Net-Zero Energy Homes: The Basics of What You Need to Know

Building Science Corporation
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The 2010 HVACR & Plumbing Instructor Workshop:
Advancing Green Mechanical Concepts
March 24-26, 2010

Background

Definitions

- NZE: A building that produces as much energy in a typical year as it consumes.
  - Consumes grid power when it needs it
  - Feed power to grid when it has extra
- ALL energy considered
  - Electric is not special.
- NOT Zero Carbon, or Zero GHG
- NOT off-grid
  - Much more difficult

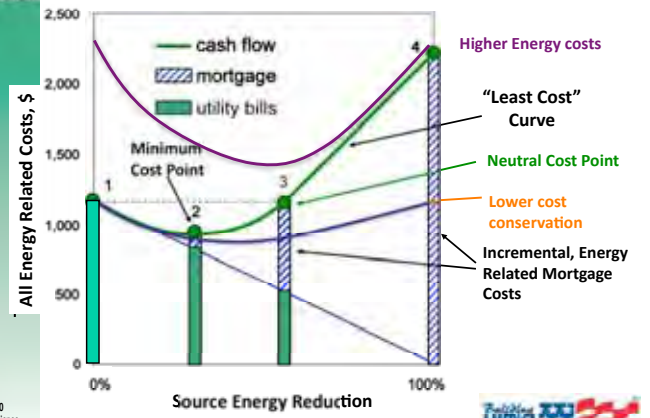
Why Buildings?

- Building Sector is largest energy consumer and GHG emitter

NZE Design Targets

- Produce as much as we consume
- Production is usually MUCH more expensive than reducing waste (efficiency/conservation)
  - Hence the energy demanded by building should always be reduced, reduced, reduced before adding production
  - Check cost of reducing demand vs cost if supplying energy

Capital Investment vs. Operating Cost



Underlying Source: Dr Ren Anderson, NREL

Takeaway Lessons

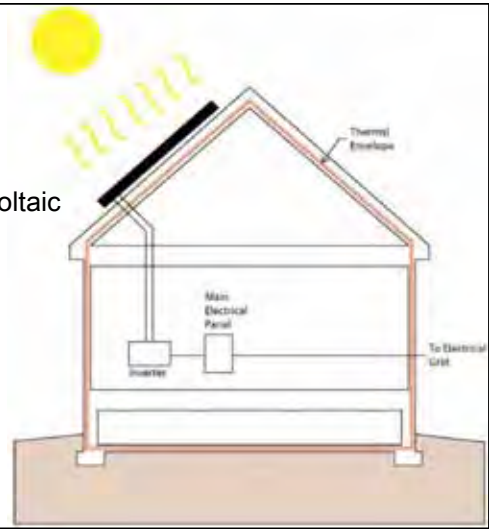
- Conservation measures first! Good design/orientation, good enclosure (shell), good mechanicals
- Then start adding renewable energy
- Insulation has diminishing returns
- Renewables can be more cost-effective than insulation after a point!
- Net zero energy: good & noble target, but out beyond "neutral cost"

Renewables

Energy Supply

- Renewable energy (RE) or cleaner energy (CE)
- Net Zero currently demands *site production*
  - This eliminates some good economical RE
- Common choices
  - Photovoltaic: Electricity
  - Solar thermal Warm / Hotwater
  - Combined heat and power
  - Wind electricity

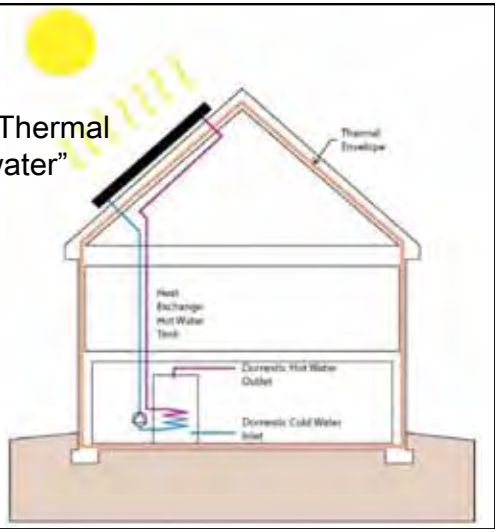
- PV photovoltaic



Energy Supply (RE)

- PV
  - Straightforward installation, easy to predict output
  - Expensive but electricity is very useful and excess can easily be sent to the grid (grid=battery)
  - Rated by peak output under standard solar conditions ("peak Watt" or W_p)
  - Costs now \$8/W_p (before subsidy) installed

- Solar Thermal "hot water"



Solar thermal

- Intermittent source of hot water
- Well developed
- Requires big storage tanks in most application
- Freezing, over heating, glycol thickening failures, and low temperature efficiency are issues
- Not the most economically-viable choice ($6-10 K): but if going to net zero…

Combined heat and power

- Aka “CHP”
- Efficient use of fuel to produce heat & electricity within the building complex (e.g. hospital) or home
- Remember: grid ~30% efficient; waste heat = cooling towers, river water
- Much lower GHG emissions
- Supplies on demand
- Ratio of electricity to heat is fixed

- Effectiveness varies on case-by-case basis

Mechanical Systems

Mechanical Systems

Energy consuming functions

- Heating
- Cooling
- Domestic Hot Water
- Ventilation & Filtration

Fundamental problem: small loads!

Furnaces

- Condensing gas furnaces: 90%+ AFUE—mature technology
- Sealed combustion
- ECM motors ("variable speed") reduces fan electrical energy

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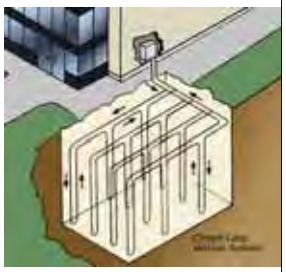
Ground-source heat pumps

- Uses constant ground temperature to provide heating & cooling
- Fluid pumped through underground tubes; heat extracted or rejected
- One of the highest efficiency space conditioning systems (measured ~3.5 COP)
- But….



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Ground-source heat pumps

- Installed cost of system very high (drilling ground loops)
- Nameplate efficiency < actual efficiency (previous example: 5 COP rated number)
- Pumping energy
- Systems with problems—difficult to diagnose, expensive to fix
- Can still suffer from normal ductwork-based system problems
- For small loads, is it worthwhile?

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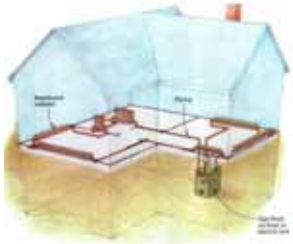
Heating: Hydronic Systems

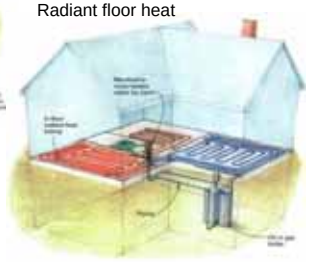
- 80% & 90%+ options
- Condensing boilers (90%+)—needs some thinking/ design
- Outdoor reset controls for 90%+
- Can't add cooling

Radiators/Radiant Floors



Baseboard radiators

Radiant floor heat



Mini Splits

Mini-split non-ducted head

Mini-split short ducted system

Mini-split outdoor unit

- Both heating & cooling
- Multi-splits (single outdoor unit)
- Systems with SEER=26 and HSPF=11 available

Mini-Splits Heating/Cooling in Cold Climate

- 1818 sf house, solar-oriented, superinsulated (12" spray foam walls, R-80 roof), triple glazed windows, very airtight
- Central Massachusetts location
- Net zero performance

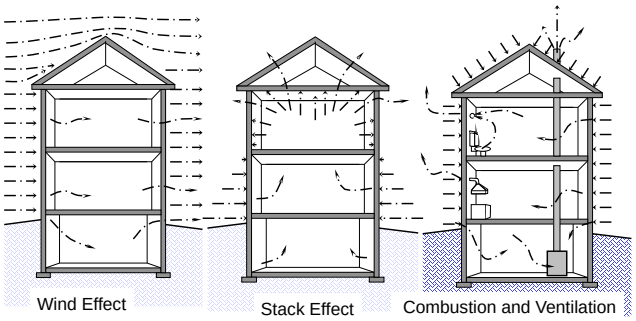
- Provides for both heating & cooling; 11,000 BTU heating load
- Installed costs in the 1,818 square foot "Farmhouse" was $6,850
- Two 9,000 BTU heads upstairs, One 12,000 BTU head downstairs
- Electric heater back up, no heat production below zero degrees outside

Ventilation

Need for Ventilation

- Greater airtightness for energy reasons, in net zero houses
- Also improves sound, odor, pest control, dust control
- But people still stink! (+ activities)
- Controlled mechanical ventilation
  - Point source control (exhaust fans)
  - General dilution ventilation

Air Change Driving Forces



Indoor Air Quality

- Pollutant production
- Pollutant removal
- Dynamic Balance= pollutant level
  - Not a IAQ problem if it is not in the air
- Solutions
  - Reduce pollutant production
  - Increase pollutant removal

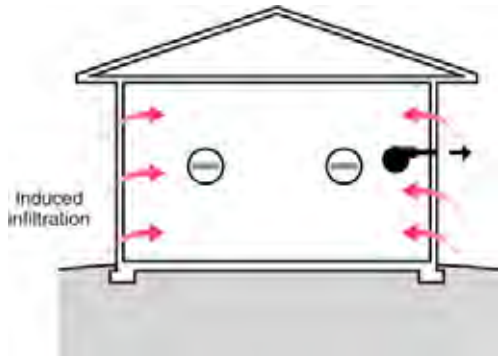
Ventilation

- Given sensible source control, constant ventilation can dilute pollutants to a low level
  - Ventilation rates are mostly about odor and humidity, not oxygen
  - 7.5 cfm/person + 0.01 cfm / sq ft
  - Commercial and highrise 15 cfm/person (!)
- Mixing or separate supply to each room is necessary to achieve best IAQ

Types of Controlled Ventilation Systems

- Exhaust Ventilation
- Supply Ventilation
- Balanced Ventilation

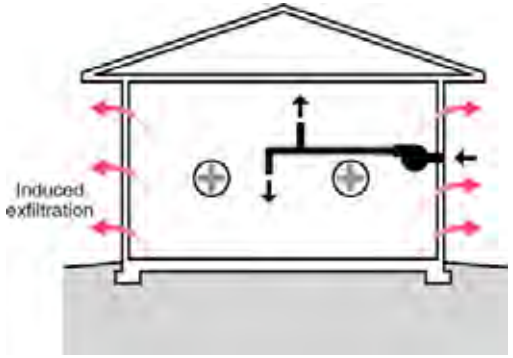
Exhaust Only: Depressurize

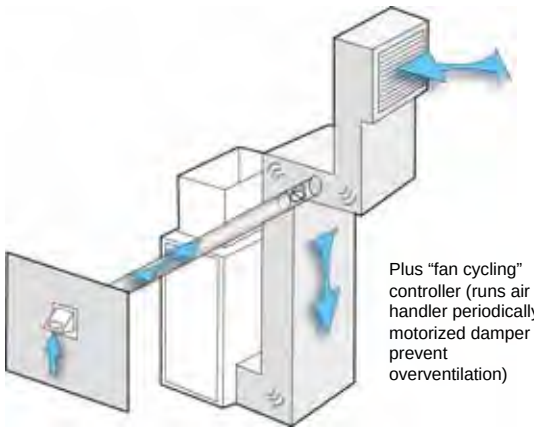


Exhaust pros and cons

- Lowest cost installed system (typical), but problems associated:
- Carbon monoxide alarms
- Lack of filtration
  - Dust marking on light carpets
  - Dirt/grit particles settling on horizontal surfaces
- Lack of distribution
  - Moisture accumulation and odor buildup in rooms remote from exhaust fan
- Objections to fan noise
- Risky in hot-humid climates

Supply Only: Pressurized





Plus “fan cycling” controller (runs air handler periodically + motorized damper to prevent overventilation)

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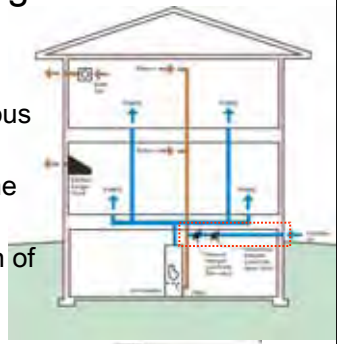
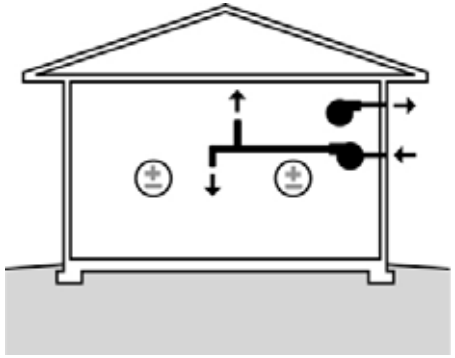
Central fan-integrated ventilation

- “Smart” controller (accounts for previous runtime)
- Set minimum runtime (e.g., 20 min/hour)
- Provides distribution of ventilation air throughout house



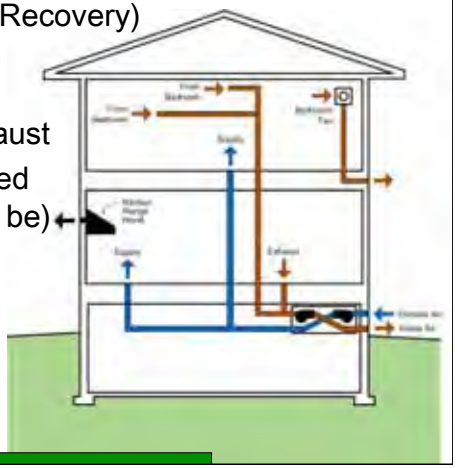
Balanced Supply and Exhaust



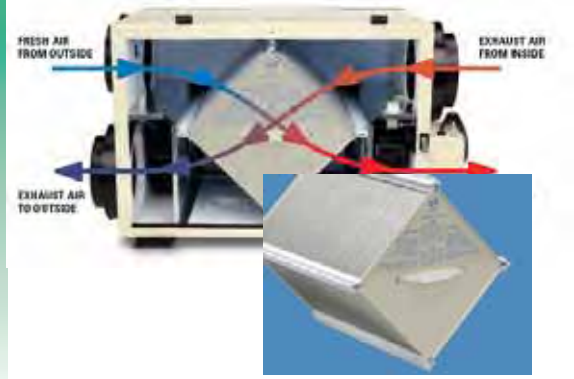
Common for commercial solutions
Residential often combine with HRV/ERV

Balanced Ventilation
(with Heat Recovery)

- HRV/ERV
- Point exhaust
- Fully ducted (need not be)



Heat Recovery Ventilation



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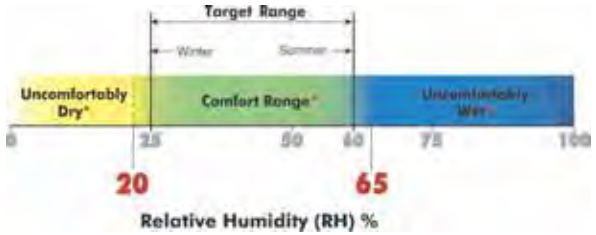
Efficient Equipment

- HRV/ERV always
  - choose better than 1 CFM/Watt (current high end ~2 CFM/Watt)
  - Choose > 60% efficient
  - Right size ventilation!—overventilation can defeat the benefits of adding heat recovery!

Humidity



Recommended Range of Relative Humidity

- 25 percent during winter
- 60 percent during summer

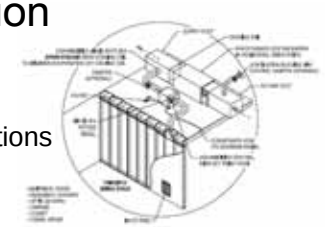
Supplemental Humidity Control

- Good energy efficient design reduces sensible cooling loads—insulation, good windows, airtightness
- Latent load remains the same!
- Thermostat (temperature control) → humidity is not controlled
- Need supplemental dehumidification in hot-humid and mixed-humid climates (high performance houses)
- Demonstrated in 20 research houses

Information Sheet 620: Supplemental Humidity Control
RR-0505: Residential Dehumidification Systems Research for Hot-Humid Climates

Dehumidification

- High efficiency supplemental dehumidification options (standalone ducted boxes)
- E.g., draw from main space, dehumidified air to supply duct
- Humidistat control in main space (near thermostat)

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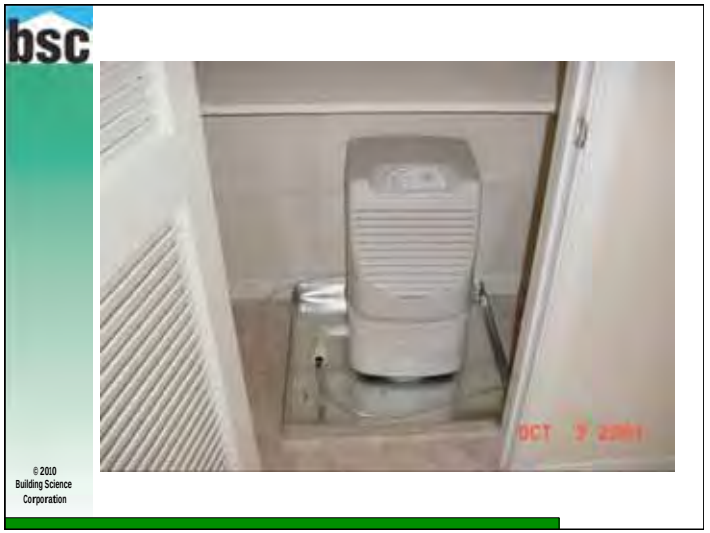
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Combustion
Safety
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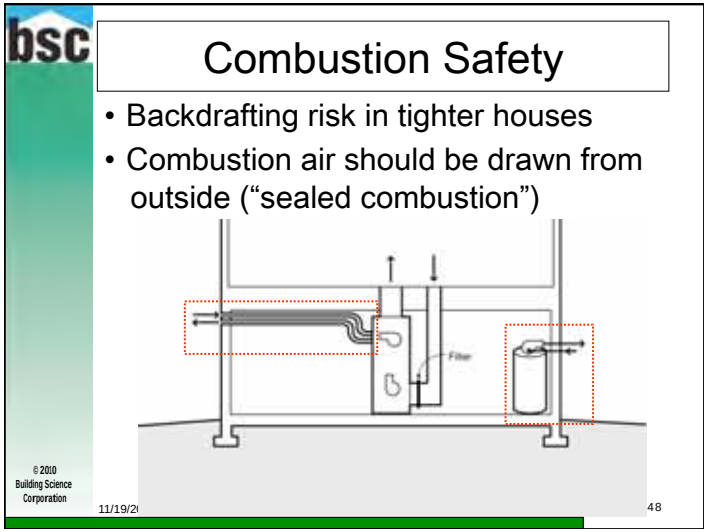
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Combustion Safety
• Backdrafting risk in tighter houses
• Combustion air should be drawn from outside (“sealed combustion”)
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Case Study: Westford

Case Study House (Westford Habitat for Humanity)

- Based on recently-built house
- Super-insulated enclosure
- Very airtight (1.5 ACH 50)
- Best-in-class mechanical systems
- Energy Star appliances
- Compact fluorescent lighting
- No renewable energy added: not NZE (PVs or solar DHW)

Westford House:
1.5 Story Single Family Home with Conditioned Basement (2200 ft² total)

Westford House Under Construction

Building Science Insight: "Building America/The Westford House"

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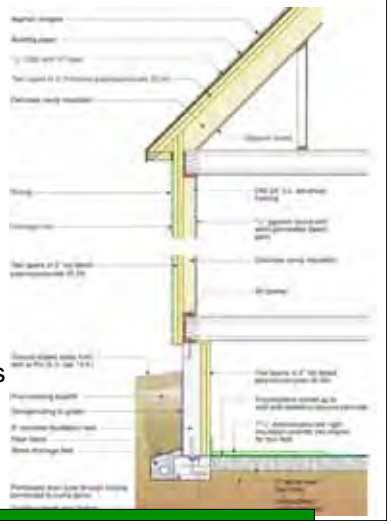
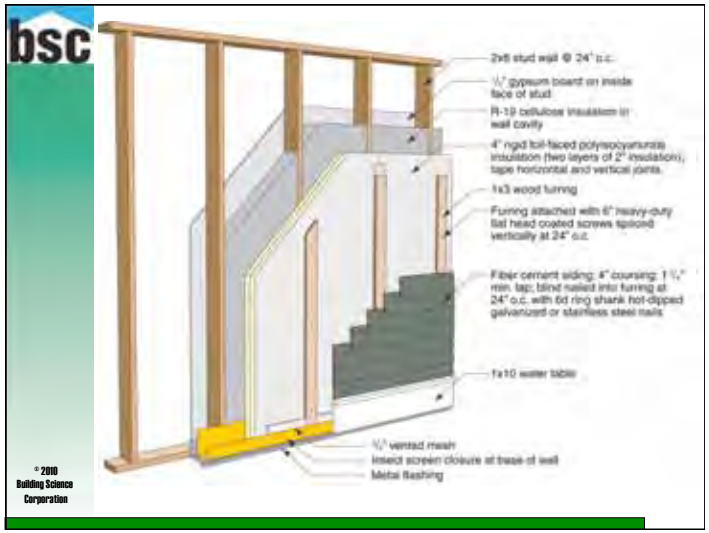
Enclosure Details

- R-66 roof insulation
- R-45 walls
- R-26 basement walls
- R-10 basement slab
- Low e double glazed windows
- 1.5 air changes per hour at 50 Pascals ("ACH50")




2x6 stud wall @ 24" o.c.
½" gypsum board on inside face of stud
R-19 cellulose insulation in wall cavity
4" rigid foil-faced polyisocyanurate insulation (two layers of 2" insulation), tape horizontal and vertical joints
1x3 wood furring
Furring attached with 6" heavy-duty flat head coated screws spaced vertically at 24" o.c.
Fiber cement siding; 4" coursing; 1¼" min. lap; blind nailed into furring at 24" o.c. with 6d ring shank hot-dipped galvanized or stainless steel nails
1x10 water table
¼" vented mesh
Insect screen closure at base of wall
Metal flashing
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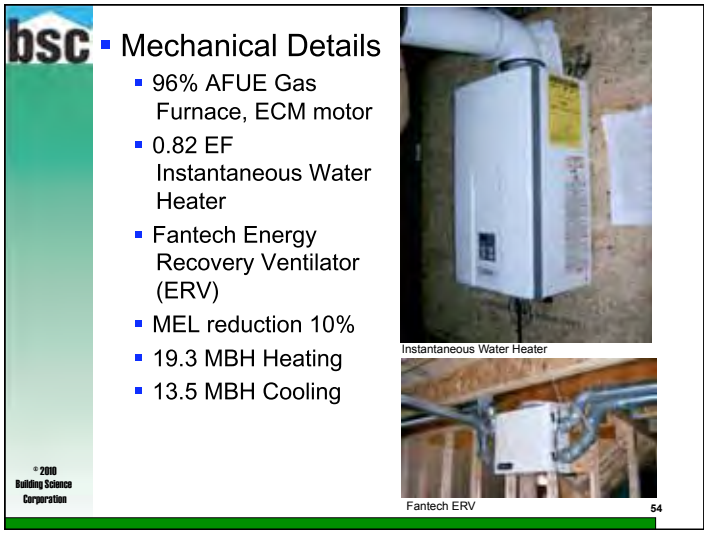
Mechanical Details
96% AFUE Gas Furnace, ECM motor
0.82 EF Instantaneous Water Heater
Fantech Energy Recovery Ventilator (ERV)
MEL reduction 10%
19.3 MBH Heating
13.5 MBH Cooling
Instantaneous Water Heater
Fantech ERV
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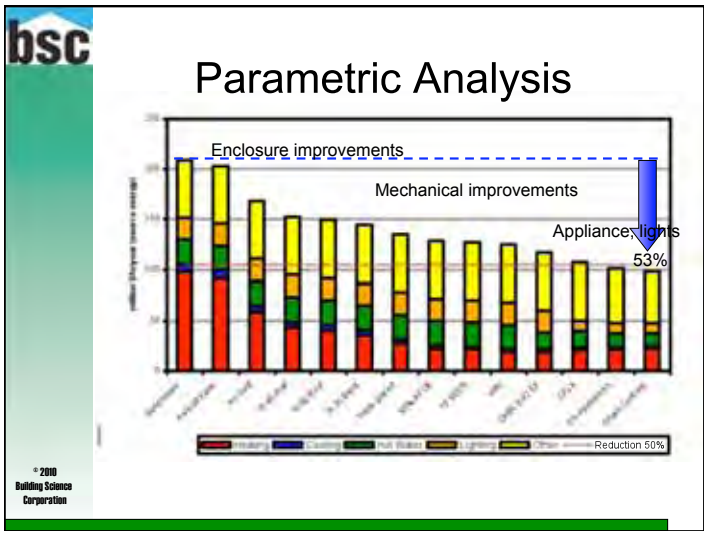
Parametric Analysis
Enclosure improvements
Mechanical improvements
Appliance, lights
53%
Reduction 50%
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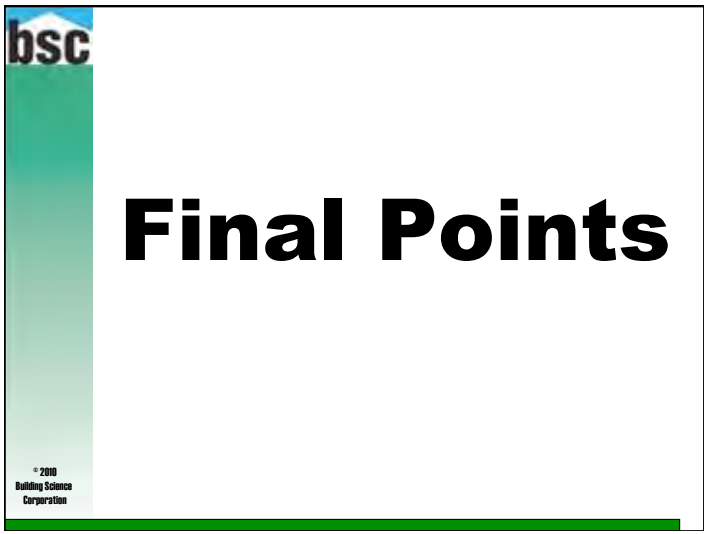
Final Points
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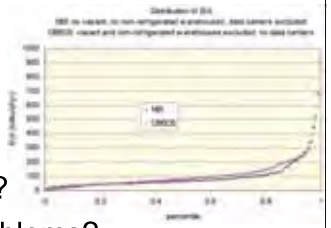
What about LEED?

- A green points-based rating system: energy is only one component
- Some serious disappointments in actual energy performance
- USGBC now requires usage data
- How is the house/ building operated?
- ASHRAE 90.1 problems?



Source: BSI-007: Prioritizing Green—It's the Energy Stupid*

Questions/ Comments