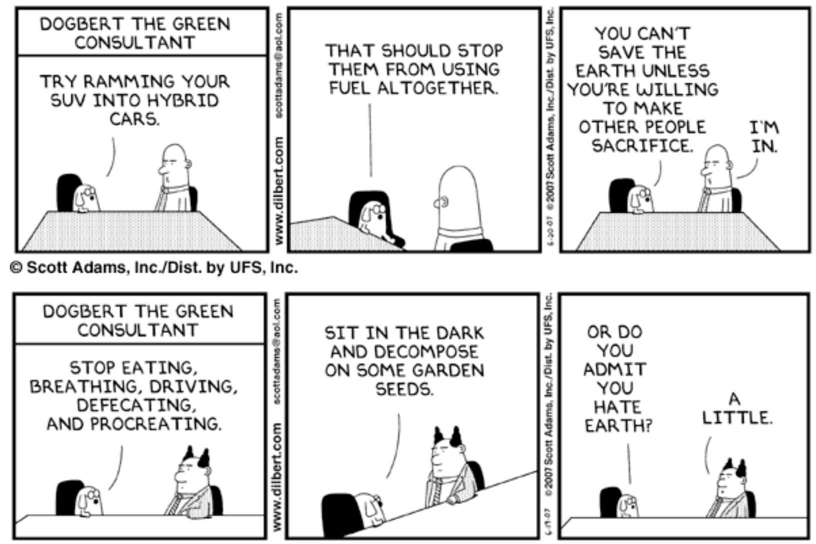
Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

John Straube, Ph.D., P.Eng, Assoc. Professor

Energy, Buildings, and the Future

Building Science Corporation

www.buildingscience.com



This presentation

- We have a couple big problems
- Environment & Energy Supply
- Solutions?
  - Reduce Energy + Alternate Energy Sources
  - Hydrogen, biofuels, photovoltaics, etc
  - Green Buildings

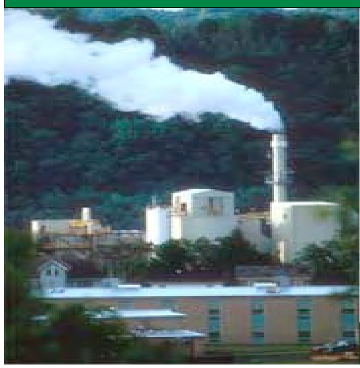
"If we do not change our direction we are likely to end up where we are headed."
- Chinese Proverb

Buildings & the Environment

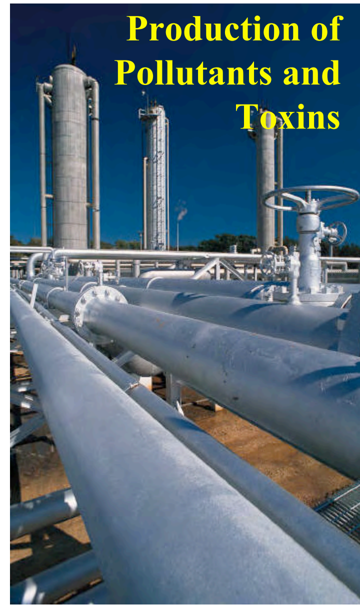
- Largest single global industry
- Hence, buildings consume resources
  - Lots of materials
  - Lots of energy
  - Lots of money
  - Pollute, displace, and destroy habitats
- Last a long time: A "durable good"
  - Running shoe (1 yr), car (10 yr), bldg (100yr?)
- Hence - more careful long-term design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

Resource Depletion & Pollution

- Buildings consume 35-50% of world energy in production and use
- about 40% North America



Production of Pollutants and Toxins



- Landfill waste
- Energy pollution
- Toxic materials

- Buildings consume 40+% of all harvested or mined resources

Ecological Damage

Urban Planning-

- Solar heating
- Rainwater run off
- Need to drive
- Transit cant work

Buildings and their connections (roads) displace and destroy habitat

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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

Buildings, Energy, Pollution

- Buildings consume *68%* of all electricity
- Operation of US buildings
  - Purchased energy costs $500 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

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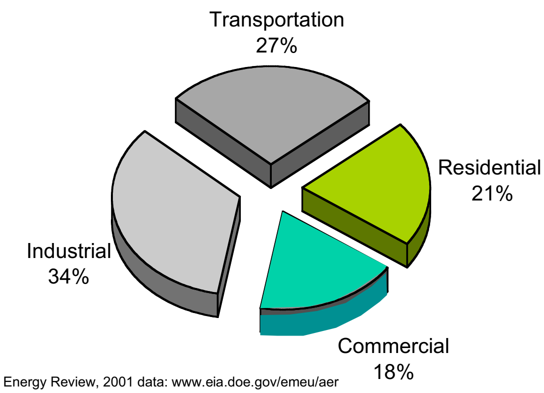
Building Energy Use

Primary Energy Consumption by Sector, 2001



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

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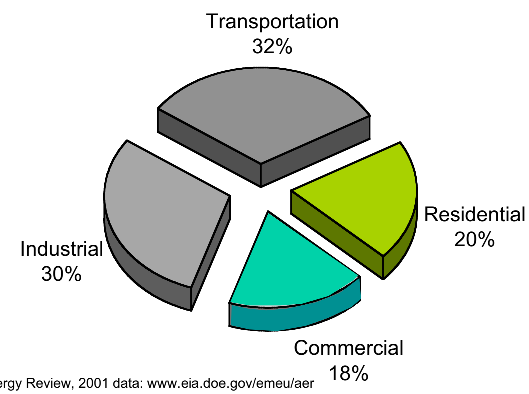
Building Carbon Emissions

Carbon Dioxide Emissions from Energy Consumption by Sector, 2001



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

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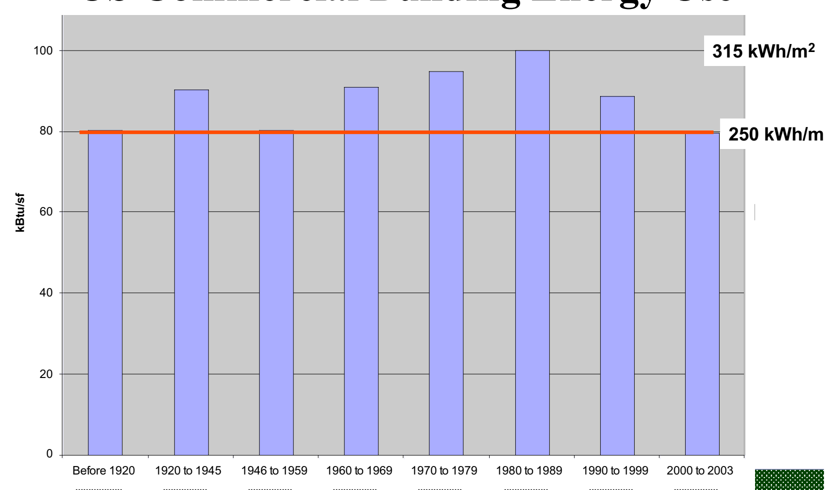
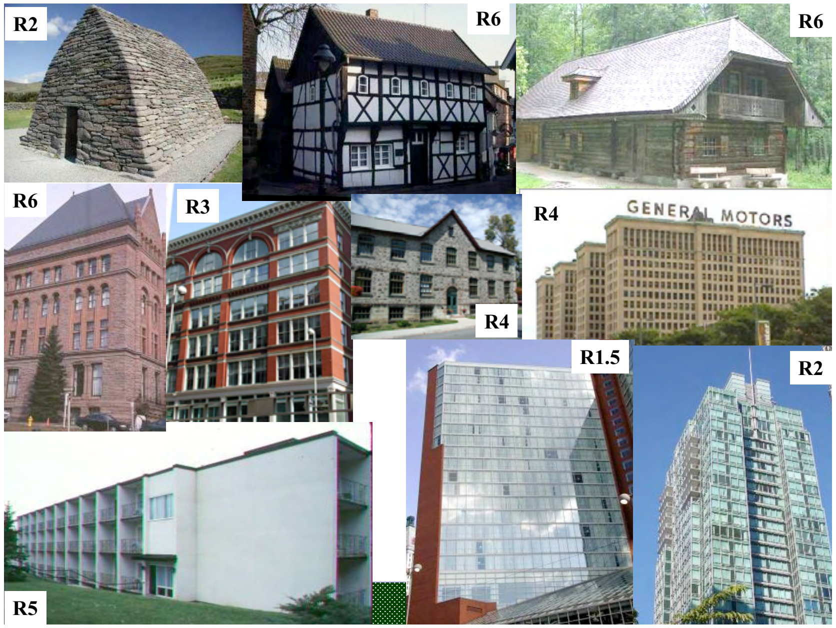
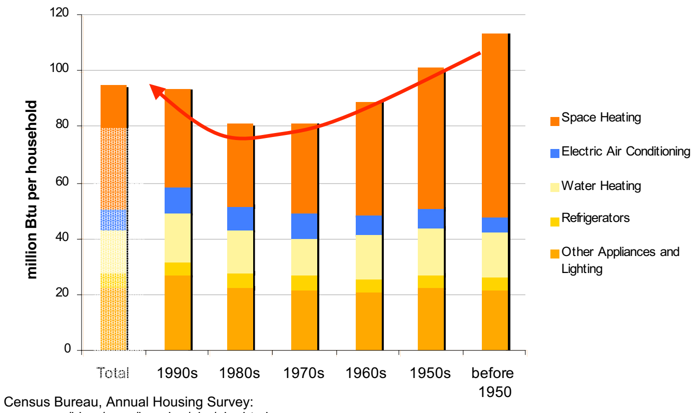
US Commercial Building Energy Use





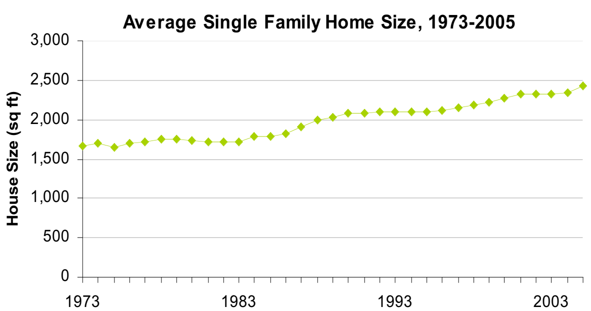
Old & New Houses Energy Use



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

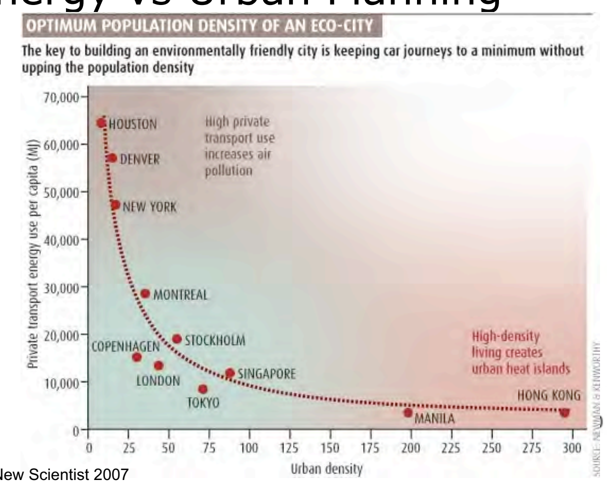
More Efficient, but Bigger

- 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**



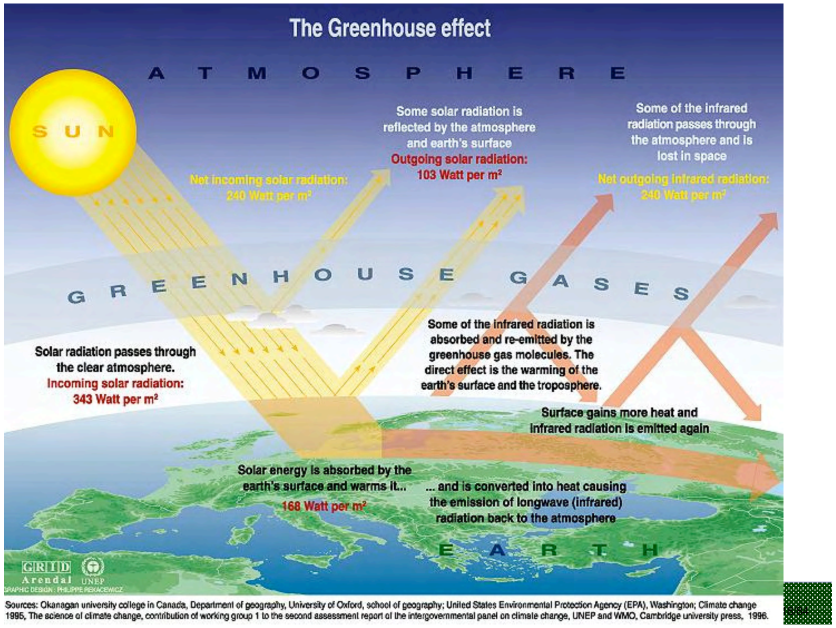
1. Wilson, Alex and Jessica Boehland "Small is Beautiful" *Journal of Industrial Ecology*, Vol 9, No 1-2. 2005
2. EIA, Annual Energy Review, 2001 data: www.eia.doe.gov/emeu/aer

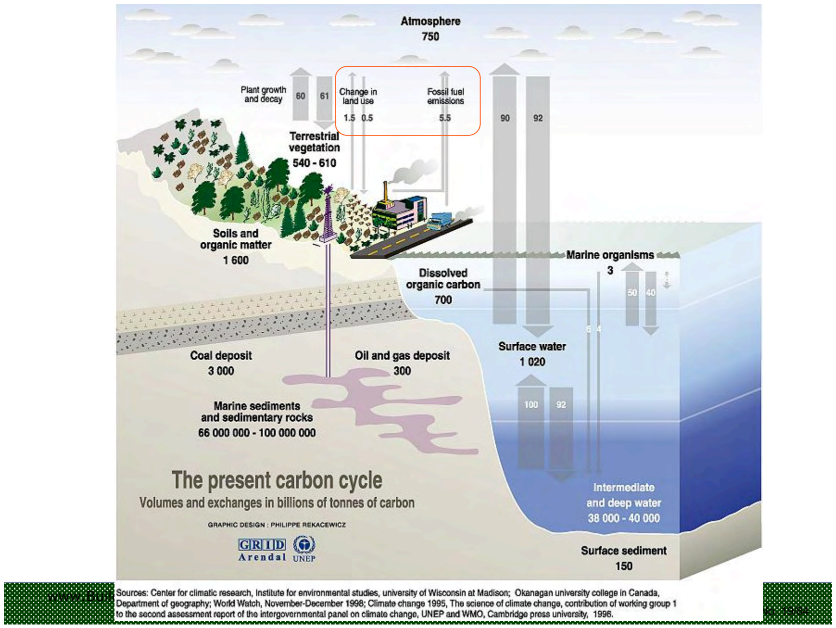
Energy vs Urban Planning

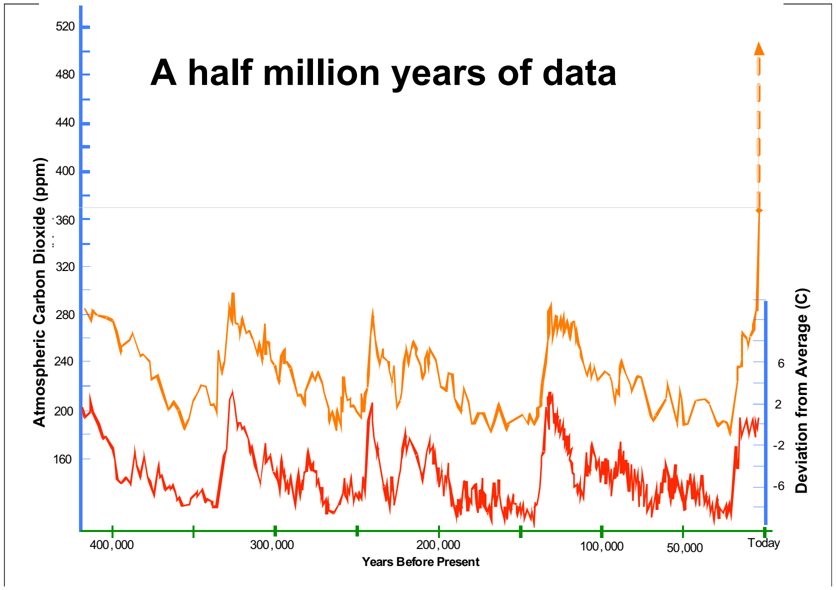


Source: New Scientist 2007

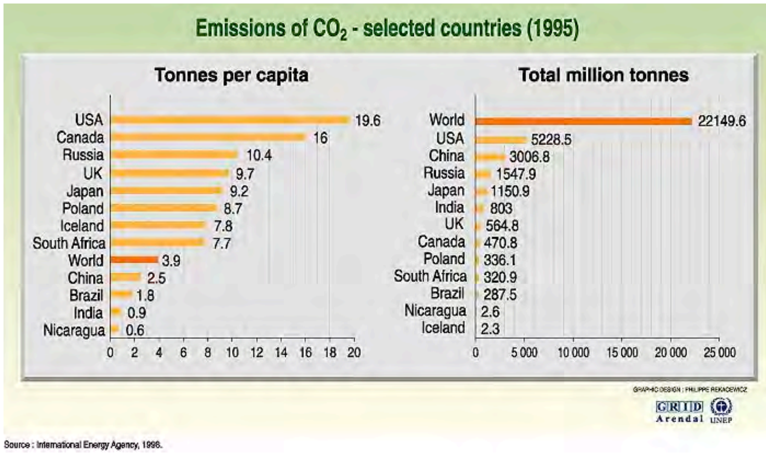
Climate Change



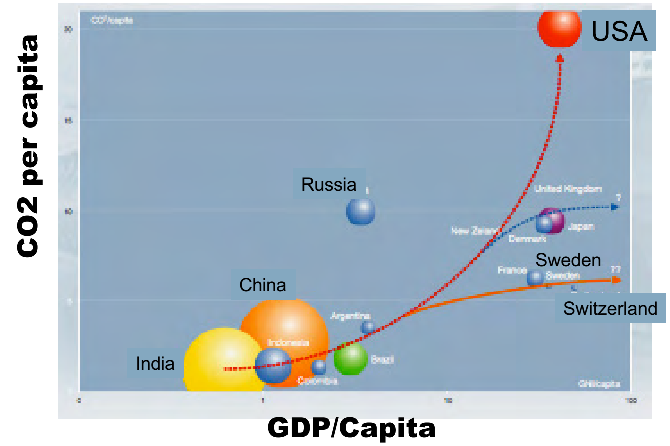




Who is emitting what?



GDP vs CO2



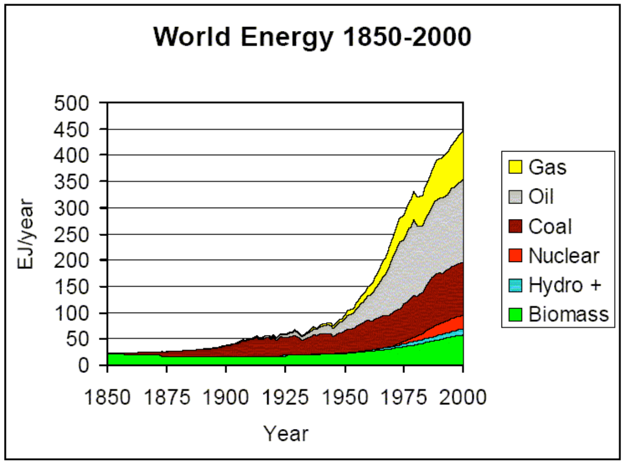
Where does all the energy go?

- Heating, Cooling, lights, equipment
- Type of energy influences CO2
  - Natural gas 1.0
  - Oil 1.3
  - Coal 2.0+
  - Electricity 2-3 +/- current supply mix

Solution: Emit less Carbon

- Damaging climate change can be minimized by drastically reducing CO2 emissions
  - Also methane, etc.
- Either reduce fossil fuel consumption
  - Especially coal!
- Capture and store Carbon
  - Costs money

Last 150 yrs – Carbon (fossil) fuels



US
Source: US EIA

www.BuildingScience.com

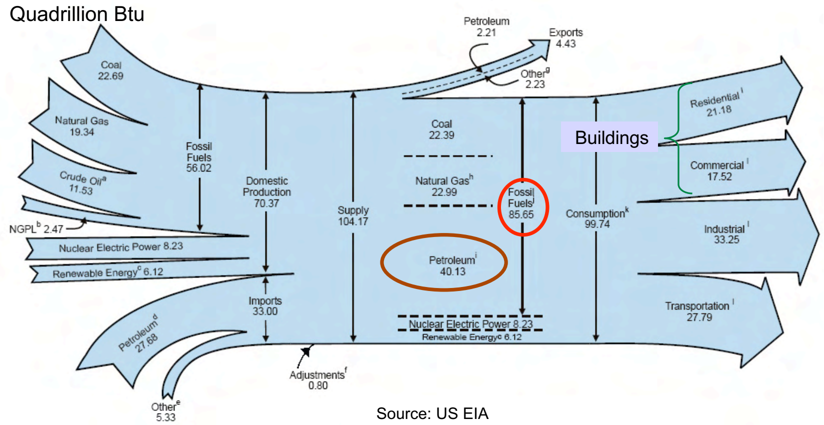
Where does energy come from?

. . . and where does it go?

Total Energy

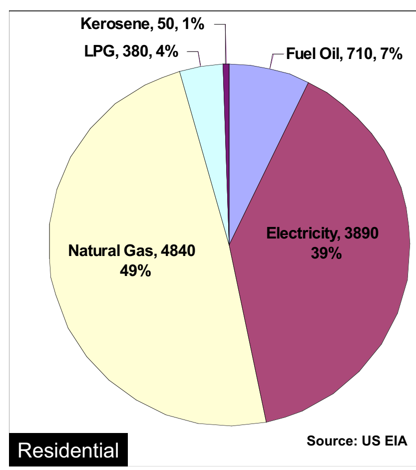
Domestic Supply almost 70%
40% of total supply is petroleum
23%of total supply is Nat gas
Buildings are #1 use (40%)
Urban planning? Embodied Energy?

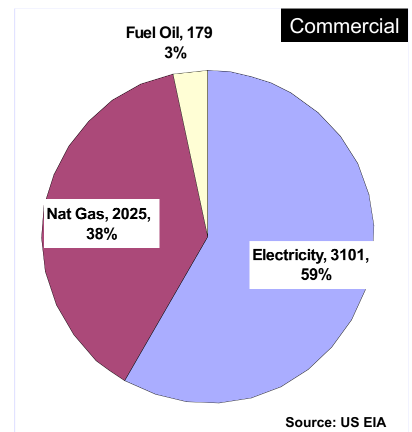
Quadrillion Btu



Source: US EIA

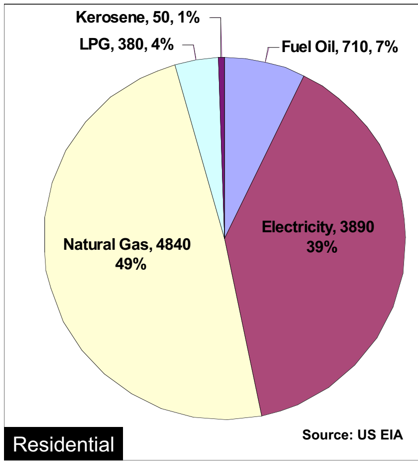
Building Energy Use

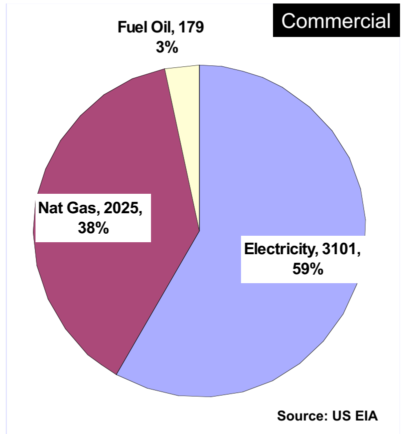




Mostly NG (heating, hotwater) and electricity (cooling, lighting, etc)

Building *Energy* Use



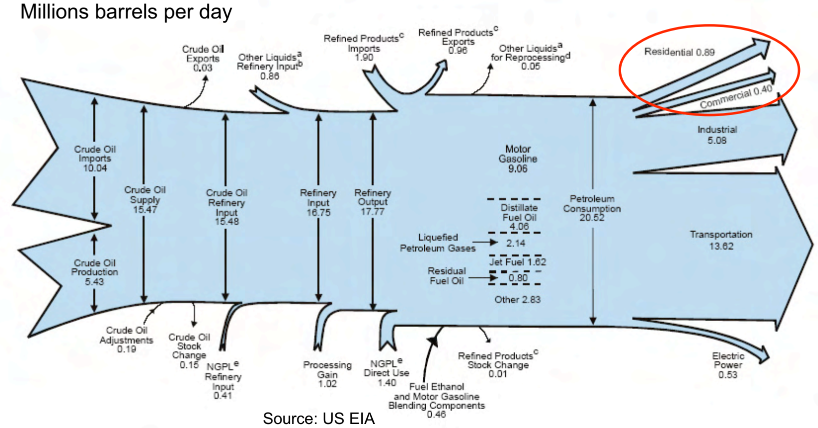


Mostly NG (heating, hotwater) and electricity (cooling, lighting, etc)

Petroleum Energy

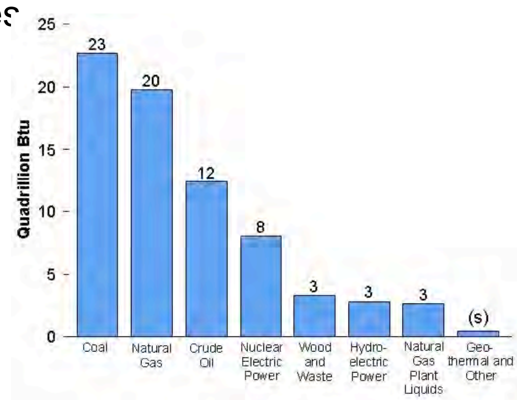
2/3 of oil is imported!
2/3 is used in transportation
Building use is negligible

Millions barrels per day



Fossil Fuels Use

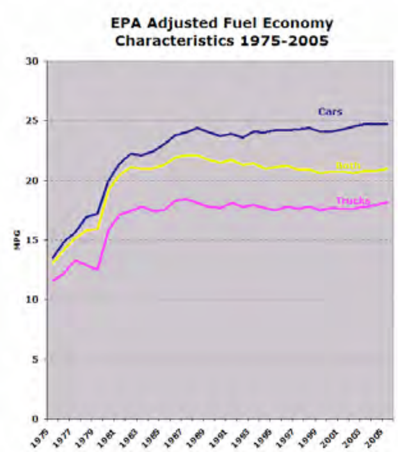
- All uses



Oil & transportation

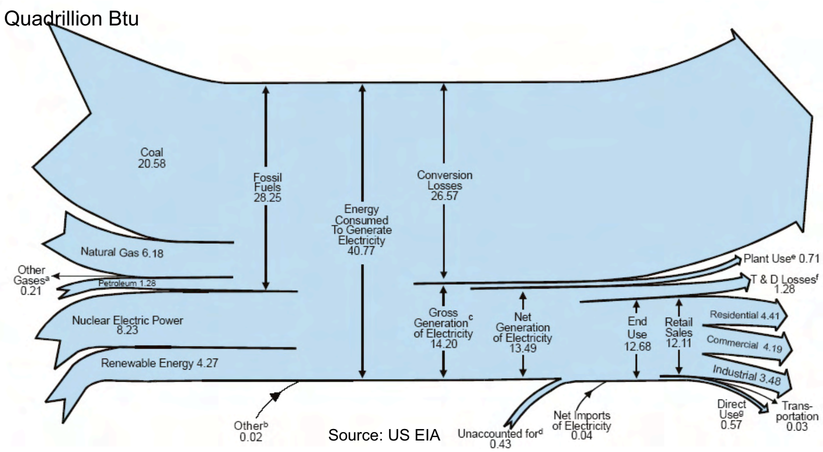
www.FUH2.com

- Moving backwards
- $6/gallon will help
- Terrorist tax?

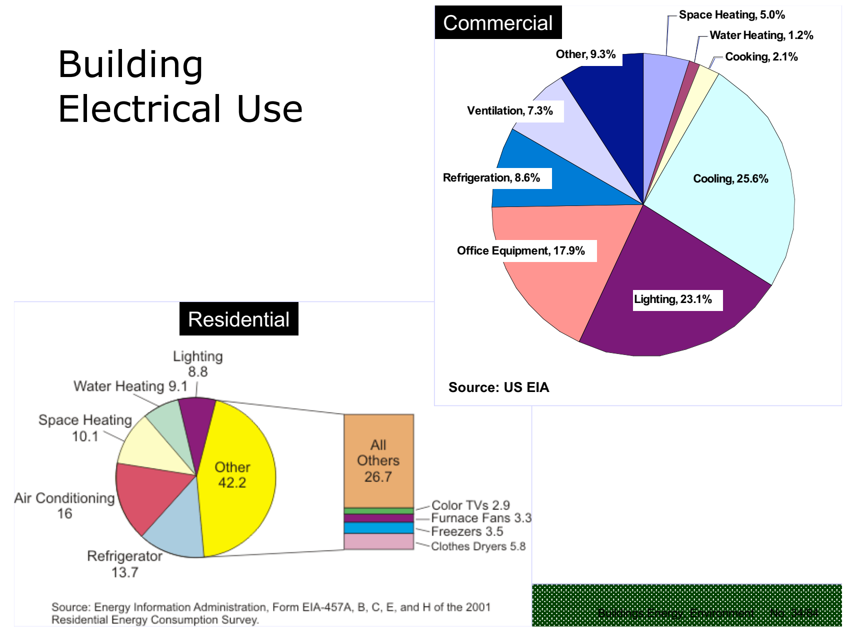


Electrical Energy

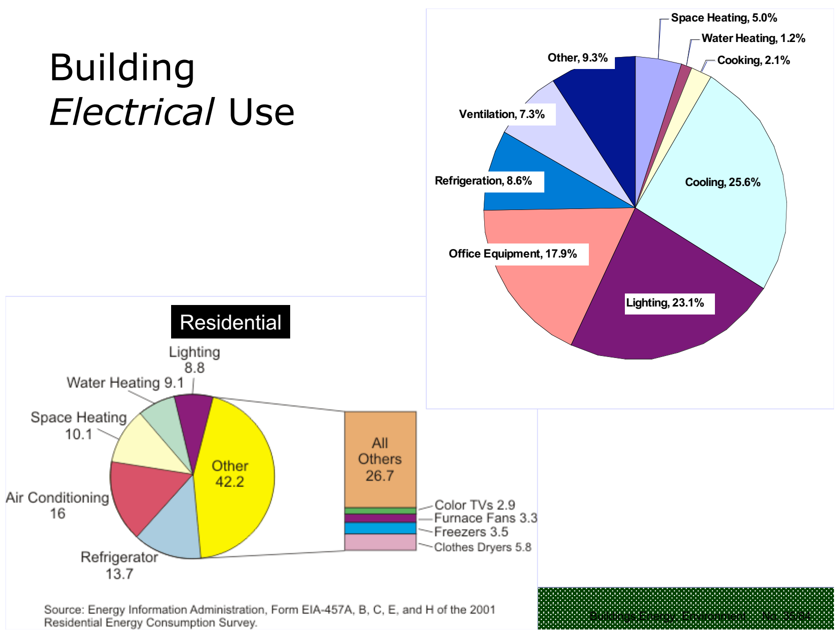
_ from coal
Oil very small
2/3 is lost at generating plant
2/3 used in buildings!



Building Electrical Use



Building *Electrical* Use



Summary

- Oil is primarily (75%) transportation
- Electricity is primarily (65%) used in buildings
- Nat Gas is 20% of electricity generation

Chevron Energy Ad 2005

Production vs Discovery

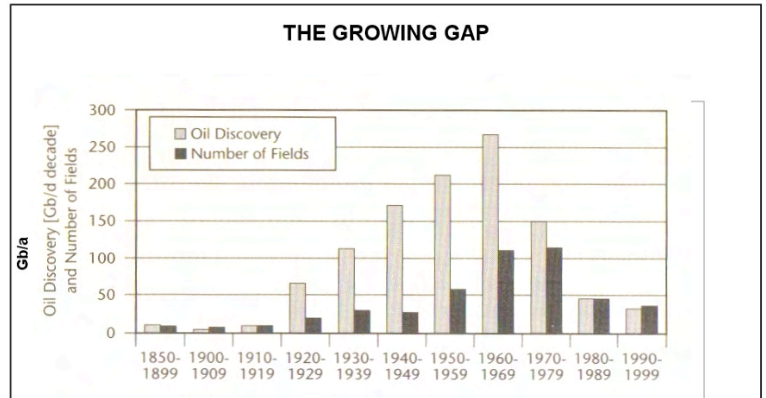
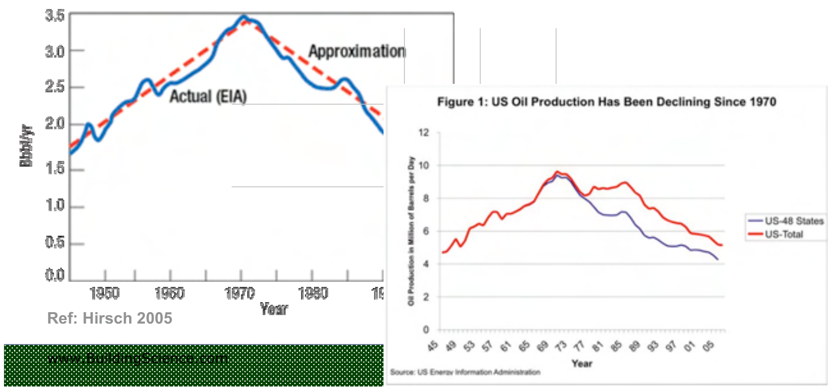


Figure 15. Giant oil field discoveries by decade.
(Source: International Energy Agency, "World Energy Outlook 2004.")

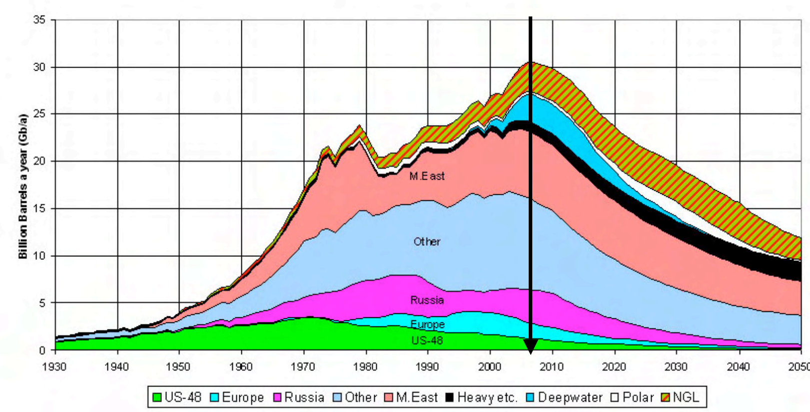
Hubbert's Peak, the "Peak Oil"?

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



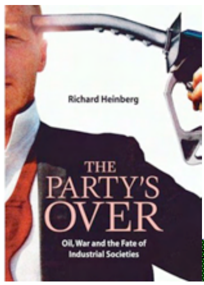
Ref: Hirsch 2005

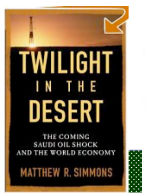
OIL AND GAS LIQUIDS
Uppsala Hydrocarbon Depletion Study Group

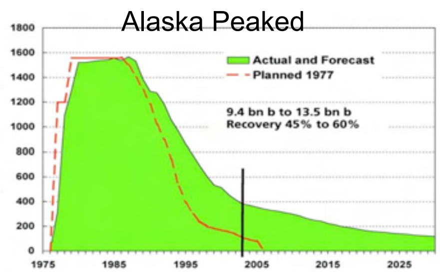


Peaking happens, is happening

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



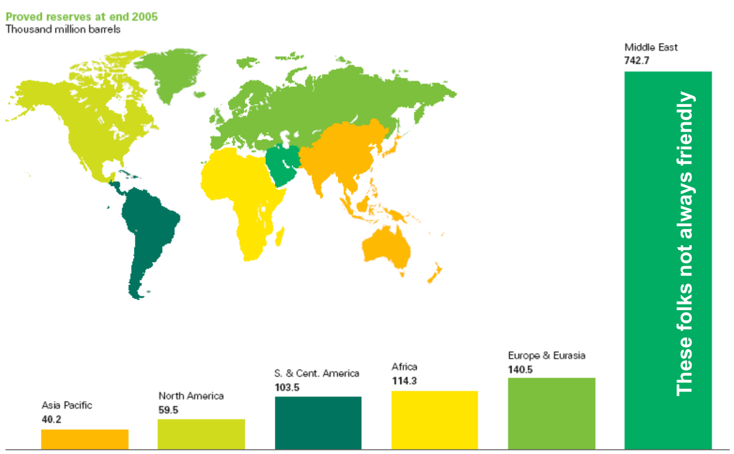




Is this "End of Oil"?

- Peak oil means "half depleted"
- But 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
- Oil supply *rate* will peak sometime
  - "It is the size of the tap, not the size of the tank that matters"

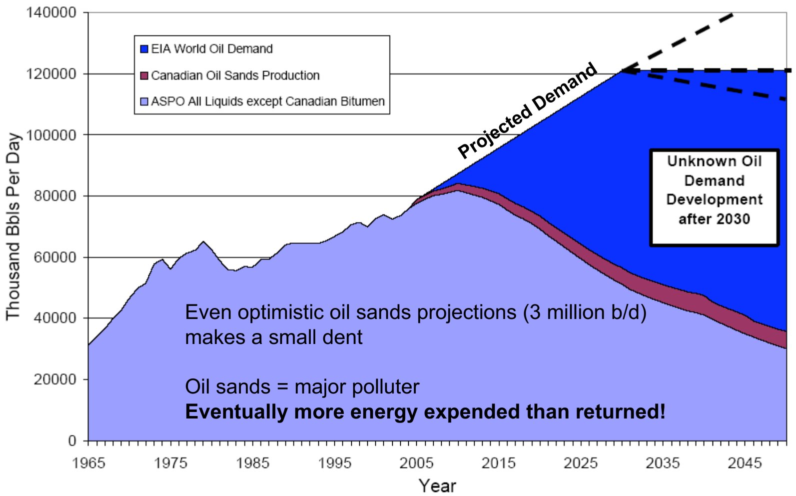
Where is the oil?



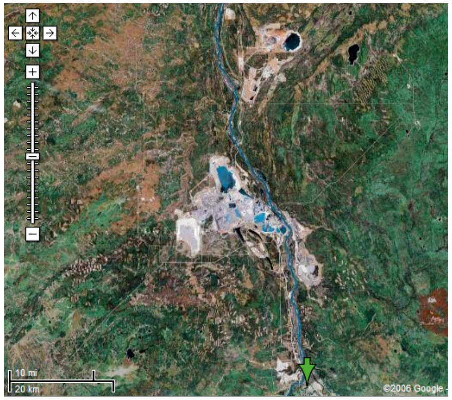
America is no longer in control

- Oil 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 <10% of oil
- Demand is driven by China, India
- We are now along for the ride . . .

Tar Sands can't save us



Oil Sands



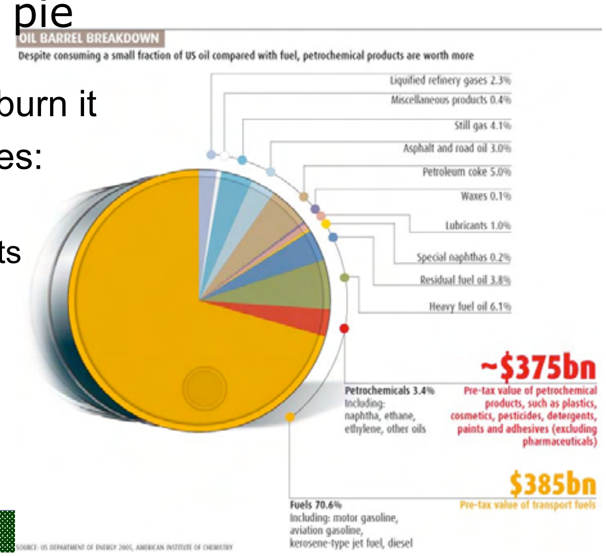
- Use 1 to 2 barrels water per oil barrel
- Emit more CO_2 than Denmark
- Use 1 unit of NG to get 3 units oil
- Newer tech is hopeful
- Even optimists don't project production of more than 4% of world consumption

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?

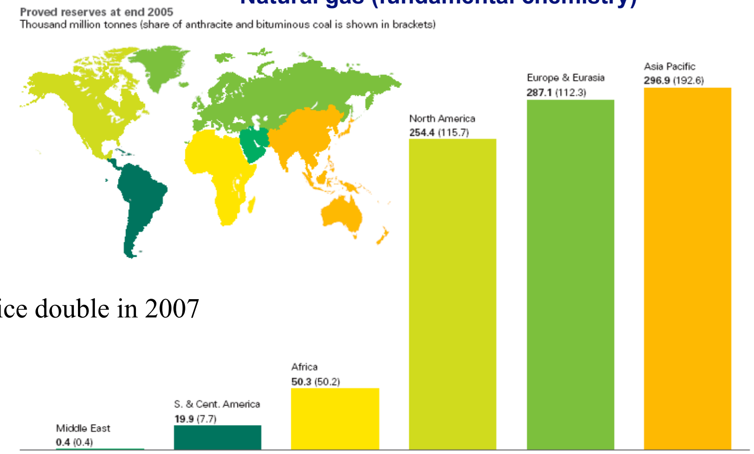
Oil value pie

- Crazy to burn it
- Better uses:
  - Plastic
  - lubricants



Coal

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



Price double in 2007

Coal

- Clean coal (Integrated gasification)
  - Almost none in America (new plants in Europe)
- Carbon Capture and Sequestration (CCS)
  - Costs about 2-3 cents/kWh extra
  - Reduces CO2 output over 90%!
  - Could be major transitional energy source 2010-2075
- Mining causes environmental damage
- Coal can be converted to liquid fuel
  - Well known Fischer-Tropsch process (German WW2)
  - Turns coal to synthesis gas and then liquids for fuel
  - Coal gas can used directly instead of NG
  - Major CO2 emissions, lots of coal 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 / 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

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, intermittent
- Combined Heat and Power (CHP)
- Need smart Grid

Implications

- Coal usage likely to increase – cheap, plentiful
  - CO_2, pollution, ecological destruction a huge issue
  - 50% of US electricity made using coal today
  - Largest single CO_2 source
- Nat Gas will peak 20 yrs after oil
  - Requires major LNG shipment and infrastructure
- Substitution of oil
  - Significant transition to electric heating / plug-in hybrid cars?
- Nuclear will be chosen by some
  - it is expensive and environmental challenged
  - requires insurance waivers and subsidies despite mature technology
- Alternative Sources Growing v. quickly
  - Soon will compete with oil and NG

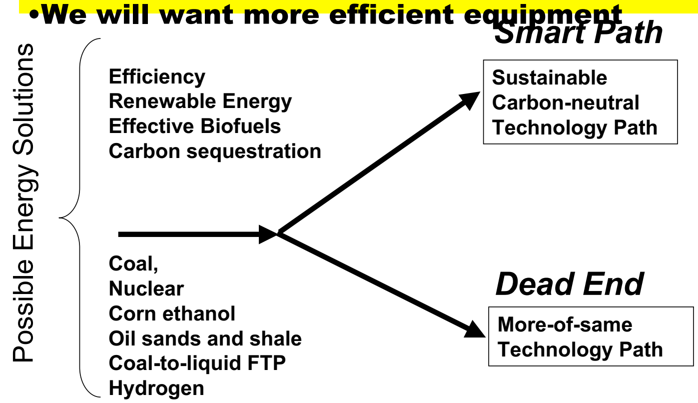
Path

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



Climate Change vs Energy Security

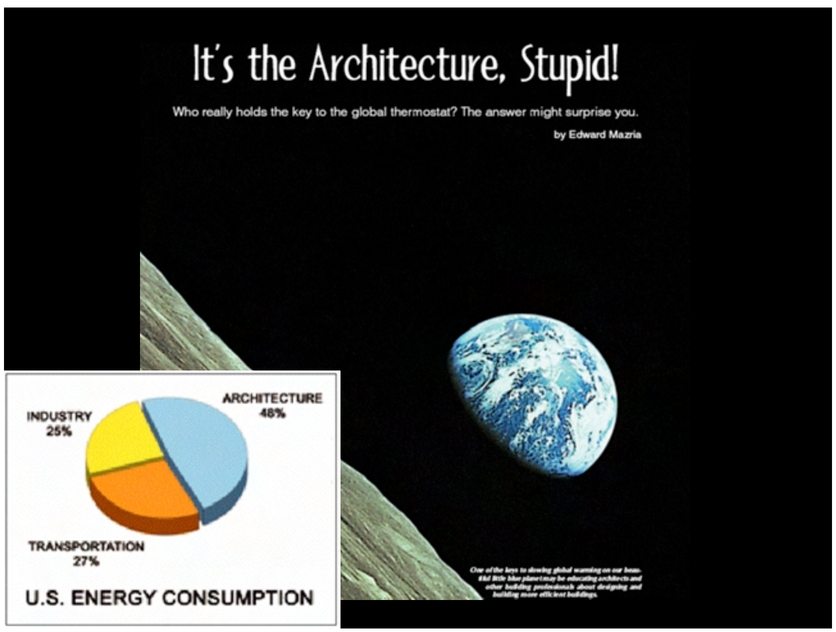
- Many proposed "energy solutions" result in equal or much greater carbon emissions
  - Coal
  - Tar sands
  - Coal to liquids
- Any energy source that generates more CO_2 is a dead end.

Climate Change vs Energy Security

- NO question about <u>if</u> 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/or new energy sources (coal?)
- Solving Energy Security incorrectly will <u>worsen</u> Climate Change
- Solving Climate Change correctly also <u>solves</u> Energy Security

What can we do?

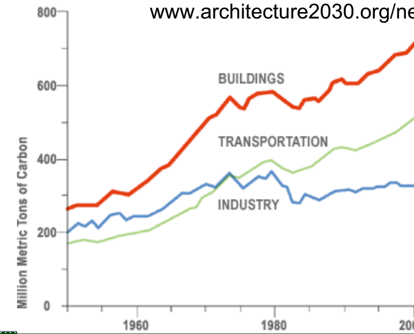
and how do you do it?



Mazria 2030 Challenge

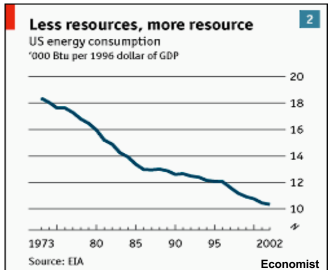
- Set targets, measure performance
  - 60% reduction by 2010

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!”



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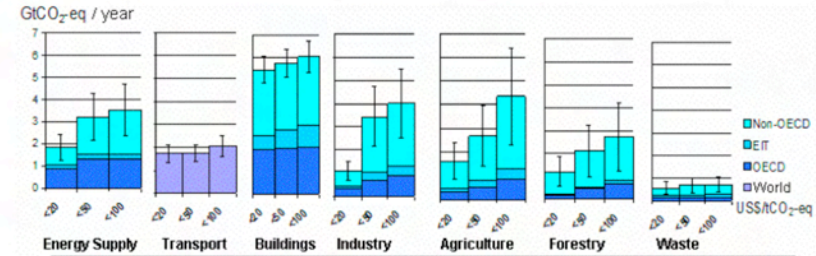
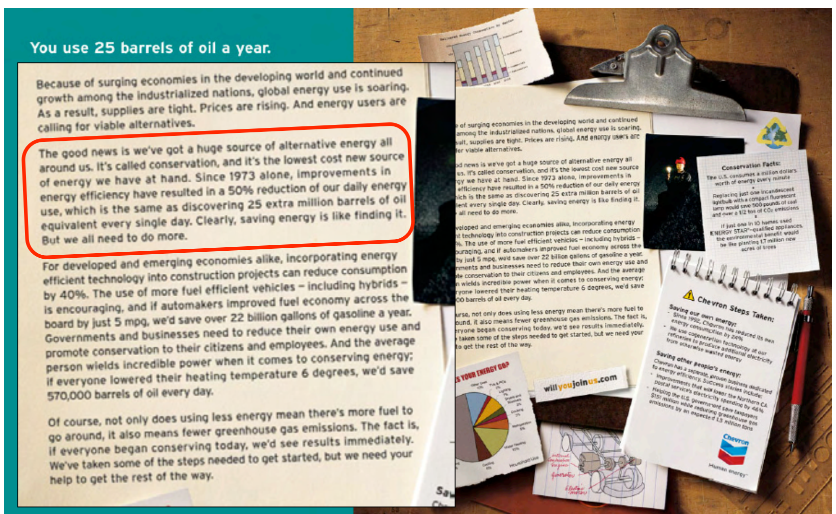
United Nations IPCC Mitigation Report May 2007



Energy Supply	Transport	Buildings	Industry	Agriculture	Forestry	Waste
(potential at <US$100/tCO$_2$-eq: 2.4 - 4.7 Gt CO$_2$-eq/yr)	(potential at <US$100/tCO$_2$-eq: 1.6 - 2.5 Gt CO$_2$-eq/yr)	(potential at <US$100 /tCO$_2$-eq: 5.3 -6.7	(potential at <US$100/tCO$_2$-eq: 2.5 - 5.5 Gt CO$_2$-eq/yr)	(potential at <US$100/tCO$_2$-eq: 2.3 - 6.4 Gt CO$_2$-eq/yr)	(potential at <US$100/tCO$_2$-eq: 1.3 - 4.2 Gt CO$_2$-eq/yr)	(potential at <US$100/tCO$_2$-eq: 0.4 - 1 Gt CO$_2$-eq/yr)

***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 emissions, but still this is not enough to solve the problem.

Process and Philosophy

- Decide to value energy consumption
- Set targets, predict usage, measure performance

Simple Powerful things

- Building smaller, simpler
- Better insulation, airtightness, shading
- Proper window area, good windows
- Efficient lights, motion sensors
- Efficient equipment, better controls

What should we do?

- "*Use energy & material more effectively both in production & operation of buildings while polluting & damaging ecology as little as possible*"
- Follow this over the whole life-cycle
  - Durable
  - Energy Efficient
  - Affordable
  - Healthy

Technology to reduce energy + pollution

- 1. Reduce heat loss and gain
  - 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, fans
  - Use daylighting, motion sensors, etc
- 3. Then, generate renewable energy
  - Passive solar then active

The Process

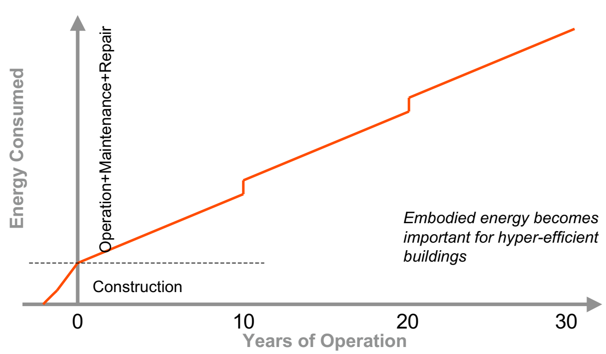
- Decide on shared goal with client
- Define “green”, “local”, “natural”, “toxic”, etc.
- Choose strategies to achieve goals
- Develop metrics
- “Design”
  - Choose
  - Predict & measure performance
  - Modify design and consider alternates
  - iterate!

Common Pitfalls

- Focus on materials, not systems
- Focus on recycling, not durability/performance
- Same process, just add more
- Unwilling to choose performance
- Follow the points, not performance

Operation vs Embodied Energy

- Embodied is << Operational Energy

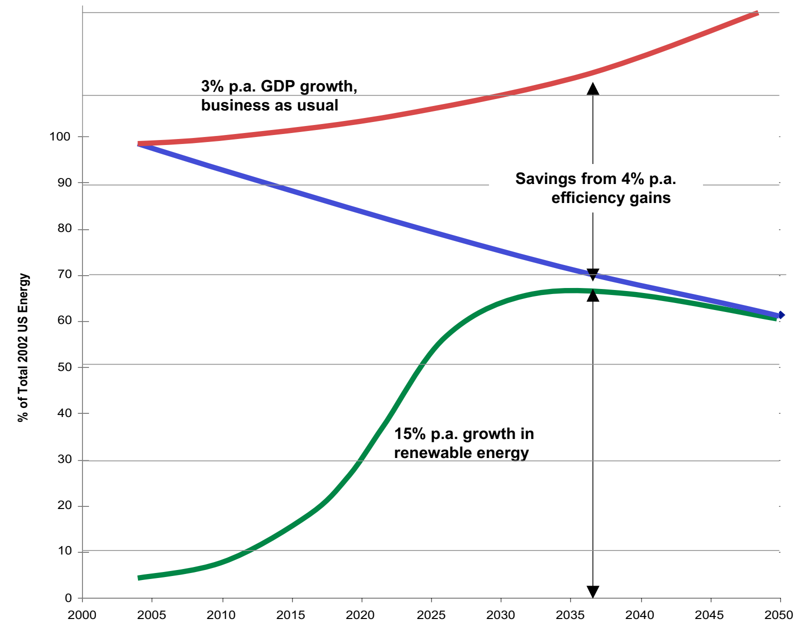


Retrofit of Existing building

- About _ of all households were built before 1950
- Almost _ 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

Efficiency, Renewables, Retrofits

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



Moving forward

- Efficiency is a key to climate change & security
- In new buildings we know how to
  - reduce energy by 30% at no cost
  - reduce energy by 50% for about 5%
  - Requires owner / designer commitment
- Retrofit of buildings must be a major part
- Renewable and clean power only make sense with efficiency

Conclusions

- Cheap oil is/may soon run out
  - Energy prices are/will rise
- Climate change is happening
  - Energy efficiency & carbon restrictions are likely
- Green Buildings use fewer resources of their life
  - We need to count to how many to get there
- Efficiency and Renewables only smart path forward
  - Retrofit of existing will be needed.
  - Reclad, new windows, airtighten, efficient equipment

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

Take aways

- We have a problem
  - Energy supply and Climate Change
- There is no silver bullet
  - All realistic packages of solutions requires very significant improvements in efficiency
    - Move to Non-fossil fuel energy
    - Biofuels and Coal-to-liquid can only make small contribution
    - More efficient cars driven less (urban planning)
    - Reduce building energy by well over 50% ASAP
    - All levels of government must change some priorities
    - Every person and business needs to understand

Green Building & Durability

- Green Buildings are very efficient
- Green Buildings are Durable
  - For two buildings otherwise the same a 25 yr life span will use twice the resources of a 50 yr lifespan
- If we use fewer resources it is greener
- Green buildings work well for users
  - Likely to be used longer and more

Green Buildings require Change

- Must make them the new normal
- Need to use different thinking and process
- Different materials and systems secondary

"Great spirits have always been met with violent opposition from mediocre minds."
- Albert Einstein

"To achieve results never before accomplished, we must employ methods never before attempted."
- Sir Francis Bacon

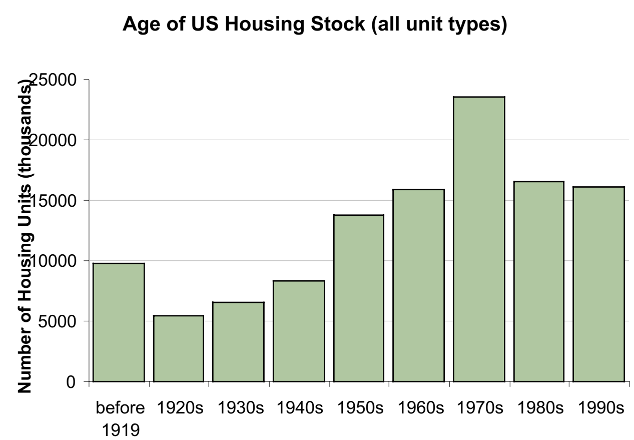
Measuring Green Building

- Resource Use - in construction and operation
  – Depletion of limited resources
  – Renewable? Recyclable
- Energy Use - in construction and operation
  – Embodied in materials and construction
  – Operational
- Ecological Damage
  – Pollutant Production
  – Habitat destruction

Measuring Green Building

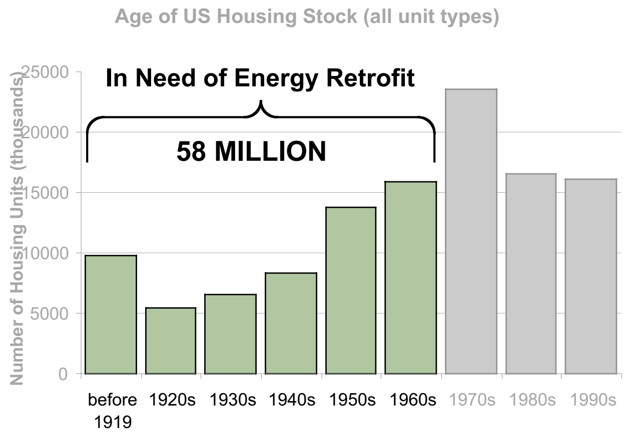
- Precision is difficult
  – relative impact more important than absolutes
- Basic strategies can be used (BREAM, LEED)
- Count
  – resources used in construction and maintenance
  – energy used for operation
- Don't be dogmatic
- Examples:
  – a 6000 sq ft strawbale house likely no better than a 2000 sq ft smart wood frame home
  – foam plastic insulation almost always saves enough energy to be a good choice

Existing Housing Stock



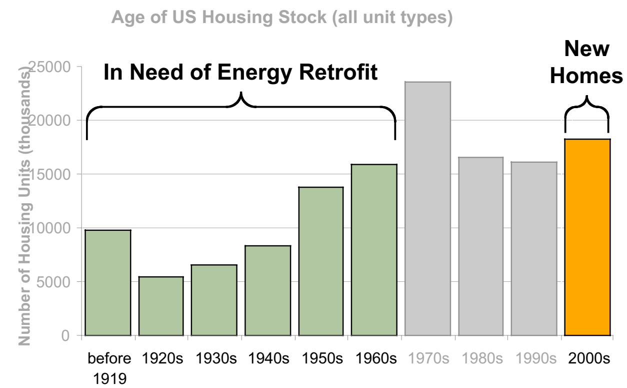
Source: US Census Bureau, Annual Housing Survey: http://www.census.gov/hhes/www/housing/ahs/ahs.html

Existing Housing Stock



Source: US Census Bureau, Annual Housing Survey:

Existing Housing Stock



Source: US Census Bureau, Annual Housing Survey:

So what to do?

- We need to make better buildings for a lot of reasons
  - Climate change, energy security, cost, health
- No magic bullets- must cut all energy, esp. oil and carbon
- You, your family, your company, your country should prepare for energy-smart, CO_2-reduced future
- This will be a huge change/business
  - New technology, techniques, products, etc.
  - New and *retrofit* buildings

Green Buildings

- Recognize buildings have an impact
- Minimize or eliminate:
  - non-renewable resource use
  - non-renewable energy consumption
  - damage to the local and global ecology
  - production of waste and pollutants
- *A sustainable society, process, or product is one that can be sustained or continue to be produced over the long term, without adversely affecting the conditions necessary to support those same activities in the future.*

The new "buzz" words

- Net Zero Energy & Carbon-neutral
- LEED
- "xx% below ASHRAE 90.1"

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

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?

Green Buildings are Energy Efficient

- Current Buildings
  - Vast majority of damage done by energy consumption *during operation*
  - As energy consumption drops, the energy and resources in the construction itself becomes important
- Energy consumption reduction is key
- Material choices less significant
  - Nice to choose lower energy lower polluting alternatives

"Good" Building

•Green Buildings are just one part of Good Buildings

- Functional
  - meet the program of present & future occupants
- Safe and Healthy
  - Fire, structure, chemicals, no mould, fresh air
- Durable
  - so that they can be used for a long time
- Adaptable
  - for many uses so they can be re-used easily
- Energy efficient
  - in operation and in construction
- Capital Efficient
  - to allow investment on other uses
- Non-polluting
  - in operation and production

“Good” Buildings Are “Green”

- No magic material, widgets
- A holistic approach is required
- Trade-offs, compromises
- *Optimal* design requires a broad understanding:
  - people and their behaviour
  - city planning, transportation
  - ecology, appliances
  - materials & production
  - building science & technology