Load Shifting with Heat Pumps

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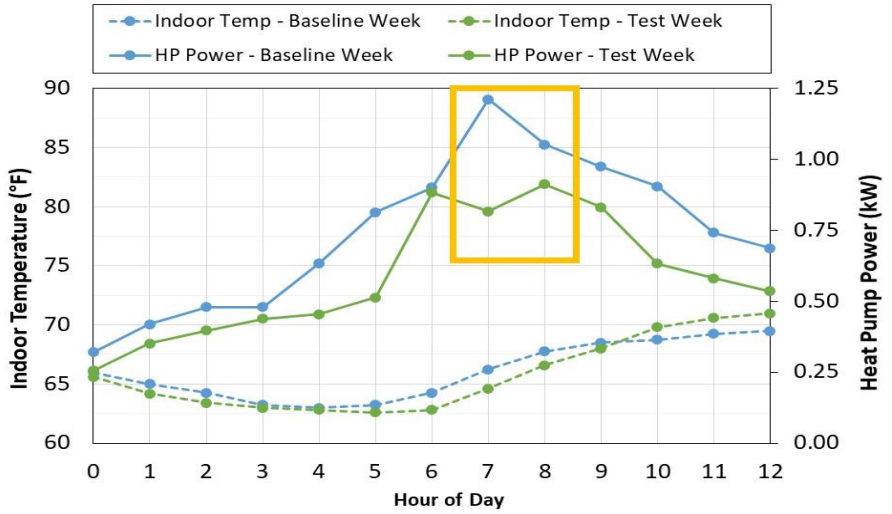
WBS 1.4.1.19

Project Summary

Objective and Outcome:

- Install and monitor ductless heat pumps (DHPs) in 3 homes in Cordova, AK
- Evaluate load shifting capability of DHPs in very cold climates
- Evaluate performance of DHPs in cold climates
- Evaluate occupant comfort during load shifting/DR
- Evaluate the potential of DR-enabled electric space heating to improve energy equity in rural communities



Team and Partners:

PNNL

Samuel Rosenberg, Alex Vlachokostas, Chitra Nambiar

Partners

Copper Highway Heating

Cordova Electric Cooperative

Stats:

Performance Period: FY21–FY24

DOE FY23 Budget: $200k, Official Cost Share: $0k

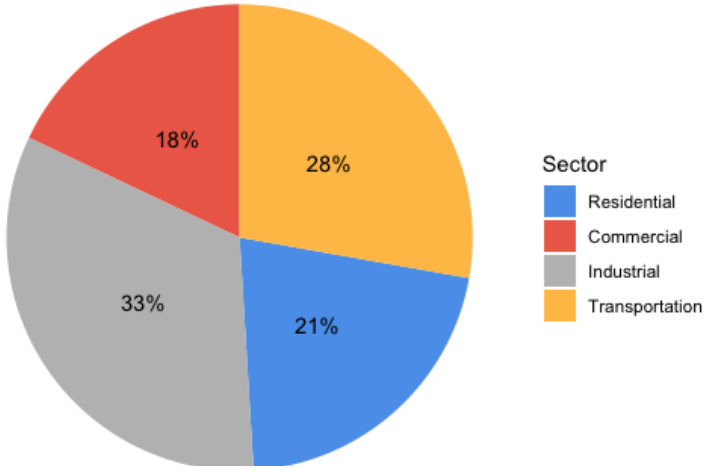
Milestone 1: DRAFT technical report

Milestone 2: FINAL technical report

Problem

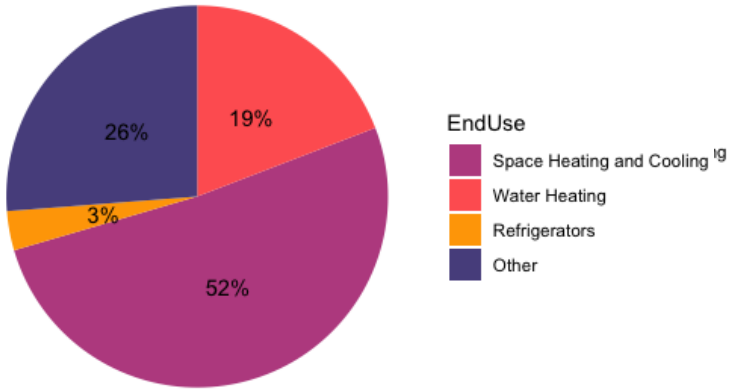
- Decarbonization of the U.S. residential building stock requires installation of electric end uses, and powering the grid with renewable energy resources
- Increasing electric end uses has the potential to increase peak loads
- Heat pumps can save 50-60% of space conditioning loads compared to electric resistance heating sources[1]

Distribution of U.S. buildings by sector



Source: U.S. Energy Information Administration, Monthly Energy Review Table 2.1a, and Table 2.1b, 2023

Residential energy use by end use

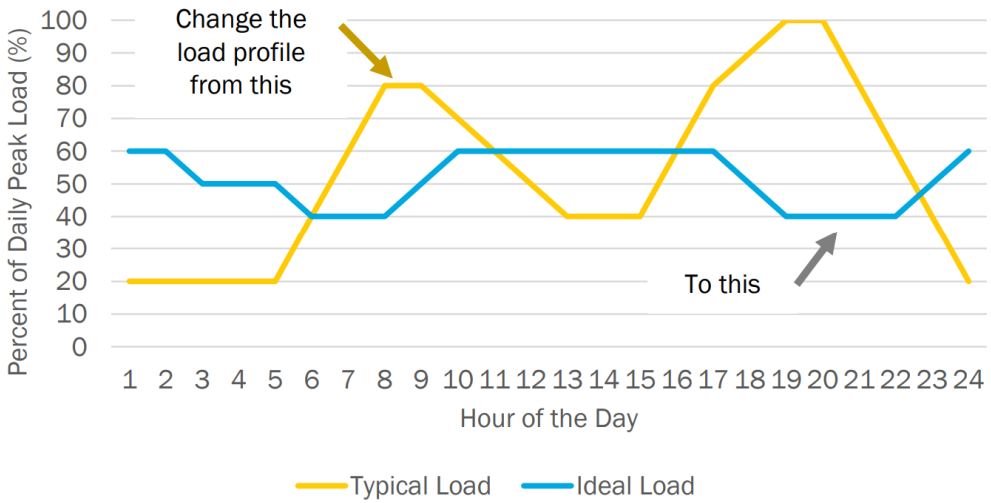


Source: U.S .Energy Information Administration, RECS Survey Data, 2015

[1]energy.gov/energysaver/heat-pump-systems

Alignment and Impact

- The Building Technologies Office has a goal to **decarbonize the building stock by 2050**
- Residential electric loads fluctuate, and peak power is more expensive. These costs are passed onto customers.
- Thermal characteristics of buildings provide utilities with an option to manage peak power requirements by shifting when HVAC systems operate
- **Efficient heat pump technology, combined with load shifting strategies, enables the decarbonization of the building stock without adding undue burden to the grid** (and when combined with time-of-use rates, greatly reduce energy bills)



Primary Project Scope: Quantifying Load Shifting Impact using Heat Pumps

Photos Courtesy of NREL PICS Database

Approach – Phase 1 Load Shifting Using Heat Pumps in Oregon

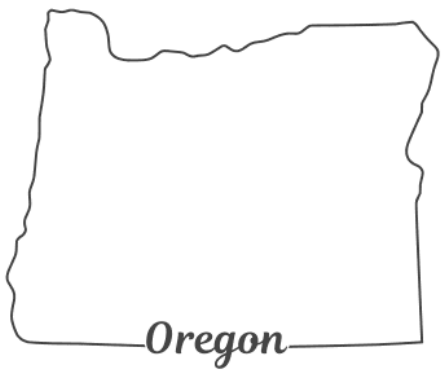
Recruitment
- Identify homes with CTA-2045 compatible heat pumps
- Recruit participants for the study.

Development & Data Collection
- Install communication devices and data collection equipment.

Load Shed Strategy #1
- One-time setpoint adjustment as 6:00 am for a duration of 3 hrs.

Load Shed Strategy #2
- Reoccurring setpoint adjustment starting at 6:00 am and updating every 15 min.

- Original research questions
  - Is demand response with CTA-2045* effective in space conditioning?
  - What is the potential load shifting impact?
  - Is there an energy savings impact?



Phase 1: 2020-2022

Phase 2: 2022-2024

*ANSI/CTA-2045 is interface and communications standard to facilitate communications with residential devices for energy management applications.

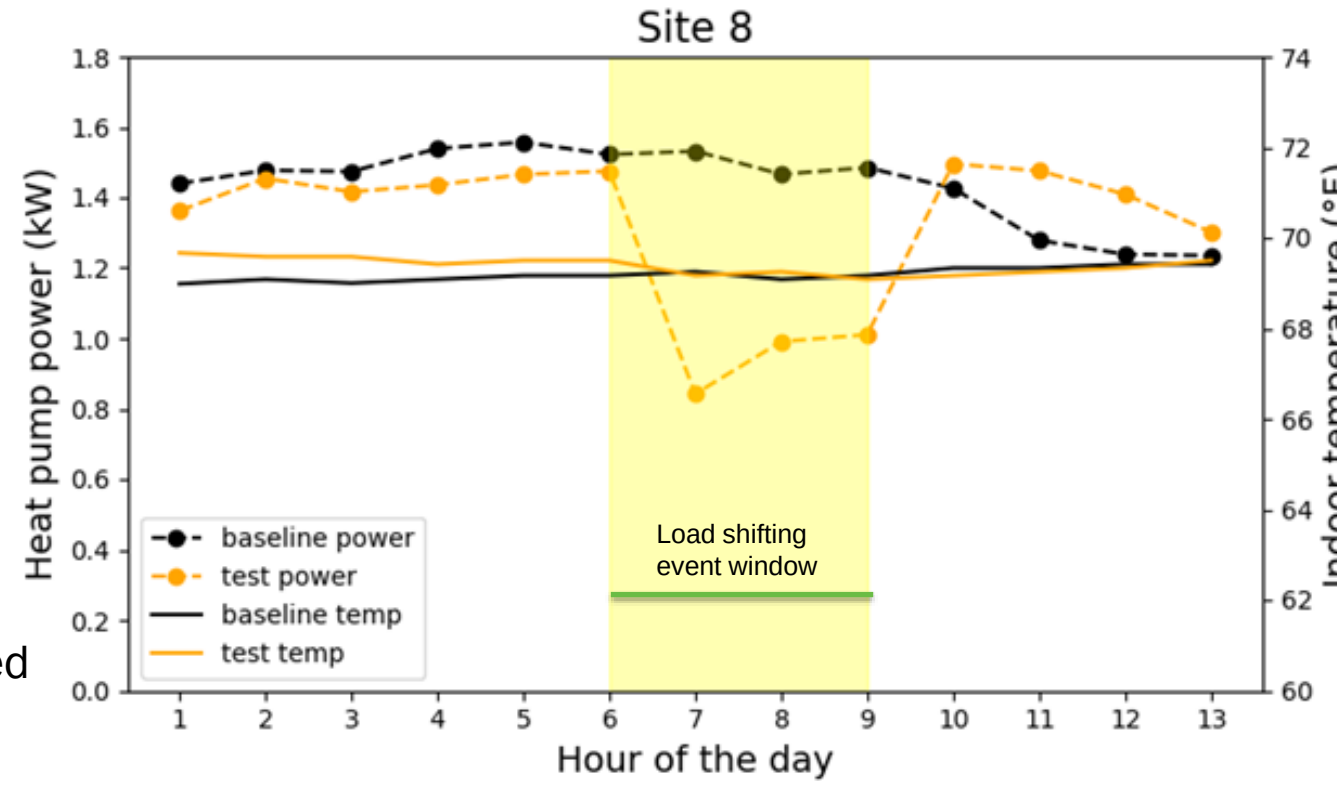
Progress – Results from Phase 1

Results:

- **CTA-2045 is an effective method of sending demand response signals to DHPs**
- Difference between thermostat setpoint and recorded air temperature found to be higher in DHPs compared to typical central space conditioning equipment
- Manufacturers considering adding new or more CTA-2045 ports on equipment
- Occupant comfort largely uncharacterized in Portland, will emphasize in Alaska sample

Figure Explanation:

- Figure shows an example of one site's aggregated baseline and load shifting results during heating season
- **Yellow shaded region shows large power reduction during designed peak period on test days**

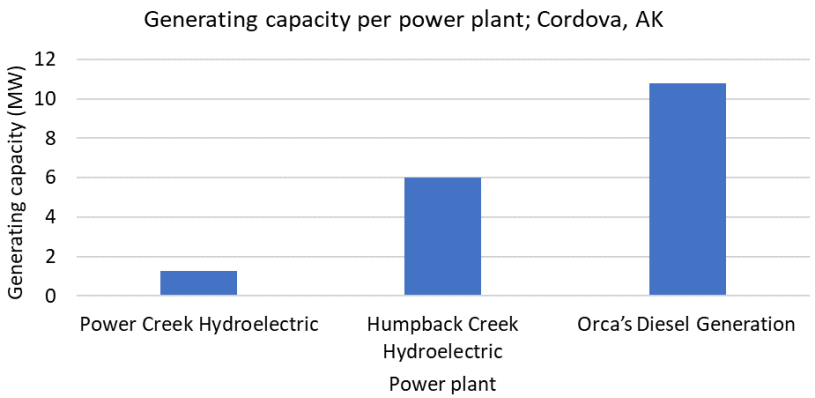


Approach – Building on Learnings from Phase 1

- **Rural communities in cold climates are spread across the U.S.**
  - Constrained grids are common everywhere, especially in cold rural areas
  - Solutions are needed to enable electrification in these areas
- **Non-electric end uses are dominant for primary space conditioning (82%) in cold climates and most residents in rural areas have no option to switch**
  - Fossil fuel end uses pose health and comfort problems to occupants
  - HVAC contractors lack training opportunities for electric space conditioning systems
  - Demand response programs can address current grid concerns

Approach - Phase 2 Constrained Grid in Cold Climate

- **Cordova, Alaska**
  - Cold climate
  - Extremely rural community
  - Microgrid community with co-op utility
  - Renewable/non-renewable generation mix is similar to many communities nationwide

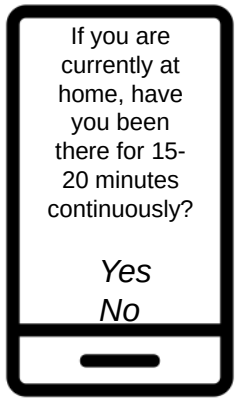


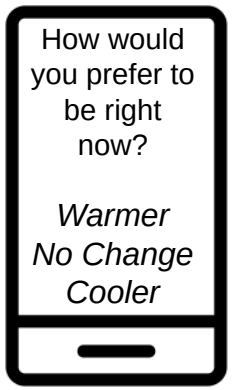
Approach – Phase 2 Focus on Thermal Comfort

I. Occupant engagement:

Entrance Interview
(Share objectives, get informed consent, collect data on energy use behaviors and comfort preferences, communicate research objectives)

Targeted Occupant Survey
(Right-now surveys triggered by discrete changes in physical environment)

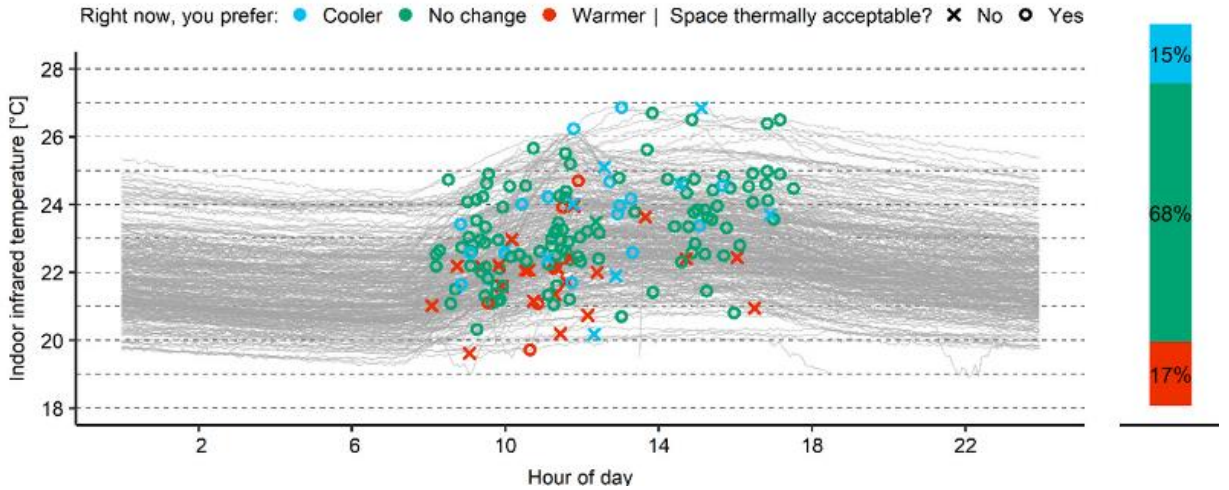




II. Physical environment sensing and monitoring:

- Indoor temperature
- Relative humidity
- Thermostat setpoint
- Carbon dioxide

III. Analysis: Thermal comfort during DR



Approach – Phase 2 Methodology and Expected Outcomes

- **Demand response methodology**
  - Step 1: Measure baseline
  - Step 2: Assess pre-heating capabilities of each site
  - Step 3: Evaluate setpoint-based load control (within comfort guidelines set by ASHRAE-55)
  - Step 4: Examine load reduction events during unique peak times
  - Step 5: Develop real-time/price responsive setpoint event schedule

- **Expected Outcomes**
  - Approximated load curve assuming widespread adoption of communicating (D)HPs
  - Standard load curve-based demand response strategy and studied impact
  - Real-time/price responsive demand response strategy and studied impact

Progress – Phase 2

- **Training Rural Contractors**
  - This project worked with a manufacturer and distributor to send the **only** local HVAC technician in Cordova to manufacturer training program, allowing them to purchase, service, and warranty HPs
  - Local contractors are necessary to provide timely service and repair, especially in cold/very cold climates
  - Properly trained (installation & service) contractors are necessary for quality installs

Progress – Phase 2

- **HP Delivery and Installation in Alaska**
  - HP equipment was ordered in early August 2022 to be delivered late August 2022. COVID delays results in actual delivery of late December 2022
  - Fall/Winter weather delayed installs to mid-winter
    - Unusually extreme weather limited contractor and researcher travel
    - “No-heat” calls took up most of contractors' time and availability during Jan/Feb




Progress Summary

- **Major Accomplishments (Phase 1 and Phase 2)**
  - Studied 9 homes in Oregon and quantified peak load shifting potential with CTA-2045 in marine climate
  - Improved data collection and demand response methodology for Phase 2
    - Introducing occupant comfort evaluation
    - Revamped power monitoring protocol to minimize lost or unusable data
    - Lessons learned from previous CTA-2045 DR studies informing new load shifting methodologies and capabilities
  - Worked with only local HVAC company to achieve training and certification statuses for HP install and maintenance
  - Installed DHPs in 2 homes in Cordova, AK
  - Identified barriers for heat pump/electrification in cold rural climates

Future Work

- As of April 10th, 2023, 2 sites have installed DHPs, 3rd coming soon
  - Data collection equipment will be installed in all three sites after third site DHP install
- Team conducting initial load shifting during Spring 2023 (still quite cold in Cordova)
  - Finalize methodology for testing over the 2023–2024 heating season
- Consumer interest from first installs, triggering up to 15 more heat pumps will be installed in Cordova over the Summer of 2023. Project team will take advantage of these extra heat pumps and focus on larger-scale, full-winter data collection in Winter 2023–2024

Thank You

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Project Execution

	FY2022				FY2023				FY2024			
Planned budget	$295,582				$304,474							
Spent budget	$218,122				$123,930							
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
Compile results from winter load shifting for 10+ Portland multi-split heat pump sites. - Draft technical report or conference paper			◆									
Current/Future Work												
Draft technical report on load shifting capabilities in using ccHP in Cordova, Alaska							◆					
Final technical report on load shifting capabilities in using ccHP in Cordova, Alaska								◆				

Team

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