Why ASHPs in MN?

• Cold-climate technology improvements
• Significant amounts of electric heating
• Growing discussion around fuel switching
  – Electric grid getting greener
  – Delivered fuels can be expensive
    • CEE’s initial work started in response to propane shortages in winter of 2014
Study Overview

- Field Study
  - 8 ccASHP in a variety of MN residences
    - 6 ducted whole house system
    - 2 ductless mini-split systems
  - Monitor installed field performance of ASHP & backup

- Incorporate into utility energy conservation program
- Climate zones 6 & 7
- Detailed monitoring system installed at each site
Ducted Whole House Installation
Flex Fuel Systems
Ducted Whole House Installation
All Electric Systems
Installation Considerations

Control and Operation

Integration with backup

Sizing
Design and Sizing for Ducted Systems

- Trade-offs between HP size and fraction of heating load meet.
- Rule of thumb: Sizing for heating increases HP size by 1-ton over sizing for cooling.

Percentage of heating load meet by ASHP:
- 4 ton ~ 86%,
- 3 ton ~ 77%,
- 2 ton ~ 60%
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![Graph showing percentage of heating load meet by ASHP with furnace back-up heating line.](image)
Design and Sizing for **Ducted** Systems

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**Electric booster heating**

**House heating load**

Outside Air Temperature (F)
Heating cycle COP of a flex fuel system
Heating Cycle COP of all electric
Annual Characteristics and Savings

• Ducted Flex fuel ccASHP compared to condensing furnace (LP)
  – Annual COP improved to 1.3 (over 0.85)
  – ~40% site energy reduction
  – ~30% cost reduction
  – ~60% reduction in propane use
  – ~5% reduction in emissions (J. Edwards Thurs 8/16, Session 2)

• All-electric Ducted ccASHP
  – Annual COP ~1.9
  – ~60% site energy reduction
Conclusions

- Heat pump’s preformed as expected when heating
- Annual COPs are lower than HSPF ratings due integration with auxiliary heating and freeze protection
- Flex Fuel ccASHPs can heat below 5F, all electric systems below -13F
- Paybacks are attractive when existing heating or cooling system need to be replaced

<table>
<thead>
<tr>
<th></th>
<th>Site Energy</th>
<th>Percentage Reductions for ccASHPs</th>
<th>Source Energy</th>
<th>Homeowner Cost</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual fuel ASHP vs Prop. Furn.</td>
<td>40%</td>
<td></td>
<td>10%</td>
<td>30%</td>
<td>5%</td>
</tr>
<tr>
<td>All elect. ducted &amp; ductless vs elect. resistance</td>
<td>55%</td>
<td></td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
</tr>
</tbody>
</table>
What’s Next?
Remaining Barriers

- Controls
  - Ductless and Electric Resistance Baseboards
  - Ducted – All electric and Auxiliary Booster
  - Frost protection
- Contractor training
- Install with existing systems to reduce costs
- Programs, deemed savings, and quality install
Beneficial Electrification

• When is fuels switching beneficial?
  – Reductions in
    • Emissions
    • Source energy
    • Homeowner cost

• Biggest market in MN: Propane furnaces
• Potential market: AC and should heating for nat. gas furnaces
Practical energy solutions for homes, businesses, and communities
THANK you!

Ben Schoenbauer:
bschoenbauer@mncee.org
extras
Installation Considerations

• Controls :
  – Ducted Systems: automated controls to bring up backup
  – Ductless Systems: manual action by homeowner

• Interaction with back-up systems
  – Ducted Systems: Integrated installs with shared controls
  – Ductless Systems: Separate systems

• Sizing
  – Ducted Systems: Contractors typically sized for cooling
  – Ductless: Partial or full load design
Replacement System Install Costs

• For the 4 ducted systems:
  – Our average cost was ~$14,000*

• NREL Residential equipment install database:
  – $6,340 for ducted 3ton ccASHP
  – $4,000 for a new condensing propane furnace ($3,000 for an 80%).
    • $10,340 Total
  – $5,540 for a new comparable SEER A/C
    • $800 incremental for ccASHP

• Limited installs leading to higher costs
• Requirement for new air handler or furnace increases costs considerably
Instrumentation

Power Measurements:
1) Outdoor unit
2) Indoor unit
3) Indoor fan
4) Reversing valve

Temperatures:
5) Supply Air
6) Return Air
7) Mechanical area ambient
8) Conditioned space

Additional:
9) Back up fuel consumption
10) Delivered air flow
11) NOAA data
# Site Equipment

<table>
<thead>
<tr>
<th>Site Number</th>
<th>ASHP System</th>
<th>ASHP Size</th>
<th>ASHP Type</th>
<th>Backup</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrier Infinity with Greenspeed [25VNA048A003]</td>
<td>4 ton</td>
<td>Ducted</td>
<td>LP Cond. Furnace</td>
</tr>
<tr>
<td>2</td>
<td>Bryant Extreme Heat Pump [280ANV048]</td>
<td>4 ton</td>
<td>Ducted</td>
<td>LP Cond. Furnace</td>
</tr>
<tr>
<td>3</td>
<td>Carrier Infinity with Greenspeed [25VNA036A003]</td>
<td>3 ton</td>
<td>Ducted</td>
<td>LP 80% Furnace</td>
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<tr>
<td>4</td>
<td>Trane XV20i [4TWV0036A]</td>
<td>3 ton</td>
<td>Ducted</td>
<td>LP Cond. Furnace</td>
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<tr>
<td>5</td>
<td>Mitsibishi Ductless Hyper Heat [MUZ-FH18NAH]</td>
<td>1.5 ton</td>
<td>Ductless</td>
<td>Electric Resistance</td>
</tr>
<tr>
<td>6</td>
<td>Mitsibishi Ductless Hyper Heat [MSZ-FH12NA]</td>
<td>1 ton (2 units)</td>
<td>Ductless</td>
<td>Electric Resistance</td>
</tr>
<tr>
<td>7</td>
<td>Mitsibishi Hyper Heat System [PVA-A30AA7]</td>
<td>3 ton</td>
<td>Ducted</td>
<td>Electric Booster</td>
</tr>
<tr>
<td>8</td>
<td>Mitsibishi Hyper Heat System [PVA-A30AA7]</td>
<td>3 ton</td>
<td>Ducted</td>
<td>Electric Booster</td>
</tr>
</tbody>
</table>

Whole house ducted systems
Energy Use Vs OAT Models

Site 2 Ducted ccASHP

- ccASHP Meas. Propane Use
- ccASHP Propane Use Fit
- ccASHP Meas. Elec. Use
- ccASHP Elec. Use Fit
- Furnace LP Use

Energy Consumption (btu/hr)

Outdoor Air Temperature [°F]
Cold Temperature Performance of ASHPs

- Ducted ASHPs were capable of delivering heat at outdoor temps from 5 to 10 F
- Ductless systems operated below -13 F.
  - Homeowner in WI has removed several ER baseboards
Cold Temperature Performance of ASHPs

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- Ductless systems operated below -13°F.
- Homeowner in WI has removed several ER baseboards.
System Performance

Annual COP: ductless ~1.9 to 2.1
Flex Fuel ~1.2 to 1.3