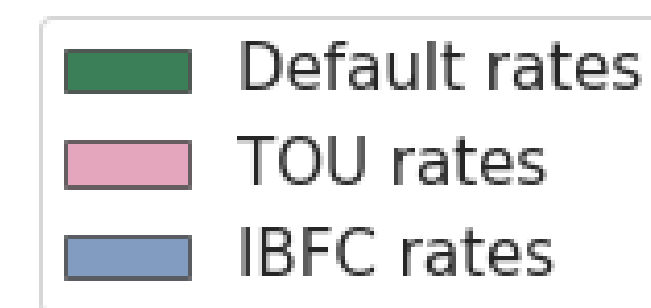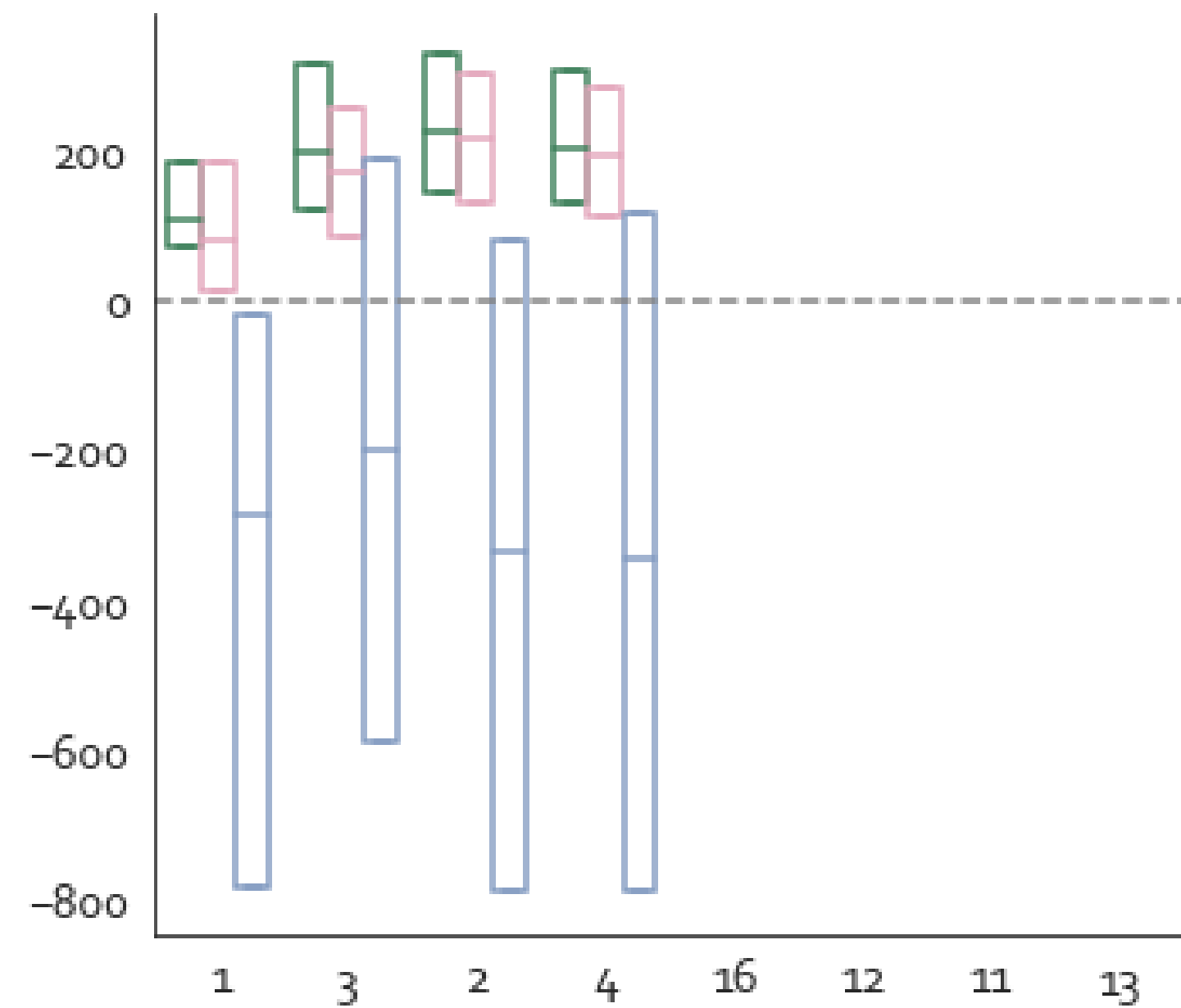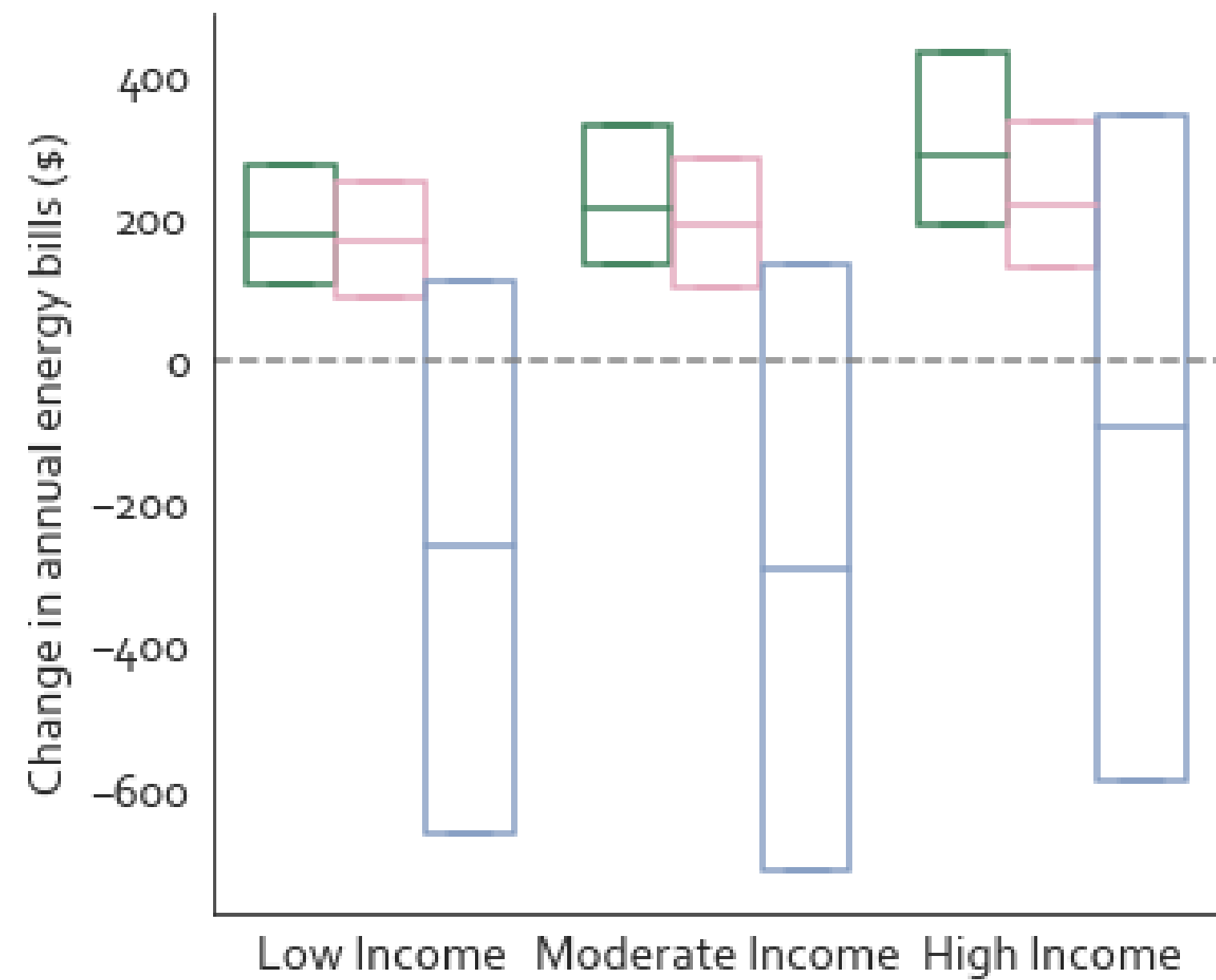
Rates, electrification and Energy Burden

Effect of higher variable costs in IBFC rates

Change in annual energy bills ($)

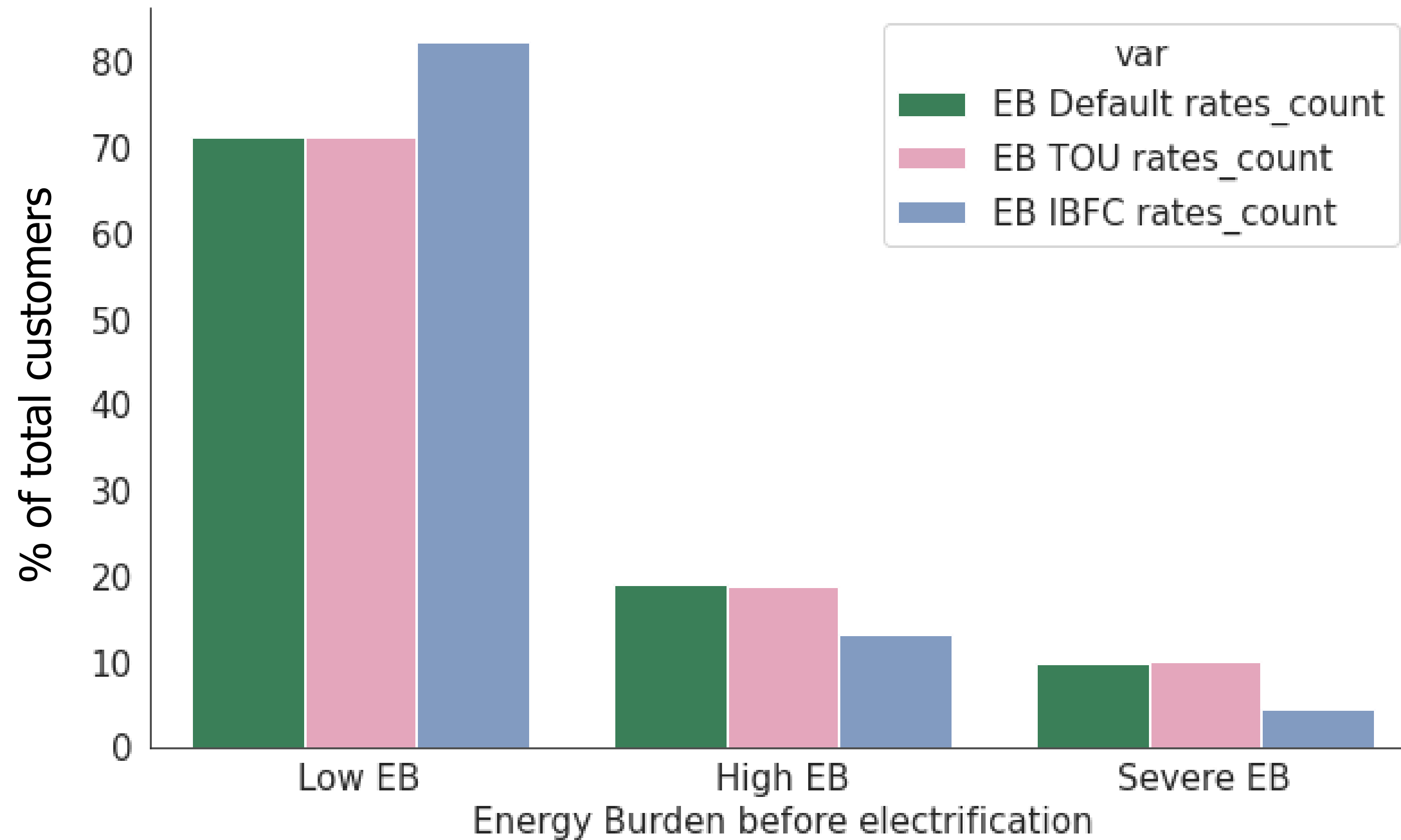# Temp stations selected

All temp stations

2015 temp stations

2017 temp stations

2016 temp stations

2018 temp stations

2019 temp stations

2019 stations, *ELECTRIC* CUSTOMERS

Under 10
10-25
25-50
50-75
75-100
Over 100

2019 stations, *GAS* CUSTOMERS

Under 10
10-25
25-50
50-75
75-100
Over 100
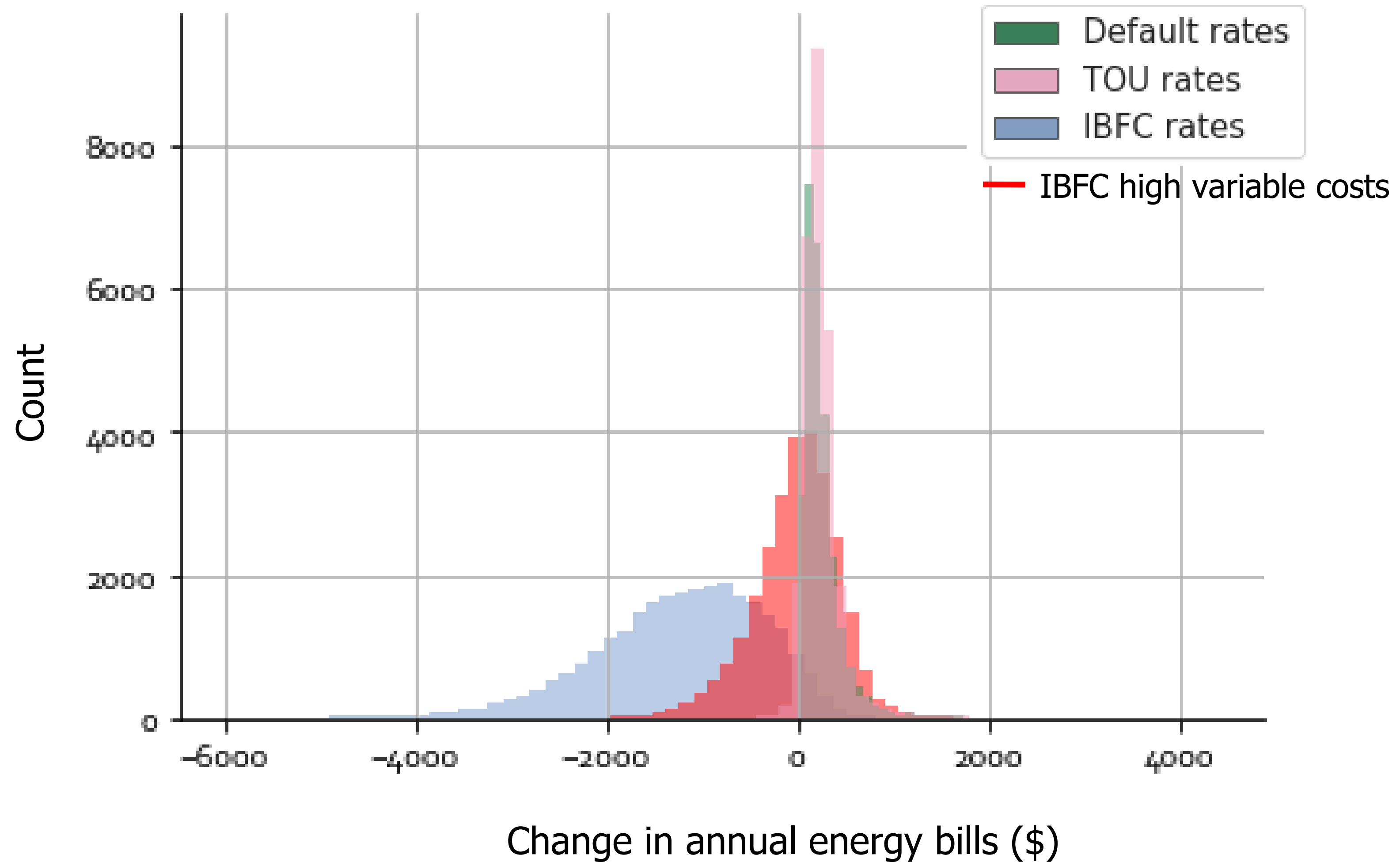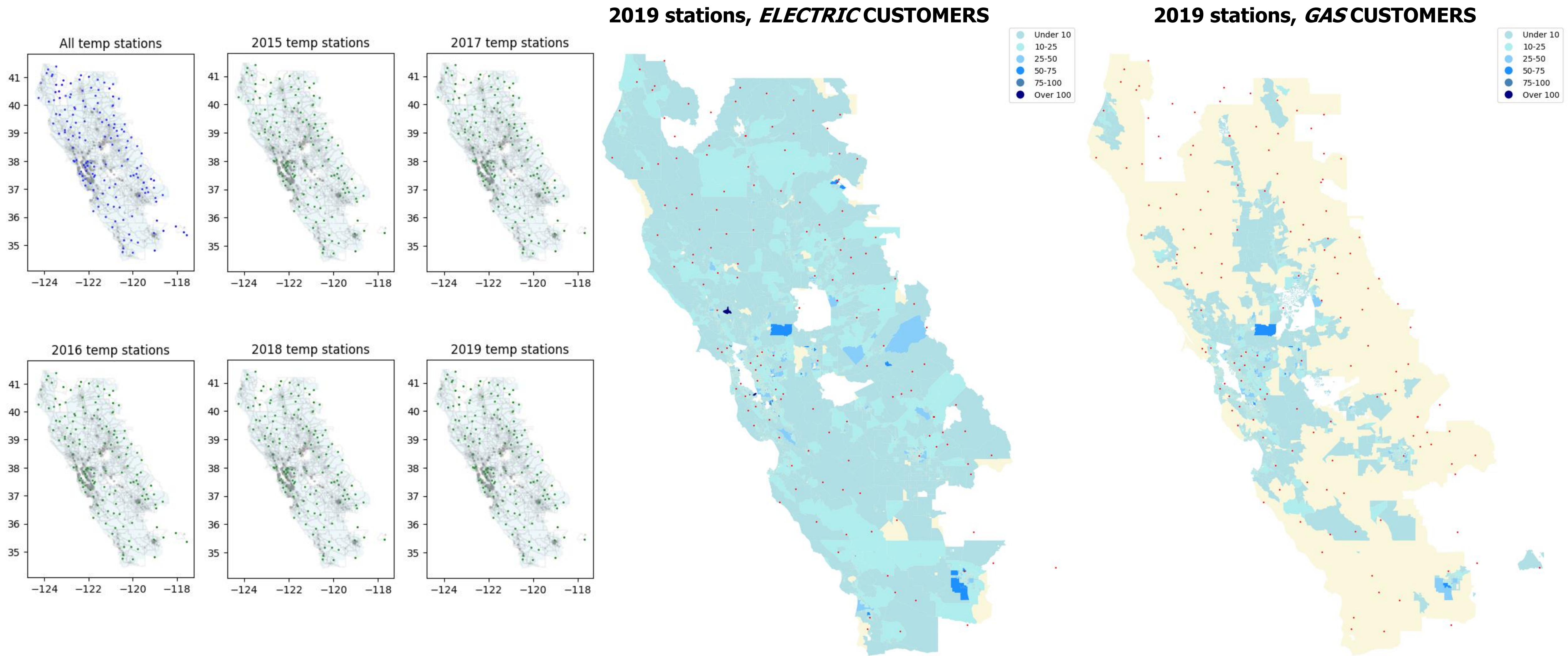
Distance from temp stations to smartmeter

Overall distances 15-19 / Distances 2015 / Distances 2016 / Distances 2017 / Distances 2018 / Distances 2019

Max 9 days to interpolate
90% completness
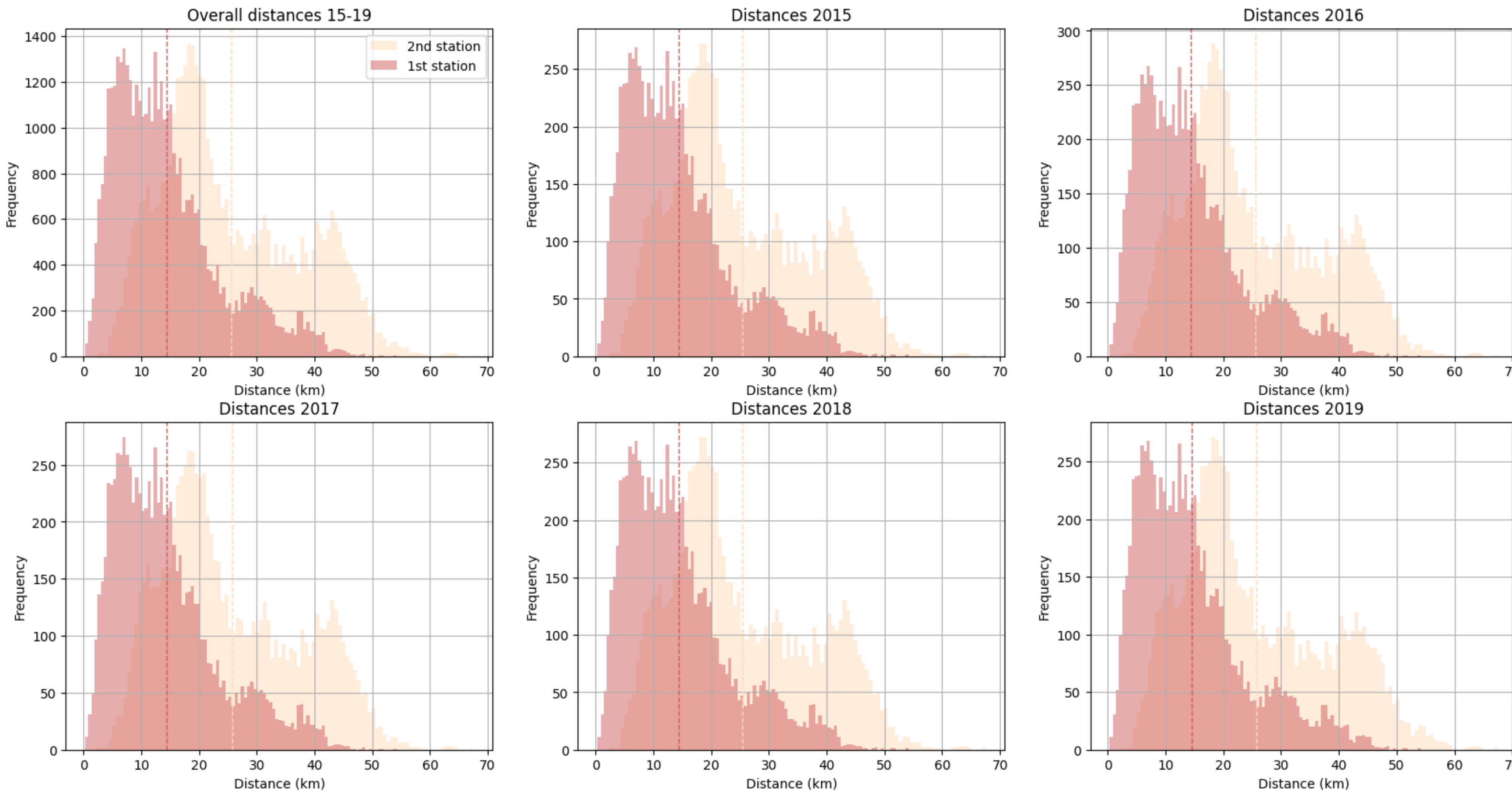
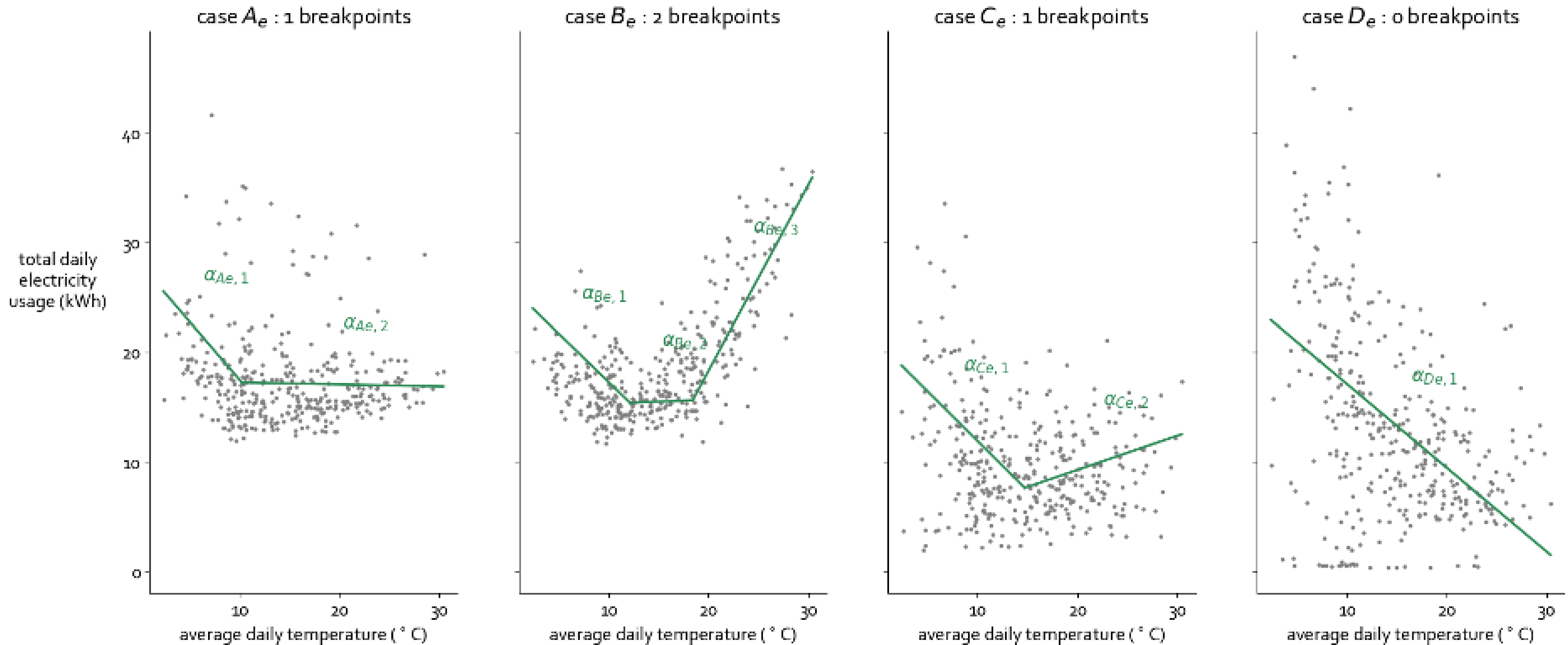| Year	Mean distance to 1st station (km)	Median distance to 1st station (km)	# unique stations matched (WITH validity test)
ALL	14.38	12.43	155
2015	14.32	12.53	145
2016	14.40	12.43	142
2017	14.35	12.43	145
2018	14.34	12.46	144
2019	14.48	12.43	144

Climate zone mismatch: 9% (3627/39713)

Elec-usage temp relationship fit

Examples of the four possible cases of electricity usage-temperature piecewise regression results
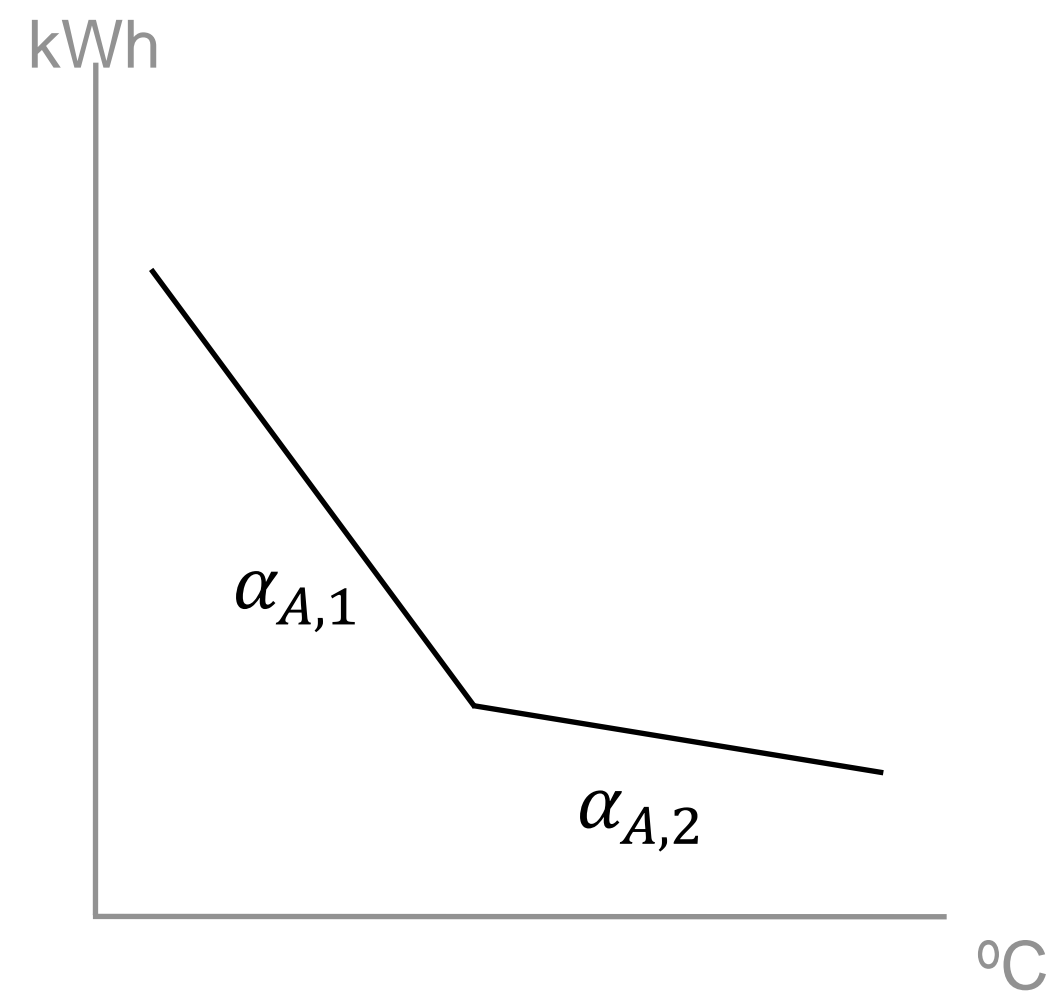
Gas-usage temp relationship fit
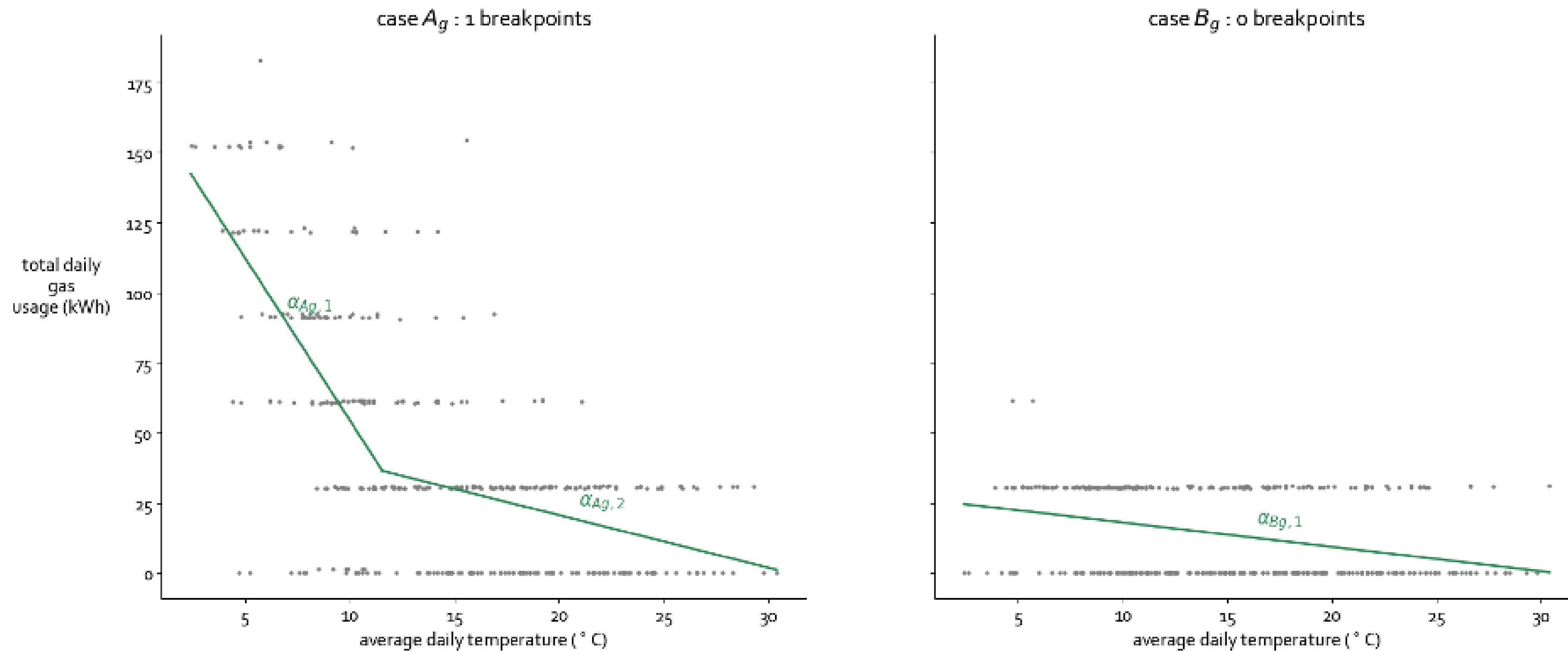
Examples of the two possible cases of gas usage-temperature piecewise regression results

Gas heating heuristics

CASE $A_{g,h}$ (1bp)

kWh

$\alpha_{A,1}$

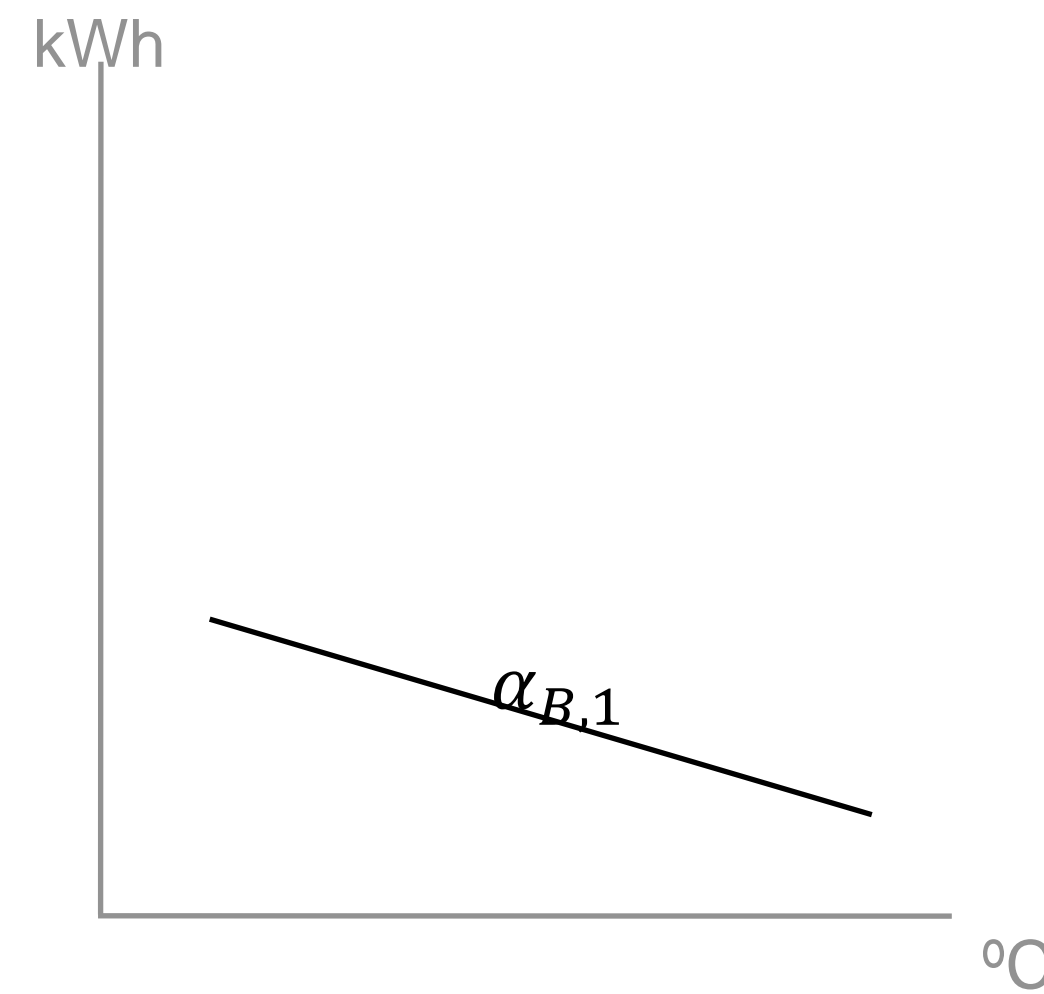$\alpha_{A,2}$

ºC

Gas heating exists if:

$\alpha_{A,1} < 0$

$|\alpha_{A,1}| > |\alpha_{A,2}|$

$0 \notin CI(\alpha_{A,1})_{95}$

$CI(\alpha_{A,1})_{95} \cap CI(\alpha_{A,2})_{95} = \emptyset$

CASE $B_{g,h}$ (0bp)

kWh

$\alpha_{B,1}$

ºC

Gas heating exists if:

$\alpha_{B,1} < 0$

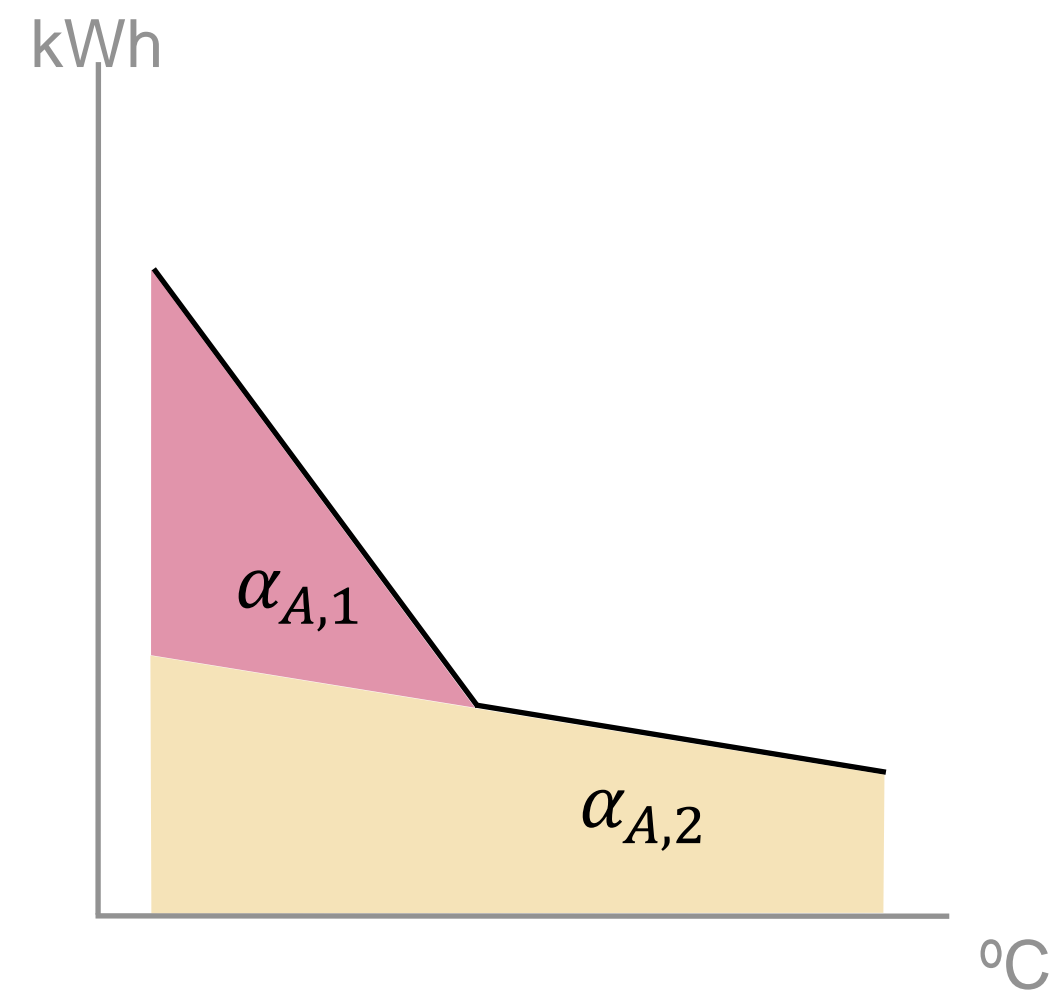$\alpha_{B,1} \in [-\infty, 0.5\tilde{\alpha}_{A,1}]$

Notes:
Homes classified into CASES based on the number of breakpoints.
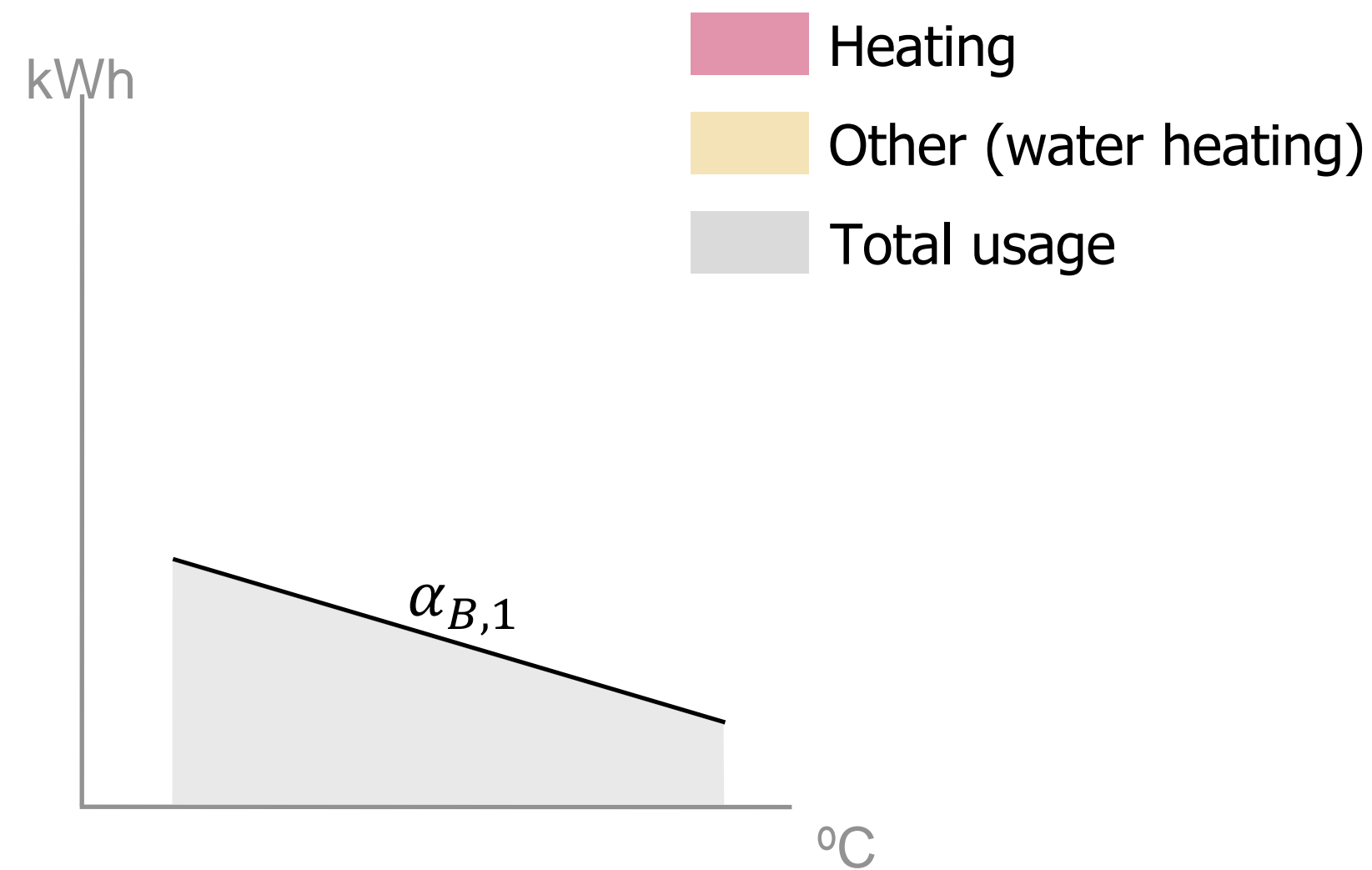$CI(\alpha_{A,1})_{95}$ stands for $\alpha_{A,1} \pm 1.96 se_{\alpha_{A,1}}$

$\tilde{\alpha}_{A,i}$ stands for the median of $\alpha_{A,i}$ (CASE $A_{g,h}$)

Gas heating disaggregation

CASE $A_{g,h}$ (1bp)

CASE $B_{g,h}$ (0bp)

kWh

kWh

$\alpha_{A,1}$

$\alpha_{A,2}$

°C

Heating

Other (water heating)

Total usage

$\alpha_{B,1}$

°C

$HDD(i) = T_{avg,i} - T_c \quad$ for $i \in 1, \dots, 365$

$\alpha_{g,heat} = \alpha_{A,2} - \alpha_{A,1}$

$SpaceHeating_g = \sum_{i}^{365} \alpha_{g,heat} HDD(i)$

$Other_g = Total_g - SpaceHeating_g$

Use RASS end use estimates per climate zone to divide the total usage across heating and other usage

24

Converting gas to electric heat

- Generate hourly electric heating demand profiles with heat pumps adoption in homes heating with gas:

  - Convert *annual* gas heating demand to electric heating demand given efficiencies of gas furnace and COP of heat pumps

  - Use heating degree days to convert *annual* electric heating demand to *daily*.

  - Use hourly heat pump electric demand from modeled dataset in Northern California (NREL's End-Use Load Profiles) to fit *daily* electric heating demand to *hourly*.