LEAN
(Low income Energy Affordability Network)

• LEAN = 25 Massachusetts agencies that deliver the energy efficiency and fuel assistance programs to low income households.
• Ma CEC provided funding to LEAN for installation of renewable thermal technologies in low income households 2013-2015.
• Mostly used to install “cold climate” ASHPs in state supported public housing.
• LEAN installed 437 ASHPs at 12 different sites.
• Most were mini splits in one bedroom apartments serving the elderly. Some family units also served with larger equipment.
• Displaced electric baseboard or electric storage heat.
• Cost information on 12 projects, and some savings data on 8 projects.
## LEAN ASHP Costs

<table>
<thead>
<tr>
<th>type</th>
<th>BTU size</th>
<th>condensers</th>
<th>$ range</th>
<th>average</th>
<th>cost per room served</th>
</tr>
</thead>
<tbody>
<tr>
<td>mini split</td>
<td>9000</td>
<td>48</td>
<td>3858-3858</td>
<td>3858</td>
<td>3858</td>
</tr>
<tr>
<td>mini split</td>
<td>12000</td>
<td>313</td>
<td>4305 - 5785</td>
<td>5009</td>
<td>2505</td>
</tr>
<tr>
<td>mini split</td>
<td>15000</td>
<td>48</td>
<td>4548-7405</td>
<td>6027</td>
<td>2257</td>
</tr>
<tr>
<td>mini split</td>
<td>18000</td>
<td>24</td>
<td>4548 - 8139</td>
<td>6697</td>
<td>2392</td>
</tr>
<tr>
<td>multi zone</td>
<td>24000</td>
<td>1</td>
<td>8500 est</td>
<td>8500</td>
<td>2833</td>
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<tr>
<td>multi zone</td>
<td>36000</td>
<td>1</td>
<td>18125 est</td>
<td>18125</td>
<td>4531</td>
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<tr>
<td>city multi</td>
<td>92000</td>
<td>2</td>
<td>216,890</td>
<td>216,890</td>
<td>6379</td>
</tr>
</tbody>
</table>
# LEAN ASHP Savings

<table>
<thead>
<tr>
<th>Type</th>
<th># Units</th>
<th>Estimated Year 1 Savings</th>
<th>Realized Year 1 Savings</th>
<th>Possible reasons for differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>city multi</td>
<td>1</td>
<td>50%</td>
<td>41%</td>
<td>Bathroom heaters used extensively after change out. Stairwell wall heaters maximized.</td>
</tr>
<tr>
<td>min splits</td>
<td>24</td>
<td>50%</td>
<td>35%</td>
<td>Possibly oversized.</td>
</tr>
<tr>
<td>min splits</td>
<td>4</td>
<td>40%</td>
<td>na</td>
<td>Extreme variation in savings - 15% to 40%.</td>
</tr>
<tr>
<td>min splits</td>
<td>20</td>
<td>40%</td>
<td>na</td>
<td>Extreme variation in savings - 2% to 47%.</td>
</tr>
<tr>
<td>min splits</td>
<td>44</td>
<td>50%</td>
<td>54%</td>
<td>Hallways/stairwells not heated.</td>
</tr>
<tr>
<td>min splits</td>
<td>6</td>
<td>50%</td>
<td>na</td>
<td>Rehabbed in 2014 utilizing advanced energy efficiency measures. After mods, energy usage has been remarkably low compared to similar sized all electrical buildings. LEAN has not yet identified respective contributions of savings from various EE measures.</td>
</tr>
<tr>
<td>min splits</td>
<td>12</td>
<td>50%</td>
<td>37%</td>
<td>Large hallways on 2 floors remain heated with electric baseboard. Demand usage reduced by 50%.</td>
</tr>
<tr>
<td>min splits</td>
<td>68</td>
<td>50%</td>
<td>50% ?</td>
<td>Upon complete installation in March, saw an immediate 53% reduction year over year @ normalized degree day levels.</td>
</tr>
</tbody>
</table>
LEAN

Elliott Jacobsen, Action, Inc. & John Wells, ABCD, Inc., LEAN Co-Chairs

Bruce Ledgerwood, Manager LEAN Alternative Energy Program

Amisi Nazaire-Hicks, Technical Assistant AEP
Residential ASHPs: Performance Monitoring and Modeling

NEEP Workshop
October 2015

Robb Aldrich
Steven Winter Associates, Inc.
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Monitoring

• DOE funding through Building America Program

• Partnership with Efficiency Vermont

• 10 DHPs in homes around New England

• Monitored winter 2013-14

• Report online:
Air Temperatures
Flow Testing
Flow vs. Fan Current

\[ y = 5195.8x - 347.6 \quad R^2 = 0.9937 \]

\[ y = 6610.2x - 364.36 \quad R^2 = 0.8587 \]

\[ y = 3049.6x - 201.76 \quad R^2 = 0.9991 \]
Air Flow Measurement

Ductless Heat Pump Flow Calibration

- Low Fan
- Med. Fan
- High Fan
- Listed Flow

Air Flow [SCFM] vs. Current [mA]

- $y = 6.6102x - 364.36$
- $y = 5.1958x - 347.6$
- $y = 3.0496x - 201.76$

0 50 100 150 200 250

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## SCOP Summary

<table>
<thead>
<tr>
<th>Month</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>5</th>
<th>8</th>
<th>9</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>Nov 2013</td>
<td>1.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Dec 2013</td>
<td>1.6</td>
<td>-</td>
<td>2.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Jan 2014</td>
<td>1.4</td>
<td>2.0</td>
<td>2.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Feb 2014</td>
<td>1.6</td>
<td>1.9</td>
<td>2.2</td>
<td>1.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mar 2014</td>
<td>1.8</td>
<td>2.0</td>
<td>2.3</td>
<td>1.7</td>
<td>2.2</td>
<td>1.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Apr 2014</td>
<td>2.2</td>
<td>1.9</td>
<td>3.0</td>
<td>-</td>
<td>2.5</td>
<td>1.3</td>
<td>2.4</td>
</tr>
<tr>
<td>Overall</td>
<td>1.6</td>
<td>2.0</td>
<td>2.3</td>
<td>1.7</td>
<td>2.3</td>
<td>1.1</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Same HP- Different Results

Site 1 (FE18) - Daily COP

Western MA
HDD65: 6,929
Design Temp: 2°F
SCOP: 1.6

Site 4 (FE18) - Daily COP

Near Burlington, VT
HDD65: 7,956
Design Temp: -4°F
SCOP: 2.3
Heat Output-FE18

Site 1

Site 4
Possible Reasons for low COPs

• Low fan speed (not just low flow)
• Higher return air temperatures
High Return Temp?
NYSERDA Modeling Study

Used published studies to create calibrated energy models. Studies included:

- Heating electricity consumption
- Building specifications (all SF homes)

Two studies, 5 home types, ~30 homes

Modeling tools used:

- Energy Plus & BEopt
- EQUEST
- REM/Rate
- TREAT
Preliminary Modeling Results

Predicted ASHP Elec. Use

Energy Plus / BEOPT

EQUEST

REM/Rate

TREAT

25-40% Low
Preliminary Modeling Results

Predicted ASHP Elec. Use

Energy Plus / BEOPT 25-40% Low
EQUEST 25-40% Low
REM/Rate
TREAT
Preliminary Modeling Results

Predicted ASHP Elec. Use

Energy Plus / BEOPT  25-40% Low
EQUEST            25-40% Low
REM/Rate          30-40% High
TREAT
Preliminary Modeling Results

Predicted ASHP Elec. Use

Energy Plus / BEOPT 25-40% Low
EQUEST 25-40% Low
REM/Rate 30-40% High
TREAT Pretty Accurate
Heat Output – FE12

Site 2

- Heat Output
- Max Heat Output
- Listed Output at Intermediate
- Listed Output at Max
Site 2: CT Passive House

Modeled ASHP Electricity:

PHPP: 613 kWh/y
BEopt (Energy Plus): 738 kWh/y
REM/Rate: 1,053 kWh/y

Measured ASHP Electricity: 1,446 kWh/y

(values are for heating season only)
Questions?

Thanks to:

• U.S. DOE Building America Program
• Efficiency Vermont
• NYSERDA
• NEEP

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