• Eco Performance Builders
• Home Performance all electric retrofits
• General, HVAC, and Insulation contractor
• Design/Build/Commission
All Electric High-Performance Retrofits

Goals:
- Great indoor air quality
- Comfort
- Efficiency
- All electric
All Electric High Performance Retrofits

All electric retrofits
Ducted heat pump
Attic insulation removal
Air seal and insulate attic
Vapor barrier/condition
Ventilation
Heat Pump water heater
State of the Industry
CEC Study on HVAC Performance

Sensible Capacity at Register / Nominal Total Capacity vs. Outdoor (Condenser Entering) Temperature, F
## Commissioning

<table>
<thead>
<tr>
<th>Supply Airflows (use only Energy Conservatory flowmeter)</th>
<th>Temp (°F)</th>
<th>CFM</th>
<th>Flow Correction</th>
<th>Constant</th>
<th>Delta T</th>
<th>Calculation</th>
<th>Btu/HR</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Grille #1 Room:</td>
<td>51.5</td>
<td>143.0</td>
<td>1.01</td>
<td>1.08</td>
<td>20.5</td>
<td>Delta SG1 - Weighted Return Temp</td>
<td>3208</td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
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<tr>
<td>Supply Grille #2 Room:</td>
<td>50.5</td>
<td>134.0</td>
<td>1.01</td>
<td>1.08</td>
<td>21.5</td>
<td>Delta SG2 - Weighted Return Temp</td>
<td>3153</td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
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<tr>
<td>Supply Grille #3 Room:</td>
<td>53.0</td>
<td>96.0</td>
<td>1.01</td>
<td>1.08</td>
<td>19.0</td>
<td>Delta SG3 - Weighted Return Temp</td>
<td>1992</td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
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<tr>
<td>Supply Grille #4 Room:</td>
<td>52.0</td>
<td>113.0</td>
<td>1.01</td>
<td>1.08</td>
<td>20.0</td>
<td>Delta SG4 - Weighted Return Temp</td>
<td>2468</td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
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<tr>
<td>Supply Grille #5 Room:</td>
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<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
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<tr>
<td>Supply Grille #6 Room:</td>
<td></td>
<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
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<tr>
<td>Supply Grille #7 Room:</td>
<td></td>
<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
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<td></td>
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<tr>
<td>Supply Airflow (continued from page 1)</td>
<td></td>
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<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
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<tr>
<td>Supply Grille #8 Room:</td>
<td></td>
<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Grille #9 Room:</td>
<td></td>
<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Grille #10 Room:</td>
<td></td>
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<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Grille #11 Room:</td>
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<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Grille #12 Room:</td>
<td></td>
<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td>1.08</td>
<td></td>
<td>Delta SG8 - Weighted Return Temp</td>
<td>10820</td>
<td>Btu/hr (delta x 1.08 x CFM x Flow Correction)</td>
</tr>
<tr>
<td>Total Delivered BtuH as measured at supply grilles</td>
<td>10820</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total Btu/hr Delivered (sum entire column)</td>
<td>10820</td>
<td></td>
</tr>
<tr>
<td>Heat Pump Capacity at test condition - or: Sum of furnace rated output &amp; Furnace Fan Watts x 3.4</td>
<td>12110</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BtuH (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Delivered BtuH(1) by capacity BtuH(2)</td>
<td>89%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BtuH (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturer System Power at test condition (Indoor + outdoor) AC &amp; Heat Pumps only</td>
<td>930</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>% Sensible Delivered energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivered EER divided by manufacturer EER</td>
<td>86.6%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Watts</td>
<td>13.0</td>
<td>Manuf. EER</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Manuf. capacity divided by kW (x1000)</td>
<td>960</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Measured System Power</td>
<td>11.3</td>
<td>Delivered EER</td>
</tr>
</tbody>
</table>

### Room Temperature stratification testing at 3°F AFF, center of all rooms

#### 6) All temps after continuous minimum 15 minutes of system operation, system running, all doors open

<table>
<thead>
<tr>
<th>Room</th>
<th>Temp (°F)</th>
<th>CFM</th>
<th>Flow Correction</th>
<th>Constant</th>
<th>Delta T</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Room:</td>
<td>71.0</td>
<td>Pascals across door</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2 Room:</td>
<td>70.0</td>
<td>Pascals across door</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3 Room:</td>
<td>70.0</td>
<td>0.5 Pascals across door</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4 Room:</td>
<td>69.0</td>
<td>2.5 Pascals across door</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 7) Ventilation Location

<table>
<thead>
<tr>
<th>Location</th>
<th>CFM Flow</th>
<th>Supply or Exhaust / continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Room:</td>
<td>Up Bath</td>
<td>116 exh / continuous</td>
</tr>
<tr>
<td>#2 Room:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3 Room:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4 Room:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#5 Room:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Commissioning

Gas furnace tests - Calculate % Sensible Delivered energy and leave EER sections blank

Manuf. EER = 13.0
Manuf. capacity divided by kW (x1000)

Measured System Power = 960
Measured System Pwr (Watts)

Delivered EER = 11.3
Delivered BtuH divided by measured power (kW x 1000) = Delivered EER

Measure all exhaust flows and make sure and whether continuous or demand controlled...
All Electric High-Performance Retrofits

Barriers:

• Our housing stock
  • Is leaky
  • Is poorly insulated
  • Has terrible duct systems
  • Some has knob and tube wiring
  • A lot have asbestos ducts
  • Need the air handler relocated
  • Has small crawlspaces
  • Has small attics
  • Small accesses
All Electric High-Performance Retrofits

Barriers continued:
• Space for equipment and return
• Space for outdoor units
• Complicated houses are tough
• Attic insulation should be removed
• Finding workers is very difficult
• Current supply acquisition issues
• Supply and labor prices are increasing
• Heat pump water heater location & noise issues
Barriers continued:

• The HVAC industry is largely unaware of how poorly their equipment performs and how to design, install or commission properly.
• Good people that don’t know their work isn’t good.
• Pricing issues are a part of this.
• Going off of old myths about equipment and duct sizing and selection.
Fixing Houses

There are a lot of houses
They’re all different
None were designed for us to fix them!
Attics
HVAC Systems
Multi Zones
Multi Zones
Mechanical design for ductless
Ducted Mini Splits Work Best in Most Cases
Duct Location Considerations

Duct locations
• Attics with buried ducts
• Ducts as short as possible
• Sealed crawlspace
• Ducts always as short as possible
Mechanical Design
Air Sealing Before and After
Quality and Air Quality
Simple Filtration
Home Ventilation

Minimum standard
• Continuous running low flow bath fan(s)
• Ducted range hood with good flow and low noise

The great solution
• Balanced HRV/ERV ducted to bedrooms and bathrooms
Electrification

Why does it have to be so complicated with ducts, insulation, etc?

- Smaller systems
  - Smaller ducts to fit in the space
  - Less air = one central return
  - Lower watt draw
    - Battery capable, peak demand, etc.
  - Low noise
  - Better comfort.
- Panel space / capacity
- Less energy usage
- We’re already in there and it will be much harder later.
- Lower equipment cost and easier to purchase
- Less grid impact
- Air sealing and insulation is fantastic load shifting battery
- People will tell their friends that it’s great!