The Quirkiness of Heat Pumps

Bruce Harley
Technical Director, Conservation Services Group

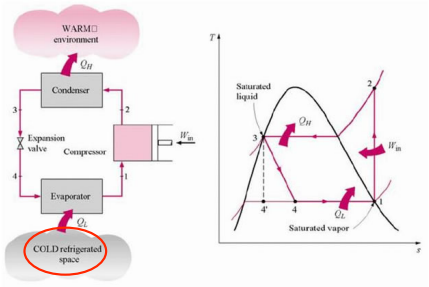
Westford 2014

Outline

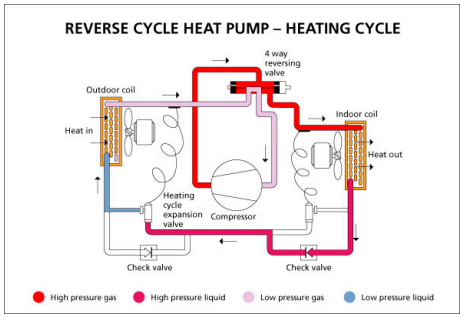
- Heat pumps (briefly) explained
- My own heat pumps
  - Measurements and results
- Design and Application insights
- Some program experience

Heat pumps explained

Engineering concepts…

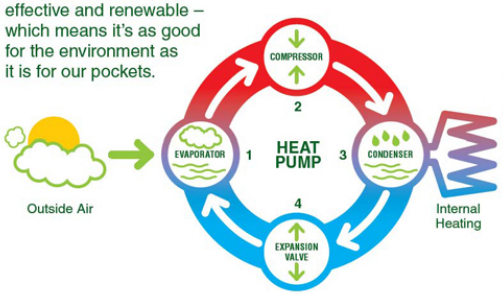


Schematic…



Fluffy marketing…

The process is simple, effective and renewable – which means it's as good for the environment as it is for our pockets.



Ductless Heat Pumps

1. Indoor unit

2. Outdoor unit

3. Line set

4. Control

Residential Air Source Heat Pumps

- 1980s – lots of ASHPs in northern climates
  - Duct leaks, air flow/charge problems
  - "blowing cold air" complaints
- Electric resistance heat compensates
  - Leading to very low average system efficiency
- People *believe* ASHPs don't work in cold climates *because of the climate*

Ductless Split Heat Pumps

- 40+ years of mass-production
  - Originally single-point cooling
- Steady advances:
  - System size – wider range
  - Flexibility (heating cycle, multi-head, mini duct, etc)
  - Efficiency increase - variable speed "inverter drive"
  - Climate (***optimizing for cold weather heating***)
- No built-in electric resistance backup heat

DHP Residential Use Cases

- Offset existing heating source
  - Oil, LP, Electric resistance
  - 1-2 zones –through– complete replacement
- Exclusively heat low-load homes
  - Deep retrofit, new near/net zero
- Add HVAC to addition or new zone

The Quirkiness of Buying a DHP

- 2 Local contractors I tried to get bids from:

"It won't heat your house in Vermont… maybe if you were in Texas or Oklahoma."

"You should really get a 'geothermal' system… my dad and I installed lots of heat pumps in the '80s and they don't work that well..."

Conservation Services Group

Old Myths Die Hard

- Installer's advice: "Shut it off at -10C"
  - Unit is rated at least to -20C, albeit at lower capacity

Conservation Services Group

The Quirkiness of Measuring

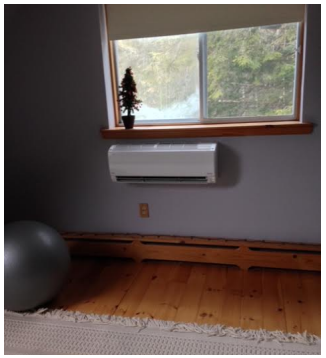
- Summary:
  - DHP Installation: Stamford, VT July, 2012
  - Modestly efficient, 2400 SF house
  - 2 units, 3 zones
  - Monitored 9/2012-4/2014,
  - Co-heat test: resistance heat, 14 days

1st Floor Unit - 12 HSPF

A bit of recirculation…

Outdoor Unit

Attic room - 2nd floor



2-zone, 9 HSPF

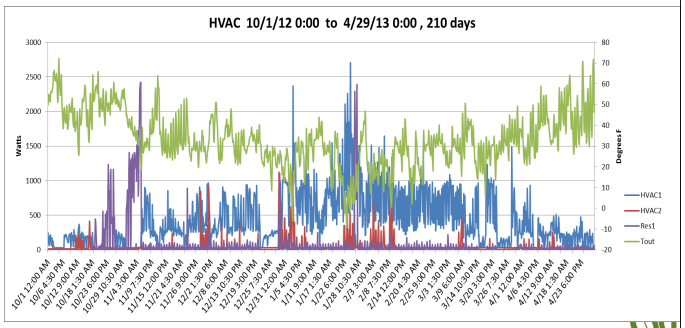
2nd Floor Air Handler

Methodology, Discrepancies

- Adjustment for power factor—inverter(!)
- Removed days away, incl. recovery time
- Daily average Tout, not instantaneous
- Solar gain contributed to heating
  - Coheat test included some sunny days
  - Solar has most influence in mildest weather

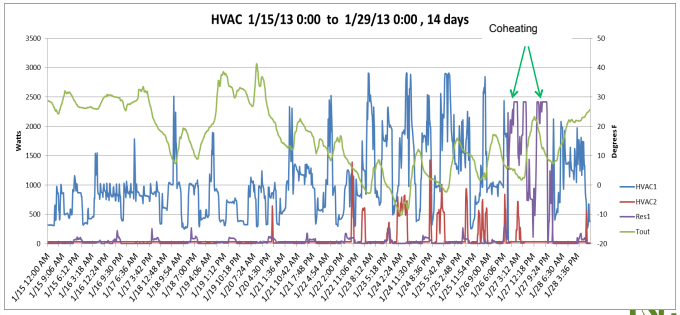
The Quirkiness of Data

HVAC kWh and Tout



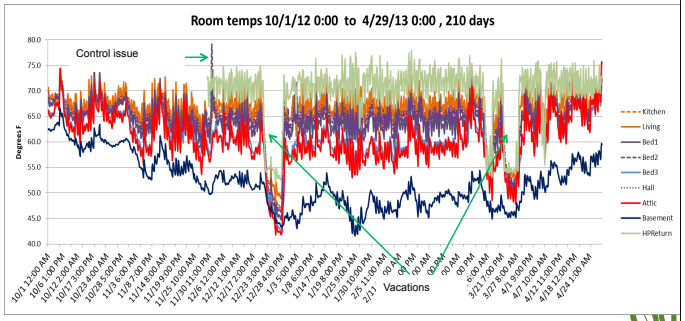
Conservation Services Group

HVAC kWh and Tout



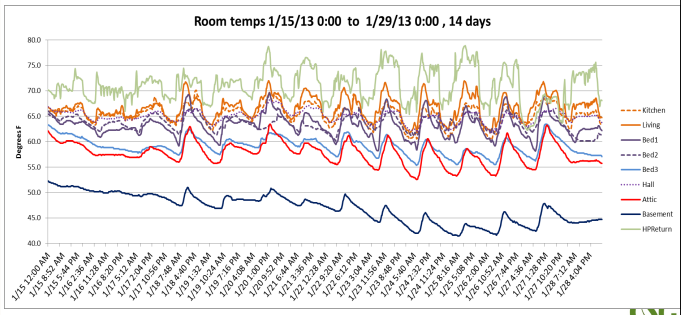
Conservation Services Group

Room Temperatures



Conservation Services Group

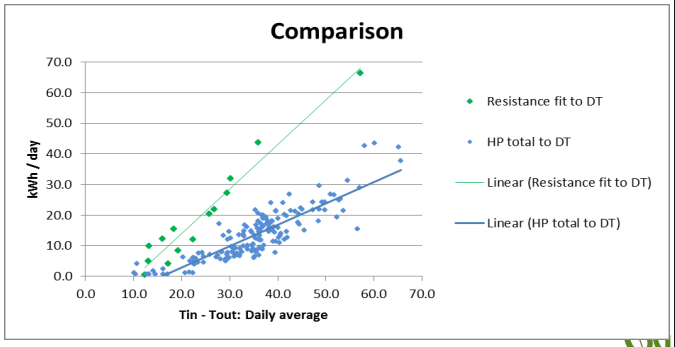
Room Temperatures



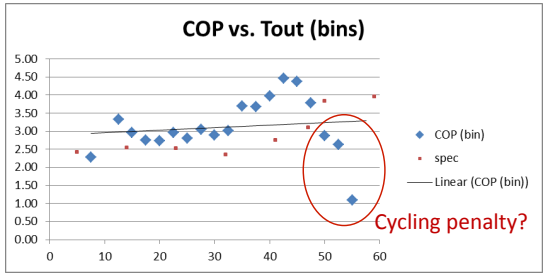
Conservation Services Group

Analysis

Resistance vs DHP

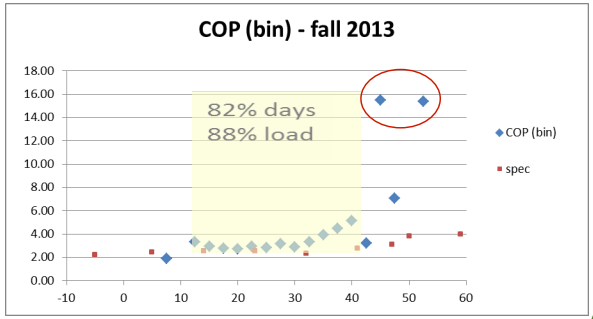


COP Variation with Tout



Tout

COP Variation with Tout



Tout

Some conclusions

- Efficiency in mild weather is highly dependent on user settings
  - But little impact on annual cost/energy
- Direct solar gain affects mild-weather efficiency
  - Again, little impact on annual results

Projected (bin analysis) vs. Actual

	Projected	Actual
Load	7740 kWh	7358 kWh
Consumption	3067 kWh	2245 (2794) kWh
Cost	$460	$337 ($419)
COP	2.5	2.6 – 2.8

RESULTS

"Heating-only" COP

	Both DHP monitoring period only	Both DHP Adj for full year, incl. all standby	1st Floor unit, no CC heater	1st no cc – no sunny days
COP	2.75	2.63	3.04	2.88
"HSPF"	9.5	9.0	10.4	9.8
Total cost:	*$337*	*$419*		
kWh:	*2245*	*2794*	2-system COP	

Cooling: 5.5 kWh/day max, typical AC 2 kWh/day
Hot week = 30 kWh

Insights

- Crankcase Heater: ~0.5 kWh/day max
  - Only <~34F & compressor off
  - ~120 kWh annually (mostly for 2nd system) – small
- Fan Speed – "Low" is quieter
  - Preferred during our first winter
- "Auto" fan boosts capacity
  - Important in colder weather
- Don't use auto-changeover (H/C) setting

The Quirkiness of Controls

- Setup is NOT intuitive
  - 2F increments, w/ "energy saving" mode …
- Ensure communication with remote
  - Wired unit eliminates issue (2015 wifi option?)
- Remote isn't thermostat! (most brands)
  - Wired control, remote sensor or compensate

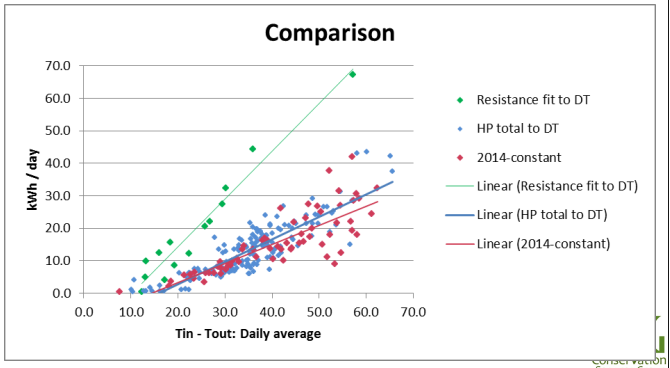
More control quirks (installer controls)

- Air handlers (Fujitsu) – runs fan to sample cabinet temperature periodically
  - Run system if >6F from setpoint, overriding remote temp sensing setting
- Need to override setting that reverts to factory default on power outage (!)

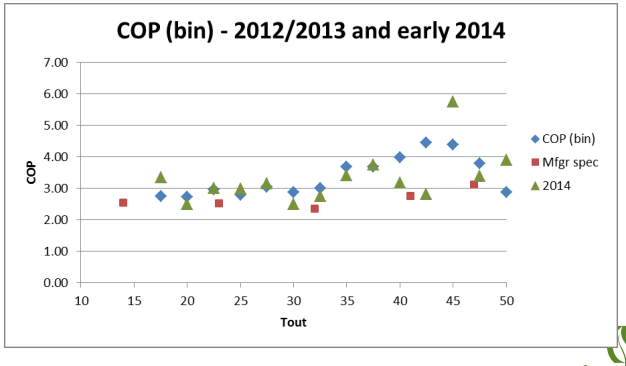
The Quirkiness of Setbacks

- For DHP, temperature setbacks *don't* save
  - Deep setback = long recovery, in high speed mode
  - Early morning recovery = lowest outdoor temps
  - Both of these = least efficient operation
- Better to "set it and forget it"
  - Use modest setback for > several days away

Feb-Apr 2014 Performance



Feb-Apr 2014 Performance



Conservation Services Group

Feb-Apr 2014 Performance

- Excluded "away" times (comparable analysis)
- Tout average was colder (26.4 vs 33.0) during Feb-Apr 2014 period than winter 2012-2013
- Comparison to resistance heat kWh test using temperature setbacks makes these COP estimates more conservative
  - DHP was actually *more* efficient when set at a constant temperature than with a setback

Conservation Services Group

Design thoughts: retrofit

- 1st floor unit primary heating for 2-story house
  - 2nd floor unit great for cooling 2-story house
    - Ducts help—3 very low load rooms
- Most savings from first heating unit
  - Sometimes 2-3 heads for cut-up floor plans
- Any more will be for comfort, convenience
- Balance multi-head vs. multiple outdoor units
- What are client's priorities/commitment?

Conservation Services Group

More Thoughts

- In heating climate: indoor unit low on wall
  - Window sill height provides balance between heating and cooling performance in cold climate
- Retrofit: you do need to operate the heat pump to get savings
  - Set DHP warmer than backup heat!

Conservation Services Group

Design tips:

- Don't use HSPF "as-is" to estimate or even compare performance
  - Adjust for climate using bin analysis for actual equipment and application
  - Be careful about what manufacturers specs you use:

Mitsubishi FE12NA

Nominal capacity: 12,000 Btu/h
Rated capacity: 13,600 Btu/h (3,000 – 21,000 Btu/h)
HSPF: 10.6

3) HEATING CAPACITY

Model	Indoor air IDB (°F)	Outdoor intake air WB temperature (°F) 5 TC	5 TPC	43 TC	43 TPC
MUZ-FE12NA MUZ-FE12NA1	70	6.5	0.55	13.6	0.98

COP: 3.5 COP: 4.1

Fujitsu 12RLS2

Nominal capacity: 12,000 Btu/h
Rated capacity: 16,000 Btu/h (3,300 – 22,100 Btu/h)
HSPF: 12.0

Outdoor temperature °FDB	°FWB	Indoor temperature 60 °FDB TC	60 IP	65 TC	65 IP	70 TC	70 IP	75 TC	75 IP
5	3					16.8	2.10		
47	43					22.1	2.00		

COP: 2.3 COP: 3.2

Mitsubishi FE12NA

3) HEATING CAPACITY

Model	Indoor air IDB (°F)	5 TC	5 TPC
MUZ-FE12NA MUZ-FE12NA1	70	6.5	0.55

Heating at 5° F
Maximum Capacity . . . . . 12,507 Btu/h

Design tips:

- Focus on the application
  - Sole heating source: cold weather performance/ capacity is critical
  - Retrofit to offset oil/LP/resistance heat: overall performance matters more
- Conventional concepts of "right-sizing" may not be relevant for some uses
- Avoid drain-pan heaters

Thoughts

- A DHP doesn't interfere with future deep energy efficiency improvements
  - No 'stranded investment'
- Some benefits aren't limited to "ductless"…
  - Inverter drive variable speed, cold climate becoming available in central split systems
  - These may be better suited to replace central split systems…
    - If ducts are OK, or accessible and can be fixed

~3,000 Ductless Heat Pumps in Maine

Slides courtesy of Andy Meyer – Program Manager
CSG – program implementer

Two Maine DHP programs:

1. All Income Pilot:
   a. 1,000 DHPs
   b. $600 rebate, on-bill financing
   c. HSPF ≥ 10.0
   d. Average install cost: $3,230
   e. 91% **definitely recommend**
2. Affordable housing
   1. Electric space heat
   2. Free to customer
   3. 1894 Units, avg. cost $2,073

ME Low Income DHP evaluation (The quirkiness of heat pump users)

- Gross heating savings pre/post = 37%
- Comparison-adjusted heat saved = 40%
- Realization rate 70% on heat pump projects
  - Based on pre-evaluation assumption of 75% offset of pre-existing resistance heat
  - 50% replacement more realistic for these units
- Small loads (avg 5400 kWh heating)
  - Large variation in savings between units

Low Income Program Billing Analysis

1. **Methodology**
   a. First year actual vs. prior year
   b. 249 upgraded units
   c. 58 non-upgraded (controls)
   d. Normalized results for weather and usage

2. **Findings**
   a. Pre-upgrade heat load: 5,399 kWh/year
   b. Net savings: 25 – 54%
   c. Simple payback: ~7 years
      i. $0.14/kWh
      ii. $2,073 install cost

49

Low Income Tenant Interviews

1. 24 in-home interviews
2. 25% of tenants *did not use heat pump at all*
3. Only 45% of tenants heated "most of apartment" with heat pump*
4. Behavior influences
   a. Subsidized utilities (open windows, high setpoints, unused units)
   b. Limited occupant education

* Consistent with Bonneville Power 2012 study showing only 43-75% of electric resistance heat offset "*Ductless Heat Pump Retrofits in Multifamily and Small Commercial Buildings*"

Thanks!

Bruce Harley,
Technical Director, Conservation Services Group

bruce.harley@csgrp.com
802.694.1719