



Heat Pumps in Mild Weather



Electrification and Technology Adoption

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Climate Policy, Grid Conditions, & Technology Adoption

■ California Energy

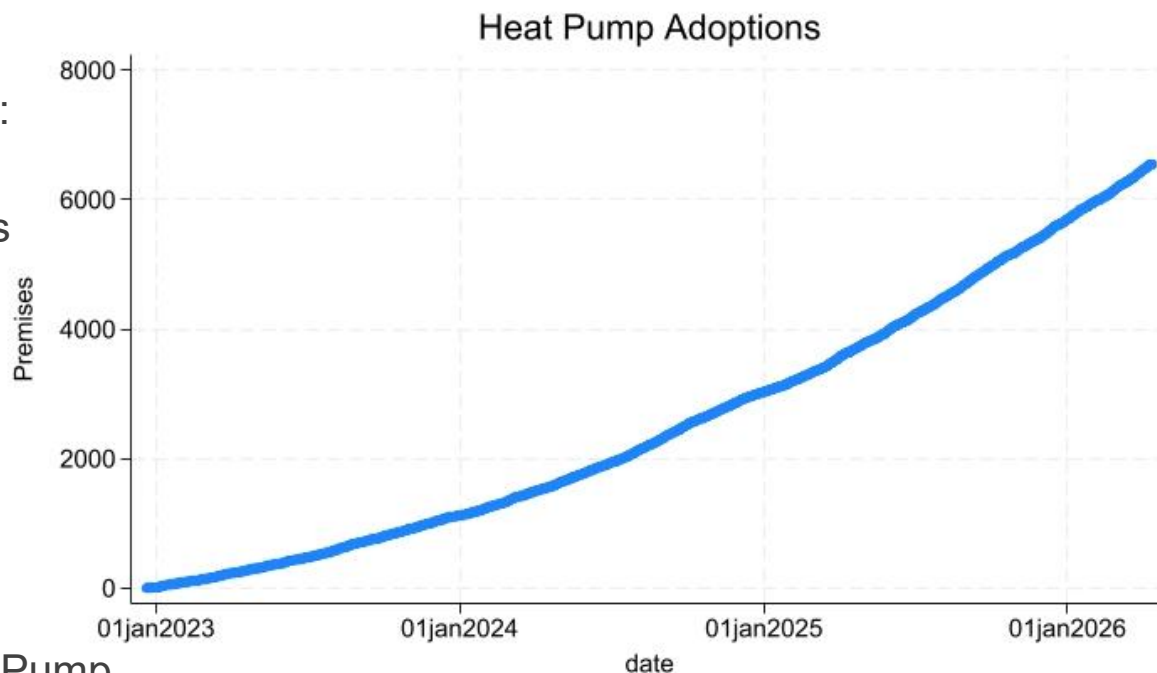
Transition: Reduce emissions to 15% of 1990 level by 2045 through:

- Changes in generation mix
- Electrification and Clean Fuels in Transportation
- Building Decarbonization and Energy Efficiency
- Carbon Capture & Removal

■ Electricity demand projected to 'nearly double' in 2045 under California Scoping Plan

- 20x Residential Heating Heat Pump Stock
- 2x Industrial Electricity Use
- 30x Zero-Emission Vehicle stock

■ SDG&E ordered to track heat pump adoption by CPUC



Available Data about Heat Pumps

Three Sources

- Self-Reported Technology Adoption [Survey Data]
 - Survey asks incoming customers at all 3 IOUs about
 - ▶ Use of electric space heating equipment
 - ▶ Use of electric water heating equipment
 - Coils vs Heat Pump
 - ▶ Use of propane for any appliance other than a Grill
- TOUELEC Rate [Eligibility Operand]
 - Customers eligible for the rate indicate presence of Heat Pump, Electric Vehicle, or Storage technology at each premise. Along with technology's adoption date.
 - New rate has small enough number of customers to be analyzed at the individual level
 - Beneficial for large users with time-flexible load: off-peak is ~\$0.08/kWh (16%) lower than default residential rate
- Additional Resources
 - Water Heater Rebate Upgrade Program: \$20 - \$500 available through 2024

Electrifying the Population

Technology Adoption Paths

Excluding Heat Pumps	Always Electric Water Heating	Always Gas Water Heating	Gas to Electric Water Heating
Always Electric Space Heating	72,102	35,470	267
Always Gas Space Heating	8,409	756,025	877 "Water Heater"
Gas to Electric Space Heating	51	3,619 "Space Heater"	1,079 "Decarbonizer"

- Concept: Use Single + Multi-family households adopting one appliance (Space Heater, Water Heater) to identify the bill impact for individual technology
- Bill impacts: **Electricity Consumption, Gas Consumption, Total Charge**
- Difficult to detect a signal at the monthly level due to high variance in consumption even after accounting for climate, building type, and income.
- Noisy observation of technology adoption date attenuates estimates towards zero
 - Instead of **Technology Path**, estimation targets **"Renovation Activity"**

Electrifying the Population

Technology Adoption Paths

Excluding Heat Pumps	Always Electric Water Heating	Always Gas Water Heating	Gas to Electric Water Heating	N/A to Electric Water Heating
Always Electric Space Heating	72,102	35,470	267	7,253
Always Gas Space Heating	8,409	756,025	877 "Water Heater"	186
Gas to Electric Space Heating	51	3,619 "Space Heater"	1,079 "Decarbonizer"	163
N/A to Electric Space Heating	603	318	112	6,215

- 14,850 sites with unknown prior technology who later report electric appliances, vs 5,626 with known gas appliances beforehand
- New tenants reporting a new technology is evidence of remodel or upgrade
- Control Group: Premises who report Gas appliances for Space & Water throughout the panel
- Treatment Group: Premises who report a new electric space or water heater (no Heat Pumps)
- Preview of Estimated Monthly Effect: ↑ Electricity, ↓ Natural Gas, ↓ Total Charge

Electrifying the Population

Technology Adoption Paths

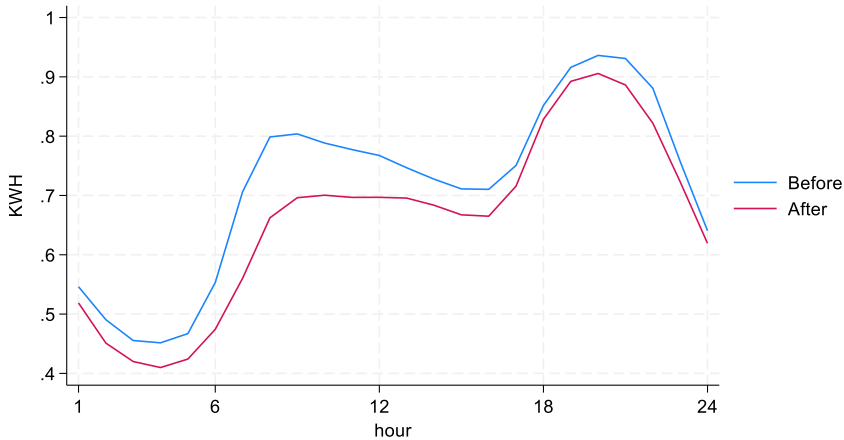
Heat Pump Renovations: Early Adopters	Always Electric Water Heating	Gas to Electric Water Heating
Always Electric Space Heating	1,487 “Modernizer”	46
Always Gas Space Heating	40	191
Gas to Electric Space Heating	5	185 “Decarbonizer”

- Most heat pump adoptions happen at premises that were fully electric
- Even split between gas and electrified space heating among gas water heater renovations
- Bill impacts may hide important grid impacts:
 - Efficiency gain for electric modernizers reduces load, while energy transition away from gas increases load
 - Load shifting throughout the day may have ancillary benefits

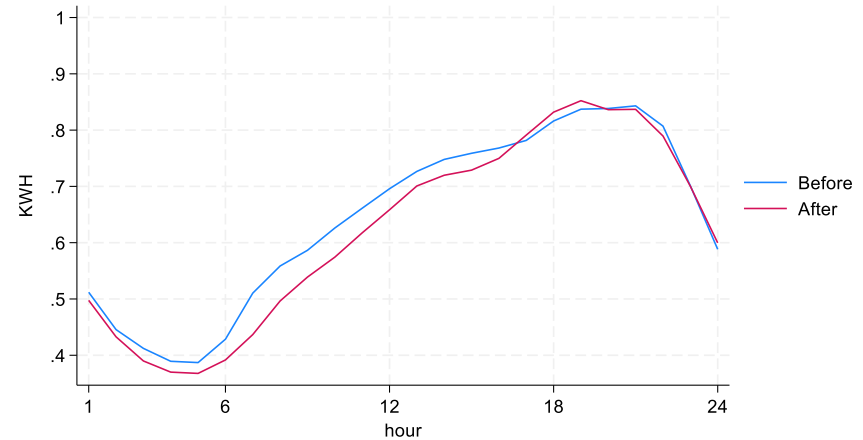
Load Shapes of Heat Pump Adopters

Non-NEM Modernizers: Upgrading from Electric Appliances

Modernizers: Electric WH to HPWH Impact
non-NEM Winter



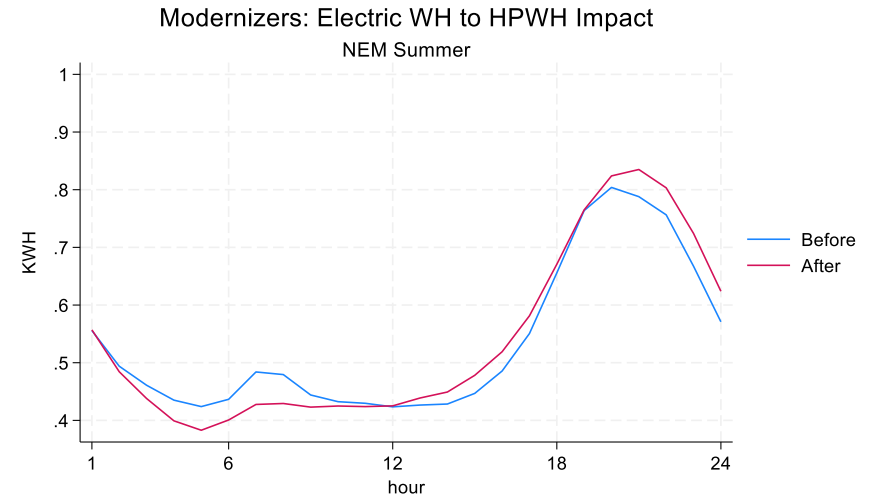
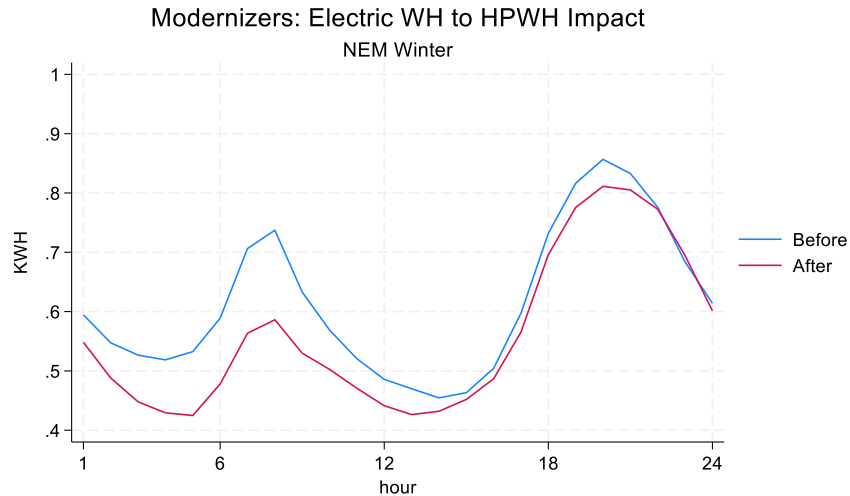
Modernizers: Electric WH to HPWH Impact
non-NEM Summer



- Non-NEM customers with electric appliances who modernize their water heater see a reduction in electricity consumption across the day
- Efficiency of heat pumps offsets the “Morning Peak” associated with showers and breakfast
- Intra-day shifting is important benefit that is not easily captured by bill impacts

Load Shapes of Heat Pump Adopters

NEM Modernizers: Upgrading from Electric Appliances

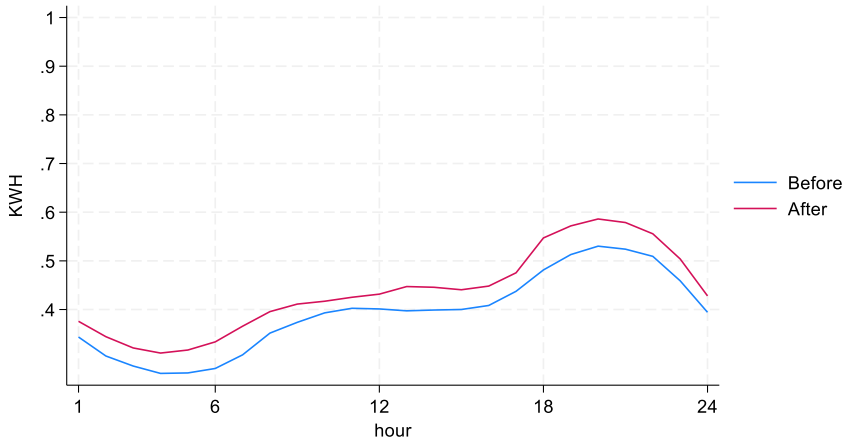


- Notably smaller delivered loads during the summer – solar generation sufficient to offset load
- Heat Pumps effective at shaving morning peak even before solar panels reach maximum capacity

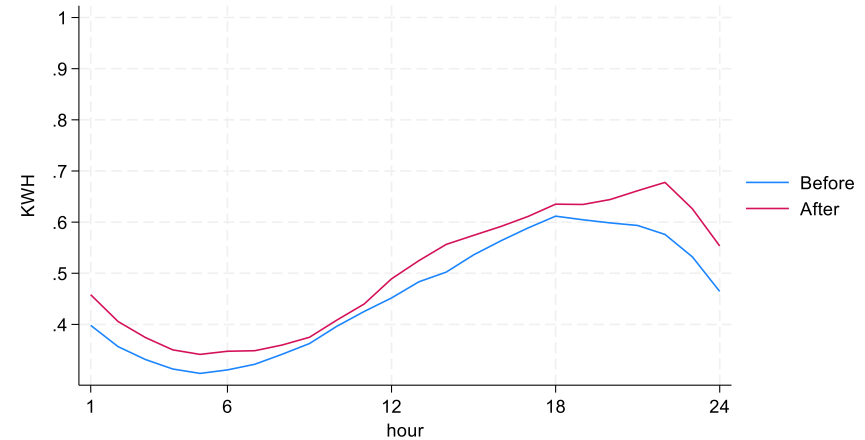
Load Shapes of Heat Pump Adopters

Non-NEM Decarbonizers: Replacing Gas Appliances with Electric

Decarbonizers: Gas Appliances to Electric
non-NEM Winter



Decarbonizers: Gas Appliances to Electric
non-NEM Summer



- Increased grid load for newly electrified premises is small
- Difference in pretreatment load shape highlights variety of consumption pattern across premise-types and starting technologies
- Decarbonizers with heat pumps are about 20% of overall decarbonizer population

Estimating the Bill Effect

Residential Premises with self-reported water heating technologies

■ Bill information

- Residential Bills for single family households and apartments
- Customer and Premise characteristics
 - ▶ Low-income support
 - ▶ Climate zone
 - ▶ Pre-treatment max demand
 - ▶ Solar Adoption (ever, or installed)
- Data Cleaning: Bill Cycle Normalization
- Technology adoption date*
 - ▶ Noisy observation attenuates estimated effects downward

■ Regression Approach

- Difference-in-Differences approach: Compare average bills before and after renovation for treated vs. control group premises

Estimated Effects

Population	Net kWh Billed	Therms Billed	Total Bill Charge
All Renovators	+38 kWh/mo	-6.7 therm/mo	+5.17 \$/mo
Electric to HP "Modernizer"	-56 kWh/mo	-14.2 therm/mo	-25.71 \$/mo
Gas to HP "Decarbonizer"	-33 kWh/mo	+0.25 (not significant)	-12.19 \$/mo

- Electrification adds +10% electricity, -13% gas, +3% total billed
- For Electric Modernizers, the efficiency story for heat pumps is clear – the drop in gas usage implies a larger scale of renovation than can be captured with this survey
- Decarbonization HPWH households: Confounded by cooling load / modernizing existing AC units

TOUELEC HP Load Impacts

Objectives:

- Identify load impacts of HP adoption in each season, (summer/winter).
- Explain the HP technologies behavior during the summer season by comparing to A/C load.
 - Why? To determine whether any increase is weather or technology driven. Is this a concern for future impacts to system peak?

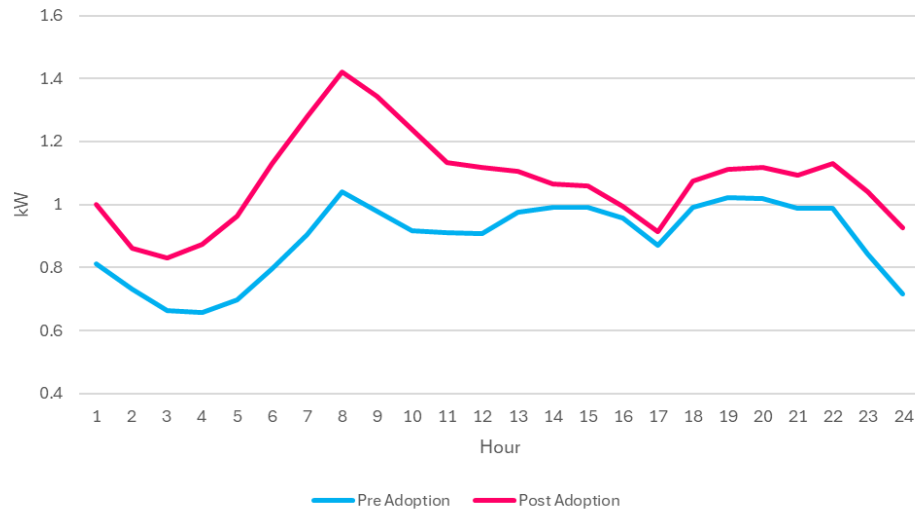
Data:

- 76 customers out of 235 customers under HP operand.
 - ▶ Pre-HP and Post-HP adoption period: 1 year of interval data before and after HP adoption date.
 - ▶ Includes customers under battery storage (STO) and electric vehicle (VEH) operand.
 - Only if: STO and VEH adoption date is outside their interval data.
 - ▶ Adding in estimated generation for customers that have adopted solar.

TOUELEC HP Load Impacts



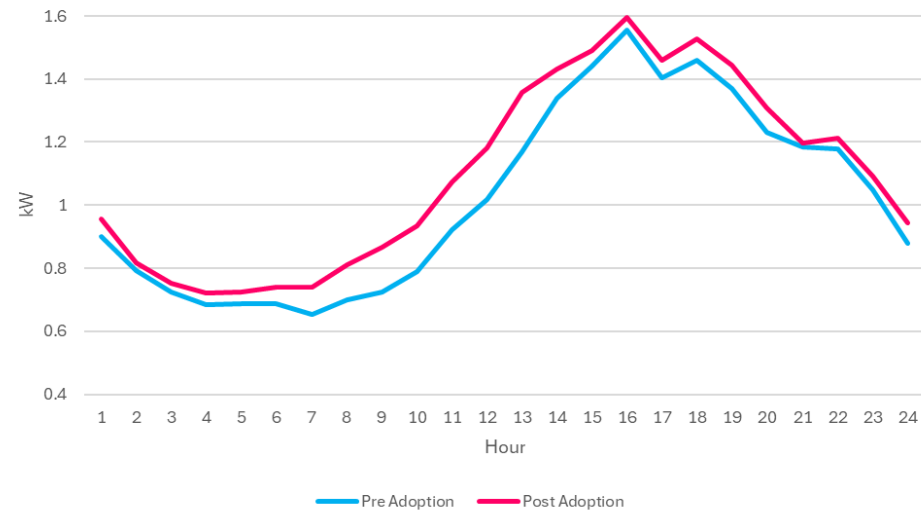
Winter (Dec - Feb, 2016 - 2026) (n = 76)



Daily avg increase of
4.5 kwh

Monthly avg increase of
134 kwh

Summer (Jul - Sep, 2016 - 2026) (n = 76)



Daily avg increase of
1.8 kwh

Monthly avg increase of
55 kwh

Disaggregating HP Load

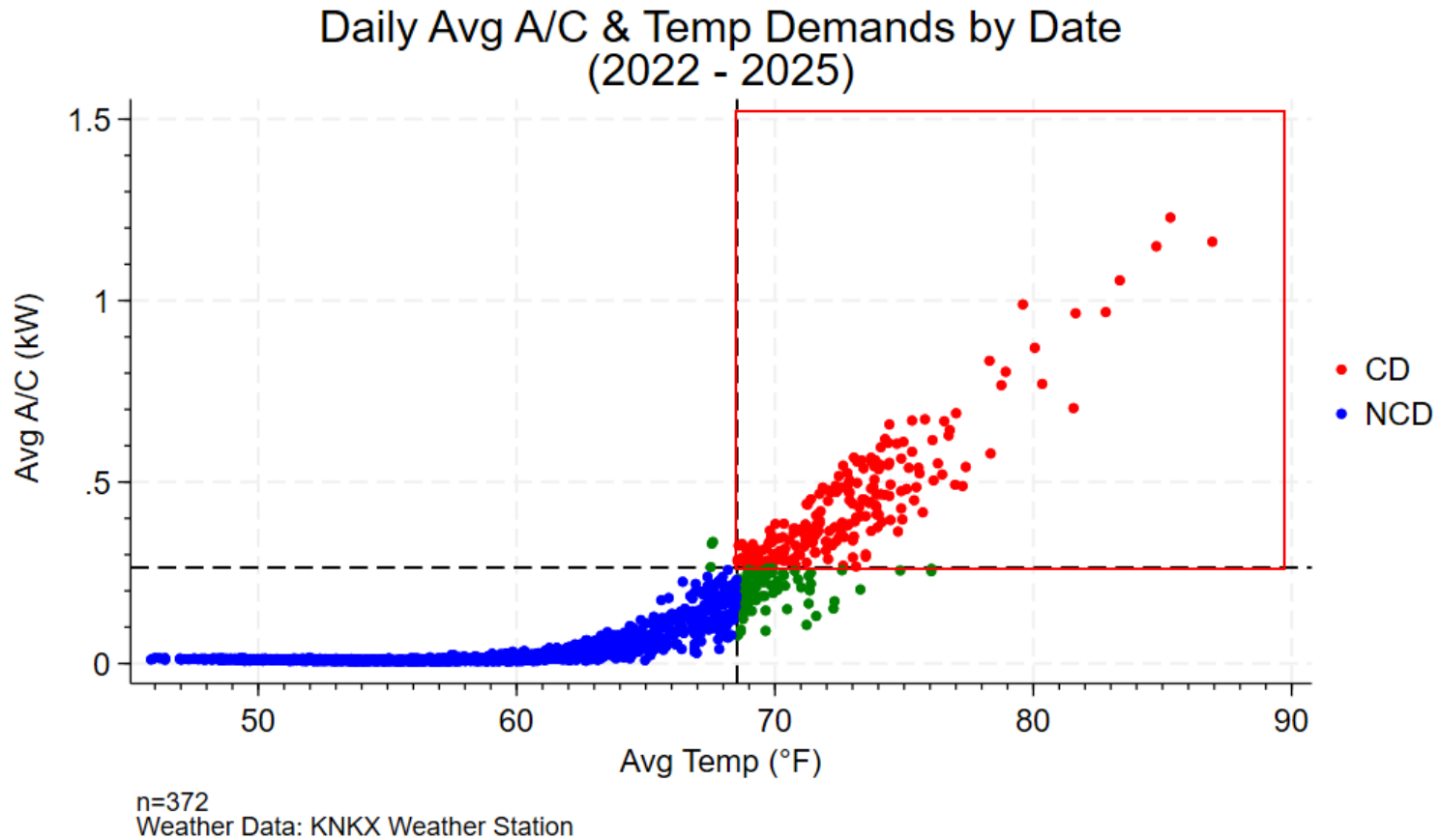
Data:

- Sample of 372 Residential customer's **separately metered A/C load** between 2022-2025.
- Hourly temperature data (KNKX weather station)

Objectives:

- Create a threshold to determine cooling days.
- Ensure cooling days capture our 3 hottest months (Jul – Sep).
 - Truncate data to months where cooling load is identified.
 - Why? To see if we also identify any non-cooling days.
- Apply cooling and non-cooling days to our TOUELEC heat pump customers' house load.
- Isolate heat pump load by taking average hourly house on a cooling day load minus average hourly house load on a non-cooling day.
- Compare disaggregated heat pump load to separately metered A/C load to see impact of new technology during system peak season.

Disaggregating HP Load



Cooling days identified, occur only in summer months:

- Jun – Sep

Disaggregating HP Load

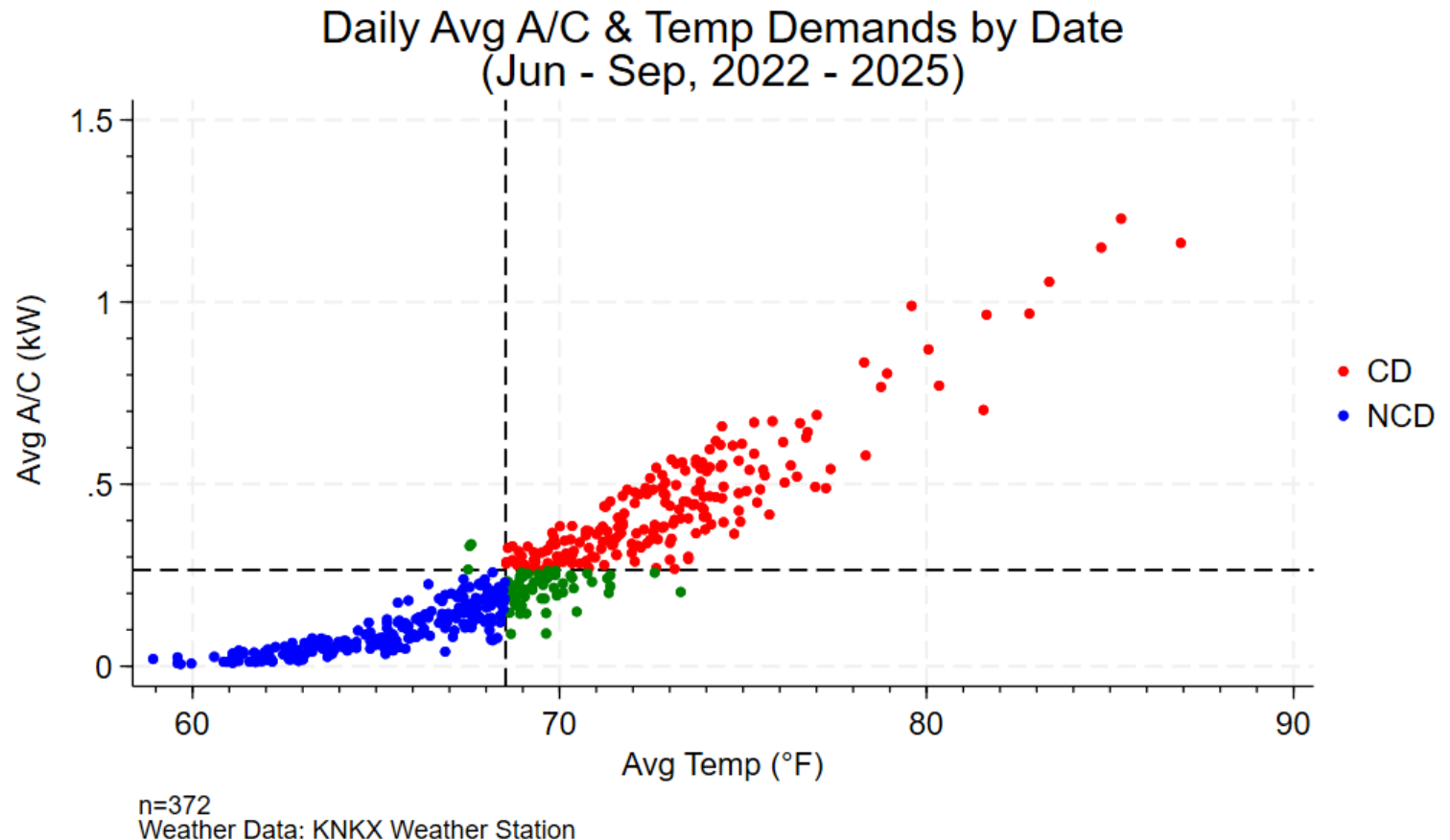
Summer Season

Cooling and
Non-cooling
Identification:

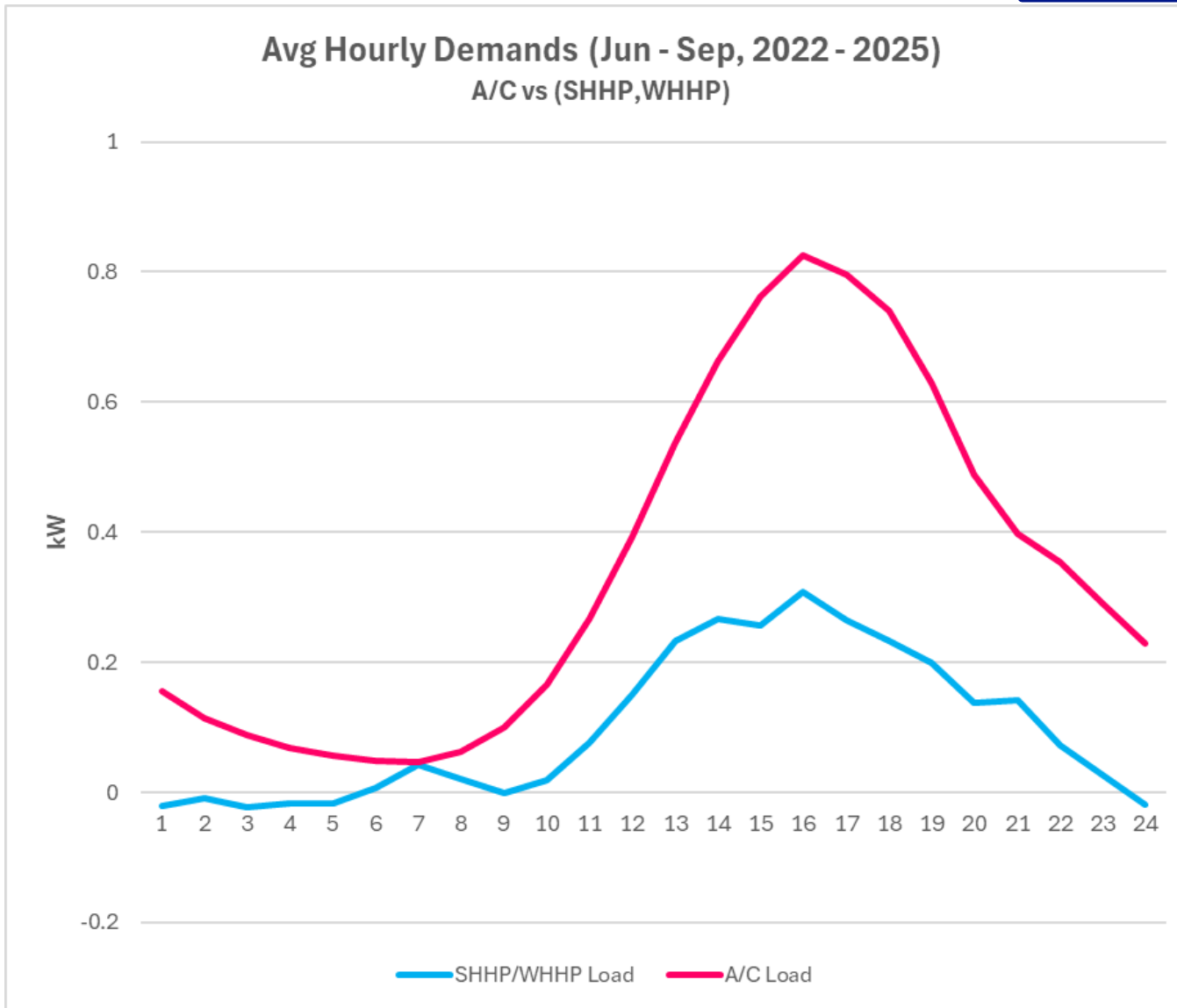
- 202 CDs
- 220 NCDs

Run on the full 12-month year, all cooling days identified occur in summer months:

- Jun – Sep



A/C vs SHHP/WHHP



Avg A/C usage:
8.3 kWh

Avg HP usage:
2.4 kWh

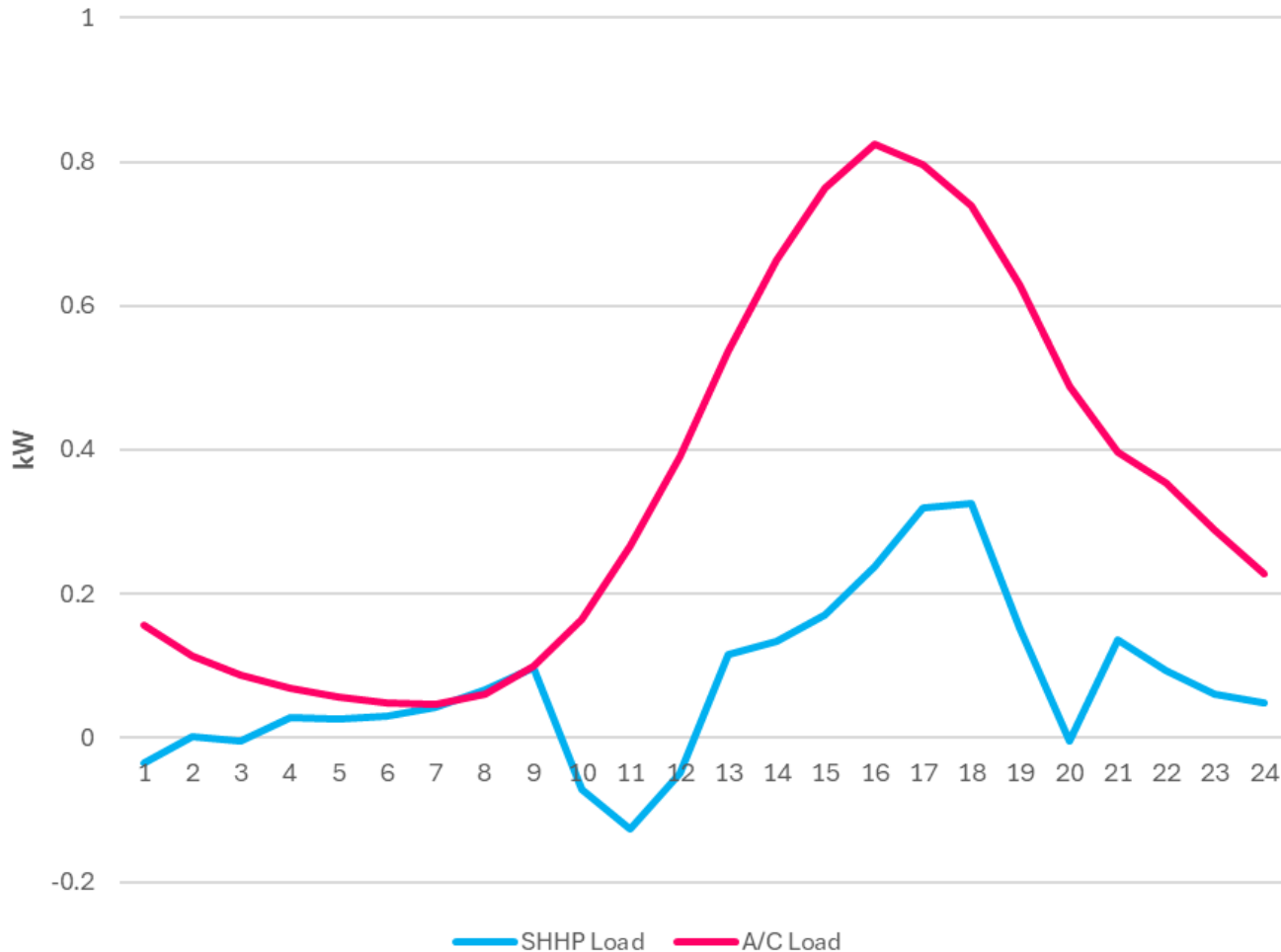
Monthly decrease
of ~178 kWh

A/C
n = 372

SHHP, WHHP
n = 53

A/C vs SHHP

Avg Hourly Demands (Jun - Sep, 2022 - 2025)
A/C vs 1 SHHP Customer



Avg A/C usage:
8.3 kWh

Avg Space HP
usage:
1.8 kWh

Monthly decrease
of ~194 kWh

A/C
n = 372

SHHP
n = 1

WHG, SHG > WHG, SHE

Key Takeaways

- Early Adopters of heat pumps in renovations can be used to identify impacts of new technology compared to traditional appliances (gas OR electric)

Population	Net kWh Billed	Therms Billed	Total Bill Charge
All Renovators	+38 kWh/mo	-6.7 therm/mo	+5.17 \$/mo
Electric to HP "Modernizer"	-56 kWh/mo	-14.2 therm/mo	-25.71 \$/mo

- Peaking behavior changed by heat pump adoption, specifically:
 - New Winter morning peak
 - Smaller cooling load than air conditioner
 - Subtractive estimation method relies on good division between cooling & non-cooling degree days in mild climates

