Performance Validation and Demonstration Projects

• Ground Source Heat Pumps
  – ~50 existing residential systems statewide
  – ~45 additional residential systems on Long Island

• Air Source Heat Pumps
  – 20 residential replacements in Brooklyn and Queens
  – 20 residential displacements in the Hudson Valley
Performance Validation and Demonstration Projects

- Air Source Heat Pumps (Cont.)
  - 5 residential air to water systems in Tompkins County
  - 5 residential low capacity gas furnace/ASHP hybrids in Central NY
  - 2 VRF systems
    - One commercial in Westchester
    - One Multifamily building in NYC
Performance Validation and Demonstration Projects

• Goals:
  – Determine what information the market needs on technical and economic performance
  – Collect performance information that can be communicated accurately and confidently
  – Disseminate the information to the market and make data available to create change
Scope and Status

- Energy Futures Group, Bruce Harley, Integral Building & Design
- Oversaw the installation of Mitsubishi “cold climate” air-source heat pumps in 20 single family, year round homes in Hudson Valley
- eGaugues in each home to remotely measure usage and savings
- Data on at least one heating season for 14, partial season data for 6
- Tech transfer development under way (interviews, videos)
- Providing data and resources for NYSERDA to better promote air-source heat pump benefits
Lessons Learned

- ASHPs can be effective at displacing (and even replacing) heating energy use in existing homes
- When installed correctly, ASHP performance seem to be in the 2.4 – 2.7 seasonal COP range
- Installed costs can be $3500-$4000/ton range (after incentives)
- Some contractors have latched on to ASHPs as a growing business opportunity
- Installation contractors do not always follow the NEEP Guidelines, so QA has been helpful
- Customers with an interest in reducing their fossil fuel use are particularly interested in heat pumps, regardless of “payback”
HVHPP (EFG) Analysis Results

- Collect Utility Bills (or Fuel Logs) Pre- and Post-Installation
- Measure ASHP & House Power with eGauge data loggers (also Solar-PV, DHW, etc.)
- Measure Boiler/Furnace Power to infer runtime (for Oil only)
- Analysis Approach:
  - Correlate bills/logs with ambient temperature for each period
  - Determine difference between Pre and Post trends with temperature
  - Determine (piece-wise) linear trend of HP Electric Use
  - Use temperature bin analysis with typical year weather to predict savings and impacts
  - Develop average daily demand profiles based on temperature for utility analysis
- Next Steps: Cooling Savings
Site EFG-1

**EFG S1 - Pre & Post Utility Gas Analysis**

<table>
<thead>
<tr>
<th>Year</th>
<th>Gas (therms/day)</th>
<th>HP Electric (kWh/day)</th>
<th>Total Heating Costs ($)</th>
<th>Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-2011</td>
<td>852.7</td>
<td>4,016</td>
<td>565</td>
<td></td>
</tr>
<tr>
<td>Pre-2012</td>
<td>445.5</td>
<td>4,016</td>
<td>697</td>
<td></td>
</tr>
<tr>
<td>Pre-2013</td>
<td>407.2</td>
<td>4,016</td>
<td>697</td>
<td>132</td>
</tr>
</tbody>
</table>

**Implied Seasonal COP**

2.3
Site
EFG-2

### Heating Only

<table>
<thead>
<tr>
<th></th>
<th>PRE-Retrofit</th>
<th>POST-Retrofit</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric (kWh/yr)</td>
<td>13,273.0</td>
<td>9,343.7</td>
<td>3,929.3</td>
</tr>
<tr>
<td>Total Heating Costs</td>
<td>$ 1,991</td>
<td>$ 1,402</td>
<td>$ 589</td>
</tr>
<tr>
<td>Implied Seasonal COP</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HP Electric (kWh/yr)</td>
<td></td>
<td>4,661</td>
<td></td>
</tr>
</tbody>
</table>

**Post readings appear to be “estimated”**
**Site**

**EFG-3**

**EFG S3 - Pre & Post Utility Oil Analysis**

<table>
<thead>
<tr>
<th>Year</th>
<th>Fuel Oil (gal/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre - 2016</td>
<td>745.5</td>
</tr>
<tr>
<td>Pre - 2017</td>
<td>412.2</td>
</tr>
<tr>
<td>Post - 2018</td>
<td>333.3</td>
</tr>
<tr>
<td>Post - 2019</td>
<td>2</td>
</tr>
</tbody>
</table>

**EFG S3 - Heat Pumps: 1 Outdoor, 3 Indoor, 3.0 tons total**

<table>
<thead>
<tr>
<th>Month</th>
<th>Total HP Electric Use (kWh/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>20</td>
</tr>
<tr>
<td>Feb</td>
<td>40</td>
</tr>
<tr>
<td>Mar</td>
<td>60</td>
</tr>
<tr>
<td>Apr</td>
<td>80</td>
</tr>
<tr>
<td>May</td>
<td>100</td>
</tr>
<tr>
<td>Jun</td>
<td>120</td>
</tr>
<tr>
<td>Jul</td>
<td>140</td>
</tr>
<tr>
<td>Aug</td>
<td>160</td>
</tr>
<tr>
<td>Sep</td>
<td>180</td>
</tr>
<tr>
<td>Oct</td>
<td>200</td>
</tr>
<tr>
<td>Nov</td>
<td>220</td>
</tr>
<tr>
<td>Dec</td>
<td>240</td>
</tr>
</tbody>
</table>

**Heating Only**

<table>
<thead>
<tr>
<th></th>
<th>PRE-Retrofit</th>
<th>POST-Retrofit</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil (gal/yr)</td>
<td>745.5</td>
<td>412.2</td>
<td>333.3</td>
</tr>
<tr>
<td>HP Electric (kWh/yr)</td>
<td>4,489</td>
<td>(4,489)</td>
<td></td>
</tr>
<tr>
<td>Total Heating Costs</td>
<td>$ 1,854</td>
<td>$ 1,474</td>
<td>$ 380</td>
</tr>
</tbody>
</table>

**Implied Seasonal COP**

2.5
EFG-3 Avg Daily Profiles
(also can be normalized per ton to combine sites)

AVG Heating Profiles: EFG S3 - 1 Outdoor, 3 Indoor, 3.0 tons total

AVG Cooling Profiles - 1 Outdoor, 3 Indoor, 3.0 tons total
Downstate ccASHP Demo

Sites
• 20 Sites in Brooklyn, Queens, Bronx, Yonkers, Long Island
• 1-4 family buildings

Goals
• Understand and demonstrate viability, costs, savings
• Increase awareness, confidence
• Market exposure
• Case studies

Scope
• Whole heating system replacement
• Weatherization

Motivation
• Comfort
• Increase home value
• Reduce energy costs

Status
• 19 complete and collecting data
• 1 on the way

Jordan Dentz, The Levy Partnership, Centsible House
Site Characteristics
• 1-4 family buildings
• Owner-occupied with rental units
• Tight urban lots
• Masonry and wood frame
• Attached and detached
• Gas and oil
• Mostly boilers with window AC
• Old buildings, minimal insulation

Equipment
• NEEP-listed cold climate air source heat pumps
• 3-4 condensing units
• 6-12 air handlers
• Wall mounted mini and multi-splits
• A few ducted systems
• Sizing challenges

Costs
• Project value $15,000 to $50,000
• Up to $20,000 envelope measures
• Up to $8,000 in incentives/discounts/rebates
• $2,500-$3,900 per zone for HP
• Energy cost savings: slightly negative up to $2,795
Downstate (TLP) Results

- Collect Utility Bills (or Fuel Logs) Pre- and Post-Installation
- Measure ASHP Power for all Units
- Measure Burner Runtime (for Oil only)
- Analysis Approach:
  - Correlate bills/logs with ambient temperature for each period
  - Determine difference between Pre and Post trends with temperature
  - Determine (piece-wise) linear trend of HP Electric Use
  - Use temperature bin analysis with typical year weather to predict savings and impacts
  - Develop average daily demand profiles based on temperature for utility analysis
- Next Steps: Cooling Savings & Separate ASHP and Envelope impacts
Site TLP-3

**TLP-3 - Heat Pumps: 3 Outdoor, 7 Indoor, 6.5 tons total**

<table>
<thead>
<tr>
<th>Ambient Temp (F)</th>
<th>Total HP Electric Use (kWh/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

**TLP-3 - Boiler Runtime/Oil Use**

<table>
<thead>
<tr>
<th>Ambient Temp (F)</th>
<th>Oil Boiler Use (gal/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
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<tr>
<td>40</td>
<td>0</td>
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<tr>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

**TLP-3 - Pre & Post Utility Oil Analysis**

<table>
<thead>
<tr>
<th>Outdoor Temperature (F)</th>
<th>Fuel Oil (gal/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>40</td>
<td>15</td>
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<tr>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>25</td>
</tr>
<tr>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>80</td>
<td>35</td>
</tr>
</tbody>
</table>

**Using fuel bills & measured runtime:** 1.7 gal/h

**Operating Pattern Changed for March & April**

**Heating Only**

<table>
<thead>
<tr>
<th></th>
<th>PRE-Retrofit</th>
<th>POST-Retrofit</th>
<th>Savings</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil (gal/yr)</td>
<td>2,266.3</td>
<td>975.6</td>
<td>1,290.7</td>
<td>$3.60</td>
</tr>
<tr>
<td>HP Electric (kWh/yr)</td>
<td></td>
<td>17,460</td>
<td>(17,460)</td>
<td>$0.20</td>
</tr>
<tr>
<td>Total Heating Costs</td>
<td>$8,159</td>
<td>$7,004</td>
<td>$1,155</td>
<td></td>
</tr>
</tbody>
</table>

**Implied Seasonal COP**

2.5
Site  
TLP-12.1  
(owner)  

**TLP-12.1 - Pre & Post Utility Gas Analysis**  
WUG: JFK  

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>20</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
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<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>40</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>60</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>70</td>
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<td>0</td>
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</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>90</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>1</td>
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<td>1</td>
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<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

**TLP-12.1 - Heat Pumps: 2 Outdoor, 5 Indoor, 4.0 tons total**  
WUG: JFK  

<table>
<thead>
<tr>
<th>Ambient Temp (F)</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total HP Electric Use (kWh/day)</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
</tr>
</tbody>
</table>

**Heating Only**  

<table>
<thead>
<tr>
<th></th>
<th>PRE-Retrofit</th>
<th>POST-Retrofit</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas (therms/yr)</td>
<td>566.8</td>
<td>307.5</td>
<td>259.3</td>
</tr>
<tr>
<td>HP Electric (kWh/yr)</td>
<td>3,257</td>
<td>(3,257)</td>
<td>0.21</td>
</tr>
<tr>
<td>Total Heating Costs</td>
<td>$1,015</td>
<td>$1,234</td>
<td>$(220)</td>
</tr>
</tbody>
</table>

**Implied Seasonal COP**  

1.8
Site
TLP-12.2 (tenant)

**TLP-12.2 - Pre & Post Utility Gas Analysis**  
**WUG: JFK**

---

### Heating Only

<table>
<thead>
<tr>
<th></th>
<th>PRE-Retrofit</th>
<th>POST-Retrofit</th>
<th>Savings</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas (therms/yr)</td>
<td>598.5</td>
<td>362.8</td>
<td>235.8</td>
<td>$1.79</td>
</tr>
<tr>
<td>HP Electric (kWh/yr)</td>
<td>3,203</td>
<td>(3,203)</td>
<td>(219)</td>
<td>$0.20</td>
</tr>
<tr>
<td>Total Heating Costs</td>
<td>$1,071</td>
<td>$1,290</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Implied Seasonal COP: 1.7

---

**TLP-12.2 - Heat Pumps: 1 Outdoor, 3 Indoor, 2.0 tons total**  
**WUG: JFK**

---

**Outdoor Temperature (F)**

- 20 30 40 50 60 70 80 90

**Gas (therms/day)**

- Pre - 2015
- Pre - 2016
- Pre - 2017
- Post - 2017
- Post - 2018
- Post - 2019

---

**Ambient Temp (F)**

- 0 20 40 60 80 100

**Total HP Electric Use (kWh/day)**

- Dec Jan Feb Mar Apr May Jun Jul Aug

---

**Non-linear HP Power Trend is Expected**

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---
### TLP-5 - Pre & Post Utility Gas Analysis  WUG: JFK

#### Gas (therms/day) vs. Outdoor Temperature (F)

- **Pre - 2015**: Data points for the year 2015 are shown in blue diamonds.
- **Pre - 2016**: Data points for the year 2016 are shown in green diamonds.
- **Pre - 2017**: Data points for the year 2017 are shown in cyan diamonds.
- **Post - 2018**: Data points for the year 2018 are shown in red circles.

#### Heat Pumps: 4 Outdoor, 10 Indoor, 8.5 tons total  WUG: JFK

- **Ambient Temp (F)**: Data points for ambient temperature are shown.
- **Total HP Electric Use (kWh/day)**: Data points for total HP electric use are shown.
- **Limited Heating Data**: Additional data points are shown in the inset chart.

### Heating Only

<table>
<thead>
<tr>
<th></th>
<th>PRE-Retrofit</th>
<th>POST-Retrofit</th>
<th>Savings</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas (therms/yr)</td>
<td>3,060.2</td>
<td>792.1</td>
<td>2,268.1</td>
<td>$1.79</td>
</tr>
<tr>
<td>HP Electric (kWh/yr)</td>
<td>18,698</td>
<td>(18,698)</td>
<td>0.21</td>
<td>$0.21</td>
</tr>
<tr>
<td>Total Heating Costs</td>
<td>$5,478</td>
<td>$5,344</td>
<td>$133</td>
<td></td>
</tr>
</tbody>
</table>

**Implied Seasonal COP**: 2.8
TLP-3 Avg Daily Profiles
(also can be normalized per ton to combine sites)

AVG Heating Profiles: TLP-3 - 3 Outdoor, 7 Indoor, 6.5 tons total

AVG Cooling Profiles - 3 Outdoor, 7 Indoor, 6.5 tons total
Utility
Geothermal Community
Riverhead, Long Island

nationalgrid
Geothermal Gas REV

- Test-and-learn demonstration to provide cost-effective heating and cooling using GHP as an alternative to extending pipe.

- First hand experience, efficacy, and verify performance.

- Project partners with NYSERDA and PSEG-LI, Miller Environmental, and GEO-NII.
Sample Learnings

- The approximate combined heating savings from January 2018 to May 2018 at Glenwood Village ranged from 31% to 58%.
- Minimal to no auxiliary electric heat was required for most homes during the cold snap with sub-zero outdoor conditions.
- Utility involvement may improve technology confidence and accelerate market adoption.
- Continue to explore how utilities can support expanded utilization of GHPs.
national grid
National Grid Riverhead Common Loop System

• Detailed Data Collection since December 2017
• Measured heating COPs from 2.2 to 3.5. Variations for a number of reasons:
  – Some Resistance backup heat (behavioral)
  – Variations in pumping power, fan power, fan control
• Low stage heating COPs lower than in high stage (due to constant flow pumping)
• Unusual Ground Loop Temperatures and Flows Observed (next pages)
Loop Temperature Trend

- Supply has ranged from Low 40s mid 70s
- Moderate loop temperatures implies conservative design
- Summer delta-T larger than expected

National Grid Riverhead
Unexpected Loop Temperatures
National Grid Riverhead

- Supply Temperature to HP2 is too high
- Supply Temperature to HP1 and HP3 are normal
- Other HPs are also affected to varying degrees
What if one pump is reversed?
Many other HPs are affected

Loop Temperatures **not** affected (HP1 & HP3)
Loop Temperatures **are** affected (like HP4, etc)

National Grid Riverhead
Confirmation that HP2 Pump was Reversed

- When HP2 flow shut off:
  Sum of HP flows = Main flow
Special Care Required for Common Loops with Individual Pumps

- Mistake affects reversed HP unit
- ..but also affects other units on system
**HP2 Piping Fixed**

Supply Temperature (F)

Piping Fixed on November 6

National Grid Riverhead
3127 Geothermal Project

- Applied Energy Group – Prime Contractor
- ZBF Geothermal, LLC geothermal installation partner
- Funding per site to the client - ~$5,000.00 – discount per job
- Total of 36 sites representing about 60 heat pumps
- Other partners include WaterFurnace and PSEG Long Island
  - Promotional pricing on the equipment
  - PSEG Long Island assisted in target marketing
AEG/LI GSHP Field Test

- Collecting Monitored Data With the Symphony™ System
  - Power measurements (some surrogate measurements)
  - Statuses and diagnostic temperatures
  - Loop flow and temperatures (provide heat rates, loads, COP, EER)
- Installing “BTU Meter” on 10 of the sites (as a confirmation)
- Taking on-site measurements at 4 of the sites (check power, flow, temperatures, etc. with handheld meters)
- We now have some data from first sites
Symphony Measurements

Thermostat
- EAT
- RH
- TSET

Aux Heat
- WAUX
- OEH1
- OEH2

Supply Air

DHW Tank(s)
- TH

Desuperheater
- LWT

Ground Loop
- WP
- FL
- EWT

Loop Pump

Fan
- ORV
- ODHW
- WF
- OF, VF

Indoor coil
- VC, OCC
- comp

Unit Boundary
- WT = WC + WF
- WU = WC + WF

Total System Boundary
- WT = WC + WF + WAUX + WP

Measured points shown as red

AEG GSHP
### S01 – WaterFurnace NDV026

<table>
<thead>
<tr>
<th>Month</th>
<th>Year</th>
<th>Days with HP</th>
<th>Valid Recs</th>
<th>Avg EWT Htg (F)</th>
<th>Avg EWT Clg (F)</th>
<th>Loop Extract (MBtu)</th>
<th>Heat Reject (MBtu)</th>
<th>Heating Load (MBtu)</th>
<th>Cooling Load (MBtu)</th>
<th>Total Htg COP (-)</th>
<th>Total Clg EER (Btu/Wh)</th>
<th>Total Heating (kWh)</th>
<th>Total Cooling (kWh)</th>
<th>Total (kWh)</th>
<th>Comp (kWh)</th>
<th>Fan (kWh)</th>
<th>Pump (kWh)</th>
<th>AUX (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2017</td>
<td>100% 26</td>
<td>45.2</td>
<td>-</td>
<td>-</td>
<td>3,173</td>
<td>3,905</td>
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Annual: 99% 242 45.8 63.1 16,232 2,936 20,891 2,691 3.7 27.0 1,638.2 99.7 1,737.9 997.6 76.5 304.0 363.2 94% 6% 57% 4% 17% 21%
Loop Temperatures for Long Island GSHP System

Average EWT Heating = 46°F

Average EWT Cooling = 63 °F
Rated COPs vs. Field Measured COPs?

- **Geothermal HPs:** (ISO/AHRI 13256-1 “GLHP” rating)
  - GLHP ratings at 33°F EWT, 70 °F entering air
  - Includes some pump power and some fan power
  - “Real” Heating COPs include more pumping power & more fan power
  - Avg of 50 Sites: Rated COP = ~4.2 → field COPs ~3.5

- **Air-Source HPs:** DOE Regulations, AHRI 210/240, NEEP ccASHP
  - HSPF provides national seasonal estimate for wrong climate (Wash DC), with small amount of fan power
  - HSPF of 11-12 is COP = ~3.2-3.5, Bruce Harley simulation estimates for ccASHP are COP = 2.9
  - First field measurements: ~1.8 to 2.5 (Upstate)
  - Summary: Rated COP = ~3.2 → field COPs ~2.2-2.5
Questions?

Scott Smith

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