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Environmental Science

A Study of Interrelationships

Twelfth Edition

Enger & Smith

Chapter 16

Air Quality Issues: Climate Change

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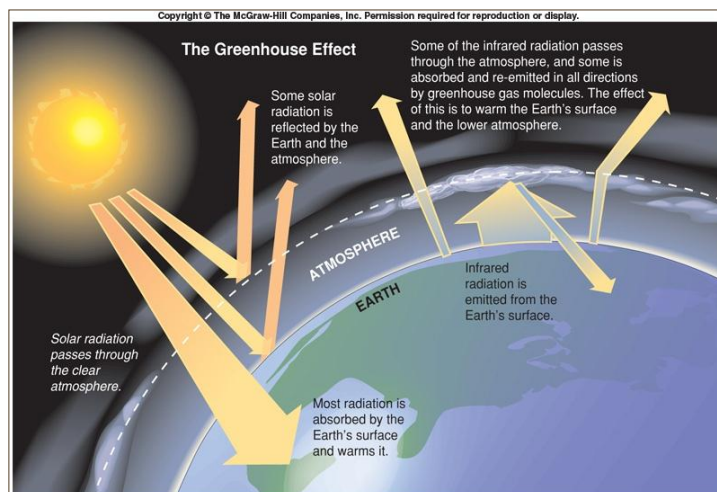
Global Warming and Climate Change

- ✿ John Tyndall, 19th Century physicist (1820-1893)
 - First to confirm the warming properties of gases in Earth's atmosphere ("greenhouse effect")
- ✿ Svante Arrhenius, Swedish scientist (1859-1927)
 - First to estimate warming effect of anthropogenic CO₂
- ✿ Greenhouse effect:
 - Greenhouse gases allow sunlight to penetrate the atmosphere.
 - Sunlight is absorbed by Earth's surface.
 - It is reradiated as infrared energy (heat).
 - The heat is absorbed by gases in the atmosphere.

Global Warming and Climate Change

- ❖ 1900 to 1950 there was a period of debate over the importance of CO₂ and temperature.
- ❖ 1950s and 1960s evidence for warming mounted but new thinking on aerosols (pollution) also made an argument for some cooling
- ❖ 1970s Scientists increasingly predicted warming as future trend
- ❖ 1988 UN established the **Intergovernmental Panel on Climate Change (IPCC)**

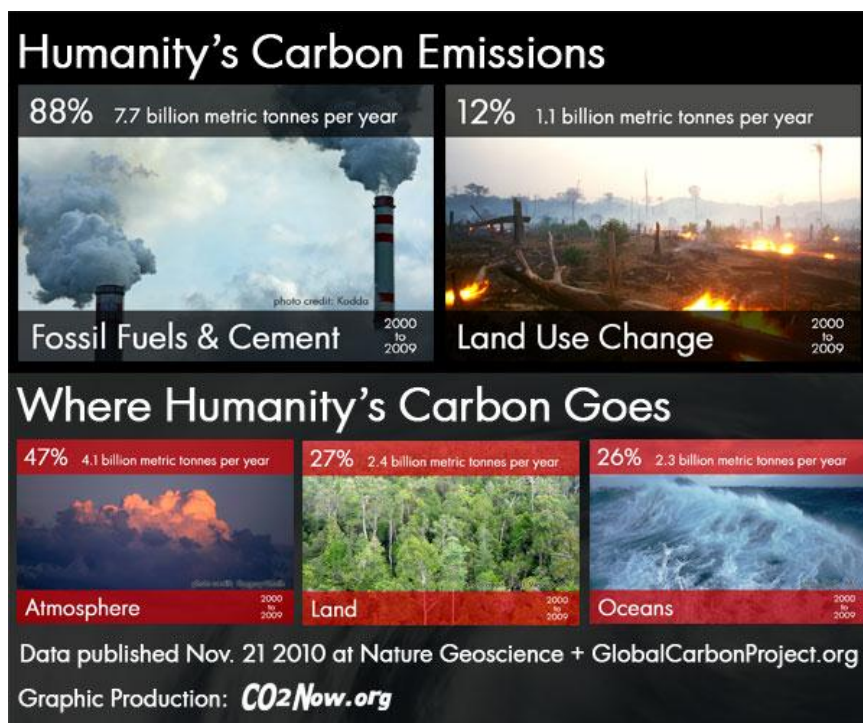
Global Warming and Climate Change

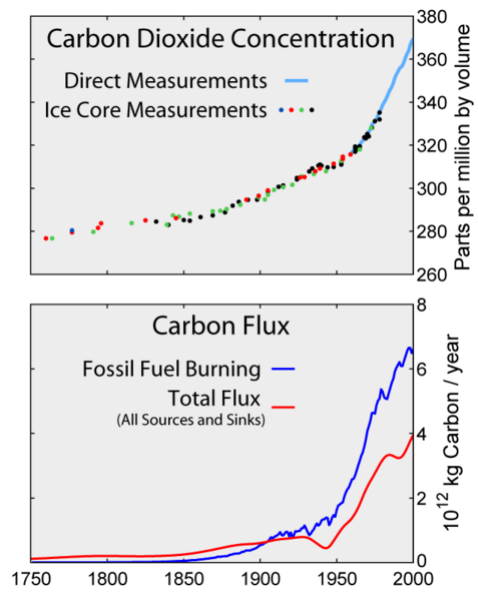
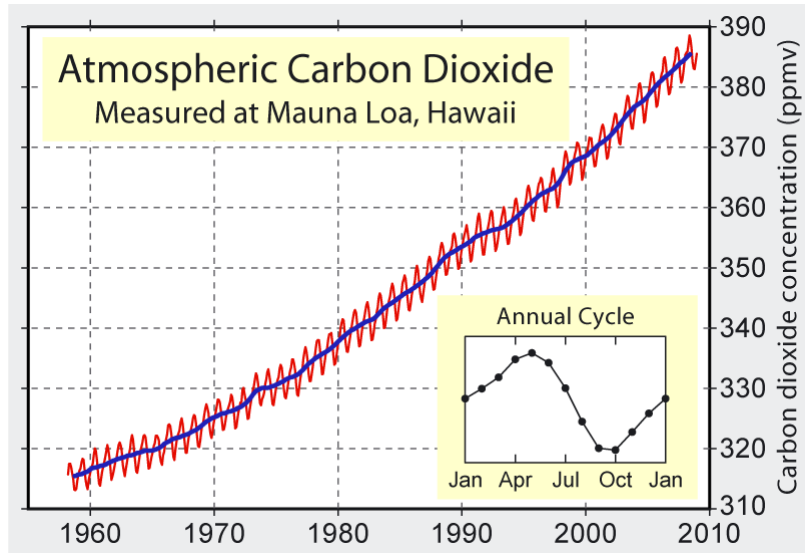


Greenhouse effect

Greenhouse Gases

- ✿ Carbon dioxide is the most abundant of the greenhouse gases.
 - Deforestation contributes to the amount of carbon dioxide in the atmosphere.
- ✿ Methane comes from biological sources and from some fossil-fuel burning activities.
- ✿ Nitrous oxide enters the atmosphere from fossil fuels and fertilizers.
- ✿ Chlorofluorocarbons from refrigerants, cleaning solvents, and propellants are also a component of the greenhouse effect.



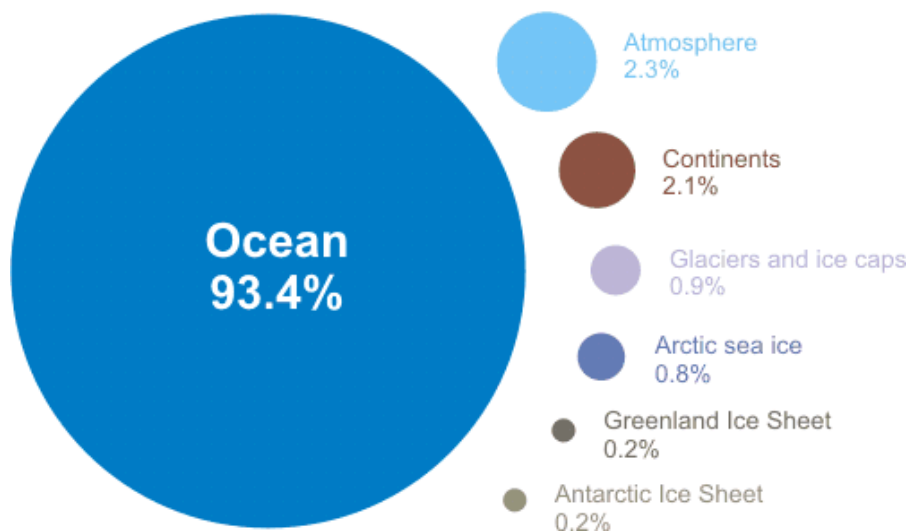


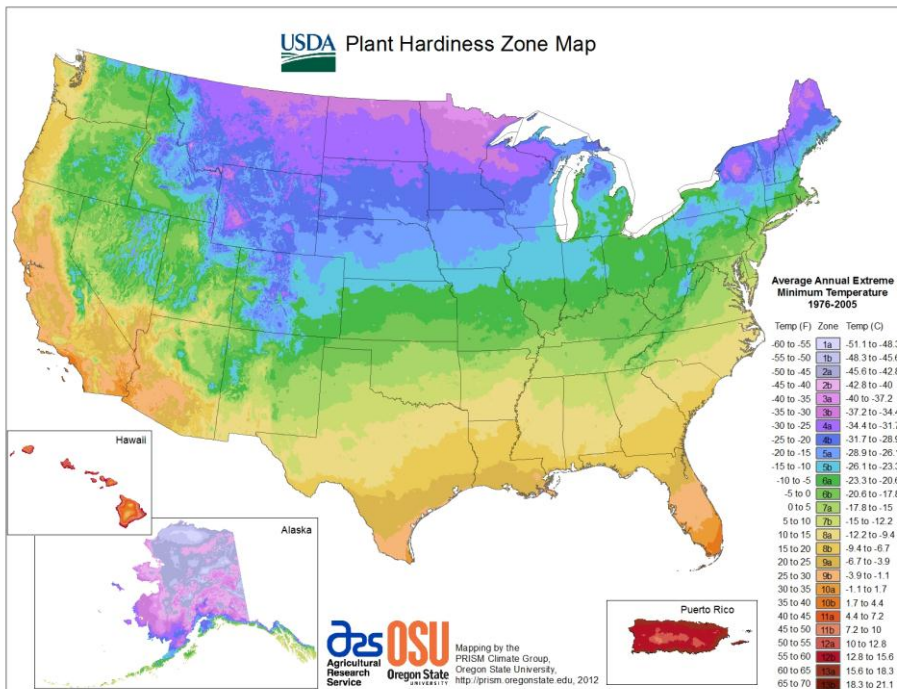
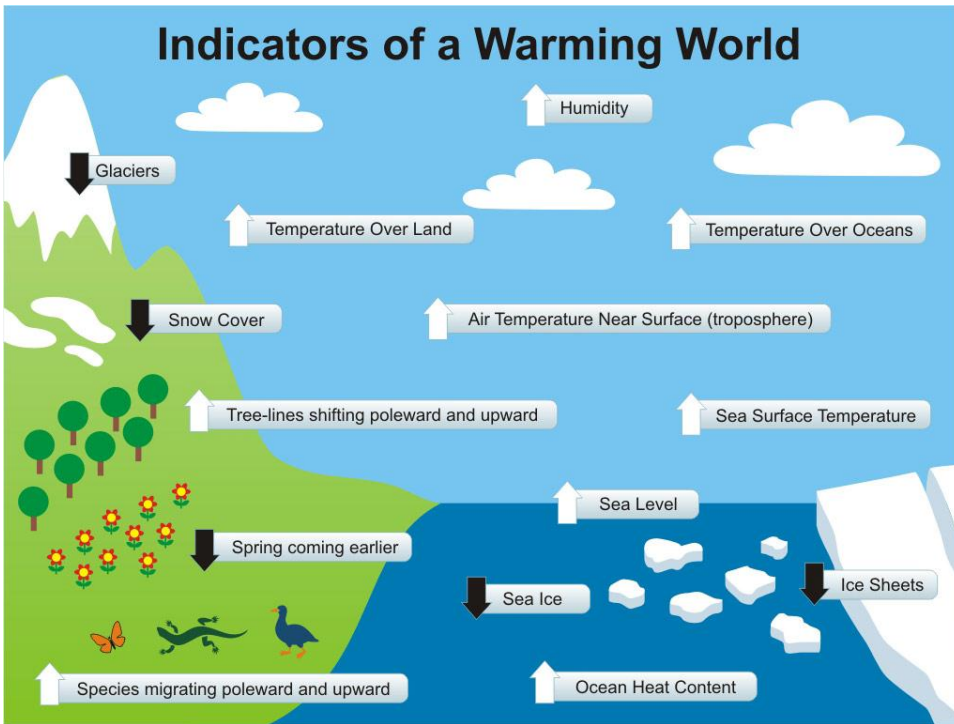
Global Warming and Climate Change

✿ The Fourth Assessment Report, Climate Change 2007, concluded:

- The average temperature on Earth has increased 0.56 to 0.92°C (1.0-1.7° F) in the past 100 years. 1998 was the hottest year on record; 2005 was the second warmest; 2002 was the third.
- Sea level is rising about 1.8 mm/yr or 18 cm in 100 years (*these numbers have been updated...quite a change*).
- A strong correlation exists between temperature increase and amount of greenhouse gases in the atmosphere.
- Human activity greatly increases amounts of greenhouse gases in atmosphere.

Where is global warming going?





Global Warming and Climate Change

- ✎ Although a small increase in the average temperature of the Earth may seem trivial, it could set in motion changes that could significantly alter the climate of major regions of the world.
 - Computer models suggest a cascade of consequences that affect the hydrologic cycle, sea level, human health, the survival and distribution of organisms, and the use of natural resources by people.

Potential Consequences of Global Warming

- ✎ Rising Sea Level
 - Water expands when it is warmed.
 - Melting glaciers add more water to the oceans.
 - Ice sheets and glaciers calving (add ice to the sea)
- ✎ Beaches and coastal wetlands erode, inundating low-lying areas, and coastal areas become more vulnerable to flooding from storm surges and intense rainfall.
- ✎ By 2100 sea level was expected to rise 15–90 cm or 6–35 inches
 - Recent papers suggest SLR more like **75 to 190 cm** from 1990 to 2100 (Vermeer and Rahmstorf 2009).
 - A 50 cm rise results in **substantial land loss** in North America, especially FLORIDA (Tampa and South Florida - ~1/3 our pop.).

Potential Consequences of Global Warming

- Health effects
 - Most direct effect of climate change would be impacts of hotter temperatures.
 - Hot temperatures force cardiovascular system to work harder to cool the body.
 - Heat exhaustion and some respiratory problems increase.
 - Aggravate air quality problems.
 - **Spread of tropical disease** such as malaria, dengue fever, yellow fever, and encephalitis to temperate parts of the world.

Potential Consequences of Global Warming

- Geographic distribution of organisms will be altered.
 - Equatorial organisms move toward the poles, and tundra biomes are affected due to the thawing of permafrost.
 - Coral reefs are affected by increased water temperature and increased acidity of ocean water from dissolved CO₂.
 - Low lying islands and shorelines are impacted by rising sea level. Mangrove forests and marshes will be inundated and subjected to violent weather and storm surges.

Potential consequences of global warming

- ✿ Climate strongly affects crop yield.
- ✿ In regions with drought and heat stress, yields will fall.
- ✿ Yields will increase in areas with warmer temperatures and more rainfall.
- ✿ Episodes of severe weather will cause crop damage that will affect yields.
- ✿ Changing conditions will greatly affect the success of current agricultural areas (i.e., some may no longer be suitable for agriculture)

Global Warming and Climate Change

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TABLE 16.3 Consequences of Increases in Greenhouse Gases

Change	Climate Consequences	Ecosystem Consequences	Cultural Consequences
Warmer air	Permafrost melts Less snowfall and accumulation Glaciers melt	Tundra biome changed Changes in flow of rivers Changes in flow of rivers	Arctic native communities affected Less regular release of water from snowmelt Glaciers less reliable as a source of water
Warmer oceans	Less sea ice Sea water expands	Coral reefs threatened by warmer water Arctic and Antarctic food chains altered Coastal flooding affects mangroves and salt marshes	Loss of biodiversity and marine resources Impact on fishing industry Cost of combating flooding
Changes in weather patterns	Warmer weather Less rainfall in mid latitudes and some subtropical regions More rainfall in high latitudes and parts of the tropics More heat waves and severe storms Carbon dioxide dissolved in water acidifies the ocean	Northward shift of plant and animal distributions Drier deserts and droughts in some regions Increased runoff causing erosion and increased flow in rivers Ecosystems altered by wind, flooding, and erosion Corals and organisms that make shells threatened	Tropical disease may migrate to temperate regions Air pollution problems become more intense Patterns of agriculture will change Water shortages in arid climates Flooding of cities and agricultural land Heat effects of health Destruction of buildings and loss of agricultural productivity Loss of biodiversity and marine resources

Addressing Climate Change

7 Principles from Chevron

<http://www.chevron.com/globalissues/climatechange/sevenprinciples/#b5>

Accords from the UN

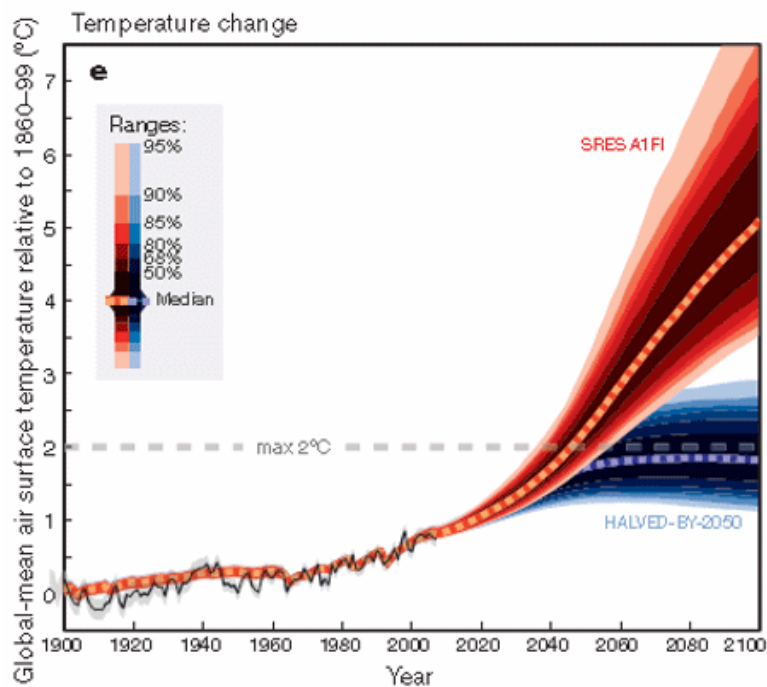
<http://www.un.org/en/globalissues/climatechange/index.shtml>

American Petroleum Institute

<http://www.api.org/ehs/climate/new/companiesaddress.cfm>

What you can do: EPA

<http://epa.gov/climatechange/wyacd/index.html>

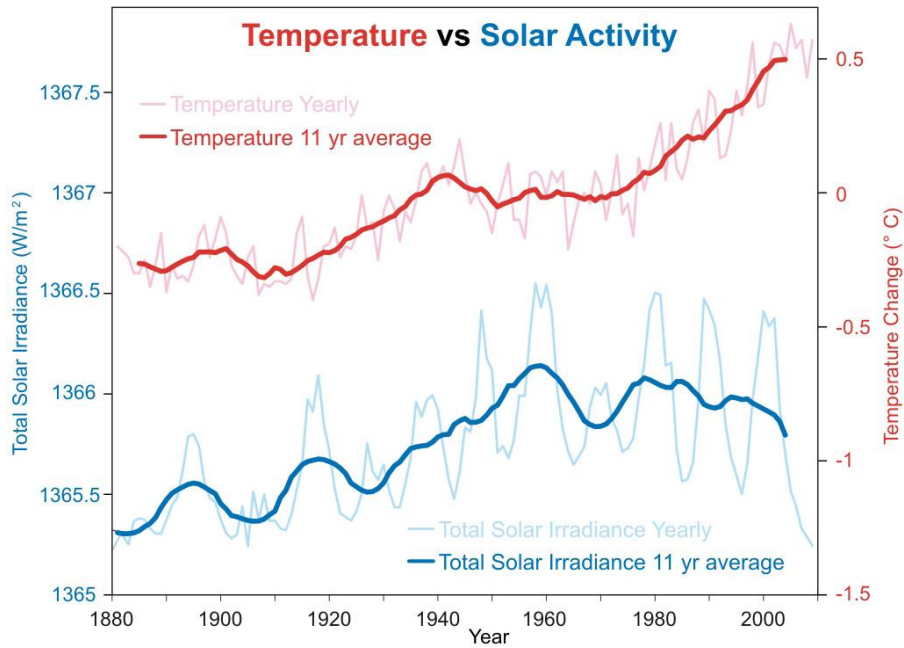


Climate change: Is it real? Is it us?

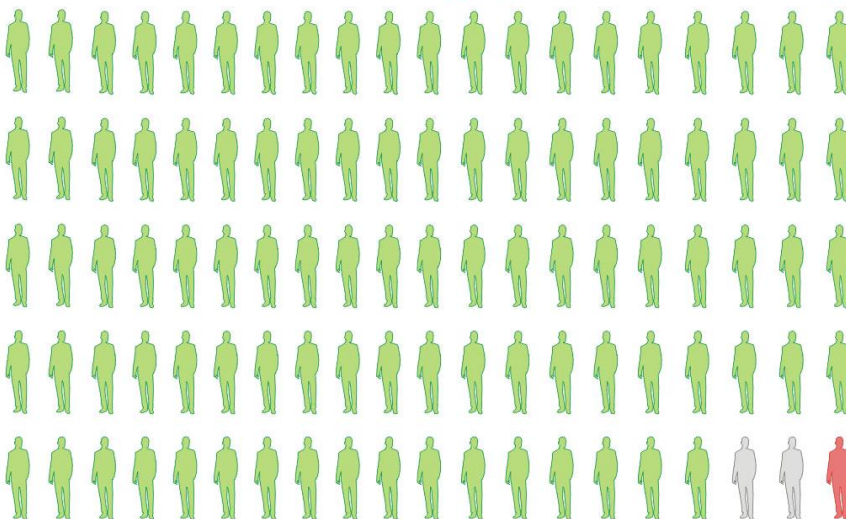
- It is critical to separate the scientific understanding of climate change from the 'social' understanding of climate change, especially here in the U.S.
- American opinions on climate change:
- <http://www.economist.com/blog/s/dailychart/2011/09/american-public-opinion-and-climate-change>

Learning about climate change: science, media, and blogs

- ✎ A quick google on climate change can provide a wide range of information, suggesting it is anything from an imminent disaster to a complete hoax
- ✎ Scientific research shows increasing greenhouse gases, changes in many aspects of our climate (temp, ice formation, tropical storm intensity, sea level), and provides a range of future climatic conditions based on our best knowledge and modeling
- ✎ The media presents climate change news in a variety of ways, often highlighting the latest study (w/o putting it on context of all research) or sensational studies (any study that suggests something unique), and often attempts to be "fair" by presenting "both sides" even if one side represents an extremely fringe (or practically non-existent) view
- ✎ Blogs, online opinion sites, etc., may misrepresent information, present information out of context, or present false information to validate their viewpoint
 - <http://www.rightsidenews.com/200907155494/energy-and-environment/un-models-on-global-warming-fundamentally-wrong.html>
 - http://www.eurekalert.org/pub_releases/2009-07/uoha-ag071609.php
- ✎ If you ever have questions, visit: <http://www.skepticalscience.com/argument.php>

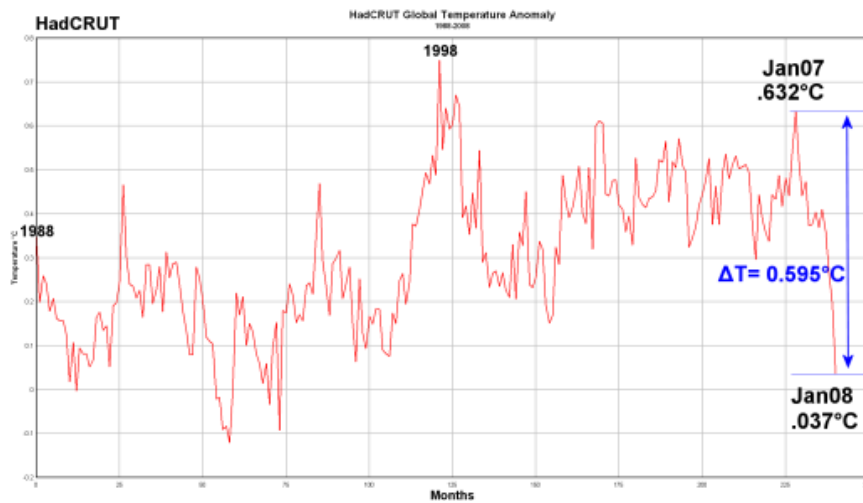


97 out of 100 climate experts think humans are causing global warming



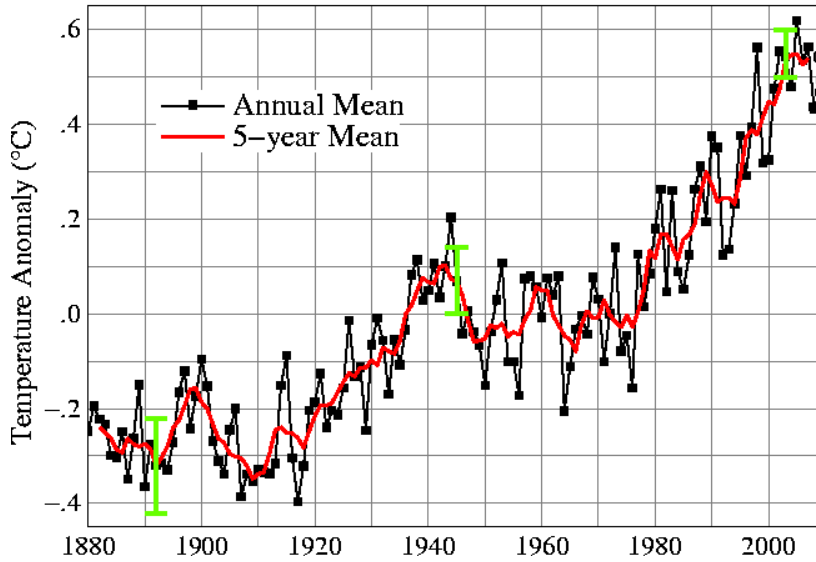
Skeptics? Or deniers?

- ✿ Analysis of a couple global temperature data sets can show us:
 - Global temperature has been stable since 1997
 - Global temperature has decreased since 1998
 - Global temperature has increased since 1999
- ✿ How can this be?



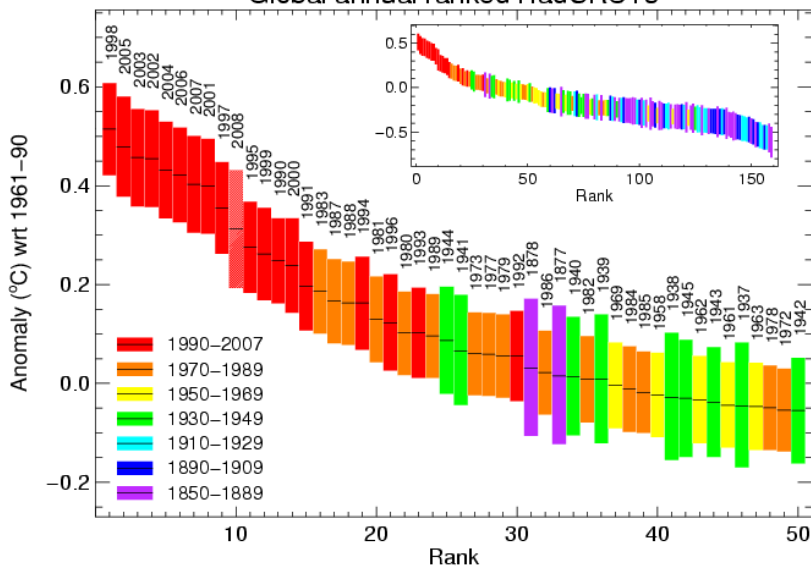
NASA Data

Global Land–Ocean Temperature Index



Has it been cool lately?

Global annual ranked HadCRUT3

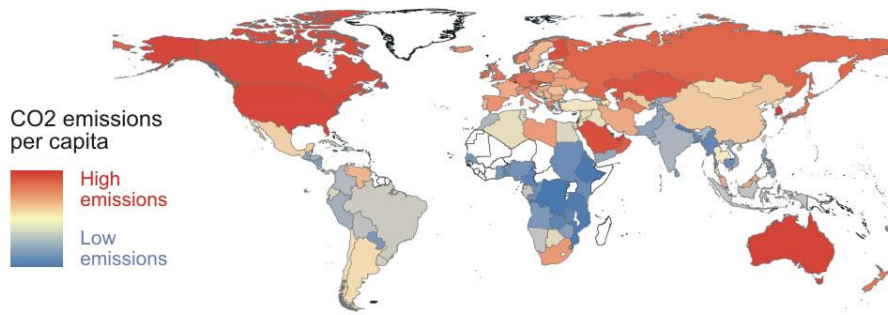


Joint Science Academies' Statement

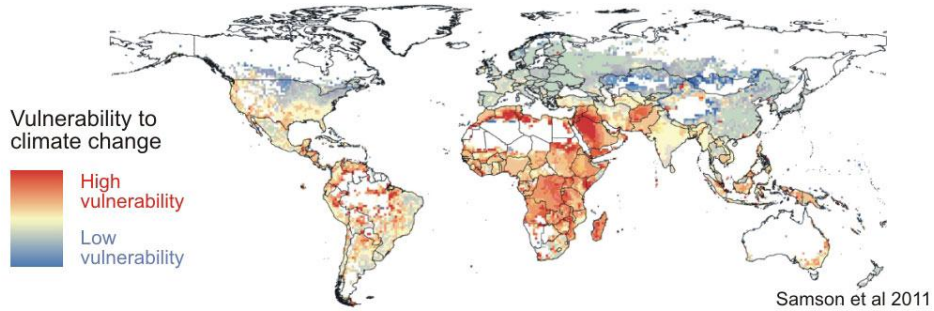
- ✿ Climate change is real.
 - Yes it is difficult to fully understand such a complex system, but there is strong evidence significant global warming is occurring
 - Rising air temps, ocean temps, sea levels, retreating glaciers, & changes to biological systems
 - It is likely that most of the warming in recent decades is attributable to human activities
- ✿ Greenhouse gases are well above pre-industrial levels
 - CO₂ has increased from 280 ppm in 1750 to over 375 today (actually 384.78 as of September 2009)
 - Higher than any levels that can be reliably measured (i.e., in the last 420,000 years)
- ✿ The Earth has warmed by approximately 0.6 O C over the 20th Century, and is predicted to warm by another 1.4 to 5.8 O C in the 21st Century

Joint Science Academies' Statement

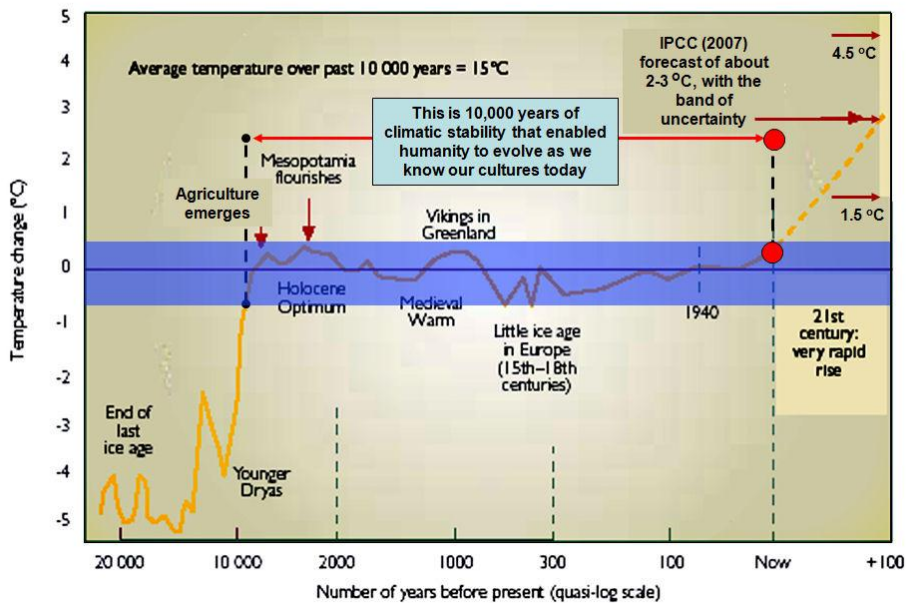
- ✿ Reduce the causes, prepare for the consequences
 - Beneficial and harmful changes predicted at the regional level, faster change means harmful conditions may dominate
 - Poor countries face severe threats since they have few resources to respond to changes
- ✿ Urge all nations to take prompt action to curb the causes of climate change
 - ✿ Signed by Science Academies from USA, Russia, China, Japan, India, Mexico, Canada, Brazil, South Africa, Italy, Germany, France, UK



Those who contribute the least greenhouse gases will be most impacted by climate change



The Last 20,000 Years seems to have been Ideal for the Development of Human Societies. Is this a Historic “Sweet Spot” that Enabled Humans to Flourish?

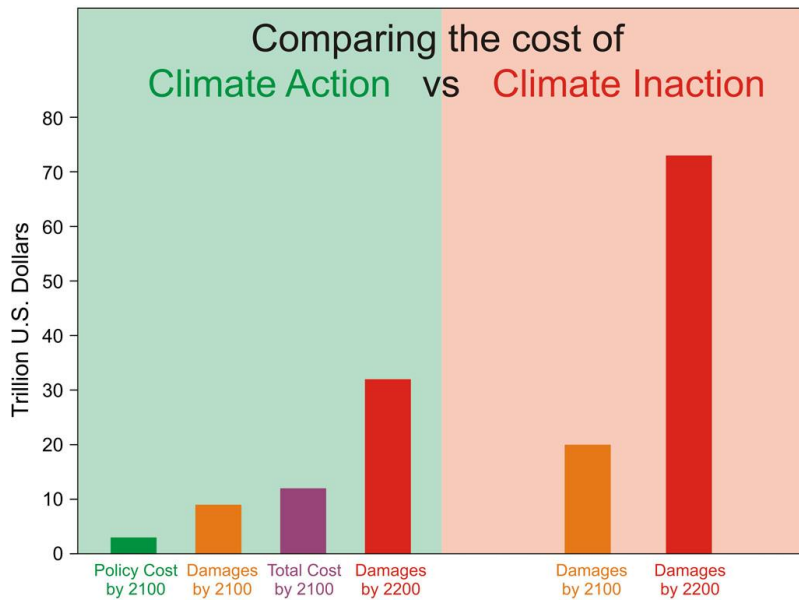


Arctic Amplification

- ✎ Climate-change researchers have found that air temperatures in the region are higher than would be normally expected during the autumn because the increased melting of the summer Arctic sea ice is accumulating heat in the ocean. The phenomenon, known as Arctic amplification, was not expected to be seen for at least another 10 or 15 years and the findings will further raise concerns that the Arctic has already passed the climatic tipping-point towards ice-free summers, beyond which it may not recover.
- ✎ “The recent [Arctic] sea-ice retreat is larger than in any of the (19) IPCC [climate] models” — said a [Norwegian expert](#) in 2005. Unfortunately, **the retreat has accelerated in the past three years.**
- ✎ Bottom line: we are learning more about various feedbacks that may occur as temperature increases, and many are positive and may push us towards more or faster changes

The Economics of Climate Change

- ✎ Recent studies suggest we should spend ~2% of global GDP to limit the impacts of climate change
- ✎ A study by the NYU School of Law surveyed 144 economists and found almost all viewed climate change as a threat to the US and (~95%) thought the US should sign a global treaty to reduce emissions (<http://policyintegrity.org/publications/documents/EconomistsandClimateChange.pdf>)
- ✎ Economists (and others) view climate change as a threat because reports estimate that climate change could lead to global losses of 5% to 19% of GDP



Conclusion

- 🌿 Science is overwhelming in support of significant ongoing climate change due largely to anthropogenic causes
 - Over a century of work investigating the link between greenhouse gas levels and warming
 - Multiple lines of evidence from many fields of study
- 🌿 The climate **is** changing
 - In a sense, we are “lucky” that much of the warming is anthropogenic so we can take actions to limit or slow future changes, allowing more time for mitigation or adaptation

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Chapter 8

Energy and Civilization: Patterns of Consumption

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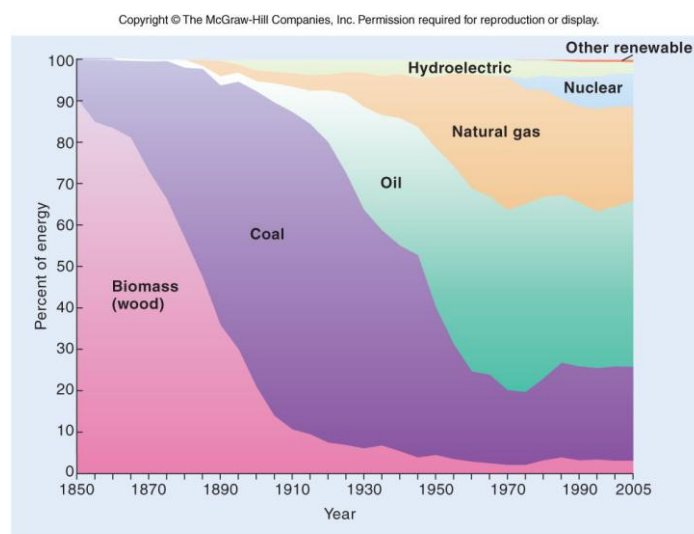
History of Energy Consumption

- ✎ A great deal of energy emanates from Earth's core, enabling us to harness geothermal power.
- ✎ Energy also resides within the bonds among protons and neutrons in atoms, providing us with nuclear power.
- ✎ **Most of our energy comes from the sun.**
 - Solar radiation, wind, and hydroelectric power
 - Photosynthesis produces biomass (current sunlight)
 - **Fossil fuels:** highly combustible substances formed from the remains of organisms from past geological ages (ancient sunlight)
 - The majority of energy in the modern world comes from these fossil fuels (oil, coal, and natural gas)

Resources are renewable or non-renewable

- **Renewable energy:** supplies will not be depleted by our use
 - Sunlight, geothermal energy, and tidal energy
- **Nonrenewable energy:** at our current rates of consumption, we will use up Earth's accessible store of these sources in a matter of decades to centuries
 - Oil, coal, natural gas
 - They cannot be replaced in any time span useful to our civilization.
 - Nuclear energy could last longer w/ new technology

History of Energy Consumption



Changes in energy sources

History of Energy Consumption

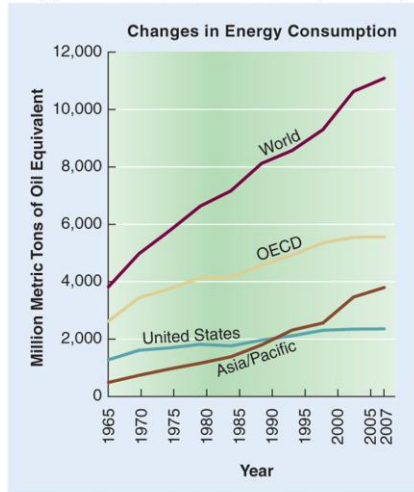
- ✿ The invention of the automobile dramatically increased the demand for oil products.
- ✿ The growth of the automobile industry led to roadway construction, which required energy.
 - Better roads permitted higher speeds.
 - Higher speeds permitted bigger, faster cars.
 - Bigger, faster cars required better roads.
- ✿ Convenience of the automobile led to two-car families.
 - Job growth in automobile-related industries.
 - Major role in development of industrialized nations.

History of Energy Consumption

- ✿ Cars altered people's lifestyles:
 - Vacationers could travel greater distances.
 - People could live farther from work, leading to sprawling cities and suburbs.
 - In the suburbs, labor-saving, energy-consuming devices became essential in the home.
 - We expect to see Florida oranges, California lettuces, and Central American bananas in any supermarket in North America.
 - They must be processed, refrigerated, and transported to distant locations.

Energy Consumption Trends

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Source: Data from BP Statistical Review of World Energy, 2008.

Changes in world energy consumption

- ☑ Total energy
- ☑ Crude oil
- ☑ Oil products
- ☑ Natural gas
- ☑ Coal, lignite
- ☑ Power
- ☑ Renewables
- ☑ CO2-fuel combustion

Electricity domestic consumption



Ranking

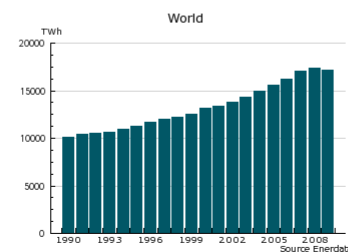
Electricity domestic consumption
Year: 2009 Unit: TWh

United States	3,747
China	3,149
Japan	962
Russia	800
India	621
Germany	510
Canada	499
France	453
South Korea	420
Brazil	410

Glossary

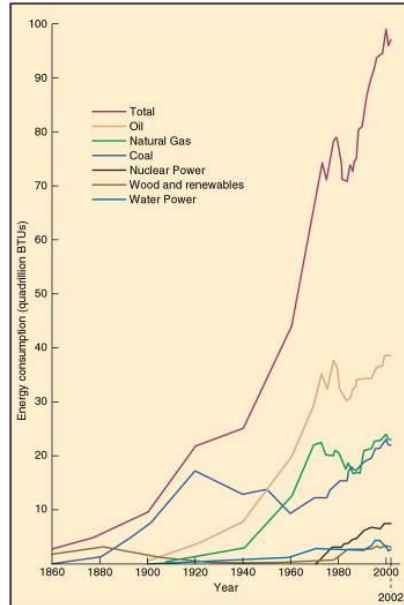
Sources

How to use

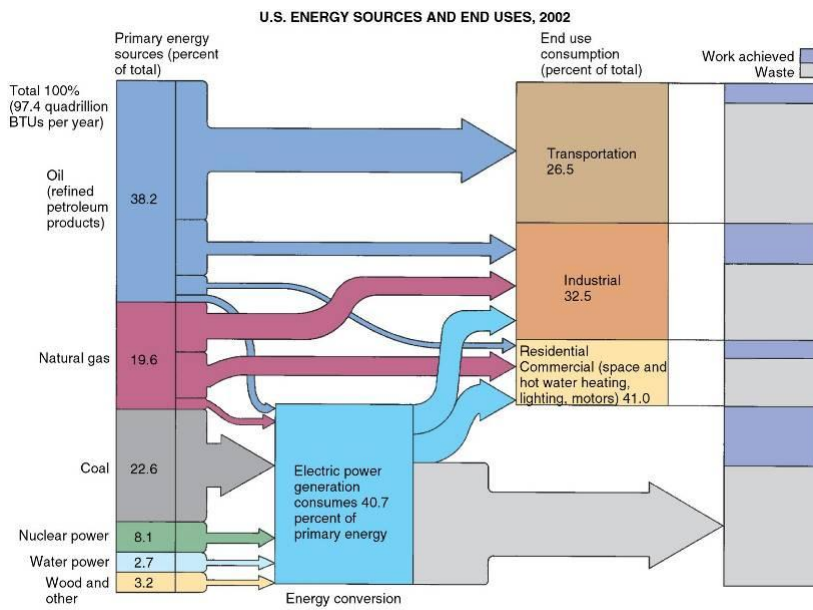


At the world level, electricity consumption was cut down by 1.5% during 2009, for the first time since World War II. Except in Asia and Middle East, consumptions reduced in all the world regions. In OECD countries, accounting for 53% of the total, electricity demand scaled down by more than 4.5 % in both Europe and North America while it shrank by above 7% in Japan. Electricity demand also dropped by more than 4.5% in CIS countries, driven by a large cut in Russian consumption. Conversely, in China and India (22% of the world's consumption), electricity consumption continued to rise at a strong pace (+6-7%) to meet energy needs related to high economic growth. In Middle East, growth rate was softened but remained high, just below 4%.

Energy Consumption in the United States



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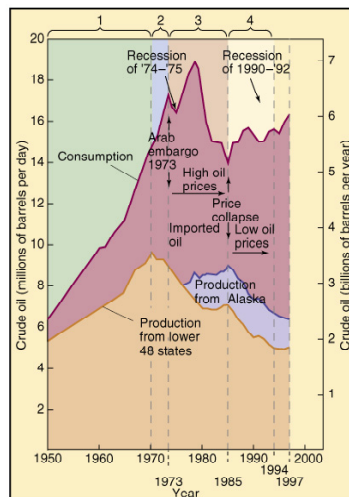


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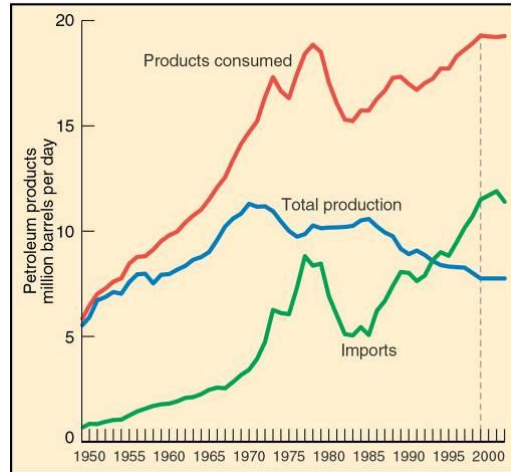
Source	New England*	United States	World
Nuclear power	29.1	20.7	16.9
Natural gas	29.4	16.8	17.4
Coal	15.3	51.2	39.1
Oil	14.2	3.4	7.9
Hydro	5.0	5.8	17.1
Other (wood, refuse, renewables)	7.0	2.1	1.6

*Does not include an additional 11.5% from national energy grid.
 (Sources: ISO New England, U.S. Energy Information Administration, International Energy Agency.)
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Oil Production and Consumption in the United States



Consumption, Domestic Production, and Imports of Petroleum Products



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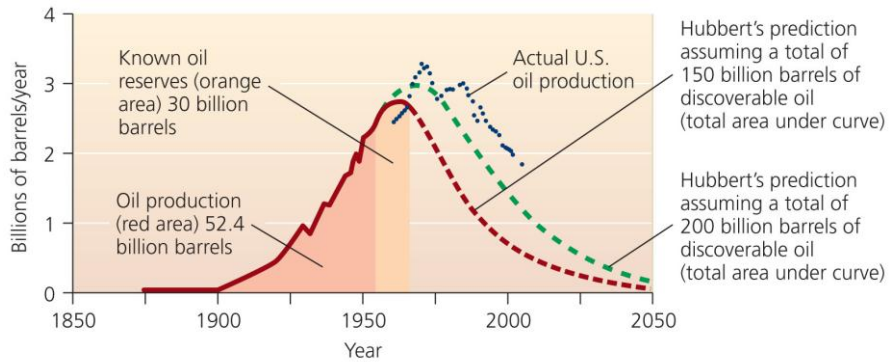
Petroleum products have many uses

Oil is refined to create many products.



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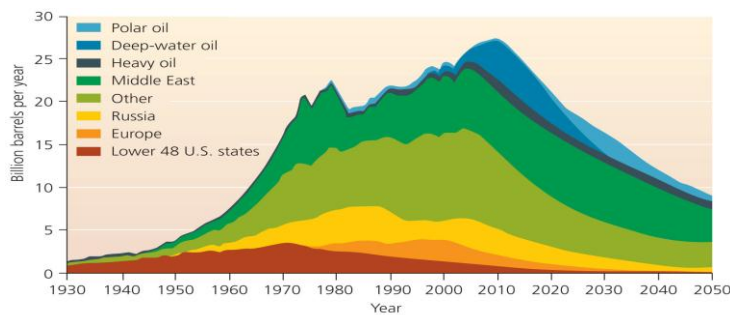
U.S. oil production has already peaked



(a) Hubbert's prediction of peak in U.S. oil production, with actual data

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Global oil production is peaking



(b) Modern prediction of peak in global oil production

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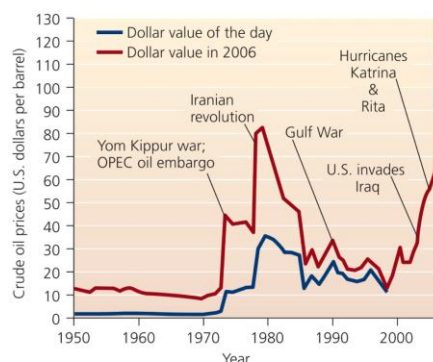
According to a recent report from the UK ERC, after reviewing over 500 studies and examining the predictions from all stakeholders, it appears peak oil production will occur by 2030 at the latest – if not much sooner.

Peaking oil production: consequences?

- ✘ Coming divergence of demand and supply **could** have momentous economic, social, and political consequences
- ✘ “The long emergency”: economies could falter and reorganize locally from lacking cheap oil to transport goods
 - Suburbs could be deserted as people move back to cities (higher density living required b/c of lack of fuel).
- ✘ More optimistic observers argue that as supplies dwindle, conservation and alternative energy supplies will kick in.
 - We could be saved from major disruptions, IF we can conserve enough and switch to alternate fuels fast enough (which most say we are not doing at the moment, maybe fracking will give us a few more years?)

The oil embargo of the 1970s caused panic

- OPEC’s (Organization of Petroleum Exporting Countries) oil embargo caused widespread panic, skyrocketing prices, and spurred inflation.

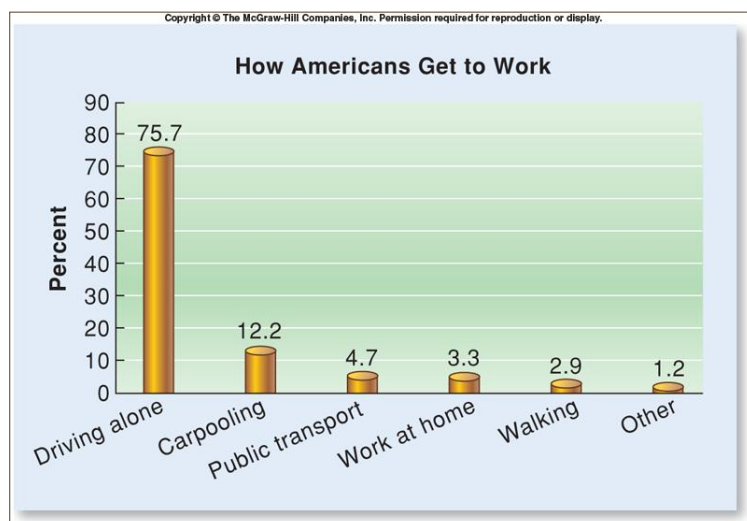


(a) Global price of oil, 1950–2008
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How Energy Is Used

- ✿ In North America, government policies have kept energy costs artificially low to support the automobile industry while removing support for bus and rail transport.
 - Private automobiles in North America consume over 40% of world gasoline production.

How Energy Is Used



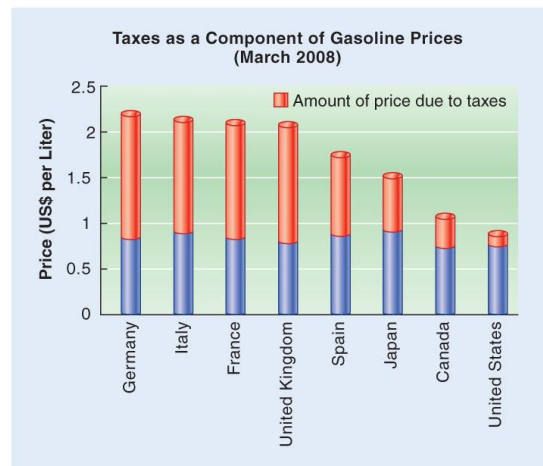
How Americans get to work

The Economics and Politics of Energy Use

- Governments often charge road users to help build and repair roads by taxing fuel.
 - Many European countries raise more money from fuel taxes than they spend on building and repairing roads.
 - The average European car driver pays >2 times as much as a U.S. driver, but uses 26% less fuel to drive the same distance as a U.S. driver.
 - U.S. only raises 60% of monies needed for roads from fuel taxes.
 - Low fuel costs in the U.S. encourage more travel, which increases road repair costs.

The Economics and Politics of Energy Use

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Source: International Energy Agency.

Gasoline taxes and fuel efficiency

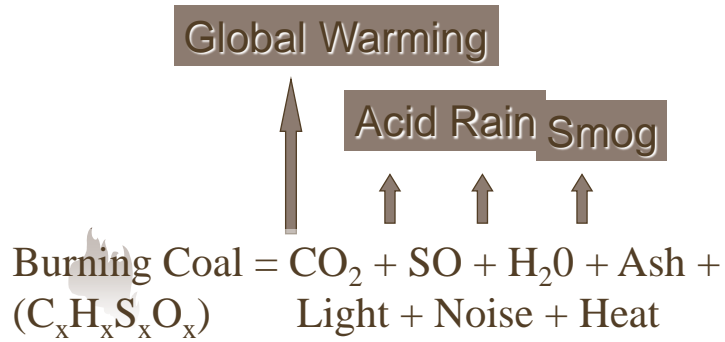
Electrical Energy

- ✎ Electricity is both a way that energy is consumed and a way that it is supplied.
- ✎ Most electrical energy is produced as a result of burning fossil fuels.
- ✎ Because electricity is easily transported and its uses are so varied, electricity is a major world energy source.
 - Industrialized nations have 20% of the world's population, but use 60% of the world's electricity.
 - Per capita use in North America is 10 times greater than that in less-developed countries.

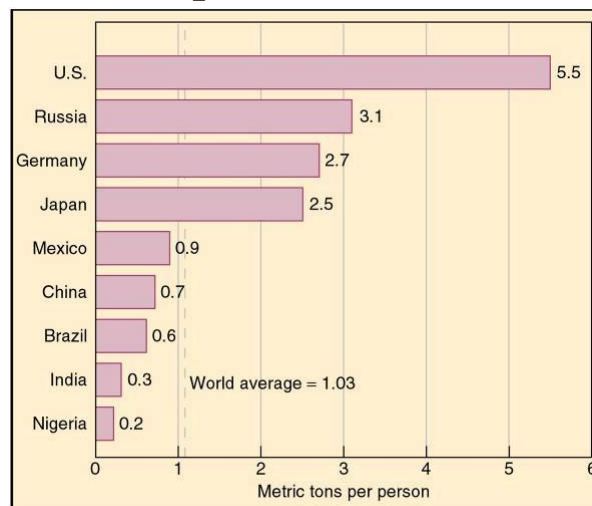
Coal contains impurities

- ✎ Sulfur, mercury, arsenic, and other trace metals
- ✎ Sulfur content depends on whether coal was formed in salt water or freshwater.
 - High sulfur coal in the eastern U.S. was formed in marine sediments.
 - Burning high-sulfur coal releases sulfate air pollutants, which contribute to smog and acidic deposition.
- ✎ Mercury can **bioaccumulate**.

Primary and Secondary Effects from Burning Coal



Carbon (CO₂) Emission Per Capita



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Chapter 8

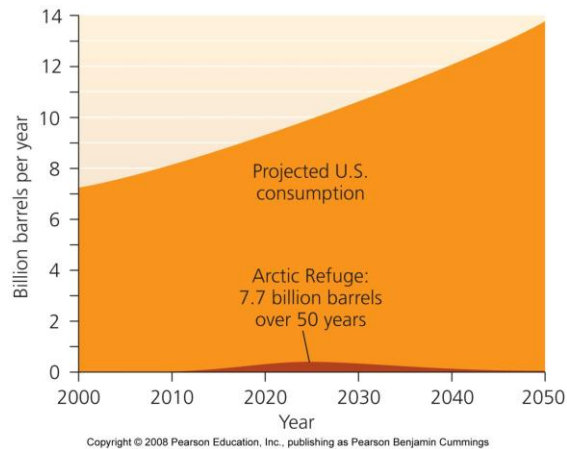
Energy and Civilization: Patterns of Consumption

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Fossil fuels: yesterday's energy

- ✿ Fossil fuels are declining in abundance and in their energy return on investment, and are increasing in price
- ✿ Fossil fuels cause many types of environmental destruction from their extraction, transport, and combustion
- ✿ Main source of carbon dioxide, increasing global warming – the single largest threat to many species on Earth, including *Homo sapiens*
- ✿ Alternative energy sources are required for our future

We cannot drill our way out of this problem

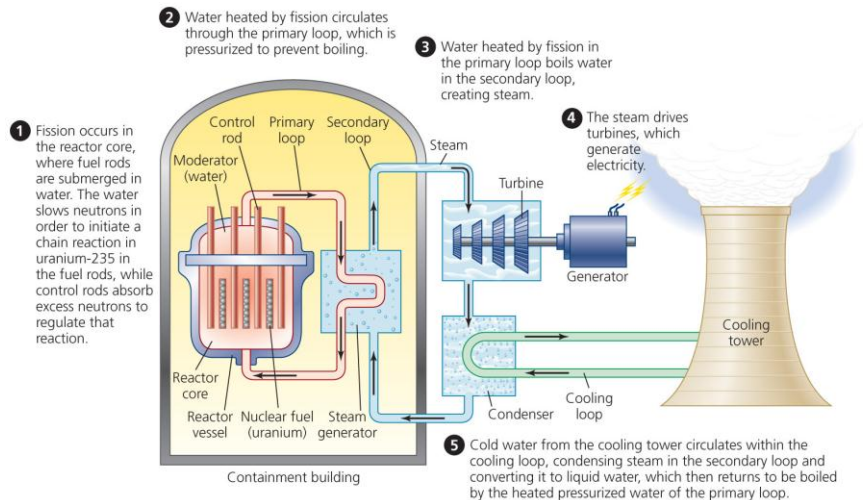


ANWR's estimated 7.7 billion barrels represents just one year's supply for the U.S. at current consumption rates.

Nuclear Power

- Nuclear power occupies an odd and conflicted position in our energy debate.
 - It is free from the air pollution produced by fossil fuels.
 - But there are issues of nuclear weaponry, radioactive waste disposal, and previous accidents.
- The U.S. generates the most electricity from nuclear power.
 - 20% of U.S. electricity comes from nuclear sources.
 - Other nations rely more heavily on nuclear power (i.e., France gets 78% of its electricity from nuclear power).

A typical light water reactor



Nuclear power delivers energy cleanly

- Nuclear power prevents 600 million metric tons of carbon emissions each year.
 - Equivalent to 8% of global greenhouse gas emissions
 - Poses far fewer chronic health risks than fossil fuels
- Nuclear power plants cause less landscape damage, generate less solid wastes, and are safer for workers than coal-fired plants.
- Drawbacks of nuclear power:
 - Nuclear waste is radioactive.
 - If an accident occurs, or the plant is sabotaged, the consequences can potentially be catastrophic.
- Today, the world has 439 operating nuclear plants in 31 nations.

Coal versus nuclear power

Environmental Impacts of Coal-fired and Nuclear Power		
Type of Impact	Coal	Nuclear
Land and ecosystem disturbance from mining	Extensive, on surface or underground	Less extensive
Greenhouse gas emissions	Considerable emissions	None from plant operation; much less than coal over the entire life cycle
Other air pollutants	Sulfur dioxide, nitrogen oxides, particulate matter, and other pollutants	No pollutant emissions
Radioactive emissions	No appreciable emissions	No appreciable emissions during normal operation; possibility of emissions during severe accident
Occupational health among workers	More known health problems and fatalities	Fewer known health problems and fatalities
Health impacts on nearby residents	Air pollution impairs health	No appreciable known health impacts under normal operation
Effects of accident or sabotage	No widespread effects	Potentially catastrophic widespread effects
Solid waste	More generated	Less generated
Radioactive waste	None	Radioactive waste generated
Fuel supplies remaining	Should last several hundred more years	Uncertain; supplies could last longer or shorter than coal supplies

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Nuclear power poses small risks of large accidents

- The possibility of catastrophic accidents spawns public anxiety.
- **Three Mile Island (1979):** the most serious accident in the U.S.
 - **Meltdown:** melting of uranium fuel rods, releasing radiation, as coolant water drained from the reactor vessel, and increased temperatures
 - It proceeded through ½ of one reactor core.
 - Radiation remained trapped in the containment building.
 - The cleanup cost billions of dollars.
- Three Mile Island is regarded as a near-miss: the emergency could have been far worse.

Chernobyl was the worst accident yet

- The 1986 explosion at the Chernobyl plant in Ukraine caused the most severe nuclear power plant accident the world has seen.
 - Human error combined with unsafe design
 - For 10 days, radiation escaped from the plant while crews tried to put out the fire.
 - The Soviet government evacuated more than 100,000 residents.
 - The landscape around the plant for 30 km (19 mi) remains contaminated.
 - The accident killed 31 people directly and many became sick or developed cancer.

The Chernobyl accident

The destroyed reactor was encased in a massive concrete sarcophagus to contain leakage — but a new, larger sarcophagus must be built.



(a) The Chernobyl sarcophagus

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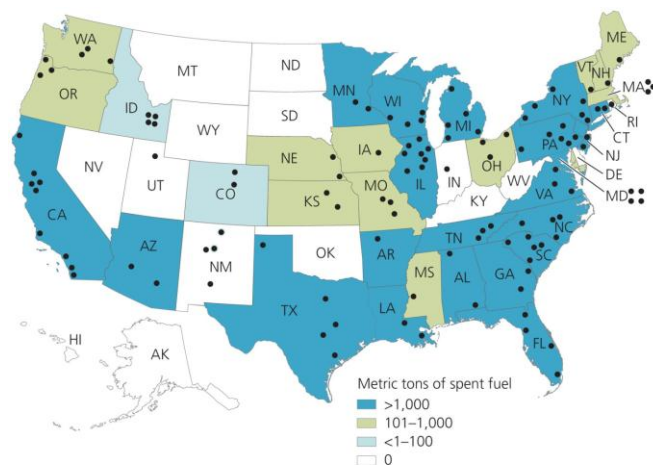
(b) Technicians measuring radiation

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Spent fuel rods must be stored

- Nuclear waste will remain radioactive for thousands of years.
 - Is currently held in temporary storage at nuclear power plants across the U.S. and the world
- Spent fuel rods are sunk in pools of cooling water to minimize radiation leakage.
- U.S. power plants store 56,000 metric tons of high-level radioactive waste, as well as much more low-level radioactive waste.
 - Waste is held at 125 sites in over 39 states.
 - Over 161 million U.S. citizens live within 125 km (75 mi) of temporarily stored waste.

U.S. storage of high-level radioactive waste



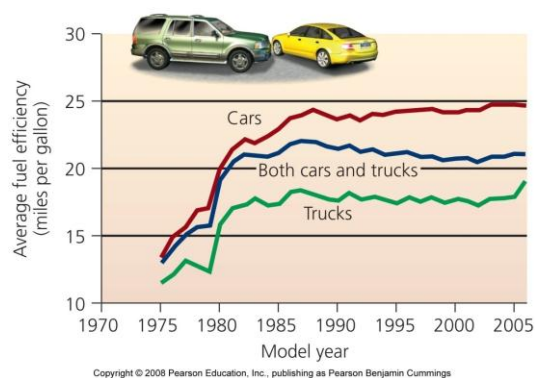
Energy conservation

- **Energy conservation:** the practice of reducing energy use to:
 - Extend the life of our nonrenewable energy supplies
 - Be less wasteful
 - Reduce our environmental impact
- Conservation is the “low hanging fruit” that can help buy time as we move to alternative energy sources

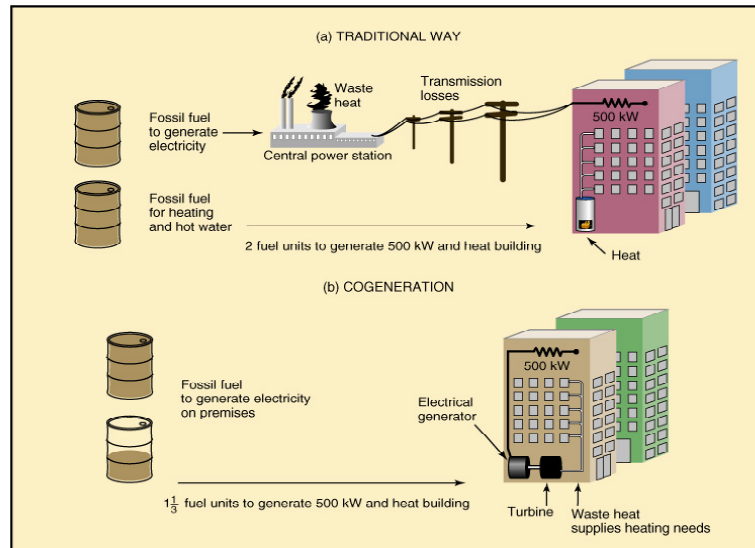
CAFE standards

After years of little progress, in 2007, Congress passed legislation to raise average fuel efficiency to 35 mpg by 2020, but this is still far lower than in other developed nations.

In May, President Obama announced an agreement for 35.5 by the year 2016.

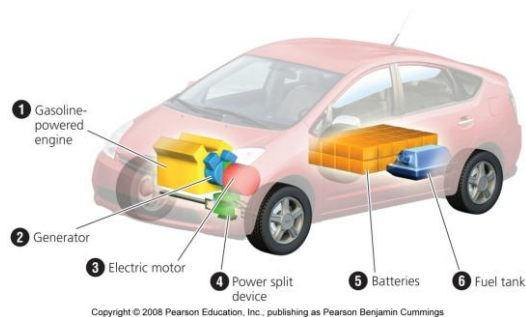


Combined Heat and Power: Cogeneration



Personal choice and efficiency

- Individuals can choose to reduce energy consumption.
 - Driving less, turning off lights, turning down thermostats, buying efficient machines
- Society can make more efficient devices.
 - Fuel efficient cars, electric or hybrid vehicles

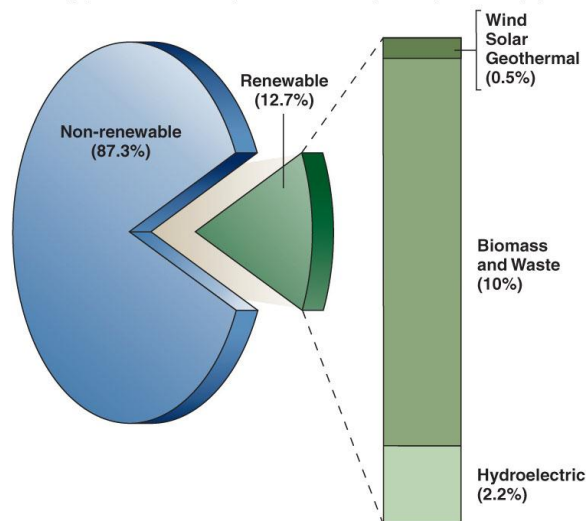


Energy Conservation

- ✿ Many conservation techniques are relatively simple and highly cost-effective.
 - Highly efficient fluorescent light bulbs give the same amount of light as incandescent bulbs for 25% of the energy, and produce less heat.
 - Lighting and air conditioning (removing the heat from inefficient incandescent lighting) account for 25% of U.S. electricity consumption (>40% just for AC in FL).
 - Automatic dimming or light-shutoff devices are being used in new construction.

Renewable Sources of Energy

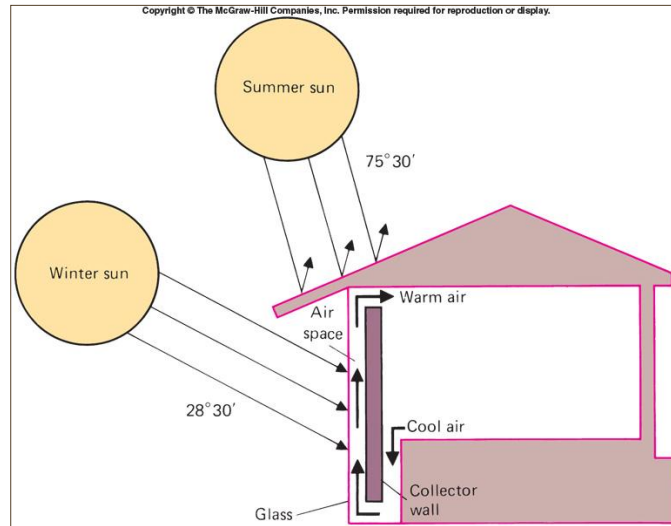
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Source: International Energy Agency.

Renewable energy as a share of total energy consumption (World 2006)

Renewable Sources of Energy

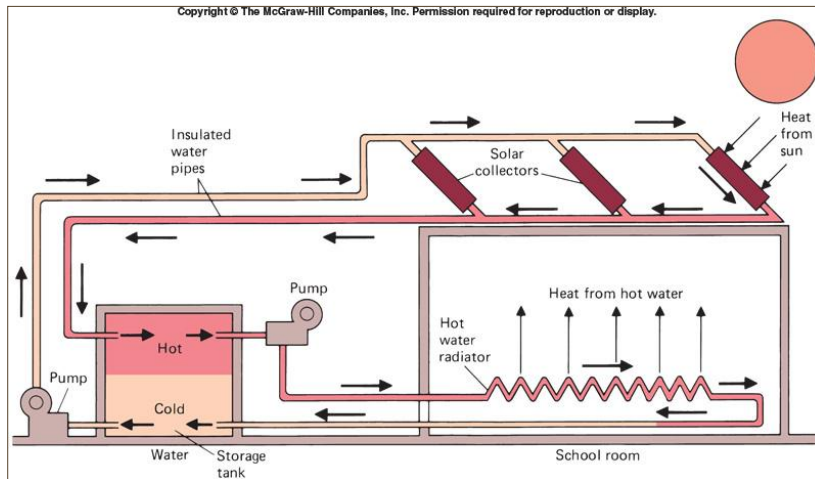


Passive solar heating

Renewable Sources of Energy

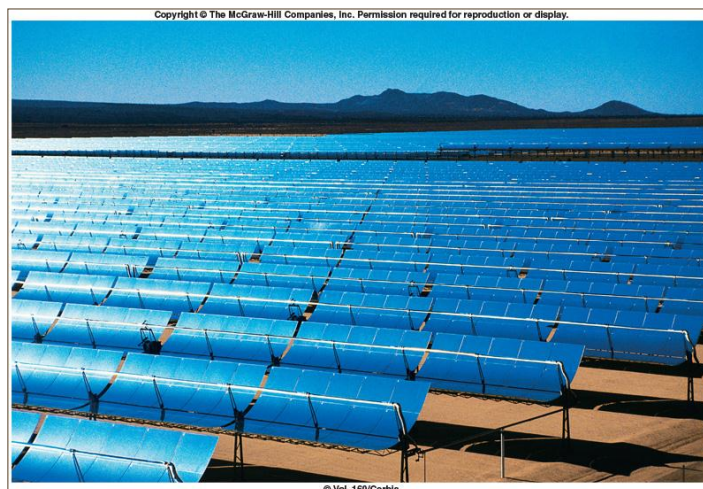
- ☛ Daily energy from the sun is 600 times greater than energy produced each day by all other energy sources combined.
 - The major problems with solar energy are its intermittent and diffuse nature.
- ☛ Solar energy is utilized in three ways:
 - In passive heating, the sun's energy is converted directly to heat and used at collection site.
 - In an active heating system, the sun's energy is converted into heat, but transported elsewhere to be used.
 - Solar energy is also transformed into electrical energy.

Renewable Sources of Energy



Solar heating designs

Renewable Sources of Energy



Solar generation of electricity

Renewable Sources of Energy

🌿 Ocean Power

- Tidal power
- Ocean currents (underwater “windmills”)
- Ocean temperature differences (OTEC)
- Cold water used for air conditioning systems near coast

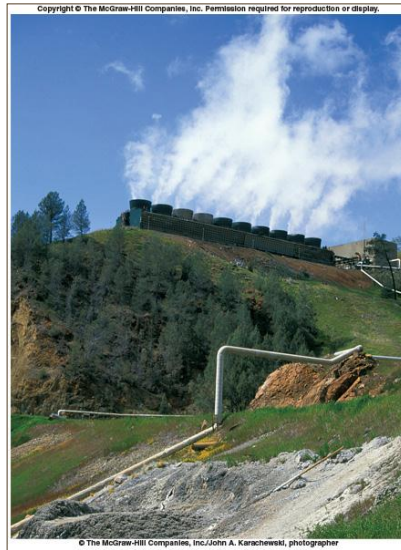
- Florida Atlantic University has an Ocean Energy research program, details at <http://coet.fau.edu/>

Renewable Sources of Energy

🌿 Geothermal Power

- In geologically active areas hot magma moves to the surface and heats water.
 - The hot water can heat buildings or generate electricity through a steam turbine.
- Wells are drilled to obtain steam trapped underground, and the steam powers electrical generators.
- The U.S. produces 30% of world’s geothermal electricity, with the world’s largest plant in San Francisco.
- However, this accounts for less than 1% of U.S. electrical consumption.

Renewable Sources of Energy



Geothermal power plant

Renewable Sources of Energy

🌿 Wind Power

- As warm air becomes less dense and rises, cooler, denser, air flows in to take its place. This flow of air is wind.
- Some areas are better suited than others, and winds are variable. Wind energy must be coupled with other sources of energy.
- Only 0.5% of total worldwide electrical production is from wind.
- Only 1% of U.S. electricity is from wind. 20% could be generated by 2030.

Biofuels can power automobiles

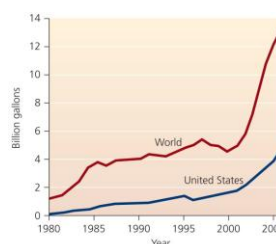
- **Ethanol:** produced as a biofuel by fermenting carbohydrate-rich crops
 - Ethanol is widely added to U.S. gasoline to reduce emissions.
 - Any vehicle will run well on a 10% ethanol mix.
- But, corn is perhaps one of the least efficient ways to produce ethanol

In 2007, the U.S. produced 30 billion L (6.5 million gal) of ethanol in 100 ethanol plants. (In 2006, corn ethanol production received \$7 billion in federal subsidies).



(a) Corn grown for ethanol

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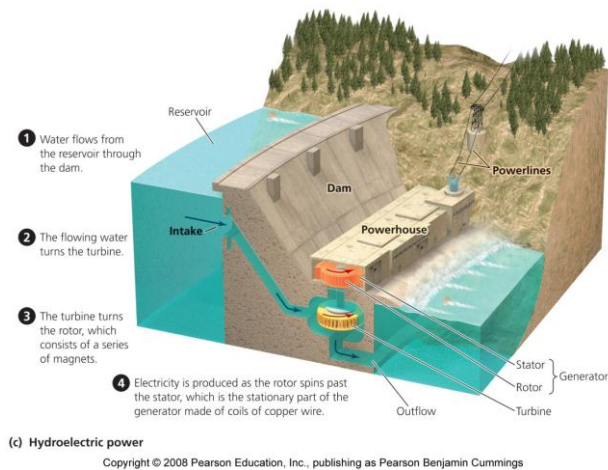
(b) Ethanol production, 1980-2006

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Hydropower is clean and renewable

- Hydropower has two clear advantages over fossil fuels for producing electricity:
 - It is renewable: as long as precipitation fills rivers, we can use water to turn turbines.
 - It is clean: no carbon dioxide is emitted.
- Hydropower is efficient.
 - It has an EROI of 10:1, as high as any modern-day energy source.

A typical dam



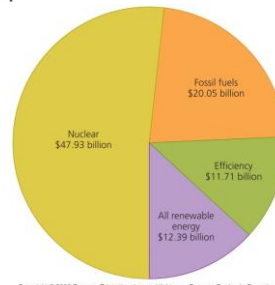
Hydropower has negative impacts

- Damming rivers destroys riverine habitats.
- Natural flooding cycles are disrupted.
- Sediment deposition
- Thermal pollution of downstream water
- Reducing fish populations and aquatic biodiversity

Rapid growth in renewables will continue, but will it be fast enough?

- Due to: population and consumption growth, increased energy demand, declining fossil fuel supplies, and the demand for a cleaner environment
- Political, technological, and economic barriers prevent a quick switch to renewables.
 - Renewables receive little government help.

The 2007 energy bill passed only after Congress dropped requirements to shift subsidies from non-renewables to renewables and for utilities to increase using renewables.



The future of energy

- Improved efficiency to reduce the energy needs of each person
- A diverse portfolio of clean, renewable sources
- Distributed power generation, increases in “microgeneration” (small amounts of energy produced where needed)
- May involve a re-organizing of the population to decrease energy needs or to increase population density in energy-rich areas