~~John F. Straube~~ Kohta Ueno

Why Energy Matters

February 10, 2011

BETTER BUILDINGS BY DESIGN | 2011

Building Science Corporation

Efficiency Vermont

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

BETTER BUILDINGS BY DESIGN | 2011

Efficiency Vermont

Learning Objectives

At the end of this program, participants will be able to:

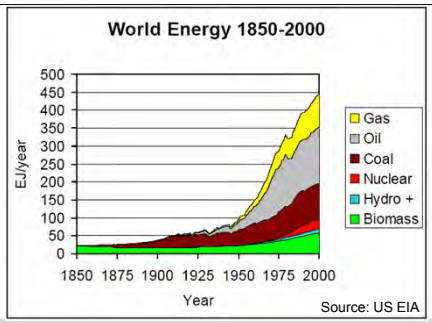
- *Understand a brief overview of the current status of climate change*
- *Demonstrate the importance of energy use in buildings with respect to their impact on the planet*
- *Understand the importance of embodied energy versus energy use over the life of the building*
- *Discuss the importance of good design over a reliance on technology*

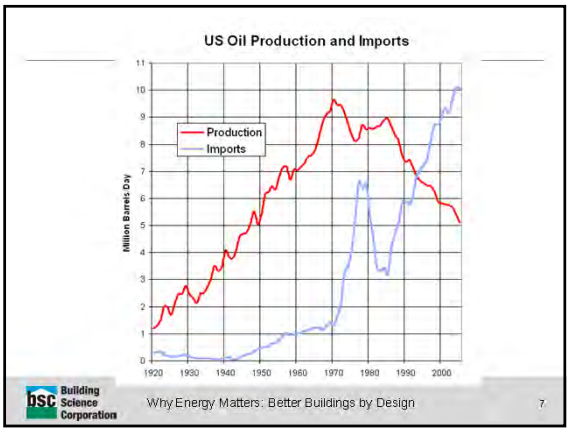
Course Evaluations

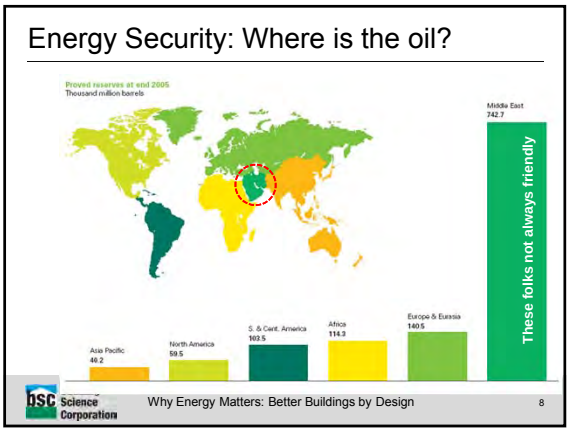
In order to maintain high-quality learning experiences, please access the evaluation for this course by logging into CES Discovery and clicking on the Course Evaluation link on the left side of the page.

Background: Fossil Fuels

Last 150 yrs – Carbon (fossil) fuels

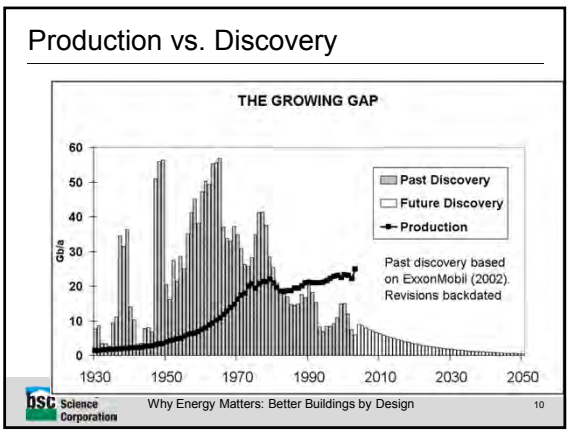






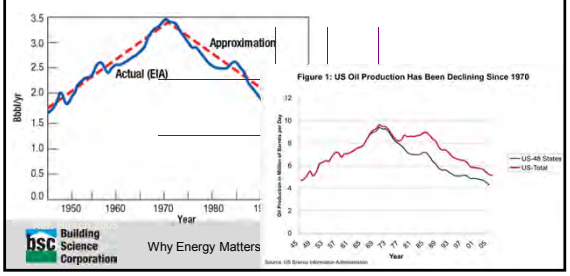
America is no longer in control

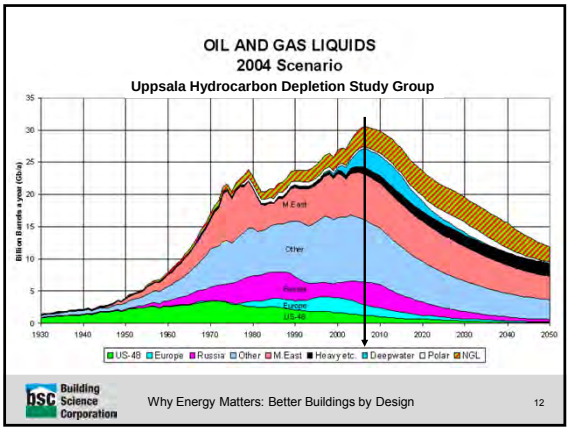
- 80+% reserves in foreign companies (NOC)
- Rebels and unstable governments in control (Venezuela, Nigeria, Russia, Iraq, etc)
- Int. Oil Companies (Exxon, Chevron, Conoco, BP, Shell) produce <20% of oil
- Demand is driven by China, India
- We are now along for the ride . . .



Hubbert's Peak, the "Peak Oil"?

- Shape of oil production in the US lower 48
- Predicting the peak made Hubbert famous



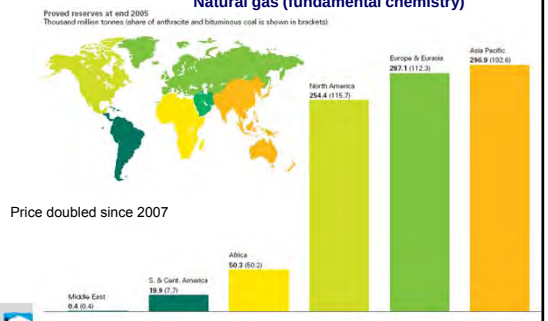


Is this "End of Oil"?

- Peak oil means "half depleted"
- Extraction rate slows
- We will always have some expensive oil
- "The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil."
  - Zaki Yamani, Saudi Oil Minister 1962-1985
- "It is the size of the tap, not the size of the tank that matters"

Coal

- **Fastest Growing Source of Energy (!)**
- **America is the "Saudi of Coal"**
- **Carbon Dioxide production twice that of Natural gas (fundamental chemistry)**



Price doubled since 2007

Coal

- Clean coal (Integrated gasification)
  - None in America (some new plants in Europe)
  - Does not solve CO_2
- Carbon Capture and Sequestration (CCS)
  - Reduces CO_2 output by about 70%
  - No plants anywhere
  - Could be major transitional energy source 2010-2075
- Mining causes environmental damage
- Coal to liquid fuel
  - Well known Fischer-Tropsch process (German WW2)
  - Major CO_2 emissions, lots of coal and money needed

Agriculture will save us?: Biofuels

- Biofuels/mass: wood, ethanol, bio-diesel
- Carbon absorbed by plants -> released when burnt = carbon neutral
- Ethanol for corn 1.2x energy input
- Ethanol sugarcane can 5-8x energy
- Ethanol from cellulose ….eventually
- All assumes SUSTAINABLE FARMING
- All of this COSTS more money

Biofuels & Biofoods

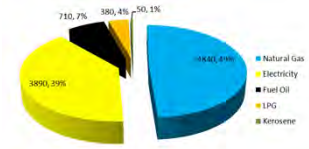
- Ravenous appetite for fuel + poor efficiency of production = major consumer of food crops
- Corn & land prices rising quickly
  - 25% of corn crop in US
- Poor people suffer
  - 1 SUV tank of corn = 1 person year corn
- Water aquifiers depleted to irrigate corn
- Fuel and food get expensive

Renewables

- Biomass
  - Makes sense in limited volumes sustainably grown, esp for liquid fuel, feedstocks
- Photovoltaics
  - Expensive, intermittent, but clear future
  - Printed and organic PV will soon be competitive
- Wind
  - Lowest-cost RE, but intermittent
- Combined Heat and Power (CHP)
- Need Smart Grid

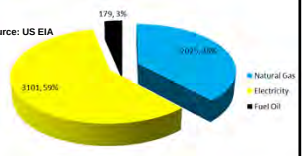
So what does all this have to do with buildings?

Building Energy Use



Residential

Source: US EIA



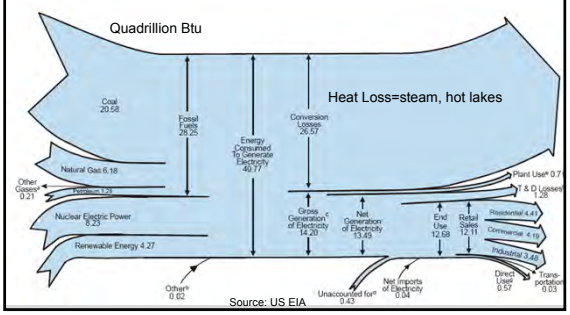
Mostly NG (heating, hot water) and electricity (cooling, lighting, etc.)

Commercial

Source: US EIA

Electrical Energy

½ from coal
Oil very small
2/3 is lost at generating plant
2/3 used in buildings!



Source: US EIA

Buildings, Energy, Pollution

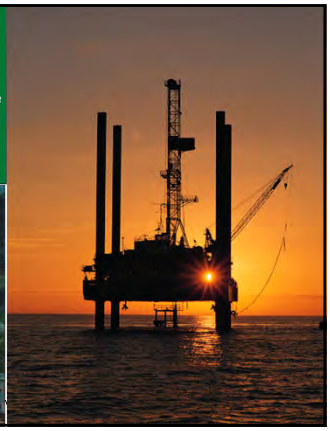
- Buildings consume *68%* of all electricity
- Operation of US buildings
  - Energy over $400 Billion in US
  - 750 million tons of CO_2 per year
  - 38% of US total and 9% of global CO_2 production
  - 49% of US total SO_2

Buildings & the Environment

- Largest single global industry
- Hence, buildings consume resources
  - Lots of materials
  - Lots of energy
  - Lots of money
  - Pollute, displace, and destroy habitats
- Last a long time: A “durable good”
  - Running shoe (1 yr), car (10 yr), bldg (100yr?)
- Hence - more careful long-term design
  - i.e. societal involvement is justified

Resource Depletion & Pollution

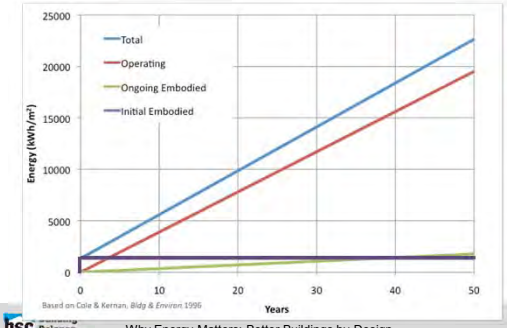
Buildings consume about 40% of North America in production and use



Damage Components

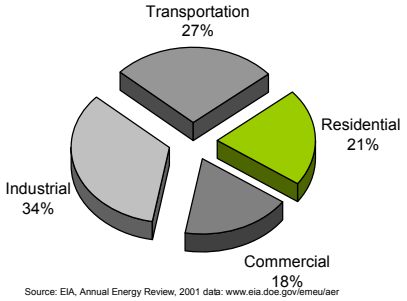
- Resource Extraction
  - Cutting trees, mining, drilling oil, etc.
- Processing
  - Refining, melting, etc. Pollutants and energy
- Transportation
  - Mass and Mode (ship/truck) and Mileage
- Construction
  - Energy, worker transport
- Operational Energy **The Majority of Impact**

Office Building Example



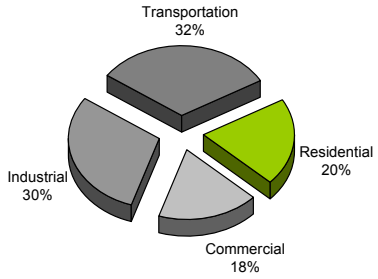
And what about Houses? (Residential)

Primary Energy Consumption by Sector, 2001



Source: EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

Carbon Dioxide Emissions from Energy Consumption by Sector, 2001



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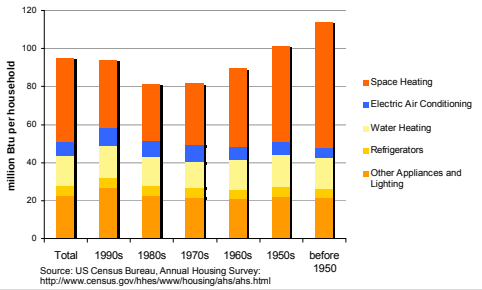
How Houses Use Energy

Total Btu Consumption per Household, 2001



Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

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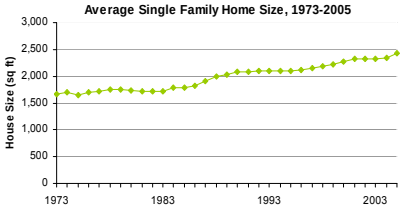
Getting Bigger as Time Goes On

- Average House Size in **1940:** **~1100 sq ft**[1]
- Average House Size in **1973:** **1660 sq ft**[2]

Average Single Family Home Size, 1973-2005



- Average House Size in **2005:** **2434 sq ft**

1. Wilson, Alex and Jessica Boehland "Small is Beautiful" *Journal of Industrial Ecology*, Vol 9, No 1-2. 2005
2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

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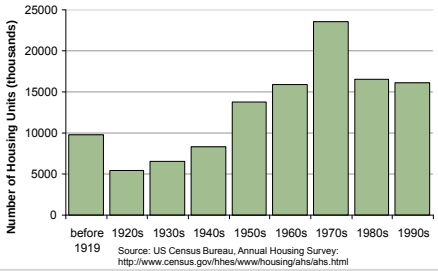
Existing Housing Stock

Age of US Housing Stock (all unit types)



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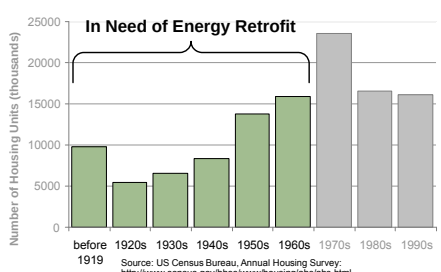

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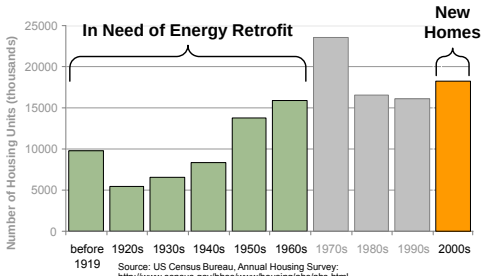

Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

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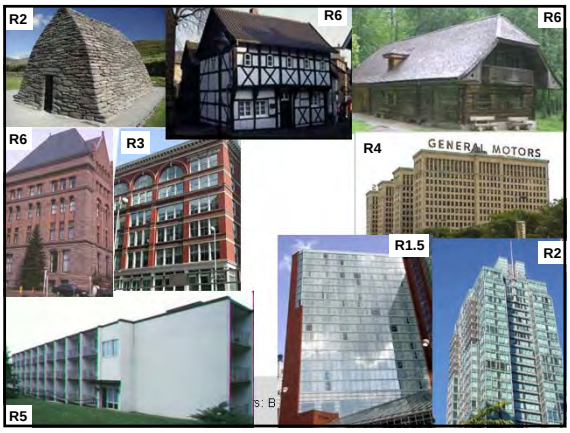
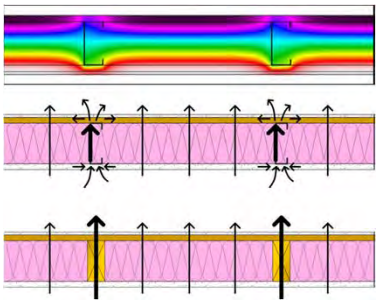
A Bit of History (of building enclosures)

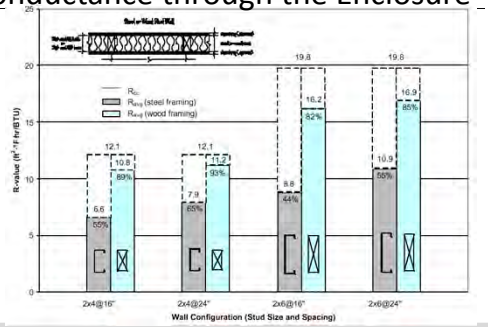


High R Value Assemblies

Conductance through the enclosure



Conductance through the Enclosure



Conductance Thru the Enclosure

"Find the thermal bridge…"
(see BSI-005: A Bridge Too Far)

Eliminate the Thermal Bridge

See BSI-001: The Perfect Wall & BSI-005: A Bridge Too Far

Eliminate the Thermal Bridge

"High R" Metrics for Residential

Climate Zone	Wall	Vented Attic	Compact Roof	Basement Wall	Exposed floor	Slab edge[1]	Windows (U/SHGC)	Sub-slab[2]
1	10	40	35	5	10	none	yes	none
2	15	50	40	10	20	5	0.35/<.25	none
3	20	50	45	10	20	7.5	0.30/<.3	5
4	25	60	45	15	30	7.5	0.30/<.35	7.5
5	30	65	50	15	30	10	0.24/<.50	7.5
6	35	75	60	20	40	10	0.18/--	10
7	40	90	65	25	45	15	0.15/--	15
8	50	100	75	35	50	20	0.15/--	20

Table 0.2: Current Recommended "True" Minimum R-value (+/-)[3] including thermal bridging

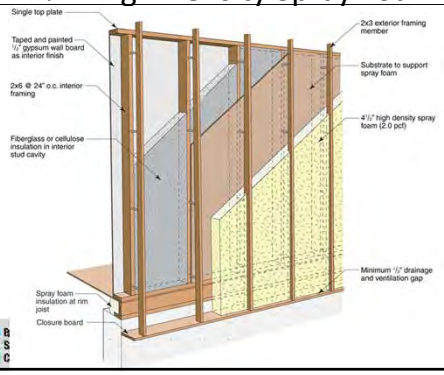
Research Report – 1005: Building America Special Research Project: High R-Value Enclosures for High Performance Residential Buildings in All Climate Zones

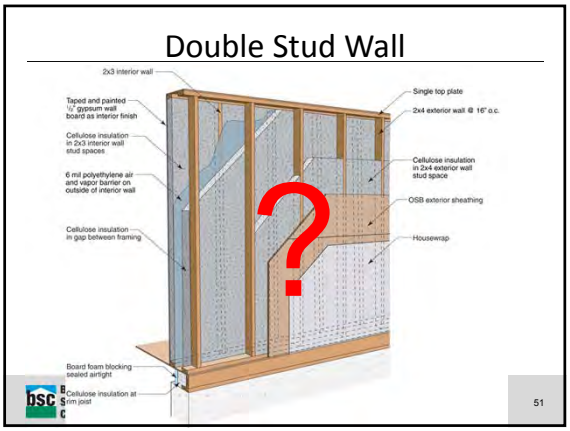
1. Slab edge insulation includes all of stem wall or monolithic slab edge
2. Full area coverage of slabs
3. these are recommended values based on experience - see economics section

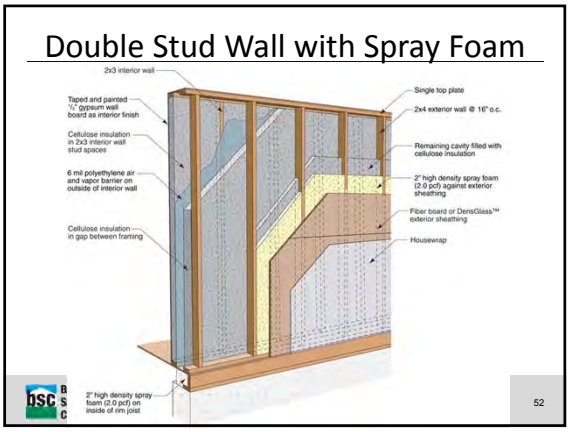
4" Polyisocyanurate Foam

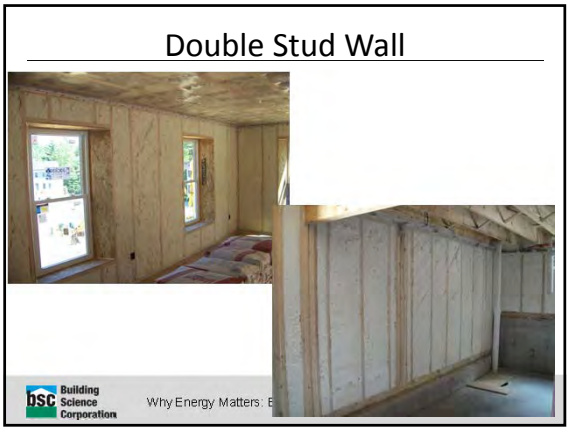
4" Polyisocyanurate Foam

4-½" High Density Spray Foam




Double Stud Wall
2x3 interior wall
Taped and painted ½" gypsum wall board as interior finish
Cellulose insulation in 2x3 interior wall stud spaces
6 mil polyethylene air and vapor barrier on outside of interior wall
Cellulose insulation in gap between framing
Board foam blocking sealed airtight
Cellulose insulation at rim joist
Single top plate
2x4 exterior wall @ 16" o.c.
Cellulose insulation in 2x4 exterior wall stud space
OSB exterior sheathing
Housewrap
?
51


Double Stud Wall with Spray Foam
2x3 interior wall
Taped and painted ½" gypsum wall board as interior finish
Cellulose insulation in 2x3 interior wall stud spaces
6 mil polyethylene air and vapor barrier on outside of interior wall
Cellulose insulation in gap between framing
2" high density spray foam (2.0 pcf) on inside of rim joist
Single top plate
2x4 exterior wall @ 16" o.c.
Remaining cavity filled with cellulose insulation
2" high density spray foam (2.0 pcf) against exterior sheathing
Fiber board or DensGlass™ exterior sheathing
Housewrap
52


Double Stud Wall
Building Science Corporation
Why Energy Matters:


"Superwindows" Now Available
SERIOUS MATERIALS
ThermaProof® 1125
More energy savings than any other window. Period.
R-11
Insulating foam
Proprietary triple reverse seal
Unique warm-edge spacer system
Inert gas fill
Suspended coated film
Wide insulating glass unit
High strength, low conductivity fiberglass frame
Wet glazing
Triple weather stripping*

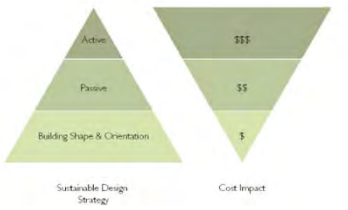
Overall "Green" Strategies

Green Buildings

- Impact the environment less in construction, and operation
- Less impact for same function = **efficient**

Energy Saving Strategies

- Proper choices early on result in no or little in increased cost



Green Strategies

- 1. Keep it simple (compact) & small, orient to sun
- 2. Reduce heat loss and gain
  - Lots of **insulation**, avoid thermal bridges (true R-values)
  - Use very good **windows** (heat and solar)
  - **Airtight**, then control ventilation properly
- 3. Avoid energy use
  - Efficient heating, cooling, lighting, elevators, fans, appliance
  - Use daylighting, motion sensors, etc. Off=very efficient.
- 4. Durable
  - Moisture control: Drained, airtight, drying capacity
- 5. Only then, generate renewable energy
  - Passive solar then active

Energy Metrics

"If you can not measure it, you can not improve it."

-Lord Kelvin (William Thomson)

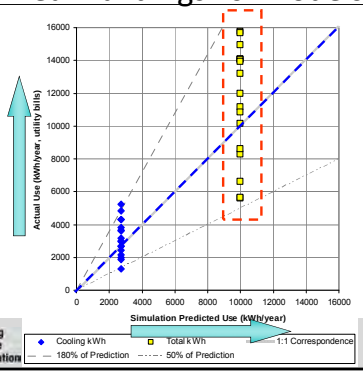
Many "green" buildings don't save energy. Why? They have too much glass, they are over-ventilated, they are leaky to air, they are fraught with thermal bridges and they rely on gimmicks and fads rather than physics.

Joseph W. Lstiburek, PhD, P.Eng., "Prioritizing Green"

Real Buildings vs. Models

- Any comparison "50% vs. compliant house"
  - Energy Star/HERS
  - ASHRAE 90.1 (used in LEED rating)
  - California Title 24
  - Building America Benchmark
- Problem: model not capturing complexity or realities of actual building
- Occupant effects have huge effect on actual building energy use

Real Buildings vs. Models



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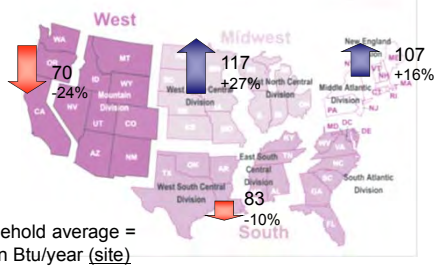
United States EIA Household Averages

- Regional site energy use vs. US average



US household average =
92 million Btu/year (site)

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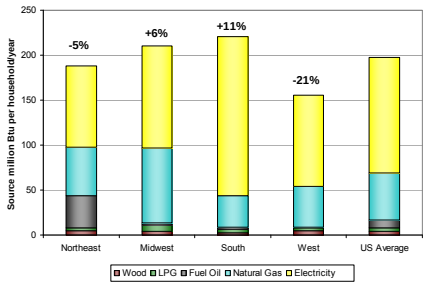
Calculated Source by Region



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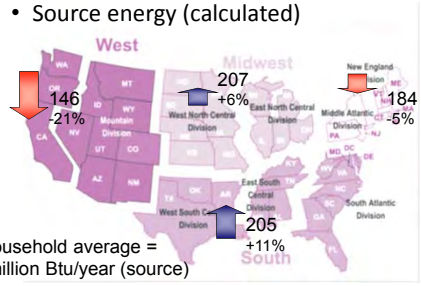
Calculated per household source energy

- Source energy (calculated)



US household average =
187 million Btu/year (source)

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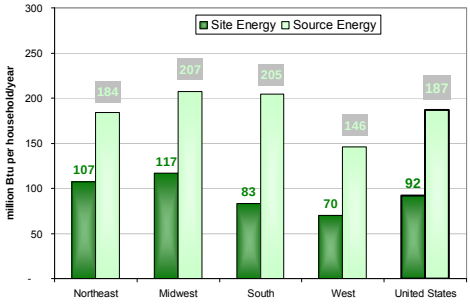
Calculated per household energy



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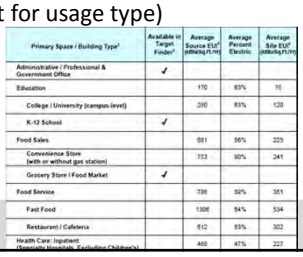
Energy Use Intensity (EUI)

- Normalization by dividing by square footage
- Result is kBtu/sf·year or kWh/m²·year
- Works well for commercial building (if you account for usage type)



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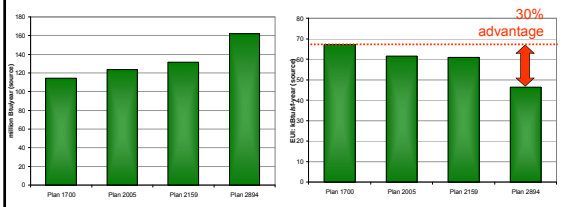
Problems with EUI

- Commercial use vs. residential use
- Accounting for climate
- Small house penalty

Small House Penalty



Per household energy use
Million Btu per year (source)

Energy Use Intensity
kBtu/sf·year (source)

Problems with EUI

- Commercial use vs. residential use
- Accounting for climate
- Small house penalty
- Counting the basement

Other Energy Metrics

- Normalizing for climate: kBtu/sf·year·HDD?
- Normalizing by occupant? "energy per person should always be one of the metrics considered, in addition to indicators that divide energy use by building floor area, dollar of GDP, ton of industrial output, etc."
- Occupants = # Bedrooms + 1? Or # bedrooms?
- All metrics can and will be gamed

To Wrap Up…

Energy Conclusions

- Cheap oil is/may soon run out
  - Energy prices are/will rise
- Climate change is happening
  - Energy efficiency & carbon output restrictions are likely
- Efficiency and renewables only smart path forward
  - Hyper efficiency of enclosures
  - Integration of renewables
  - Retrofit of existing buildings will be needed.

Building Science

- Buildings will need to change
- Need Building Science to develop and implement new technology
  - Knowledge and Science, not opinion and faith
- Materials will change
- Moisture flow impacted by energy flow
  - Will require new assemblies, different HVAC

The Future

- Paradigm shift from “least evil” to “as much good”
- Buildings must eventually
  - Produce energy
  - Clean air and water
  - Enhance local ecology, provide habitat
  - Reuse materials, low-energy recycle

Resources

- BSD-005: Green Building and Sustainability http://www.buildingscience.com/documents/digests/bsd-005-green-building-and-sustainability
- BSD-011: Thermal Control in Buildings http://www.buildingscience.com/documents/digests/bsd-011-thermal-control-in-buildings
- BSD-007: Historical Development of the Building Enclosure http://www.buildingscience.com/documents/digests/bsd-007-historical-development-of-the-building-enclosure
- BSD-151: Understanding Primary/Source and Site Energy http://www.buildingscience.com/documents/digests/bsd151-understanding-primary-source-site-energy
- BSD-152: Building Energy Performance Metrics http://www.buildingscience.com/documents/digests/bsd152-building-energy-performance-metrics
- RR-1005: Building America Special Research Project: High R-Value Enclosures for High Performance Residential Buildings in All Climate Zones http://www.buildingscience.com/documents/reports/rr-1005-building-america-high-r-value-high-performance-residential-buildings-all-climate-zones/view?searchterm=high%20r%20value
- BSI-028: Energy Flow Across Enclosures http://www.buildingscience.com/documents/insights/bsi-028-energy-flow-across-enclosures

Resources

- High R-Value Wall Assemblies http://www.buildingscience.com/resources/high-r-value
- RR-1005: Building America Special Research Project: High R-Value Enclosures for High Performance Residential Buildings in All Climate Zones http://www.buildingscience.com/documents/reports/rr-1005-building-america-high-r-value-high-performance-residential-buildings-all-climate-zones
- BSI-001: The Perfect Wall http://www.buildingscience.com/documents/insights/bsi-001-the-perfect-wall
- BSI-005: A Bridge Too Far http://www.buildingscience.com/documents/insights/bsi-005-a-bridge-too-far
- BSI-007: Prioritizing Green—It's the Energy Stupid* http://www.buildingscience.com/documents/insights/bsi-007-prioritizing-green-it-s-the-energy-stupid/