Polling Question:

Please Define Your Occupation Type?

1. OEM
2. Contractor
3. Wholesaler-Distributor
4. Consultant
5. End-User
6. Internal
7. Other

Getting Comfortable with Designer Air

Brandy Powell
Vice President
Variable Speed Marketing
Emerson Climate Technologies

Jeff Christian
Energy Efficiency Specialist

Part 1: Technologies Homeowners Are Ready To Invest In For Comfort

EMERSON
Climate Technologies

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
- Recognized Subject Matter Expert In Energy Efficiency And Renewable Energy As Well As Building Science Trainer Of Facility Managers, Building Decision Makers, And Building Owners Working With Private Industry To Develop And Demonstrate Profitable Energy Efficient Technologies, Practices, And Facilities.

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?

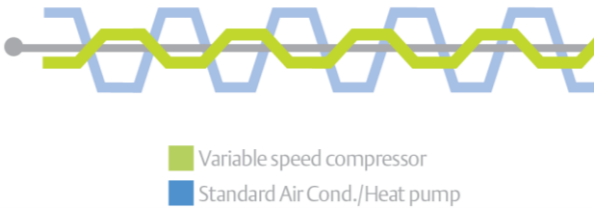
- It's A Perception
- Can Be Different For Everyone
- Can Be Ambiguous And Difficult To Define
- Discomfort Is Easier To Identify Than Comfort
- Tends To Be Stable And Not Fluctuating
- Goldilocks Effect
  - Not Too Hot, Not Too Cold, It's Just Right

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

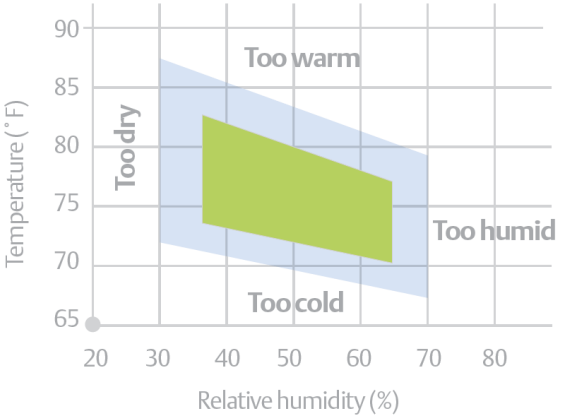
Enhanced Comfort – Precise Climate Control

Temperature Control



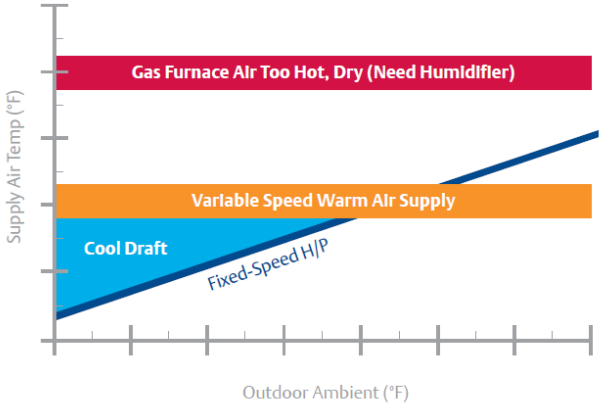
Maintains Precise Temperature Control for Enhanced Comfort

Humidity Control



Broad Turndown Range Enables More Consistent Humidity Control

Hot Supply Air



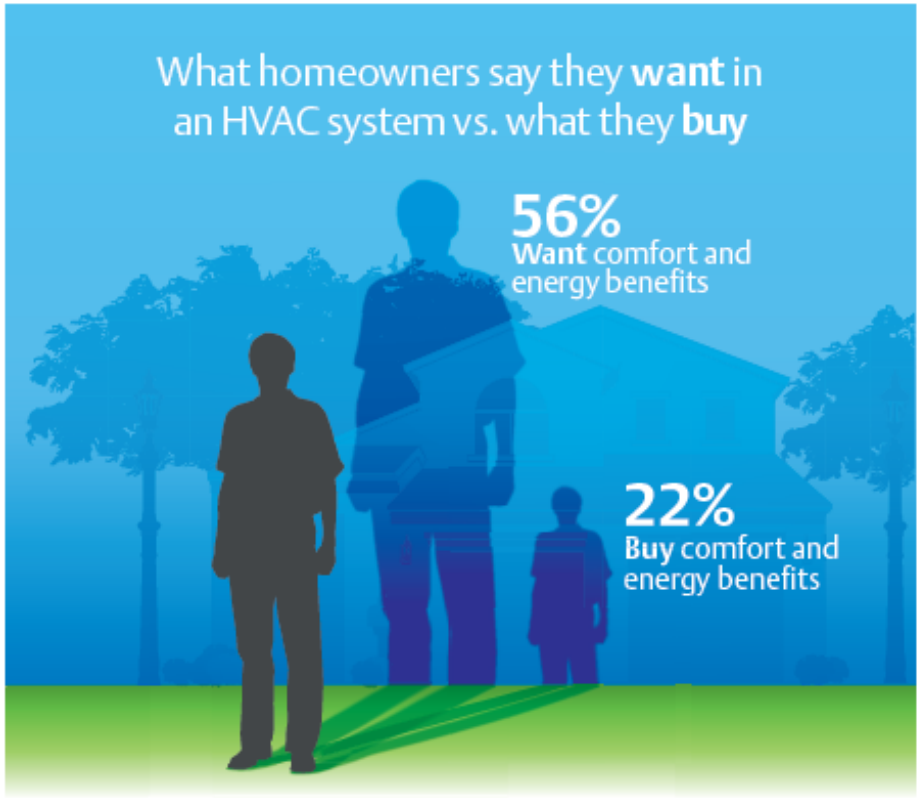
Compressor Design Enables Heat Pumps to Supply Hotter Air During Cold Winter Conditions

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

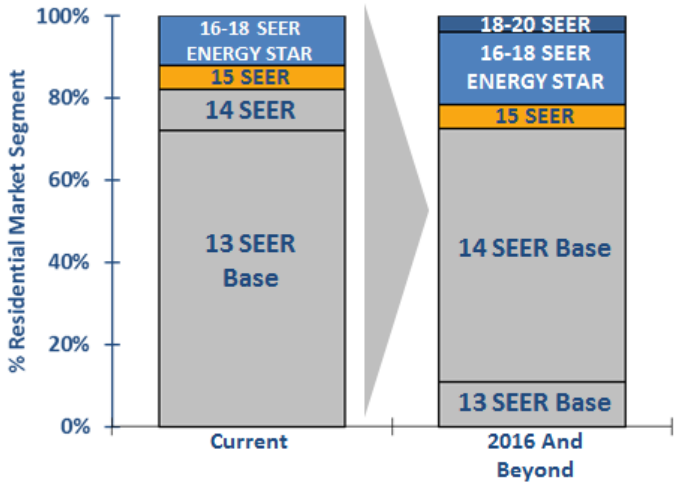
- **Budget / Competing Upgrades**
- **Initial Cost Versus Total Cost Of Ownership**
- **HVAC Is Out Of Sight, Out Of Mind**
- **Changing Loads**
- **Shifting Schedules**
- **Traditional Technologies**
  - Fixed Capacity Compressors
  - Fixed Speed Fans

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

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

Modulation Technology	Products	Range	Part Load Efficiency	Full Load Efficiency	Comfort
Fixed Speed		2-6HP (Resi)	Medium	Highest	Medium
UltraTech (Two-Step)		2-6HP (Future 2-8HP)	High	High	High
Variable Speed		2-15HP	**Highest**	Medium	**Highest**

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)

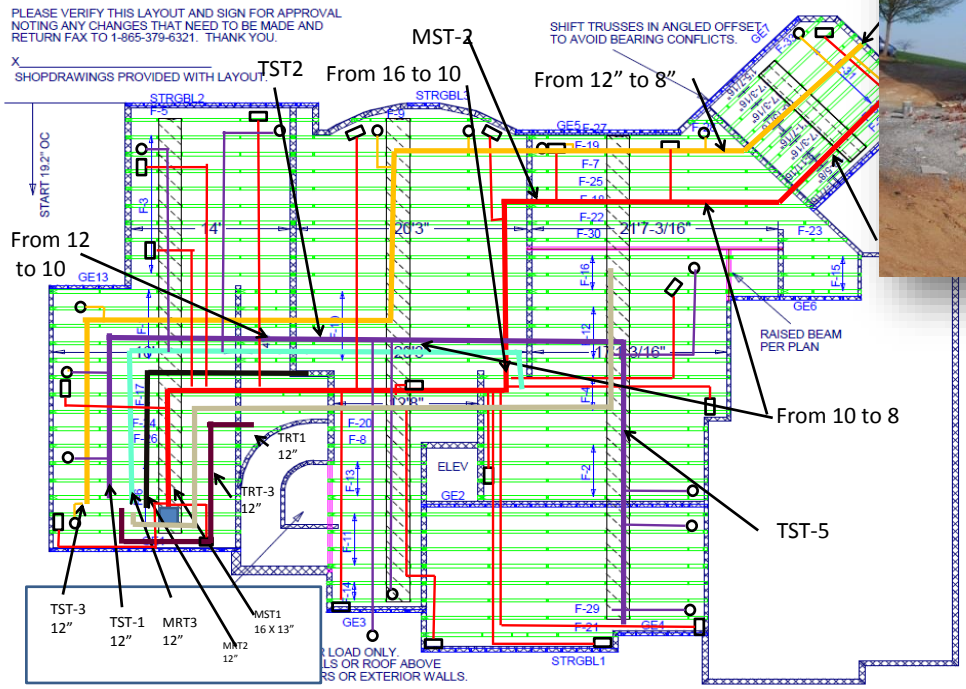
Variable Speed Field Studies

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.

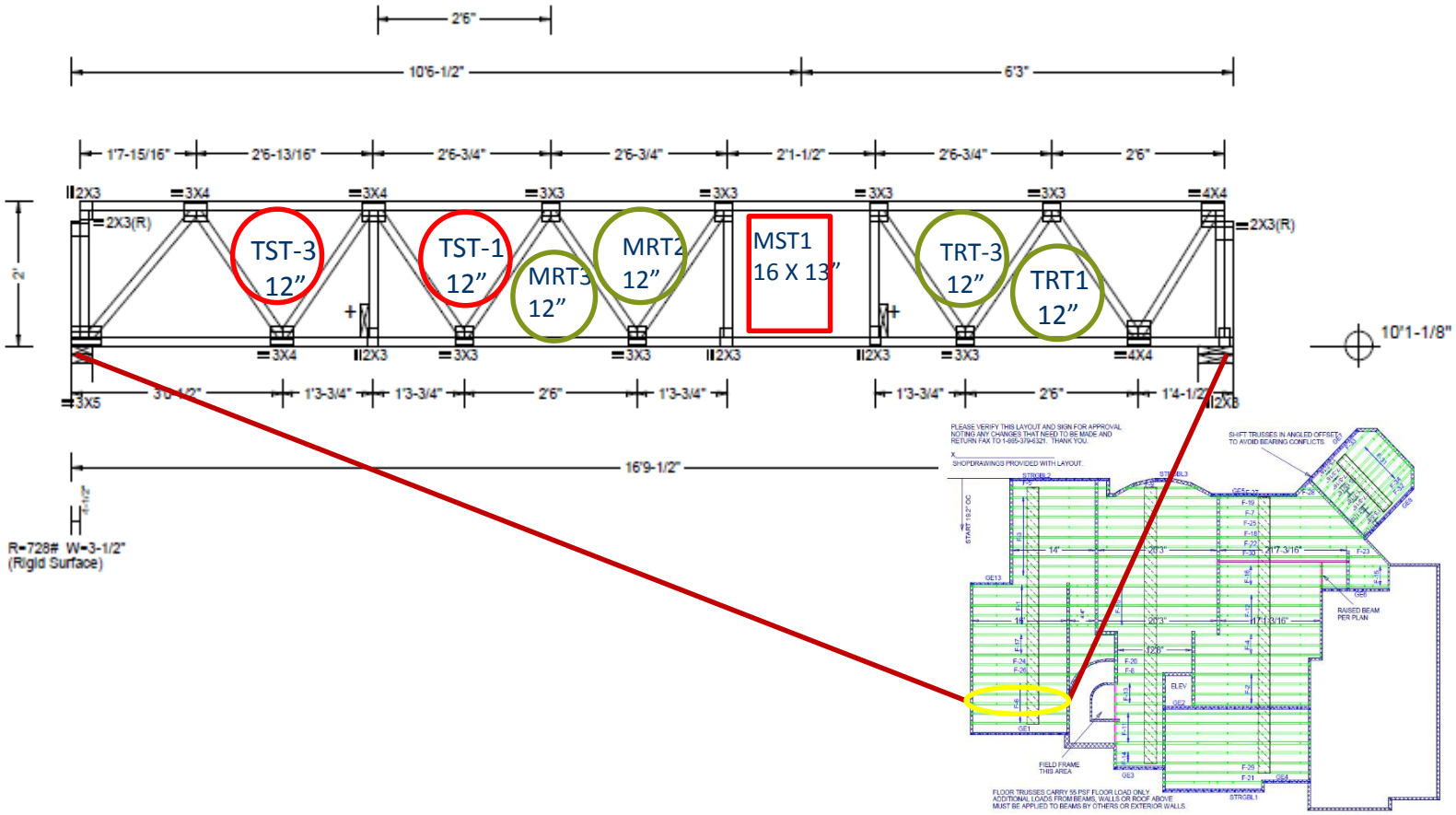
Field Study One: Mega House (Large New Home)

Lessons Learned

- Lower Electric Capacity Cost
- Ease Of Code Compliance



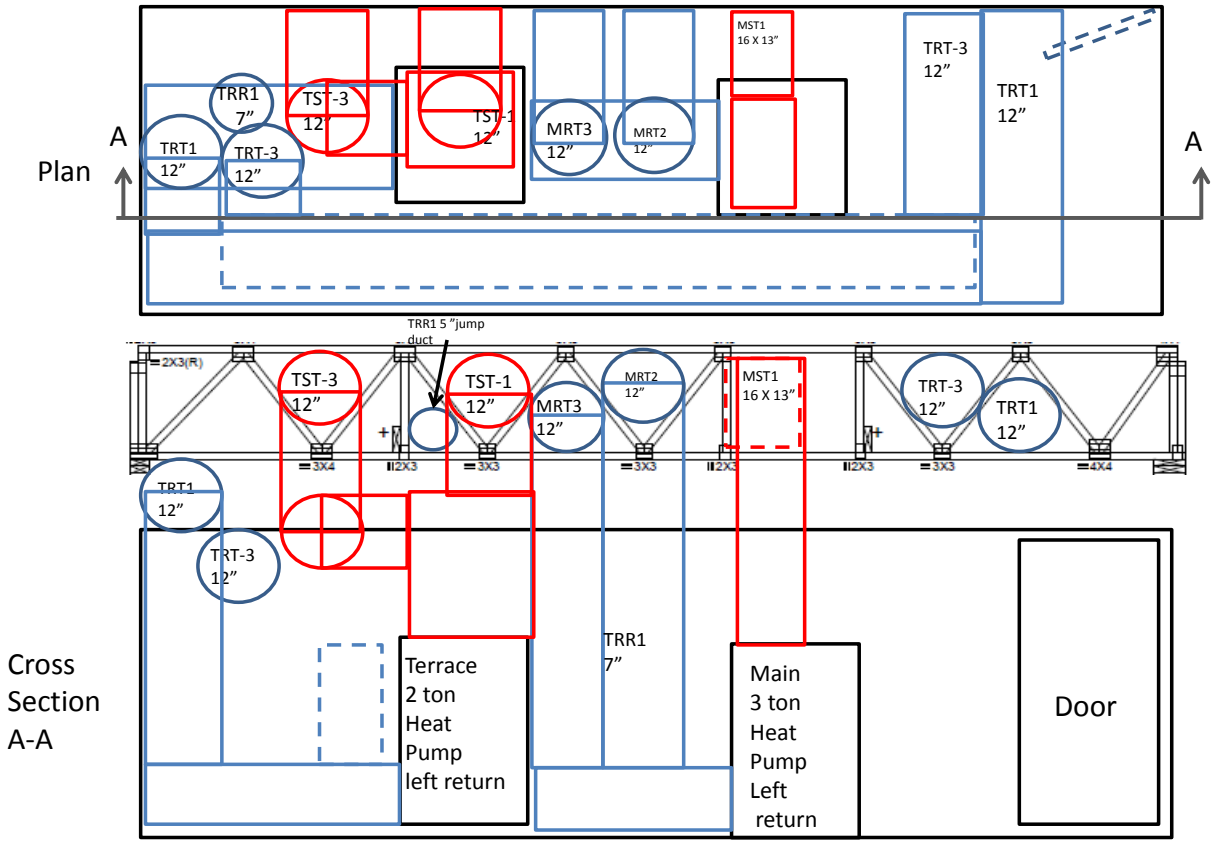
Truss Above Back Wall Of The Mechanical Room



Mechanical Room Layout Option One

Two Separate Units

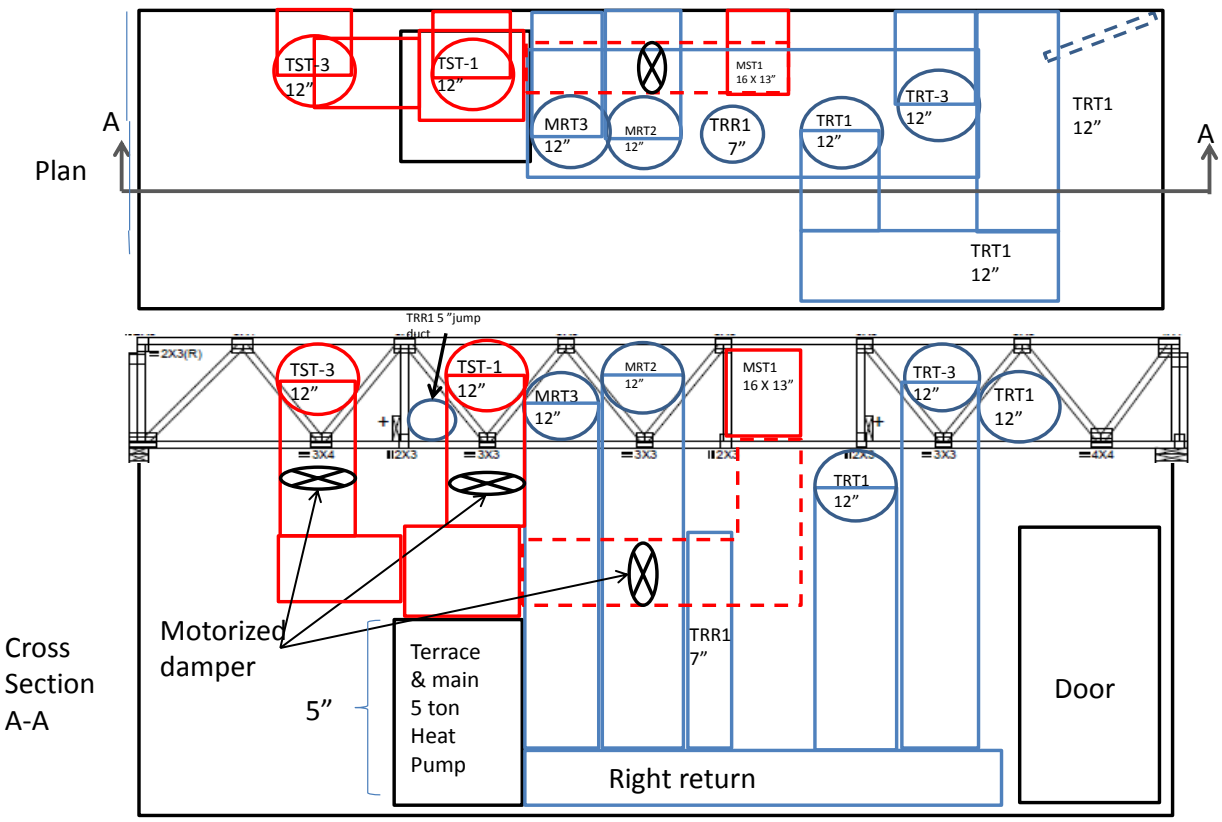
- 2 Ton For The Lower Level
- 3 Ton For The Main Level



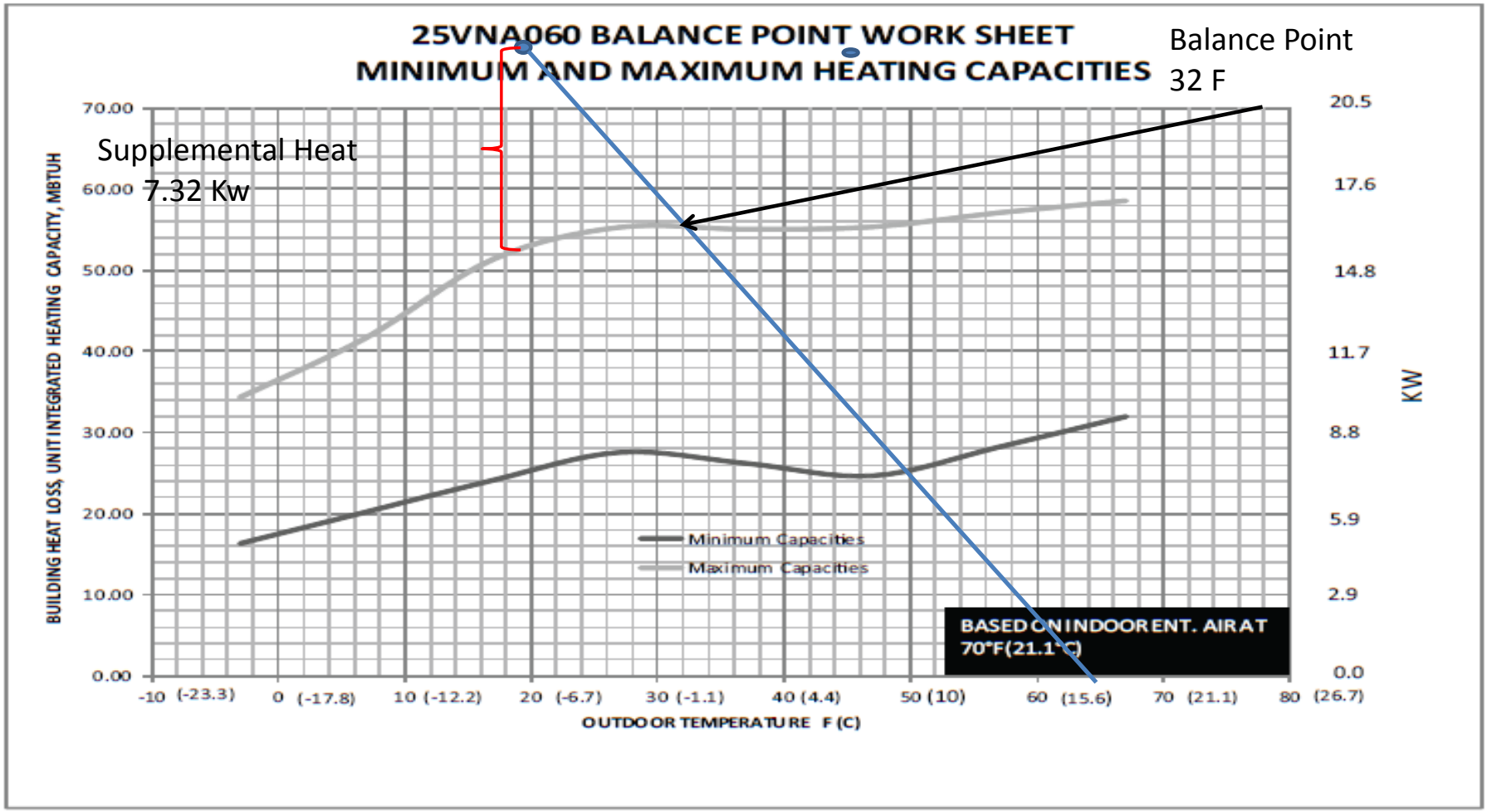
Mechanical Room Layout Option Two

Single Smart Zoned 5 Ton Unit

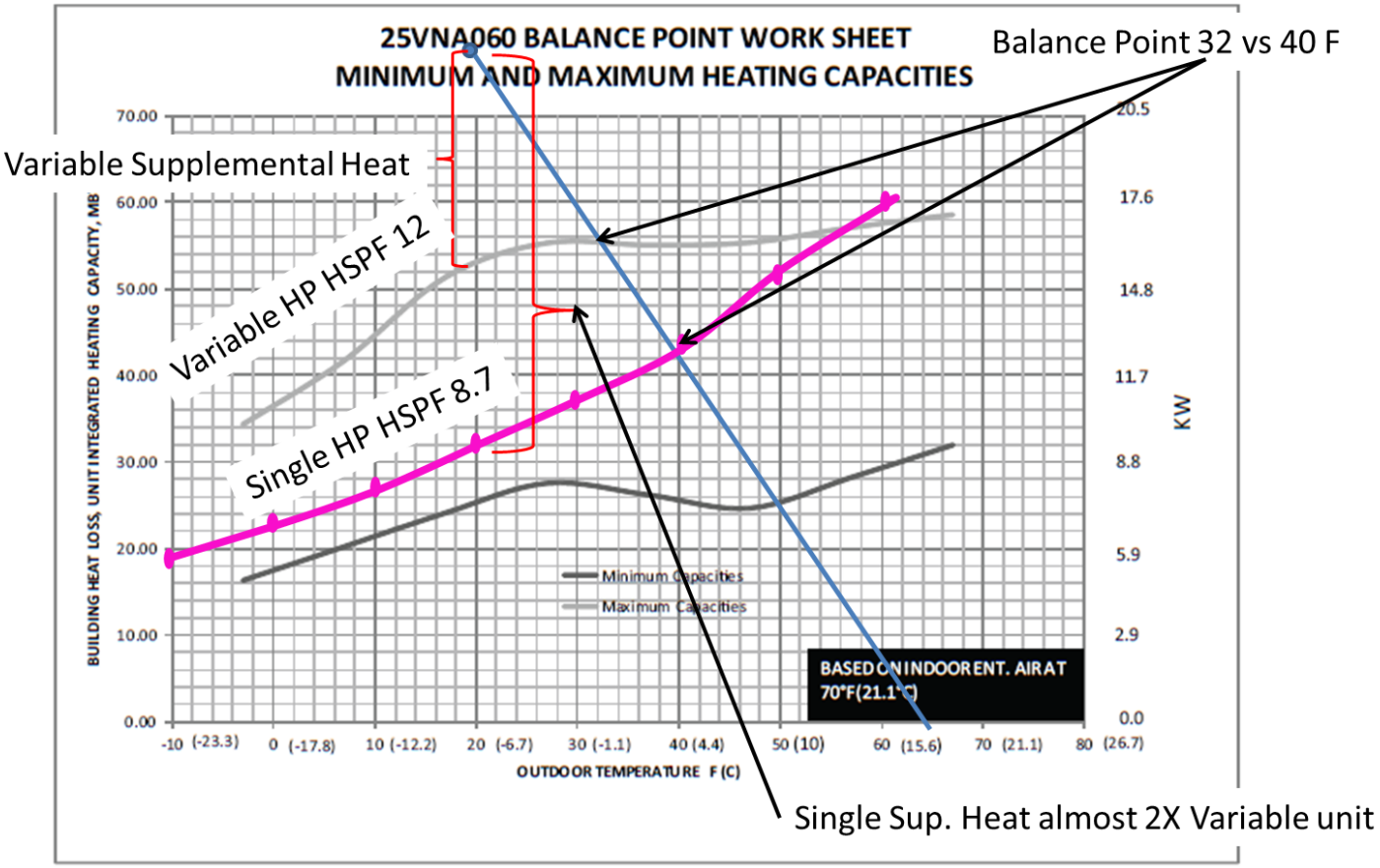
- Services Both Lower And Main Levels
- Much More Efficient Duct Connections To Single Unit
- Lower Initial Cost
- This Is Suggested Layout Due To Space Constraints In Tight Mechanical Room With Width Of Less Than 5 Feet



Balance Point Analysis For Main And Lower Unit In Mechanical Room for Variable Speed

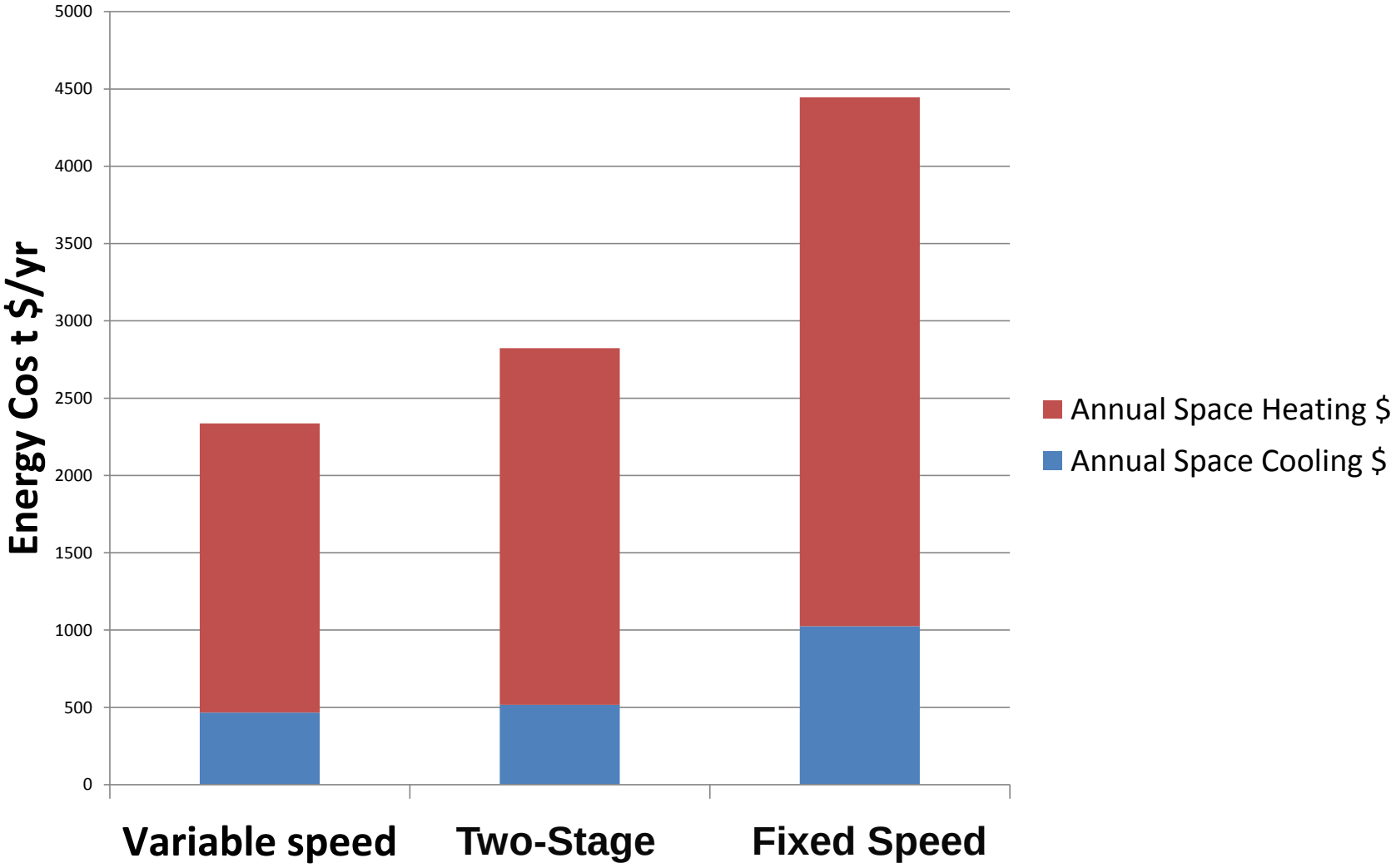


Balance Point Analysis For Single Smart Zoned 5 Ton Unit, Variable compared to Fixed Speed



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

Mega House Heat Pump Options, Knoxville, TN



Cost For Systems ($)

	Variable Speed	Two Stage**	Single Speed. 95 AFUE	Lowest Cost Fixed Speed***
Systems	21900*****		11250	9089
Labor	7000	7000	7000	7000
Material*	7500	7500	6750****	7500
Overhead And Profit	6560		6720	5661
Total	42960	34285	31720	29250

* 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

- Variable Speed $42,960-$31,720 = $11,240
- Two-Stage $34,285-$31,720 = $2,565
- Lowest Cost Fixed Speed $29,250-$31,720 = ($5,470)

Equation Used To Calculate The Annual Cost To The Homeowner

Assuming 15 Year Mortgage @ 3.68%

- $\Delta \boldsymbol{S}$ = Energy Savings Per Year ($)
- R = Incremental Cost Above Base Case ($)
- Net Annual Cost($) = $\left(\boldsymbol{R}\ \boldsymbol{X}\ \left(\frac{\frac{\mathbf{0.0368}}{\mathbf{12}}}{\mathbf{1}-\left(\mathbf{1}+\frac{\mathbf{0.0368}}{\mathbf{12}}\right)^{-\mathbf{180}}}\right)\ \boldsymbol{X}\ \mathbf{12}\right)\ -\Delta \boldsymbol{S}$

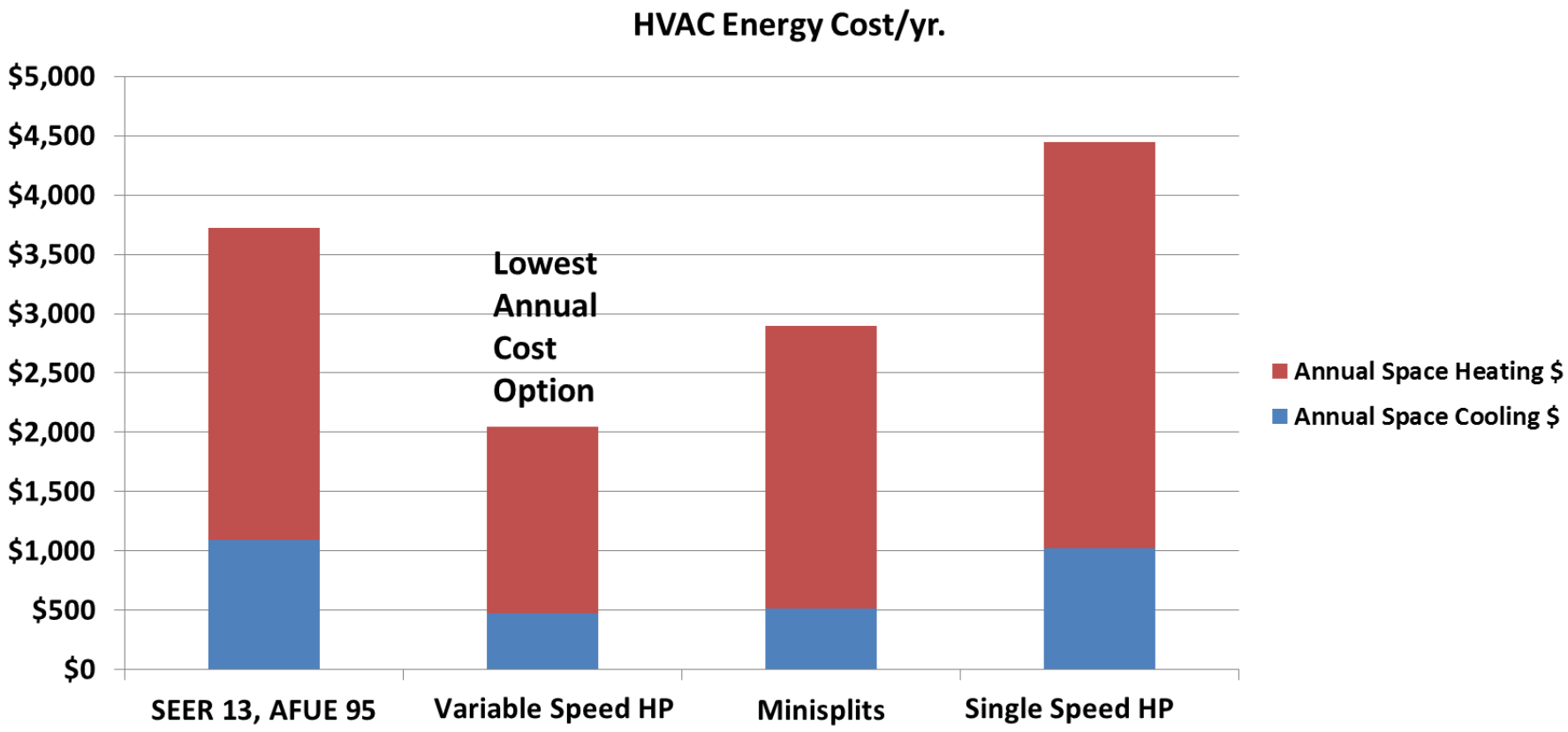
Annual Cost

Based On Assumed 5 ACH@50

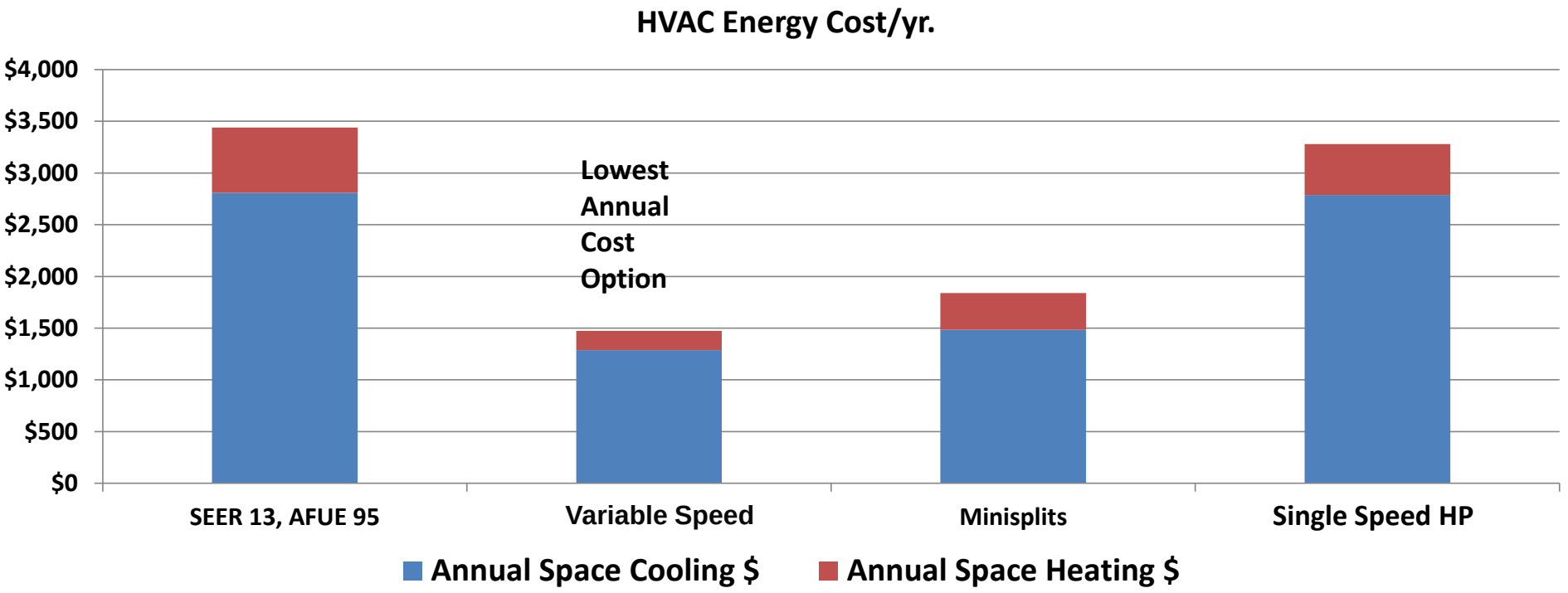
Description	Annual Space Cooling	Annual Space Heating	Total Energy Cost	HERs	Energy Saving Value Compared To Basecase	Incremental Cost Above The Base Case	Amortized Cost	Annual Cost	Simple Payback
Original Condition	$	$	$		$/Yr		$/Yr	$/Yr	
Fixed Speed 5-ton SEER 13, AFUE 95 (Base Case)	$1,049	$2,444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

Homeowner Saves $267/Year Compared To The Base Case Solution

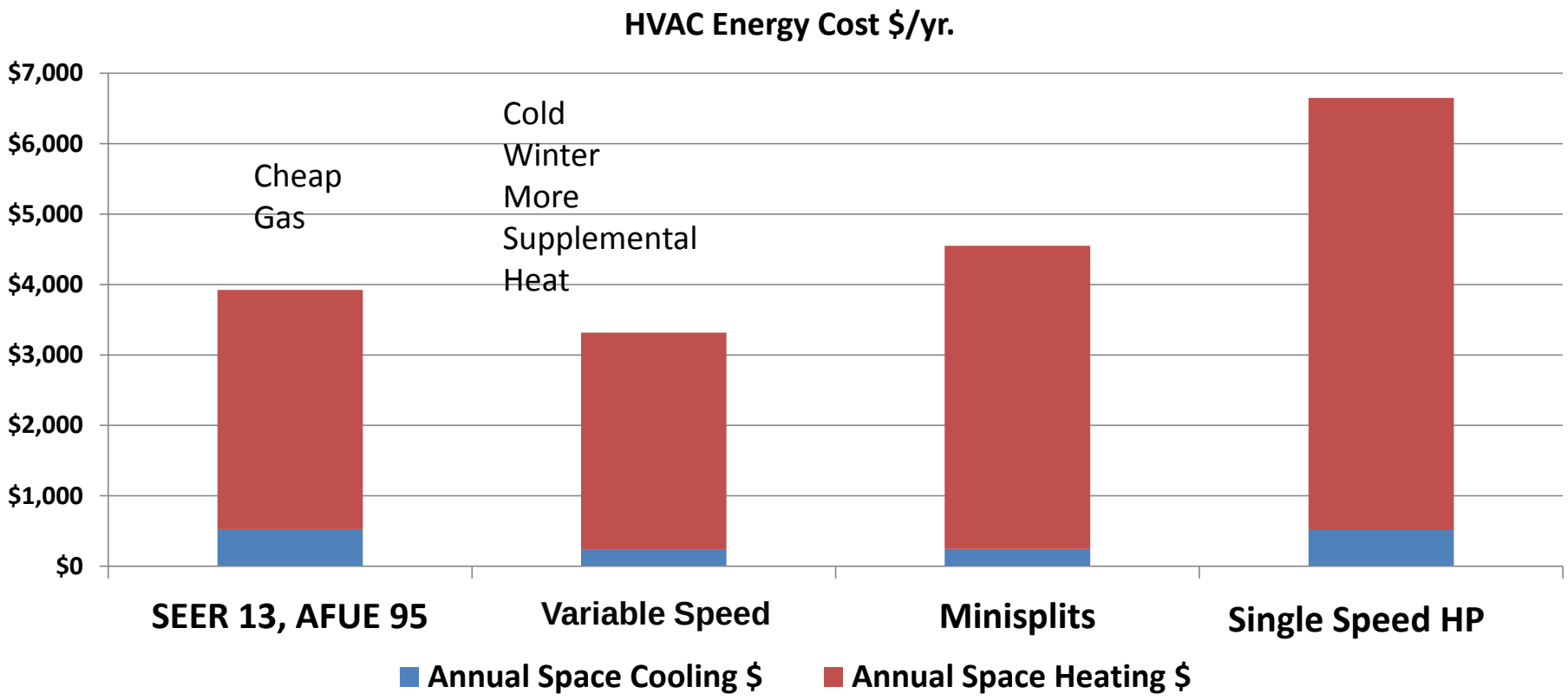
Knoxville Mega-House



Orlando Mega-House



Columbus Mega-House



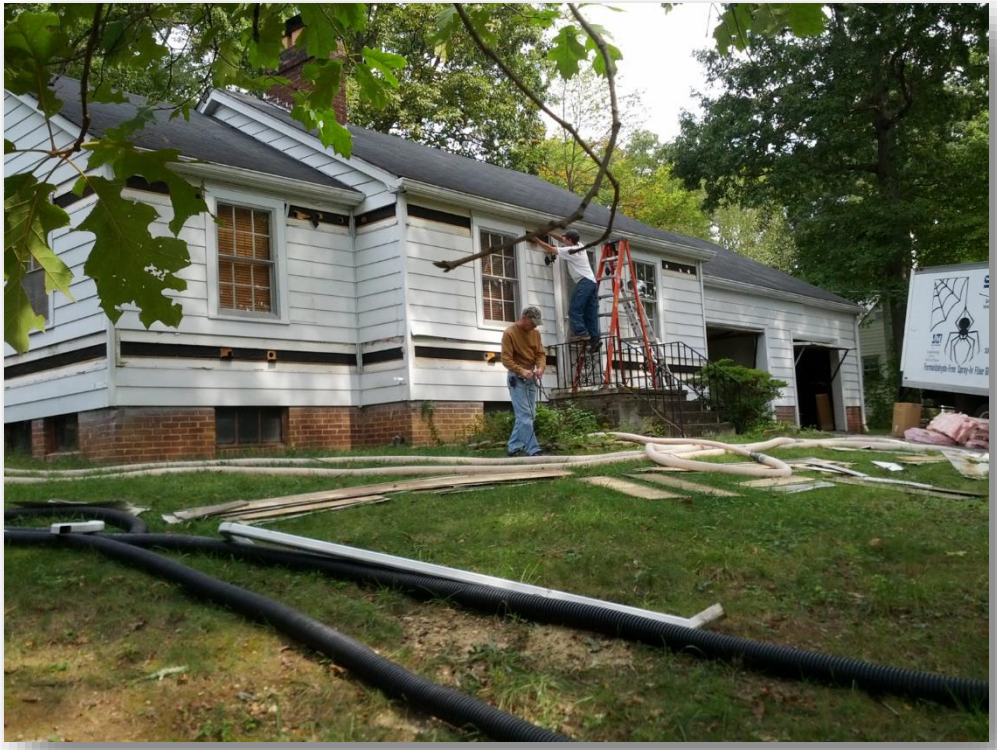
Field Study Two: Craftsman Cottage House (Small Retrofit)

- 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

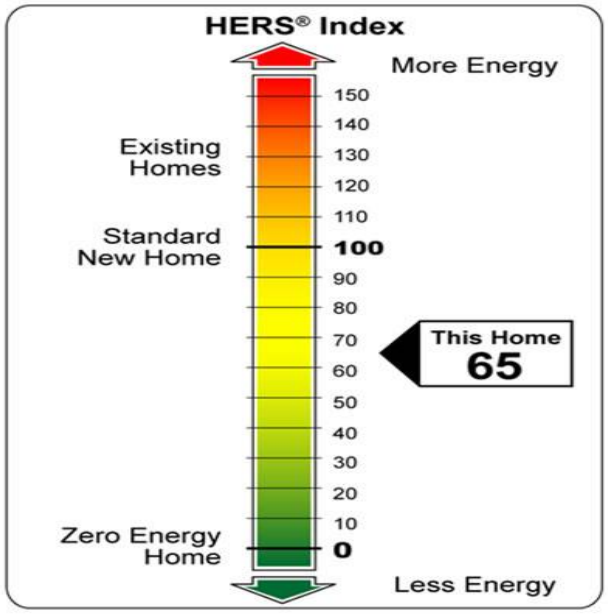
The Biggest Extreme Energy Makeover Step

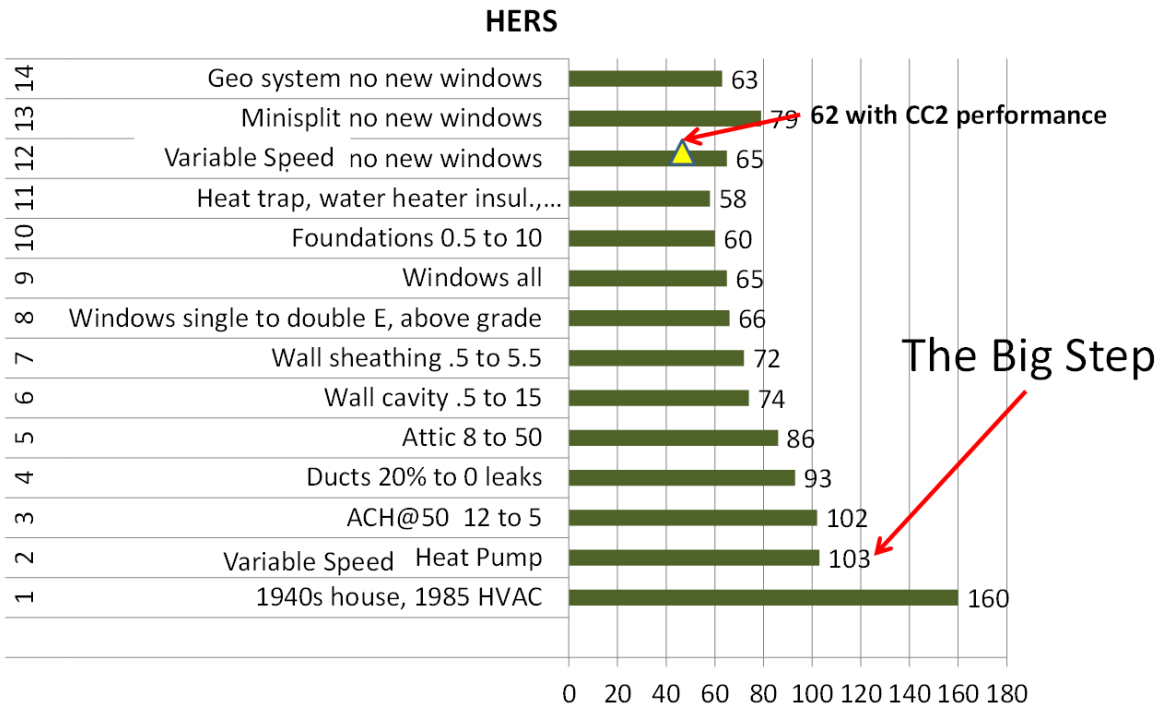
Variable Speed Heat Pumps

Old Fixed Stage

New Variable Speed

The Extreme Energy Makeover Metric Stick: HERS





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

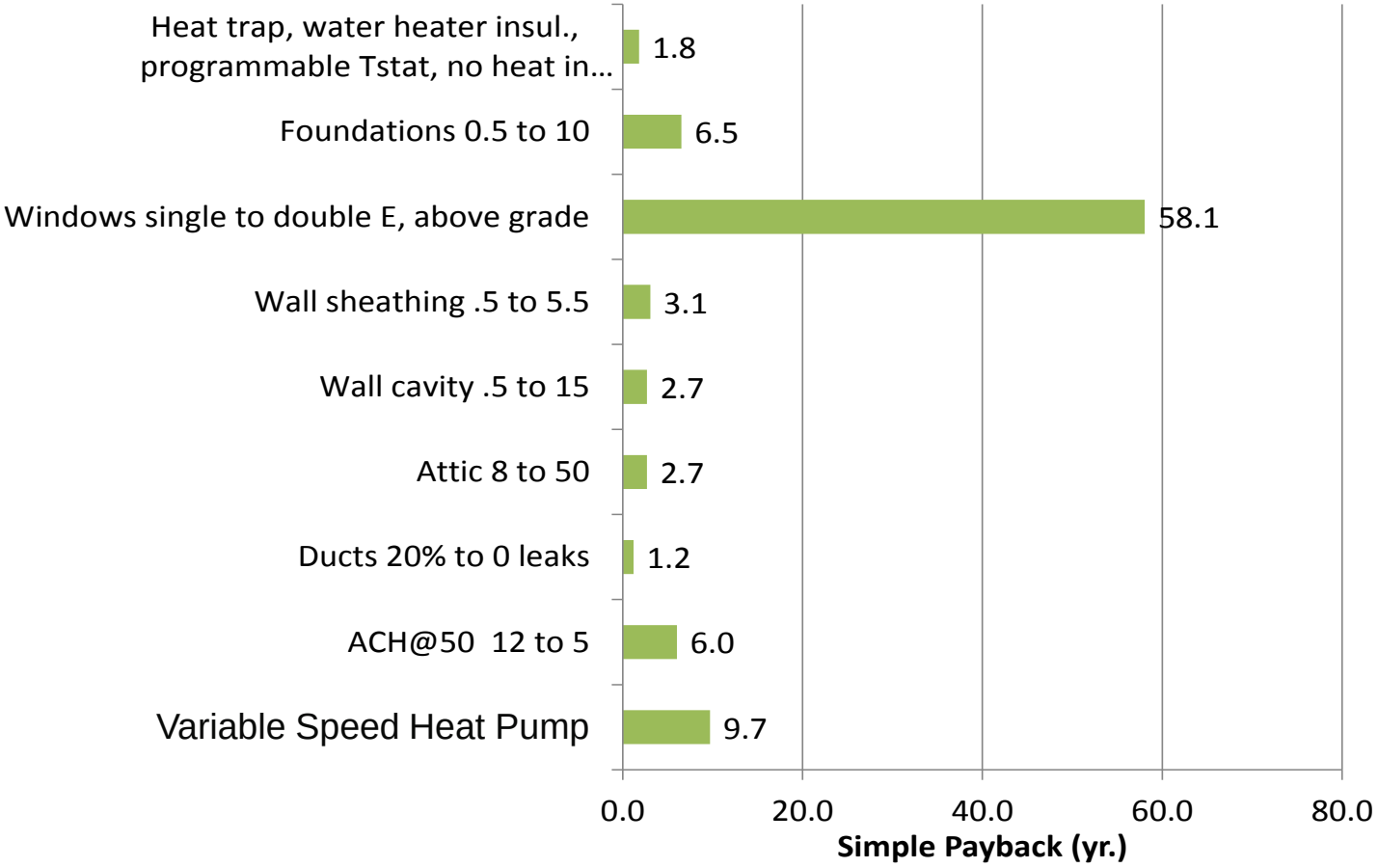
Home Energy Ratings

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

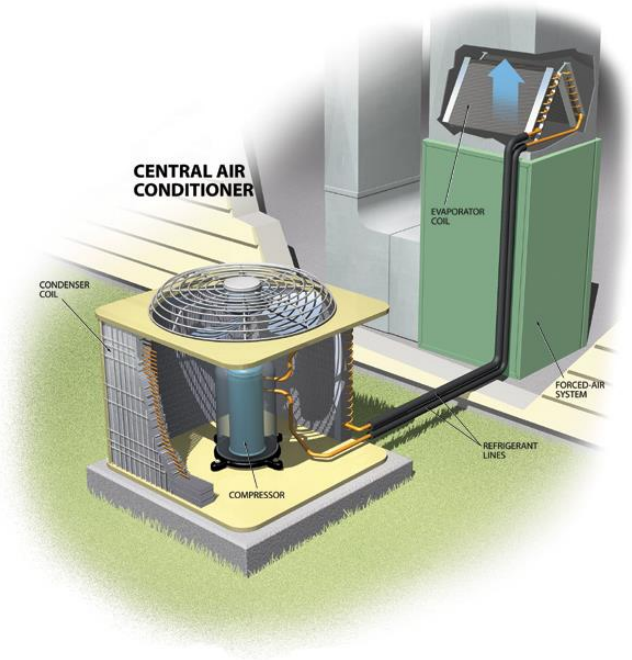


Variable Speed Heat Pumps

- 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

Fresh Air

SEER 20.5, HSPF = 13*

Variable Speed Helps Make Marketing Statement

Annual Energy Summary

Wholehouse Summary

George and Kammy Young
1011 Laurel Ave
Knoxville, TN 37901-

Project Title:
Green House
Building Type: User

TMY_City:TN_KNOXVILLE_MCGHEE
Elec Util: Knoxville Utilities Boar
Gas Util: Tennessee Averag
Run Date: 08/12/2013 08:05:4

End-Use	Energy Consumption	Annual Cost
Cooling Electric	842 kWh	$80
Cooling Fan	227 kWh	$22
Mechanical Vent Fan	244 kWh	$23
Total Cooling	**1313 kWh**	**$125**
Heating Electric	4129 kWh	$393
Heating Fan/Pump	661 kWh	$63
Mechanical Vent Fan	270 kWh	$26
Total Heating	**5060 kWh**	**$482**
Hot Water	1270 kWh	$121
Hot Water Pump	0 kWh	$0
Total Hot Water	**1270 kWh**	**$121**
Ceiling Fans	0 kWh	$0
Clothes Washer	100 kWh	$10
Dehumidifier	0 kWh	$0
Dishwasher	212 kWh	$20
Dryer Electric	751 kWh	$71
Lighting	750 kWh	$71
Miscellaneous	2745 kWh	$261
Pool Pump	0 kWh	$0
Range Electric	525 kWh	$50
Refrigerator	400 kWh	$38
Television	0 kWh	$0
Total (kWh)	13126 kWh	$1249
Total (Therms)	0 Therms	$0
Total (Oil Gallons)	0 Gallons	$0
Total (Propane Gallons)	0 Gallons	$0
PV Produced (kWh) Assumes net metering	-1936 kWh	$-184
Total Cost		$1065

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

HVAC Option For The Green House	Heating	Cooling	Total Energy	Savings ΔS
Variable Speed	$482	$125	$607	$568
Lowest Cost Fixed Speed HPs	$874	$301	$1175	$0

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

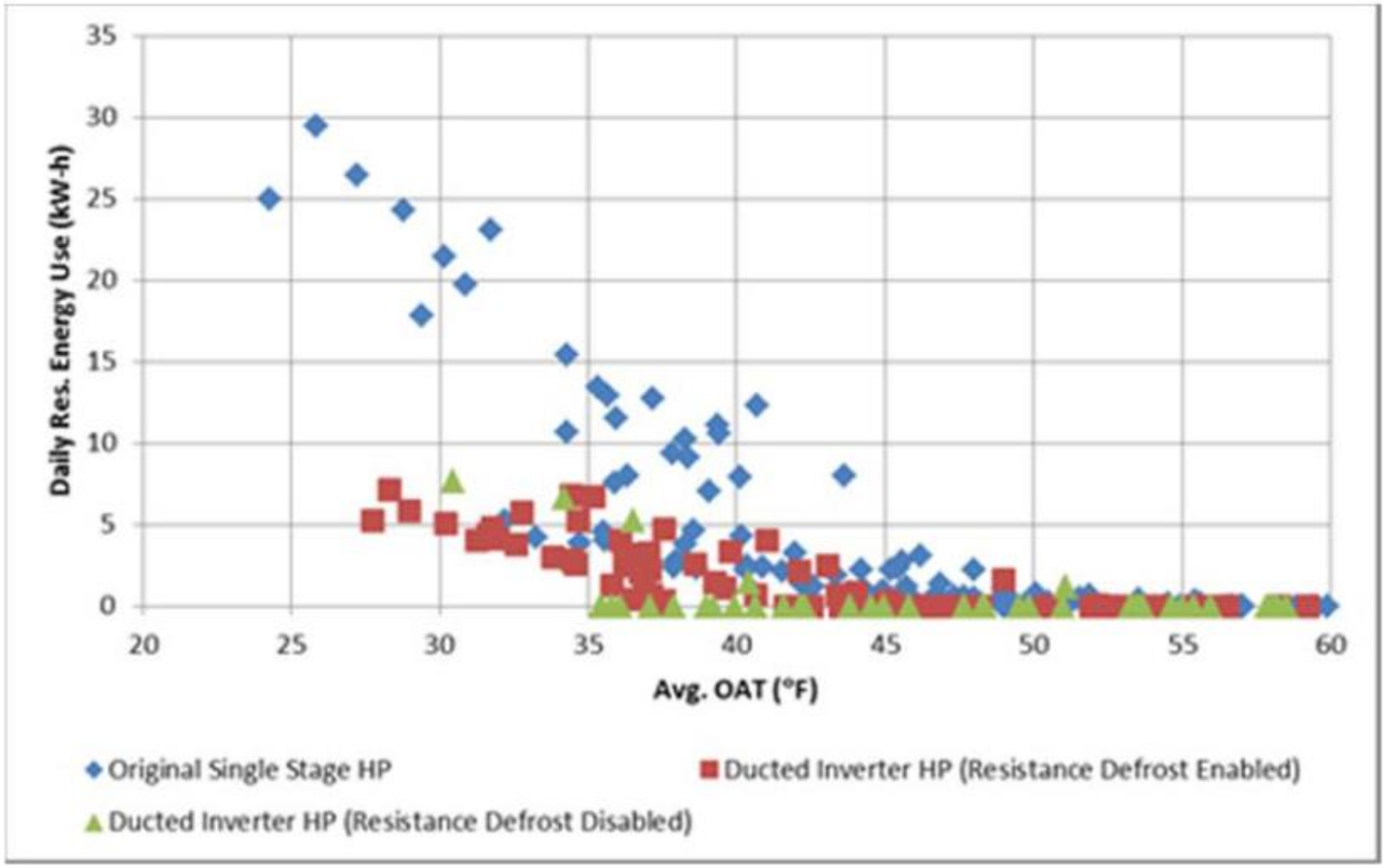
Munk, Jeffrey D., Gehl, Anthony C., Jackson, Roderick K., “Performance of Variable Capacity Heat Pumps in a Mixed Humid Climate”, ORNL/TM-2012/17, April 2012.

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


Q&A

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!