Reducing Applied Losses in Heat Pumps: Breaking the 4.0 Heat Pump Barrier

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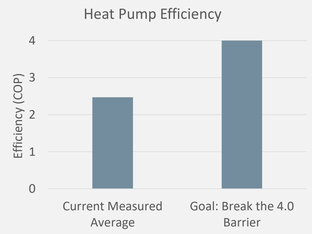
Introduction

Heat pumps are recognized as a primary path to decarbonization. The International Energy Agency has stated that, "Heat pumps, powered by low-emissions electricity, are the central technology in the global transition to secure and sustainable heating."[1] In early-adopter communities, virtually all new buildings are built with heat pumps, or soon will be.[2,3,4] The Air-Conditioning, Heating, and Refrigeration Institute (AHRI) reports that air source heat pump shipments almost tripled in the past ten years.[5]

However, implementation in building *retrofits* is only in its early stages, and anecdotal evidence suggests that these retrofits are largely limited to market-rate housing, and that retrofits in single-family housing in disadvantaged communities have barely begun.

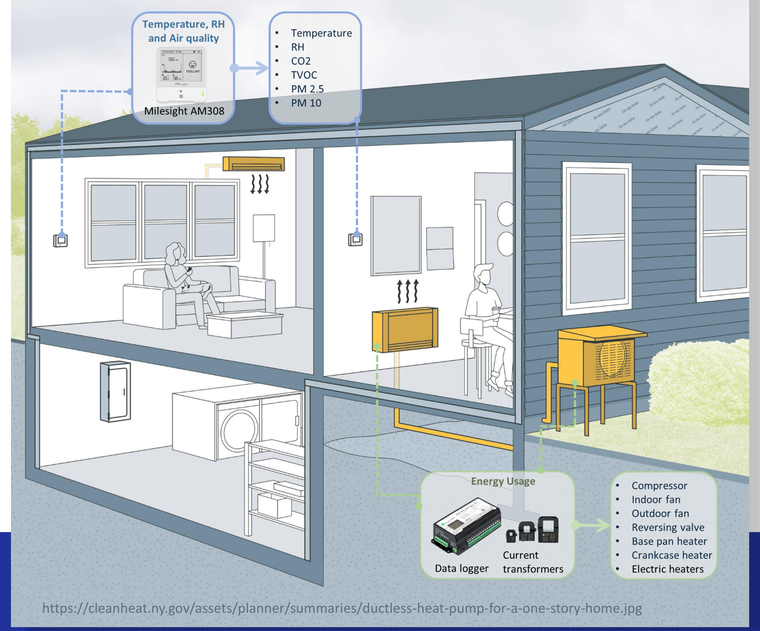
Problem Statement

Previous studies have found actual heat pump efficiency to be low:
COP = 2.46, Shapiro 2017 (summary of other studies)
COP = 2.34, CADMUS 2022
But ratings and energy modeling predict much higher efficiency:
COP = 4.0



Project Goals:

- Assess electrification needs in disadvantaged sector
- Develop improvements that meet these needs
- Demonstrate in field installation
- Affordability



https://cleanheat.ny.gov/assets/planner/summaries/ductless-heat-pump-for-a-one-story-home.jpg

Methods

- Identify improvements.
- Screening/scoping estimates of savings.
- Where savings are higher, do more in-depth analysis.
- Estimate the market penetration for each improvement.
- Screening/scoping estimates of incremental construction cost.
- Wherever possible, use more than one source/estimate for savings.
- Rank "Estimated effective savings" from estimated savings x market penetration.
- Choose a system that maximizes improvements.

Overview of Pre-and-Post retrofit data collection tasks

Pre-Retrofit

- Product literature reviews
- Improvements literature reviews
- Heat pump baseline survey
- Resident survey
- Affordable housing resident survey
- Contractor survey (HVAC and minority contractors)
- Short-term monitoring
- Air quality monitoring
- Energy monitoring by using utility bills

Post-Retrofit

- Short-term monitoring
- Long-term monitoring
- Energy monitoring using datalogger and CTs (current transformers)
- Air quality monitoring
- Temperature and relative humidity monitoring
- Resident survey
- Energy monitoring by using utility bills

Proposed Improvements

Item		Estimated Efficiency Increase
1	Optimized user control	15%
2	Fan speed selection	9%
3	Choose high-efficiency unit	13%
4	Floor mounted indoor unit	8%
5	Reduced cycling/hunting	5%
6	One-on-one units	4%
7	Short pipe lengths	3%
8	Reduce air recirculation	3%
9	Optimized basepan heater	6%
10	Regular filter cleaning	3%
11	Ductless instead of ducted	7%
12	Control power energy savings	1%

The project is proposed in three basic phases. The project team will:

1. **Engage with multiple communities** to identify needs and challenges in the operation of heat pumps. These communities will include housing organizations serving disadvantaged communities, such as the Syracuse Housing Authority, Home Headquarters, and Blueprint15 service area.
2. **Bench-test and/or model solutions** in the *applied design* and *operation* of heat pumps, at a minimum in the areas listed in the table above. Tests will be in Syracuse University's BEESL lab and/or its BEST house. Modeling will be CFD, EnergyPlus, TRNSYS, and/or specialty computer models (for example, refrigerant thermodynamic cycle model).
3. **Integrate the solutions in a field demonstration** to show that a 4.0-COP *applied efficiency* is feasible in air source heat pumps.

Equipment Selection

	Split System Heat Pumps				Room Heat Pumps		
	Ducted Split System	Multi-Split Ductless High-Wall	One-on-One Ductless Floor Mounted	One-on-Two Ductless Floor Mounted	Wall Mounted Packaged Heat Pump	Window Mounted Heat Pump	Wall Mounted Packaged Terminal Heat Pump (PTHP)
Example Photo:							
Availability	🟢	🟢	🟢	🟢	🟢	🔴	🟢
Applied Efficiency[1]	🔴	🔴	🟢	🟠	🟢	🟠	🔴
NEEP rated	🟢	🟢	🟢	🟢	🟢	🟠	🟢
Temperature stratification[2]	🟠	🔴	🟢	🟢	🟠	🟠	🟢
Distribution losses[3]	🔴	🔴	🟢	🟠	🟢	🟢	🟢
Risk of refrigerant leaks[4]	🟠	🔴	🔴	🔴	🟢	🟢	🟢
Product Cost	🟠	🟠	🟢	🟠	🔴	🟠	🟢
Installation Cost	🔴	🔴	🔴	🔴	🟢	🟢	🟠
Total Cost[5]	🟠	🔴	🟠	🔴	🟠	🟠	🟠
Availability	🟢	🟢	🟢	🟢	🟠	🔴	🟢
Training and Certification[6]	🔴	🔴	🔴	🔴	🟠	🟢	🟠

Legend	
Best	🟢
Medium	🟠
Obstacle	🔴

Notes
1. Shapiro et al, Building America study, ongoing.
2. Per location of return air, impact on heating efficiency.
3. Inferred from CADMUS study.
4. According to the number of field-assembled refrigerant joints for a 3-bedroom house, e.g. 4 for ducted, 16 for all other splits, none for room heat pumps.
5. Single family house with 3 bedrooms, costs per the entire house, not each bedroom.
6. Split systems require EPA 608 certification and training in refrigerant system assembly. Room heat pumps require training in efficient through-wall assembly, except window heat pump which is designed for assembly by an untrained mechanic.

References

[1] Laura Cozzi et al, International Energy Agency, The Future of Heat Pumps, 2022. [2] NRDC, California Passes Nation's First Building Code that Establishes Pollution-free Electric Heat Pumps as Baseline Technology, 2021. Accessed 2/25/2024.
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[4] Town of Ithaca Energy, Chapter 144, Energy Code Supplement, 2023.
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