Climate Change Basics

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

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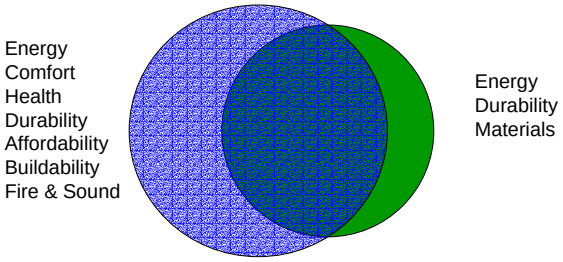
This presentation

- Climate Change, Peak oil, etc
- Green Buildings
  - What, How

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

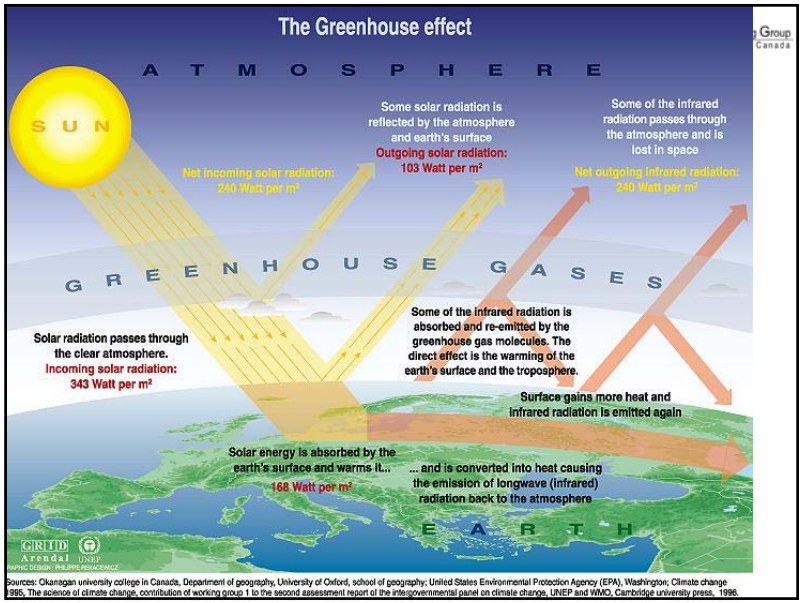
Building Science=Green Buildings

- What is Building Science
  - The science of making buildings that work
- What are Green Buildings
  - Buildings that work . . . well

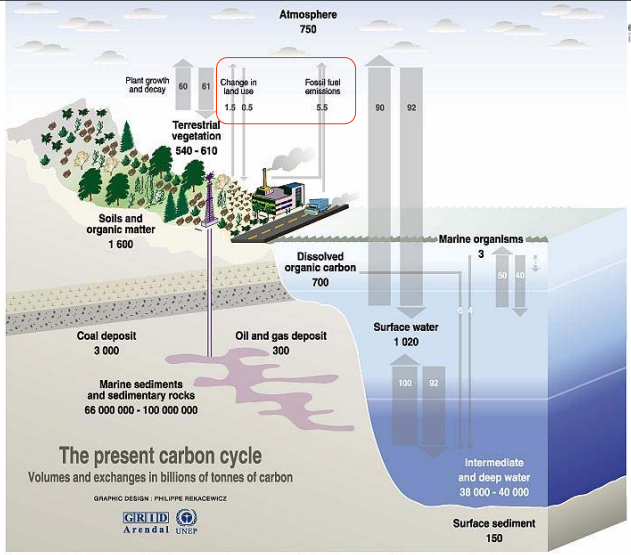


Climate Change

- Carbon dioxide is a very small percentage of atmosphere, BUT
  - It allows visible solar energy through atmosphere
  - It does not allow absorbed solar energy to leave
  - Acts just like high solar low-e glass



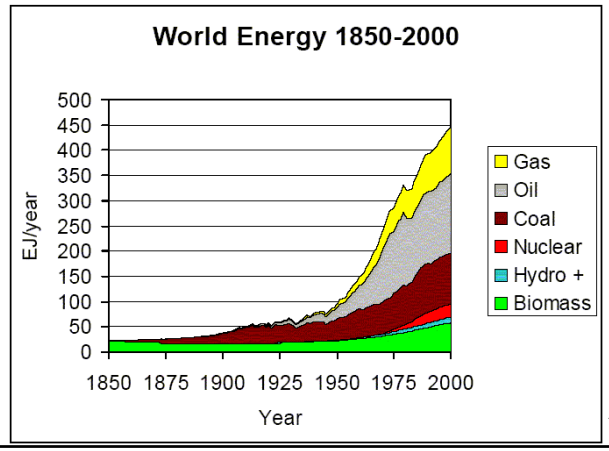
Sources: Okanagan university college in Canada, Department of geography; University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.



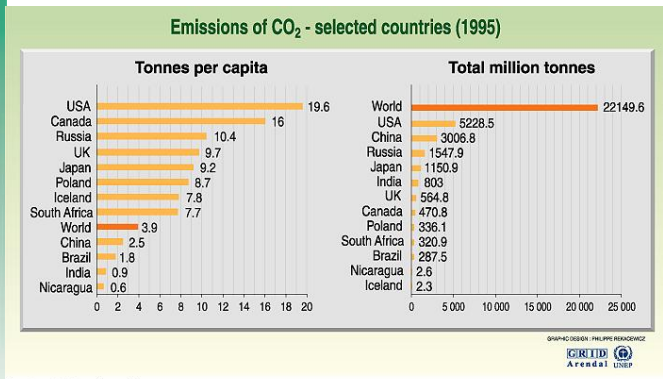
Sources: Center for climatic research, Institute for environmental studies, university of Wisconsin at Madison; Okanagan university college in Canada, Department of geography; World Watch, November-December 1998; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

US
Source: US EIA

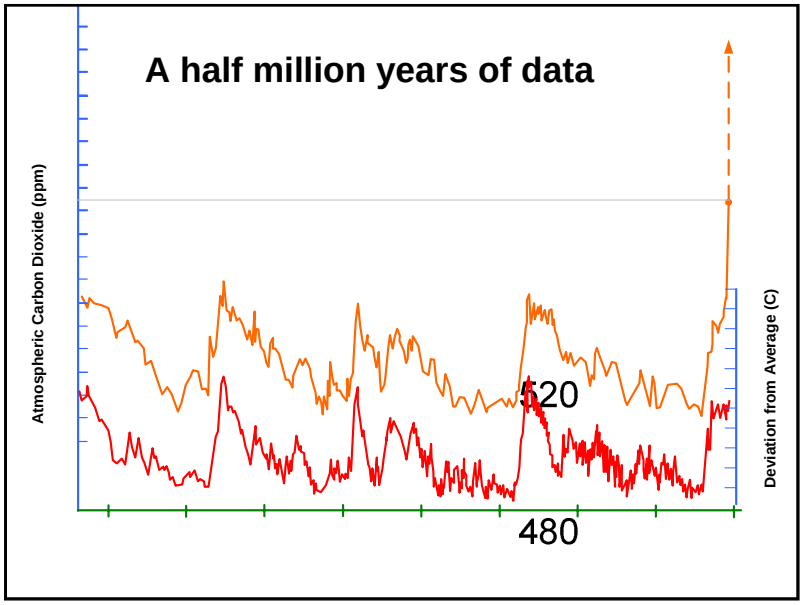
Last 150 yrs – more fossil fuels

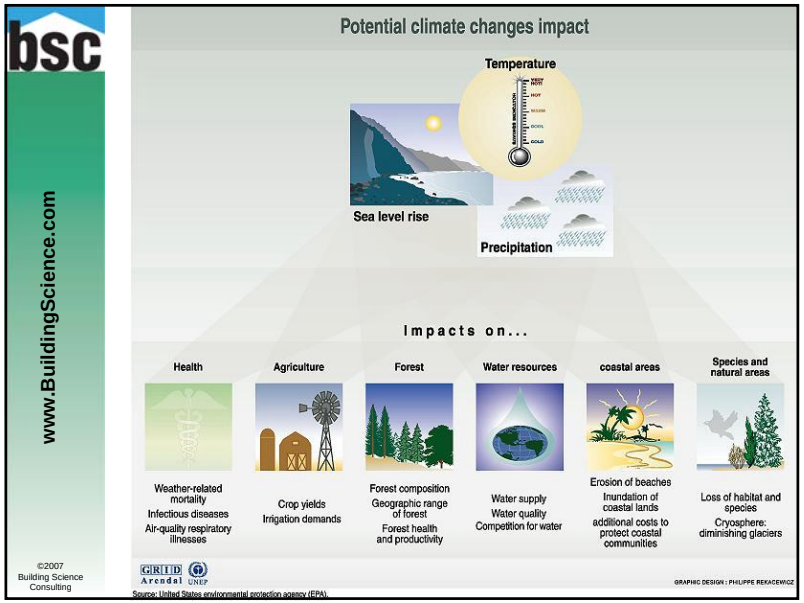


Who is emitting what?



Source : International Energy Agency, 1998.


A half million years of data
Atmospheric Carbon Dioxide (ppm)
Deviation from Average (C)
520
480
440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Potential climate changes impact
Temperature
Sea level rise
Precipitation
Impacts on...
Health
Agriculture
Forest
Water resources
coastal areas
Species and natural areas
Weather-related mortality
Infectious diseases
Air-quality respiratory illnesses
Crop yields
Irrigation demands
Forest composition
Geographic range of forest
Forest health and productivity
Water supply
Water quality
Competition for water
Erosion of beaches
Inundation of coastal lands
additional costs to protect coastal communities
Loss of habitat and species
Cryosphere: diminishing glaciers
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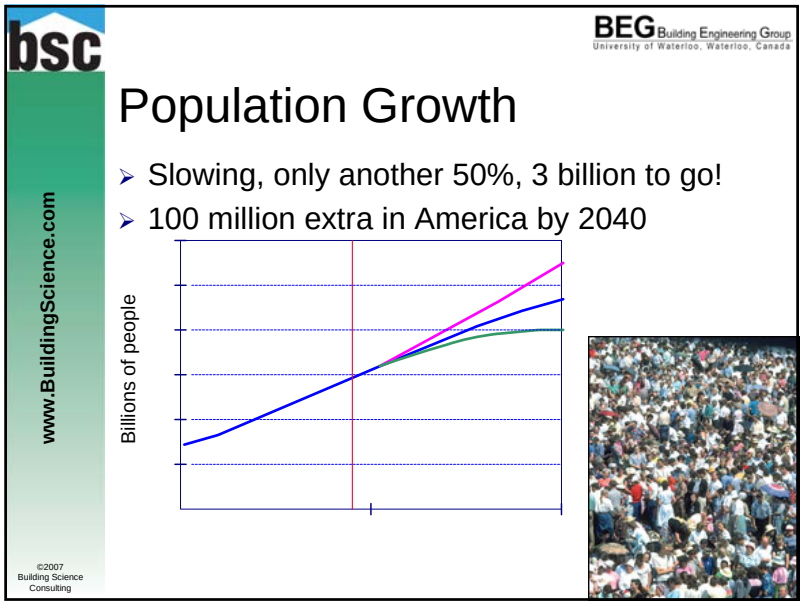
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Population Growth
Slowing, only another 50%, 3 billion to go!
100 million extra in America by 2040
Billions of people
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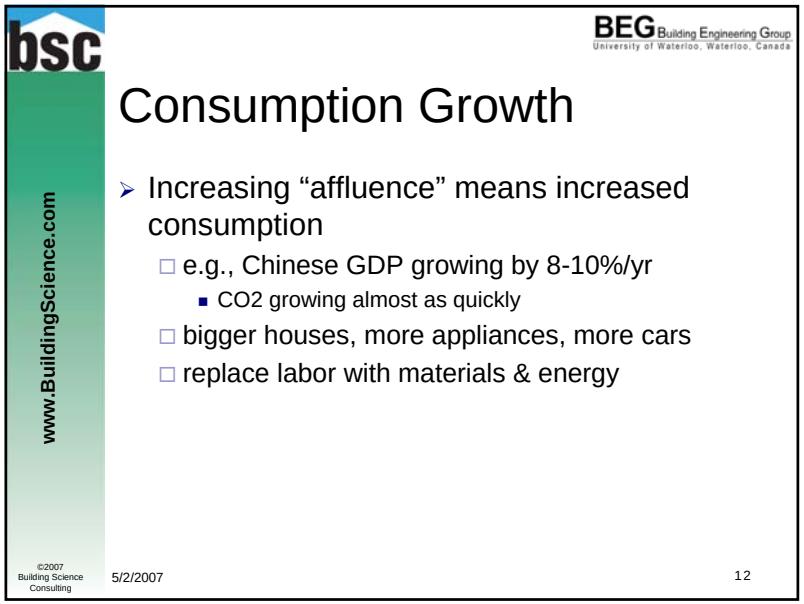
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Consumption Growth
Increasing “affluence” means increased consumption
e.g., Chinese GDP growing by 8-10%/yr
CO2 growing almost as quickly
bigger houses, more appliances, more cars
replace labor with materials & energy
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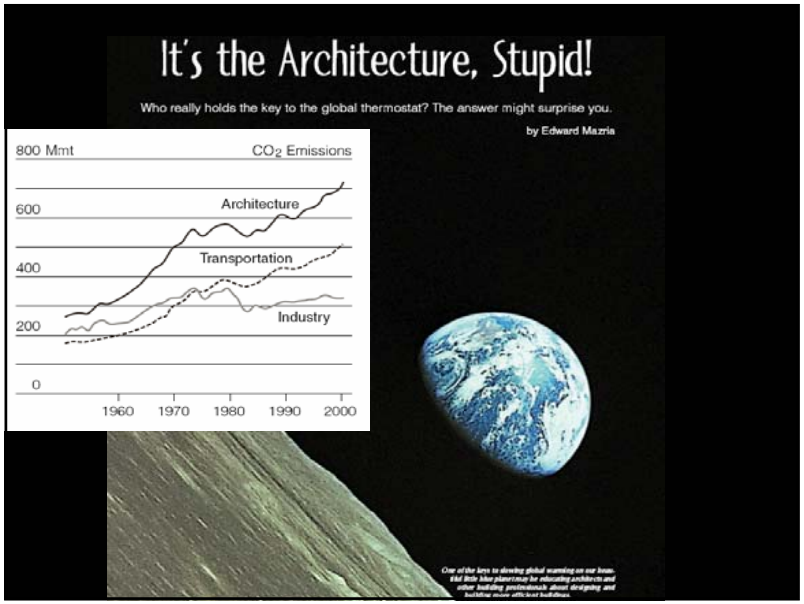
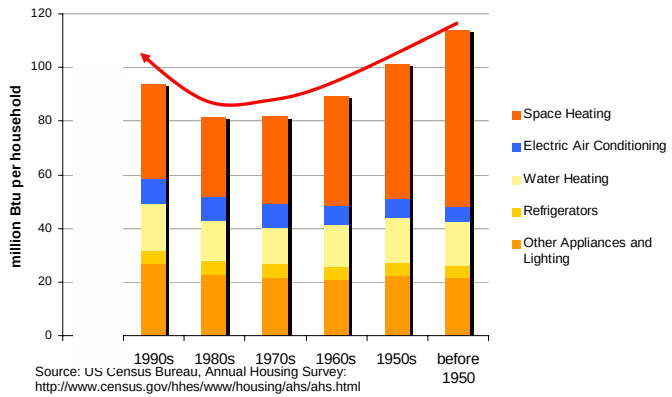
Buildings and the Environment

- Building Industry is a/the major
  - Consumer of resources
    - 40% + of all mined resources
  - Emitter of pollutants
    - Almost 50% of CO_2
    - 50% of SO_2
- Designers have a strong ethical responsibility



Home Energy Use

Total Btu Consumption per Household, 2001

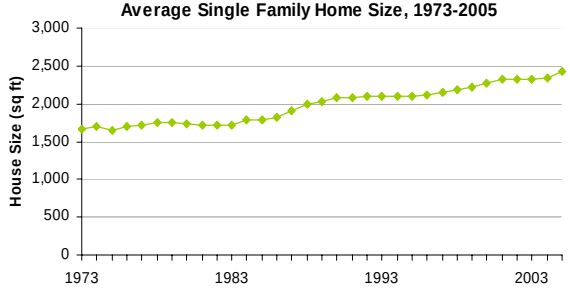


Source: US Census Bureau, Annual Housing Survey:
http://www.census.gov/hhes/www/housing/ahs/ahs.html

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



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

Where does all the energy go?

- Heating, Cooling, lights, equipment
- Type of energy influences CO2
  - Natural gas 1.0
  - Oil 1.3
  - Coal 2.0+
  - Electricity 3 +/-

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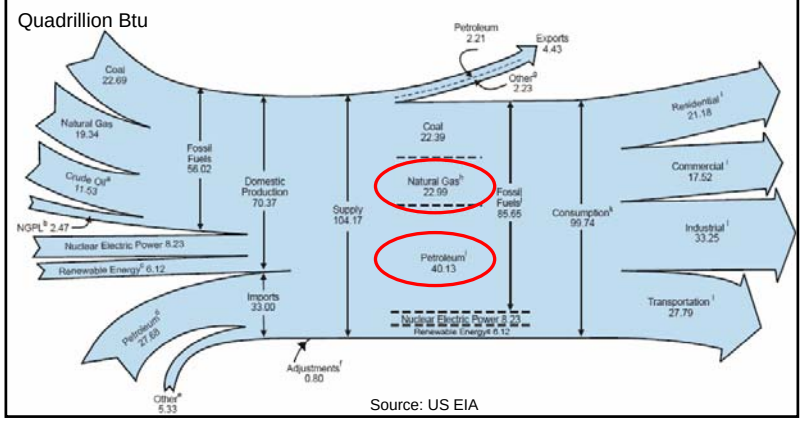
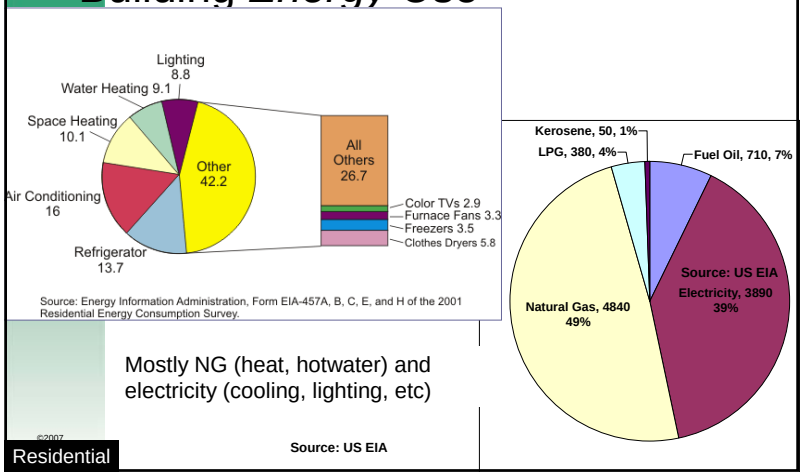
Total Energy

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?



Source: US EIA

Building *Energy* Use

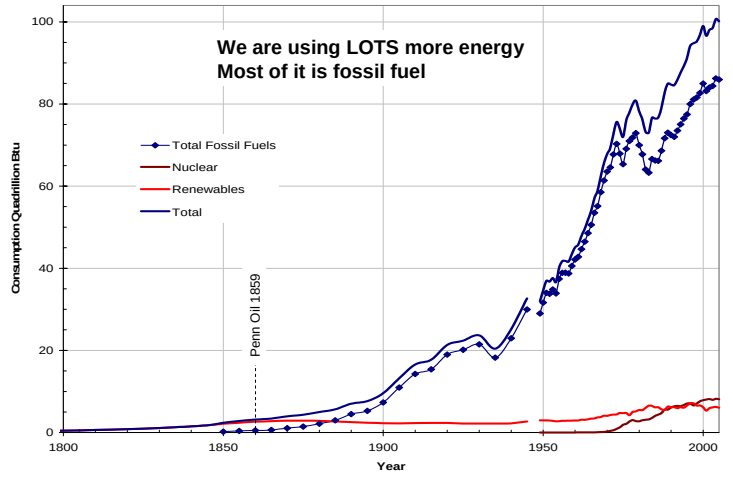


Mostly NG (heat, hotwater) and electricity (cooling, lighting, etc)

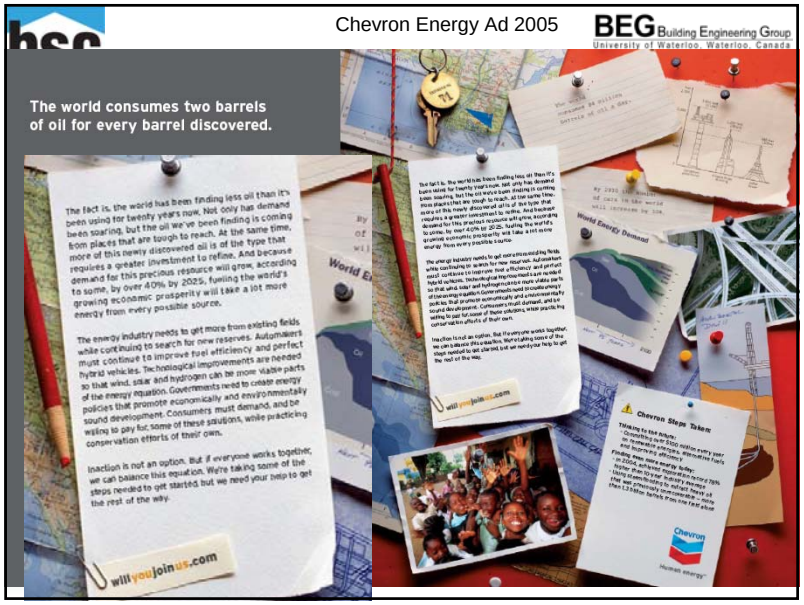
Source: US EIA

Residential

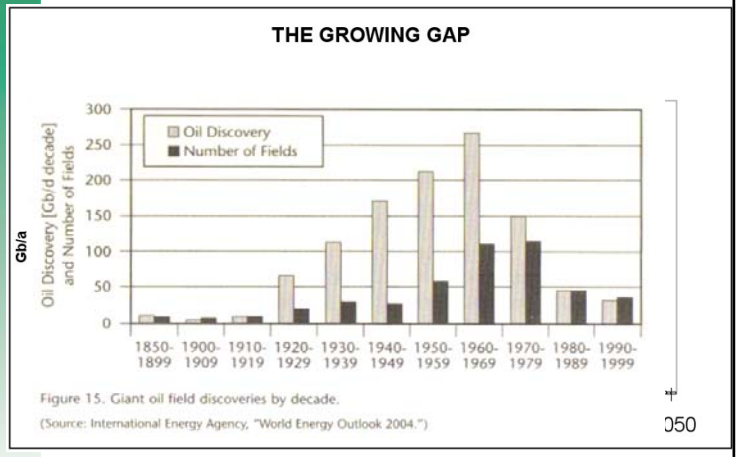
History American Energy Consumption 1800-2005



Chevron Energy Ad 2005



Production vs Discovery



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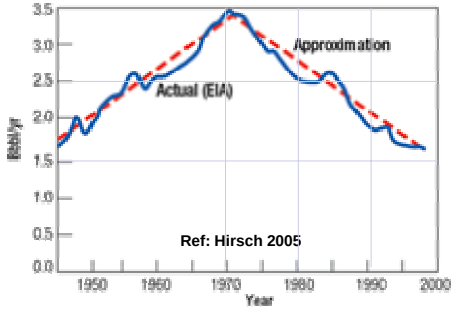
Hubbert's Peak, End of Oil etc

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



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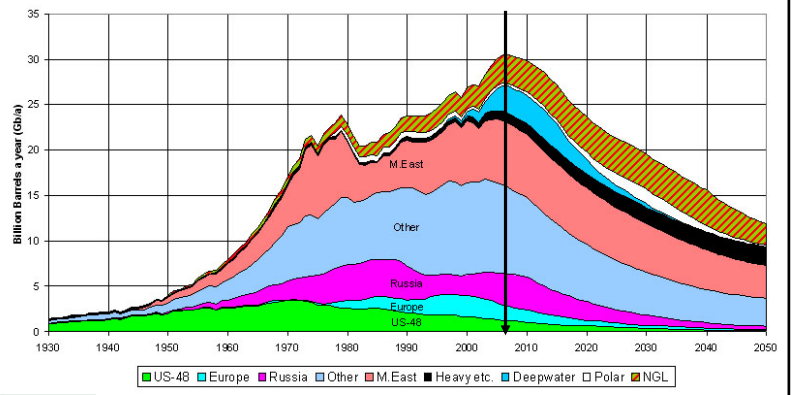
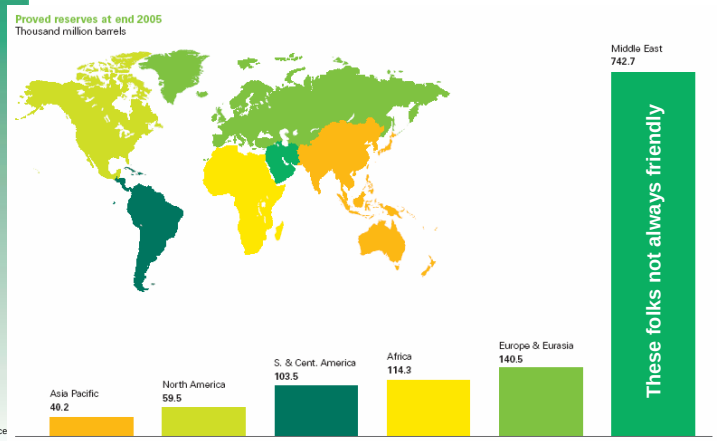


Where is the oil?



So will we "run out"?

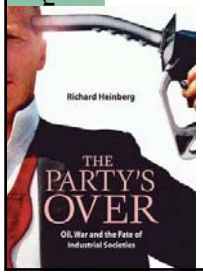
"The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil."

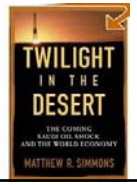
Zaki Yamani, Saudi Oil Minister 1962-1985

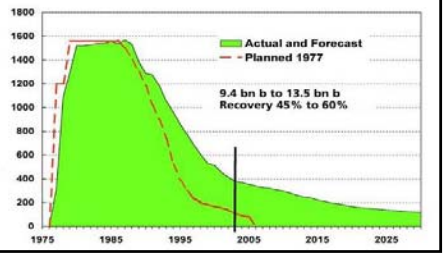
- Oil supply will peak sometime
  - This will increase prices
- We will always have expensive oil, rate of flow is the question

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





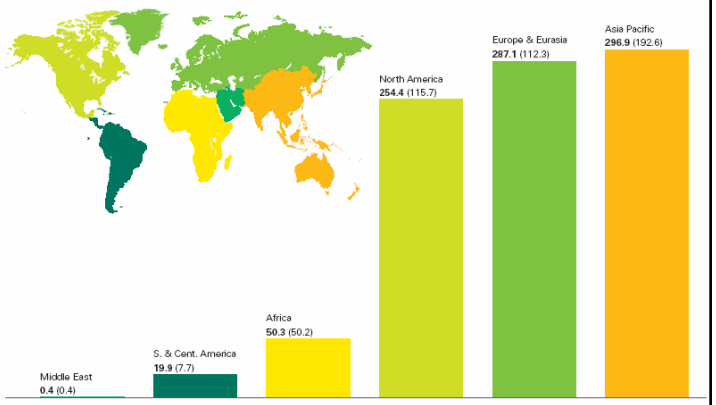


Coal (50% of US electricity)

- North America/China/Europe has lots
- Unfortunately it is very dirty (CO2, etc)
  - Mining causes damage
- Capturing and Storing Carbon is feasible
  - Cost money 2-3 cents/kWh
- Causes energy costs to increase
- Bankers refusing to invest!
- Can convert to liquid fuel but dirty & expensive

Coal

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



Climate Change

- Many "solutions" to depleting oil & gas result in greater carbon emissions
  - Coal
  - Tar sands
  - Coal to liquids

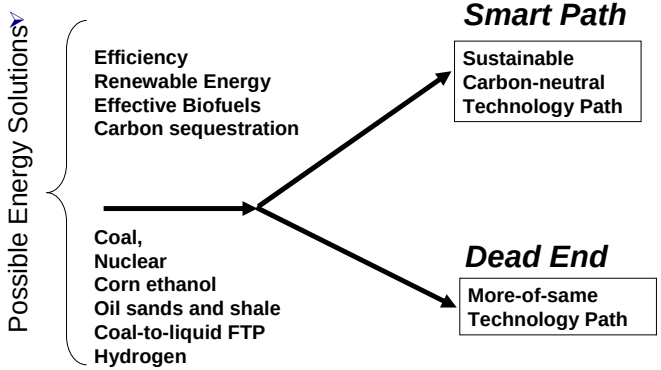
Agriculture will save us?: Biofuels

- 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 of this COSTS more money

Biofuels & Biofoods

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

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



Climate Change & Energy Security

- NO question about if climate change is happening,
  - only when and what/how bad
  - Looks like sooner than expected (sulfur reductions)
  - Solution – reduce CO2 through efficiency,RE, sequester
- Energy Security is a "decoupled" issue
  - Solution - efficiency and new energy sources (coal?)
- Solving Energy Security the wrong way will worsen Climate Change
- Solving Climate Change correctly also solves Energy Security

"Green" Buildings as a Solution?

- "Green" Buildings should
  - Reduce energy use, CO2 emission, resource use, and pollution
- Given all the warning signals:
  - We need to quickly change
  - Build new buildings at 50% reduction
  - Retrofit old buildings for about the same performance
- We need to increase insulation and airtightness!!

Solutions?: Net Zero / Carbon Neutral

- **Net Zero buildings** produce as much energy as they consume over the year
- **Carbon neutral.** If energy production is from renewable sources, and offsets other consumers, the building is carbon neutral

- These are high goals, and may not be necessary
- 50% reduction for small cost (5%) is possible and the starting point
- Increased energy costs will help

How to make Low Energy Buildings?

Good Design

- Design, not just materials & technology is least cost, biggest impact, readily available solution
- Requires Designers to act
- Helps if code/insurance/banks/government do not obstruct
- Building America programs times ten

Is it Green? Learning to count

- Depends on answers to:
  - Does it use less non renewable energy to operate?
  - Will it last longer? (less life-cycle resources)
  - Does it use fewer non renewable resources to build?
  - Does it pollute less?
- Compared to what?:
  - Zero (sustainable)
  - Better than average (move forward, "green")
    - What is average?
  - LEED? Less than MNECB?

How to reduce energy + pollution

- 1. Reduce heat loss and gain
  - Small compact form and/or grouped homes
  - Lots of insulation
  - Avoid thermal bridges (true R-values)
  - Use very good windows (triple)
  - Build Airtight, then control ventilation properly
- 2. Avoid energy use
  - Efficient appliances, lighting, elevators
  - Use daylighting, motion sensors, etc
  - Efficient pumps, AC, heat, fans
- 3. Then, generate renewable energy
  - Passive solar then active solar/wind/water

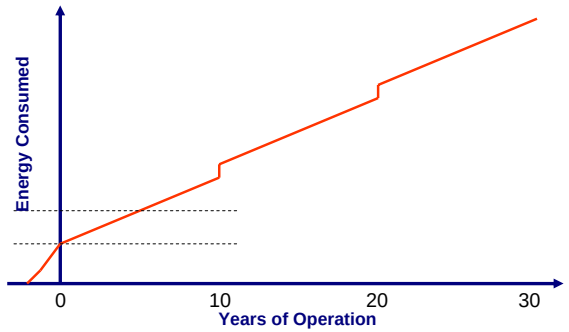
Damage Components

- 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

Operation vs Embodied Energy

- Embodied is << Operational Energy



The new "buzz" words

- Net Zero Energy
- Carbon-neutral
- LEED
- "xx% below code"

- How about good buildings?
  How about reducing energy use?

- E.g Building America Benchmark

Is it Green? Learning to count

- Depends on answers to:
  - Does it use less non renewable energy to operate?
  - Will it last longer? (less life-cycle resources)
  - Does it use fewer non renewable resources to build?
  - Does it pollute less?

- Compared to?:
  - Zero (sustainable)
  - Average (move forward, "green")

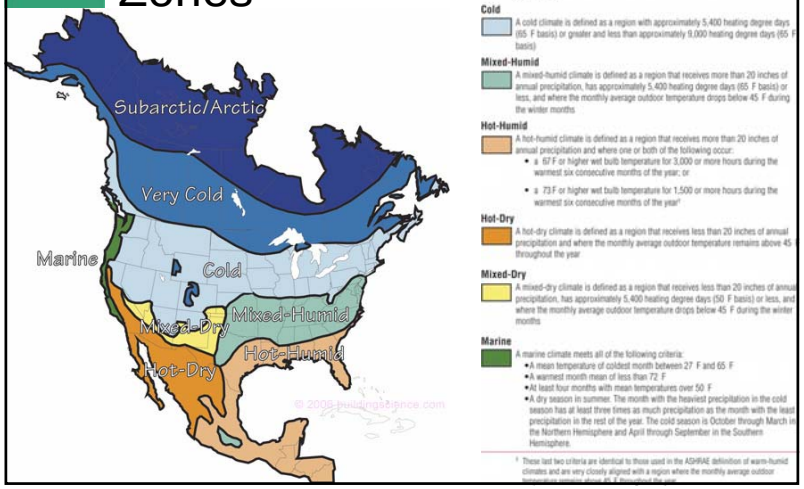
Green Practice

- Reduce heat loss and gain
  - Insulation
  - Avoid thermal bridges
  - Use good windows
  - Airseal and test!
- Avoid energy use
  - Efficient appliances and elevators
  - Collect from sun
  - Use daylighting
- Then, generate renewable energy

Site

- Climate!
  - Hot? cold? both?
- Earth Sheltering
  - Berms, tree lines, ponds

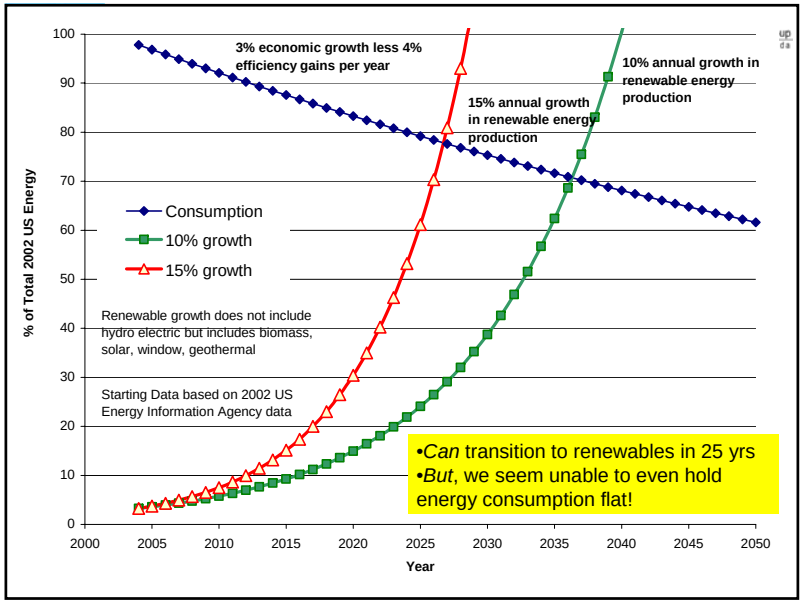
Zones



Efficiency, Renewables, Retrofits

- Reducing energy used (efficiency) allows renewables to be economically and environmentally practical
- Both are needed!
- Huge existing stock of buildings, means..

Energy Efficient Retrofits must be part of any solution!



Basic Strategies (cold/mixed)

- Keep heat in
  - When it is cold
- Keep heat / sun out
  - When it is warm/hot

Insulation
Airtightness
Solar Control
Rain Control

- Last a long time
  - Reduce construction/repair resources over time
- Use efficient equipment
  - Efficient lighting
  - Efficient computers, elevators

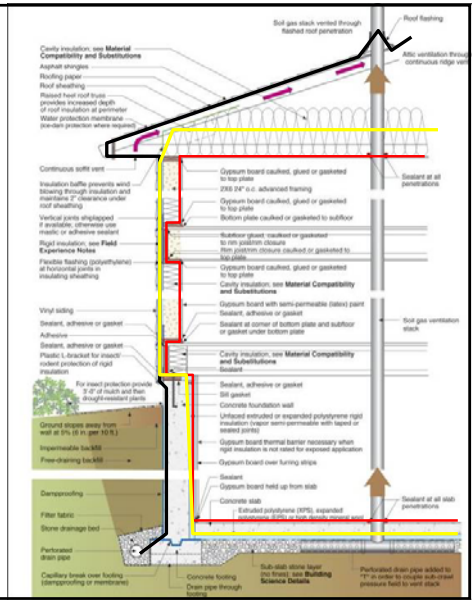
Off is very efficient

Good Practice

1. Structure
   - connect all parts together to foundation
2. Continuous Rain Control
   - Drainage plane, gap and flashing is needed
3. Continuous Insulation
   - Exterior insulation layer to slow heat flow, blunt cold spots (R>5)
4. Air barrier
   - Continuous air barrier to control air flow
   - Vapor retarder less important, may have holes

Houses

- Rain
- Heat
- Air



How much insulation?

- Regardless of type, use *more*
- For Comfort & Moisture Control
  - **True** R5-10 is enough (!), but …..
- For energy and the environment
  - As much as practical & economical
  - Cold/mixed R20-40 walls and R30-60 roofs
  - Cold Slabs R5-15, basements R15-20
- Increased insulation should reduce HVAC capital cost as well as operating!

Insulation

- We often use lots of insulation . . . . . but not everywhere
- We need *to plug the holes*!
- Heat gained/lost because of
  - Thermal bridging through structural components
  - Too many/ too bad Windows
  - Uncontrolled Air leakage
  - Poor Installation of air permeable insulation

Solar Control

- Visual Transmittance (VT)
  - Ratio of daylight that hits a window that enters the room
- Spectrally selective
  - Control solar heat gain (SHGC<<0.50)
  - Allow plenty of daylight (VT >0.50)

Air leakage & Ventilation

- Hard to save energy with the door open
- Buildings getting tighter, but . . .
  - Many still leak way too much
  - We can't identify the leakers
  - Need to test
- Many try to improve air quality by increasing quantity
  - Target good air when and where needed

Air Barriers and Energy

- Require a strong, stiff, durable, and above all continuous barrier to airflow over the whole building
- Easily 1/3 of total heat loss is due to air leakage in well insulated building

Durability

- Keep the rain out
- Control air leakage condensation
- Beware cold side vapor barriers
  - Cold side = inside in summer
- Keep the structure warm and dry

Retrofit of Existing housing

- 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
- Any solutions need to address this!
- Good news: some low-hanging fruit
  - Attics, airtightening, efficient furnaces, windows, insulated over clad

Resource Efficiency

- Same safety with fewer materials
  - No new research, just better design
  - Simple shapes = fewer resources
- Switch to more renewable resources
  - Need to develop standards
  - Code acceptance
    - E.g. wood windows in schools

Conclusions

- Green Building requires Building Science
- Focus on operational energy
  - Eventually embodied will matter more
  - Insulation with no thermal bridges
  - Airtight w/controlled supply
  - Better windows, solar control
- Durability matters!
  - Drainage plane, airtightness

Resources

- This presentation will be at
  - **www.BuildingScienceSeminars.com**
- Much more free downloadable info at
  - **www.BuildingScience.com**

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

High performance

- Compromise
  - Wood
  - High R-value
    - R40+