Guidehouse DTE

DTE Income Qualified Residential and Multifamily Whole-Home Mini-Split Cold Climate Heat Pump Pilot

Presentation to EWR Collaborative

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DTE Income Qualified Mini-Split Cold Climate Heat Pump Pilot

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Executive Summary

Guidehouse evaluated the whole home heating season energy savings for single and multi-family DTE Energy (DTE) customers due to the installation of mini-split cold climate heat pumps (CCHP) compared to existing baseboard electric heaters.

OBJECTIVES

- Quantify the whole home energy savings for single family (SF) and multi-family (MF) DTE customers due to the installed CCHP.
- Understand customer's expectations, concerns, and changes in usage pattern (e.g., thermostat set point changes)
- Understand customer's experience with the initiative and best practices in operating CCHP and original heating and cooling equipment.

APPROACH

- Conduct AMI Analysis for all SF and MF sites.
- Install data loggers at some customer sites and validate the accuracy of AMI analysis approach using the collected data.
- Interview participants and MF property manager.

KEY FINDINGS

- Mini-split CCHPs reduced the average heating season energy consumption of MF and SF homes by 36% and 7% respectively and cooling season energy consumption by 10% and 27% respectively.
- SF savings were much lower than expected, likely because the heat pumps were designed to heat the entire home, including areas not previously heated, and several customers continued to use inefficient baseboard heaters.

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Project Background

Study Participants

DTE installed mini-split CCHPs in 20 SF and 44 MF income qualified homes.

Building Type	Study Participants	HVAC Units		
		Type	**Pre-Install**	**Post Install**
MF- Low Rise	44 homes[1] 28- One Bedroom (BR) homes 16- Two BR homes	**Heating**	• Baseboard electric heaters and space heaters	• Mini-split CCHP[2] + Baseboard electric heaters for bathroom • *Baseboard electric heaters disabled at electric panel*
		Cooling	• Window Air Conditioners (AC)	• Mini-split CCHP • *Window AC's not removed but customers advised to use to mini-split CCHPs as primary cooling unit*
Single Family	20	**Heating**	• Baseboard electric heaters	• Mini-split CCHP • *Baseboard electric heaters **not** disabled at electric panel for most homes, but customers advised to use to mini-split CCHPs as primary heating unit*
		Cooling	• Window ACs or no cooling unit in homes	• Mini-split CCHP • *Window AC's not removed but customers advised to use to mini-split CCHPs as primary cooling unit*

Single-family (Low Rise) Building Complex

Multifamily (Low Rise) Building Complex

Mini-split CCHPs Installed

DTE installed high efficiency mini-split multi-head CCHPs in each participant home.

Building Type	Average Home Size (Sq. ft.)	Average HP Cooling Capacity (BTU/hr)	Average HP Heating Capacity (BTU/hr)	Average HSPF	Average SEER	Average EER
Multi Family (One Bedroom)	600	20,000	22,000	9.8	17	13.5
Multi Family (Two Bedroom)	750	20,000	22,000			
Single Family	1438	34,929	39,247	10.7	18.1	12.6

- Installation contractor determined the cooling and heating load for each home as per (Air Conditioning Contractors of America (ACCA) Manual J or equivalent), and the mini-split heat pumps were sized as per ACCA Manual S or equivalent.

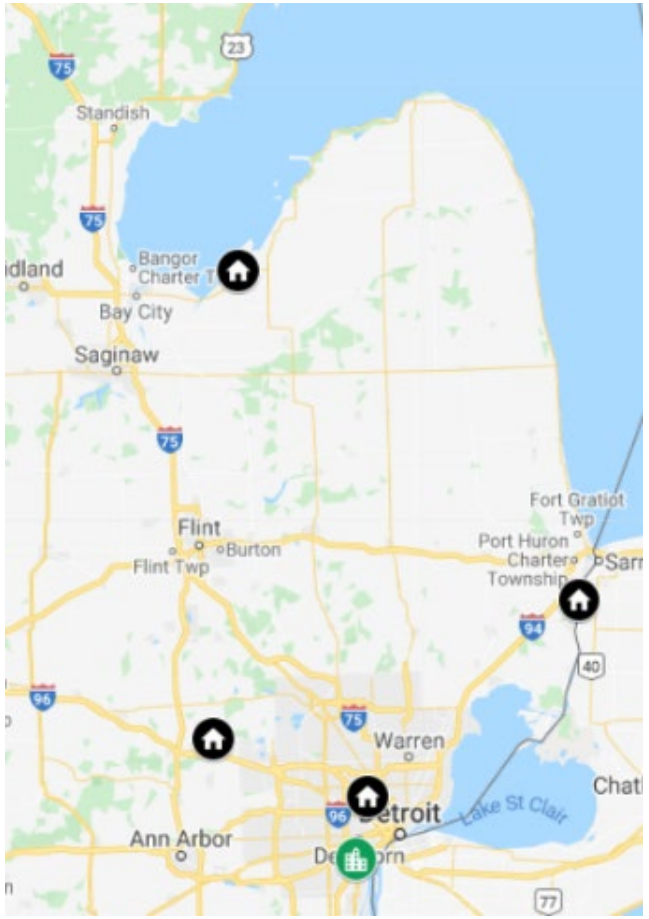
Data Logger Installation

Guidehouse installed data loggers at 10 homes to measure HVAC energy consumption.

Selected homes were installed with:

- **eGauge data loggers** to record the power consumption of the new mini-split CCHP and each baseboard unit.
- **Cell modems** to remotely connect to the eGauge loggers
- **HomePlug adapter** to enable communications between the eGauge and the cell modem

Building Type	Number of Homes with Data Loggers	Logger Install Dates
Multi Family (One Bedroom)	3	Sept 2020
Multi Family (Two Bedroom)	3	Sept 2020
Single Family	4	Jan to Feb 2021



Location of Study Participants with Data Loggers

Impact Evaluation Process

Overview of AMI Data Analysis

Data Cleaning

- Visual inspection of AMI Data
- Filter erroneous data
- Remove sites with less than 4 weeks of data in pre and post install data in
  - peak heating/cooling seasons (Dec to Feb, Jul to Aug)
  - shoulder season (non-peak months)
- Combine AMI data with weather data from the nearest weather station
- Sum hourly kWh consumption data across all meters

Model Training

- Derive weather predictor variables: heating/cooling degree hours (HDH/CDH), 4-hour and 24-hour rolling average HDH/CDH, normalized heat build up
- Fit separate models for each site
- Split data for each site into training and test sets, and tune models on the training set using 5-fold cross validation to prevent overfitting
- A variety of model types (Linear Model, Elastic Net, Random Forest, Support Vector Machine) were tuned for each site.

Model Predictions

- Evaluate performance of the tuned models using the test set.
- Predict energy consumption and savings using Typical Meteorological Year (TMY3) weather data.
- Create three sets of predictions using final model for each site, i.e., whole home without heat pump (pre), whole home with heat pump (post), and base (non-HVAC) load (using average weather in non-heating months).
- Subtract base load from pre and post whole home to derive HVAC consumption, take the difference pre/post to derive savings.

Validation using Logger Data

- Compare modeled post-install HVAC consumption with the metered HVAC energy use from data loggers installed at selected sites.

Impact Evaluation Results

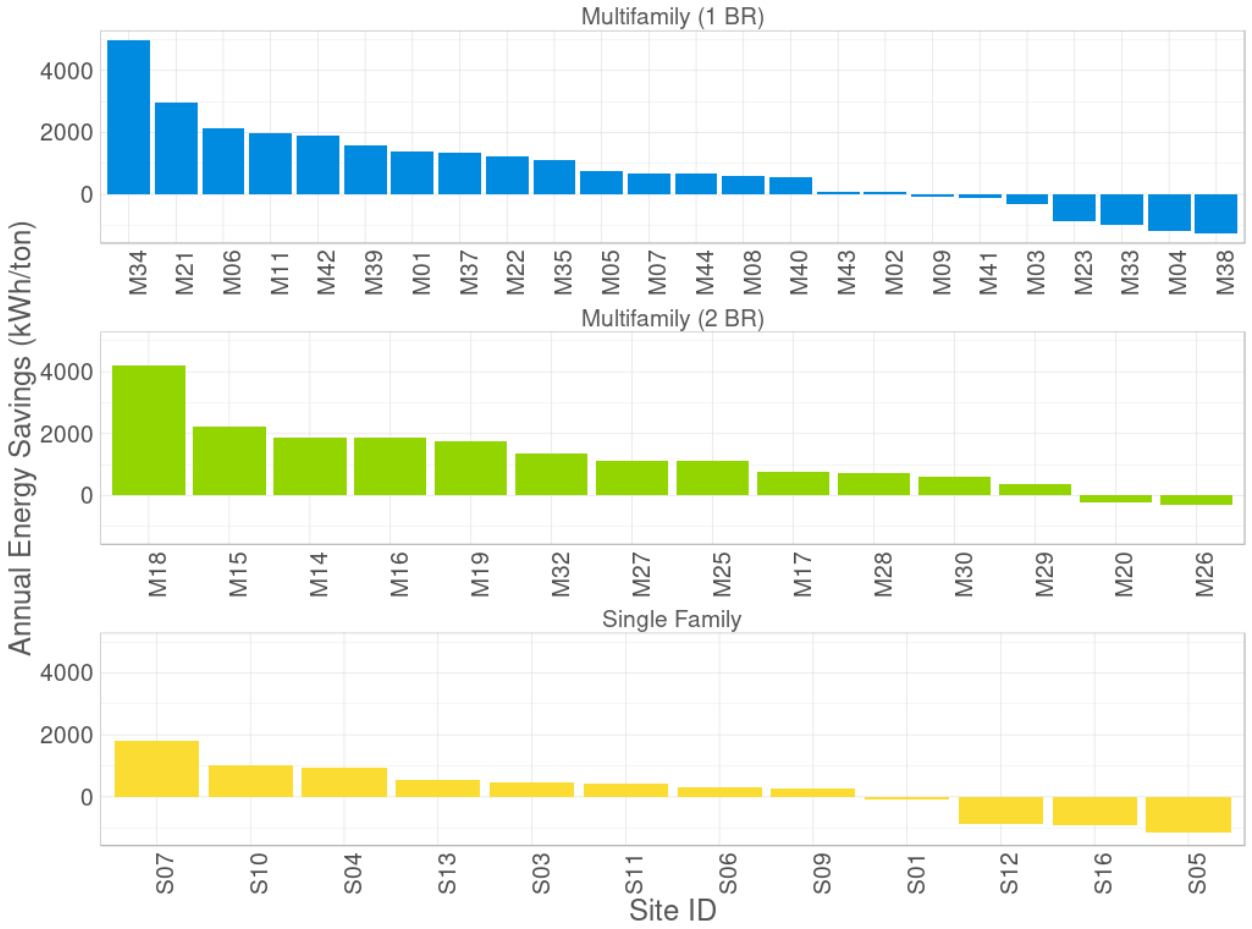
Impact Evaluation Results – Heating Season

Mini-split CCHPs reduced the average heating season energy consumption of MF and SF homes by 36%[1] and 7% respectively.

Building Type	Average kWh Savings	Average Pre-Install Consumption (kWh/Ton)	Average Savings (kWh/Ton^2)	Average Savings (%)
Multifamily (1BR)	1342	2482	805	32%
Multifamily (2BR)	2088	3082	1253	41%
Single Family	1133	3484	237	7%

There could be several reasons for lower-than-expected energy savings:

- **Customers continued to use baseboard electric heaters** after CCHP installation
- **Previously unconditioned spaces**: original baseboard electric heaters may have only been serving part of the home
- **Customers changed their behavior** (e.g. raised the heating setpoint) after the CCHP installation
- **COVID-19** may have led to behavior and occupancy changes which impacted the results
- **All HPs were two-head systems**, which have been found to have lower operating efficiencies than single-head systems in some other studies

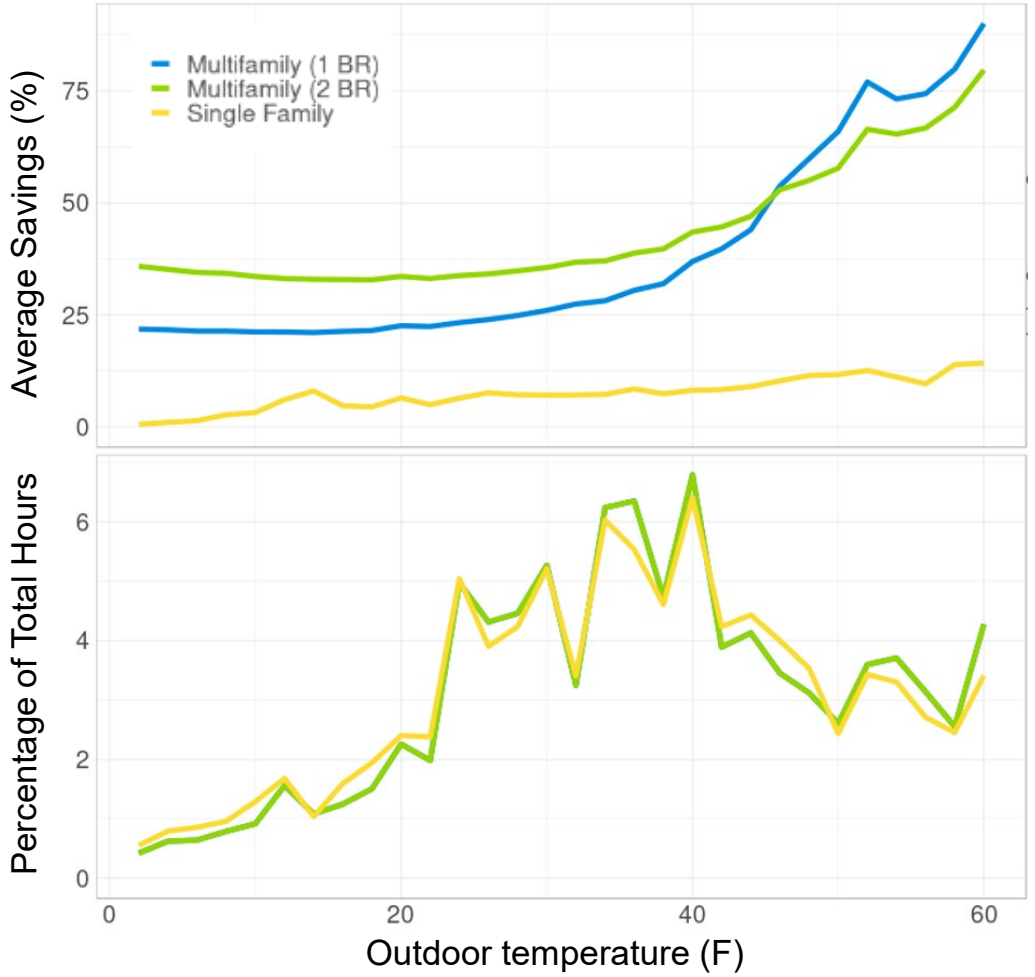


Site-level annual heating energy savings

Impact Evaluation Results – Heating Season

Savings were lower than expected across the range of outdoor ambient temperatures.

- Average energy savings as a function of ambient temperature for MF and SF homes vary from 21 to 90% and 1 to 14%, respectively.
- MF units showed an unexpectedly steep reduction in savings from 60°F to 40°F, but then a surprisingly consistent level of savings below 40°F (CCHP COP is expected to drop linearly with temperature). SF units showed low savings across all temperatures.
- A large portion of heating season hours fall between 20 to 40°F ambient temperature where the average savings were significant, at least for MF homes, but lower than expected.

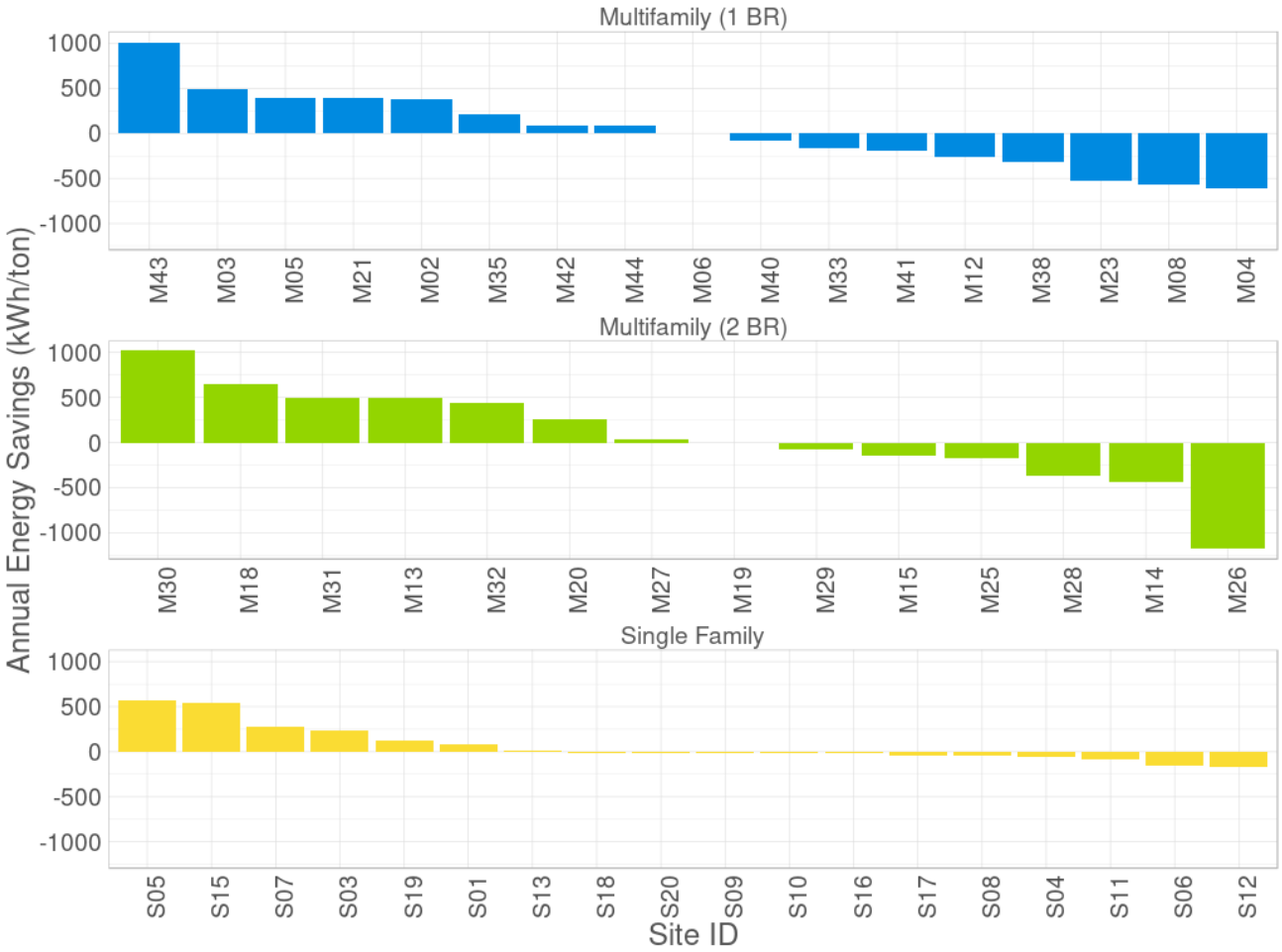


Impact Evaluation Results – Cooling Season

Mini-split CCHPs reduced the average cooling season energy consumption of MF and SF homes by 10%[1] and 27% respectively.

Building Type	Average kWh Savings	Average Pre-Install Consumption (kWh/Ton)	Average Savings (kWh/Ton²)	Average Savings (%)
Multifamily (1BR)	31	319	19	6%
Multifamily (2BR)	119	517	71	14%
Single Family	194	251	69	27%

- Since the annual heating load is significantly higher for Michigan than the annual cooling load, the average kWh savings are much lower than the average heating savings.
- The percent savings is also lower than heating due to a smaller increase in efficiency over the baseline cooling system (EER ~10 to ~18) than over the baseline heating system (HSPF 3.1 to ~9.8).
- The cooling season also has less consistent HVAC usage as customers may open windows or turn off air conditioning in the summer either to save money or when not at home. However, there is a more continuous usage of space heating in the winter.



Site-level annual cooling energy savings

Previous Air-Conditioning in Participant Homes

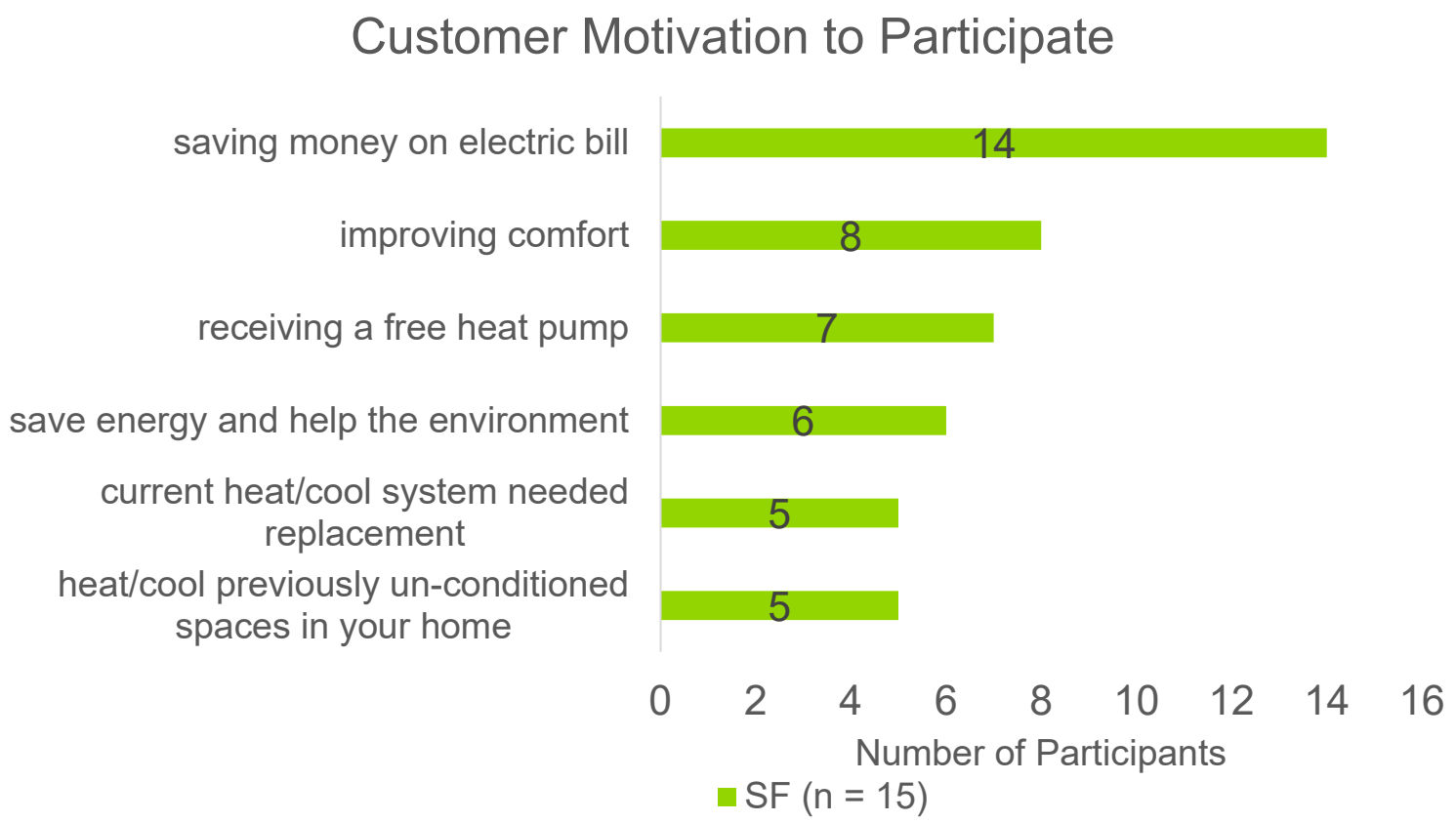
- Guidehouse found that MF customers may have continued to use window ACs after new HPs were installed.

- Only three SF survey respondents self-reported having Air conditioning in their home prior to heat pump installation however 13 out of 20 SF homes had window AC's prior to HP installation [1].
  - All three reported improved comfort compared to their old AC systems.
  - None of the SF respondents reported that they were still using their old AC units to cool any spaces in their home.
- All MF apartments had been previously equipped with window AC units.
  - Only one out of four MF survey respondents reported that they continued to use window AC unit(s) to cool a portion of their home.

Customer Survey Results

Motivation to Participate

Saving money on their electric bill was the most prevalent motivation for SF participants to enroll in the pilot program.



**customers were able to select more than one response option.*
***Since Multi-Family participants were not involved in the decision to install their heat pump, they were not asked this question.*

Occupancy Duration

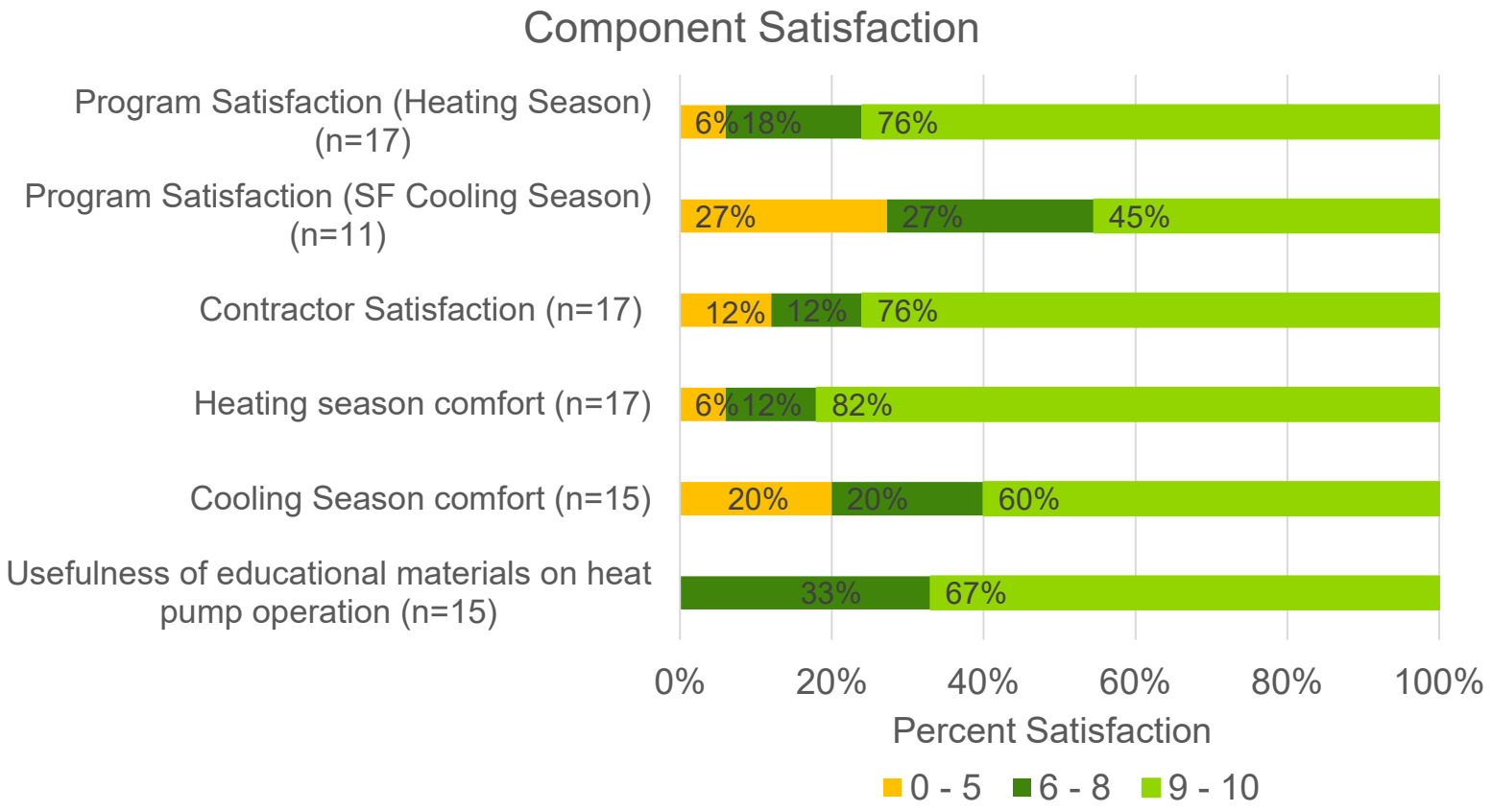
- 73% of SF customers have lived in their home over a decade.

Occupants per Home

- The number of occupants per household for SF customers ranged from one to seven (average = 2.33).

Satisfaction and Comfort Level

Customers had high satisfaction with the Heat Pump Pilot Program and reported improvement in comfort level after heat pumps were installed.



- Overall, most customers were satisfied with the contractor who installed their heat pump (Average score = 8.76).
- Most (14 out of the 17 total customers) said their **comfort level had improved** during the heating season after the heat pumps were installed (the remaining three customers' comfort stayed the same).

Findings

Findings

Customer Satisfaction

- Overall customers were satisfied with the program.
  - Average satisfaction rating (heating season) = 8.8
  - Average satisfaction rating (cooling season) = 7.9

Impact of Baseboard Heaters on Energy Savings

- Mini-split CCHPs reduced the average heating season energy consumption of MF and SF homes by 36% and 7% respectively and cooling season energy consumption by 10% and 27% respectively.
- Customer survey and data logger information confirmed that most SF customers continued to use their baseboard heaters in addition to their new heat pumps to serve as backup units or to obtain their preferred comfort level in specific parts of the home, which lowered the energy savings.
- The heating kWh savings (in absolute terms, rather than %) were much higher than the cooling kWh savings, due to the annual heating load being significantly higher than the annual cooling load.

Customer Expectations

- Some SF customers did not see a reduction in their electric bills and were not clear that continued usage of the baseboard electric heaters would impact energy savings and potentially increase the electric bills if baseboard electric heaters are used in addition to CCHP to heat their home.
- Some SF customers preferred the comfort level from baseboard electric heaters and continued to use them after CCHP were installed.

Acknowledgements

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Appendix

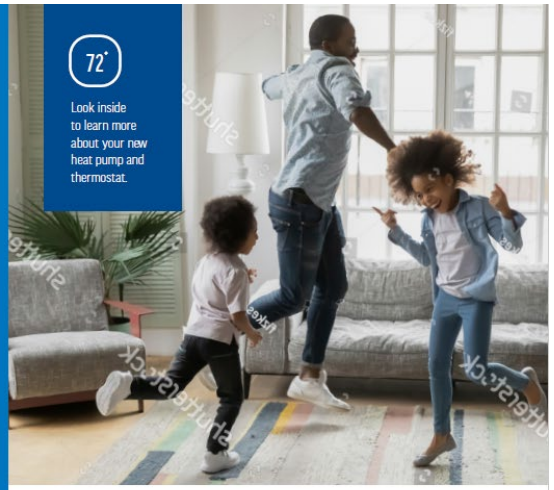
Education Material- Heat Pump Operation

DTE provided each participant with following heat pump operation education material.

DTE

Questions? We're here to help.

Contact us at **855.539.1906** or email us at **dteheatpumppilot@icf.com**.



Congratulations

Your heating system upgrade is ready to deliver energy savings

DTE

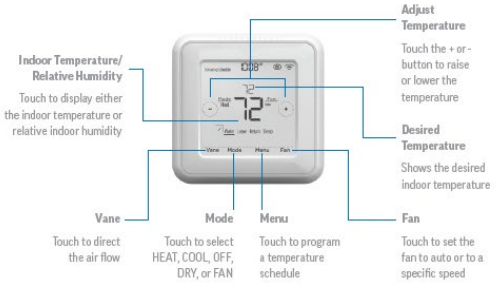
Say hello to year-round comfort and lower energy costs

Your new heat pump is on average 200% more efficient than an electric baseboard heater. That means you can save energy all year long, keeping you warm in winter and cool in summer.

Follow these tips to get the most from your new heating system:

- **Focus on your comfort, not temperature.** Set your thermostat to the temperature that makes your home feel the most comfortable. Select HEAT in the winter and COOL in the summer. It may take a few days and some adjustments until you find the temperature that's just right.
- **Set it and forget it.** The heat pump operates best when it maintains a steady temperature. Once you set the right temperature, leave it that way to stay comfortable.
- **Optimize comfort by directing the air flow.**
  - Direct warm air towards the floor and away from room occupants.
  - Direct cool air up or directly at room occupants.
  - Use higher fan speeds for greater efficiency.

Navigating your heat pump thermostat



Operating your heat pump

- **Set the system mode.** Tap MODE on the touch screen to cycle through HEAT, COOL, OFF, DRY, or FAN. The mode that the system is running will appear to the left of the current temperature.
  Note: If your residence has more than one heat pump, they must both be in the same mode.

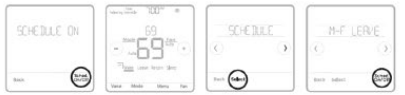
- **Change the temperature.** Tap the + or - symbol to adjust the temperature.

- **Change the fan speed.** Tap FAN to cycle through QUIET, LOW, MEDIUM, HIGH, SUPER HIGH, or AUTO.

- **Direct the air flow.** Tap VANE to cycle through AUTO, SWING, CEILING, HIGH, MIDDLE, LOW, or FLOOR.

Programming a temperature schedule

You can program different heating and cooling settings for four periods each day: Wake, Leave, Return, Sleep. These periods appear on the controller home screen. To set custom temperature settings for each period, select MENU, then SCHEDULE.



Default settings

Controller schedule is **turned ON**					
Period	**Start Time**	**Heat** (Mon-Fri)	**Cool** (Mon-Fri)	**Heat** (Sat-Sun)	**Cool** (Sat-Sun)
Wake	6:00 a.m.	69 °	79 °	69 °	79 °
Leave	8:00 a.m.	61 °	86 °	61 °	86 °
Return	6:00 p.m.	69 °	79 °	69 °	79 °
Sleep	10:00 p.m.	61 °	83 °	61 °	83 °