bsc

University of Waterloo

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Energy, Global Warming, and Buildings

University of Waterloo
Building Science Corporation

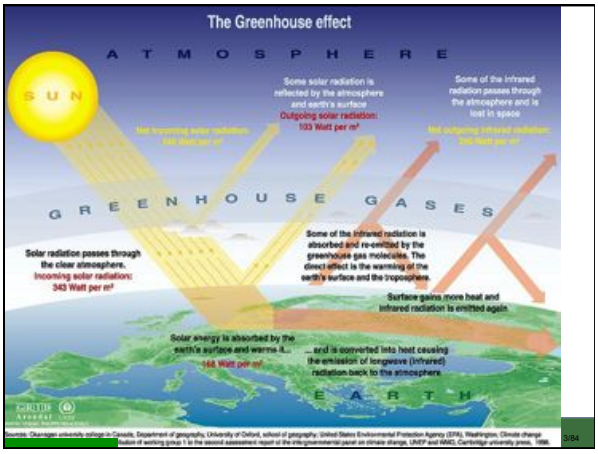
Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

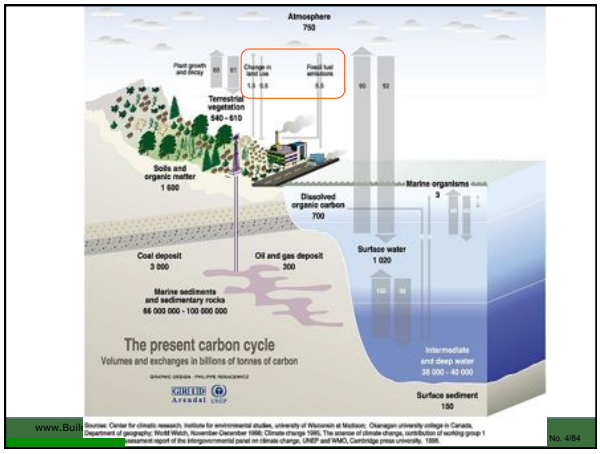
www.buildingscience.com

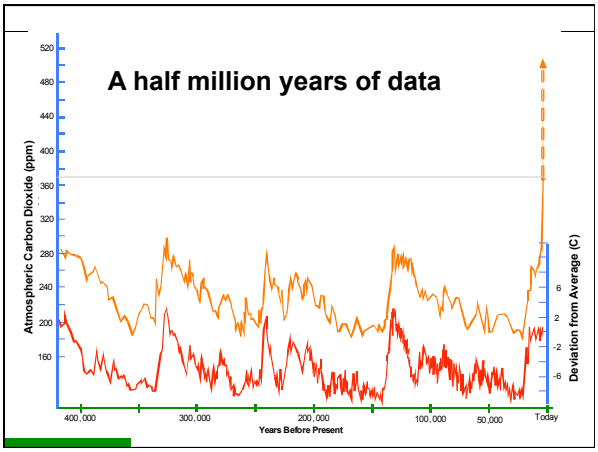
This presentation

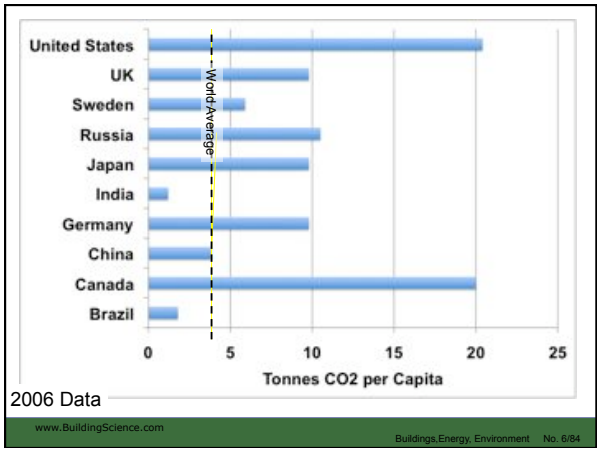
- We have a couple big problems
- Climate Change & Energy Supply
- Solutions?
  - Green Buildings: Net Zero, LEED
  - Hydrogen, biofuels, photovoltaics, etc.
- Role of Building Science

"If we do not change our direction we are likely to end up where we are headed."
- Chinese Proverb

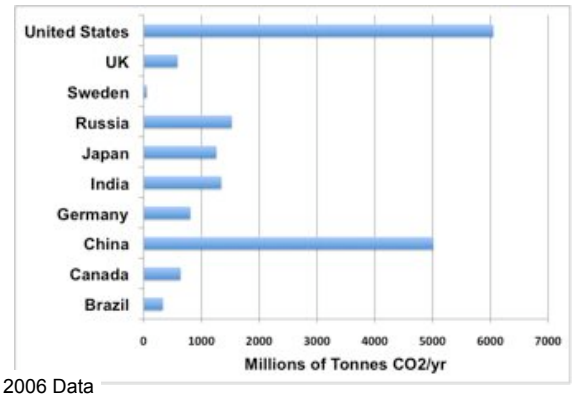






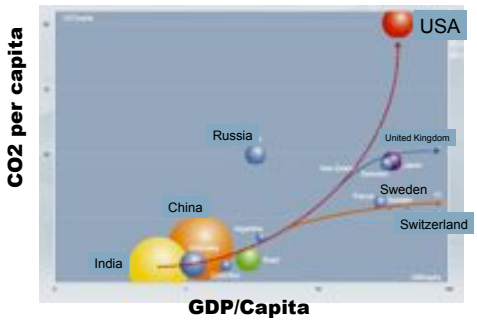


2006 Data



2006 Data

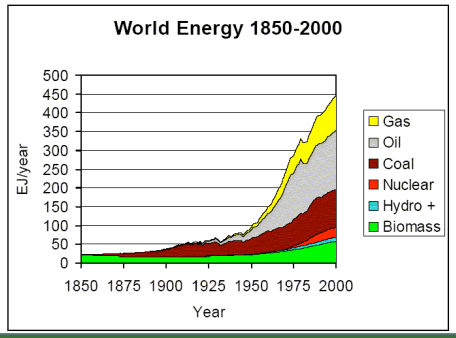
GDP vs CO2: Waste ≠ Wealth



Solution: Emit less Carbon

- Damaging climate change can be minimized by drastically reducing CO_2 emissions
  - Also methane, SF_6 etc.
- *Either* **reduce** fossil fuel consumption
  - Especially coal!
- *Or*, **capture** and **store** carbon
  - Costs money, needs technology

Last 150 yrs – Carbon (fossil) fuels



US
Source: US EIA

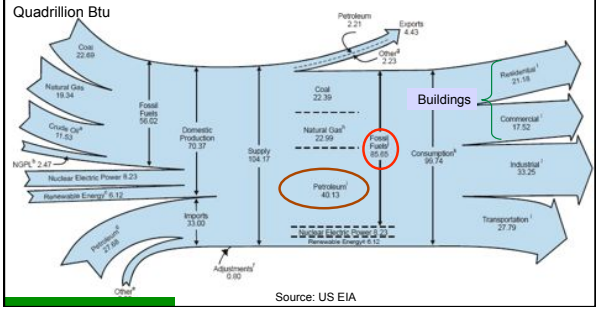
Where does energy come from?

. . . and where does it go?

Total Energy

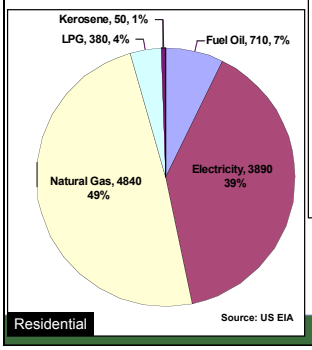
Domestic Supply almost 70%
40% of total supply is petroleum
23%of total supply is Nat gas
Buildings are #1 use (40%)
Urban planning? Embodied Energy?

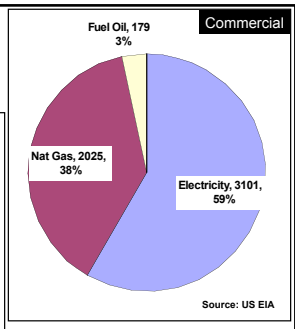
Quadrillion Btu



Source: US EIA

Building Energy Use



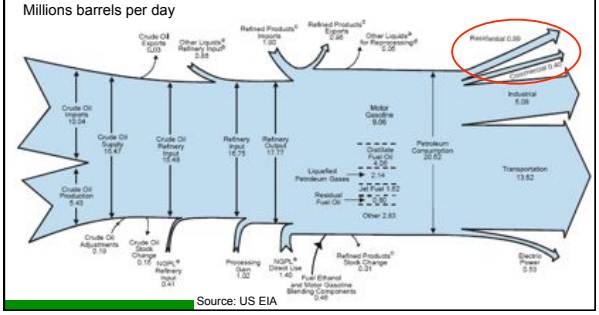


Mostly NG (heating, hotwater) and electricity (cooling, lighting, etc)

Petroleum Energy

2/3 of oil is imported!
2/3 is used in transportation
Building use is negligible

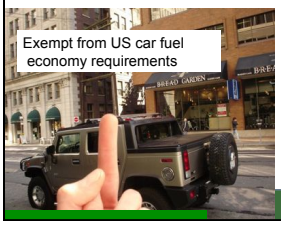
Millions barrels per day

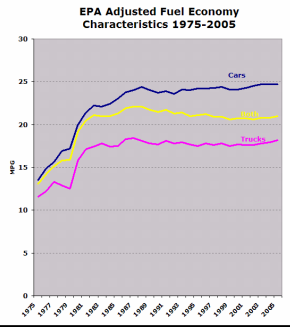


Source: US EIA

Oil & transportation

- Moving backwards
- $4/gallon will help
- Get ready for $6,$8





Future Transportation

- More train and mass transit
  - Already happening
- Plug-in hybrid
  - 100 mpg average
- Light weight vehicles
- Diesel and diesel hybrid
- Fuel cells?:
  - where is the Hydrogen

Competition Cars vs Buildings

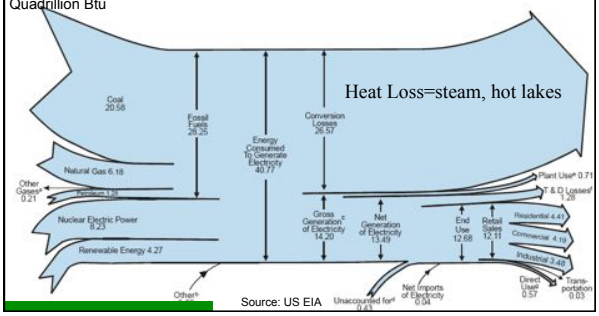
- Chevy Volt (2010)
- Prius Plug-in (2010)
- European diesels are coming….
  - 2008 and on . . .

A new competitor for building energy

Electrical Energy

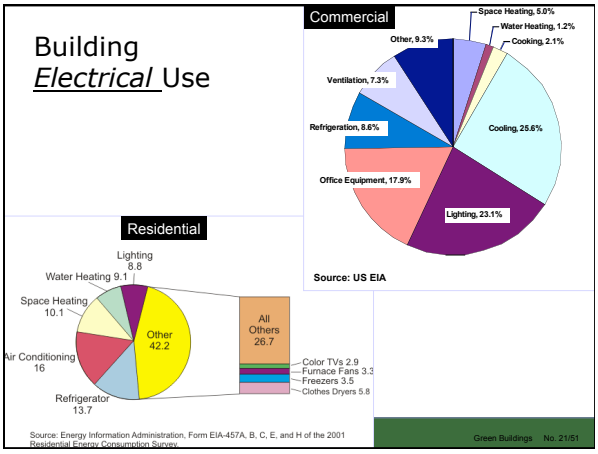
½ from coal
Oil very small
2/3 is lost at generating plant
2/3 used in buildings!

Quadrillion Btu



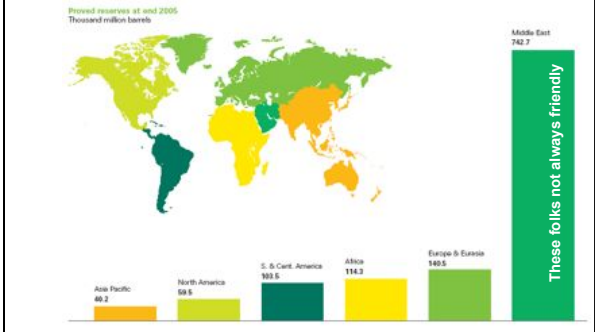
Source: US EIA

Building *Electrical* Use



Energy Security & Oil

Energy Security: Where is the oil?

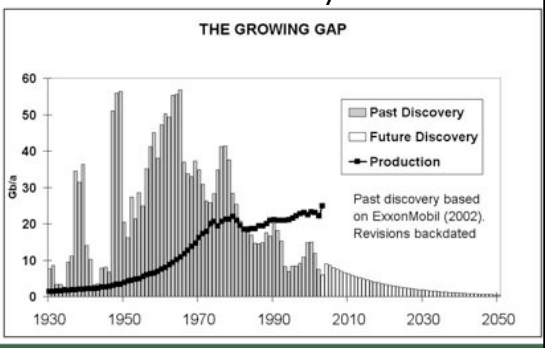


America is no longer in control

- 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 . . .

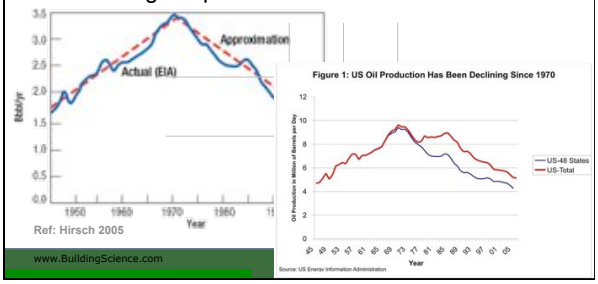
Chevron Energy Ad 2005

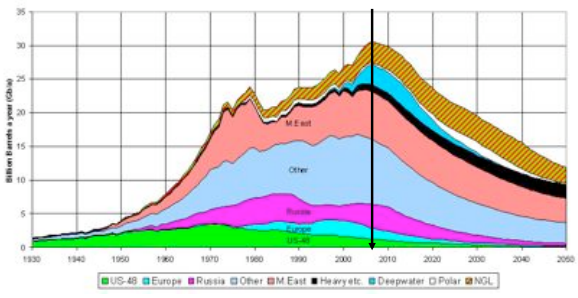
Production vs Discovery



Hubbert's Peak, the "Peak Oil"?

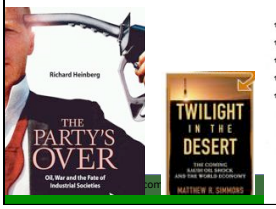
- Shape of oil production in the US lower 48
- Predicting the peak made Hubbert famous

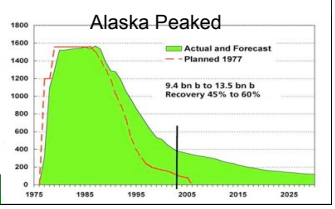




Peaking happens, is happening

- The world's 2nd largest field (Burghan, Kuwait) and 3rd largest (Cantarell , Mexico) both have peaked
- North Sea oil peaked, now 7%+ decline





Is this "End of Oil"?

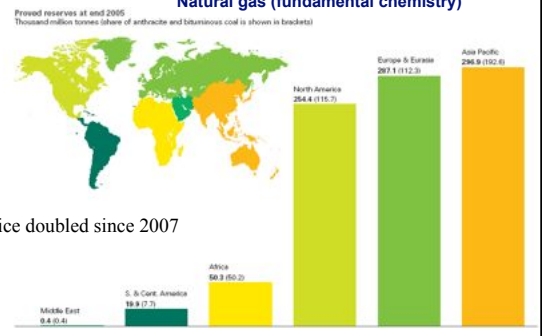
- Peak oil means "half depleted"
- Extraction rate slows
- We will always have some expensive oil
- "The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil."
  - Zaki Yamani, Saudi Oil Minister 1962-1985
- "It is the size of the tap, not the size of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

Prognosis

- Cheap % easy oil is running out
- Oil price increases will:
  1. Increase production (hard but worth it)
  2. Increase the cost of all energy (esp. natural gas)
  3. Reduce consumption (**efficiency**, switching)
  4. Stimulate alternative technology development (biofuel)
  5. Create global recession? and thereby reduce demand
- Can we react quickly enough?

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 CO2
- Carbon Capture and Sequestration (CCS)
  - Reduces CO2 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 CO2 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

Climate Change vs Energy Security

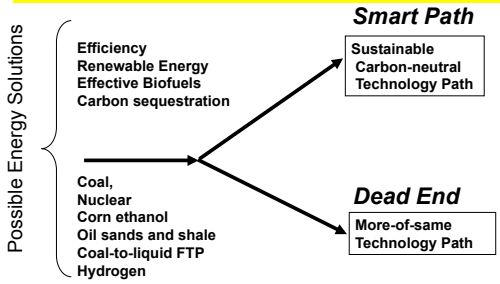
- Many proposed "energy solutions" result in equal or much greater carbon emissions
  - Coal
  - Tar sands
  - Coal to liquids
- Any energy source that generates more CO2 is a dead end.

Climate Change vs Energy Security

- Climate hange is happening,
  - only when and what/how bad
  - Solution – reduce CO2 through efficiency, RE, sequester
- Energy Security is a "coupled" issue
  - Solution - efficiency and/or new energy sources (coal?)
- Solving Energy Security incorrectly will worsen Climate Change
- Solving Climate Change correctly also solves Energy Security

Path

All of this means energy is going to cost more
•We will want more insulation
•We will want more airtightness
•We will want more efficient equipment



What does all this have do with buildings?

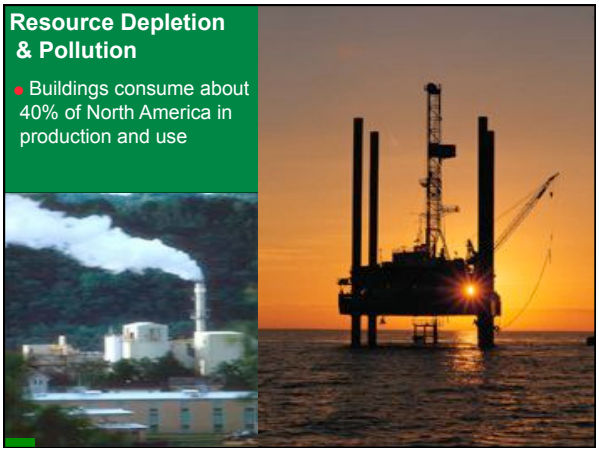
And building science?

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



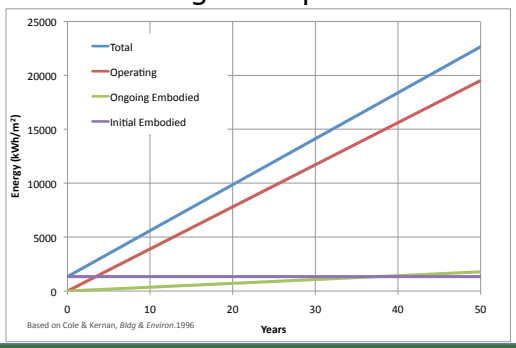
Damage Components

- 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

www.BuildingScience.com Buildings.Energy. Environment No. 45/84

Office Building Example



Building Science 2008 Green Buildings No. 46/51

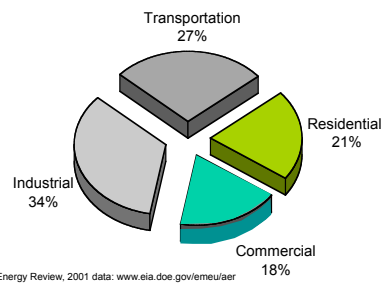
Buildings, Energy, Pollution

- 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

www.BuildingScience.com Buildings.Energy. Environment No. 47/84

Building Energy Use

Primary Energy Consumption by Sector, 2001

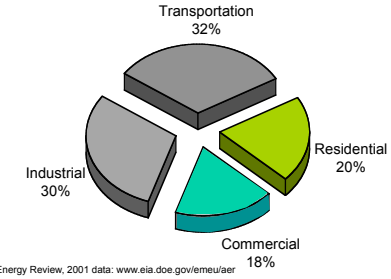


Source: EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

www.BuildingScience.com Buildings.Energy. Environment No. 48/84

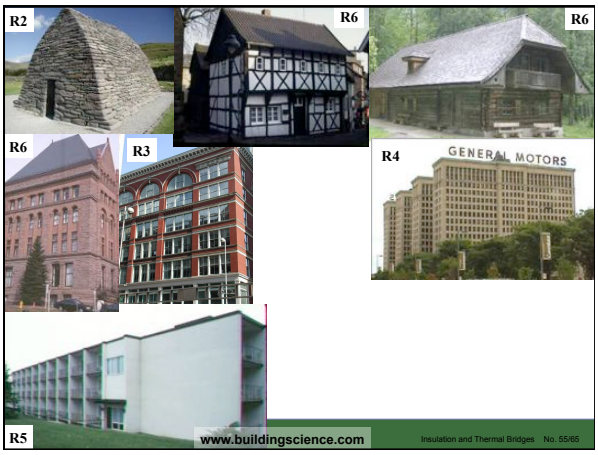
Building Carbon Emissions

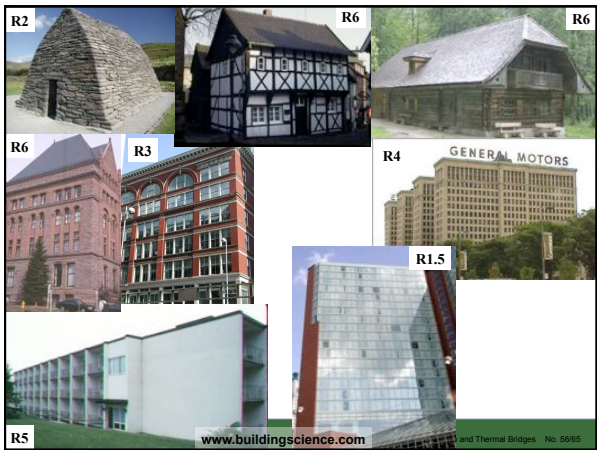
Carbon Dioxide Emissions from Energy Consumption by Sector, 2001



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

…n - History


R2
R6
R6
R6
R3
R4
GENERAL MOTORS
R5
www.buildingscience.com


R2
R6
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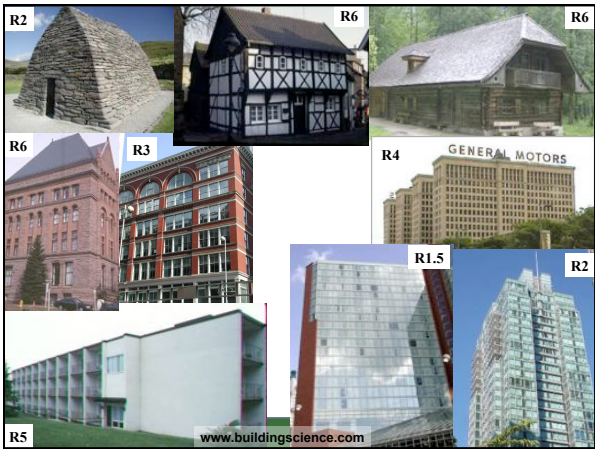
GENERAL MOTORS
R1.5
R5
www.buildingscience.com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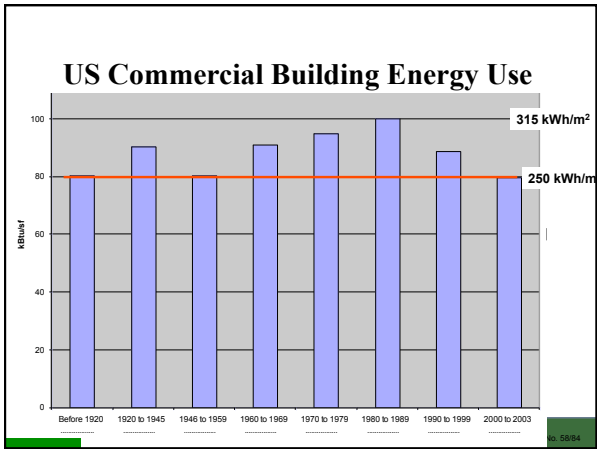
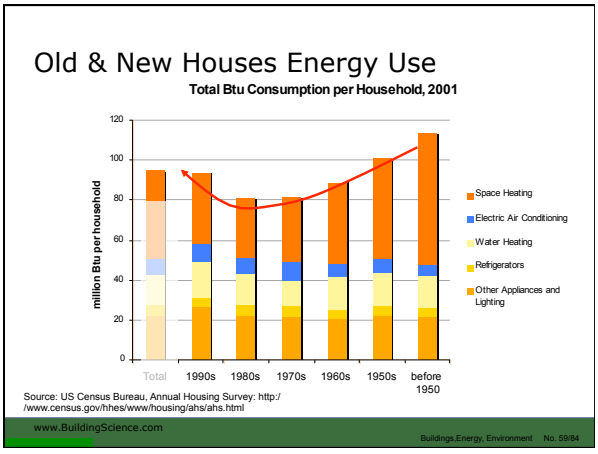
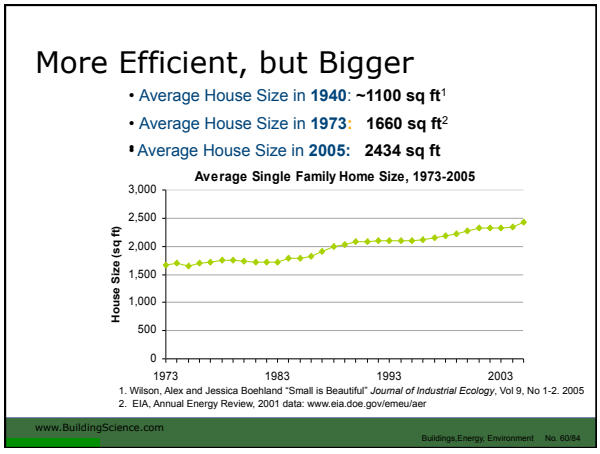
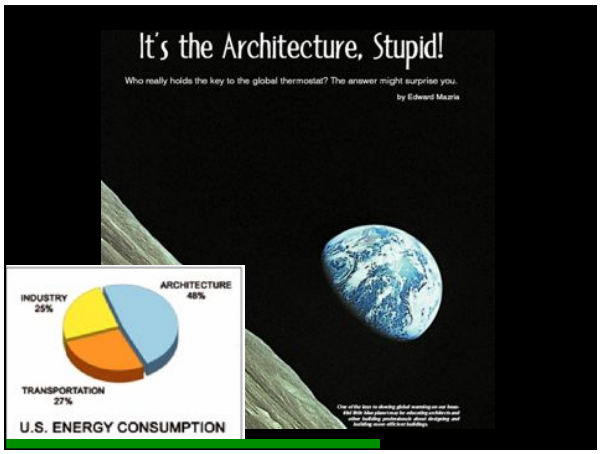

US Commercial Building Energy Use
315 kWh/m²
250 kWh/m
kBtu/sf
100
80
60
40
20
0
Before 1920
1920 to 1945
1946 to 1959
1960 to 1969
1970 to 1979
1980 to 1989
1990 to 1999
2000 to 2003


Old & New Houses Energy Use
Total Btu Consumption per Household, 2001
million Btu per household
120
100
80
60
40
20
0
Total
1990s
1980s
1970s
1960s
1950s
before 1950
Space Heating
Electric Air Conditioning
Water Heating
Refrigerators
Other Appliances and Lighting
Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html
www.BuildingScience.com


More Efficient, but Bigger
• Average House Size in 1940: ~1100 sq ft[1]
• Average House Size in 1973: 1660 sq ft[2]
• Average House Size in 2005: 2434 sq ft
Average Single Family Home Size, 1973-2005
House Size (sq ft)
3,000
2,500
2,000
1,500
1,000
500
0
1973
1983
1993
2003
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
www.BuildingScience.com

We can and must do better

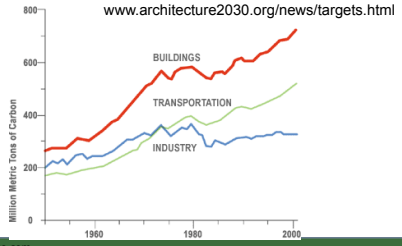
- Easy to reduce consumption
- Need to reduce 30 to 50% ASAP
  - R21 batts instead of R19 is not enough
- Need to measure it correctly
  - Actual energy use



Mazria 2030 Challenge

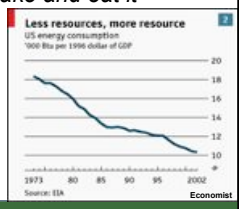
- Set targets, measure performance
  - 60% reduction by 2010

www.architecture2030.org/news/targets.html



Energy & Efficiency

- People want services not energy
  - Warm house, not natural gas
  - Light, not electricity
- Efficiency means "*have our cake and eat it*"
- Efficiency= less waste
- Energy reductions after '73 / '79
- "Stop the bleeding!"



United Nations IPCC Mitigation Report May 2007

"Biggest & Cheapest CO2 reduction are in buildings"

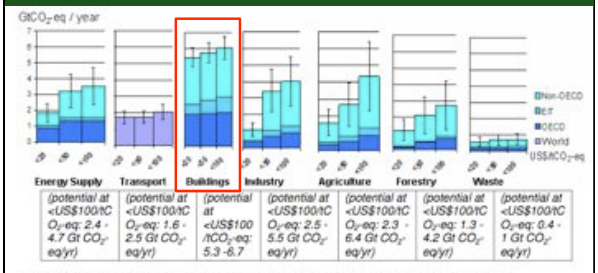
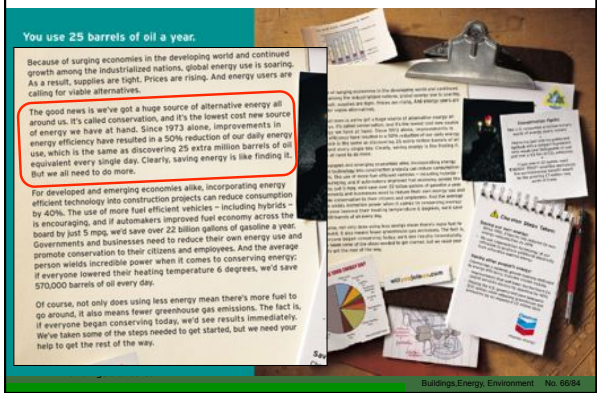


Figure SPM 6: Estimated sectoral economic potential for global mitigation for different regions as a function of carbon price in 2030 from bottom-up studies, compared to the respective baselines assumed in the sector assessments. A full explanation of the derivation of this figure is found in 11.3.



Royal Dutch Shell Chief Executive Jeroen van der Veer's article in The Times (London), published on 25 June 2007.
25-Jun-2007

Efforts to fight global warming will be wasted unless we concentrate on energy efficiency.

When it comes to the future of energy, the world needs a reality check. Contrary to public perceptions, renewable energy is not the silver bullet that will soon solve all our problems. Indeed, in the decades ahead, three hard truths will generate turbulence in the global energy system.

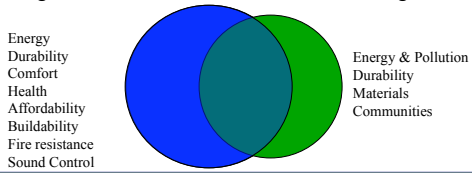
We all know that global demand for energy is growing, but the reality of how fast hasn't really sunk in. The first hard truth is that demand is accelerating. Energy use in 2050 may be twice as high as it is today, or higher still. The main causes are population growth, from six to more than nine billion people, and higher levels of prosperity. China and India are entering the energy-intensive phase of their development. This is the point when people buy their first television or car, or board a plane for the first time, and start to consume much more transport fuel and electricity. And most people in China and India have never boarded a plane yet! The pace of change is startling. Last year, China enlarged its electricity capacity by roughly the equivalent of Great Britain's entire stock of power stations.

The second hard truth is that the growth rate of supplies of "easy oil", conventional oil and natural gas that are relatively easy to extract, will struggle to keep up with accelerating demand. Just when energy demand is surging, many of the world's conventional oilfields are going into decline. The problem is not the availability of resources as such. Overall, the International Energy Agency believes that there could be roughly 20 trillion barrels oil equivalent of oil and natural gas in place. This includes both conventional and unconventional resources, such as oil shale and sands. In theory, this is enough to keep us going for about 400 years at the current rate of consumption. In practice, though, less than half can be recovered with existing technology. The world now produces 135 million barrels oil equivalent a day of oil and natural gas. We could still raise that number with new technologies, but only gradually and certainly not indefinitely.

The third hard truth is that increased coal use will cause higher CO2 emissions, possibly to levels we deem unacceptable. The IEA believes that coal use could grow by around 60 per cent in the next 20 years. The main reason that countries turn to coal is energy security. China and India will continue to exploit their domestic coal reserves to be less dependent on oil and gas imports. So will the United States, which even now generates more than half its electricity with coal. But burning coal for electricity generates twice as much CO2 as burning natural gas. Gasifying coal, instead of burning it, reduces

Building Science=Green Buildings

- Building Science?
  - The science of making buildings that work
- Green Buildings?
  - Buildings that reduce environmental damage



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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

Building Science 2008
Green Buildings No. 69/51

Building Science & Energy

- Increasing resistance to heat flow
  - Better insulation values
  - Reduced thermal bridges
  - Better air leakage resistance
  - Better windows
  - Better solar control
- Impact of above on moisture & durability

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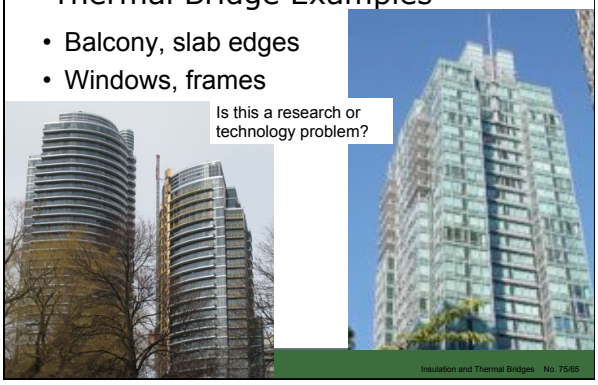
Buildings,Energy, Environment No. 70/84

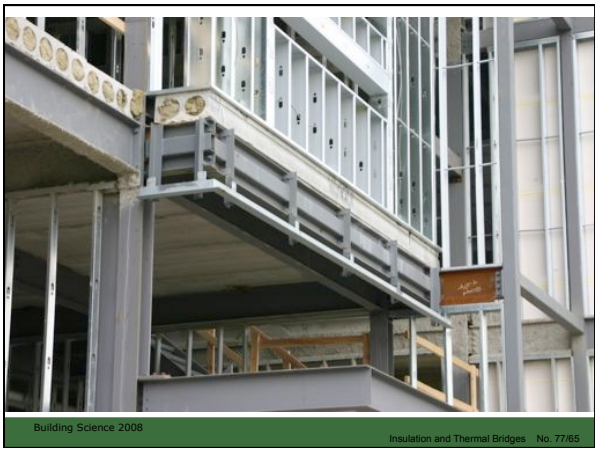
Window vs Wall Performance

	Window	Wall	Ratio
Conduction: Q_c=U ΔT	**U=0.33 / R3**	**U=0.05 / R20**	
T_{in}=70 F T_{out}=10 F	**Q_c= 20** Btu/sf/hr	**Q_c= 3** Btu/sf/hr	**6.6**
Solar: Q_s = SHGC I	**SHGC=0.60**	**SHGC=0.015**	
I_s= 250 Btu/sf/hr (bright sun)	**Q_s= 150** Btu/sf/hr	**Q_s=3.5** Btu/sf/hr	**42**
Alternate: solar control glazing	SHGC=0.3 Q_s= 75 Btu/sf/hr	U=.125 / R8 Q_c= 7.5	10

Thermal Bridge Examples

- Balcony, slab edges
- Windows, frames

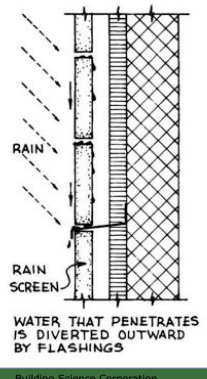


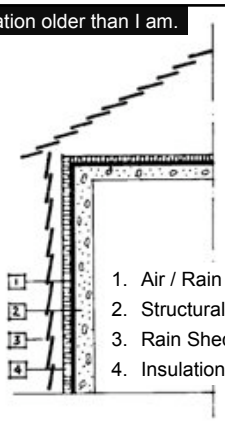


This is not a research problem!

- Education
- Values
- Economic sticks & carrots
- Real measures/enforcement of heat flow control
  - R-value
  - Airtightness
  - Solar Control

Design Information older than I am.

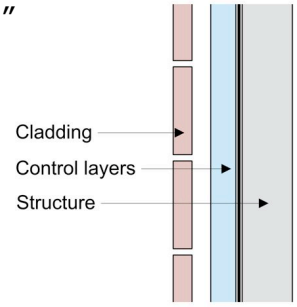


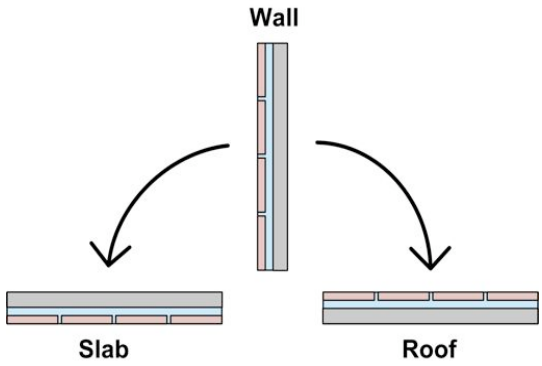


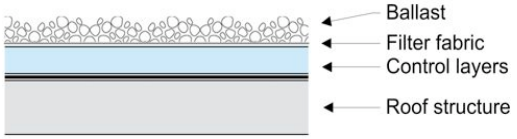
1. Air / Rain Barrier
2. Structural Support
3. Rain Shedding
4. Insulation

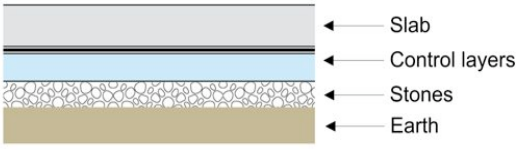
The "Perfect Wall"

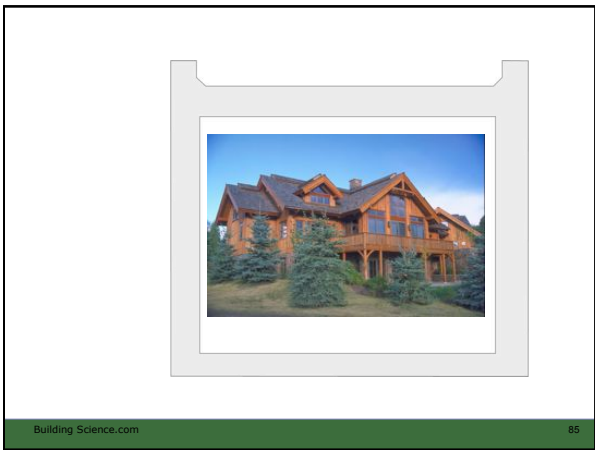
- Finish of whatever
  - May need ventilation
- Control layer continuity
  - Drainage gap + plane
  - Air barrier
  - Insulation
  - Vapor control
- Structure can be anything







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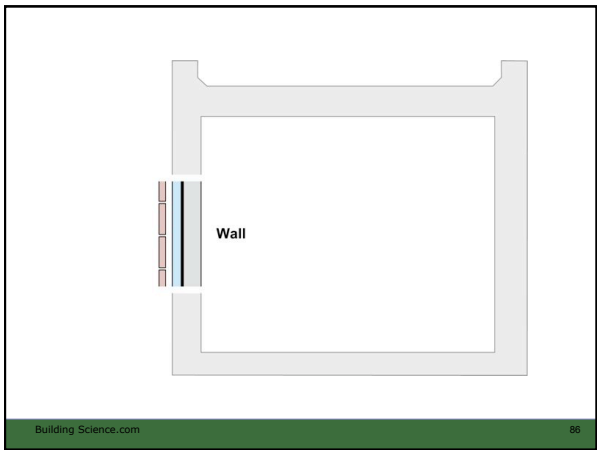
Wall
Building Science.com
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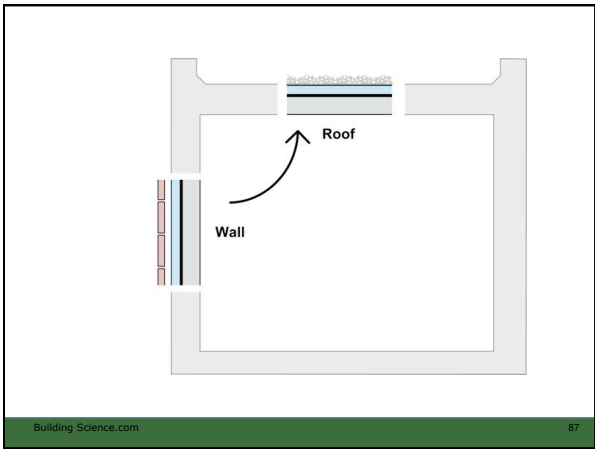
Roof
Wall
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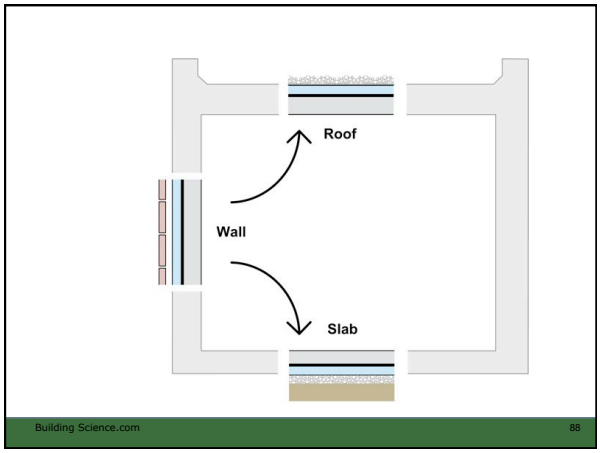
Roof
Wall
Slab
Building Science.com
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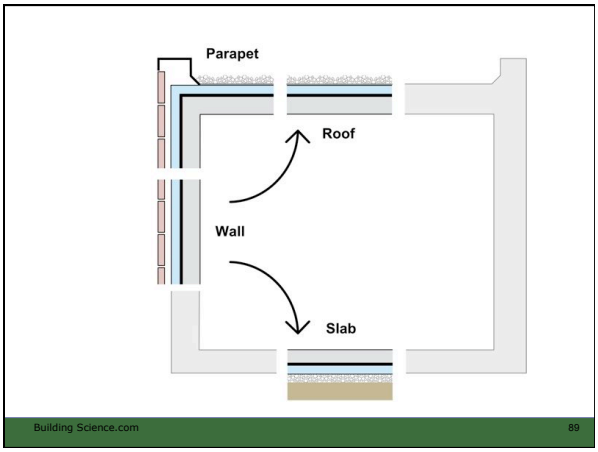
Parapet
Roof
Wall
Slab
Building Science.com
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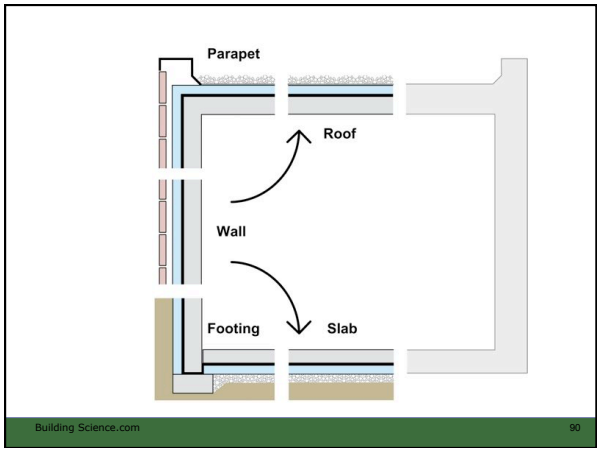
Parapet
Roof
Wall
Footing
Slab
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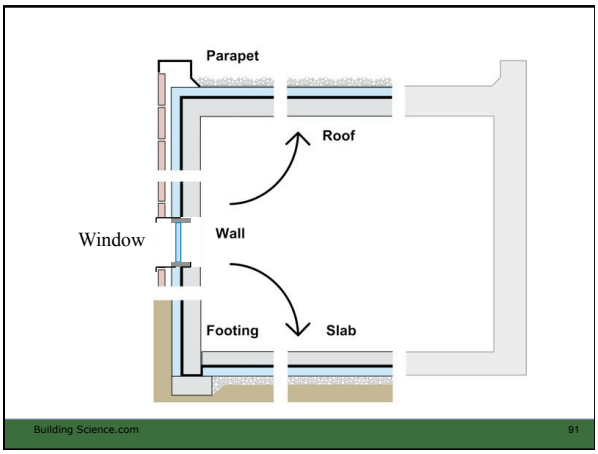
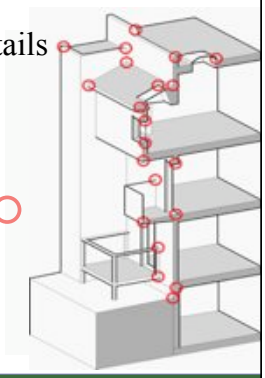
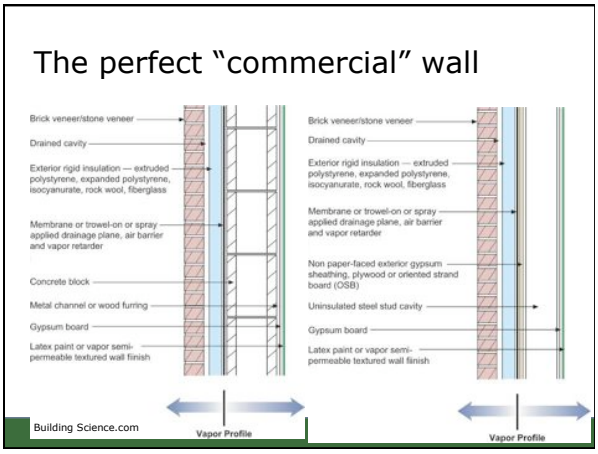


Enclosure Design: Details

- Details demand the same approach as the enclosure.
- Scaled drawings required at

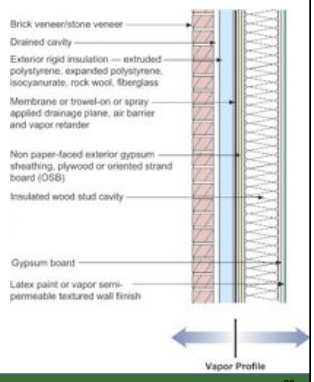


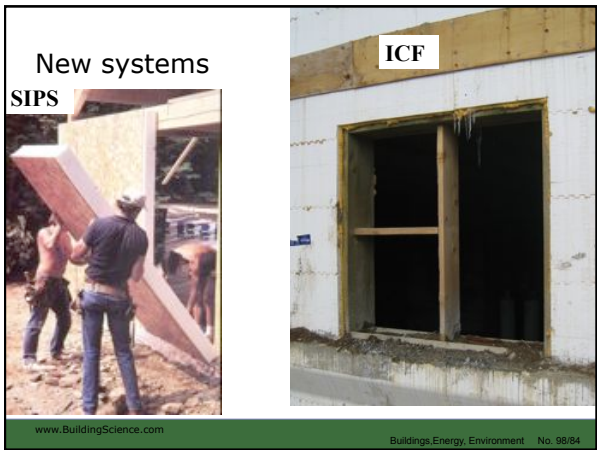
The perfect "commercial" wall



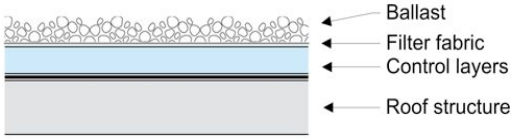
More challenging

- Compromise
  - Wood studs
    - Wood insulates
  - High R-value steel
    - R40+
- The future?
  - Net-zero
  - Carbon neutral

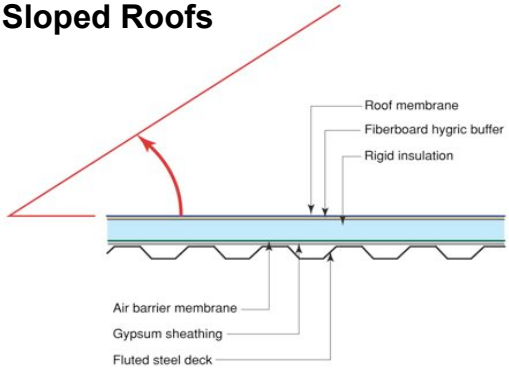




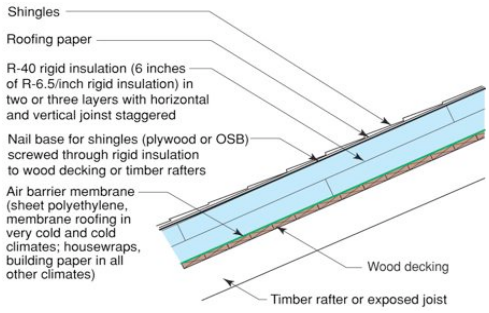
Low Slope Roofs



Sloped Roofs



Unvented Sloped Roofs



Energy Efficiency & Durability

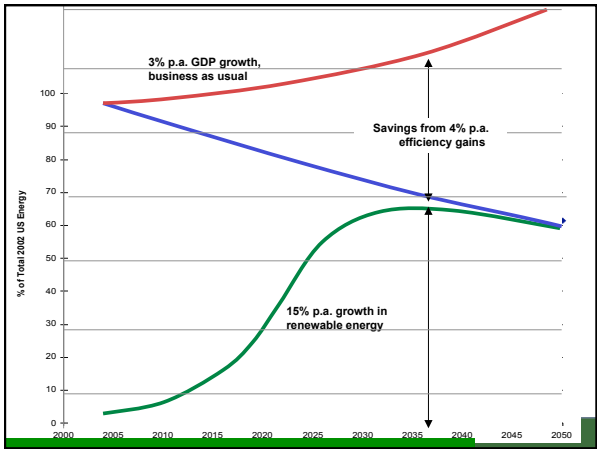
- Better insulation means
  - Cold exterior and/or interior surface
  - More extreme variations at exterior
  - Colder surfaces
    - = more likely condensation
    - = higher RH = higher moisture content
- More insulation reduces durability!
- Air leakage dried as well as wets
  - Airtightness can reduce drying!

Efficient Enclosures & HVAC

- Airtight buildings require ventilation systems
  - Don't over ventilate. Quality≠Quantity
- Better windows, insulation and lighting
  - = Low heat gain
  - = dehumidification, less sensible cooling
- Thermal mass matters more
- Different HVAC systems can now be applied
  - Radiant cooling

Efficiency, Renewables, Retrofits

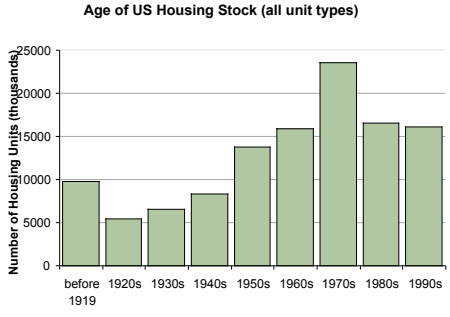
- Reducing energy wasted (efficiency) allows renewables to be economically and environmentally practical
  - Need to increase Energy Return on Investment
- Huge existing stock of buildings, means:
  - **Energy-efficient retrofits** must be part of any solution
- Both renewables and retrofit are needed!



Existing building

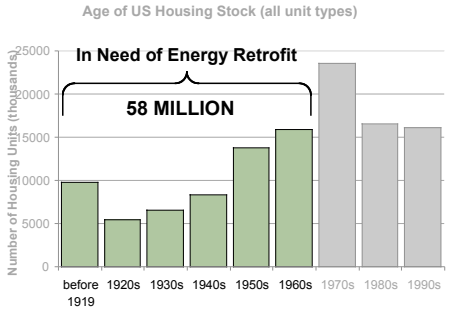
- About ¼ of all households were built before 1950
- Almost ¾ before 1980
- 80% of residential energy is consumed by homes built 1980 or earlier
- This is a *huge* energy consumption sector
- Retrofit solutions need to address this!
- Good news: some low-hanging fruit
  - Attics, airtightening, efficient furnaces, windows, insulated over clad

Existing Housing Stock



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

Existing Housing Stock



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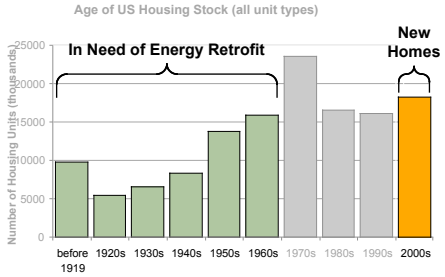
Existing Housing Stock



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

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

- Need Building Science to develop and implement new technology
  - Knowledge and Science, not opinion and faith
- Buildings will need to 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

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Thanks

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Building America U.S. Department of Energy Research Toward Zero Energy Homes