Real Life Air Source Heat Pumps

NESEA Building Energy Conference
9 March, 2018

Bruce Harley Energy Consulting
Outline

• Overview

• Some field research results

• Recent measurements and results

• Design and application resources and insights
Terminology

• COP = Coefficient of Performance
  = Energy Out / Energy In (like units)
  typical range 2~6 depending on conditions
• HSPF = rating of heating efficiency
  = Energy Out / Energy In (btu/watt)
  – this is a seasonal model based on lab test
  – Like a COP * 3.41 but it’s not measured
  – Many baked-in assumptions, minimal test points
George Box (1919-2013)

“All models are wrong, but some are useful”

All **ratings** are wrong, but some are useful

CSA: EXP07 test procedure
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 low system efficiency / high cost

• People believe ASHPs don’t work in cold climates because of the climate
Buying a DHP in 2012

- 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...”
  - Old myths die hard...
Why heat pumps?

• Strategic electrification
  – Carbon reductions will require getting buildings off of fossil fuels
  – The grid can get “greener” over time
  – Heat pumps can get more efficient over time
  – PV on-site or off-site can provide electricity for individual heat pump(s) annually
  – Fossil fuel combustion will never be more efficient or have lower carbon emissions than it does now
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
Hidden in soffit or above ceiling
Field Studies - Brief Highlights

- **1990s, Ecotope (WA):**
  - Heat pumps: more energy than electric resistance
  - Less than electric furnaces
  - Big losses in ductwork, lack of zoning contributed

- **2003 (Ecotope):**
  - 14 electric heat homes retrofitted
  - Single-zone, “standard” mini-splits
  - Saved average of 40% (*range* was very wide)
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<td>Ductless Mini-Split Heat Pump Customer Survey Results</td>
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<td>EMaine LIWx Program Checkup 2014</td>
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Recent Studies

• Building Science Corp (Building America) 2014
  – Long term monitoring in 8 low-energy homes
  – Predictable issues with indoor distribution
  – Big issue with “on/off” (deep setback = poor eff.)

• Steven Winter (Building America) 2015:
  – Measured 7 mini-splits retrofitted in homes
  – COP range from 1.1 – 2.3
  – Issues: low air flow, high inlet temperature, poor integration with central heat
Recent Studies

• Cadmus 2016 MA/RA impact evaluation:
  – 152, CC/NonCC, average rated HSPF 9-11
  – Operating hours much lower than expected (only running 19-27% of the time in winter)
  – Efficiencies somewhat lower than ratings
  – Net result: savings pretty small

• Issues: lack of use (many installed w/AC focus)
  – need better controls/thermostat placement
  – multi-zone had lower efficiency
My Measurements

• Summary:
  – 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
Outdoor Unit
Attic room - 2nd floor

2-zone, 9 HSPF

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2nd Floor Air Handler – 3 rooms
- Return in hall, remote sensor in 1 room
Room Temperatures

Room temps 10/1/12 0:00 to 4/29/13 0:00, 210 days

Control issue

Vacations
Resistance vs DHP

Comparison

- Resistance fit to DT
- HP total to DT

kWh/day vs Tin - Tout: Daily average
Some conclusions

• Fan Speed – “Low” is quieter
  – Started this way during our first winter

• “Auto” fan boosts capacity
  – Important in colder weather
  – Easier to leave in auto all the time

• Don’t use auto-changeover (H/C) setting
# My house: Projected vs. Actual

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<td>Consumption</td>
<td>3067 kWh</td>
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<td>Cost</td>
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<td>COP</td>
<td>2.5</td>
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</table>
From NEEA research - cycling
My house: 9 AM “high insulation” re-set

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Temperature Setbacks

• For variable speed ASHP, don’t save much
  – 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 setback for > several days away
  – ... but don’t expect fast recovery!
Feb-Apr 2014 added, no setback:

**Comparison**

- **kWh/day**
  - Resistance fit to DT
  - HP total to DT
  - 2014-constant

- **Tin - Tout: Daily average**
  - Linear (Resistance fit to DT)
  - Linear (HP total to DT)
  - Linear (2014-constant)

**With setback**

**Without setback**
1 site from a current project:

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Daily data

kWh vs. daily avg Deg F

\[ y = -0.4128x + 34.502 \]

\[ R^2 = 0.5133 \]
Gas Boiler, 1.5T Cold Climate HP

• 1500 SF ranch, 3 bedroom. Open floor plan
  – Separate gas DHW – conventional tank (new)
  – Moved boiler thermostat to master bedroom
  – Installed wall-mount thermostat opposite HP

• Savings: approx. 70% of gas heating

• Savings: approx. 60% of all gas
  – VERY preliminary: 2 months, imprecise gas data
  – M&V: CDH Energy for official results later
Electric Resistance Heat

- 2-story, 1 ½ bedroom
- Pre-heat pump billing data
- 21 days of logger data:

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<th>Net COP (incl. &quot;aux&quot;)</th>
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<td>Actually used kWh</td>
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<td>kwh/day saved</td>
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ASHP & Resistance Watts vs DT

**Weekday**

\[ y = 24.846x - 62.546 \]

\[ R^2 = 0.5621 \]

**Weekend**

\[ y = 38.969x - 415.22 \]

\[ R^2 = 0.8627 \]

\[ y = 27.339x - 37.336 \]

\[ R^2 = 0.4575 \]
COP vs. Temp Diff

Estimated Daily COP vs. DT, 3 Regimes

\[ y = -0.0057x + 3.0094 \]
\[ R^2 = 0.0155 \]

\[ y = -0.0125x + 3.2766 \]
\[ R^2 = 0.1309 \]
EFG Co-Heating Test Results

- Very preliminary – need more data

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<td>10/1-11/28 no MHK, setback, 100% ERV (higher uncertainty-less comparable)</td>
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<tr>
<td>21</td>
<td>2.9</td>
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<td>22</td>
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<tr>
<td>38</td>
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<td>All recorded since 11/01/17</td>
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</table>
7000 SF – office/classroom

Manual override ("service disconnect") used frequently in meeting/classroom spaces
Discomfort – fan set to continuous run

Misguided efforts to conserve

Please don’t forget to turn unit off when you leave for the day.
Fixes...

• Changed programing to allow occupant fan control
• Told people to leave temp settings constant
  – And reset at night even if they turn it off
• Results:
  – Base energy: modest decrease
  – Heating energy: virtually the same
  – Happier, more comfortable people!

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Before (hourly Oct-Dec ’16)

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Jan-Apr ‘17 – no setbacks or fan-on

Standby >1 to 0.6kW, virtually same slope (2.4 kW/°F)
Resources: Equipment Selection

• NEEP Cold Climate Listings (neep.org)
  – High heating efficiency rating: HSPF >10
  – High efficiency in cold weather: COP > 1.75
    • at 5°F outdoor temperature

• Also look for
  – High capacity (output) at low outdoor temps
  – Rated operation at -5°F, -15°F, or lower
  – Max capacity is expected when it’s cold!

3/7/2018
# NEEP ccASHP Listings

**General Information**

**Updated:** March 9, 2017

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<tr>
<th>Manufacturer</th>
<th>Brand (if applicable)</th>
<th>AHRI Certificate No.</th>
<th>Outdoor Unit Model</th>
<th>Indoor Unit Model(s)</th>
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NEEP Guides

- Sizing/selection guide and installation guide
- neep.org, “Initiatives/air source heat pumps”, “Air-Source Heat Pump Installer Resources” link on right side
- Also, “Cold Climate Air Source Heat Pump” link at right to cold climate list
- Updates coming in 2018, + consumer’s guide
Sizing and Selecting Guide

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates
A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Heating (or Heating & Cooling) Displacement

<table>
<thead>
<tr>
<th>Application Description</th>
<th>Custom Application Descriptions for Heating (or Heating &amp; Cooling) Displacement</th>
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</table>

Suggested ASHP System Configuration
(Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)

Suggested Treatment of Existing HVAC System

Load Calculation

Equipment Selection Considerations

Oversizing Concerns / Tradeoffs

Full Heating System Replacement

<table>
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<tr>
<th>Application Description</th>
<th>Typical Response to Poor Ductwork Design are Localized</th>
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Suggested ASHP System Configuration
(Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)

Suggested Treatment of Existing HVAC System

Sizing Strategy Overview

Isolated Zone

<table>
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<tr>
<th>Application Description</th>
<th>Design for design heat. If design heat is less than 60°F for a single zone, require thermostatic control.</th>
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</thead>
</table>

One room or zone that is otherwise thermally isolated, such as a newly finished basement room, build-out above garage, etc., may not have proper thermal comfort.
Introduction

High-quality installations of air-source heat pump (ASHP) systems generate referrals, increase sales, reduce callbacks and improve customer comfort and satisfaction. Installation practices also have a major impact on efficiency and performance of an ASHP system. Efficient ASHPs have seen significant sales growth in colder climates in recent years. The recent generation of cold-climate ASHPs, combined with insights from large-scale installation programs and installers, has led to a better understanding of the full range of practices to ensure maximum system performance and customer satisfaction. This guide provides a list of these best practices, as well as homeowner education and system setup guidance, to help ensure efficient air-source heat pumps and happy customers in cold climates.

Heat pumps should always be installed by licensed, trained professionals. Always follow manufacturer’s specification and installation instructions, and all applicable building codes and regulations. All installers should attend a manufacturer’s training or preferred installer program.

ASHPs come in a number of configurations, and in some cases the following guidance may be specific to one or more of those system types. There are many variations and terms used, but these guidelines will focus on the following broad categories: “ductless ASHP” refers to any non-ducted cassette type indoor unit (including wall-mount air handlers, floor mounted consoles, in-ceiling cassettes, etc.); “mini-duct ASHP” refers to remote air handlers that are typically designed for compact, concealed-ceiling or short-duct configurations; and “centrally ducted ASHP” refers to whole-house systems with central air handlers. The icons shown here are used below to indicate when guidance is specific to a certain system type. All items without icons are generally applicable to all ASHP configurations.
Access/Use of Guides

• Guides developed to be shared/used broadly
• Guides posted on NEEP’s public website, available to download
• Guides available to co-brand
• Seeking opportunities to disseminate resource
• Please send ideas about key venues to share the Guides
Issues

• Design
  – Multi-zone
  – Sizing
• Installation
  – Snow/ice / drip / drain pan heat
• Utilization
• Controls / firmware / settings
  – Wall mount thermostat
  – Temp sensing / air handler
  – Constant fan
• Setbacks
Design (Retrofit)

• 1st floor unit primary heating for 2-story house
  – 2nd floor unit great for cooling 2-story house
    • Ducts help upstairs—low load rooms

• **Most** savings from first heating unit
  – Sometimes 2-3 heads for cut-up floor plans

• More: increased comfort, convenience
  – Higher cost and lower efficiency
Design

• 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
    • Typically run at max capacity at low temperatures
    • NEEP guide is really helpful
Design - Sizing

• 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 sizing may not be relevant for some uses
  – Smaller seems to be better – as long as load is met
Sizing – New Con / DER

• Make sure to do actual load calculations
• Use equipment spec’s *at design conditions*
• Zoning: Avoid oversizing many small zone
  – Use zones strategically
  – Slim/horizontal duct systems for 2-4 bedrooms
  – Most single family homes: 2-3 zones; condos: 1-2
• Isolated room – separate zone
Design / Install

• In heating climate: indoor unit low on wall
  – Window sill height provides balance between heating and cooling performance in cold climate
  – Or use floor mounted system
  – Or ducted system with floor registers if space is available
“Floor mount” good for larger spaces

• Better heat distribution, esp. first/lower floor

• Or, ducted system with floor registers
Got Monitoring?

Bruce Harley Energy Consulting, LLC
Monitoring is *really* good to have

- See what’s happening… but adds $300-1500+
- eGauge – flexible, configurable, geeky
  - No subscription fee (need to backup data in case of failure)
- eMonitor – more consumer friendly
  - Have to pay for data storage
- Sense – Can’t “sense” variable-speed heat pump unless you put it on JUST the HP circuit
Sense – cheaper, but imperfect:
Connect only to the heat pump:
Care In Installation

• Follow manufacturers instructions carefully
  – Refrigerant charge adjustments if needed
  – Flare fittings, purge system, start-up process

• Keep above snow line – wall brackets
  – Best if mounted to foundation
  – (or wall in less noise-sensitive area)

• Surge protector at service disconnect

• Rodent-proof entry

Bruce Harley Energy Consulting, LLC
Wall mount or stand:

Beware frost heave w/stands
Drip Diverter

• Avoid eave drip, or use diverter
• Sheltering from above is good – don’t obstruct air flow (follow instructions for clearances!)
Surge protector helps avoid this:
Rodent-proofing line set entry
Controls / Settings

• Use Wall-mounted controls
  – Sense temperature *at control, not in return air*
• Fan Speed: Auto, avoid constant-fan settings
• Avoid “Auto” heating / cooling setting
• Override fan temp sensing control for air handlers in unconditioned space
• Retrofit: the heat pump needs to operate
  – Set ASHP warmer than backup heat!
  – Control location – ASHP as primary, central as backup
Thanks!

Bruce Harley
Bruce Harley Energy Consulting, LLC

bruceharleynenergy@gmail.com
802.694.1719