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Getting to Zero Cost Effectively

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So What Did BSC Bring to the Table?

- Carter = heavy lifting (i.e., building the darn houses)
- Group of high-powered energy geeks
- Energy analysis—comparison of options
- Monitoring
- Utility bill tracking

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Energy Analysis/ Net Zero

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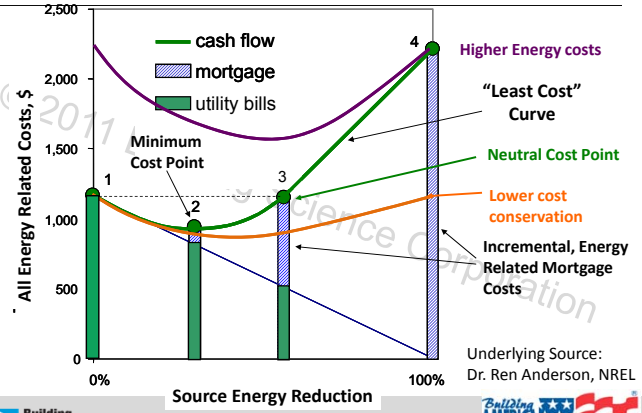
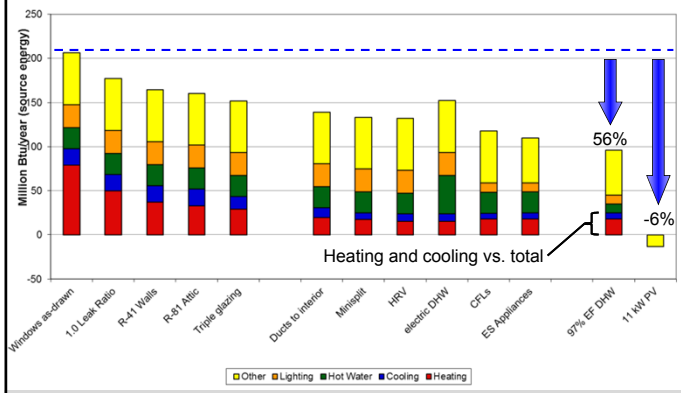
Capital Investment vs. Operating Cost



Underlying Source: Dr. Ren Anderson, NREL

Parametric Simulations



Cost Effectiveness: Beyond Simple Payback

Cost	Extended Cost Effectiveness Analysis			
	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	$ per 10^6 Btu Saved (Lifetime)

Component lifetime

Energy saved over lifetime of measure

"Cost per unit of energy saved"

Cost of upgrade

Source Energy Savings (from typical analysis)

Cost Effectiveness: Beyond Simple Payback

	Extended Cost Effectiveness Analysis			
Cost	Savings [10^6 Btu / yr]	$ per 10^6 Btu Saved (1 year)	Estimated Lifetime [yr]	$ per 10^6 Btu Saved (Lifetime)
11 kWp Photovoltaic System				
$61,600	105.5	$584	30	$19.47
Heat recovery ventilator				
$1,000	1.1	$880	15	$58.65
Solar DHW system				
$5,000	5.0	$999	25	$39.95

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Ventilation Systems

- Heat recovery ventilator problems
  - Cost: ~$1500 installed (single point supply/exhaust)
  - Distribution to closed rooms—adding ductwork or a distribution fan
- Supply-only ventilation instead?
  - Tempered—draw from bedrooms & exterior; supply to corridor
  - ~$900 installed
  - Provides distributed ventilation at lower cost, but loses heat recovery

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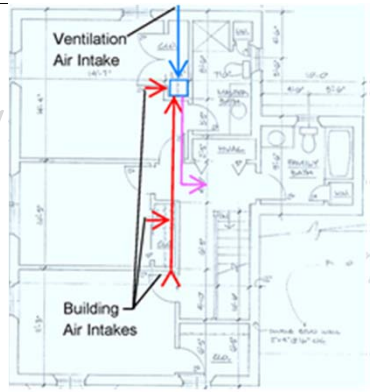
Supply-Only Ventilation System



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Supply-only vs. HRV

System	33% Runtime	100% Runtime
Supply-Only Ventilation	$45/year	$130/year
Balanced Ventilation (HRV)	$20/year	$65/year

- Total energy cost of two systems: fan energy, change of heating/cooling energy
- At 33% and 100% of ASHRAE 62.2 rate
- HRV saves energy in both cases—is an upgrade
- Test installations currently in houses
- HRV effectiveness changes with ventilation amount/runtime

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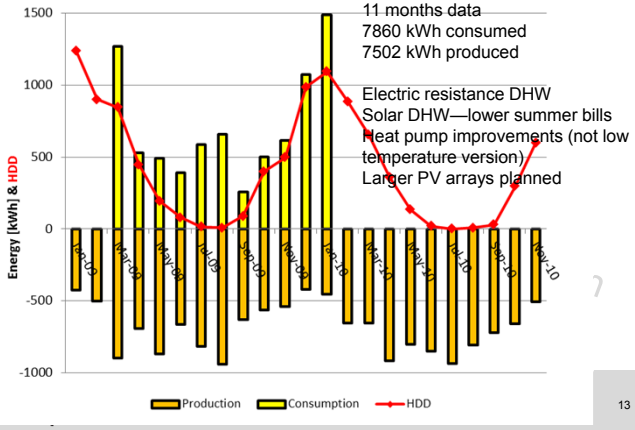
Net Zero Performance



6.4 kWp PV array
11 months data
7860 kWh consumed
7502 kWh produced

Electric resistance DHW
Solar DHW—lower summer bills
Heat pump improvements (not low temperature version)
Larger PV arrays planned

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Fuel Choices

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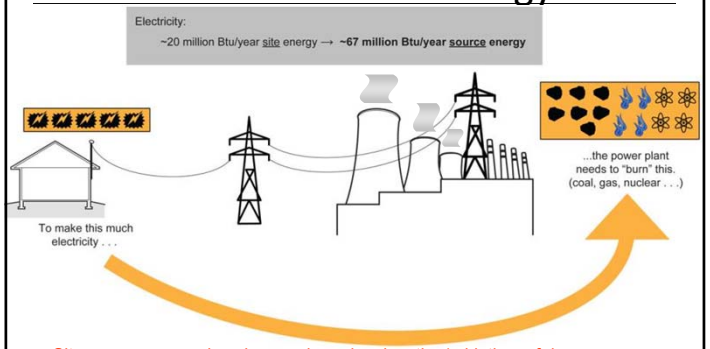
Site and Source Energy



- Site-source conversion changes based on location/grid, time of day, season
- Site-source number has change of improving with more renewable power

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Site-Source Example

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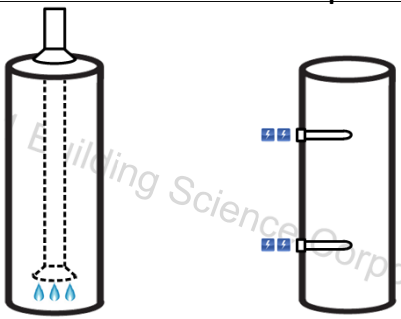

Conventional gas tank (~0.59 EF) site
"Source Efficiency" ≈ 54%

Conventional electric tank (~0.92 EF) site
"Source Efficiency" ≈ 27%

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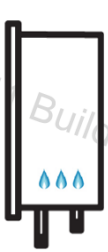
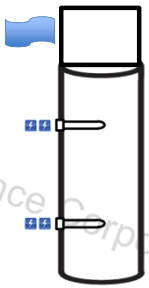
Water Heating: Best Options?



Condensing instantaneous tankless (~0.9 EF) site

"Source Efficiency" ≈ 82%



ASHP (electric) water heater (2.11 EF) site

"Source Efficiency" ≈ 63%

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But that's not the whole story…

- Monthly gas service charges (~$8/month)
- Especially at low loads—e.g., 2 therms/month
- Cost of installing gas main (e.g., new subdivision)
- All electric = easy to demonstrate net zero
- IAQ reasons to eliminate fossil fuel consumption?

- Simulations of heat pump water heater plus heat pump space heating
- +330 kWh/year heating / - 70 kWh/year cooling +260 kWh/year net = +10% space conditioning

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Single Point Heating

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Single Point Heating Background

- Used successfully with other superinsulated projects (~R-40 walls, triple glazed windows)
- SWA work: small distribution fans to bedrooms (81 CFM total)
- Conclusion: distributes ventilation air, not heat
- Need ventilation fan when bedroom doors are closed for good ventilation distribution
- Doors closed, ventilation fan on, outdoors ~20° F: Bedrooms dropped ~5° F overnight

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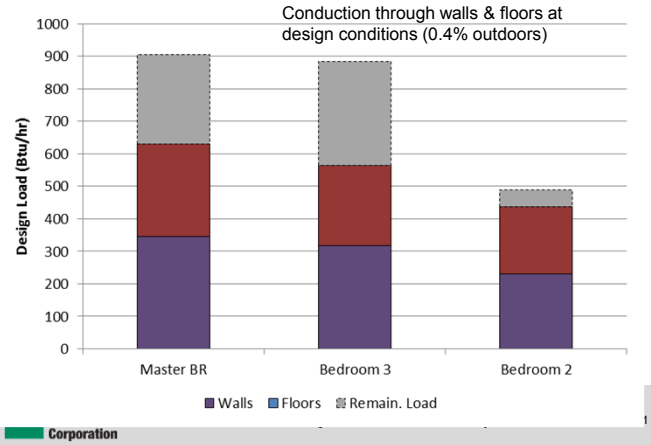
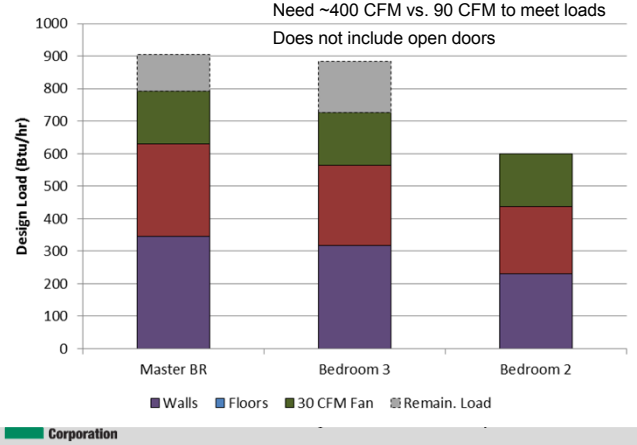
Heat Flow at ΔT=5 F Hall-to-Bedroom

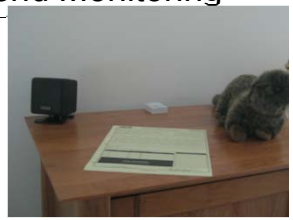


Add 30 CFM Fan (at ΔT=5 F)



Background on Townsend Monitoring

- Temperature and RH in hallway, rooms
- Runtime logging on mini splits
- Door open/closed status



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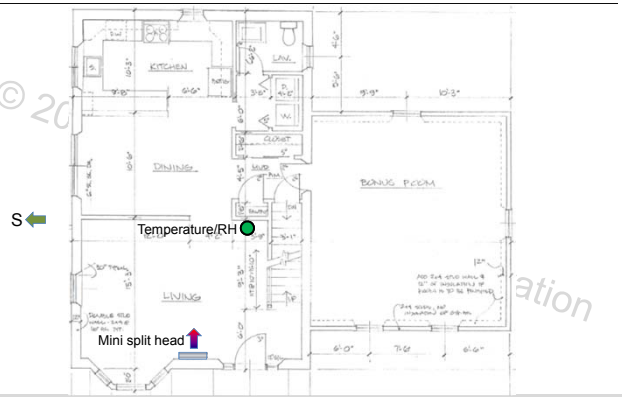
Instrumentation Setup (First Floor)



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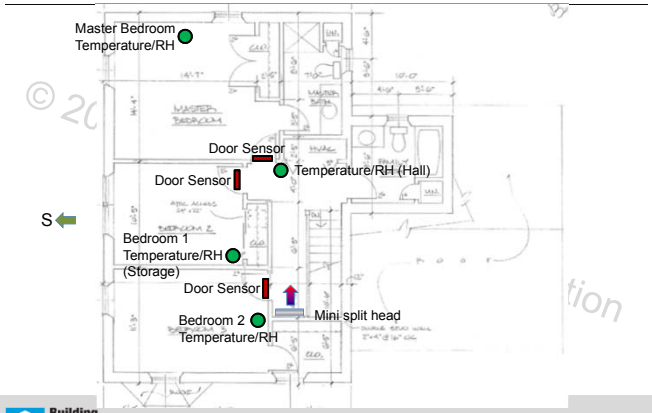
Instrumentation Setup (Second Floor)



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Single Point Heating: Results

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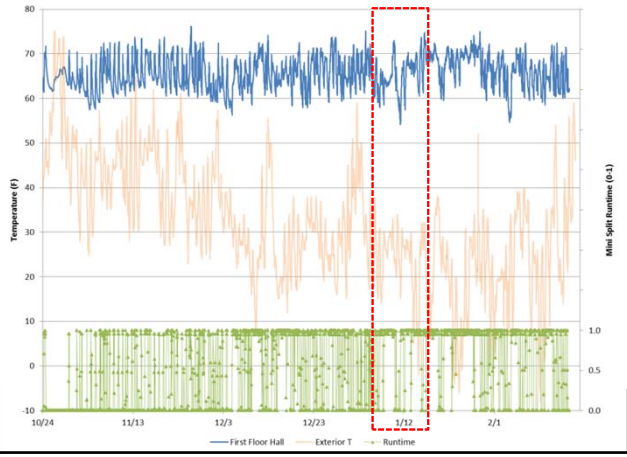
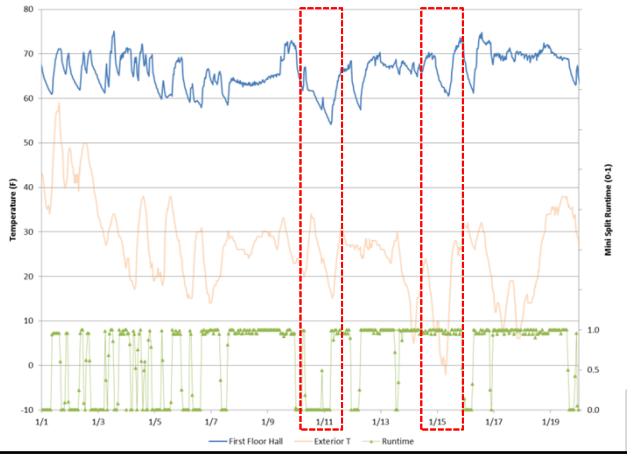
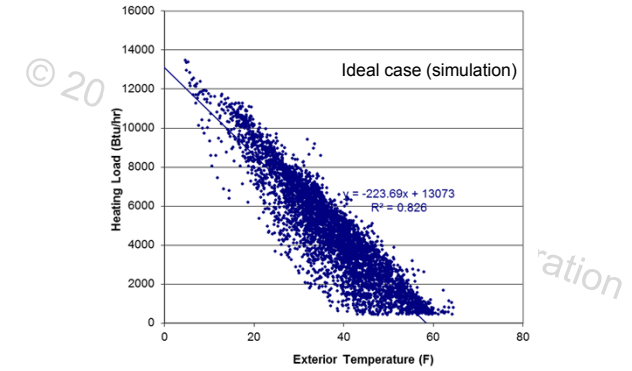
First Floor Temperature/Runtime



First Floor Temperature/Runtime



Exterior Temperature vs. Runtime



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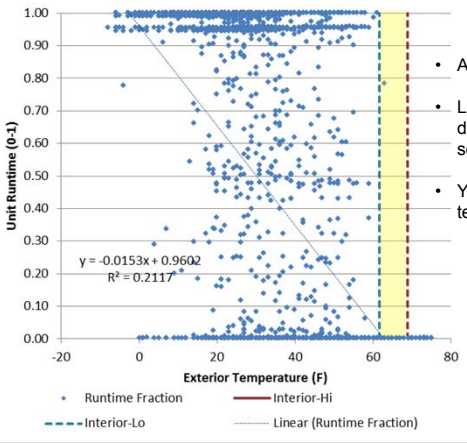
Exterior Temperature vs. Runtime



- Actual data (First Floor)
- Lack of correlation with deep temperature setbacks
- Yellow = interior average temperature ±1 S.D.

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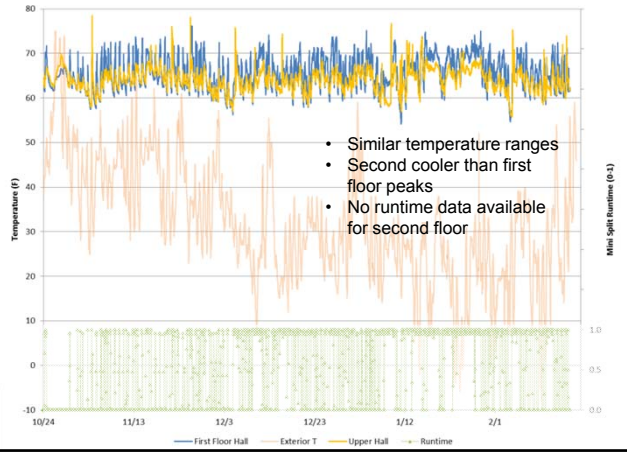
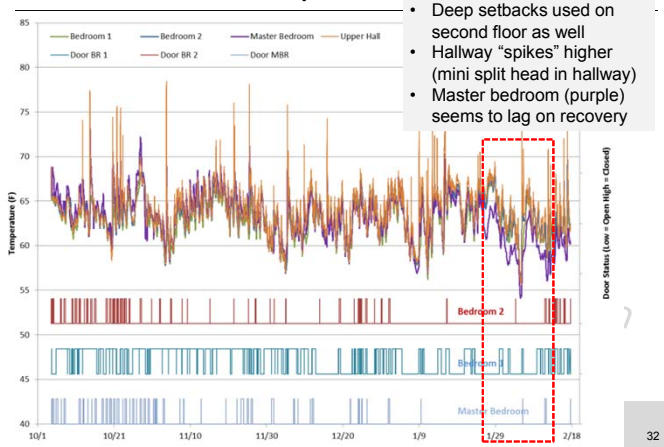
First vs. Second Floor



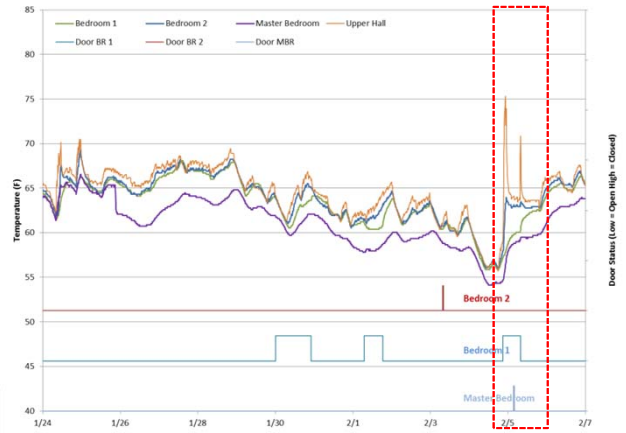
- Similar temperature ranges
- Second cooler than first floor peaks
- No runtime data available for second floor

Second Floor Temperatures



- Deep setbacks used on second floor as well
- Hallway "spikes" higher (mini split head in hallway)
- Master bedroom (purple) seems to lag on recovery

Second Floor Temperatures



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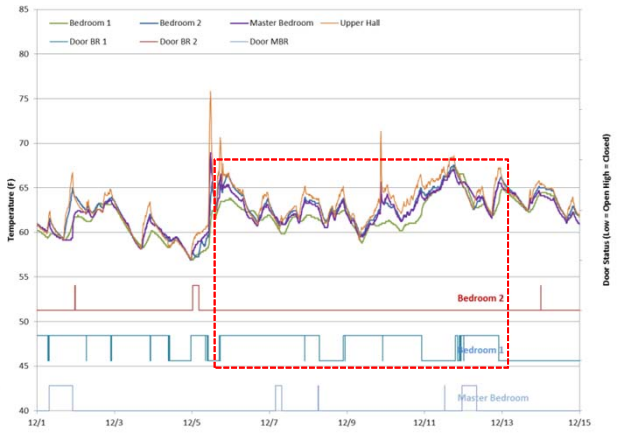
Second Floor Temperatures



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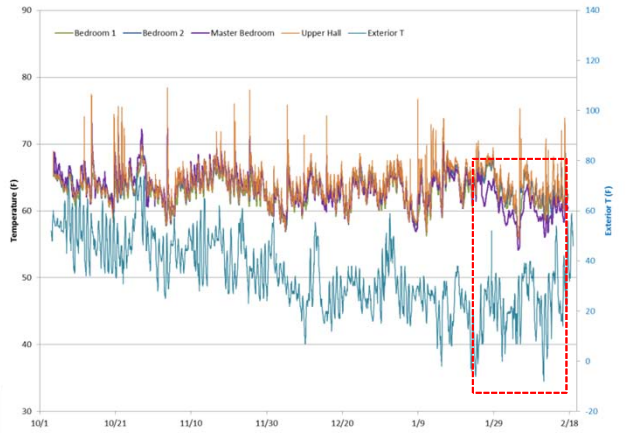
When is Master BR Colder?



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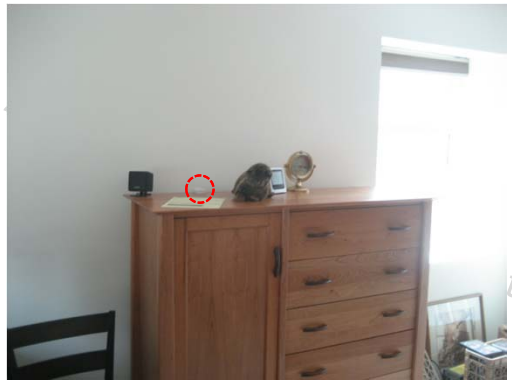
"Well there's yer problem, buddy…."



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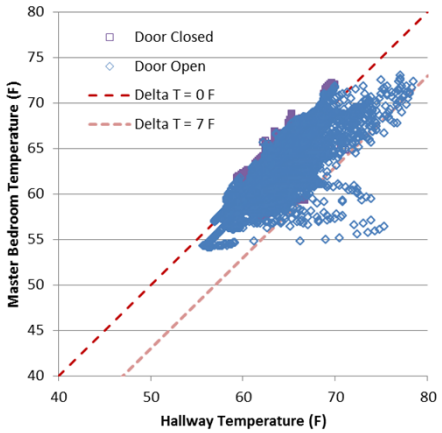
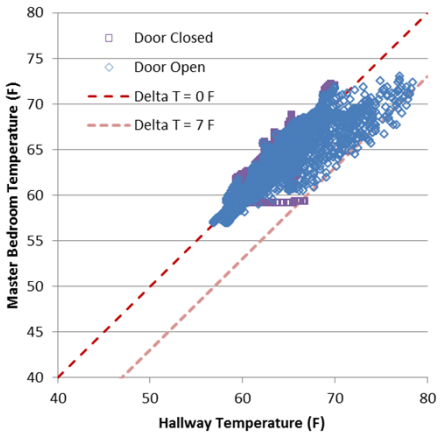
Hallway vs. Bedroom Correlations (MBR)



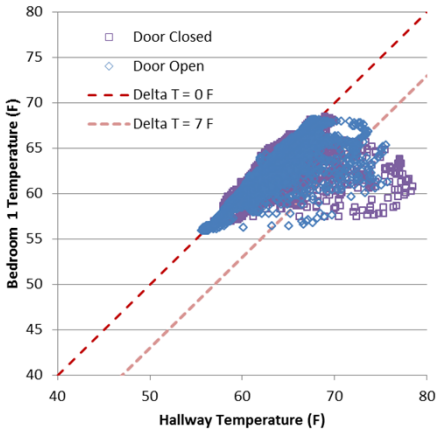
- Master bedroom door closed 8%/open 92%

Hallway vs. Bedroom Correlations (MBR)



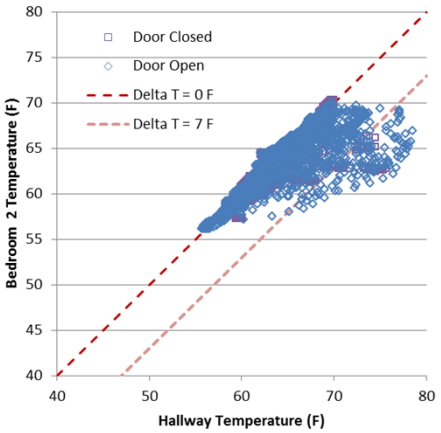
- Cull out data from 1/24/2011 onwards (large temperature difference starts)

Hallway vs. Bedroom Correlations (BR1)



- Bedroom 1 (middle) used as storage
- Door closed 56% of time/open 44% of time
- Large temperature differences—many at door closed condition

Hallway vs. Bedroom Correlations (BR2)



- Bedroom 2 (end) used as bedroom
- Door closed 8%/ open 92%

Conclusions

- Single point heating per floor can keep rooms close to setpoint (~5-7° F)
- Deep heating setbacks cause greater differences
- Leaving doors closed increases temperature differences
- Deep setbacks result in long runtimes for mini split heat pumps
- "Acceptable sizing" data inconclusive

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Thank you for your time!

QUESTIONS??

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