Building America – ORNL R&D: HVAC Research

2015 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: 10/1/2013

Planned end date: 9/30/2014

Key Milestones

1. Heating Performance Curves; 4/15/2014
2. Cooling Performance Curves; 7/15/2014
3. Final Report w/Sizing Guidelines; 2/28/2015

Budget:

Total DOE $ to date: $200k

Total future DOE $: $ 0

Target Market/Audience:

Builders, HVAC Contractors, Homeowners

Key Partners:

Tennessee Valley Authority (TVA)	Research Houses and Equipment
National Renewable Energy Laboratory (NREL)	BEopt w/EMPD model

Project Goal:

Accelerated adoption of variable-speed heat pumps (VSHPs) and implementation of new sizing guidelines leading to a 10-15% energy savings over traditionally sized VSHPs

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Purpose and Objectives

Problem Statement: Heat pumps are traditionally sized based on a home's cooling load. While this ensures that traditional non-modulating HPs provide dehumidification and comfort in the summer, the HP is often left undersized for heating, which increases the use of inefficient resistance heat. Unlike traditional HPs, when VSHPs are sized to the heating load, their ability to modulate enables summer dehumidification and comfort to be retained. Air Conditioning Contractors of America (ACCA) Manual S sizing requirements currently limit the ability to size VSHPs to the heating load in many climates.

Target Market and Audience: Builders, HVAC contractors, and homeowners. Homes with electric heating; homes/climates that have higher design heating loads than cooling loads.

Impact of Project: Accelerated adoption of VSHPs with a 10-15% target energy savings compared to traditionally sized VSHPs (estimated at 25 trillion BTUs)

Final Deliverable: VSHP sizing guide for the mixed-humid climate

Adoption of New Sizing Guidelines

-Short Term: Building America Solution Center

-Long Term: ACCA Manual S

Approach

Approach:

- Generate EnergyPlus VSHP performance curves from field data
- Calibrate VSHP performance curves to measured data
- Run simulations for various equipment capacities in a Building America Benchmark house located in different climates

Key Issues:

- Heating and cooling loads in the building are biased to different units, e.g. downstairs unit does most of the heating and upstairs unit does most of the cooling

Distinctive Characteristics:

- Utilize data from a real house that will capture how the HP/thermostat system responds to changes in the building temperature.

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Progress and Accomplishments

Lessons Learned:

- Significant interaction between systems on 1st and 2nd floor
- Duct losses have a larger impact on VSHPs due to increased runtime

Accomplishments:

- ACCA VSHP oversize limit increased from 1.20 to 1.30 in Manual S 2nd Edition 2014.
- Manual S allows simulation or bin-hour calculations to justify larger oversize limit.
- Field test VSHP model showed ability to maintain comfort as good as or better than the baseline single speed HP at cooling size ratios up to 1.7 to 2.0
- Annual energy savings increase of 3-10 percentage points by increasing cooling size ratio from 1 to 1.6-2.0 in the cold climate
- Significant peak heating power reductions are possible

Project Integration and Collaboration

Project Integration: Engaged with ACCA on manual S guidelines for VSHPs. Discussions with NREL, EPRI, and Ecotope regarding VSHP sizing and field and laboratory test data on VSHPs.

Partners, Subcontractors, and Collaborators: TVA supplied the research house and equipment. NREL provided an “in-house” version of BEopt that utilizes an improved, dual layer, effective moisture penetration depth (EMPD) model.

Communications: Prior work on VSHPs at TVA research houses has been presented at ASHRAE conferences.

Next Steps and Future Plans

Next Steps and Future Plans:

- Disseminate study results to target groups (utilities, ACCA, etc.)
- In order to utilize ACCA manual S simulation or bin-hour route for justifying larger VSHPs, additional performance data is needed.
  - Manufacturer's expanded performance tables typically only provide data at min and max compressor speeds and often do not include data for enhanced dehumidification modes that are available.
  - Need cooling performance data for enhanced dehumidification mode
  - Need to accurately capture this mode of operation in equipment models
- Peak power management is a major factor in buildings to grid activities and net zero energy homes

Background

- Research began as a utility led study to eliminate supplementary resistance heat use and reduce peak heating power.

- 2 VSHPs installed in a single home
  - 2 ton downstairs
  - 3 ton upstairs
- House had emulated occupancy, lights, clothes washer, clothes dryer, dishwasher, oven, refrigerator/freezer doors, TVs.

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Background

- VSHPs instrumentation (data interval 15 seconds)
  - Energy Use
    - Air Handler Total
      - ID Fan
      - Resistance Heat
    - Outdoor Unit Total
      - Compressor
  - Air Temperature and Humidity
    - Return (Avg of 3 sensors)
    - Supply (Avg of 5 sensors)
    - Thermostats
  - Condensate from fan coil drain
  - Supply airflow

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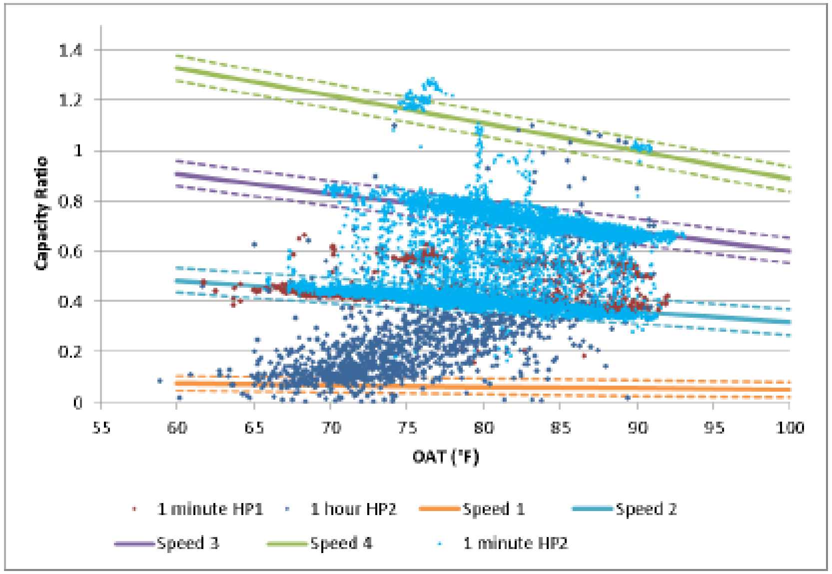
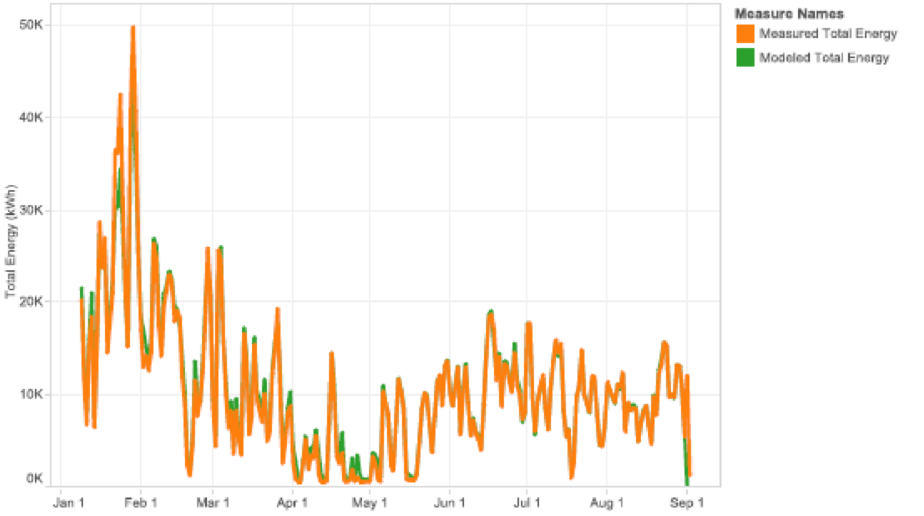
Approach

- Use measured data to generate EnergyPlus performance curves
- Calibrate performance curves
- Run simulations in Building America Benchmark houses in different cities
  - Baseline 13 SEER HP model from BEopt sized to cooling load
  - VSHP model from field test data 2-5 tons
  - VSHP model included in BEopt 2-5 tons
- Results analyzed utilizing cooling size ratio (aka oversize factor):

$$\frac{Equipment\ Total\ Cooling\ Capacity}{House\ Design\ Total\ Cooling\ Load}$$





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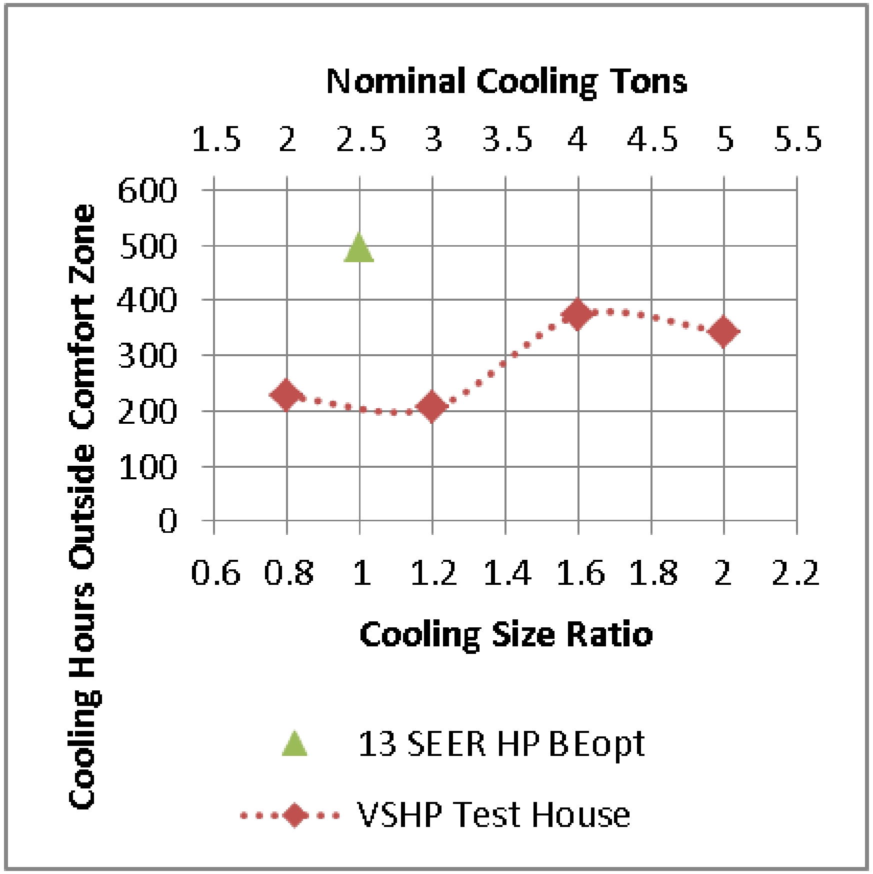
Comfort Results (Charlotte, NC)

- VSHP can provide better comfort than a single speed heat pump even when oversized for the cooling load

- VSHPs can reduce the indoor blower speed when necessary to provide additional dehumidification
- Lower indoor airflow reduces the sensible heat ratio (SHR), reduces indoor humidity, and increases comfort.



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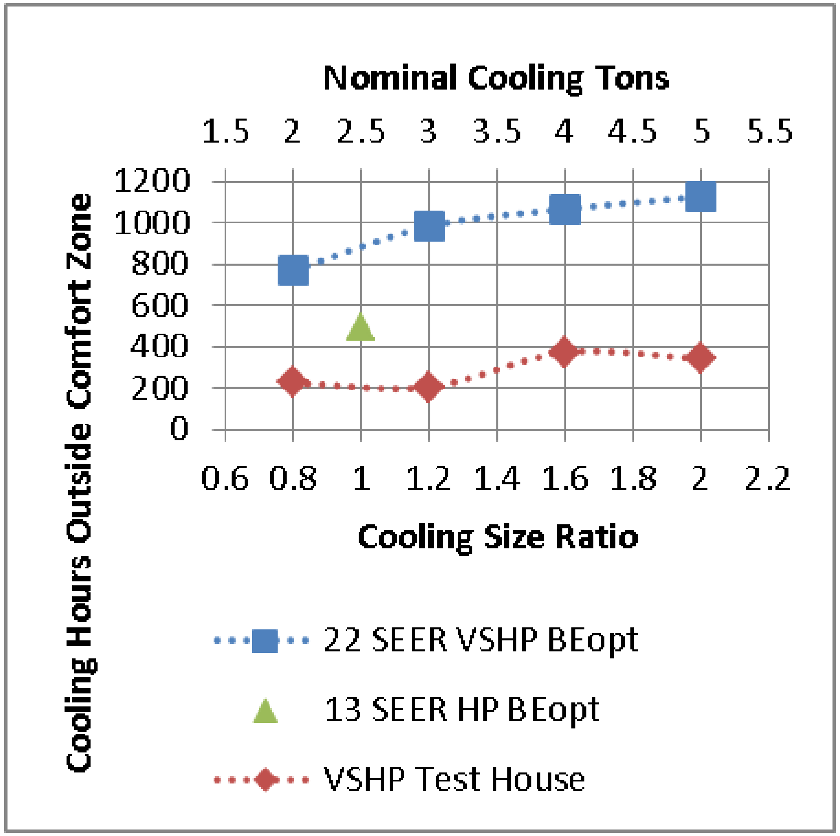
- Mode of operation is important for comfort regardless of manufacturer



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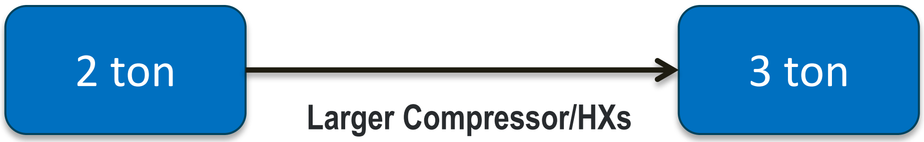
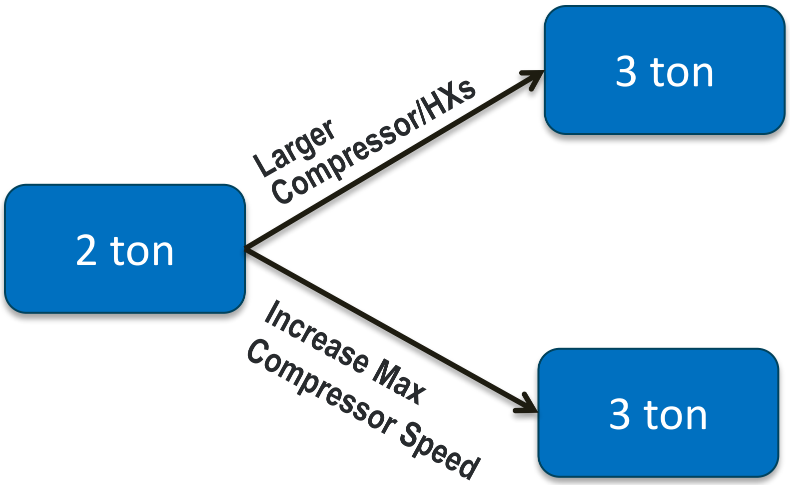
How Different Capacity VSHPs Are Designed

Traditional Single Speed HPs



VSHPs



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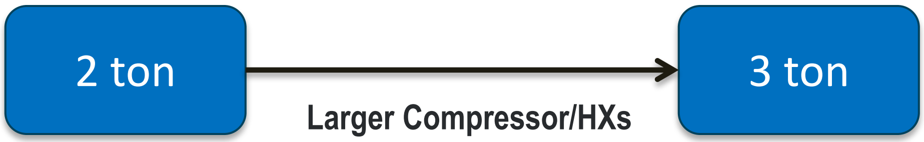
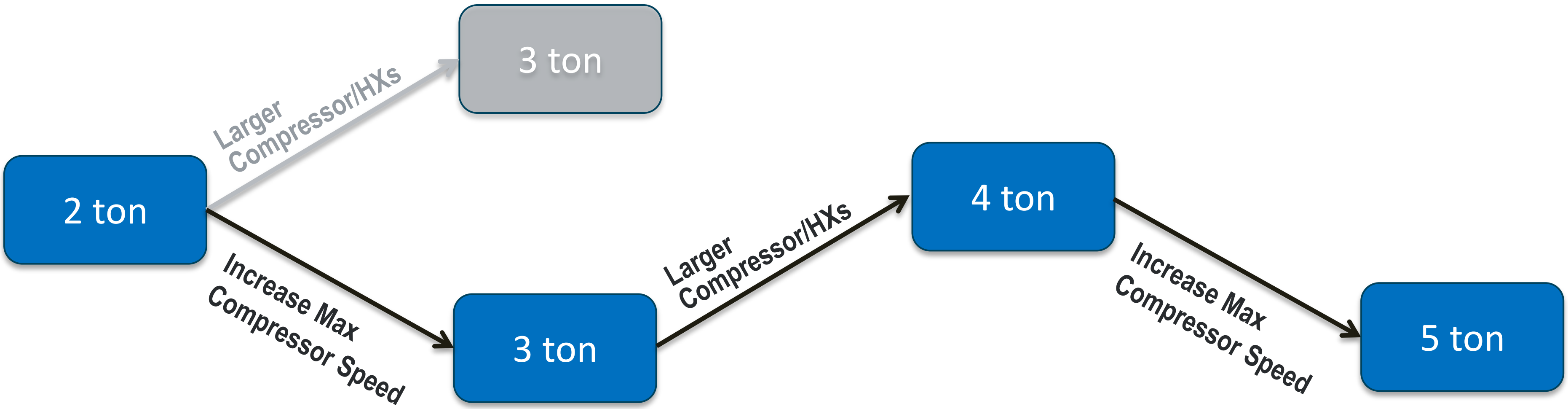


VSHPs at field test house



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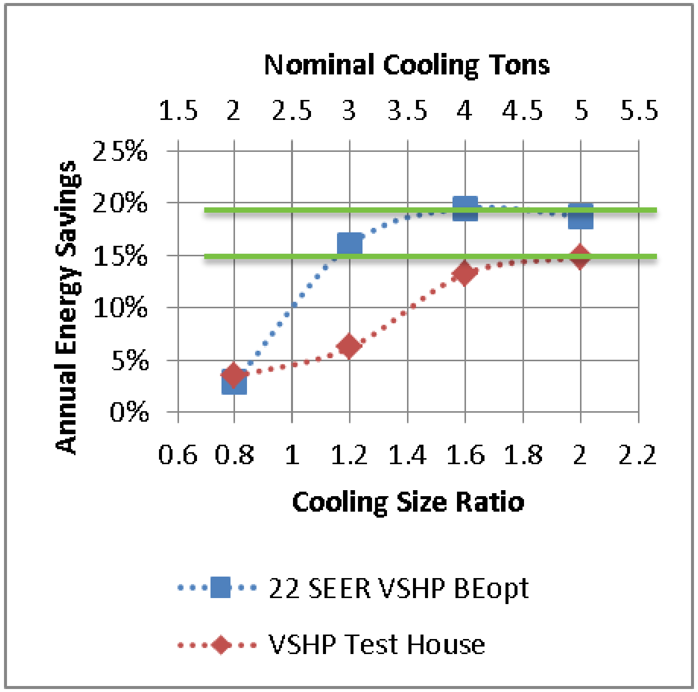
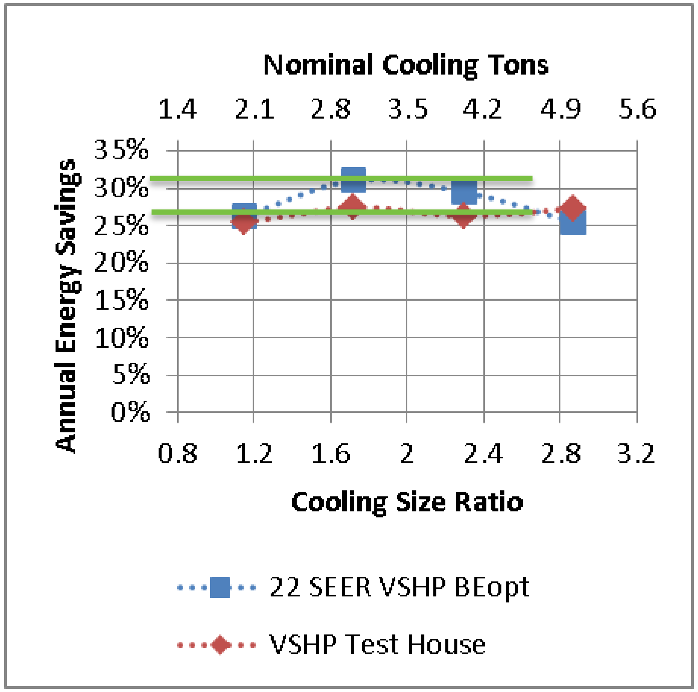
Duct Losses

- Duct losses reduce potential savings of VSHPs due to increased runtime



15% duct leakage, R-4 duct insulation

~12% additional savings over baseline when duct losses eliminated



No duct losses

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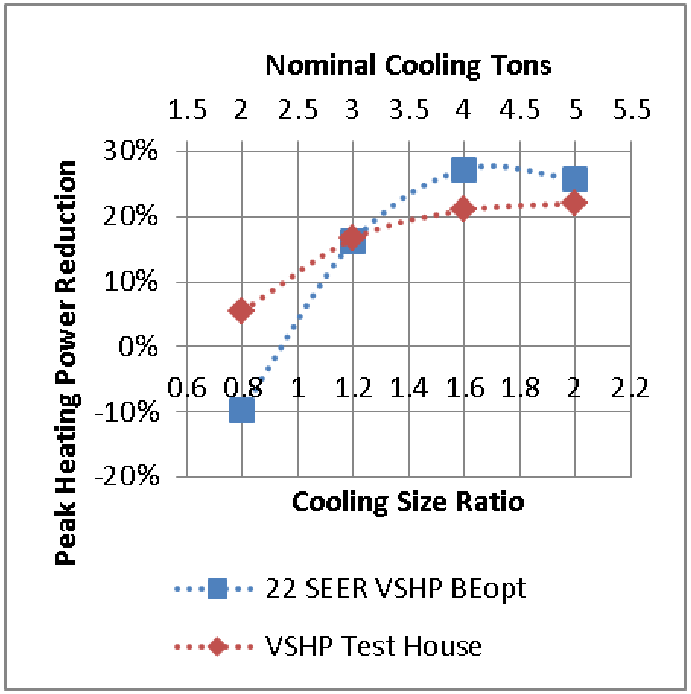
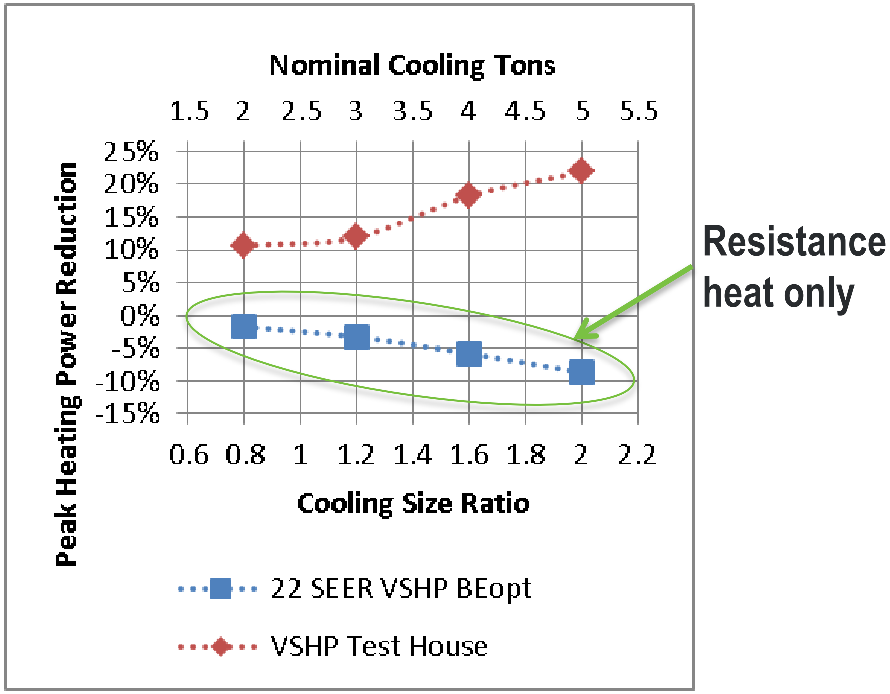
Heating Peak Power Reduction

- Sizing up to the heating load will provide peak heating power reductions in all climates
- Minimum compressor operating temperature is important in cold climates



Charlotte, NC (mixed-humid)



Pittsburgh, PA (cold)

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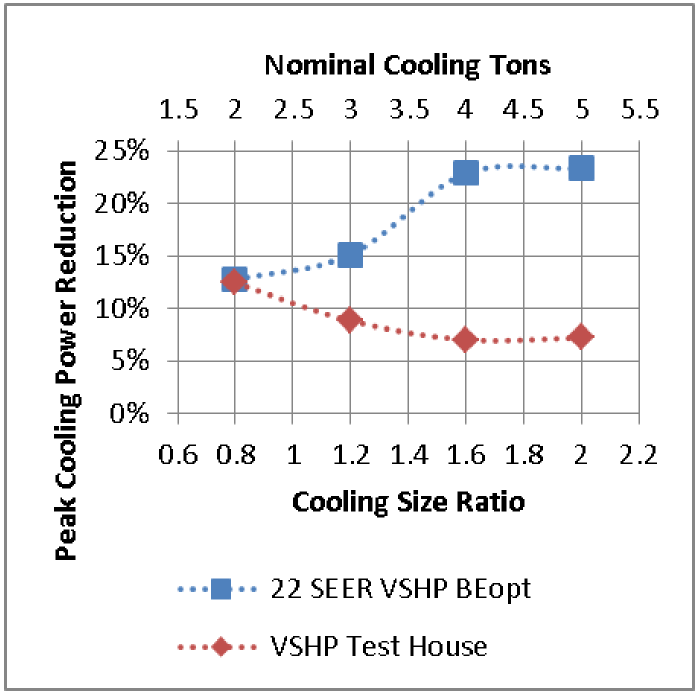
Cooling Peak Power

- Model results show different trends (compressor related?, mode of operation related?) more research needed.



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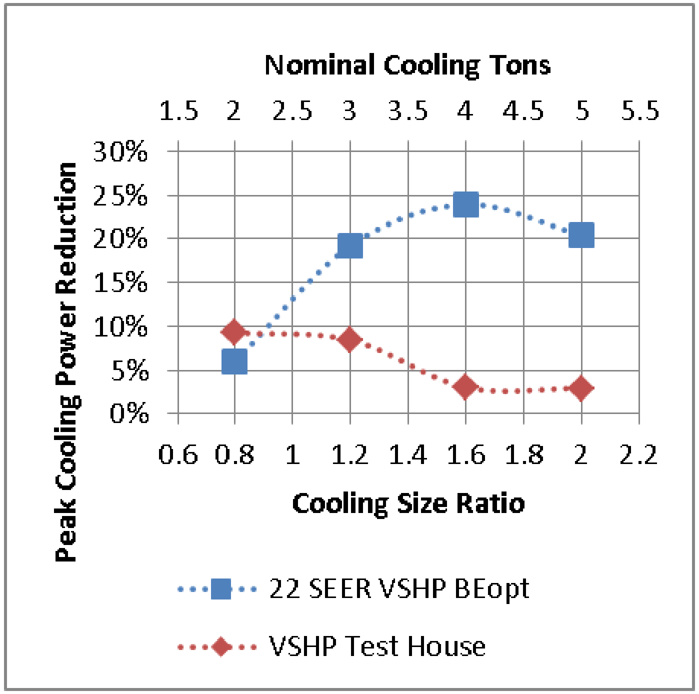

Pittsburgh, PA (cold)

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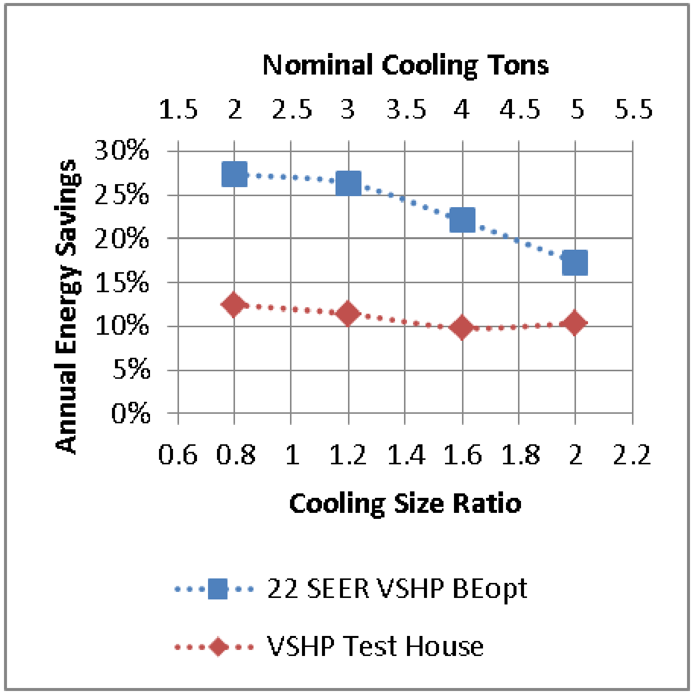
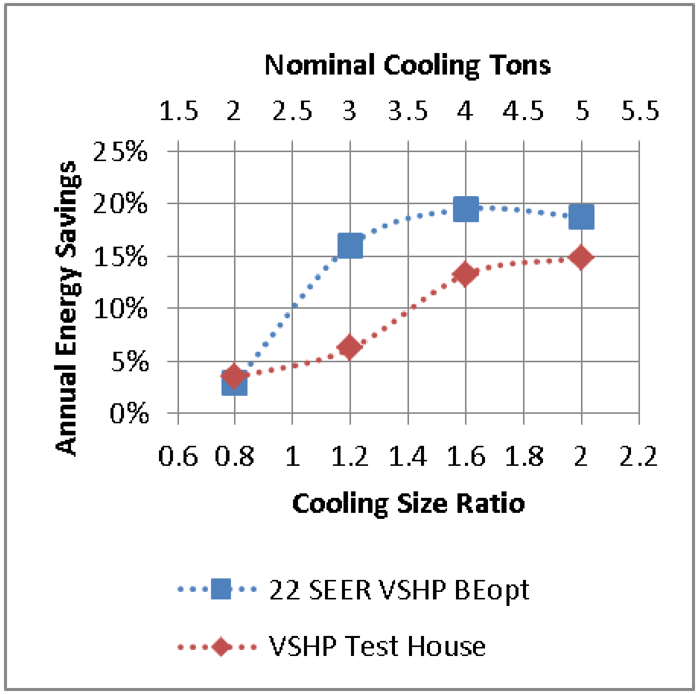
Annual Energy Savings

- No additional savings seen by oversizing in the southern portion of the mixed-humid climate
- ~10% additional savings possible for the cold climate



Charlotte, NC (mixed-humid)



Pittsburgh, PA (cold)

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Project Budget

Project Budget: 200k
Variances: N/A
Cost to Date: 200k
Additional Funding: TVA provided research house and equipment estimated at 100k/year

Budget History					
October– FY2014 (past)		FY2015 (current)		FY2016 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
200k	100k				

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Project Plan and Schedule

- Start Date: 10/1/2013
- Planned End Date: 9/30/2014 rescheduled to 2/28/2015 due to conflicting project schedules and incorporating new data into report.
- Heating Performance Curves: 4/15/2014
- Cooling Performance Curves: 7/15/2014

Project Schedule												
Project Start: 10/1/2013		Completed Work										
Projected End: 2/28/2015		Active Task (in progress work)										
		Milestone/Deliverable (Originally Planned)										
		Milestone/Deliverable (Actual)										
	FY2013				FY2014				FY2015			
Task	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Past Work												
Heating Performance Curves												
Cooling Performance Curves												
Final Report												
Current/Future Work												