Polling Question:

Please Define Your Occupation Type?

1. OEM
2. Contractor
3. Wholesaler-Distributor
4. Consultant
5. End-User
6. Internal
7. Other
Part 1: Technologies Homeowners Are Ready To Invest In For Comfort

Brandy Powell
Vice President
Variable Speed Marketing
Emerson Climate Technologies

Jeff Christian
Energy Efficiency Specialist
Today’s Presenters

Brandy Powell
- Vice President - Variable Speed, Marketing/Business Dev
- 25+ Years Experience in HVAC Industry
- Responsible For Development, Launch And Growth Of Variable Speed Compression, Power Electronics And Controls Technologies That Will Continue Emerson’s Global Technology Leadership.

Jeff Christian
- Jeffrey Christian, Energy Efficiency Specialist
- 30+ Years Experience In Engineering & HVAC
Agenda

1. Designer Air – What Is It And How Does it Relate To The Homeowner?
2. Defining Comfort
3. The Types Of Modulation Technologies
4. Case Study Examples
Many Potential Home Upgrades In Residential Spaces

• Designer Lighting
• Designer Faucets
• Designer Countertops
• Designer Windows
• Designer Appliances

Why Not Consider “Designer Air”? 
What Is Comfort?

• It’s A Perception
• Can Be Different For Everyone
• Can Be Ambiguous And Difficult To Define
• Discomfort Is Easier To Identify Than Comfort
• Tends To Be Stable And Not Fluctuating

• Goldilocks Effect
  – Not Too Hot, Not Too Cold, It’s Just Right
Comfort Has Many Aspects

• **Temperature**
  – Tighter Temperature Control

• **Humidity**
  – Reduced Humidity Levels

• **Air Speed**
  – Ability To Adjust Fan Speed

• **Noise / Sound Quality**
  – Reduced Air Flow And System Cycling
Enhanced Comfort – Precise Climate Control

**Temperature Control**
- Maintains Precise Temperature Control for Enhanced Comfort

**Humidity Control**
- Broad Turndown Range Enables More Consistent Humidity Control

**Hot Supply Air**
- Compressor Design Enables Heat Pumps to Supply Hotter Air During Cold Winter Conditions
Homeowner Buying Behavior
What They Want Vs. What They Need

• Majority Of Homeowners In The Market For An HVAC System Say Comfort & Energy Benefits Were Reasons For Purchasing A New System - Less Than A Quarter Actually Bought For Those Reasons

• Emerson’s Survey Found 59% Of Actual System Purchases Were Driven By The Failure Of Existing System Or Costly Repairs Required To Keep It Running And Not Comfort And Energy Benefits
Challenges To Achieving Comfort

• Budget / Competing Upgrades
• Initial Cost Versus Total Cost Of Ownership
• HVAC Is Out Of Sight, Out Of Mind
• Changing Loads
• Shifting Schedules
• Traditional Technologies
  – Fixed Capacity Compressors
  – Fixed Speed Fans

New Technologies Are Available To Address These Challenges And Achieve Enhanced Comfort

53% of contractors will use INCREASED COMFORT as a benefit to upsell their customers.
Role Of Modulation Technologies

Changing Landscape

• Growing Mid-Tier & Premium Tier
• Modulation Technologies Prevalent At 16 SEER And Above
• Enables Higher Efficiency And Differentiation

Customer Preferences

• Enhanced Comfort
• Reduced Energy Costs
• Premium Technology
• Overall System Value
Polling Question

What Region Of The Country Are Your Primary Operations?

1. North central
2. South East
3. North East
4. South Central
5. South West
6. North West
Benefits Of Modulation

Comfort
• Temperature Control
• Humidity Control
• Airflow Control
• Uniform Temperature Throughout Home

Energy Efficiency
• Seasonal Efficiency (SEER / HSPF)
• Part-Load Efficiency (IEER / IPLV)

Reliability & Value
• Reduced Cycling
• Overall System Value
Applications for Modulation Technologies

Residential

• Mid-Tier Systems
  (16 SEER Featured And Above)

• Premium Efficiency Systems

• High Comfort Applications

• Geothermal
# Compressor Modulation Technology Comparison

<table>
<thead>
<tr>
<th>Modulation Technology</th>
<th>Products</th>
<th>Range</th>
<th>Part Load Efficiency</th>
<th>Full Load Efficiency</th>
<th>Comfort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Speed</td>
<td>2-6HP (Resi)</td>
<td>Medium</td>
<td>Highest</td>
<td></td>
<td>Medium</td>
</tr>
<tr>
<td>UltraTech (Two-Step)</td>
<td>2-6HP (Future 2-8HP)</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Variable Speed</td>
<td>2-15HP</td>
<td>Highest</td>
<td></td>
<td>Medium</td>
<td>Highest</td>
</tr>
</tbody>
</table>
Advantages To Upgrading HVAC

Homeowners

• Comfort
• Energy Savings
• Cost Incentive Eligibility

Contractors

• Less Call Backs For High-energy Bills And Poor Thermal Comfort
• Greater Customer Satisfaction
• More Recommendations From
  • Energy Utilities (Promoting Energy Saving And Load Control)
  • Code Officials (Enforcing Increasingly More Stringent Energy Saving Codes)
Variable Speed Field Studies

1. Mega House – Large New Home
2. Craftsman Cottage House – Small Retrofit
3. Green House – Mid-Size Retrofit
4. Three TVA “Robo” Houses – New Typical 2-story
5. 38 Extreme Home Makeovers – 900 To 5000 ft.
Field Study One: Mega House (Large New Home)

Lessons Learned

- Lower Electric Capacity Cost
- Ease Of Code Compliance
Truss Above Back Wall Of The Mechanical Room
Mechanical Room Layout Option One

Two Separate Units

- 2 Ton For The Lower Level
- 3 Ton For The Main Level
Mechanical Room Layout Option Two

Single Smart Zoned 5 Ton Unit

- Services Both Lower And Main Levels
- Much More Efficient Duct Connections To Single Unit
- Lower Initial Cost
- This Is Suggested Layout Due To Space Constraints In Tight Mechanical Room With Width Of Less Than 5 Feet
Balance Point Analysis For Main And Lower Unit In Mechanical Room for Variable Speed

Balance Point
32 F

Supplemental Heat
7.32 Kw
Balance Point Analysis For Single Smart Zoned 5 Ton Unit, Variable compared to Fixed Speed

5 Ton Fixed Speed Heat Pump With Same Rated Capacity Falls Off Much Faster At Cold Temperatures Than The Variable Speed System, This Means More Use Of Back Up Heating Energy For Fixed Speed Heat Pumps
## Cost For Systems ($)

<table>
<thead>
<tr>
<th></th>
<th>Variable Speed</th>
<th>Two Stage**</th>
<th>Single Speed. 95 AFUE</th>
<th>Lowest Cost Fixed Speed***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems</td>
<td>21900****</td>
<td></td>
<td>11250</td>
<td>9089</td>
</tr>
<tr>
<td>Labor</td>
<td>7000</td>
<td>7000</td>
<td>7000</td>
<td>7000</td>
</tr>
<tr>
<td>Material*</td>
<td>7500</td>
<td>7500</td>
<td>6750****</td>
<td>7500</td>
</tr>
<tr>
<td>Overhead And Profit</td>
<td>6560</td>
<td>6720</td>
<td>5661</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>42960</td>
<td>34285</td>
<td>31720</td>
<td>29250</td>
</tr>
</tbody>
</table>

* Zone Dampers, Duct Work, Copper Line Sets, Flue Vent Pipe, Electrical, Drains And Pans, Duct Sealer, Permits
** From HVAC residential contractor Emerson survey, install 20% less than variable
*** from HVAC online supply house http://libertywholesalesupply.com/heat-pumps.html
**** Assumed Zoning Only On Upper Level $750 Instead Of $1500 For Both Units In Variable Speed option
***** Obtained From Local Subcontractor
## Incremental Installed Cost Estimates For Variable And Fixed Speed Systems

**Above The Base Case with SEER 13 And Gas AFUE 0.95**

<table>
<thead>
<tr>
<th>System</th>
<th>Cost Range</th>
<th>Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Speed</td>
<td>$42,960-$31,720</td>
<td>$11,240</td>
</tr>
<tr>
<td>Two-Stage</td>
<td>$34,285-$31,720</td>
<td>$2,565</td>
</tr>
<tr>
<td>Lowest Cost Fixed Speed</td>
<td>$29,250-$31,720</td>
<td>($5,470)</td>
</tr>
</tbody>
</table>
Equation Used To Calculate The Annual Cost To The Homeowner
Assuming 15 Year Mortgage @ 3.68%

• $\Delta S = \text{Energy Savings Per Year (}$)

• $R = \text{Incremental Cost Above Base Case (}$)

• Net Annual Cost($) = \left( R \times \left( \frac{0.0368}{12} \right) \right) \times 12 \right) - \Delta S$
# Annual Cost

Based On Assumed 5 ACH@50

<table>
<thead>
<tr>
<th>Description</th>
<th>Annual Space Cooling</th>
<th>Annual Space Heating</th>
<th>Total Energy Cost</th>
<th>HERs</th>
<th>Energy Saving Value Compared To Basecase</th>
<th>Incremental Cost Above The Base Case</th>
<th>Amortized Cost</th>
<th>Annual Cost</th>
<th>Simple Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Condition</td>
<td>$</td>
<td>$</td>
<td>$</td>
<td>$/Yr</td>
<td>$/Yr</td>
<td>$/Yr</td>
<td>$/Yr</td>
<td>$/Yr</td>
<td>$/Yr</td>
</tr>
<tr>
<td>Fixed Speed  5-ton SEER 13, AFUE 95</td>
<td>$1,049</td>
<td>$2,444</td>
<td>$3,493</td>
<td>66</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>Variable  HP Vs Fixed Speed 13</td>
<td>$451</td>
<td>$1,799</td>
<td>$2,250</td>
<td>56</td>
<td>$1,243</td>
<td>$11,240</td>
<td>$976</td>
<td>-$267</td>
<td>9.0</td>
</tr>
<tr>
<td>Lowest Cost Fixed Speeds Vs</td>
<td>$985</td>
<td>$3,194</td>
<td>$4,179</td>
<td>82</td>
<td>-$686</td>
<td>-2470</td>
<td>-$215</td>
<td>$471</td>
<td></td>
</tr>
</tbody>
</table>

**Homeowner Saves $267/Year Compared To The Base Case Solution**
Knoxville Mega-House

HVAC Energy Cost/yr.

- SEER 13, AFUE 95
- Variable Speed HP
- Minisplits
- Single Speed HP

Annual Space Heating $
Annual Space Cooling $
Columbus Mega-House

HVAC Energy Cost $/yr.

- SEER 13, AFUE 95
- Variable Speed
- Minisplits
- Single Speed HP

**Cheap Gas**
- Cold
- Winter
- More
- Supplemental Heat

**$0**

**$1,000**

**$2,000**

**$3,000**

**$4,000**

**$5,000**

**$6,000**

**$7,000**

- Annual Space Cooling $
- Annual Space Heating $
Field Study Two: Craftsman Cottage House (Small Retrofit)

- Variable Speed, Lowest Cost Biggest Bang For The Buck
- Optimum Path To Zero Energy
The Biggest Extreme Energy Makeover Step
Variable Speed Heat Pumps

Drilled And Filled R-18, Continuous Weather Barrier, Drain Planed Walls

R-50 Baffled Air Sealed Attic
The Biggest Extreme Energy Makeover Step

Variable Speed Heat Pumps

Old Fixed Stage

New Variable Speed
The Extreme Energy Makeover Metric Stick: HERS

http://www.resnet.us/hers-index

http://www.resnet.us/hers-index
Home Energy Ratings
Trending Upward

• Measurement Of A Home’s Energy Efficiency
• Used On Existing And New Homes
• Electric Utilities Becoming Bigger Proponents (Load Control)
• Residential Energy Services Network (RESNET)
  – Creation And Maintenance Of The RESNET Mortgage Industry National Home Energy Rating Standards
  – Certification And Quality Assurance On RESENT Provider Organizations
Single Retrofit Option

Simple Payback

- Heat trap, water heater insul., programmable Tstat, no heat in...: 1.8 yrs.
- Foundations 0.5 to 10: 6.5 yrs.
- Windows single to double E, above grade: 58.1 yrs.
- Wall sheathing .5 to 5.5: 3.1 yrs.
- Wall cavity .5 to 15: 2.7 yrs.
- Attic 8 to 50: 2.7 yrs.
- Ducts 20% to 0 leaks: 1.2 yrs.
- ACH@50 12 to 5: 6.0 yrs.
- Variable Speed Heat Pump: 9.7 yrs.

Simple Payback (yr.)

0.0 20.0 40.0 60.0 80.0
Variable Speed Heat Pumps

• Very Efficient Part Load Efficiency

• Up To HSPF = 13 SEER = 21 (ORNL Field Verified In 2012)

• Over Sizing For Cooling Help In Heating Season Resulting In Very
  Little Need For Back Up Heating In More Climates

• Electric Utilities Accelerating Promotions Because
  – Margins Improve With All Electric Homes (Not Always The Case
    With Single Stage Equipment)
  – Growing Migration To Time Of Day Rates
Growing Demand For Variable Speed Drivers

- ACCA Manual J Sizing Calculations A Growing Mandate
- System Wear-N-Tear Of Short-Cycling Fixed Speed Equipment
- Latent Load/tighter homes - Moisture Removal
- Variable Speed HP Systems Better Match For Many Homes With Much Higher Heating Loads Than Cooling
Field Study Two: Small House

Lessons Learned

- **Variable Speed Heat Pumps Change The Game For Typical Older Homes**
  - Minimum Thermal Upgrades
  - ~Hers 160, No Insulation In The Walls, Little In The Attic
  - ~HERS 120 With Wall Insulation And Little More In The Attic
  - Air Leakage Rates In Excess Of 5 ACH Natural (7-20 Current 44 House Study)
  - Very Inefficient HVAC Systems.

- **Replacing The HVAC System With A Variable Speed Heat Pump Results In**
  - Energy Costs Equal Or Less Than Typical Just Meet Code New Homes
  - HERS 93

- **Since The First Energy Efficiency Upgrade Is Typically The HVAC System Under Duress**
  - Homeowner Sees Major Savings On Energy Bill
  - More Motivated To Complete The Retrofit, If Variable Speed Is Installed

- **Variable Speed Allows HVAC Replacement Before Envelope Upgrades.**
Field Study Three: Green House (Mid-Size Retrofit)

- Variable Speed Provided Late Minute Push To Win LEED Platinum Award
- Helped Preserve Historic Home With Enhanced Moisture Control
- Help Proof That Historic Renovation And Extreme Energy Makeover Could Be Accomplished Under One Roof
3 Ton Variable Speed Heat Pump

Helped Bring Fresh Air Into Home When Kitchen Fan, Bath Room Fan And Dryer Were Running

SEER 20.5, HSPF = 13*
Variable Speed Helps Make Marketing Statement

### Annual Energy Summary

<table>
<thead>
<tr>
<th>End-Use</th>
<th>Energy Consumption</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling Electric</td>
<td>842 kWh</td>
<td>$80</td>
</tr>
<tr>
<td>Cooling Fan</td>
<td>227 kWh</td>
<td>$22</td>
</tr>
<tr>
<td>Mechanical Vent Fan</td>
<td>244 kWh</td>
<td>$24</td>
</tr>
<tr>
<td><strong>Total Cooling</strong></td>
<td><strong>1313 kWh</strong></td>
<td><strong>$125</strong></td>
</tr>
<tr>
<td>Heating Electric</td>
<td>4129 kWh</td>
<td>$393</td>
</tr>
<tr>
<td>Heating Fan/Pump</td>
<td>661 kWh</td>
<td>$63</td>
</tr>
<tr>
<td>Mechanical Vent Fan</td>
<td>270 kWh</td>
<td>$20</td>
</tr>
<tr>
<td><strong>Total Heating</strong></td>
<td><strong>5060 kWh</strong></td>
<td><strong>$482</strong></td>
</tr>
<tr>
<td>Hot Water</td>
<td>1270 kWh</td>
<td>$121</td>
</tr>
<tr>
<td>Hot Water Pump</td>
<td>0 kWh</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total Hot Water</strong></td>
<td><strong>1270 kWh</strong></td>
<td><strong>$121</strong></td>
</tr>
<tr>
<td>Ceiling Fans</td>
<td>0 kWh</td>
<td>$0</td>
</tr>
<tr>
<td>Clothes Washer</td>
<td>100 kWh</td>
<td>$10</td>
</tr>
<tr>
<td>Dehumidifier</td>
<td>0 kWh</td>
<td>$0</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>212 kWh</td>
<td>$20</td>
</tr>
<tr>
<td>Dryer Electric</td>
<td>751 kWh</td>
<td>$71</td>
</tr>
<tr>
<td>Lighting</td>
<td>750 kWh</td>
<td>$71</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2745 kWh</td>
<td>$281</td>
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<tr>
<td>Pool Pump</td>
<td>0 kWh</td>
<td>$0</td>
</tr>
<tr>
<td>Range Electric</td>
<td>525 kWh</td>
<td>$50</td>
</tr>
<tr>
<td>Refrigerator</td>
<td>400 kWh</td>
<td>$38</td>
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<tr>
<td>Television</td>
<td>0 kWh</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total (kWh)</strong></td>
<td><strong>13126 kWh</strong></td>
<td><strong>$1249</strong></td>
</tr>
<tr>
<td><strong>Total (Therms)</strong></td>
<td>0 Therms</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total (Oil Gallons)</strong></td>
<td>0 Gallons</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Total (Propane Gallons)</strong></td>
<td>0 Gallons</td>
<td>$0</td>
</tr>
<tr>
<td><strong>PV Produced (kWh)</strong></td>
<td>-1936 kWh</td>
<td><strong>$-184</strong></td>
</tr>
<tr>
<td><strong>Assumes net metering</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Cost</strong></td>
<td><strong>$1065</strong></td>
<td></td>
</tr>
</tbody>
</table>

**Emissions** (Calculated as Total - PV Produced)

- SO₂ = 71.28 Lbs
- NOₓ = 25.98 Lbs
- CO₂ = 7.08 Tons

**HERS = 49**
Annual Energy Savings Of HVAC Systems Predicted For The Green House

<table>
<thead>
<tr>
<th>HVAC Option For The Green House</th>
<th>Heating</th>
<th>Cooling</th>
<th>Total Energy</th>
<th>Savings ΔS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable Speed</td>
<td>$482</td>
<td>$125</td>
<td>$607</td>
<td>$568</td>
</tr>
<tr>
<td>Lowest Cost Fixed Speed HPs</td>
<td>$874</td>
<td>$301</td>
<td>$1175</td>
<td>$0</td>
</tr>
</tbody>
</table>
Field Study Four: TVA “Robo” Houses
Three New Typical 2-story

ORNL Found Variable Speed Over Performed And Lowest Cost Fixed Speed Under Performed On Energy Savings And Comfort

• Five Years Of Detailed Energy And Comfort Measurements In Laboratory Houses
• Identical Internal Energy Usage
• Simulated Occupancy

Typical 2-story Single Speed Heat Pumps

- Robo House 1
- TVA Campbell Creek Research Park

- Rated SEER 13, HSPF 7.7
- Measured SEER 7.75, HSPF 5.25
ORNL Measured 75% Daily Peak Load Savings Of Variable Speed Heat Pumps*  

*ORNL/TM-2014/666
Thank You For Attending!

To Learn More On “Getting Comfortable With Designer Air”, Please Visit Our Webpage At emersonclimate.com/designerair

Stay Tuned For More Emails Containing Information And Timing On Our Next Webinar Nov. 17th, 2015!