Residential Heat Pump Evaluation

efficiency MAINE

RIDGELINE energy analytics

Overview

Evaluation Overview

- Estimate the gross energy savings (kWh), summer and winter demand reduction (kW), and fossil fuel impacts (MMBTU) for heat pumps installed between December 2019 and June 2021
  - Conduct detailed measurement and verification on a sample of projects
  - Calculate a "realization rate" equal to the ratio of evaluated savings to claimed savings
  - Extrapolate the findings from the sample to the population
- Estimate the net-to-gross ratio (NTGR)
- Conduct a benefit/cost analysis using the evaluated savings
- Assess the annual heating and cooling produced for residential heat pumps

Evaluation Activities

- Customer surveys – facility information, project characterization, usage patterns, satisfaction with the program and contractor.
- Vendor surveys – HP sales practices and activity, equipment costs, customer decision-making, program influence, and market barriers.
- Measurement and verification – 124 systems: power of outdoor equipment, amperage to indoor equipment, temperature and relative humidity of the supply air stream, spot-measured airflow at multiple fan speeds for each type of indoor unit in a home
- Review of home floor plans and discussion with homeowners about heating strategy
- Advance Metering Infrastructure (AMI) analysis
- Analysis of benefits and costs – benefit-cost ratio.
- Net-to-gross analysis – free-ridership and spillover

For Discussion

Program Tiers and Incentives

Measure	Minimum HSPF	Incentives
HESP: Heat Pump Single Zone 1st Unit Tier 1	12	$500
HESP: Heat Pump Single Zone 2nd Unit Tier 1	12	$250
HESP: Heat Pump Single Zone 1st Unit Tier 2	12.5	$1000
HESP: Heat Pump Single Zone 2nd Unit Tier 2	12.5	$500
HESP: Heat Pump Multi-zone 2 or more zones (1st two (2) indoor units)	10	$750
HESP: Heat Pump Multizone add on (2nd indoor unit)	10	$250
LMI: Mini-Split HP LIHEAP & Mini-Split HP Property Assessed	13	$2000
LMI: Heat Pump Single Zone 2nd Unit Tier 2	12.5	$500

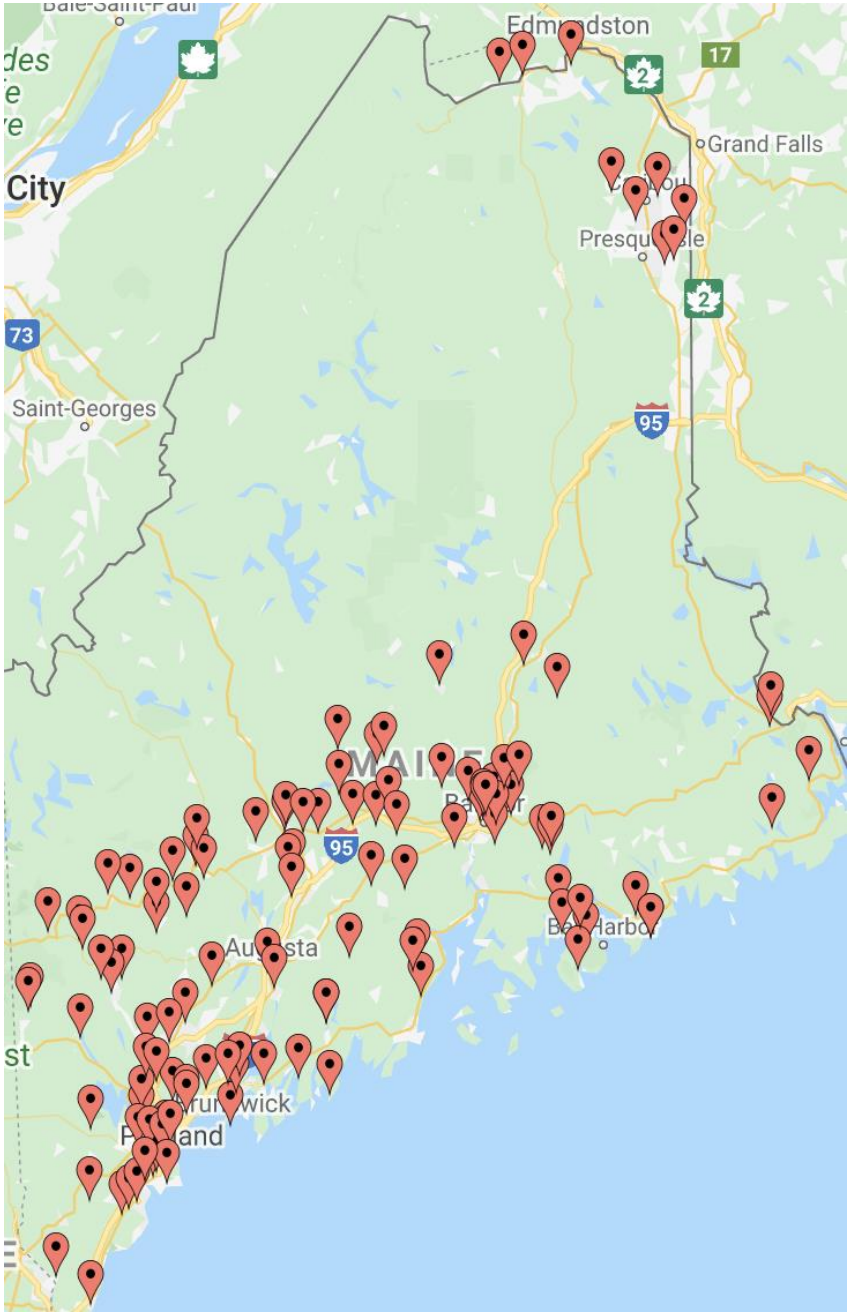
For Discussion

Sampling and Sites

Sampling (site level)

Strata	Population Size (projects)	Target Sample Size	Actual Sample
Single Zone, Tier 1	2,497	20	22
Single Zone, Tier 2	9,573	60	57
Multi-zone	4,732	25	24
Property Assessed	1,150	12	12
LIHEAP	192	9	9
TOTAL	18,144	126	124

For Discussion



124 Sites

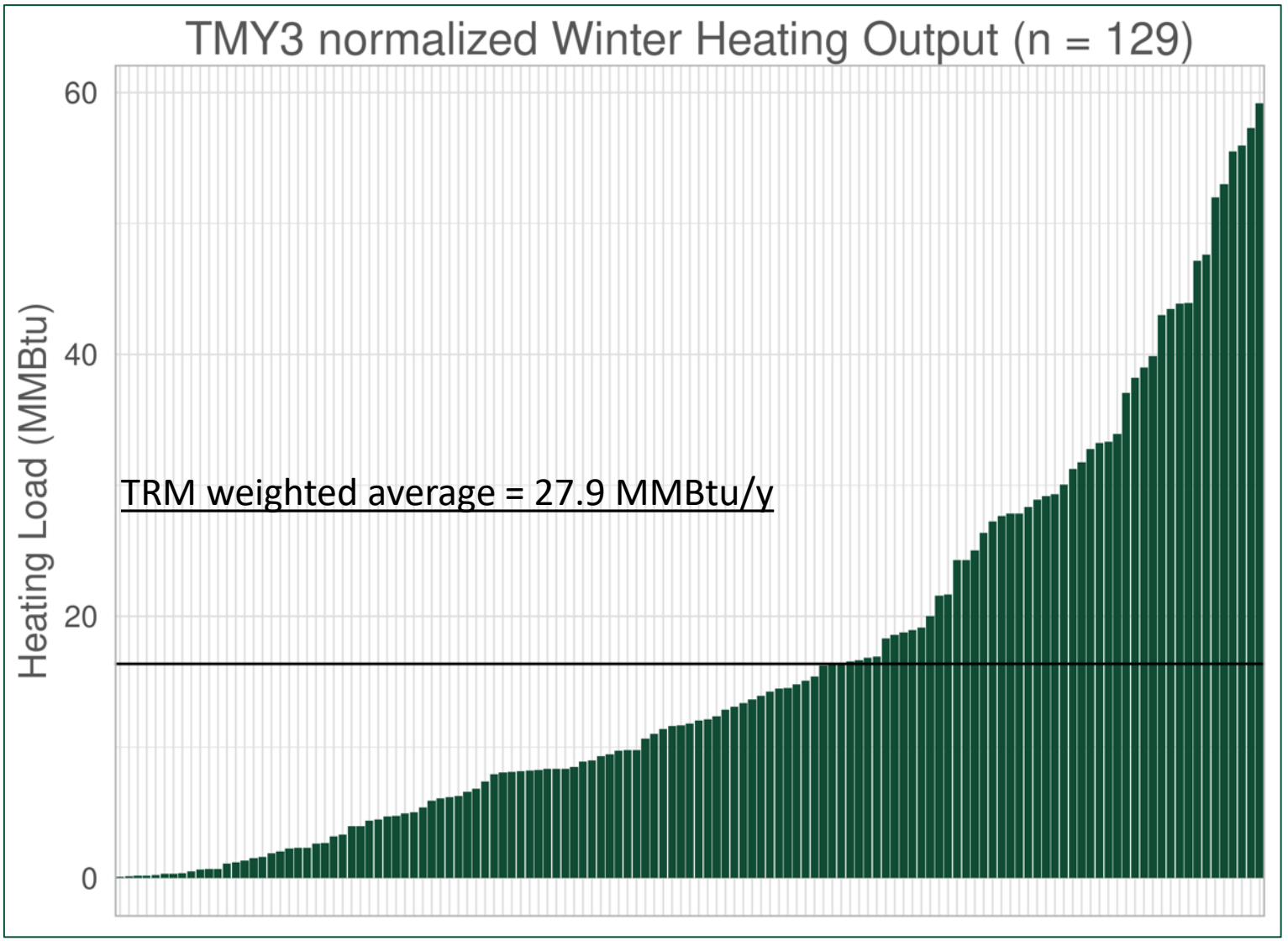
- Sites in 15 of 16 counties
- Sites in all USDA climates zone (5a, 5b, 4a, 4b)

For Discussion

Heating and Cooling Use

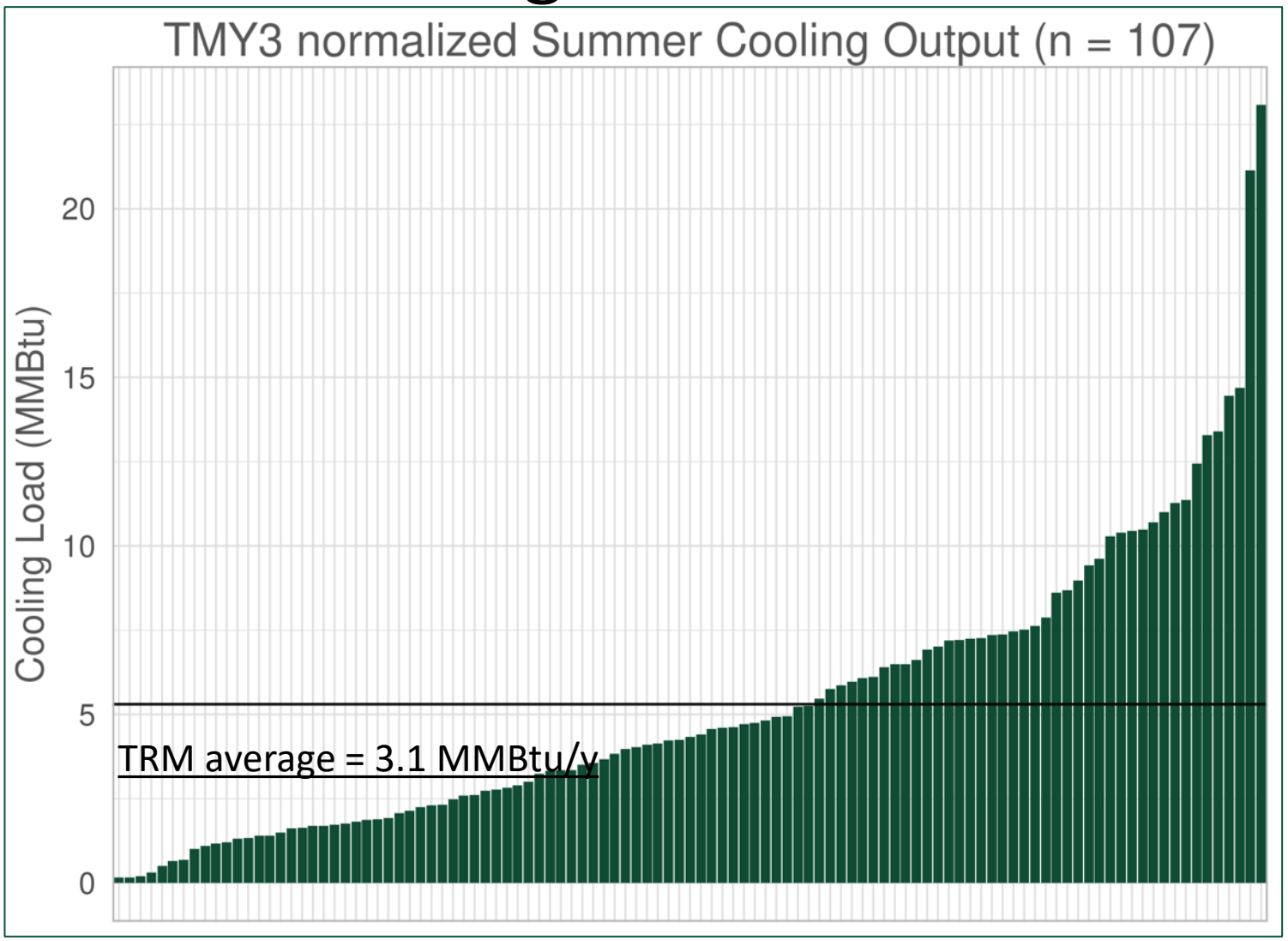
For Discussion

Mean Heat (mean = 16.4 MMBTU)



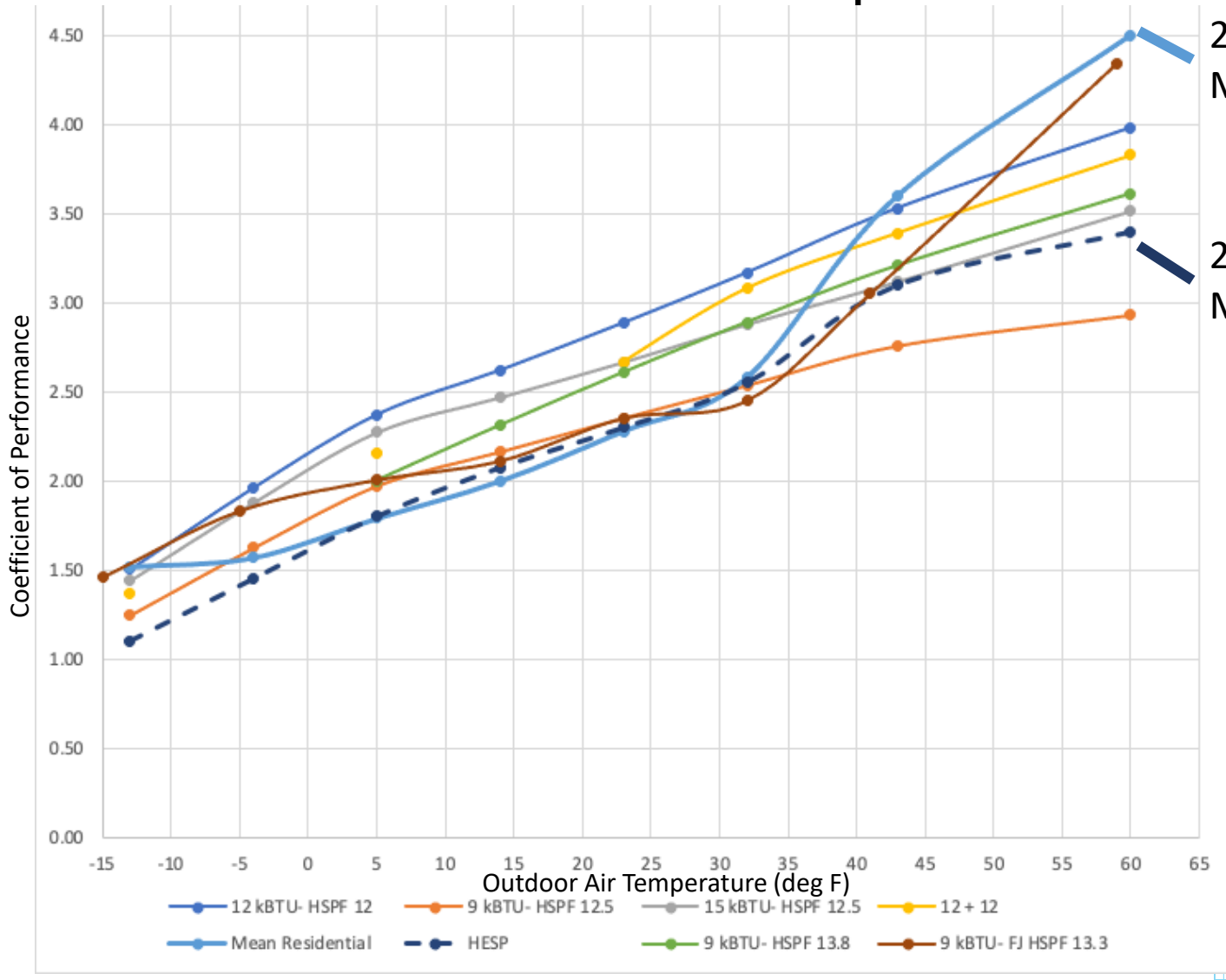
For Discussion

Mean Cooling (mean = 5.3 MMBTU)



For Discussion

Measured vs. Example Rated COPs



2023 Evaluation Metered Performance

2019 Evaluation Metered Performance

For Discussion

Coefficient of Performance (COP)

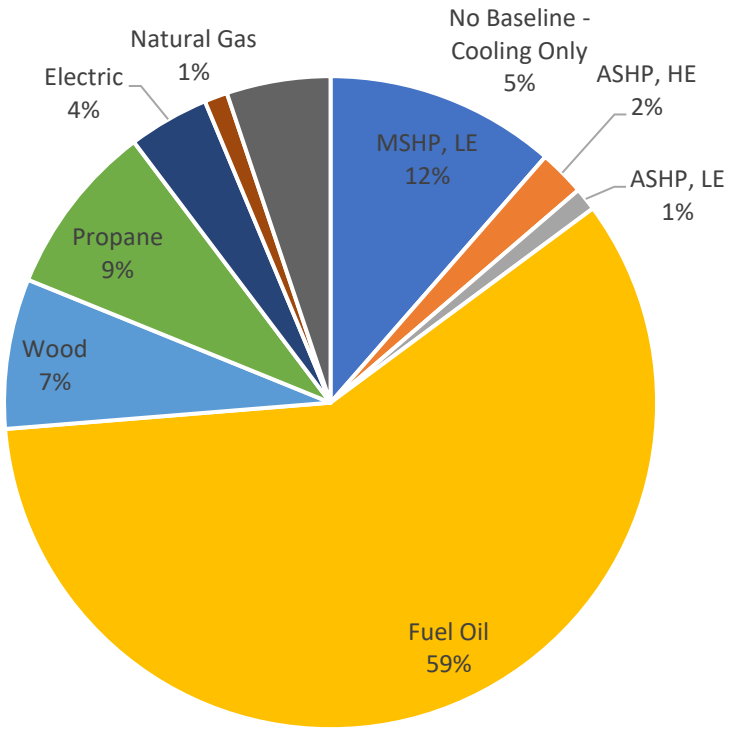
- COP decreases with decreasing evaporating temperature (outdoor unit when heating)
- The mean manufacturer reported COP for a typical 15 kBTU unit is 2.85 weighted for heat delivered
- COP for all metered heat pumps was 2.58 weighted for heat delivered

Realized Savings & Cost Effectiveness

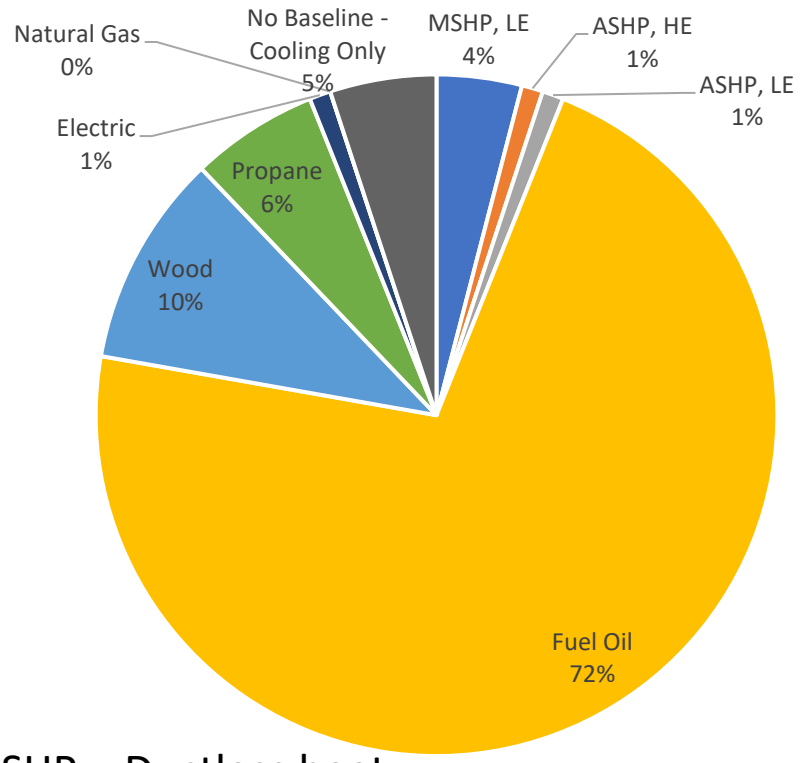
For Discussion

Baseline Heating System from Participant Survey

HESP Baseline Heat Source



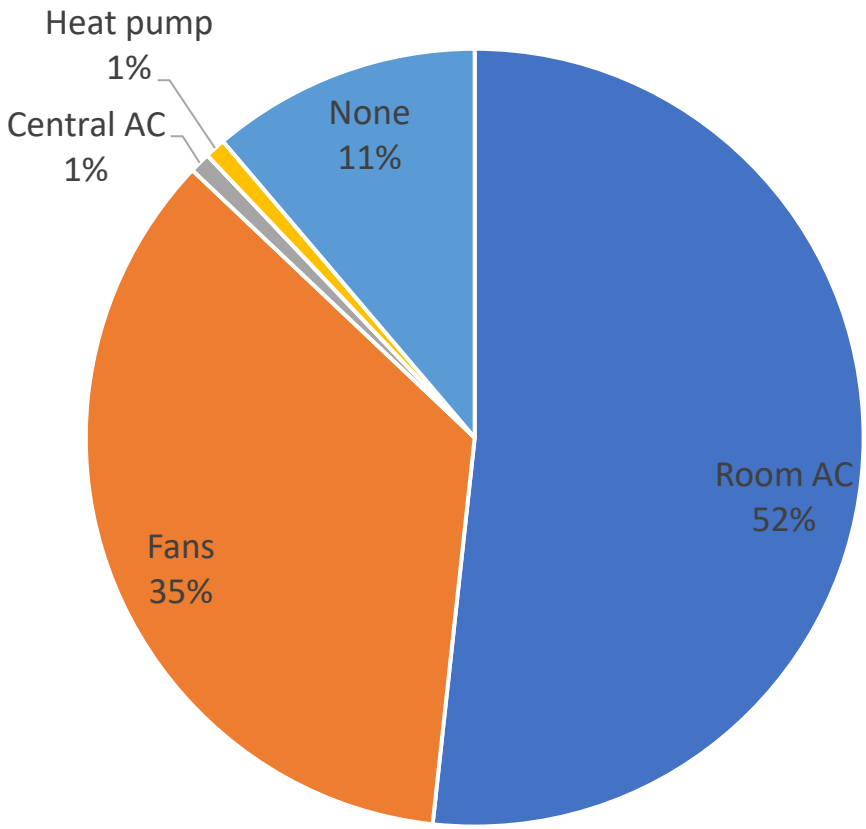
LMI Baseline Heat Source



LE – Low efficiency; HE – High efficiency; MSHP – Ductless heat pump; ASHP—Conventional ducted heat pump

For Discussion

Prevalence of Baseline Cooling by System Type



For Discussion

Project/Decision Type

Retrofit

- If not for the program, customer would have made no heating/ cooling system purchase
- Savings are measured against existing heating/cooling system(s)
- Cost is total project cost including installation labor

New Construction/Replace on Burnout

- Customer was going to purchase a new heating/cooling system within a year
- Savings are measured against most likely alternative system(s)
- Cost is incremental cost between alternative system and heat pump

Retrofit Projects (%)	HESP	LMI
Evaluated	79%	
TRM Assumption	0%	100%

For Discussion

Measure Cost

System Type	Retrofit Baseline	New/ ROB Baseline	Weighted Baseline System Cost	Installed System Cost	Measure Cost
Single Zone, Tier 2	$0	$6,080	$1,267	$3,730	$2,463
Single Zone, Tier 1	$0	$6,080	$1,267	$4,069	$2,802
Multi-zone	$0	$7,355	$1,532	$7,670	$6,138
MiniSplit HP Property Assessed	$0	$6,261	$1,304	$3,405	$2,101
MiniSplit HP LIHEAP	$0	$6,261	$1,304	$3,568	$2,264

Realized Savings

Population Total	kWh	MMBtu
Ex Ante (recorded in effRT database)	-20,843,770	317,665
Ex Post (determined by evaluation)	-31,228,170	405,197
Realization Rate (Ex Post/Ex Ante)	1.5	1.28

Per Heat Pump Unit	kWh	MMBtu
Ex Ante (recorded in effRT database)	-966	14.72
Ex Post (determined by evaluation)	-1,447	18.77
Realization Rate (Ex Post/Ex Ante)	1.5	1.28

Benefit Cost Analysis

		Retrospective	Prospective
Labels for Index-Match	**Population**	**AESC 2018 (yr1=2020)**	**AESC 2021 COC (yr1=2021)**
All Heat Pumps	21,804	1.14	1.24
Heat Pumps HESP-all	20,384	1.13	1.23
Heat Pump Single Zone - Tier 1	3,052	1.27	1.39
Heat Pump Single Zone - Tier 2	12,135	1.39	1.50
Heat Pump Multi-Zone ALL	5,197	0.82	0.90
Property Assessed and LIHEAP	1,420	1.38	1.44
MiniSplit HP Property Assessed	1,218	1.43	1.49
MiniSplit HP LIHEAP	202	0.94	1.03
Heat Pump Single Zone – ALL (100% Retrofit)	15,187	1.07	1.20
Heat Pump Single Zone – ALL (100% New/ROB)	15,187	2.94	2.74
Heat Pump Multi-Zone ALL (100% Retrofit)	5,197	0.71	0.80
Heat Pump Multi-Zone ALL (100% New/ROB)	5,197	1.78	1.70

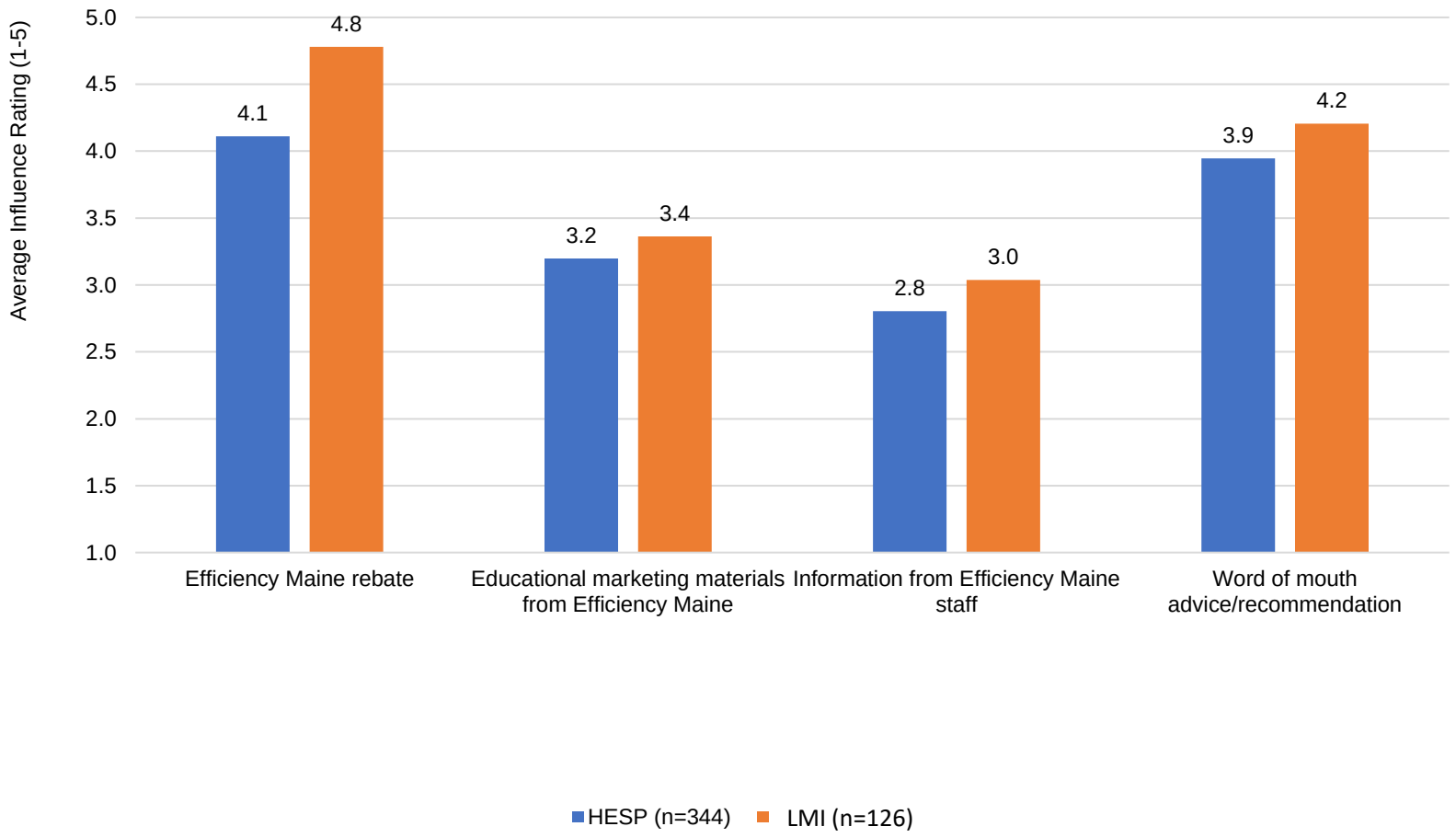
For Discussion

Customer Survey

For Discussion

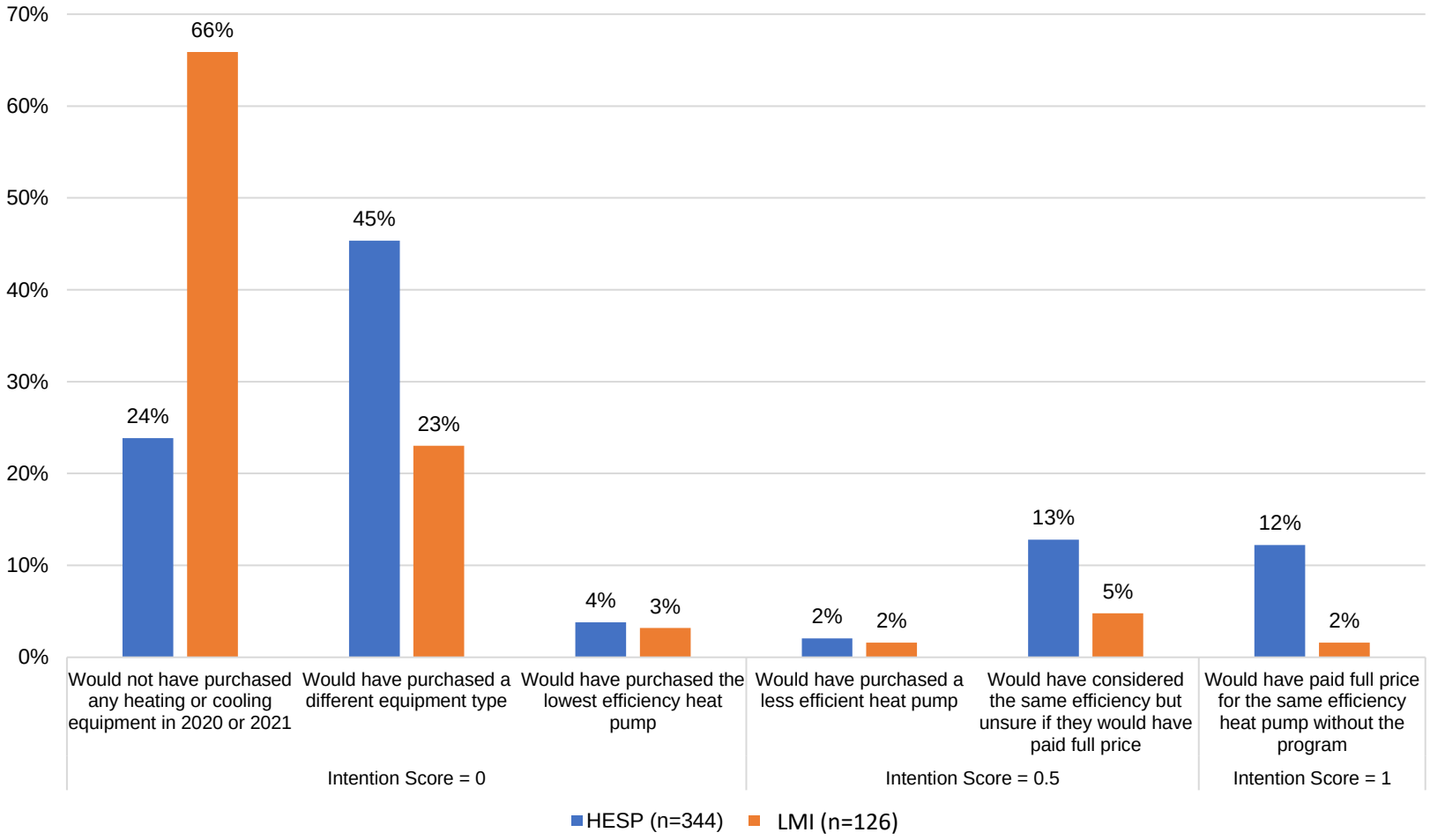
Program Influence Survey Responses

Average reported score out of 5



For Discussion

Intent Responses: Participants' Most Likely Alternative Purchase

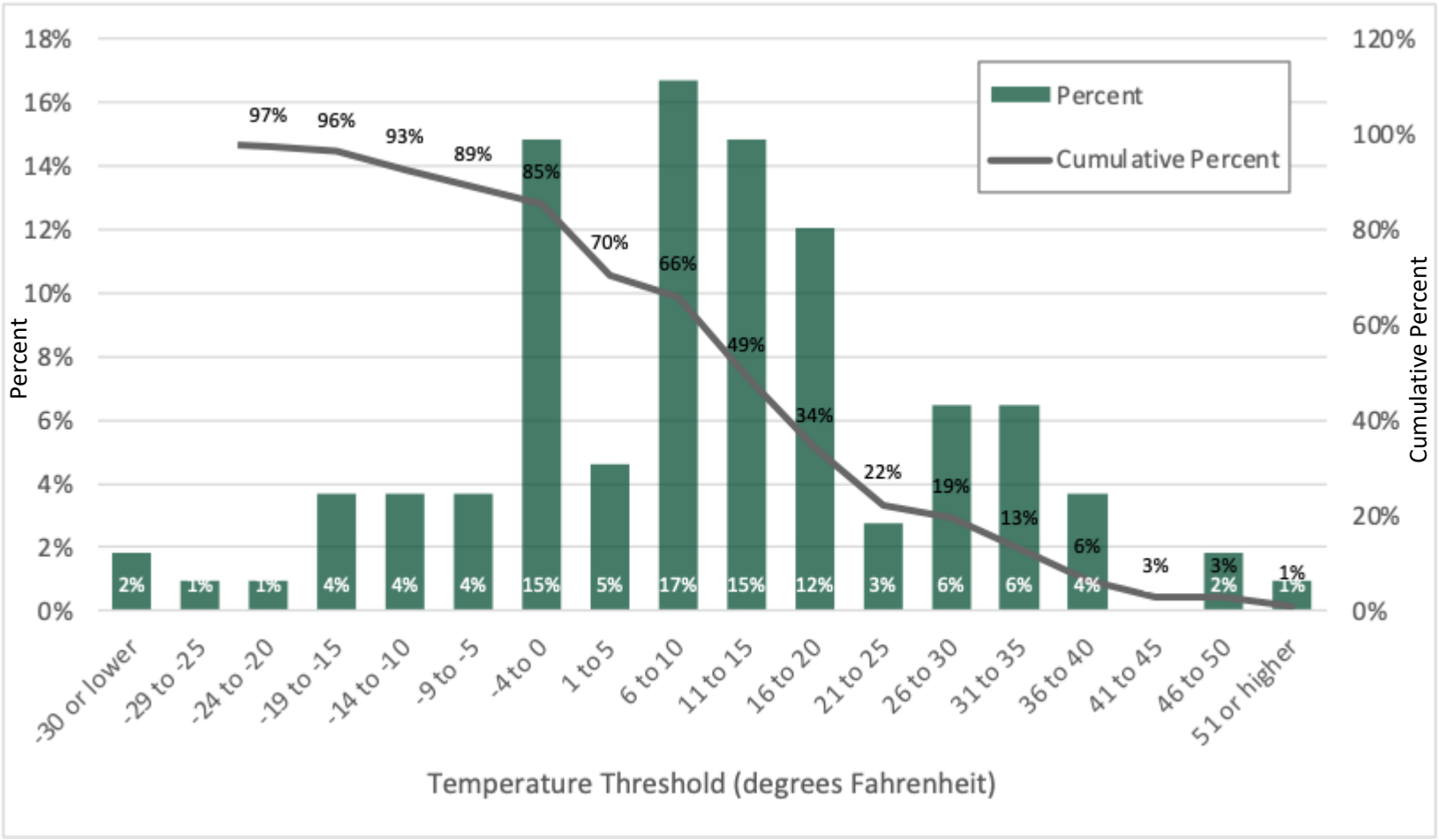


For Discussion

Free Ridership and Spillover

Program	Free Ridership (FR)	Spillover (SO)	Net-to-Gross (NTG)
HESP	16%	2%	86%
LMI	2%	0%	98%

Customer Reported Temperature of When Heat Pumps Get Shut Off



For Discussion

Customer Survey Findings

- Participants are highly satisfied with their program experiences and their heat pumps, rating 4.7/5 for cooling, and 4.4 and 4.3 for HESP and LMI for heating
- Four of five participants report using their new heat pump(s) as their primary heating system. About two-thirds of participants switch to their alternative source on very cold days.
- Most participants report that they have observed savings on their winter energy bills since installing their heat pumps.
- 55% of HESP and 37% of LMI participants reported having a backup source of power.
- 13% of homeowners report shutting their HPs off above 32F, 66% of homeowners report shutting their HPs off at or above 10F

AMI Comparison

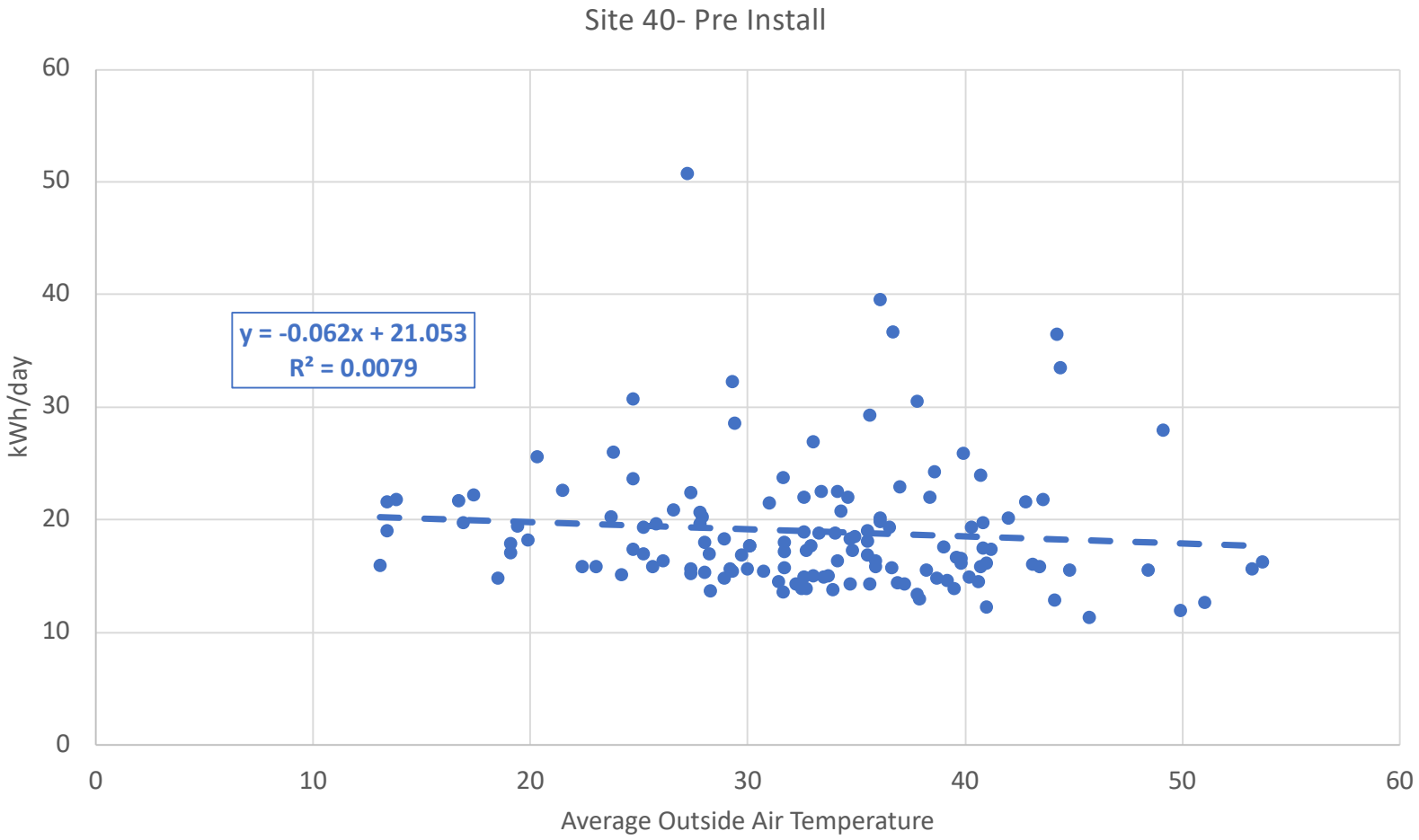
AMI Analysis

- Interval electric data was obtained for sites that gave permission for access and where it was available
- Energy use was resolved into daily kWh use and this was regressed onto daily base 65 heating degree days
- Where available, regression graphs were developed for pre- and post installation

Can AMI Data be Used to Supplement or Replace HP Metering?

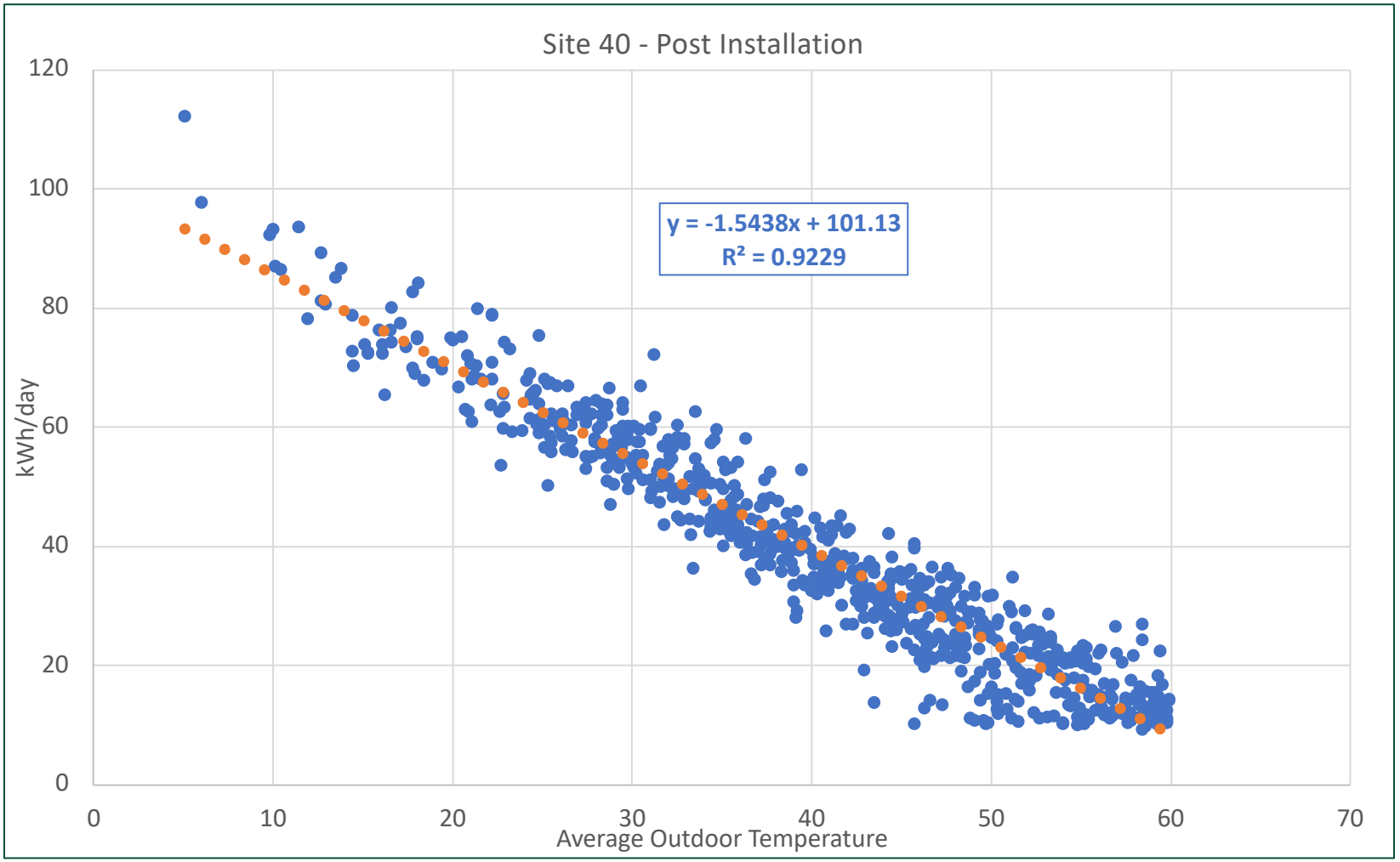
- Even in fossil fuel heated homes there can be some positive correlation between daily heating degree days (HDD) and electrical use due to furnace fans and boiler pumps
- Electrical resistance (ER) and heat pump homes will have a strong correlation between HDD and electrical use, albeit with different slopes
- The evaluation team compared AMI and meter data for several homes. The following slides show three examples
  - High HP use and fossil backup (site 40)
  - Moderate HP use and ER and wood backup (site 99)
  - Low to no HP heating use (site 22)

Low Pre-Install Weather Dependence



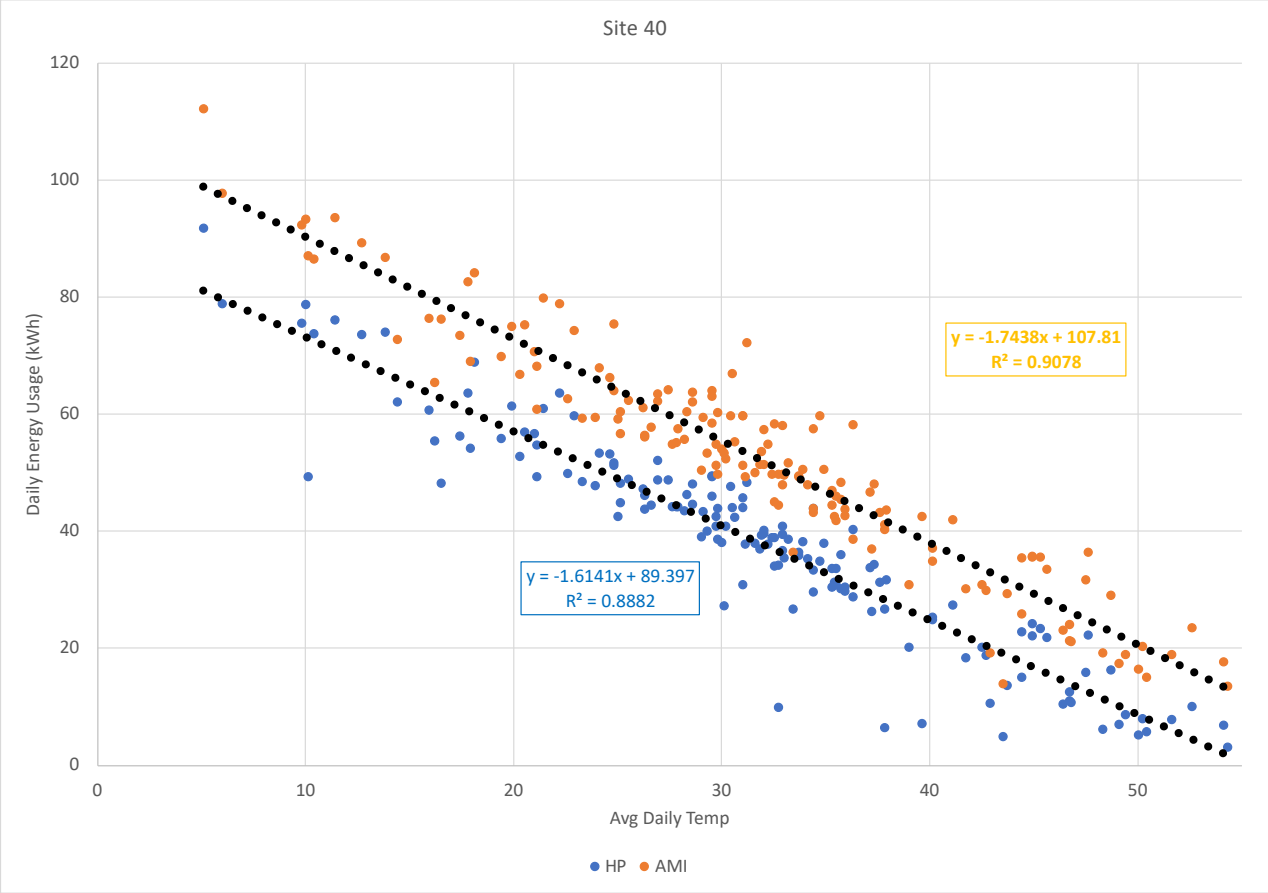
For Discussion

Clear Post-Install Weather Dependence @ < 60F



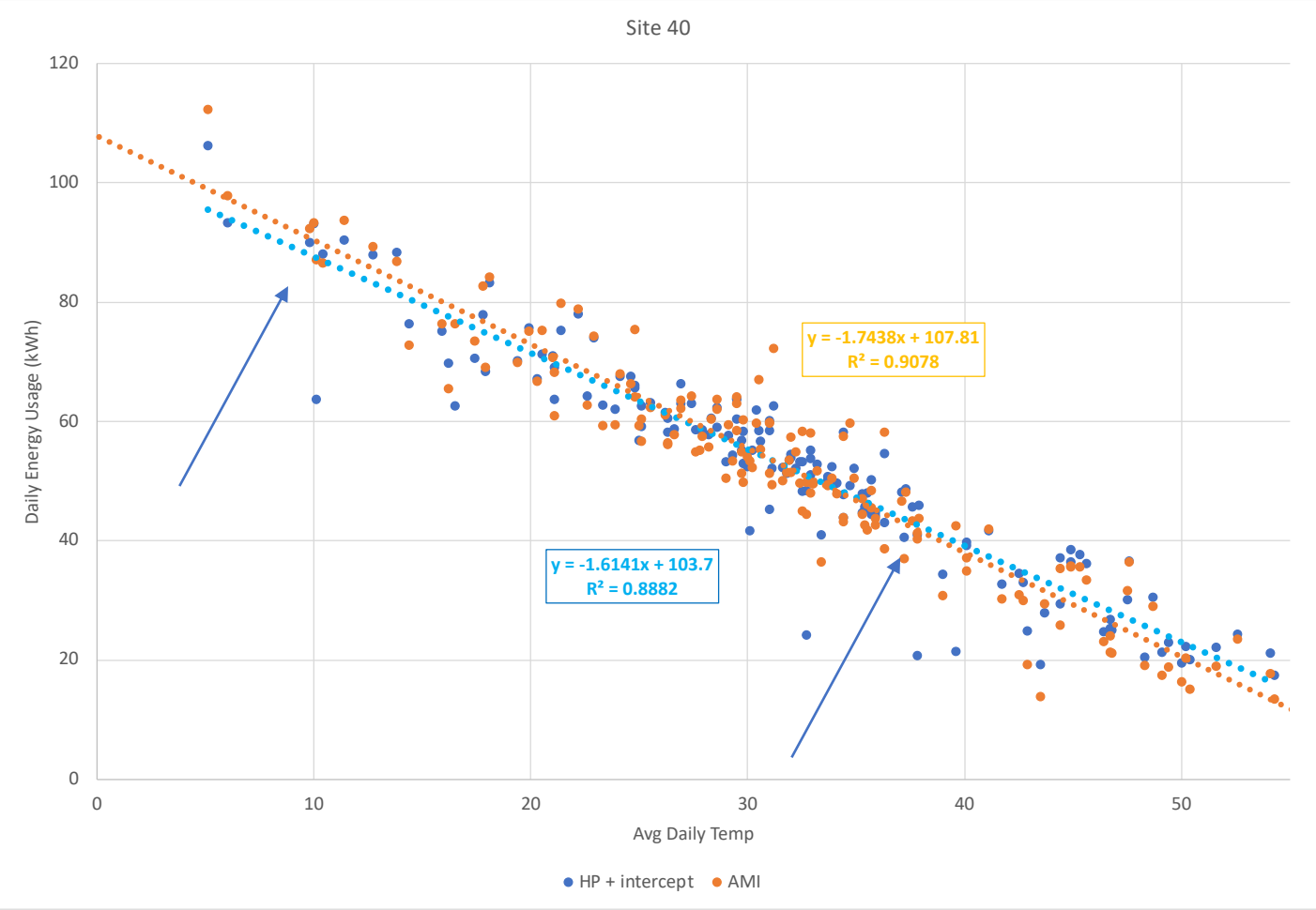
For Discussion

Meter and AMI Curves are Parallel



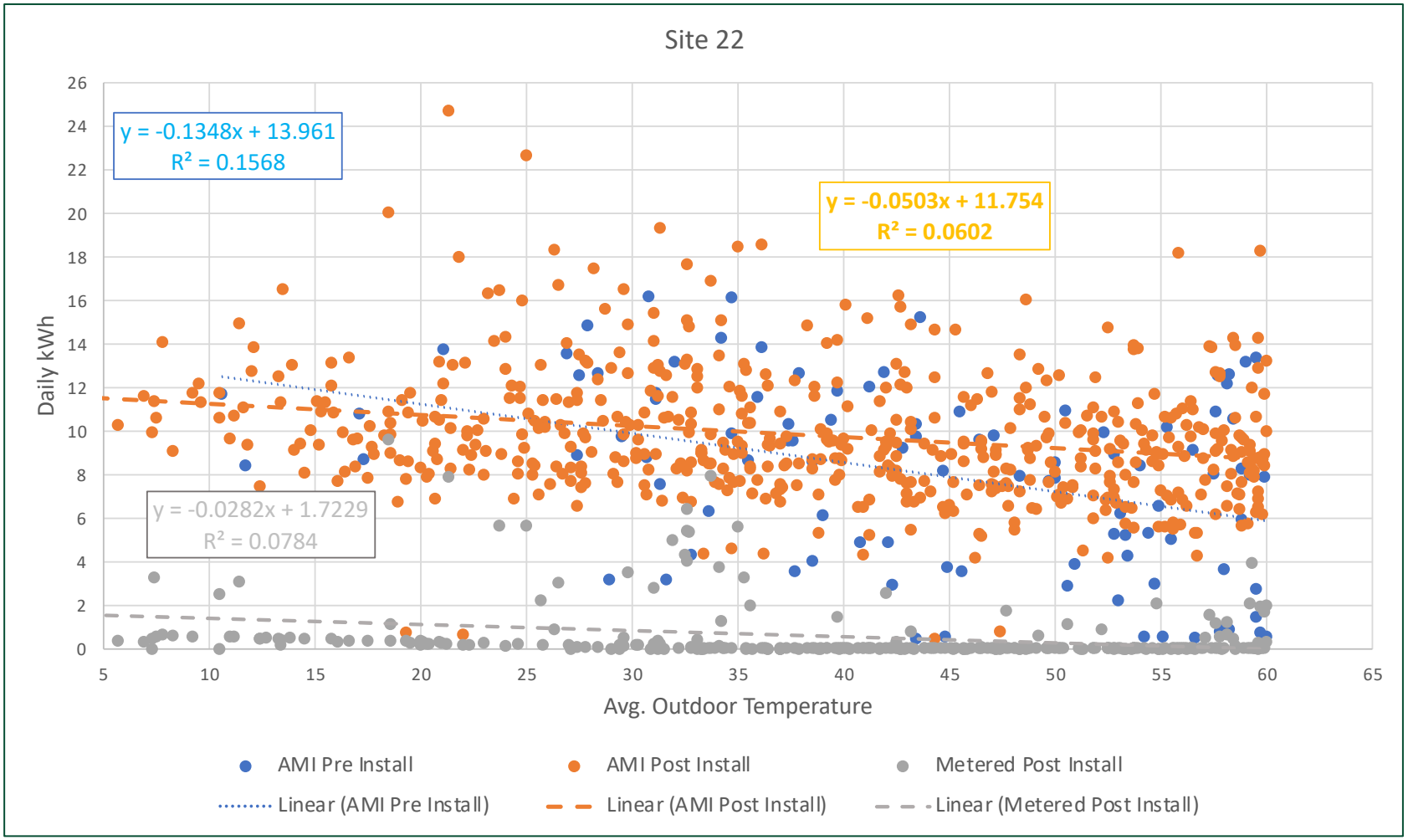
For Discussion

AMI is a Good Predictor of Metered Use



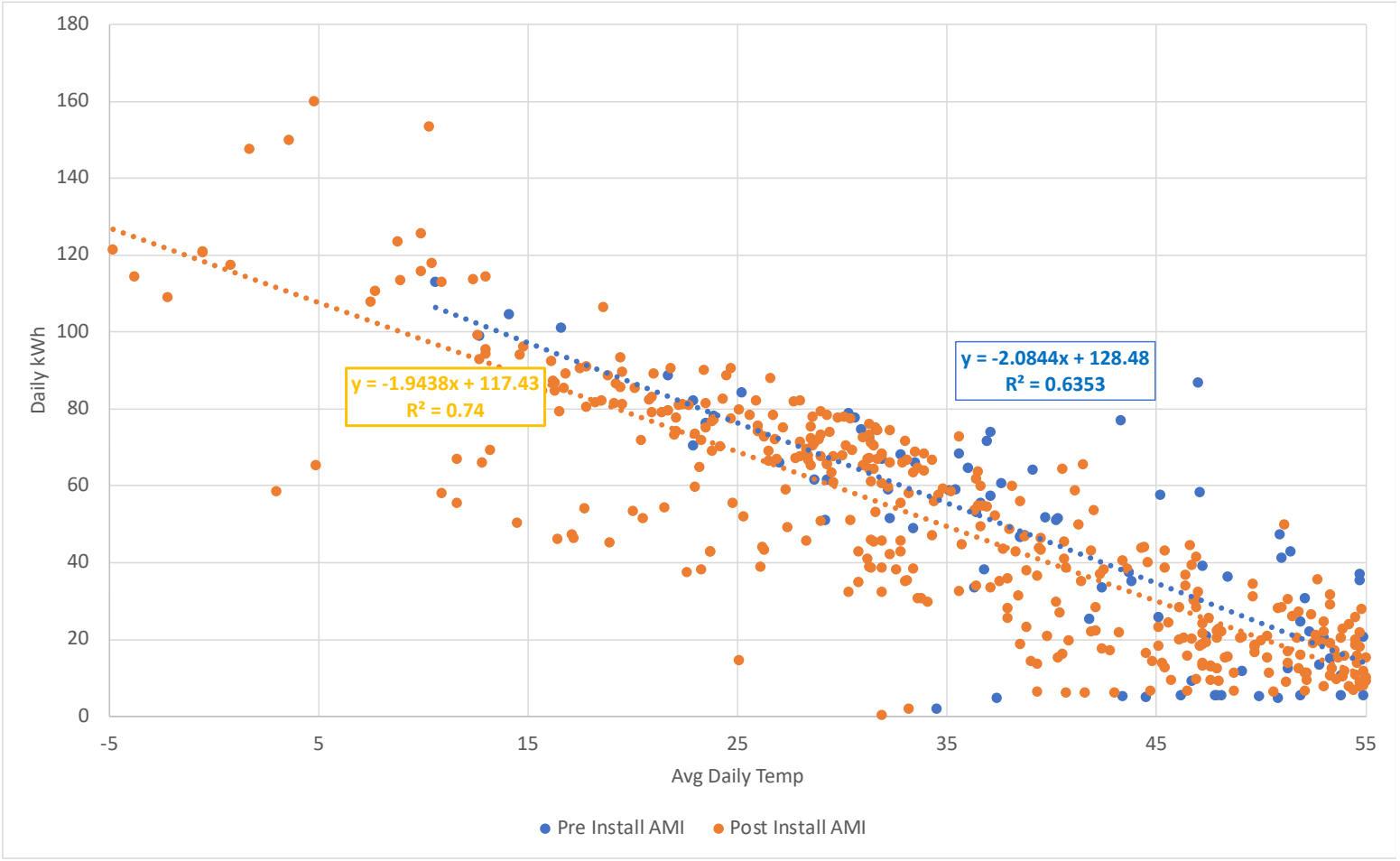
For Discussion

AMI and Metering Both Show Little to No Heating Use



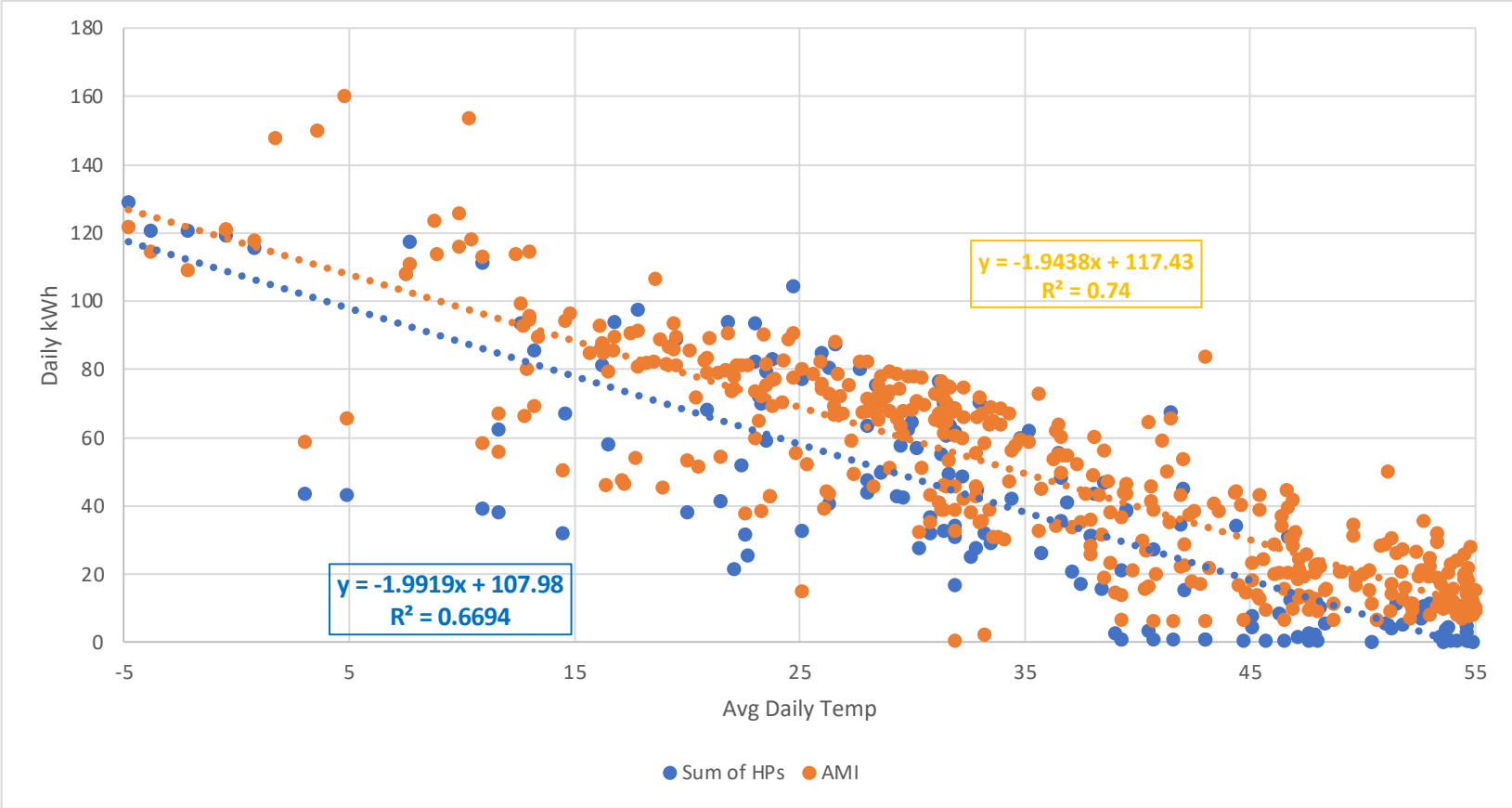
For Discussion

Site 99: Pre and Post Installation: Partial Electric Resistance shifted to HP



For Discussion

Post AMI and Metering Similar
Some Use of electric resistance Remains



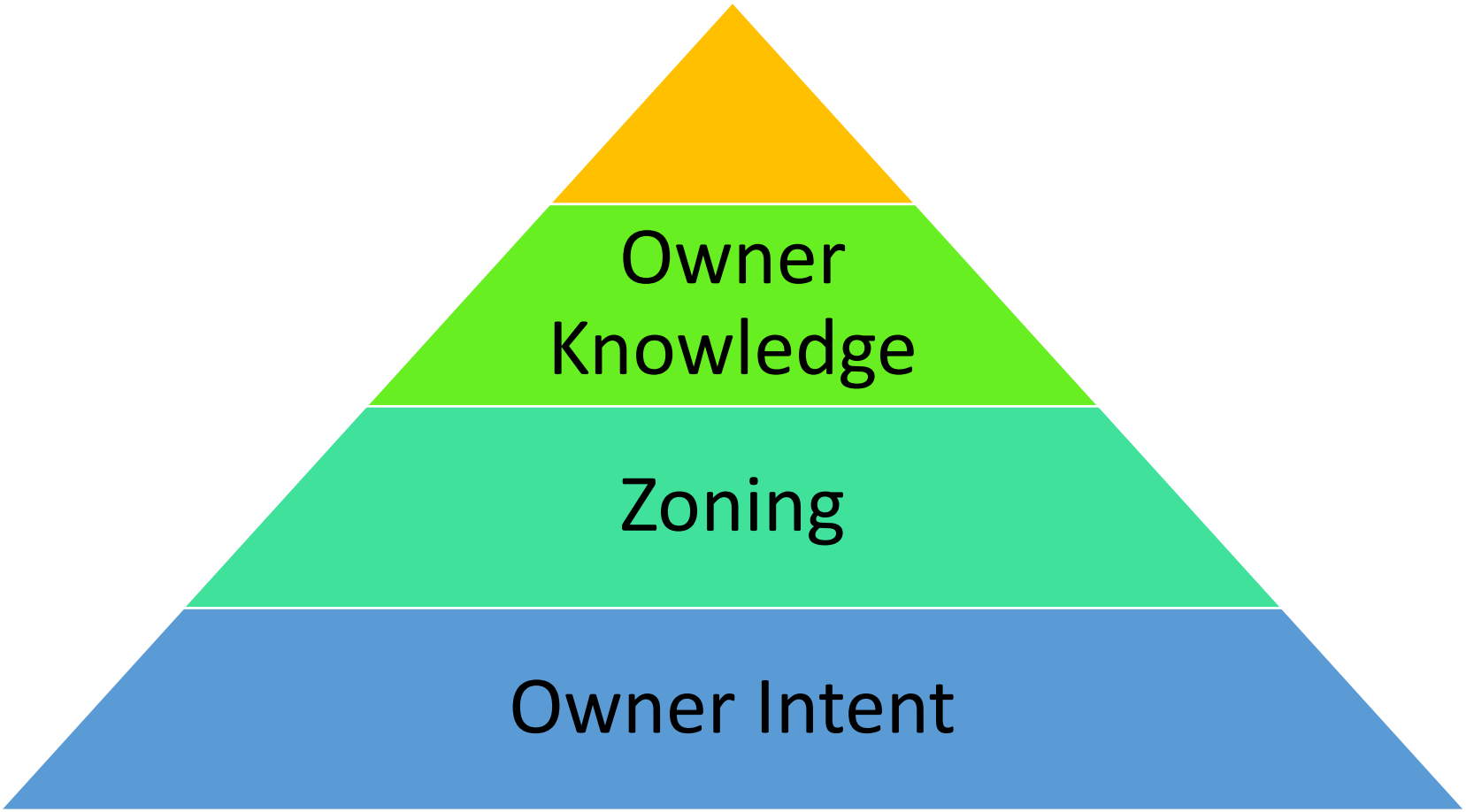
For Discussion

AMI Observations

- AMI appears to be a good tool for homes with no electrical heating for detecting high and low use
- AMI is not an ideal tool if a home has varied occupancy and partially heated with electric resistance. This is easily checked – If pre installation AMI analysis shows high electrical correlation, it is not ideal for HP analysis. Site 22 showed little change from pre to post but the user shifted from ER to heat pumps, likely with a different usage pattern
- AMI can be a good tool for sorting out customer concerns

Factors Impacting Heat Pump Use – Evaluator Observations

Three Elements Impact Heating Use



For Discussion

Owner Intent

- Only 1% of survey respondents claim to only cool with the HP, but field discussions point to 5% or higher that do not heat
- 19% turn the heat pump on and off as needed pointing to supplemental heating
- One third of homeowners shut off their heat pumps above ~20F
- Wood heat is very common as a supplement (31% of homes), and owners like it for reasons like low cost and ambiance
- Some homeowners leave Maine in October (~5-10%) and vary in whether they use fuel or a heat pump to maintain 50F

Zoning

- 31% of homes have furnaces and nearly all of these are single zone. A single zone fossil fuel system makes it difficult to fully turn off the baseline system unless the home is fully covered with heat pumps
- Often the indoor units serve a single area and can't deliver to rooms far away. Mobile homes with one indoor unit are examples where the heat won't reach many rooms even with open doors

Owner Knowledge

- We met several homeowners that didn't understand the use of a heat pump in a zone. One had a heat pump co-located with a boiler zone—perfect to maximize heat pump use. They wanted to move the boiler thermostat because they thought the heat pump was "interfering" with it.
- Another homeowner set the baseline and heat pump thermostat to the same setting reasoning that this would allow the best control
- Many homeowners struggled with using the complex remotes other than turning them on and off and setting a temperature
- Several homeowners knew that efficiency dropped at lower temperatures and shut off the heat pump at ~20F to save money (contrary to Efficiency Maine Heat Pumps Tips)

For Discussion

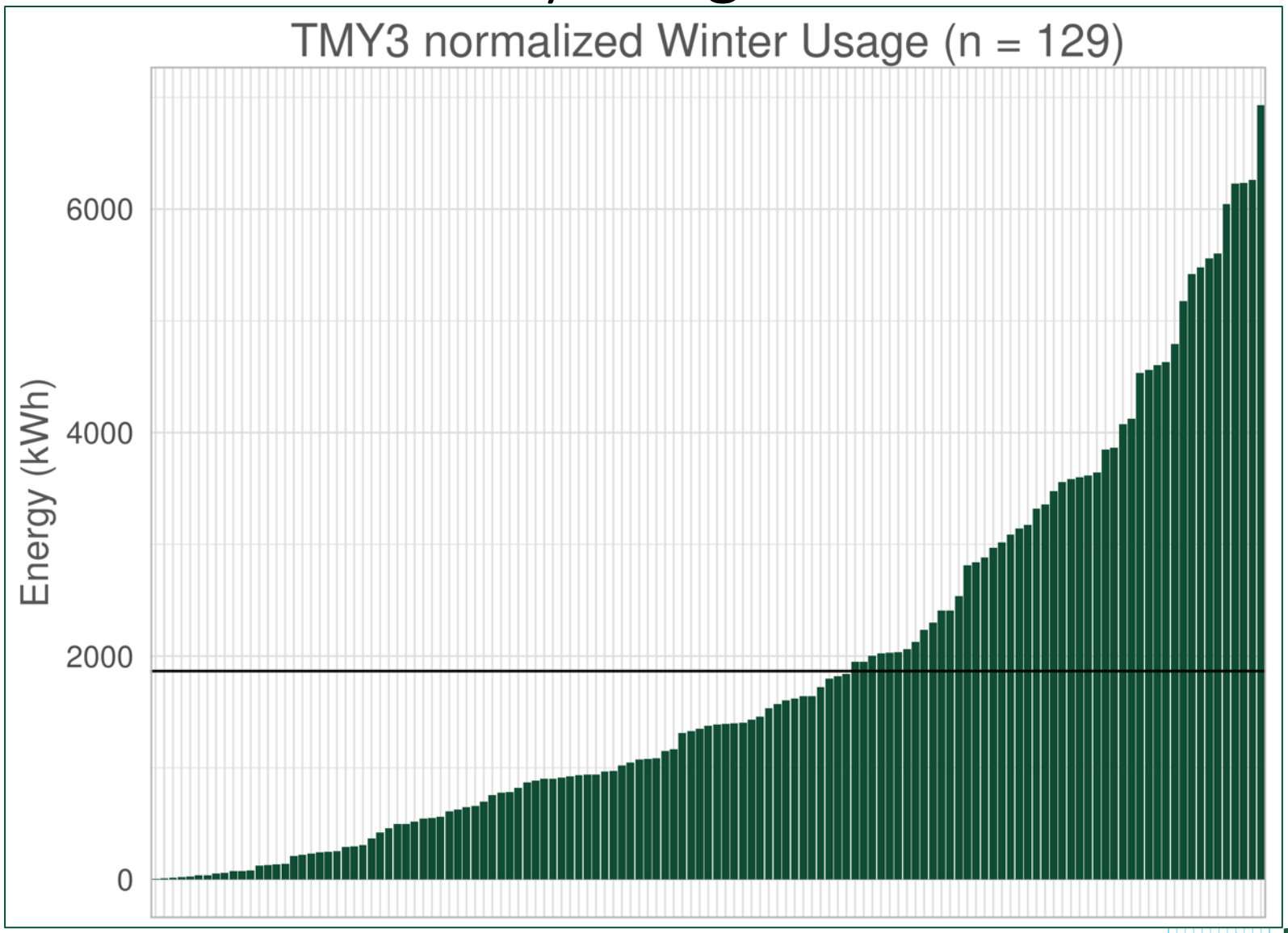
Unique Aspects of Homes

- A mobile home switched to a furnace at 30F to protect water pipes (Fort Kent)
- One homeowner had a large pellet stove so used the heat pump until it was cold enough to turn on the furnace (Easton) (October)
- One homeowner liked his kerosene monitor and only used the heat pump for dehumidification
- One homeowner heated almost entirely with heat pumps (Caribou)

Questions??

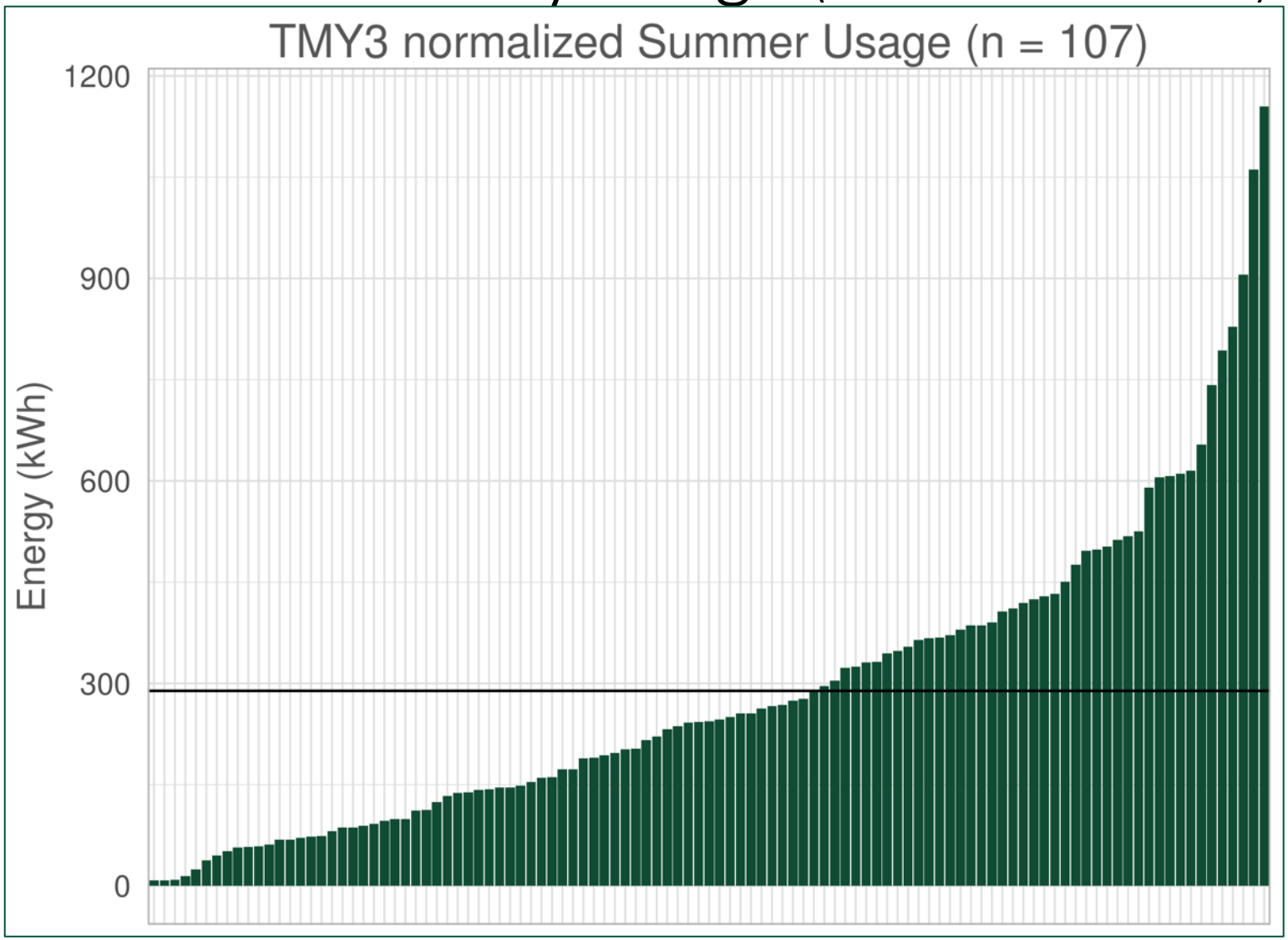
Additional Details

Winter Electricity Usage (mean = 1,866 kWh)



For Discussion

Summer Electricity Usage (mean = 289 kWh)



For Discussion