Electric Heat Pumps – Field Experience

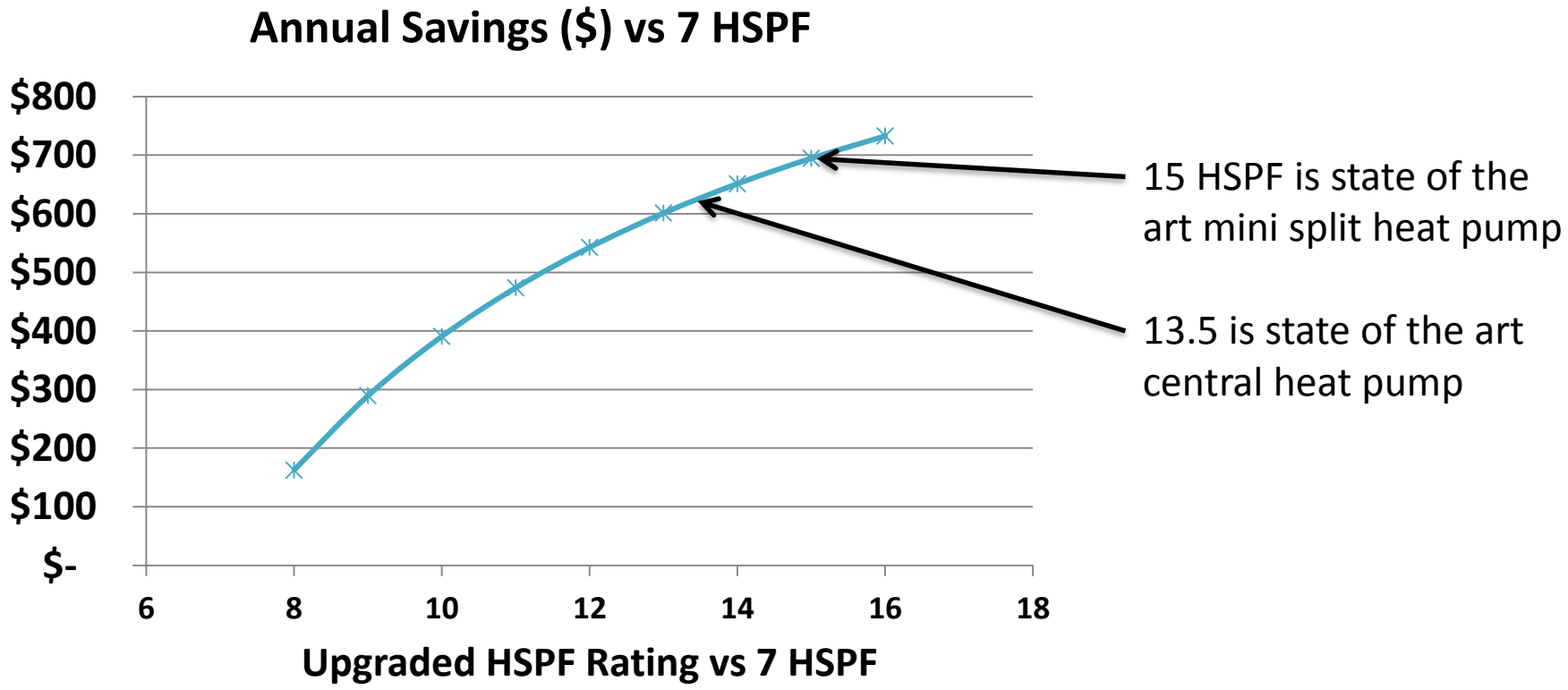
Roger Marran
Energy Kinetics, Inc.

NORA Workshop
April 3, 2019

Annual Heating Costs

Better Ratings Improve Efficiency Somewhat

Note: HSPF energy savings have diminishing returns. Upgrading from an 8.2 HSPF unit to 15 HSPF mini-split saves $504 per year ($1,303/yr at 7 HSPF)



Massachusetts example: 1200 effective full load heating hours at $0.21/kWh
3 Ton (36,000 BTU/hr) – fraction of a house

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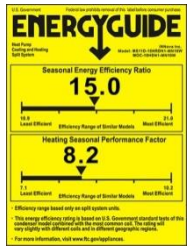
ENERGY STAR® and Federal Standards Review

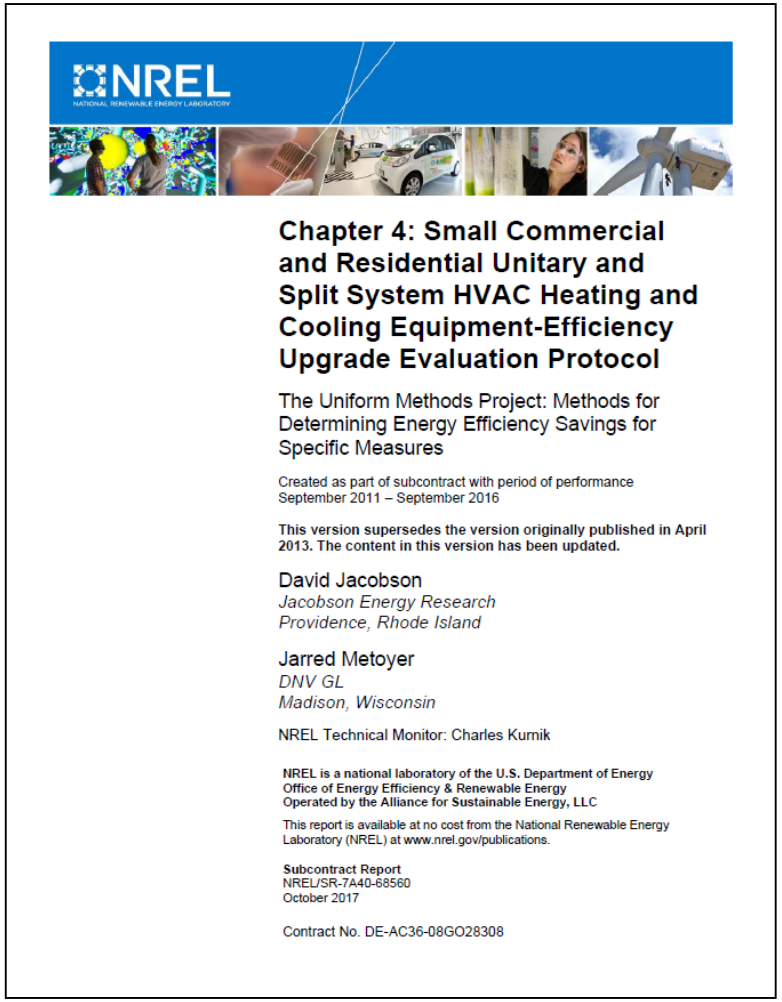
For virtually all “split systems” for rating purposes (mini splits and central heat pump)



HSPF 8.2 / SEER 14

ENERGY STAR

HSPF 8.5 / SEER 15



NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Chapter 4: Small Commercial and Residential Unitary and Split System HVAC Heating and Cooling Equipment-Efficiency Upgrade Evaluation Protocol

The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures

Created as part of subcontract with period of performance September 2011 – September 2016

This version supersedes the version originally published in April 2013. The content in this version has been updated.

David Jacobson
Jacobson Energy Research
Providence, Rhode Island

Jarred Metoyer
DNV GL
Madison, Wisconsin

NREL Technical Monitor: Charles Kurnik

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Subcontract Report
NREL/SR-7A40-68560
October 2017

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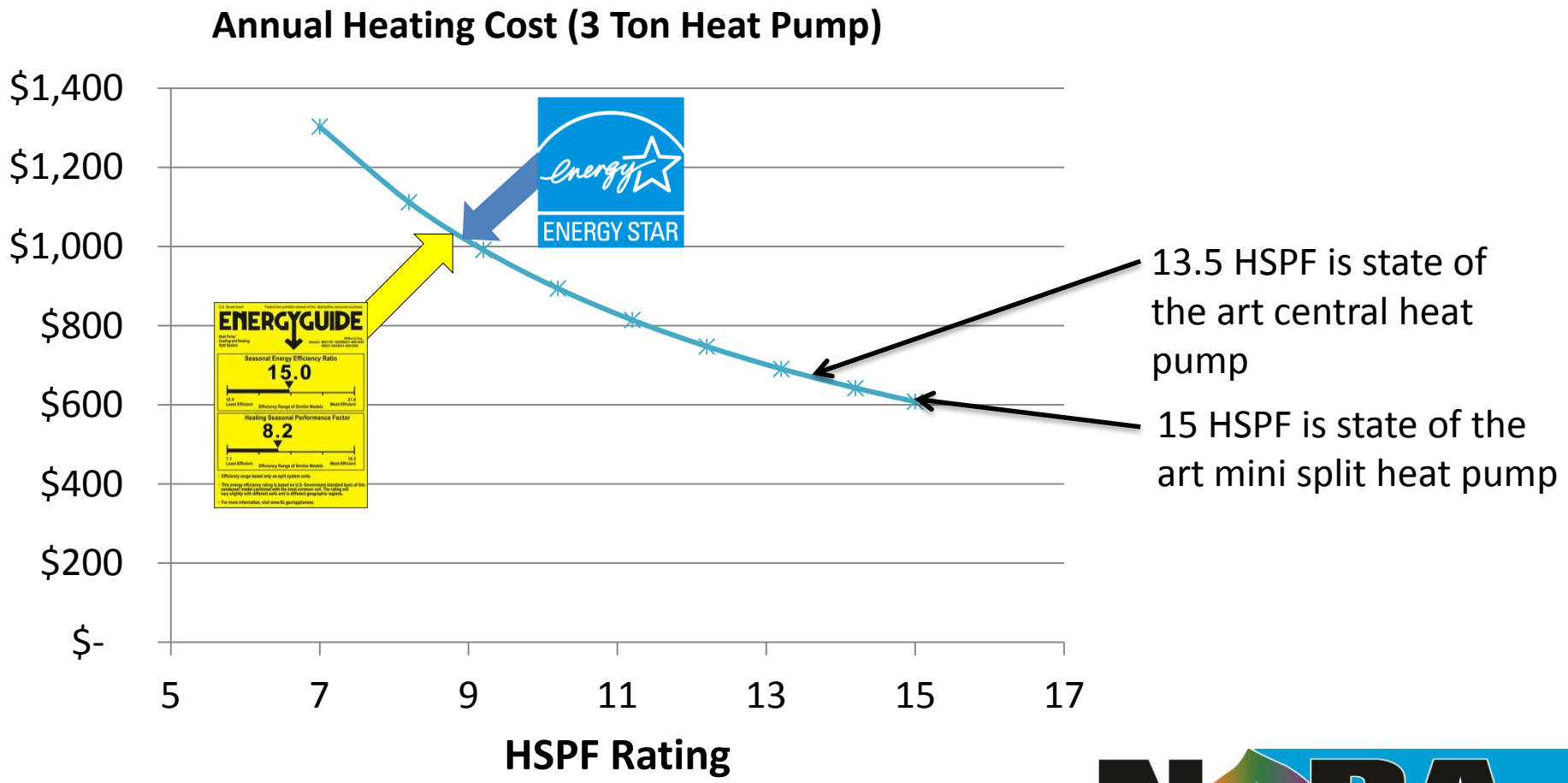
Annual Heating Costs

These are the annual operating costs based on the standard calculation for a 3 Ton heat pump.



Massachusetts example: 1200 effective full load heating hours at $0.21/kWh

U.S. Market Share Review

Product Category[2]	2017 Units Shipped (thousand units)	2017 Estimated Market Penetration[3]
CAC/ASHP	2,215	28%
ASHP[5]	1,075	*41%*
CAC	1,140	*22%*

41% of the overall Heat Pump market. Includes mini-split ASHPs

Year-to-Date			
	Dec '18 YTD	Dec '17 YTD	% Chg.
Air Conditioners & Heat Pumps	8,340,262	7,805,529	+6.9
Air Conditioners Only	5,399,760	5,185,747	+4.1
Heat Pumps Only	2,940,502	2,619,782	+12.2

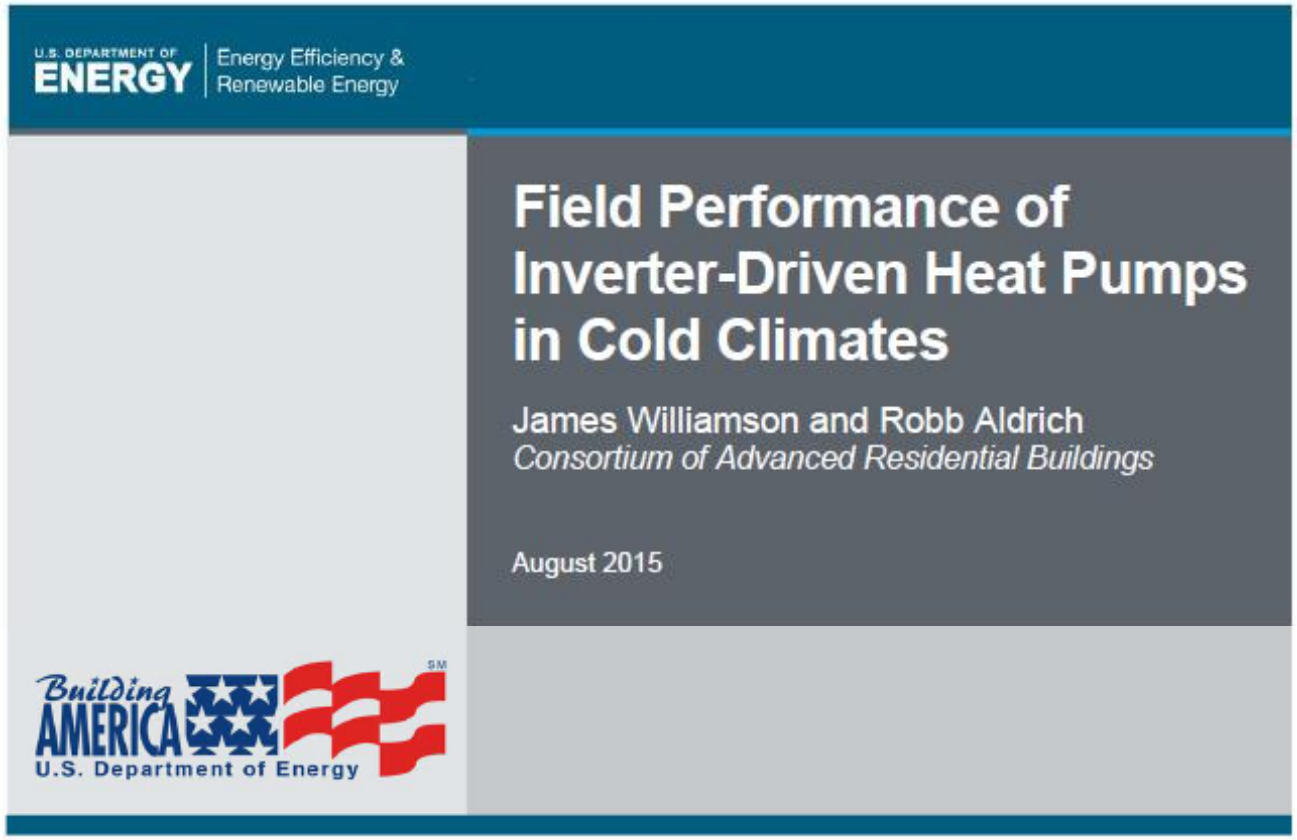
vs. 3.5 million gas and oil furnaces (27% and 19% Energy Star respectively)
Furnace market is 17% larger than HP market (2018)

ENERGY STAR: https://www.energystar.gov/ia/partners/downloads/unit_shipment_data/2017/2017%20Unit%20Shipment%20Data%20Summary%20Report.pdf?7cf2-a6b1
AHRI: http://ahrinet.org/App_Content/ahri/files/Statistics/Monthly%20Shipments/2018/December_2018.pdf

Capacity and Efficiency Uncertainty
Mini-Split Field Performance Study

Leads to:

- Skepticism among homeowners
- Poor energy savings estimates
- Suboptimal system selection
- Inconsistent energy modeling
- COP ranges from 1.4 to 2.4 in winter



Field Performance of Inverter Driven Heat Pumps, EERE, August 2015, James Williamson and Robb Aldrich Consortium of Advanced Residential Buildings, Steven Winter Associates, Inc.
https://www.nrel.gov/docs/fy15osti/63913.pdf

Performance Conclusions

- The reasons for the wide range in heating performance likely include low indoor airflow rates, poor placement of outdoor units, relatively high return air temperatures, thermostat setback (defrost cycling), integration with existing heating systems, and occupants limiting indoor fan speed.
- “Most of the heat pumps still provided heat at a lower cost than oil, propane, or electric resistance systems.”

* Williamson and Aldrich, 2015

Savings Review

What level of savings can be expected over other fuels?

While the measured COPs of systems in this study are lower than those of other studies, most of the systems still provided operating cost savings over oil, propane, or electric resistance heating. Table 13 shows operating cost increases that could be expected (compared to the ASHP) at the three sites with the most complete data. None of the ASHPs monitored would have provided operating cost savings over an efficient natural gas heating system.

Table 13. Operating Cost Percent Increase (Decrease) Compared to Heat Pump During the Monitoring Period

Heating Method	Site 1	Site 2	Site 4
Heat Pump	$386	$172	$783
Electric Resistance	61%	64%	131%
Oil (85%)	10%	12%	58%
Propane (85%)	53%	56%	120%
Natural Gas (85%)	(47%)	(46%)	(24%)

Table 10. Average New England Utility Rates

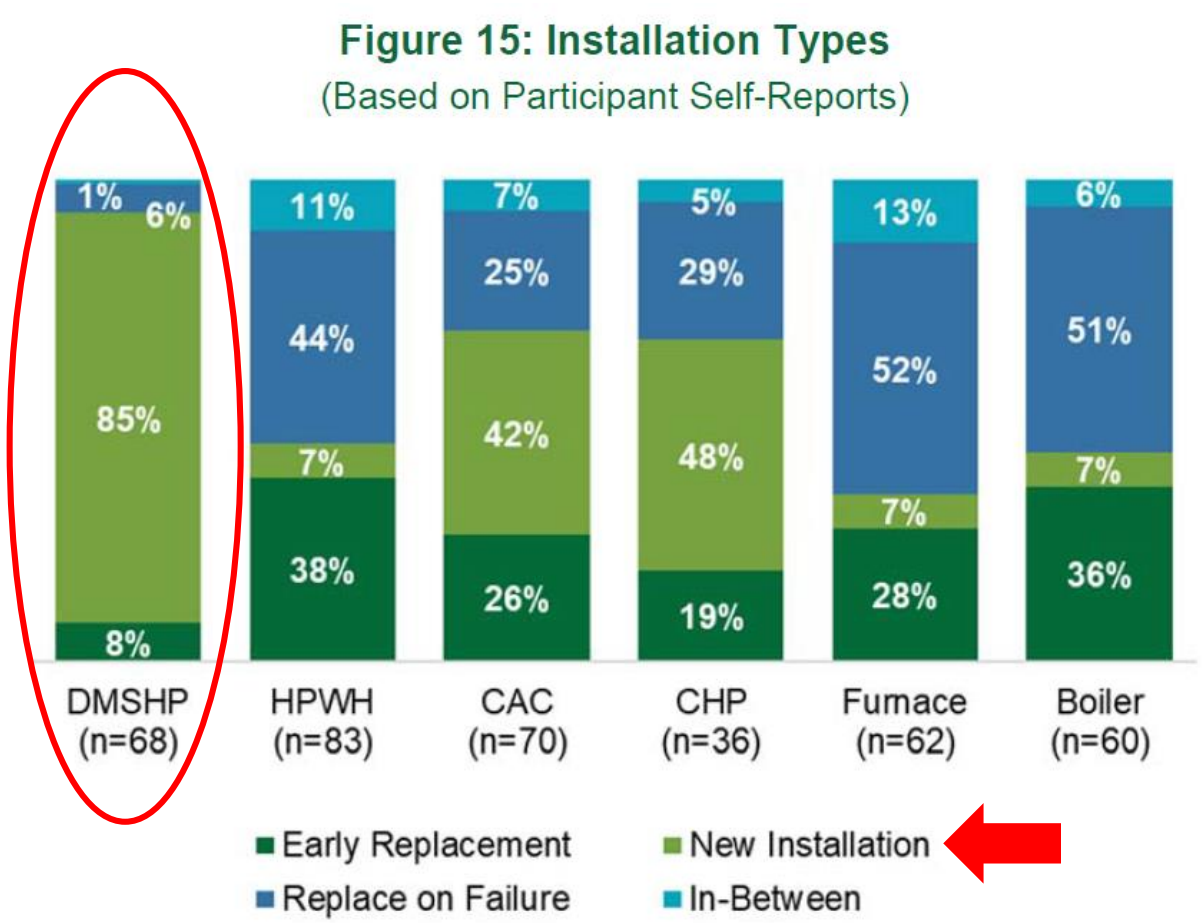
Heating Fuel	Rate
Oil	$4.16/gal
Propane	$3.85/gal
Electricity	$0.18/kWh
Natural Gas	$1.45/therm

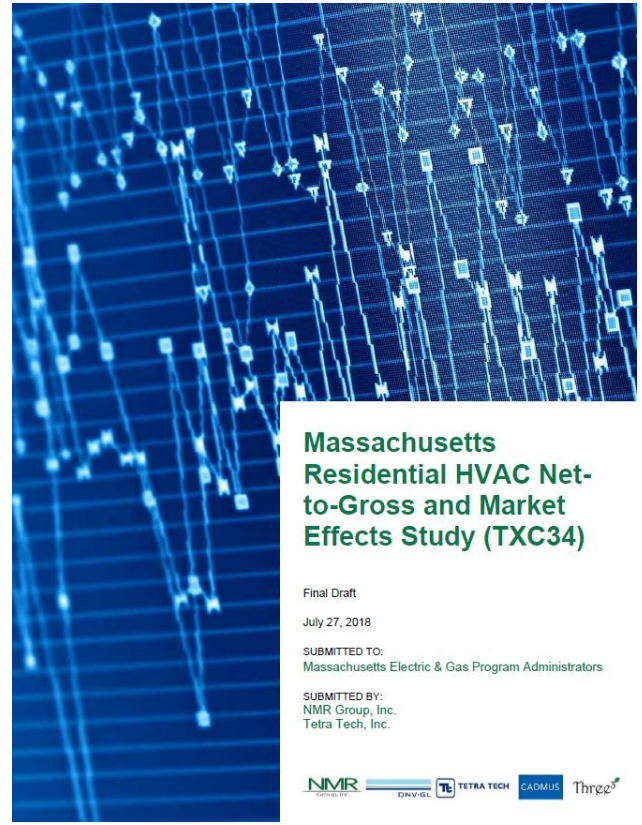
As low as $2.27 gallon in 2015 in New England
$0.1975/kWh electricity

* Williamson and Aldrich, 2015

Massachusetts MassSave Study

Part of MassCEC's $48 million Clean Heating and Cooling program

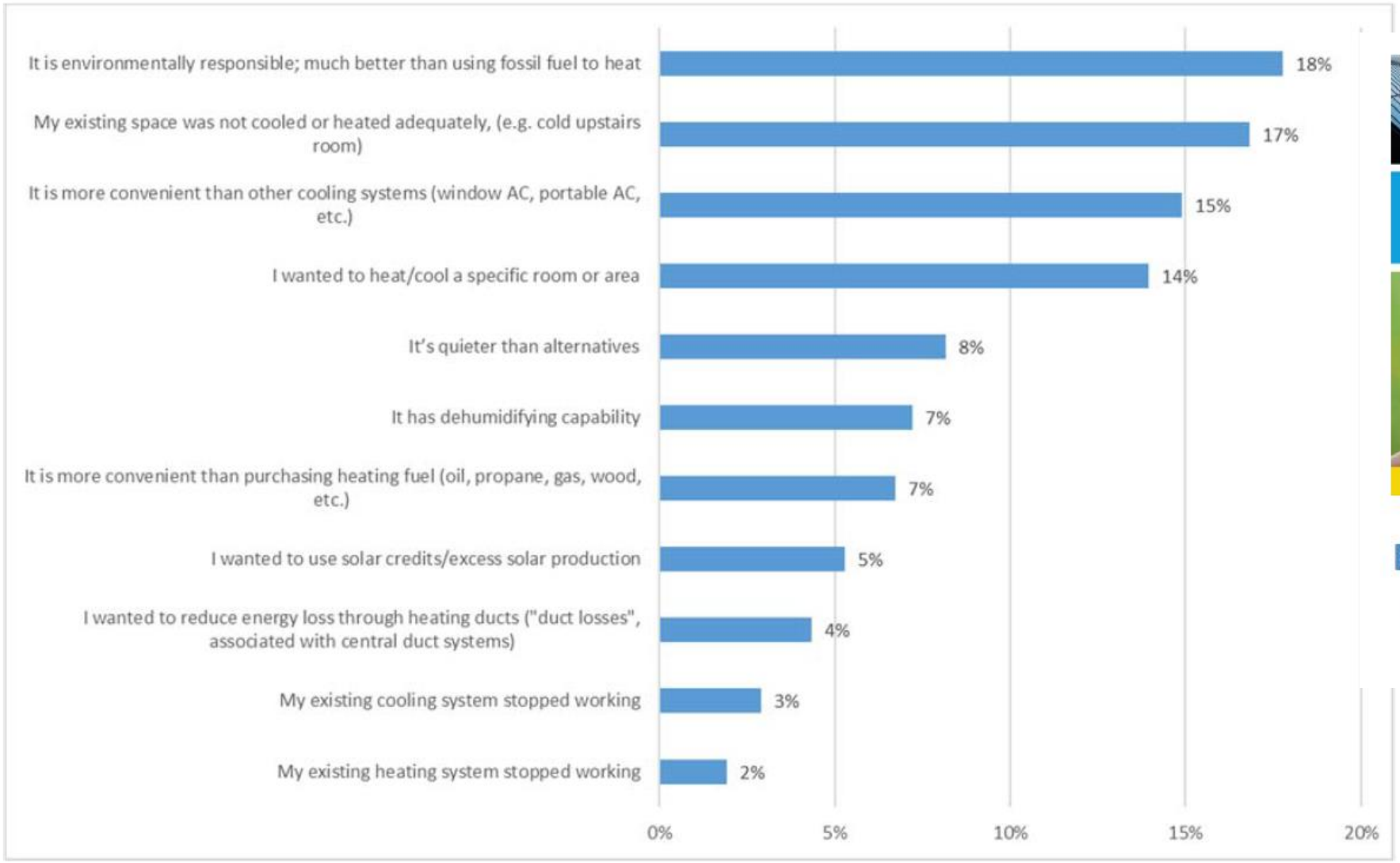


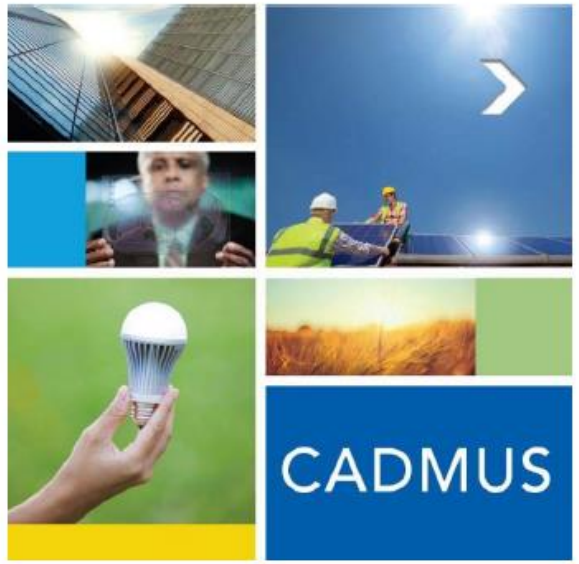


Massachusetts Residential HVAC Net to-Gross and Market Effects Study (TXC34), July 27, 2018
http://ma-eeac.org/wordpress/wp-content/uploads/TXC_34_Report_27JUL2018_Final.pdf

Cold Climate Heat Pumps in Vermont

Which of the following best describes your motivation for purchasing your mini-split heat pump(s)?





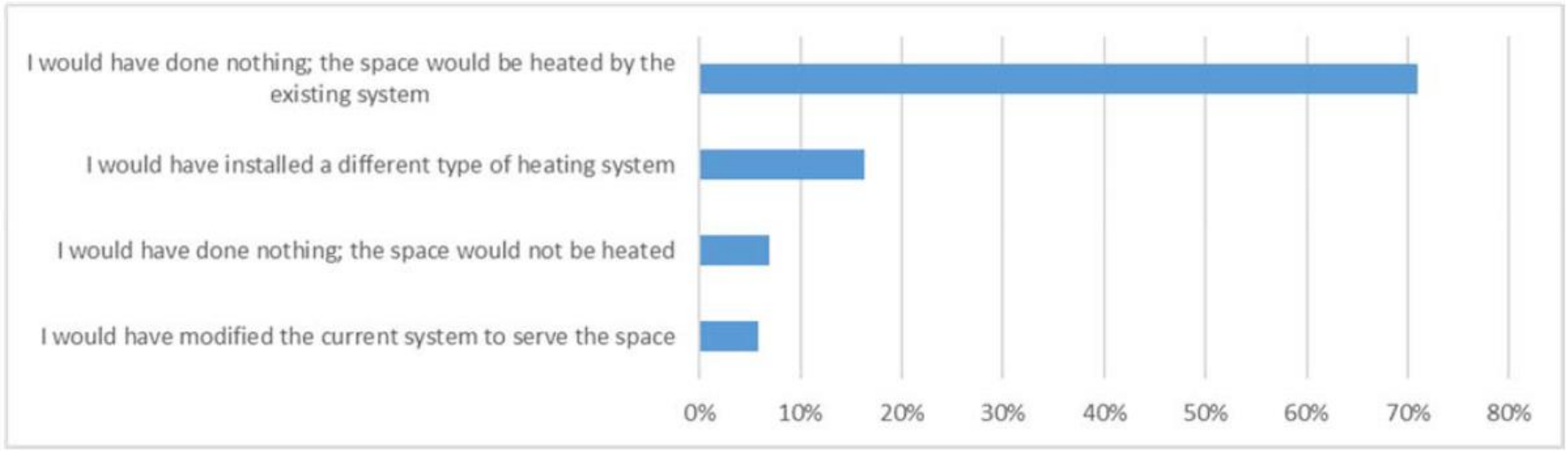
Evaluation of Cold Climate Heat Pumps in Vermont

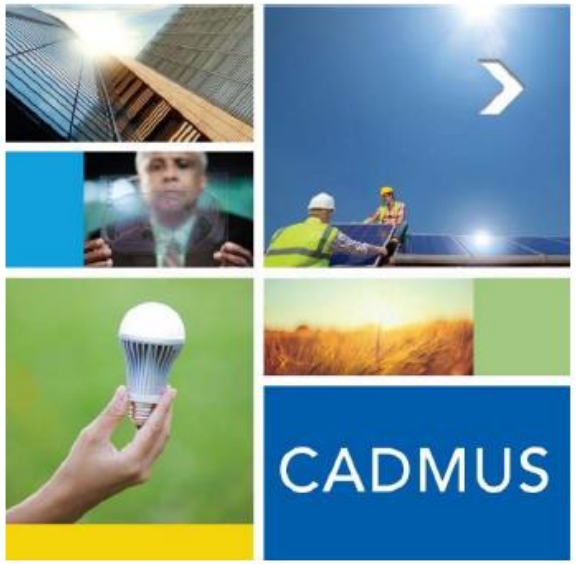
November 3, 2017

"Evaluation of Cold Climate Heat Pumps in Vermont", 11/3/17, John Walczyk, The Cadmus Group, Vermont Public Service Department, 112 State Street, Montpelier, VT 05620-2601

Cold Climate Heat Pumps in Vermont

If ductless mini-split heat pump technology was not an option for you, what would you have done to heat these rooms?



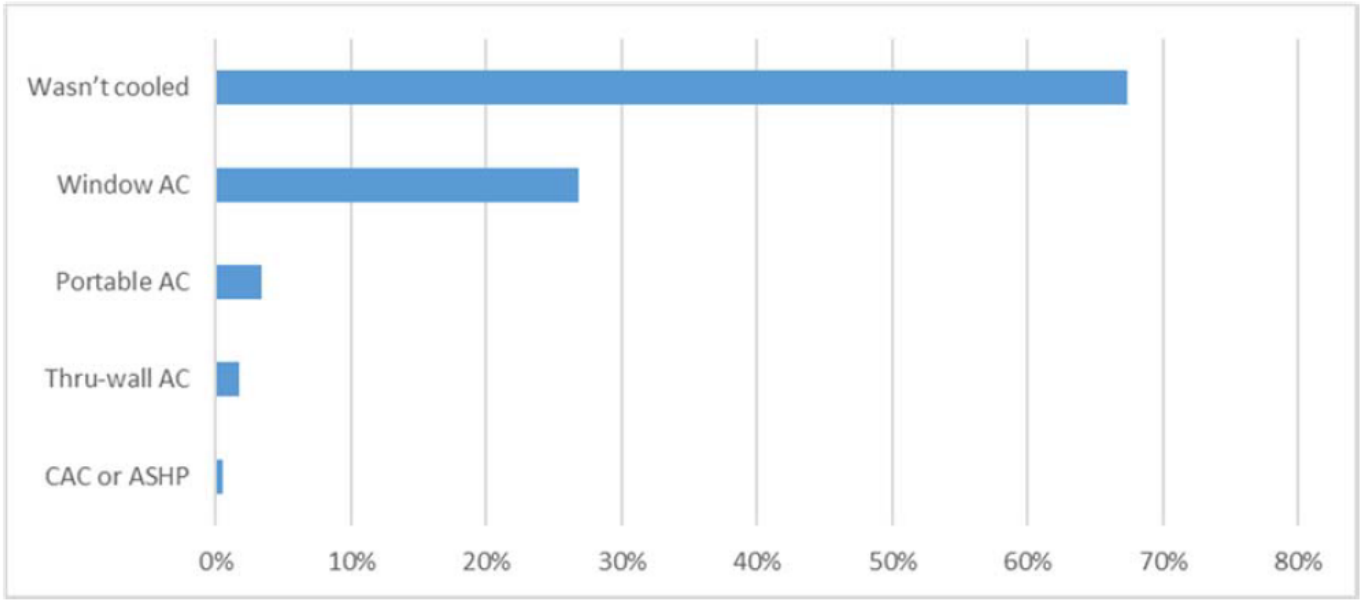


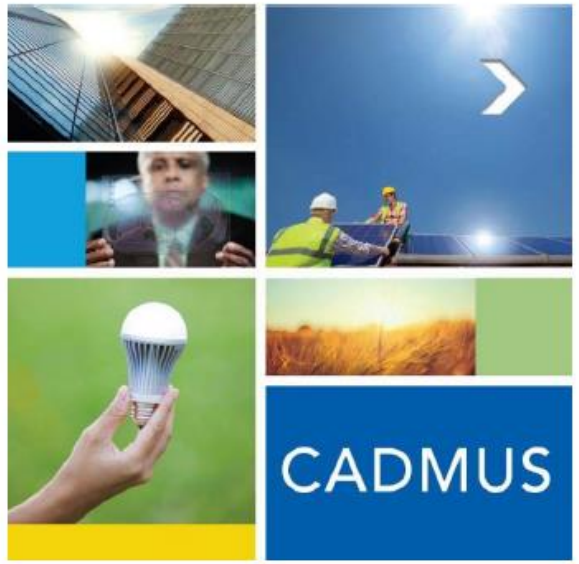
* “Evaluation of Cold Climate Heat Pumps in Vermont”, John Walczyk, 2017

Cold Climate Heat Pumps in Vermont

Cooling-Specific Information

For each room having a mini-split heat pump, how did you cool the room before you installed the mini-split?





- Other factors may have impacted homeowner fuel use. More than half of the homeowners made some type of building shell improvement during the data collection period.

"Evaluation of Cold Climate Heat Pumps in Vermont", 11/3/17, John Walczyk, The Cadmus Group, Vermont Public Service Department, 112 State Street, Montpelier, VT 05620-2601

Cold Climate Heat Pumps in Vermont

Vermont Department of Public Service 2017 Study

- 65 installations between 2015 and 2017
- The average annual energy cost savings was approximately $200 per heat pump, significantly less than had been assumed.
- Overall dollar savings are impacted by the efficiency of the back-up fossil fuel system. The higher the efficiency of the existing system, the smaller the amount of fuel use being displaced by the ccHP.
- Homes with poor insulation levels and air leaks will not get as much benefit out of a ccHP as will tight, well insulated homes.
- It is unlikely that a heat pump by itself would be sufficient to heat a typical home without use of a traditional heating system.

"Cold Climate Heat Pumps in Vermont", Barry Murphy, Vermont Department of Public service.
https://publicservice.vermont.gov/sites/dps/files/documents/Energy_Efficiency/Reports/Vermont%20ccHP%20Summary.pdf

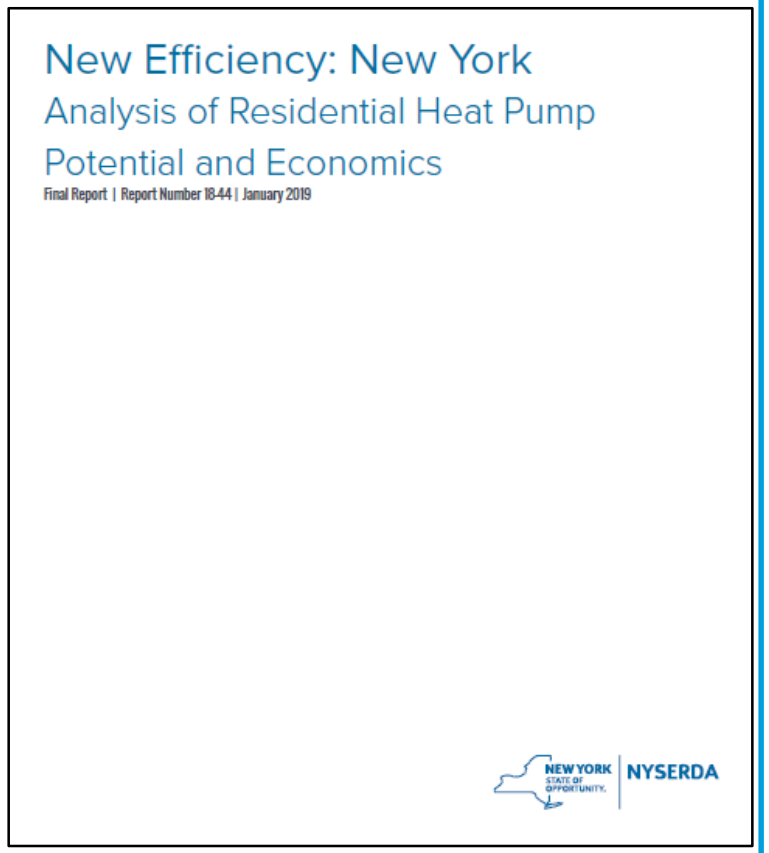
Equipment Cost Comparisons

Table 5-1. Heat Pump Capital Cost per Installation, 2018

Sector	Geography	Age	ASHP		Minisplit		GSHP	
			Tonnage	Capex	Tonnage	Capex	Tonnage	Capex
Single-Family	Long Island	Existing	3	$12,784	2	$5,682	4	$35,660
		New	5	$18,111	2	$5,682	4	$35,660
	NYC	Existing	3	$13,740	2	$6,107	4	$38,327
		New	5	$19,465	2	$6,107	4	$38,327
	Hudson Valley/ Upstate/Western	Existing	3	$12,368	2	$5,497	4	$34,500
		New	5	$17,522	2	$5,497	4	$34,500

Table 5-2. Counterfactual Capital Cost per Installation, 2018

Sector	Geography	Natural Gas Heating	Fuel Oil Heating	Central A/C	Window A/C
Single Family	Long Island	$4,651	$6,977	$3,514	$615
	NYC	$4,999	$7,499	$3,777	$661
	HV/Upstate/Western	$4,500	$6,750	$3,400	$595



New Efficiency: New York Analysis of Residential Heat Pump Potential and Economics Final Report. Report Number 18-44, January 2019
https://www.nyserda.ny.gov/-/media/Files/Publications/PPSER/NYSERDA/18-44-HeatPump.pdf

Evaluation vs. Existing Equipment
not state of the art alternatives

Table 6-1. Equipment Efficiency

Technology	Vintage	Heat Pump Efficiency			Counterfactual Efficiency				
		Heat COP	Cool COP	Cooling SEER	Nat Gas Heat COP	Fuel Oil Heat COP	Electric Heat COP	Cooling COP	Cooling SEER
ASHP	Existing Building	300%	469%	16	76%	66%	100%	381%	13
ASHP	New Constr.	250%	469%	16	76%	66%	100%	381%	13
Minisplit	Existing Building & New Constr.	300%	469%	16	76%	66%	100%	381%	13
GSHP		415%	674%	23	76%	66%	100%	381%	13

COPs are not reflective of cold climate applications. Above 35°F COP may hold.
Counterfactual equipment is not state of the art efficiency.

*NYSERDA Report, January 2019

Missing Money

Assessed to be uneconomic from the customer's point of view, the analysis provides a "missing money" output indicator that quantifies the estimated additional payment that would need to be made available in order to deliver an adequate return to a heat pump customer.

*NYSERDA Report, January 2019

Missing Money (16% IRR)

Table 8-2. Missing Money per Installation, Small Residential (2019)

Counter-factual Fuel	Geography	Sub Sector	ASHP		Minisplit		GSHP	
			Existing Building	New Constr.	Existing Building	New Constr.	Existing Building	New Constr.
Fuel Oil	Long Island	Single Fam.	$5,718	$2,218	$2,545	$2,545	$7,390	$4,559
	NYC	Single Fam.	$8,205	N/A	$3,529	N/A	$10,701	N/A
	Hudson Valley	Single Fam.	$3,901	$35	$1,838	$1,838	$5,514	$2,776
	Upstate/Western	Single Fam.	$671	$0	$565	$565	$342	$0

Oil price at $2.69 to $2.86 per gallon. Electricity $0.094 to $0.183 per kWh.

*NYSERDA Report, January 2019

Heat Pump Assumptions

The current analysis assumes that heat pumps will not be installed in homes with hydronic distribution systems (radiators), but heat pump systems serving such sites may become widely available in the near term.

Societal Costs: The analysis concludes that heat pumps present the most attractive proposition in heating oil and electric resistance heating replacement situations. Residential gas heating replacement situations do not at present succeed under this test.

*NYSERDA Report, January 2019

Conclusions

- Aggressive assumptions to support heat pump adoption still doesn't close the "missing money" gap except where electricity is very inexpensive.
- Fuel prices can wildly impact study results which may support a desired policy.
- Standards promote higher percentage of equipment represented as highly efficient for preferred equipment.
- Consumers like mini splits for AC as an add on to existing homes.
- Best solutions across cold climates do not appear to be a single technology from a cost or environmental perspective.
- Multiple technologies may suffer from excessive first cost and "missing money."