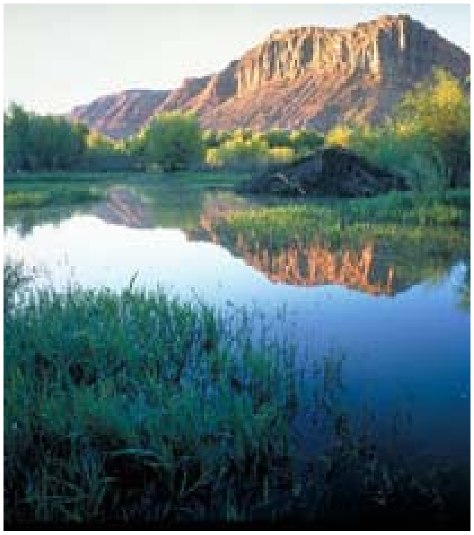
Table of Contents

NATURAL OUTLOOKS

CLIMATE CHANGES, ENERGY AND TECHNOLOGY OPTIONS, CONSERVATION PRACTICES, AND OUR HUMAN FUTURE

LARRY BELL

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Larry has authored dozens of technical conference papers and professional journal articles addressing a broad variety of space and terrestrial design and technology topics, and has co-founded several successful high-tech companies. In addition to NASA Headquarters achievement and recognition certificates, he has received two of the highest honors awarded by the Federation of Astronautics and Cosmonautics of the former Soviet Union for his contributions to international space development, the Konstantin Tsiolkovsky Gold Medal and the Yuri Gagarin Diploma. His name was placed on the Russian rocket that launched the first astronaut crew to the International Space Station. He is an Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA), and a Fellow of the Explorers Club.

About the Author

Causes and consequences of climate changes, interventions to prevent energy shortages, and the need to ensure an ecologically-healthy and resource-sustainable planet for future generations are concerns all responsible people share. These issues are enormously complex, and all are fundamentally interconnected. Those among us who seek simple or singular solutions to any of the urgent challenges we face are unrealistic. And those who believe that efforts towards progress are futile on one hand, or unnecessary on the other, are comparably misguided.

A large number and variety of very dedicated people are working to gain better understanding of vital issues, and to develop and implement constructive responses. Included are scientists who study principles and dynamic relationships that influence weather and climate patterns, research and development specialists who innovate more energy-efficient processes and devices, public and private administrators who guide conservation initiatives, and architects and building owners who put sustainable design into practice. Each of us through lifestyle routines and purchase choices determine our own impact upon the planet.

Media headlines and commentaries offer daily evidence of great public importance attached to climate, energy, conservation, and environmental issues. Many feature speculative projections of ecological catastrophes based upon climate model extrapolations, aggressive advocacy and criticism of various energy and fuel alternatives, and exaggerated claims that certain revolutionary science and technology advancements may dramatically reduce resource consumption and depletion problems. While such reports reveal healthy diversity of opinions, they also demonstrate that sensationalism often trumps real substance in media coverage.

Progress is frequently realized as a product of disagreements and controversies that motivate discourse, discovery, and innovation. Conflicting theories and observations regarding climate trends and influences motivate development of more reliable monitoring instruments and analytical methodologies along with clearer recognition of their predictive limitations. Rational debates about net benefits, growth capacities, and environmental impacts of various energy options lead to more informed policy and investment decisions. Marketplace competition between corporate power and technology providers stimulates better options that benefit everyone.

As creatures of Nature, we are integral parts of vast and dynamic systems of incomprehensible intricacy and balance. Everything we create and do is subject to natural conservation principles that we apply with various levels of economy and efficacy. Realizing this, we can learn to live more resourcefully by observing ways Nature recycles energy and nutrients, and apply those lessons at all levels of scale within our global community. Many of these basic lessons are relatively simple. We must learn to consume less, do more with what we use, and protect and preserve the environments and resources that we and other life forms interdependently require to survive.

We are endowed by Nature with the spirit to care about the consequences of our actions, the intelligence to learn from our mistakes, and the creativity to adapt and evolve. World population growth, expansion of commerce, dwindling fossil and water resources, and pollution of the biosphere are testing these gifts as never before. Passionate, wise, and innovative people are dedicating their lives to address these imperatives. We can be grateful to them, support their initiatives, follow their examples, and ultimately succeed. No other option is acceptable.

TABLE OF CONTENTS

To Table of Contents

1. Eindhoven Tech U. 2. The Cavalier Daily 3. Simon Ho 4. Israel EICI
5. Filipe Forts 6. Trek Earth 7. Trek Earth
8. Langfel Designs 9. Space Daily

PART ONE: BIOSYSTEMS & CLIMATE

IMPORTANT FACTORS THAT INFLUENCE ALL LIFE ON OUR PLANET

Living within natural systems

We humans are integral parts of marvelous, complex, intricate and dynamic natural "systems" that are constantly in a precarious state of balance.

- Unlike categories of fixed and bounded systems that we often define to divide Nature into more understandable parts and phenomena, true Nature is connected and synergetic.
  - It is important to realize that when we focus exclusively upon any of the parts in order to isolate and examine aspects that we are most interested in, we risk missing a much larger picture that more fully reveals Nature's true nature.
  - We should also recognize that we and our systems of living are parts of that picture, and that consequences of those systems are inseparable from the other parts which sustain us.

10. Wmdstar

Our Natural World

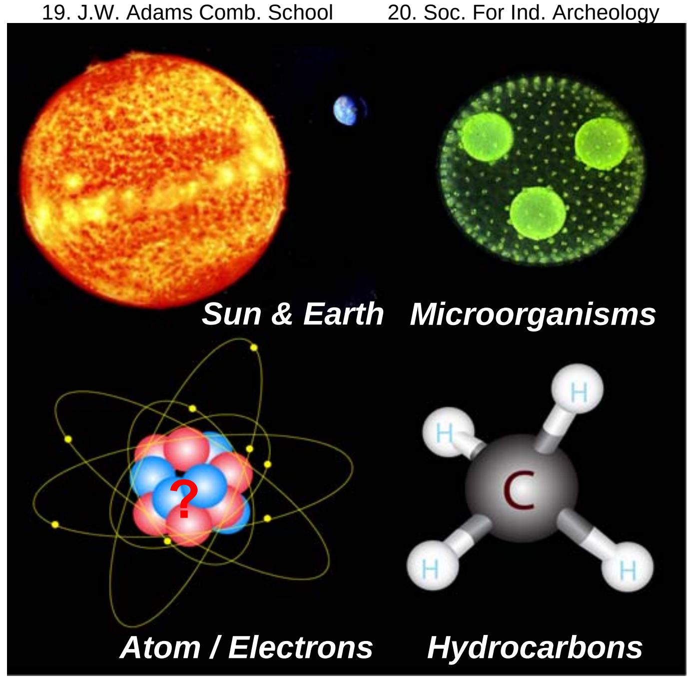
11. NASA
12. NASA
13. NASA
14. NASA
15. Wash. Native Plant Soc.
16. Associated Content

Scales of Influence

Common use of the term "system" to identify certain interrelationships between natural objects and phenomena separate from others can sometimes imply boundaries of scale or function that obfuscates connectivity within larger frameworks.

- The way we view any system depends upon our perspective and focal range:
  - From a "big picture" perspective, we can see the Sun both as part of a much larger Cosmic System, and also as the central energy source in our Solar System powered by fusion.
  - Earth viewed from space (our Geo System) reveals weather systems on closer inspection that are driven by the Sun and Moon.
  - From close up we witness living ecosystems influenced by weather and by tiny bio-systems that provide nutrients that support them.

17. Spirit Alembic 18. Microposy UK
19. J.W. Adams Comb. School 20. Soc. For Ind. Archeology

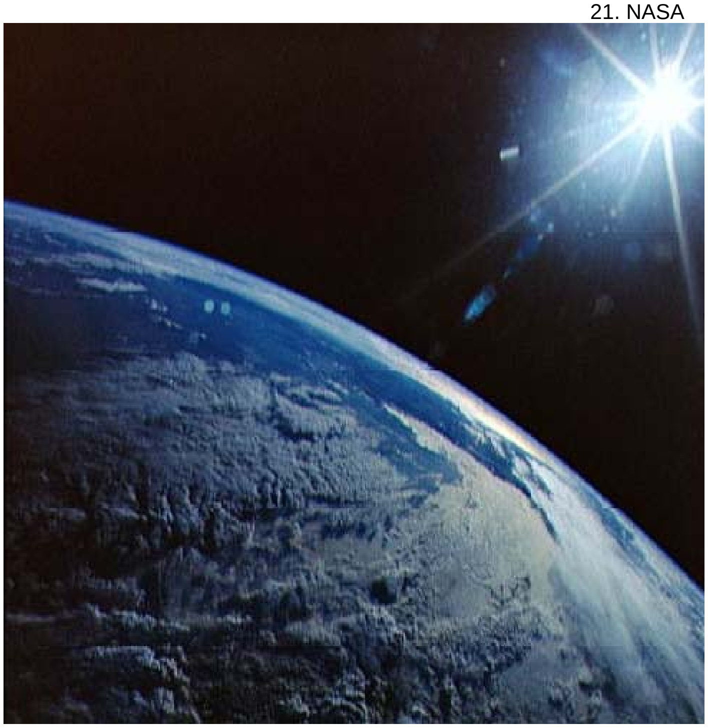


Connected Parts

In Nature's grand model, all parts are connected and synergistic, with complex forces and processes acting in concert.

- Even the largest celestial bodies and phenomena derive their essential substance from the tiniest elements:
  - Processes that occur on the Sun drive Earth's weather and enable life to exist.
  - All plants and creatures depend upon nutrients produced by microorganisms.
  - Carbon and hydrogen constitute the building blocks of all organic life.
  - Interactions between electrons that bind atoms to form molecules create the energy fuel of all chemistry.

21. NASA



The Sun is composed entirely of gas and contains more than 99.8% of the total mass in our Solar System (about 70% hydrogen and 28% helium).

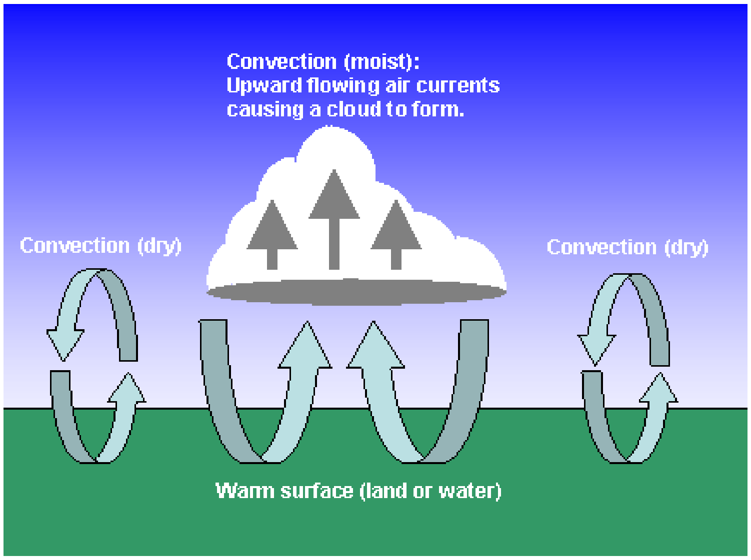
The Sun

The Sun supports nearly all life on Earth and drives our planet's weather.

- Fusion processes convert hydrogen to helium and produce photons that travel at the speed of light, reaching Earth (a distance of about 94 million miles) in approximately 8.5 minutes:
  - Photons are mass-less, have no electric charge, and do not spontaneously decay in empty space.
  - Although some of the photons are absorbed in Earth's atmosphere, about 1,000 watts per square meter are deposited on surfaces exposed to direct sunlight.
  - Leafy plants use photons to convert CO_2 to oxygen and reduced carbon compounds that support living organisms.

The mechanics of weather

22. Video Weather & Weatherstreet



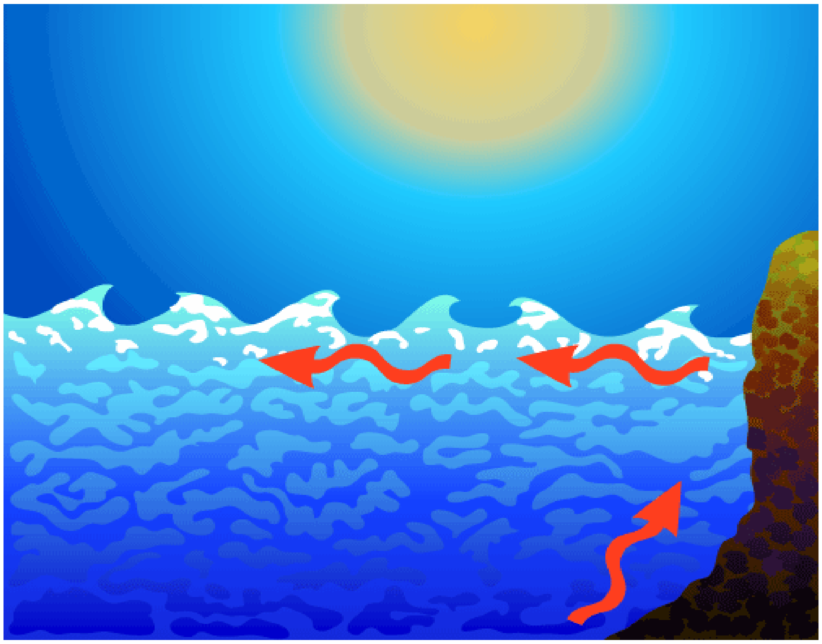
Convection currents produced by solar heat cause winds, thermals, cyclones, thunderstorms, and at a larger scale, atmospheric circulation.

Atmospheric Convection

The Sun is a primary influence on Earth's climates and weather conditions.

- Solar radiation that heats the surface and water bodies is transferred to air and circulated by convection, producing winds:
  - As heated air layers expand and become less dense, they are pushed upwards by buoyancy.
  - The rising air cools as it reaches higher altitudes in the atmosphere, becoming denser.
  - Since the denser air can't sink through the rising air beneath it, it moves laterally until it reaches the surface again and is drawn back into a rising column.

23. Carleton College Science Research Center



Solar heating and salinity differences produce convection effects in oceans that influence regional climates.

Ocean Convections

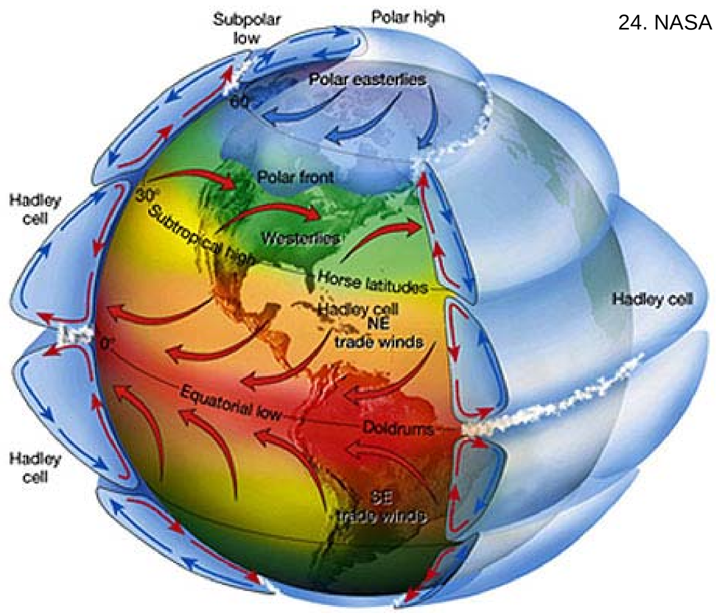
Oceanic convection driven by solar radiation and by differences in water salinity have important influences upon continental climates, particularly in coastal regions.

- Examples are the Gulf Stream which makes northwest Europe much more temperate than other regions at the same latitude, and the Hawaiian Islands, where the climate is cooler due to the California Current:
  - Equatorial water heated by solar radiation tends to circulate towards the poles, while polar water heads towards the equator.
  - "Thermohaline convection" driven by differences in salinity causes relatively warm saline water to sink, while colder fresh water tends to rise and reverse heat transport.

Earth's rotation also influences wind and weather.

- Winds are comprised of air molecules that are subject to Coriolis forces which cause air to turn as it flows:
  - Coriolis forces deflect wind flows to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere.
  - The Coriolis deflections contribute to formations of tropical cyclones that produce extremely strong winds, tornados, torrential rain and huge waves.
  - Cyclones that often cause great human and ecological disasters also provide important mechanisms to transport heat away from the tropics and maintain equilibrium in the Earth's troposphere.
  - Hurricanes in the northeastern Pacific supply moisture to the southwestern US.

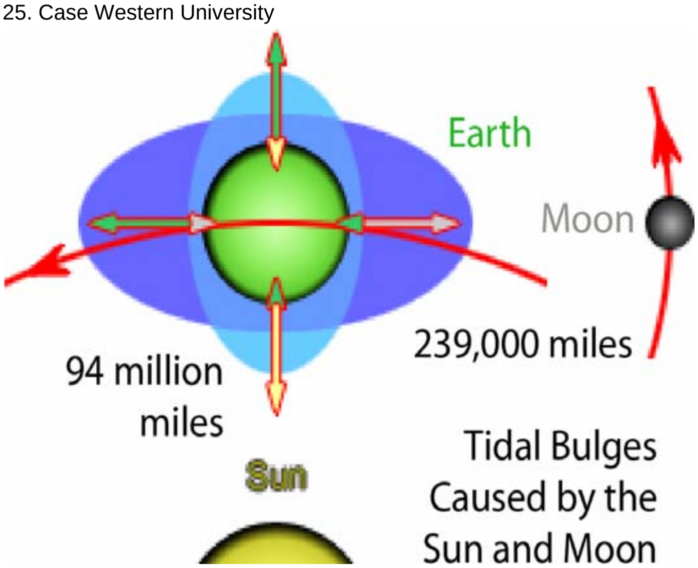
24. NASA



Coriolis forces produced by the Earth's rotation influence wind patterns that balance atmospheric heat, and transfer moisture to arid regions that need it.

Coriolis Influences Upon Weather

25. Case Western University



Since distances between the Earth, Sun and Moon vary considerably throughout a year due to elliptical orbits, tide generation forces are greatest when the Earth is closest in solar orbit (perihelion), and when the Moon is closest in its Earth orbit (perigee).

Sun/Moon-Driven Tides

The gravitational pull of the Sun and Moon produce daily sea level changes that are essential to support marine and coastal ecological systems.

- Although these gravitational forces act upon all Earth surfaces, solid land areas remain intact, while water is lifted:
  - These forces produce two bulges in oceans, one in the direction of the Moon, and one on the opposite side of the Earth.
  - Even though the Moon's mass is 27 million times smaller than the Sun's, its closer proximity to Earth gives it a tide-generating force that is more than twice greater.
  - High tides are produced in areas where water flows between the bulges, and low tides (areas of depression) occur between bulges due to withdrawal of surging water.

Solar foundations of ecosystems

26. Birding America.

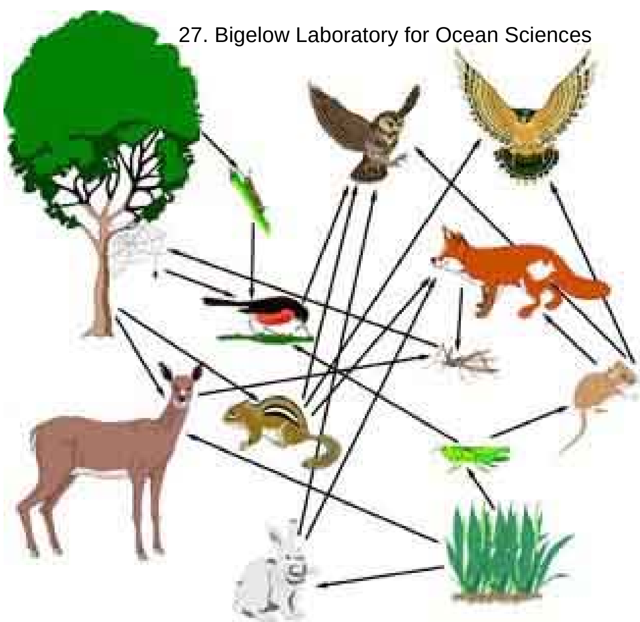
Tides deliver vital nutrients to coastal ecosystems and remove accumulated toxins that endanger living organisms that support food chains.

Tidal Benefits

Tidal effects of the Sun and Moon provide critical mechanisms to support marine life and numerous types of plants and animals that reside in marshes and estuaries.

- Tidal circulation serves a variety of essential functions:
  - Tides deliver suspended sediments necessary to replace surface soils removed by runoff land erosion.
  - Flooding tides enhance plant growth by delivering oxygen-enriched water to marsh soils and removing toxic materials.
  - Tidal waters are vehicles that carry plant nutrients onto marshlands during periods of abundance, and transport excess nutrients back to estuaries at other times.
  - Exported nutrients support growth of single-celled phytoplankton that are the foundation of marine food chains.

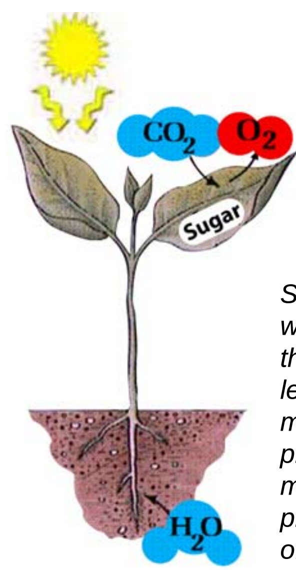
27. Bigelow Laboratory for Ocean Sciences



Most ecosystems on Earth are “solar powered”, depending upon food energy created by photosynthesis.

Photosynthesis

28. Purves, et al, *Life: the Science of Biology*



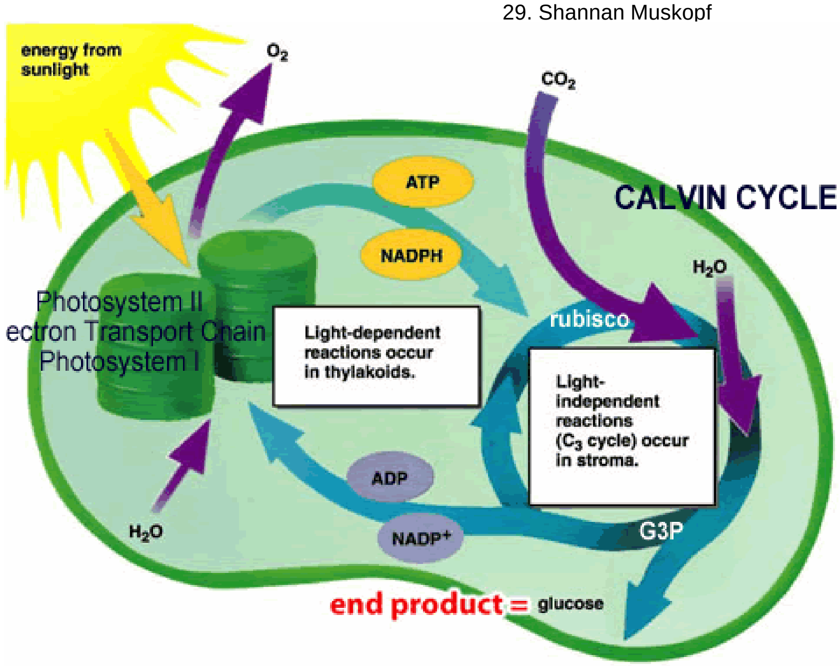
Six molecules of water taken up through roots and leaves plus six molecules of CO_2 produce one molecule of sugar plus six molecules of O_2.

$(6\ H_20 + 6\ CO_2 \rightarrow C_6H_{12}O_6 + 6\ O_2)$.

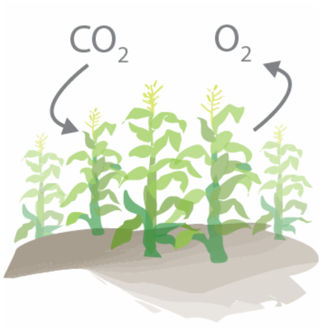
Photosynthesis uses sunlight to remove CO_2 (a greenhouse gas) from the air and convert it into oxygen, sugars, starches and high-energy carbohydrates that support life.

- The process occurs through two complex phases:
  - In a first phase “light-dependent reaction” a pigment chlorophyll molecule absorbs light, and loses an electron in the process.
  - The released electron moves down a transport chain to produce high-energy NADPH and ATP molecules, and the chlorophyll molecule regains its electron by splitting water, releasing oxygen.
  - In a second phase “dark reaction” an enzyme RuBisCO captures CO_2 from the atmosphere and through a complex Calvin-Benson cycle releases 3-carbon sugars that combine to form glucose.

29. Shannan Muskopf



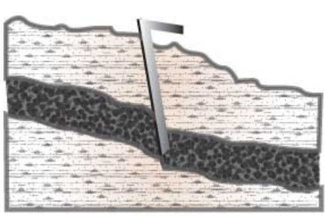
Photosynthesis Process



Air Purification

30. Larry Bell

Cleaner Fuels



Fossil Fuels

Petrochemicals

Photosynthesis Products

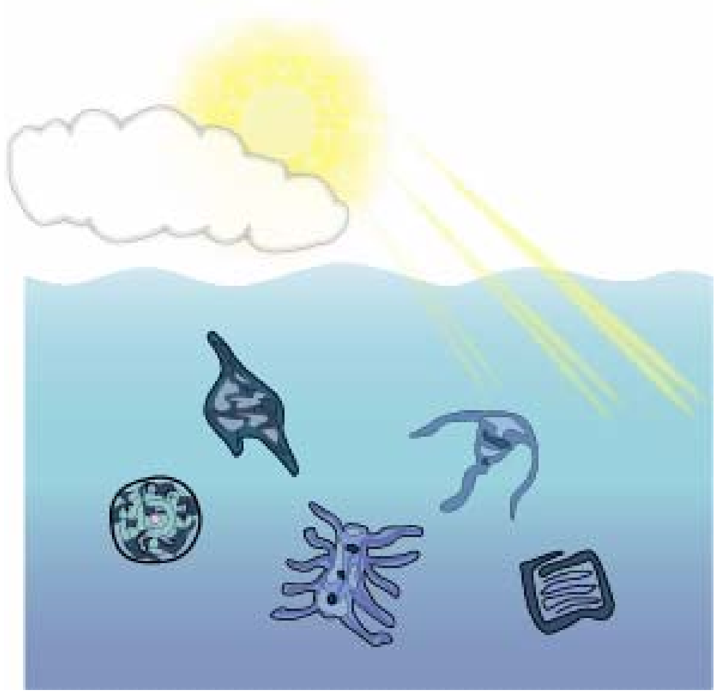
Solar-powered photosynthesis is arguably the most important biological process on Earth.

- Photosynthesis converts CO_2 and water into breathable oxygen to help ameliorate greenhouse gas produced by combustion, creating carbohydrates that we use for many other purposes as additional by-products:
  - One of the carbohydrates is cellulose that can be converted to sugar and fermented into ethanol (grain alcohol) for direct use as automotive fuel and as a gasoline additive to reduce pollutant emissions.
  - Ethanol can be readily converted to ethylene, an important feedstock for petrochemicals.
  - Carbon “fixed” through photosynthesis in ancient times created the biomass that is the source of fossil fuels we use today.

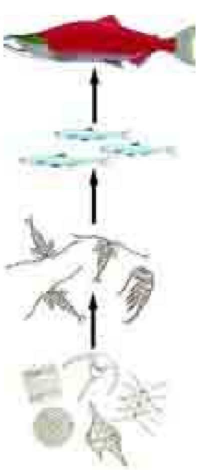
In addition to higher plants, many types of microscopic organisms (“phototrophs”) use photosynthesis to create essential food energy in marine environments.

- Despite their small size, these algae and cyanobacteria are vital to our planet’s ecological survival because they provide the base of the marine food web:
  - Each level of a food chain is called a “trophic” or “feeding level” that classifies organisms as either “primary producers” or “consumers”.
  - Phototrophs are primary producers because they convert inorganic materials to organic forms that “heterotrophs” depend upon.
  - Heterotrophs include carnivores, omnivores, vegetarians and decomposers.

31. Bigelow Laboratory for Ocean Sciences.



Marine Phototrophs

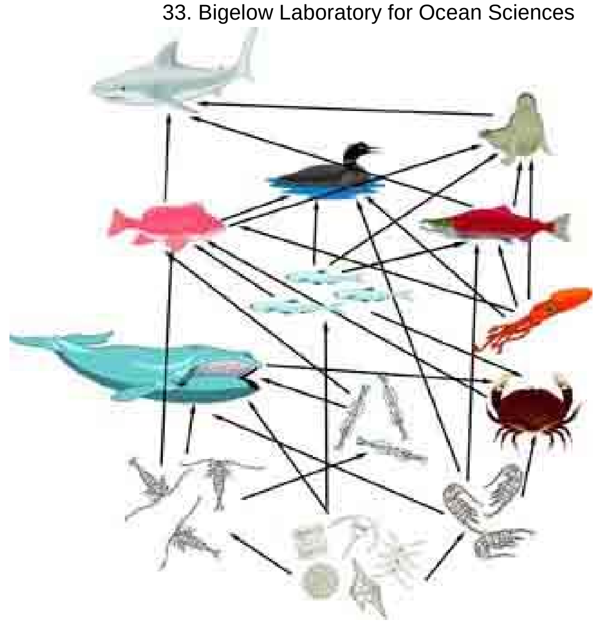


32. Bigelow Laboratory for Ocean Sciences

Organism	Trophic Type	Prey/Food
algae	primary producer	---
birds	carnivorous consumer	krill, fish
blue whales	planktivorous consumer	algae, krill
fish	omnivorous consumer	algae, krill
killer whales	top consumer	blue whales, fish, birds, seals
krill	herbivorous consumer	algae
seals	carnivorous consumer	fish, birds

Marine Food Chains

33. Bigelow Laboratory for Ocean Sciences



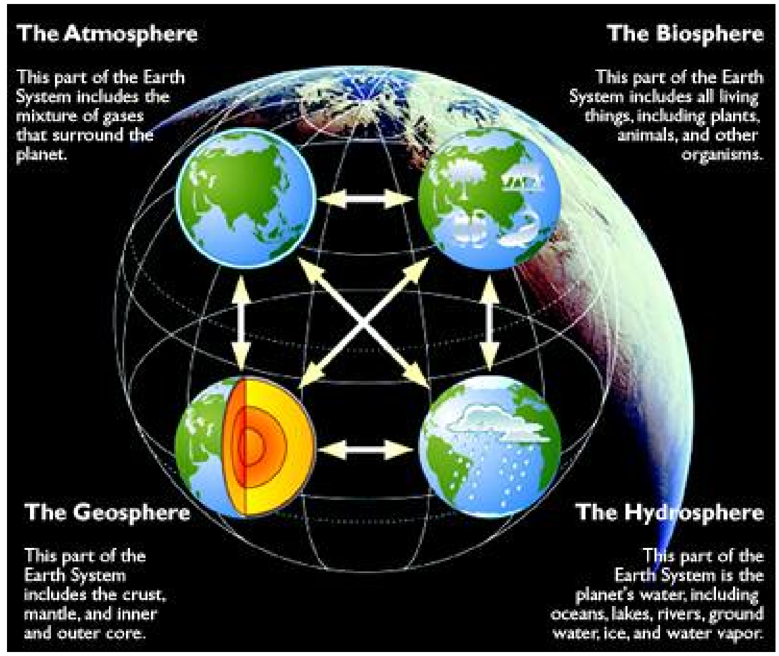
Marine Food Webs

Spheres of influence

The Earth is often characterized as being comprised of four general types of connected zones or “spheres”.

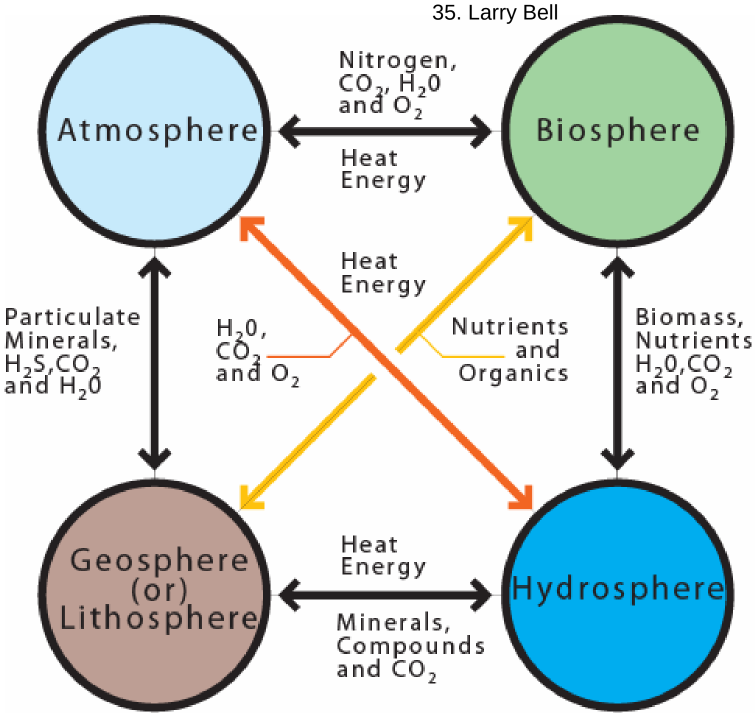
- The atmosphere provides a protective gaseous blanket:
  - It contains oxygen and nitrogen essential for life, and provides weather.
- The geosphere consists of Earth’s solid material and inner core:
  - It contains minerals and compounds that comprise organic and inorganic materials.
- The biosphere contains all living systems:
  - About 97% is contained in oceans.
  - This includes organisms ranging from viruses to humans that exist in the geosphere and hydrosphere.

34. It’s About Time



Global Spheres

35. Larry Bell



Dynamic Interrelationships

Viewed as systems within a larger system, the spheres of influence interact in dynamic and complex ways to maintain the equilibrium necessary to sustain life.

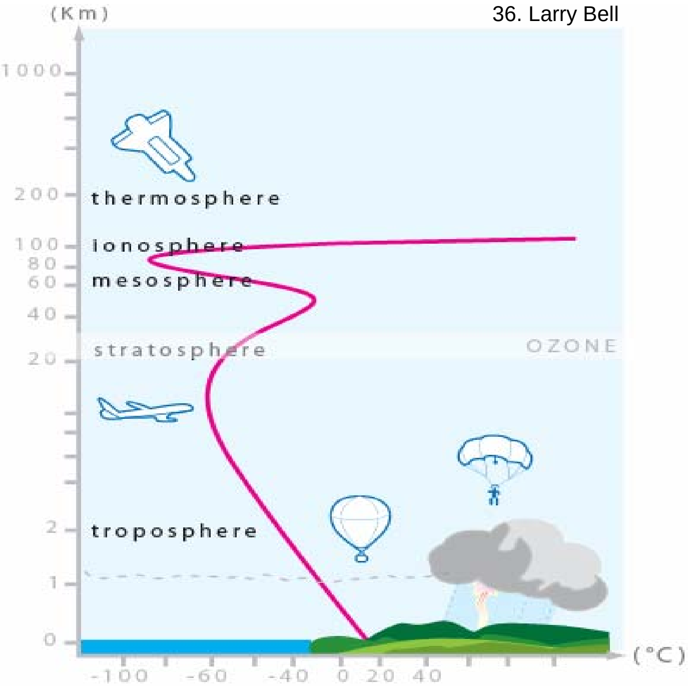
- The atmosphere serves as a large global transport system:
  - It circulates oxygen, water, nitrogen, carbon dioxide and heat among regions.
- The geosphere affords a foundation for life:
  - It provides inorganic substances to support organic chemistry, geothermal heat, and a CO_2 containment service.
- The hydrosphere supports marine life and land creatures that depend upon it:
  - It also influences weather, provides water for precipitation and cooling, and absorbs CO_2 from the atmosphere.
- The biosphere exchanges life support products and biowastes with other spheres:
  - It is the source of biomass fuels and nutrients, and converts CO_2 into O_2 and back again.

Atmospheric composition and land/ocean cycles

The atmosphere is also characterized as being comprised of different zones, or "spheres".

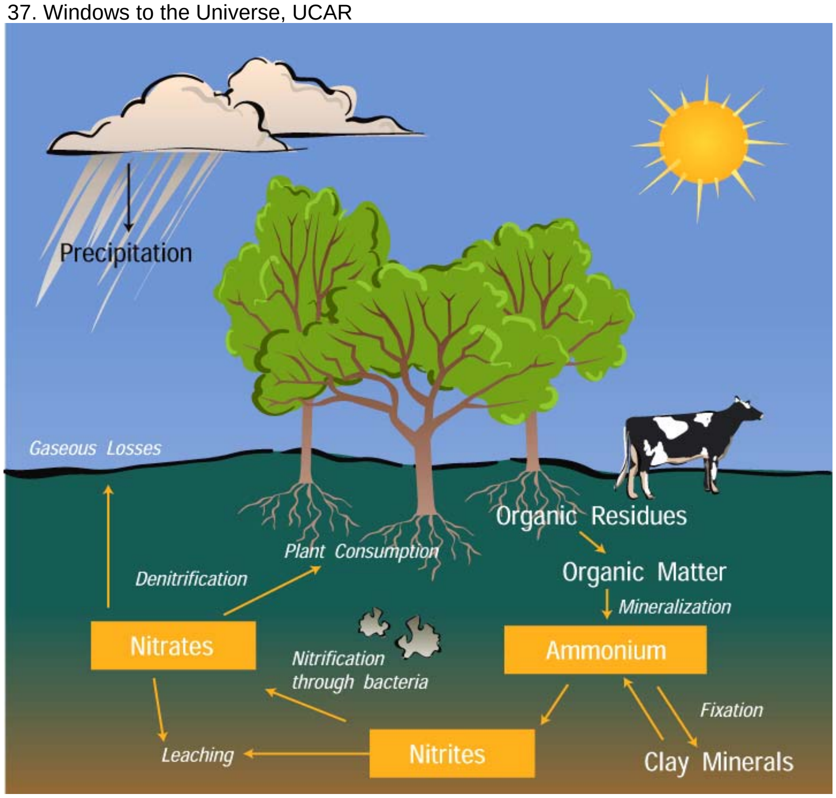
- The thermosphere is the uppermost region where solar radiation strips off (ionizes) electrons from atoms in the ionosphere below.
- The ionosphere is a layer that traps radio signals and allows them to travel around the world (unless disturbed by solar storms that disrupt communications).
- The mesosphere has no strong solar radiation absorbers, causing temperatures to decrease with altitude.
- The stratosphere is broken into different materials (stratified), including ozone which absorbs solar radiation so that temperatures increase with altitude.
- The troposphere (lowest level) is where convection occurs to produce weather, and temperatures decrease with altitude.

36. Larry Bell



Atmospheric Zones

37. Windows to the Universe, UCAR



The Nitrogen Cycle

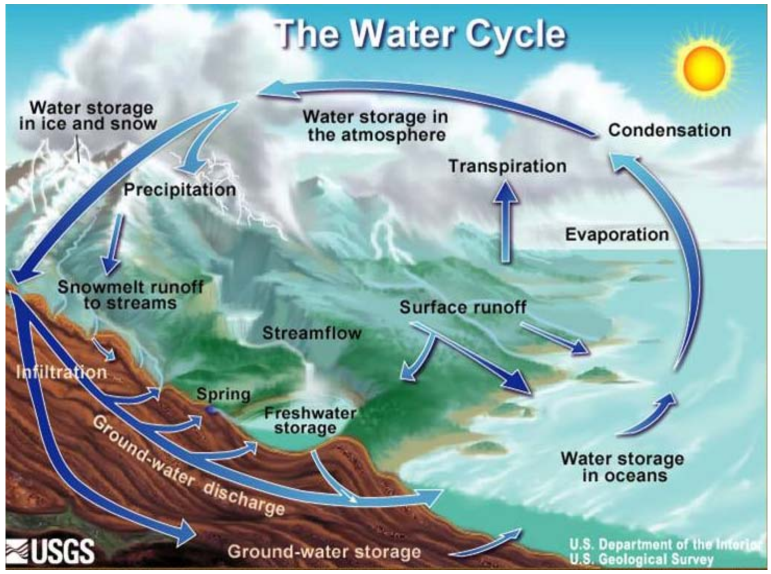
Nitrogen comprises about 78% of the atmosphere and cycles slowly through the biosphere.

- Although very little nitrogen is present on land or in the oceans, it is essential to life as a key element in proteins and DNA:
  - Nitrogen does not chemically react very readily with other substances because each molecule is made of two atoms that are tightly bound together.
  - Large amounts of energy are required to break the atomic bonds, although this can occur through lightning and fires.
  - Fortunately, an assortment of bacterial species specialize in converting nitrogen from the air into usable forms, and also release nitrogen from organic material back into the atmosphere.

Water in liquid and vapor form cycles continuously through the geosphere, hydrosphere, atmosphere and biosphere.

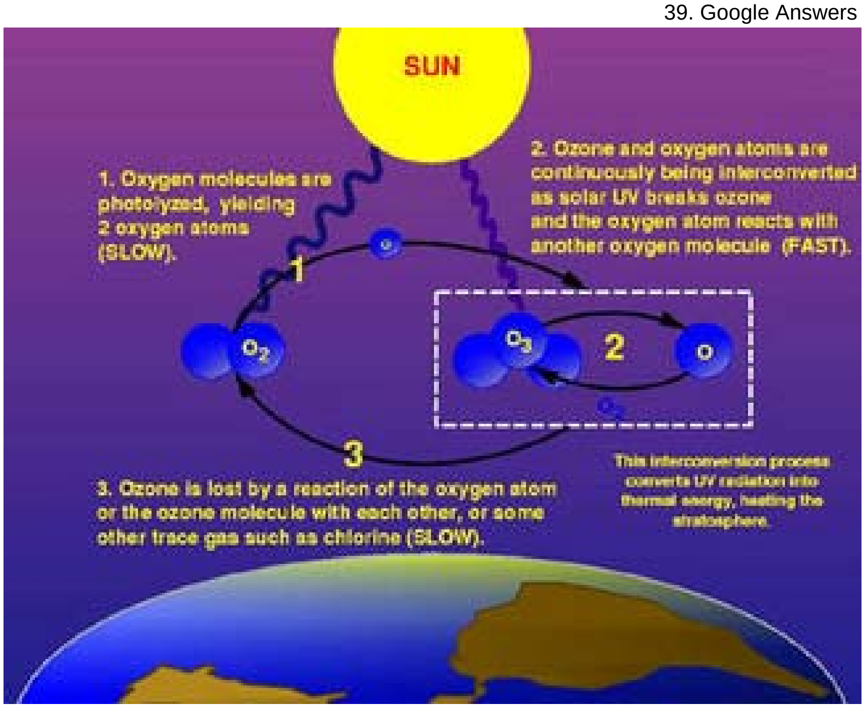
- Water molecules comprise the primary substance of all higher plants and animals:
  - It is transferred between the hydrosphere and biosphere by evaporation and precipitation, releasing heat energy in the process.
  - In the air, water vapor circulates and condenses to form clouds, and rain that falls back to the surface.
  - Plants and animals use and reuse water, and release the vapor back into the air.
  - Some water leaches into underground aquifers, releasing suspended particles in the filtering process.

38. US Geological Survey



The Water Cycle

39. Google Answers



Radiation-powered reactions in the stratosphere continuously convert oxygen molecules to ozone, which eventually reforms back to oxygen.

Oxygen-Ozone Cycles

Oxygen comprises about 21% of the atmosphere.

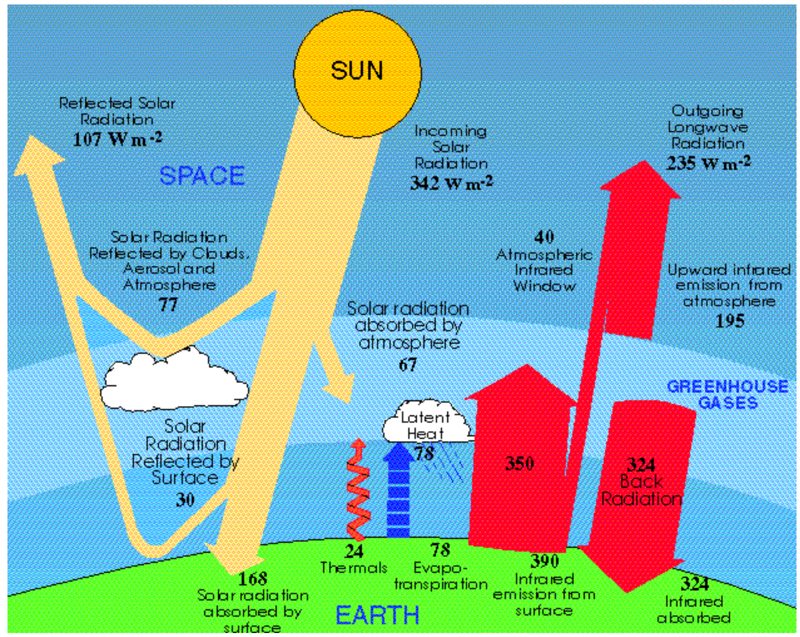
- Although oxygen is very reactive and rapidly combines with other elements and "disappears", relatively stable concentrations are replaced through photosynthesis and plant respiration:
  - Some oxygen is lofted into upper reaches of the atmosphere (the stratosphere) where a series of reactions powered by solar radiation convert it into ozone (O_3).
  - The ozone beneficially serves to absorb biologically-damaging ultraviolet (UV) radiation, reducing the amount that reaches the Earth's surface to a tiny fraction.
  - Ozone molecules eventually break apart to reform into O_2, which circulates again through the atmosphere to repeat the cycle.

Earth's thermal balancing mechanisms

The Earth's thermal balance is in a steady state when the energy stored in the atmosphere and oceans equals the incident solar radiation radiated back to space.

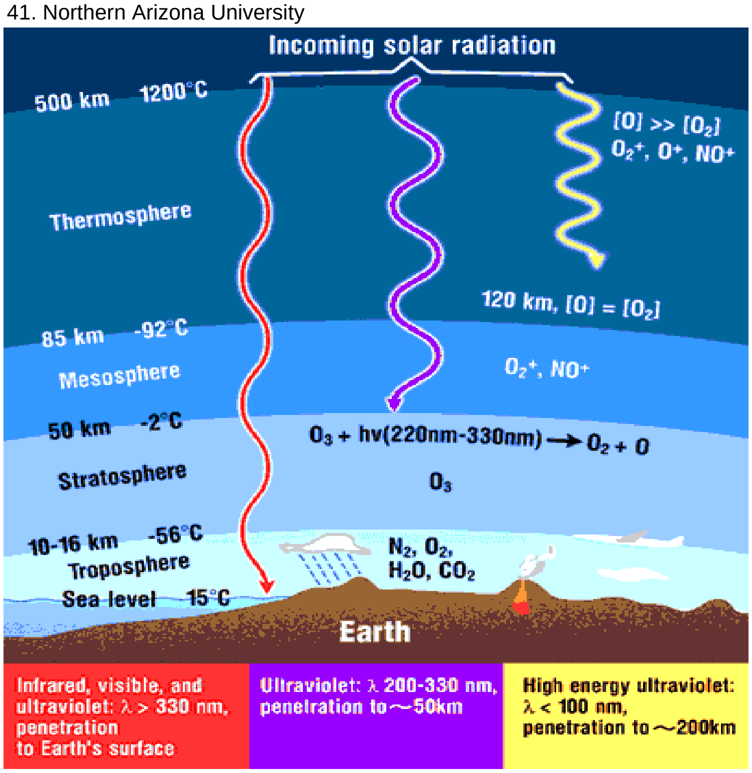
- This radiation includes reflected solar radiation and emitted thermal infrared radiation (IR):
  - The Earth receives about 30% of the incident solar radiation flux, and the remaining 70% is absorbed, warms the land, atmosphere and oceans and powers life on the planet.
  - Eventually the absorbed incident energy is radiated to space as IR photons.
  - This thermal (IR) radiation increases with rising temperatures.

40. Online Biology Book. Estrella Mountain Community College



Steady State Thermal Balance

41. Northern Arizona University

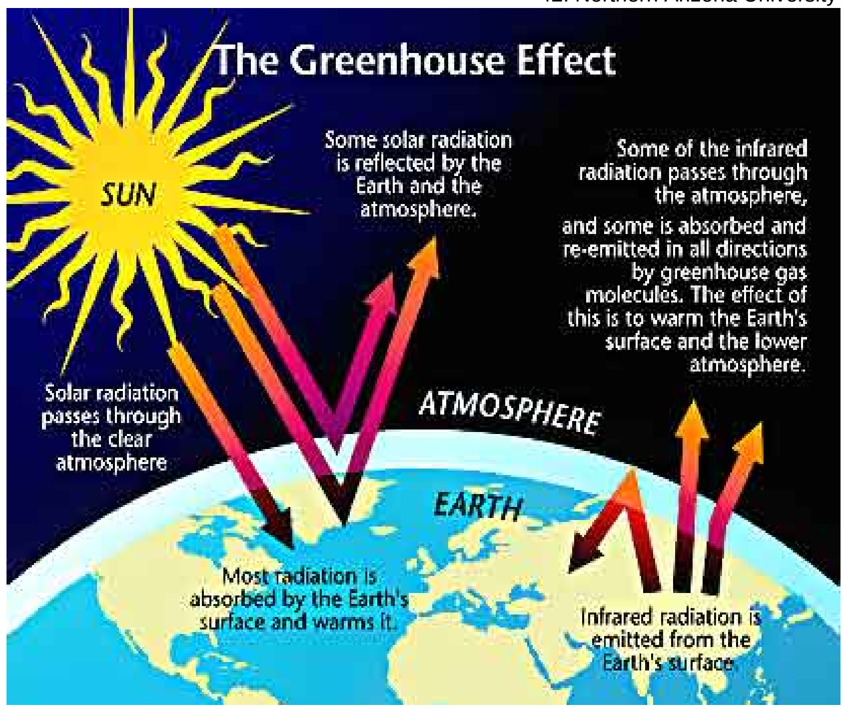


Atmosphere Transparency vs. Altitude and Incoming Radiation Wavelengths

The amount of thermal radiation released to space is influenced by the atmospheric opacity and temperature.

- These factors determine the height from which most photons are emitted to escape:
  - If the atmosphere is more opaque, an escaping photon must go higher in order to "see out" to space in IR.
  - Since IR emission is influenced by temperature of the atmosphere, the temperature will influence the emission level required to balance the absorbed solar flux.
  - The temperature of the atmosphere generally decreases with height above the surface at the rate of about 15.7°F per mile (6.5°C per kilometer) up to the stratosphere (6.2 miles - 9.3 miles [10km - 15km altitude.])

42. Northern Arizona University

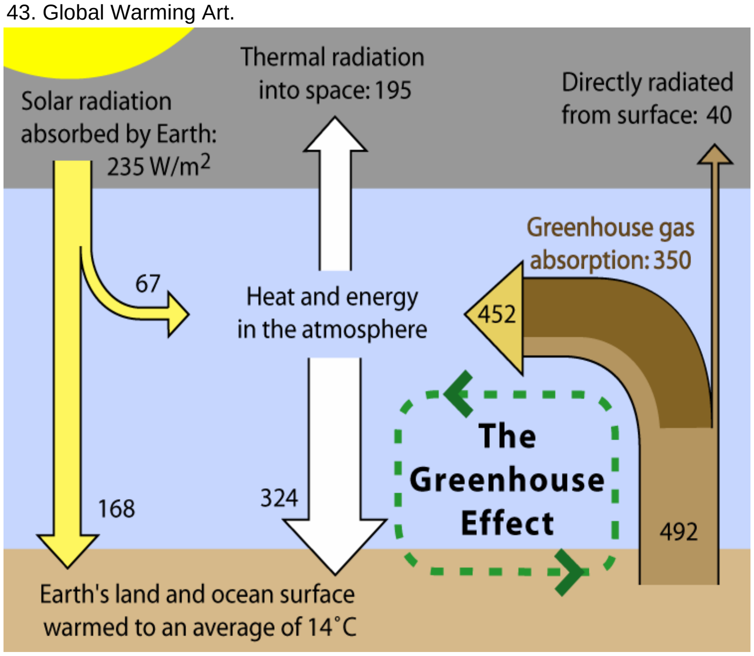


The "Greenhouse Effect"

Since the atmosphere emits IR both upwards and downwards, the temperature balance between energy radiated to space must be equal to the direct incident radiation absorbed plus the downward IR flux.

- The atmosphere is relatively transparent to the direct incident radiation in the visible range, but strongly absorbs thermal IR wavelengths emitted by the surface and atmosphere:
  - Most IR escaping to space is emitted from the upper atmosphere (not the surface).
  - Accordingly, most IR photons emitted by the surface are absorbed by the atmosphere and do not escape.
  - A large part of the thermal energy transfer to the atmosphere occurs through convection (sensible heat transport) and evaporative condensation of water vapor (latent heat transfer).*

43. Global Warming Art.



Greenhouse Mechanisms

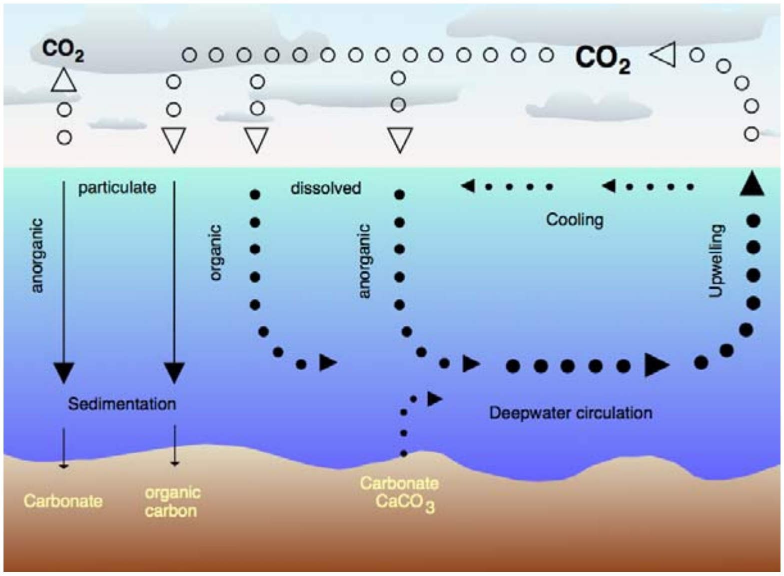
Increases in greenhouse gases, CO_2 in particular, reduce the amount of IR energy emitted to space, causing surface temperatures to rise over time.

- Dominant infrared-absorbing gases in Earth's atmosphere are water vapor, carbon dioxide and ozone:
  - Clouds are very important IR absorbers, and become more prominent through evaporation as surface water temperatures increase.
  - CO_2 is a linear molecule which becomes "floppy" and easily excited by IR so that it bends with carbon in the middle, moving one way, and oxygen on the ends moving the other to vibrate and absorb IR energy.
  - It is estimated that water vapor may contribute about 36% of the total absorbing effect, and CO_2 somewhere between 4% - 12%.

* **See Appendix: 1**

Sources and amounts of natural atmospheric carbon dioxide

44. Hanues Grobe, et al. Inst.for Polar and Marine Research



CO_2 from Ocean Carbonate

Atmospheric CO_2 derives from many natural sources, including volcanoes, ocean sediments, and respiration of living organisms.

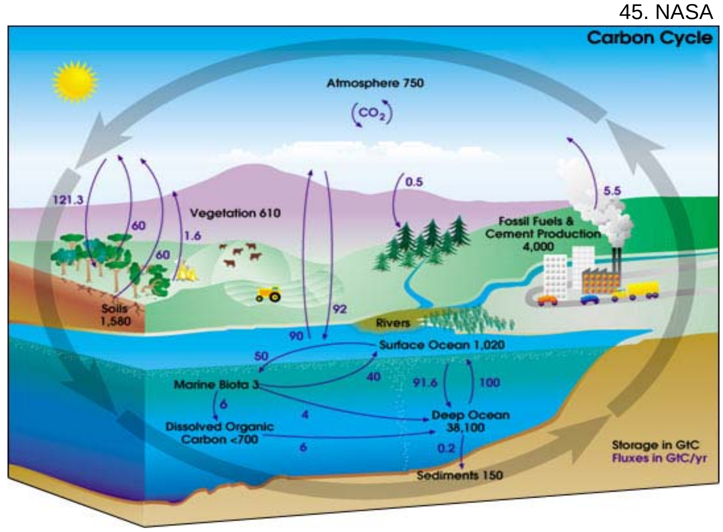
- Records from polar ice cores and ocean sediments indicate that atmospheric CO_2 concentrations have naturally fluctuated greatly throughout the Earth's history, reaching levels higher than those observed in recent decades:
  - Levels rise and fall on a seasonal basis as a result of plant growth cycles, warming and cooling changes that influence ocean absorption rates and other factors.
  - The US National Oceanographic and Atmospheric Administration estimates that about 97% of annual atmospheric CO_2 comes from natural sources, and about 3% from human activities.

Carbon, typically in the form of CO_2, cycles between "reservoirs" provided by the atmosphere, biosphere, hydrosphere and geosphere.

- Atmospheric carbon is primarily CO_2 (overall only about 0.04% on a molecular basis), although other gases containing carbon are present in even smaller amounts (e.g. methane and artificial chlorofluorocarbons [CFCs]).

- CO_2 is dissolved at ocean surfaces, particularly in polar regions where the water is cold.
- Aerobic respiration by plants and animals breaks down glucose into CO_2 and water, and photosynthesis reverses the process.
- Limestone, marble and chalk mainly comprised of calcium carbonate are eroded by ocean water to produce CO_2 and carbonic acid.

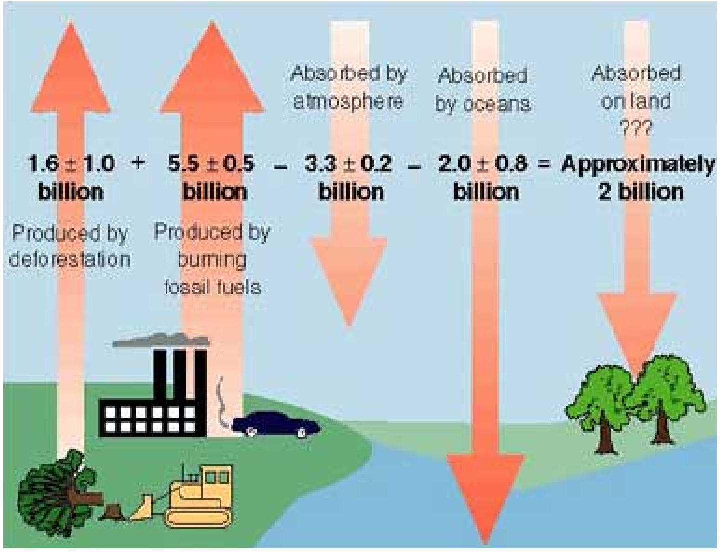
45. NASA



CO_2 is constantly being released into the atmosphere and hydrosphere from hydraulic erosion of limestone deposits, biomass decomposition, fossil fuel combustion and other sources.

Atmospheric CO_2 Sources

46. US Geological Survey



Atmospheric CO_2 is produced by a variety of human and natural sources, with much ultimately absorbed by the atmosphere, oceans, and vegetation. Many researchers believe that influences upon Earth temperature changes may be well within natural climate variability. *

Estimated Human Contributions to CO_2

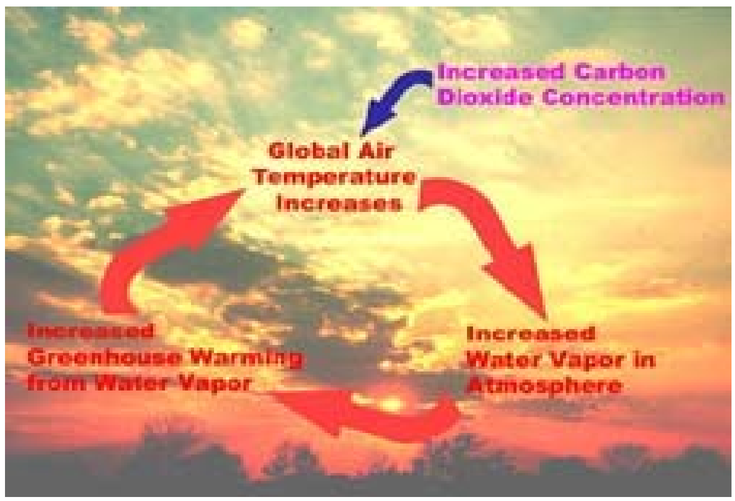
While it is evident that atmospheric CO_2 levels have increased about 110 ppm from a pre-Industrial Revolution level of 280 ppm to about 360-380 ppm now, the actual influences of this trend upon global warming or its future consequences are not nearly as clear.

- Although CO_2 represents only a very tiny amount of total atmospheric gas content (less than 4/100ths of 1% which is much lower than water vapor per volume and weight), steady increases over the past 50 years are raising international concerns:
  - Much or most of this increase is generally attributed to human causes, yet computer models cannot yet reliably predict climate change impacts.
  - Key areas of uncertainty include heating and cooling influences of clouds upon the atmosphere, roles played by oceans, and land influences such as deforestation, agriculture, and seasonal changes. **

Water vapor in combination with CO_2 and other greenhouse gases have feedback influences that compound warming effects.

- Since the concentration of a greenhouse gas in the atmosphere is a function of temperature, a feedback produced by another greenhouse gas can increase the temperature, to in turn increase the concentration of the original gas.
  - Water vapor is known to experience a "positive" feedback in response to increases in CO_2 concentrations
  - While most of the atmospheric CO_2 is released from natural sources, even relatively small increases resulting from human activities may have substantial impacts.

47. NASA



Water vapor in the atmosphere is known to act as a greenhouse gas that contributes to Earth warming. As surface temperatures rise, more water from oceans evaporates, adding to atmospheric vapor levels (A "positive water feedback"). Research based upon data from NASA's Upper Atmosphere Research Satellite (UARS) has confirmed this effect, but suggests that the impacts may not be as large as previous climate change models have assumed. ***

Water Vapor as a Greenhouse Gas

*** See Appendix: 2**
**** See Appendix: 3**
***** See Appendix: 4**

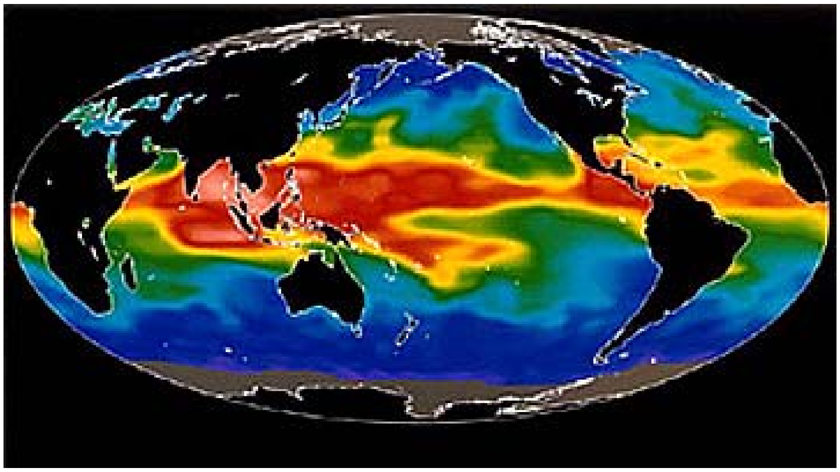
Atmospheric water vapor as the dominant greenhouse gas

Climate "forcing" factors include a variety of combined natural and human influences that impact Earth's atmospheric chemistry and surface heat balance.

- Although much attention has been directed to biogeochemical effects of CO_2, some other factors have comparable and even greater effects:

- Atmospheric water vapor may account for about 70% of all greenhouse effect (compared with somewhere between 4.2%-8.4% for CO_2), absorbing solar infrared over much of the same wavelength bands as CO_2, and even more.
- While clouds are comprised mostly of water droplets (not greenhouse gases) they absorb about one-fifth of the long-wave radiation from Earth, although their influences upon climate mechanisms are not fully understood.

48. NASA Goddard

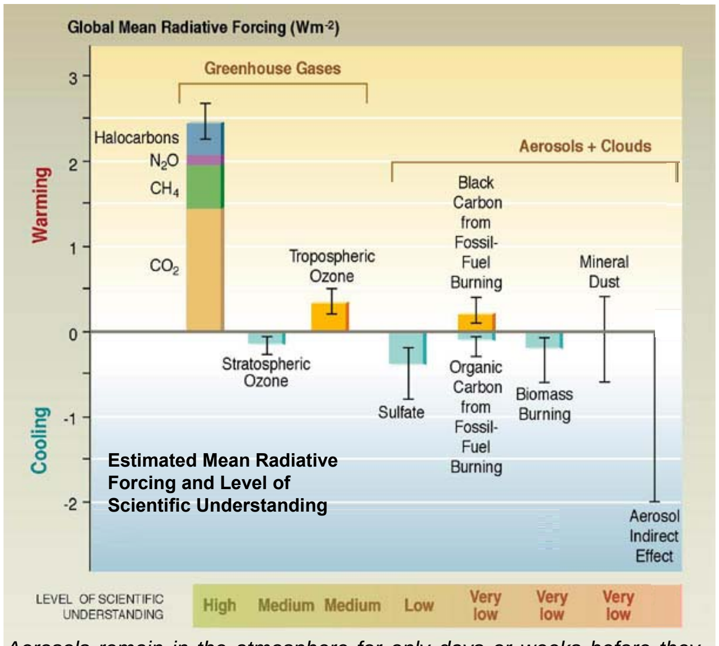


Satellite Water Vapor Imaging

Although water vapor is a primary greenhouse gas, upper atmosphere satellite measurements at a 6-9 mile (9.5-14 km) altitude show less positive feedback correlation between vapor concentration and Earth warming than previous computer models predicted. Separate satellite measurements of global surface and ocean precipitation between 1979-2004 also reveal virtually no net vapor concentration increases due to climate warming evaporation effects. * **

Water Vapor Influences

49. US Climate Change Science Program



Aerosols remain in the atmosphere for only days or weeks before they fall out or are washed out by rain. *

Estimated Aerosol / Greenhouse Influences

Aerosols include atmospheric dust particles and sulfate droplets released from natural sources such as volcanoes, sea spray and land wind erosion in combination with human activities such as fossil burning from industry and forest clearing for agriculture.

- Current models for distinguishing concentrations from natural vs. human sources, or assessing climate effects, are unreliable and often contradictory due to issue and calculation complexities:

- It is generally believed that unlike greenhouse gases, sulfate aerosols tend to cause cooling rather than heating by scattering radiation at the top of the atmosphere. This enhances reflectivity that reduces cloud lifetimes by increasing the number of droplet collisions needed to produce rain.
- Dust particles do this to some extent, but also absorb some sunlight to produce warming effects.

*** See Appendix: 4**
**** See Appendix: 5**
***** See Appendix: 6**

Possible human impacts upon climate

Human influences upon land uses and vegetation can also have a variety of complex links to weather and climate mechanisms, including surface-atmosphere greenhouse gas exchanges, reflected and absorbed radiation and thermal balances, and wind interactions with surface topologies.

- Growth of agriculture has had particularly significant land use influences over much of the world:

- Although global impacts are not well understood, replacement of dark forests with croplands is known to affect local conditions, increasing surface albedo levels to cool some regions, while denying shade to other heavily-irradiated areas to raise ground temperatures.

- Large-scale crop irrigation can also produce measurable regional cooling effects, as has been demonstrated in the Great Plains of North America since 1945.*

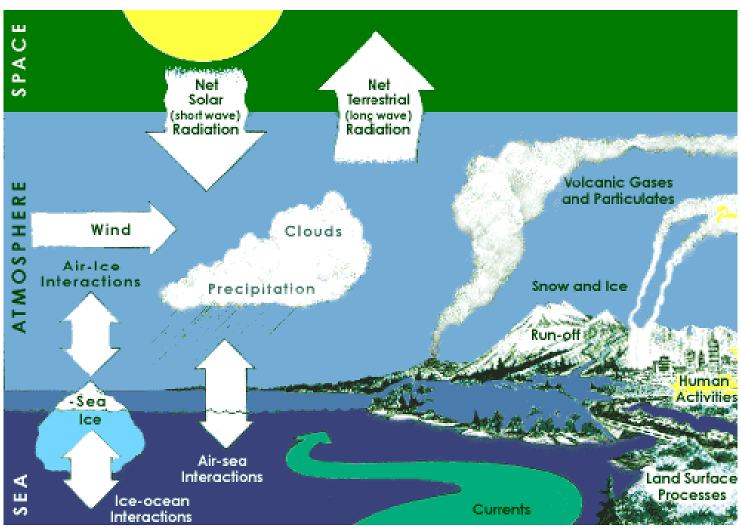
50. UCA
51. U. of Missouri
52. Exec. Action Team
53. Julian Pye




Human land use influences upon weather and climate are associated with a number of factors, including growth of farming and industry, population size and distribution, and types of technologies used in each region. The combined effects of these impacts can, in turn, affect the suitability of the land and land cover for desired future uses.

Land Use Influences

54. Solcomhouse



Climate and temperature changes are influenced by many highly interactive forcing factors that are not well understood as a basis for developing accurate or reliable models.

Climate and Temperature Influences

Simple theories about causes and consequences of climate change fail to recognize that these phenomena involve a complex interplay of overlapping cycles and events that sometimes cancel each other out.

- Extreme modeling difficulties and fluctuations that occur naturally often cast legitimate doubts about trend predictions based upon a few years or decades of limited data and incomplete understanding of interrelationships:

- Urgent concerns about human impacts upon these influences and outcomes are certainly legitimate and essential, both as a moral obligation to our planet and as a practical matter of survival.

- The challenge is to avoid premature, faulty conclusions and policies driven by inadequate models, unsubstantiated hypotheses, and alarmist observations based upon both.

* **See Appendix: 7**

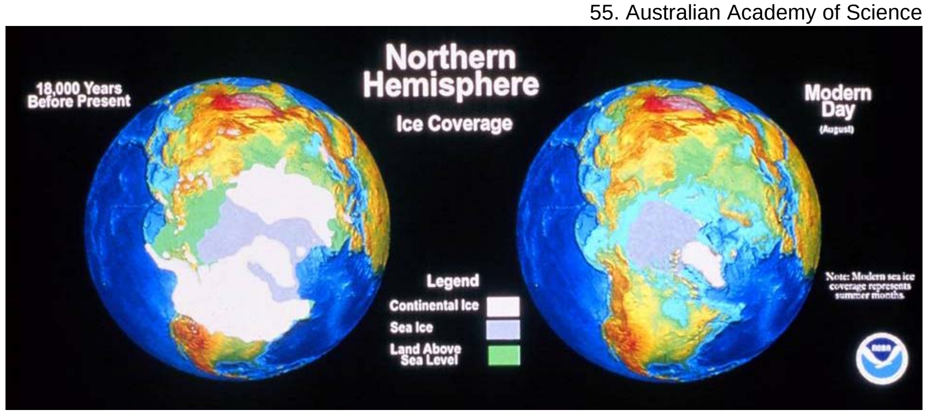
Earth's "normal" temperature

Important issues and controversies concerning human impacts upon climate revolve around questions regarding which observed trends and fluctuations are natural or "normal".

- In regard to global temperatures it can be argued that normal can be characterized by ice ages that have dominated Earth's history:

- Except during brief interglacial periods, our planet's climate has been invariably glacial, with more than half of the surface covered with ice and arid deserts.
- Present global warming trends began about 18,000 years ago near the end of the Pleistocene Ice Age when much of North America, Europe and Asia began to thaw out from a very long deep freeze.

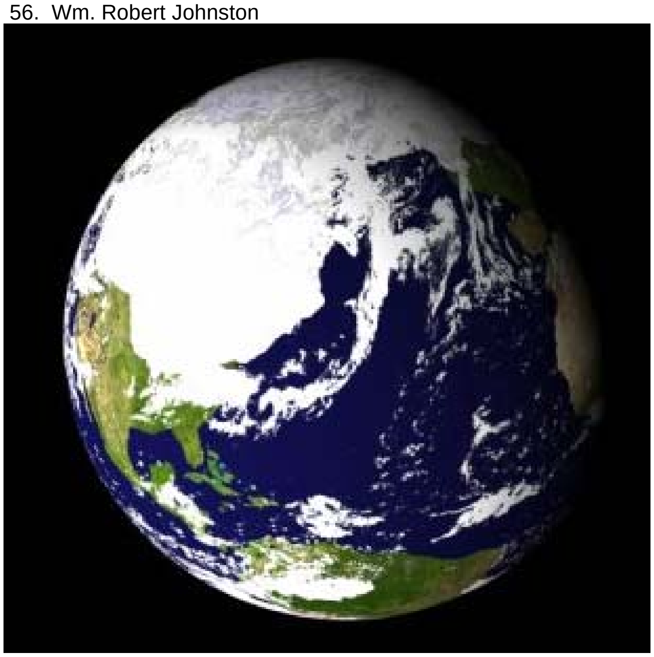
55. Australian Academy of Science



Earth has been relatively ice-free even at high latitudes, only during relatively short interglacial periods such as our current one. From a historic perspective our climate is, without doubt, "abnormally warm".

Past and Present Northern Hemisphere Ice Coverage

56. Wm. Robert Johnston



Earth has been relatively ice-free, even at high latitudes, only during relatively short interglacial periods such as our current one. From a historic perspective, our climate is without doubt "abnormally warm".

The Last Ice Age, About 16,000 BC

The average temperature of the Earth has been gradually increasing on a fairly constant basis over the past 18,000 years or so following the last 100,000 year-long Ice Age when much of North America lie buried under glaciers:

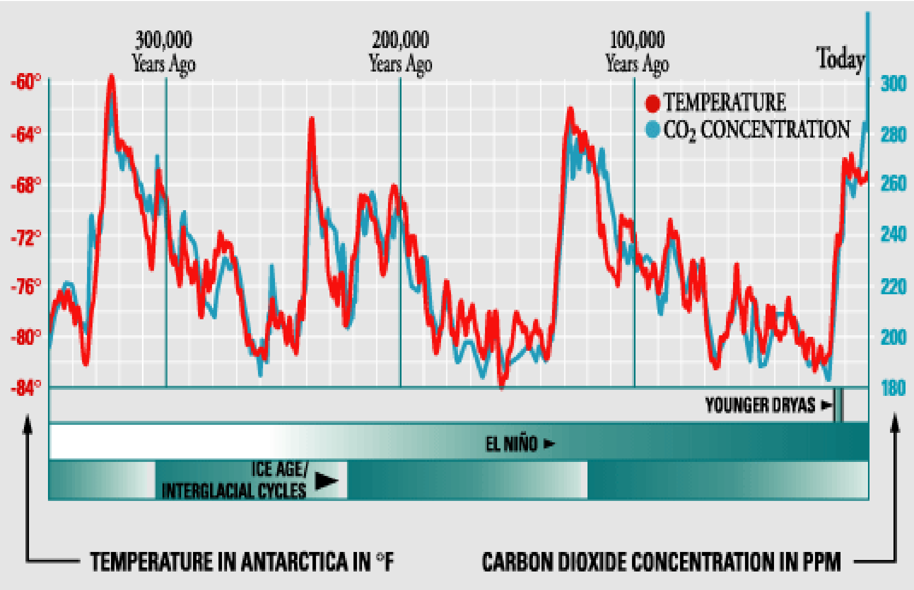
- By about 12,000 – 15,000 years ago the Earth had warmed sufficiently to halt the advance of glaciers and cause sea levels to rise.
- About 8,000 years ago a land bridge across the Bering Strait became submerged, cutting off the migration of people and animals to North America, ultimately rising about 300 feet.
- Since the last Ice Age Earth's temperature has risen about 16°F, and plant life returned to regions previously covered by ice.
- Temperatures may have continued to rise about 1 degree over the past 200 years, although the precise amount is debated according to measurement methods used.

No one can really predict how long our current interglacial period will last before the next glacial period arrives, and if the term "ice age" is used to refer to a long generally cool interval when glaciers advance and retreat, some can argue that we are still in one today.

- Although a "typical" interglacial may be estimated to last about 12,000 years, and our current one may be more analogous to a previous interglacial estimated to exist for 28,000 years:

- These warming and cooling periods seem to occur in small-scale cycles of about 40 years, within larger-scale 400 year cycles such as the Little Ice Age, within still larger 20,000 year cycles, and so on.

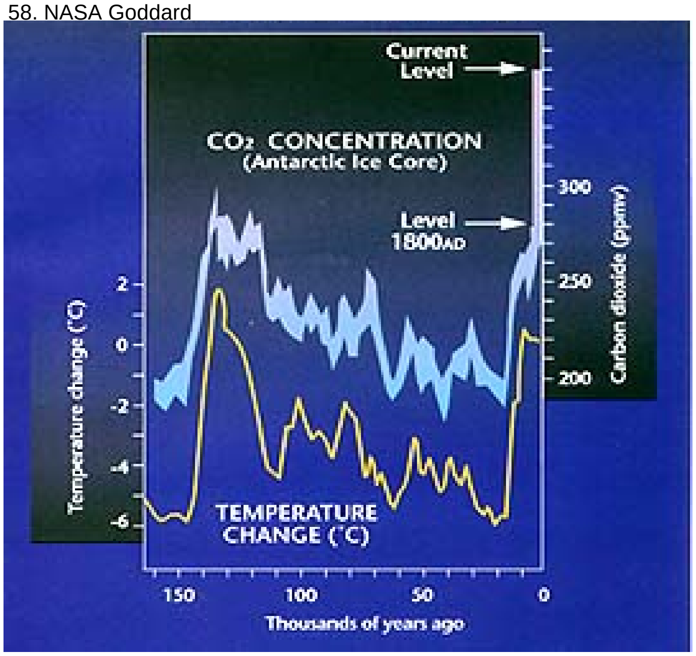
57. Maria Koshland Museum of the National Academy of Sciences



Over more than the past 400,000 years of Earth's history, ice ages have occurred at regular intervals of about 100,000 years each. These cycles have witness changes when huge glaciers have destroyed entire regional ecosystems and altered topographical surface features.

Glacial and Interglacial Cycles

58. NASA Goddard



Early Climate Changes (Past 150,000 Years)

Except for relatively brief interglacial episodes such as the "Eemian" that peaked about 125,000 years ago and our present one, much of the Earth's surface has been under a siege of ice over most of the past 160,000 years.

- Occurrences and impacts of these and other glacial periods has been verified by three types of methods:

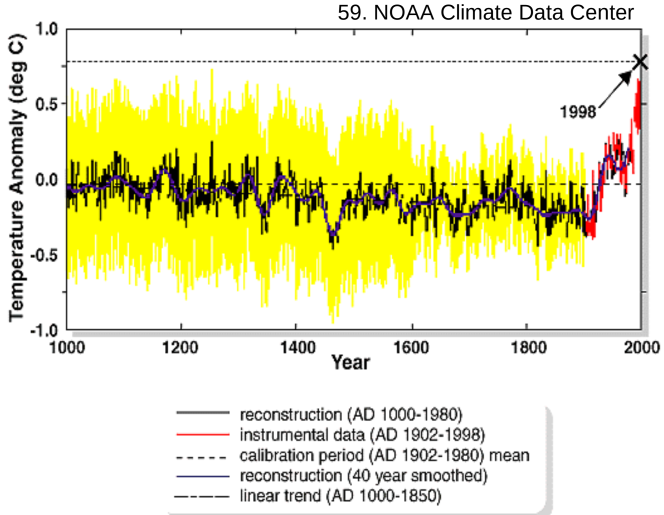
- Geological studies reveal evidence in the form of rock scouring and scratching, glacial moraines, valley cutting and other surface effects.
- Chemical analysis of isotope variations in sedimentary rocks, ocean sediment and ice cores reveal biological changes and extinctions.
- Paleontological surveys of fossil distributions indicate when and where cold-adapted organisms spread into higher latitudes, and others requiring warmer conditions became extinct or migrated into lower latitudes.

Temperature fluctuations in our current interglacial period

Interglacial periods, such as ours, appear to be characterized by great climate variability.

- Contemporary observations reveal constant fluctuations from month-to-month, season-to-season, year-to-year, decade-to-decade, and century-to-century:
  - The 19th century ended a centuries-long "Little Ice Age" that brought "abnormally cold" temperatures to many parts of the world, and may have biased observations commencing during the second half of that century as "normal", and the 20th century as "abnormally warm".
  - Today's climate is generally comparable to that of the Medieval Warm Period (believed to extend from the 9th-13th centuries AD) which preceded the Little Ice Age.
  - Dramatic, but very temporary changes were also witnessed as influences of tropical Pacific conditions that produced warming during El Niño in 1997-98, followed by cooling during La Niña.

59. NOAA Climate Data Center



The Northern Hemisphere has experienced significant climate shifts during the past 2,000 years, ranging from the Medieval Warm Period, the Little Ice Age which followed, and the warm period we are currently experiencing. *

Northern Hemisphere Climate Shifts

60. Hendrick Avercamp

Scene inspired by the harsh winter of 1608 in The Netherlands during the Little Ice Age

Rather than continued global warming, our planet may quite likely be near the end of a relatively short period between major ice ages. Periods such as these are characterized by abrupt, vacillating, and sometimes extreme climate changes, ranging from cold to hot, and wet to dry. An example during this present interglacial occurred in the Northern Hemisphere between the 16th and 19th centuries.

Little Ice Age Cooling Paradox

Ironically, much research suggests that the Northern Hemisphere of our planet is ultimately heading towards a protracted new glacial age.

- During the past million years Earth has experienced a major ice age about every 100,000 years, interrupted briefly by warmer "interglacial" periods like our current Recent Holocene that last about 12,000 years or so:
  - About 21,000 years ago, North America and northern Europe were covered by ice sheets estimated to be about 1.9 miles (3km) thick.
  - More recently, about 6,000 years ago, a thaw caused ice sheets to retreat to Greenland and Antarctica and stream into the sea.
  - Although the last thousand years have been generally mild, substantial fluctuations have occurred, such as the "Little Ice Age" which brought bitterly cold weather to many parts of the world during the 17th and 18th centuries.

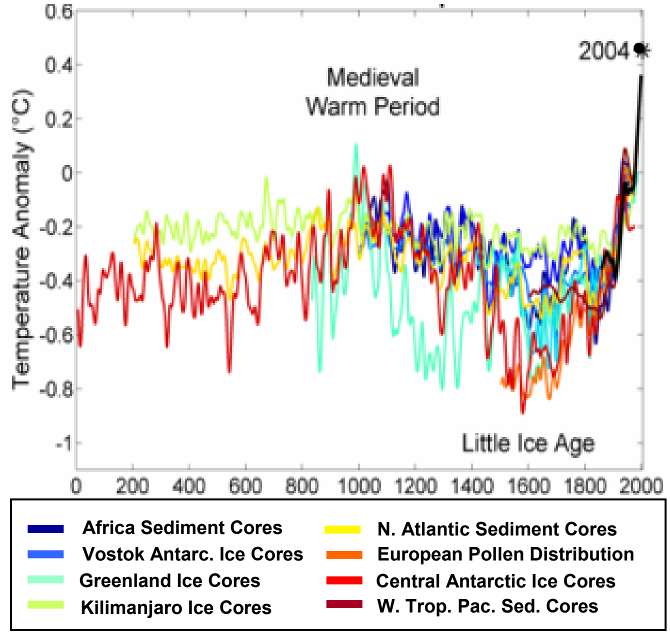
* **See Appendix: 8**

If Earth climate patterns hold true to recorded schedules, a predicted ice age may present even more serious adaptation challenges than global warming, creating both food and energy shortages.

- Results of the Little Ice Age (not a real glacial ice age) can offer some examples of such consequences:

- In 1250, Atlantic pack ice began to grow; warm summers stopped being dependable in Northern Europe in 1300; torrential rains followed, and the Great Famine of 1315-1317 required crop practices to be altered in order to adapt to shortened, unreliable growing seasons.
- Later, in the mid-17th century, glaciers in the Swiss Alps advanced to gradually engulf farms and villages; the Thames River and canals of The Netherlands froze over (as did New York Harbor by 1780); and sea ice closed shipping harbors in Iceland.
- The climate began to warm again beginning in about 1850 to more recent conditions.

61. Robert A Rhonde, Global Warming Art



Estimates of temperature changes differ based upon various studies and methodologies used.

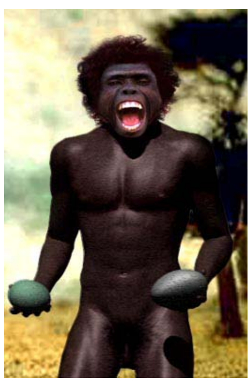
Earth Climate Changes (Past 2,000 Years)

62. Content Answers

Lucy

About 2.8 Million Years Ago

63. Archaeology Info



Homo Erectus

About 1.7 Million Years Ago

64. Michigan State U.

Homo Sapien

About 130,000 Years Ago

Another period of colder, drier African cycles about 1.7 million years ago caused Homo Habilus to die out, and a larger-brained Homo Erectus first appeared along with more sophisticated tools used by our human ancestors.

About 1 million years ago when cold, dry periods again became extreme, the genus Paranthropus became extinct, and Homo Erectus migrated from Africa to eventually evolve into modern humans, the Homo Sapiens.

Influences on Human Evolution

Analyses of ocean sediment cores drilled off the African coast indicate that climate shifts may have dramatically influenced the course of human evolution.

- These recent studies reveal occurrences of three major climate cycles that coincide with developments evident in fossil records:

- Brief, oscillating warm/wet and cold/dry climate cycles about 2.8 million years ago became progressively colder and longer, killing off fruit trees, rainforests and species that depended upon them, while grassland species thrived.
- After that period Australopithecus Afarensis (known as "Lucy") evolved and divided into at least two separate lineages, the genus Paranthropus and genus Homo, and the first stone tools appeared.

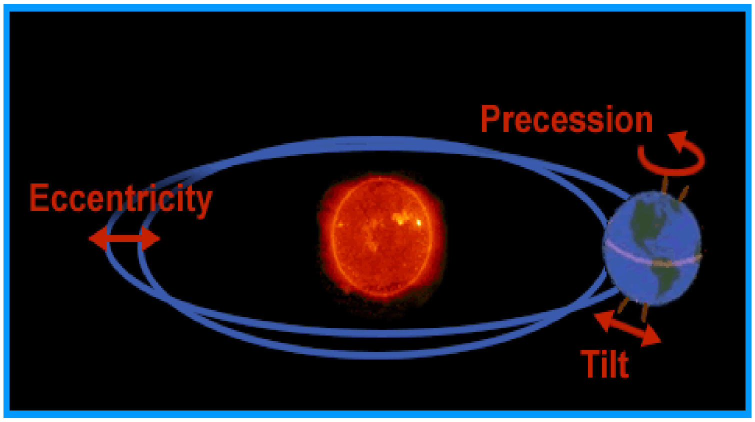
Natural influences contributing to climate cycles

Although causes of major glacial events are not confidently understood, changes in Earth's orbit are often considered to be important factors.

- Variations in the shape (or eccentricity) of Earth's orbit around the Sun (called "Milankovitch" cycles) and in the planet's tilt axis both affect the amount of sunlight received on the surface, influencing periods of warming and cooling:

- Tilt is usually considered to be the most important of these in terms of glacial and interglacial periods.
- Distance changes as Earth processes elliptically around the Sun are expected to have contributing effects, particularly with regard to climate shifts within an interglacial period.

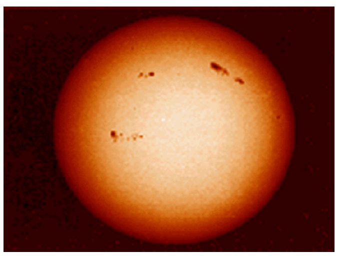
65. University Corporation for Atmospheric Research



Changes in the Earth's orbit eccentricity and its axis tilt angle can produce changes over thousands of years. Its axis is offset from the perpendicular by an angle that "wobbles" from a minimum of 22.5° to a maximum of 24° over about a 40,000-year cycle. It is currently tilted at 23.5°. Approximate 100,000-year dominant patterns of glacial periods roughly correspond with both types of changes.

Influences of Earth's Orbit

66. NASA
68. Isaac Newton Group

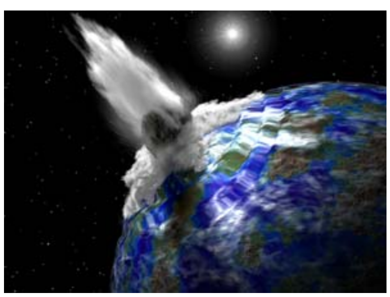


The Sun's output is estimated to increase about 10% each billion years, and sunspots produce short-term effects.

67. NASA
69. Orbit @ Home

A continent at the top of a pole (as Antarctica is presently) can block warm water flow.

Volcanoes produce dust and aerosols that block sunlight, and also release warming greenhouse gases.



Dust ejected by large meteor strikes may have blocked sunlight and cooled some regional environments in the past.

Other Potential Climate Influences

Other naturally-occurring conditions are also theoretically linked to major climate changes.

- Key among these are variations in solar outputs, tectonic plate movements and events that alter Earth's atmosphere:

- Changes inside the Sun over time affect energy that reaches the Earth's surface, causing either warming or cooling. (NASA research indicates that this may have been a factor during the Little Ice Age.) *
- Migrations of Earth's tectonic plates over long time scales may have influences. (Ice ages seem often to begin when continents are in positions that obstruct warm water flow from the equator to the poles, causing ice sheets to form.)
- Volcanoes and oceans release greenhouse gases that can produce warming effects, and large meteorite strikes release dust that block sunlight (a cause cited for dinosaur extinctions).

*** See Appendix: 9**

Influences of temperature upon atmospheric CO_2 levels

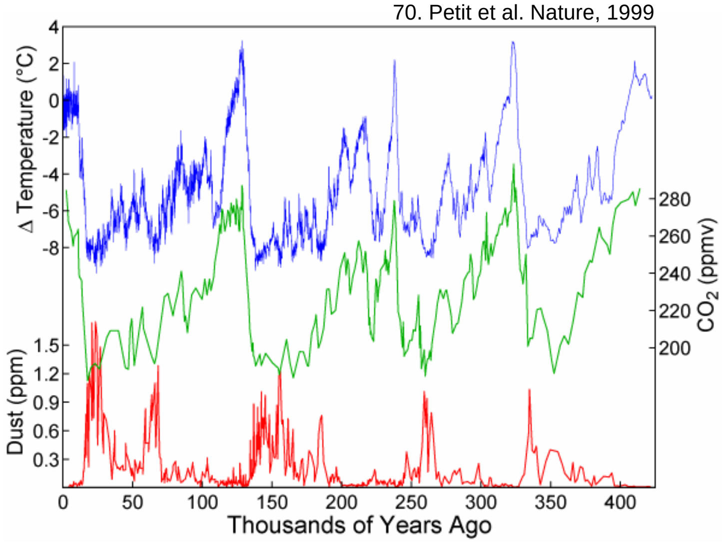
Geological evidence shows that over the past 400,000 years CO_2 levels and temperatures have greatly fluctuated at regular intervals, with temperature rises preceding CO_2 increases.

- CO_2 levels today are similar to the Eemian interglacial period that occurred between 120,000-140,000 years ago which was followed by a full-fledged ice age immediately afterwards:

- Atmospheric CO_2 has been rising steadily since about 18,000 years ago when Earth began to warm its way out of the Pleistocene ice age that covered much of North America, Europe and Asia with glaciers.

- Records indicate that CO_2 levels fall at the start of ice ages when more of the gas is absorbed by the colder oceans, and levels rise during glacial retreats when the processes reverse.

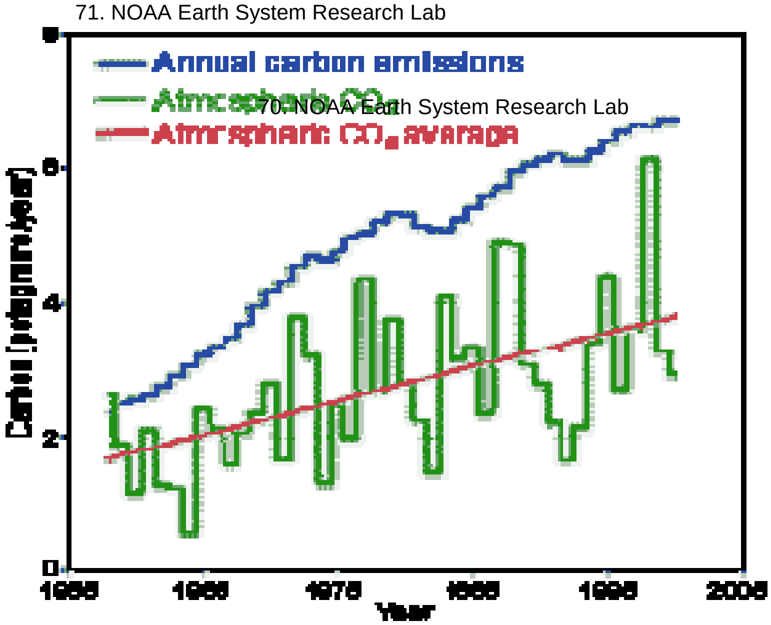
70. Petit et al. Nature, 1999



Core samples taken from Vostok ice show direct correlations between CO_2, temperatures, and dust over the last 400,000 years. Warmer global temperatures release higher CO_2 levels from oceans, events that may be triggered by Earth's orbit changes and/or other causes.

Correlations with Atmospheric Dust and CO_2 Levels

71. NOAA Earth System Research Lab



On average, only about half of CO_2 emissions released by fossil fuel combustion remain in the atmosphere, with inter-annual fluctuations due to variations in natural sources and sinks. *

Global CO_2 Fossil Combustion Emissions vs. Atmospheric Concentrations (billions of tons of carbon / year)

Influences of atmospheric CO_2 concentrations upon climate change and human-induced enhancements in particular, are issues of continued uncertainty and controversy.

- Although CO_2 levels have generally been observed to increase during warm periods and fall with colder temperatures, it is not clear which condition causes the other:

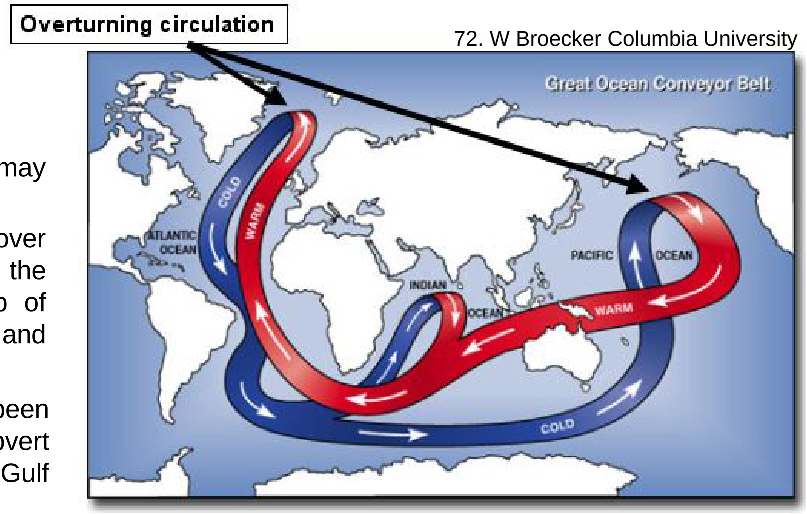
- Atmospheric CO_2 measurements at remote Northern Hemisphere sites have shown nearly linear increases of about 1.4 ppm / year since 1972, a rate seemingly unaffected by a large 45% increase in fossil fuel combustion emissions between 1972 (4.4Gt) and 1995 (6.4Gt).

- Previous climate shifts between the Medieval Warm Period and Little Ice Age also raise questions, having occurred long before the Industrial Revolution or invention of the internal combustion engine.

* See Appendix: 10

Global warming theories and arguments

72. W Broecker Columbia University



Thermohaline Circulation in the North Atlantic

Terrence Joyce who chairs the Woods Hole Physical Oceanographic Department in Cape Code, Massachusetts believes that freshwater infiltration into the North Atlantic from melting Arctic ice could shut down thermohaline circulation that powers heat transfer from the tropics to Europe in winter. Such a shutdown might possibly precipitate a sudden drop in North Atlantic water temperatures and bring colder temperatures to land masses on both sides of the ocean.

Possible Mini-Ice Age Warming Trigger

At least one theory suggests that global warming may actually trigger a mini-ice age.

- This possibility is supported by the appearance over the past 30 years of huge freshwater “rivers” in the salty North Atlantic, along with a recent drop of salinity in the Labrador Sea between Canada and Greenland adjoining the Atlantic:

- It is suspected that these events may have been caused by melting Arctic ice that might subvert northern movement of heat-laden tropical Gulf Stream waters.
- Instead of transferring heat to eastward winds that warm Europe in winter and then sinking as it cools and becomes denser, the North Atlantic fills with fresh water that is less dense and doesn’t sink, remaining on top of the ocean like a big thermal blanket

73. Larry Bell

Ground Station Measurement Critics	Balloon/Satellite Measurement Critics
If monitoring stations are located in urban areas, they may become heat islands that skew results upward.	Measurements show a lack of observed differences between urban and rural areas, indicating no bias.
Suitable measurements sample less than 30% of the global surface. Localities exhibit different temperature trends.	Evidence of warming is apparent in glacier meltings and effects upon ocean salinity levels.
Satellite measurements have global coverage, and can precisely measure tropospheric and stratospheric temperatures.	Short measurement periods, drifts over local solar times, and ozone depletion cooling of the stratosphere skew results.
Balloon radiosonde records are longer and provide accurate tropospheric temperature measurements.	Significant changes in instrumentation and data processing have produced discontinuities over the years.

Temperature Measurement Process Arguments*

Broad alarm during the mid-1980s about indications of global cooling portending the arrival of a new ice age reversed to predictions of cataclysmic warming threats by the later part of that century.

- The existence, magnitude and causes of this potential threat are subjects of contentious scientific and public policy debate:

- Measurements taken after about 1940 did seem to indicate a cooling trend, although declines slowed to halt in the late 1970s.
- Observations since the 1980s have recorded slow but steady increases in global near-surface temperatures in combination with rising amounts of atmospheric CO_2.
- Atmospheric balloon and satellite instrument measurements since 1979 have seemed to indicate smaller temperature increases than ground stations, although differences appear relatively minor and uncertain.

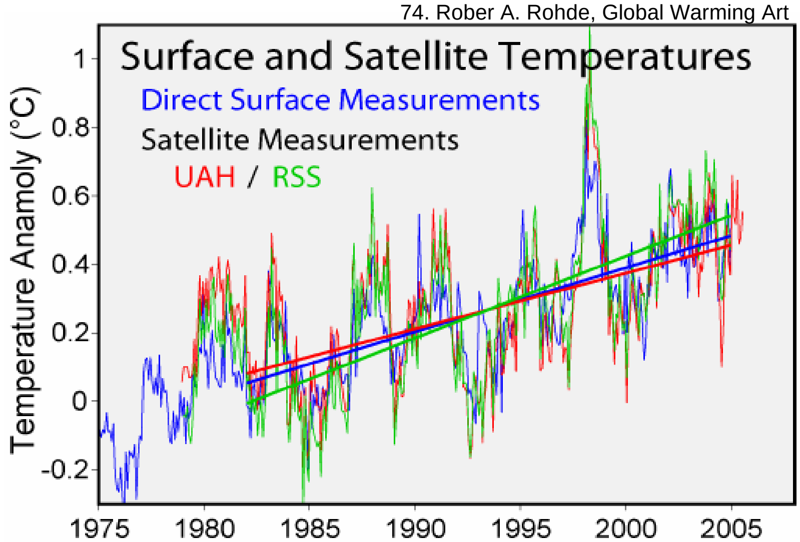
***See Appendix: 11**

There appears to be a strong consensus among climatological experts that global warming is in fact occurring, and many, but not all, agree that human activities are an important contributing factor.

- An Intergovernmental Panel on Climate Change (IPCC) established in 1988 by two United Nations organizations, the World Meteorological Organization (WMO) and the UN Environmental Program (UNEP) supported global warming assertions in a 2001 summary report:

- After much debate, the IPCC concluded that *"In the light of new evidence, and having taken into account the remaining uncertainties, most of the observed warming over the past 50 years is likely to have been due to increases in greenhouse gas concentrations."* *

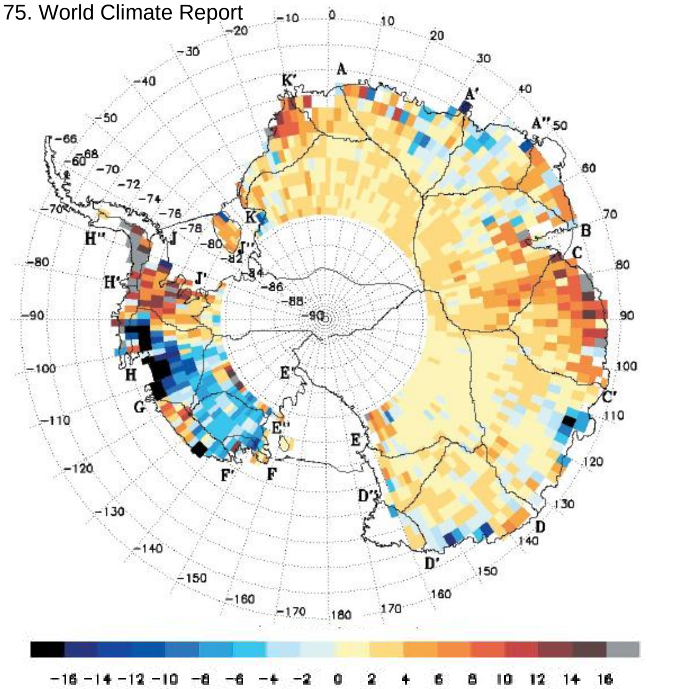
74. Rober A. Rohde, Global Warming Art



Surface ground stations have recorded temperature increases of about +0.11°F (+0.06°C) / decade and +0.31°F (+0.17°C) / decade since 1979, while Remote Sensing Systems (RSS) taken by the U of Alabama Huntsville since 1979 show increases of about +0.063°F (+0.035°C) / decade. Removing RSS measurements of the lower troposphere only to eliminate possible stratospheric cooling effects, the surface and atmospheric measurements may be closer. **

Earth Temperature Measurements

75. World Climate Report



Rate of elevation change (cm / year) from 1992 – 2003 by Satellite Altimeter Measurements (from Davis, et al., 2005).

Snow Accumulation in the Antarctic Interior

In addition to projecting continued average global temperature increases, the IPCC also predicted that sea levels will rise "under all scenarios".

- Given that rising sea levels are principally associated with anticipated Arctic and Antarctic ice melts, measurements of snow accumulations in Antarctica may offer an alternative picture:

- Satellite altimeter measurements made between 1992-2003 indicate, on average, the elevation of about 3.2 million square miles (8.5 million square kilometers) of the Antarctic interior has experienced a net snow gain of about 38.-52 billion tons/year, potentially enough to slightly lower the surrounding sea level.

- These observed snowfall increases covering about 70% of the total ice sheet area are likely to be linked to warming of southern oceans from either natural or human-influenced causes. ***

*** See Appendix: 12**
**** See Appendix: 13**
***** See Appendix: 14**

Challenges to predicted catastrophic rising sea levels

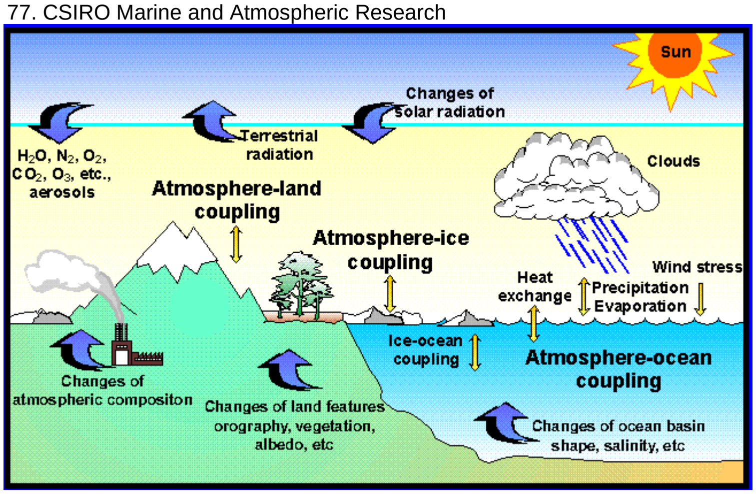
European Space Agency satellite altimeter measurements of the Greenland Ice Sheet since 1992 record recent changes similar to those observed in Antarctica, with thickness growth in higher interior areas, and thinning at coastal margins.

• While total mass balance gains or losses are yet unknown, spatial averaging indicates a net increase of 2.1 in (5.4cm) per year, with thickness increases of about 2.5 in (6.4cm) per year in interior areas above 4,900 feet (1,500 meters), and 0.79 in (2 cm) per year reductions below that elevation:

- The recording period is too short to know if these observations represent a long-term trend, since Arctic temperatures appear to naturally fluctuate in 60-80 year time cycles.

- Annual snowfall increases and melts have been observed to be strongly linked to variability in regional atmospheric circulation (the North Atlantic Oscillation), along with possible smaller influences associated with temperatures.

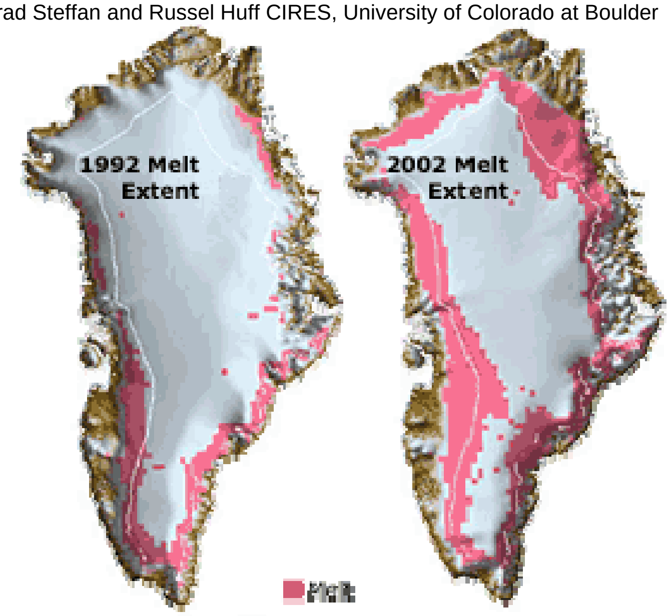
77. CSIRO Marine and Atmospheric Research



Weather is influenced by many interactive day-to-day conditions and events in a locality that are often difficult to predict with confidence. Global climate is conventionally thought to be comprised of interactive local weather conditions over large scales measured over 30 years or more, adding enormously greater complexities and uncertainties. **

Climate Modeling Challenges

76. Konrad Steffan and Russel Huff CIRES, University of Colorado at Boulder



Annual Greenland Ice Sheet melt changes revealed by satellite data since 1978 are believed to be largely influenced by regional atmospheric circulation patterns and conditions. Comparable lower-than-average total melts occurred in 1992 and 1996, and similar higher-than-average melts occurred in 1991, 2002, and 2005. Warming (from natural and human-enhanced influences) may be a contributing factor. The lower-than-average 1992 melt appears to be linked to a large Mt Pinatubo eruption that released aerosols. *

Greenland Ice Sheets

Contrary to IPCC conclusions that all global warming scenarios inevitably lead to sea level increases, the Antarctic and Greenland observations demonstrate apparent exceptions.

• However a caveat in the IPCC report acknowledged the potential fallibility of current climate prediction models, stating that: "*Such models cannot yet simulate all aspects of climate (e.g. they cannot account for the observed trend in surface-troposphere temperature changes since 1979) and there are particular uncertainties associated with clouds and their interaction with radiation and aerosols*":

- It is widely recognized that while computer simulations do provide scholarly tools, they contain substantive uncertainties, and cannot accurately reproduce many climate features. ***

***   See Appendix: 15**
**** See Appendix: 16**
***** See Appendix: 17**

Kyoto Protocol controversies

78. Larry Bell

Arguments Against:	Arguments For:
Protocol is uneconomical, subjective, inequitable and ineffective.	Costs for non-compliance may be higher than failures to act.
It excludes the largest future CO_2 emission sources (China and India)	Largest share of past / current emissions are from developed nations.
Exclusion of developing countries is unfair to developed ones.	Developing countries need to grow their industries for social needs.
Basing upon per capita emissions (not total) is unfair to Australia.	Per capita emissions in developing countries are relatively low.
Emission credit trading within the EU is unfair to single nations (the US).	If the US doesn't participate, it will have economic advantages over the EU.
The UK, Russia, and Germany have advantages due to high 1990 levels.	The US is currently the largest CO_2 emission producer.
The 2008 effective time scale is insufficient to meet compliance.	Reducing CO_2 emissions is crucially important to reverse global warming.
The CO_2-global warming connection isn't clear, but economic impacts are.	The UN and some individual national scientific groups favor the Protocol.

Key Kyoto Protocol Provision Issues

The Kyoto Protocol was established under the UN's Framework Convention on Climate Change (UNFCCC), and became active in 2005 following ratification by Russia.

Strongly influenced by the IPCC report, the Kyoto Protocol was established by the UN, and requires participating industrialized nations to reduce emissions of CO_2 and five other greenhouse gases (GHGs) by 5.2% under 1990 levels between 2008-2012.

- The US and Australia have believed certain provisions to be unrealistic and unfair, including exemptions for China and India, terms that enable the EU and Russia to trade GHG emission credits within regional countries, and advantages to previously very polluted nations:

- The EU is believed to have a large advantage because German reunification eliminated many dirty East German industries, a circumstance that also applies to Russia following the collapse of the USSR.

- The UK has an advantage following the discovery of a large North Sea natural gas deposit that enabled a major coal phase-out.*

Neither the Clinton nor Bush Administrations have found terms of the Kyoto Protocol acceptable.

- These positions follow a policy established through unanimous passage of a July, 1997 Byrd-Hagel US Senate Resolution (S. Res. 98) which stated that the US should not be signatory to any protocol that does not include binding targets and timetables for both developing and industrialized nations or "*would result in serious harm to the economy of the United States*":

- Although Vice President Al Gore symbolically signed the Protocol, the Clinton Administration never submitted it to the Senate for ratification.

- President Bush has indicated that he also doesn't plan to seek Senate ratification, not only because of the China and India exemptions, but additionally because of strains it would put on the economy and uncertainties regarding climate change assertions.**

79. CNN

The US and Australia have declined ratification of the Kyoto Protocol, while Europe and Japan are finding difficulty in meeting targets, and Canada has abandoned them. The US Senate made it clear in 1997 that it would not support the terms.

Positions

* See Appendix: 18
** See Appendix: 19

80. Sydney Morning Herald

81. Space and Motion

82. Planetsave

83. NASA

Los Angeles

India

China

Mexico City

Establishment and enforcement of universal international environmental protection standards has thus far proven to be an elusive goal.

- The Kyoto Protocol, now ratified by 163 countries, reflects common priorities but perhaps little real progress:

- The US and Australia have declined to ratify, arguing that the maximum greenhouse gas emission limits are unrealistically restrictive and costly to meet.

- Of all ratifying countries, only 31 are actually required to lower greenhouse emissions, and China and India with huge populations, exploding industrial growth and enormous pollution problems are among those excluded.

- Europe and Japan are struggling to meet the greenhouse restrictions, while Canada has given up entirely.

- Germany has exempted its coal industry from compliance.

Pursuing International Solutions

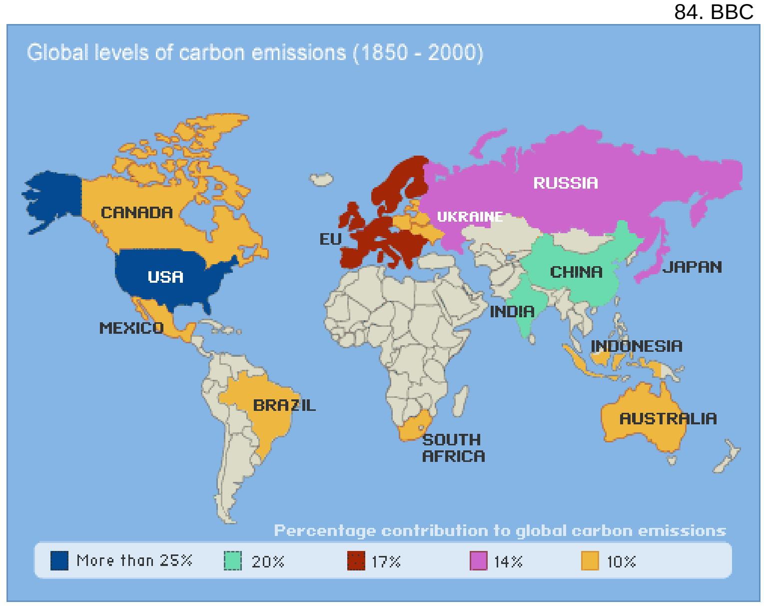
As contentious debate among public and private groups continues within the US and other countries regarding merits and faults of the Kyoto Protocol, many ratifiers and refrainers are working to pursue more satisfactory agreements.

- The US and Australian governments are signatories of an “Asian Pacific Partnership on Clean Development and Climate” sponsored by an Association of Southeast Asian Nations (ASEAN) regional forum in 2005 which enables countries to set voluntary GHG reduction goals:

- Other participating countries include China, India, Japan and South Korea who ratified the Kyoto Protocol.

- The US hopes to fulfill a pledge to reduce CO_2 emissions 18% by 2012, and the pact also appears to be gaining favor in Canada which now recognizes an inability to meet its Kyoto targets.

84. BBC



The US currently heads the world in CO_2 emissions. China is adding about one new coal-fired power plant per week, plans to do this for the foreseeable future, and is expected to be the largest GHG emitter within a few years.

Beyond the Kyoto Agreement

Key policy issues and debates

Interjections of economic considerations into national and international environmental policy decisions can be regarded by some as an inevitable compromise of principles.

- Recognizing that all-too-often these separate priorities have produced conflicts, with environment the loser, it is also important to realize ways the underlying objectives of both are interdependent:

- Commercial investment, production and profits provide employment essential to support families of all income levels, finance education and public services, and create safe and affordable energy and food used in daily life.
- Businesses that fail, or are forced to relocate to countries with lower environmental standards, compound economic stress with additional global environment impacts.
- Economic prosperity reinvested by industry provides cleaner, more efficient production methods, products and advancements.

85. Larry Bell

- Establish a responsible balance between state/regional/national economic and environmental interests by ensuring that both priorities are fully and effectively represented in policy and finance decisions.
- Provide business incentives and regulatory mechanisms that promote clean industries without imposing overly burdensome costs and restrictions that send production and jobs overseas to places that are cheaper in part due to lack of equivalent standards.
- Protect national economic competitiveness in world markets through international agreements that insist upon fairness, while also demonstrating that global cooperation benefits everyone.
- Recognize responsibilities of all nations to support less developed ones through technology funding and transfer for climate-related studies and projects.

Economic Policy Priorities and Challenges

86. Larry Bell

Less Concerned	More Concerned
Climate models have proven faulty and don't include major influences.	Humankind is performing a dangerous geophysical experiment.
Human vs. natural contributions to atmospheric CO_2 are very small.	A precautionary principle requires action to prevent crises later.
CO_2 levels follow a temperature rise, not the other way around.	Temperatures and CO_2 have risen rapidly over the past 50 years.
Temperatures always rise and fall during interglacial periods.	Most scientists today share global warming concerns.
Issues are politicized; climatologists who disagree are afraid to speak out.	Most scientists agree that human activities contribute to warming.
CO_2 is a very minor greenhouse gas, and most comes from natural sources.	CO_2-water vapor interactions can have a compounding effect.
Natural ocean and land CO_2 sinks rapidly reduce accumulations.	CO_2 has a long average atmospheric lifetime.
Solar activity is a major factor: present levels are highest in 8,000 years.	Without greenhouse forcing, solar activity doesn't account for changes.
Greenland/Antarctica melts are balanced by interior snow accumulations.	Greenland/Antarctica melts may flood global coastlines.
Global warming may have prevented an overdue new ice age.	Greenland melts may trigger a Northern Hemisphere glacial event.

How Concerned Should We Be About Global Warming/CO_2?

Many very intelligent, highly-educated and extremely dedicated people share real concerns about climate change, yet sharply disagree about specific causes, impacts and solutions.

- Such varying perspectives and opinions are powerful motivators that drive innovative ideas, exploration into new areas of investigation, and development of improved research methods and tools:

- The fact that these differences are often passionately debated reflects the enormous importance attached to their concerns, and deserves to be honored with appreciation and respect.
- Real progress demands that theories be regarded as unproven possibilities, and “established facts” be constantly tested as newer, more comprehensive information is revealed.

Pursuing informed, effective responses

Wide-spread concerns about global cooling trends during the 1970s and warming in the present may have a solid basis (possibly in reverse order), but even then do not necessarily warrant dire catastrophic forecasts.

- There are no conclusive reasons to believe that slightly lower temperatures are preferable to slightly higher ones, or that modest warming trends will trigger runaway greenhouse events:

- Recognizing that atmospheric and surface climate mechanisms may well be sensitive to relatively small influences, CO_2-water vapor interactions linked to greenhouse feedback loops do appear to be less active than climate models formerly suggested.

- It is also apparent that much of the CO_2 released from human and natural processes is absorbed by the oceans and terrestrial biosphere, providing an essential nutrient for agriculture, forests and all plant-based ecosystems.

87. Larry Bell

Causes:

- Do CO_2 changes lead or follow temperature changes?
- How important is CO_2 as greenhouse gas?
- What are other forcing factors and interrelationships?
- How significant are fossil fuel combustion influences?
- Will switches to biofuels make measurable differences?
- How important are land use change influences?

Effects:

- How warm is ultimately "too warm"?
- Is warming a micro-trend within this present interglacial?
- When is the next ice age "scheduled" to arrive?
- Are net Arctic / Antarctic water mass balances changing?
- Will Northern Atlantic salinity dilution trigger cooling?
- What human greenhouse reductions are possible/ realistic?

Global Warming Questions

88. Larry Bell

Complacency, possibly rooted in denial or apathy, promote hazardous tendencies to assume that "everything is really fine"; or "someone else will solve the problem"; or it won't happen in my lifetime or anytime soon, so why worry?"

Hysteria, potentially fueled by simplistic assumptions and sensationalism can promote desperate, misguided and costly decisions at the expense of seeking better understanding of underlying issues and pursuing the most effective intervention options.

Dangerous Extremes

The "Abrupt Climate Change: Inevitable Surprises Report" issued by the National Academy of Sciences in 2002 emphasizes that "Increased knowledge is the best way to improve the effectiveness of response; research into causes, patterns, and likelihood of abrupt climate change can help reduce vulnerabilities and increase our ability to react." *

It is rational to recognize global warming as a current reality that can possibly precipitate non-linear sudden climate shifts.

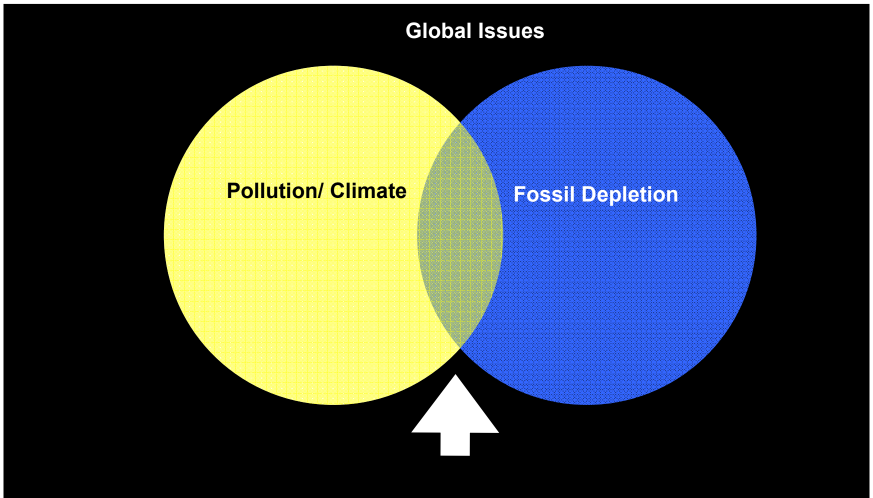
- A 2002 report titled "Abrupt Climate Change: Inevitable Surprises" issued jointly by the Ocean Studies Board, Polar Research Board, and Board on Atmospheric Sciences and Climate of the National Research Council advocated preparation without panic:

- "*The climate record for the past 100,000 years clearly indicates that the climate system has undergone periodic and often extreme shifts, sometimes in little as a decade or less*"… "*Societies have faced both gradual and abrupt changes for millennia and have learned to adapt…*"

- "*It is important not to be fatalistic about the threats of abrupt climate change*"… "*Nevertheless, because climate change will likely continue in the coming decades, denying the likelihood or downplaying the relevance of abrupt changes could be costly*."

* **See Appendix: 20**

89. Larry Bell



Information:	**Innovation:**
Determine interrelationships between causes / effects and human contributions / interventions.	Develop responsive technologies, strategies, and programs that address short- and long-term needs.
Education:	**Application:**
Disseminate accurate information to advance public, industry, and government awareness.	Put responsive plans and technology infrastructures into action through national and global initiatives.

Responsive Priorities

The fact that theories and models do not always match measured observations does not necessarily indicate that basic underlying premises are wrong, that predicted outcomes are invalid, or that reasoned interventions should be delayed until all conditions are perfectly understood.

- There is inescapable evidence that human activities are changing Earth's environment, including its climate, in ways that pose unacceptable perils to all life:

- Air, water and land pollution is an expanding global reality that must be rapidly reversed before the impacts are irreversible.
- Fossil fuel depletion is a near-term certainty that demands a greatly accelerated adjustment of consumption habits and transition to clean, sustainable alternatives.

The emergence of Homo Sapiens from the Late Pleistocene glacial period about 13,000 years ago demonstrated our remarkable human capacity to adapt and survive.

- Since that time humankind has achieved much, beginning with stone tools, and ultimately returning similar rocks during expeditions to the Moon:

- Our genus has learned not only how to adapt to the environment, but through agriculture, industry and living, to adapt the planet to serve human purposes.
- We are now realizing that our continued survival will depend upon learning how to protect the planet from our impacts, probably the greatest adaptation challenge of all.

90. Chemistryland
92. NASA

91. Chemistryland
93. NASA

Applying Knowledge and Tools

Advancing tools for knowledge

Our human capacity to gain knowledge about changes we are imposing upon our planet provides opportunities to adapt our living habits, industries and technologies to prevent events unscheduled by Nature from creating unfortunate and avoidable surprises.

- Such events, including resource exhaustion, ecosystem destruction and severe climate changes can have harsh consequences effecting all life:

- Rapid changes, even lasting over relatively short periods, can be more hazardous and disruptive than slow ones, allowing less time to respond.
- Unlike our early ancestors, we won't be able to simply "pack up and leave", since there may be few places to escape to, and it may be impossible to relocate present large populations to more favorable areas, particularly across restricted national borders.

94. Scientific American
95. European Space Agency
96. United Nations Magazine
97. Vestal Design




Penalties for Failures

98. NOAA / NASA

NOAA Polar-Orbiting Operational Environmental (NOAA-K) Satellite

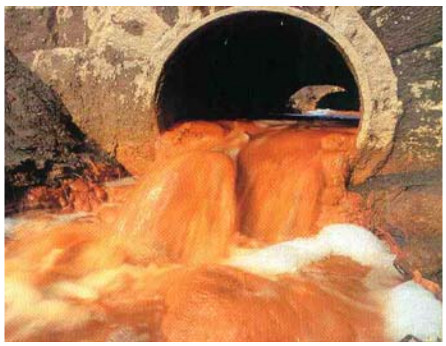
Information Advancements

International researchers from diverse disciplines using a variety of new tools are making real progress towards achieving a better understanding of natural and human-enhanced influences upon Earth's environment and climate.

- Increasingly precise methods are being used and improved to measure distant and recent climate and temperature fluctuations, and to assess observed and potential influences upon atmospheric and surface phenomena and their interactions:

- Expedited advancement and expanded application of these capabilities is vitally important to construct more comprehensive and reliable climate models, both to examine current forcing conditions, and to predict future trends and consequences.
- Rapid advancements in computing technologies are also encouraging, and are critically important to study enormously complex interrelationships between forcing influences that are continuously being revealed.

99. Asel Electronic
100. RST3
101. NOAA
102. Welfare Service Club



Lessons from Experience

Information technology is but one of many tools afforded to guide better understanding of Nature's complexities and intricacies, our influences upon these phenomena, and lessons we can apply to be more positive contributors.

- Other important tools are our natural gifts of human curiosity, reasoning, creativity and the capability to recognize our dependence upon the wellbeing and stability of other creatures, habitats and support systems that our actions impact:

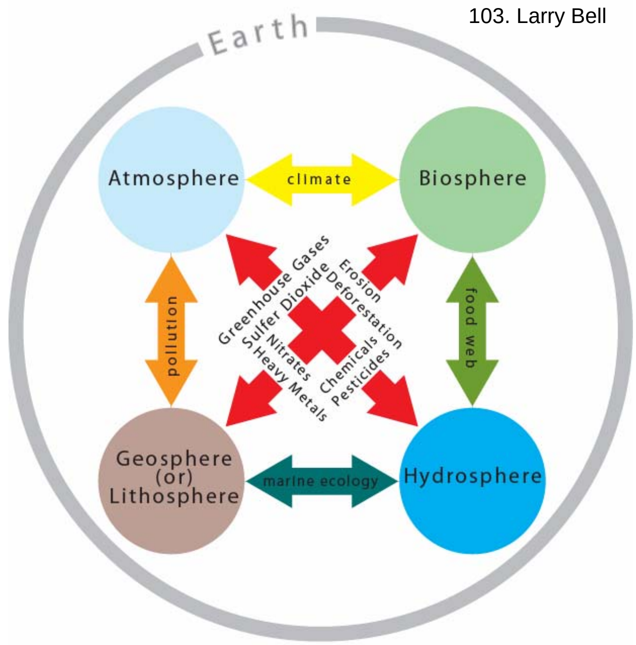
- As students of Nature and Earth's history we learn that very large events and consequences can precipitate from small compounding influences over relatively short time frames.

- We can also readily observe that pervasive human influences upon this planet's fragile lands, oceans and atmosphere are neither small nor sustainable.

The spheres of influence that impact life on our planet are always in a dynamic, complex and delicate state of balance.

- Human activities clearly impact the equilibrium of these influences, and are doing to at an accelerating rate:
  - During the past two centuries we have switched from biomass energy to fossil fuels for more than 90% of industrial energy, releasing CO_2 that has been stored for millions and billions of years.
  - Toxic pesticides created to increase food production needed to support growing world populations has entered sensitive marine ecosystems.
  - Nitrates and particulates released from combustion are polluting the atmosphere.
  - Short-sighted agricultural, mining and deforestation practices have sacrificed topsoils, leached chemicals into land and water, and effected the oxygen-CO_2 balance.

103. Larry Bell



Contributions to Global Changes

Taking responsibility

104. JCC S. Nevada

Our Legacy

There is little disagreement within our global community that we must change the ways we treat our natural environment before it responds in ways we cannot correct.

- Whether these repercussions occur rapidly or over longer time frames, present trends are unsustainable, promising unthinkable consequences that transcend geographic boundaries:
  - Citizens, children and future generations throughout the world are equal stakeholders in the outcomes of our actions.
  - Industrialized and developing nations enjoy special responsibilities and opportunities to provide essential solutions and examples.
  - Our decisions and commitments may well determine the ultimate destiny and natural legacy of human civilization.

105. Larry Bell/ Candy Feuer

Living Only In the Here and Now

Viewed from vantage points of our everyday lives it is convenient to perceive the world as an open and unbounded place with limitless self-healing ability and resource abundance.

- From this perspective we may be even more inclined to view ourselves and our communities as small, isolated parts of overwhelmingly large systems and events where our actions are inconsequential or futile:
  - Everything, including the weather, comes from "somewhere else" and we have no effect upon it.
  - If we lack adequate supplies of something we can find them "somewhere else", or eventually substitute other things that will work as well or even better.
  - We might imagine that adverse changes in our environments will occur slowly and reversibly so that we can afford to worry about them later.

106. NASA

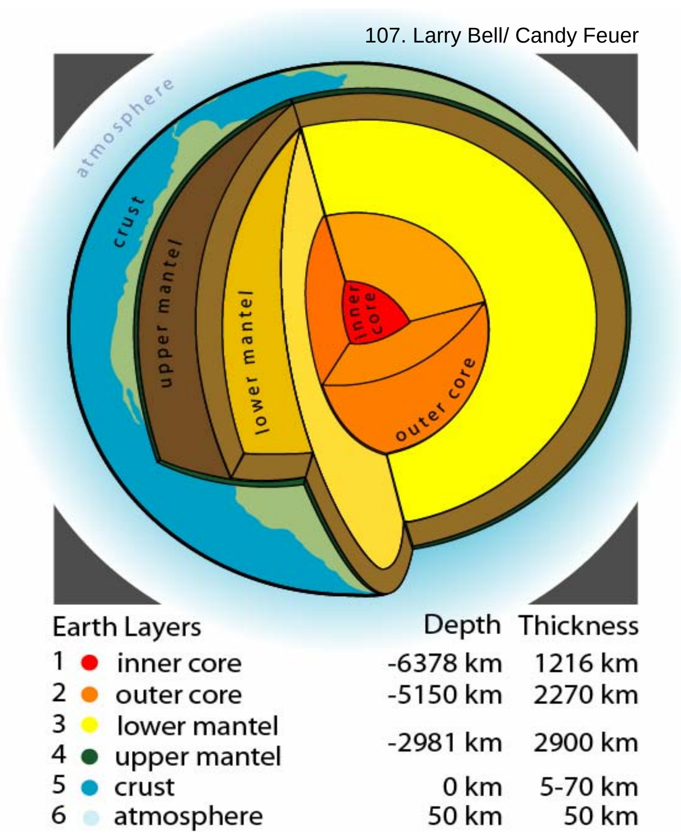
Gazing upwards towards the night-time sky, none of us alive today in “developed” regions, other than astronauts who have orbited above our small globe, have witnessed the bright and expansive starfields that our ancestors observed a few generations past.

- Lacking such a reference of change, and with views obscured by atmospheric pollutants, we may often lose sight of important realities:
  - We may be unaware of the extent and rate our activities are effecting essential life support systems.
  - We may tend not to recognize that what every community on Earth puts into the atmosphere (and oceans) is rapidly distributed through natural transport to global destinations.
  - We may often forget that nature mixes all environmental influences together with combined and interactive consequences.

Due to our visual inability to perceive depth of the atmosphere that surrounds us we may often fail to recognize its limited dimension.

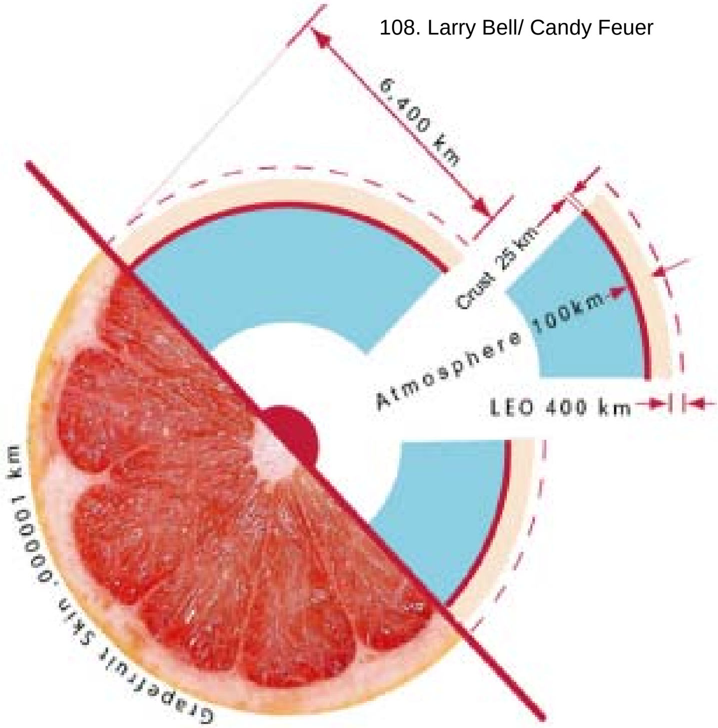
- Using the Earth as a reference, that fragile life support layer is indeed very shallow.
  - Compared with our planet’s radius of approximately 6,400km (4,100 miles), 99% of Earth’s atmosphere is contained within a layer only about 50km (31miles) thick.
  - All life on Earth inhabits a layer no more than 9km (5.6 miles) thick, extending from a few kilometers above sea level (airborne organisms and life on mountains) to a few kilometers below (deep ocean creatures and subterranean microbes).

107. Larry Bell/ Candy Feuer



Personal outlooks and insights

108. Larry Bell/ Candy Feuer



A Thin Slice of Life

Moving farther out into "space" at an altitude where space stations orbit, we continue to find ourselves well within Earth's immediate territorial border.

- Using the proportions of a grapefruit to put dimensions into perspective we are now only moving about the outer skin surface:
  - Low-Earth Orbit (LEO) at a distance of about 250 miles (400km) is less than 5% of Earth's radius away.
  - Earth's atmosphere estimated to extend outward from the surface to about 62 miles (100km) represents about 1.5% of the radius (the inner grapefruit skin).
  - Earth's crust, which constitutes all solid structures, extends inwards about 15 miles (25km) (about 0.4% of the radius) barely penetrating into the grapefruit's juicy part.

A Thin Slice of Life

109. NASA

Looking Back

From LEO we observe a dynamic Earth where forces of nature and consequences of human activities connect, interact and often collide.

- This view reveals the contiguous surface of our planet, where the only real boundaries between human nations and jurisdictions are defined only by land features and water bodies.
  - Weather forces form windswept patterns that rapidly circumnavigate the globe, distributing water and dispersing contaminants along their paths.
  - Storm runoffs and river currents transport topsoils and chemicals to marshlands and estuaries for deposit as sediments, or transfer to more distant locations by ocean tides.

110. NASA

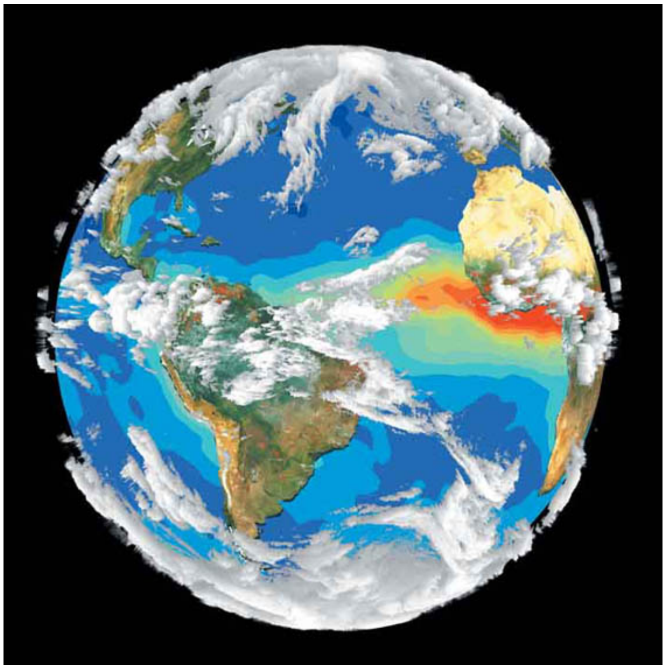


Image created using data from four satellites, showing fires burning on land areas, a large aerosol cloud over the Atlantic Ocean formed by biomass burning in Africa, and a dust cloud surrounding the globe.

Global Pollution

Earth viewed from space makes us realize that we are all members of a global civilization and aware of impacts that our common community has upon our planet and our future.

- Pollutants from all parts of the world rapidly circumnavigate through the atmosphere and oceans to distant locales, and weather and climate influences recognize no geopolitical boundaries:

- Environmental abuses everywhere are ultimately visited upon us as our problems, as are those we export to others.
- Interventions we enact, while important, offer only marginal protection from cumulative impacts of other nations, including contamination of marine ecosystems we share and the air we breathe.
- It is clear that just as the problems are global, real solutions must be also.

Viewing our tiny, fragile planet from space we can more fully realize that there is really no “them”, only us, and that we must learn to live and work within that sphere of reality.

- Our world, shared with other creatures, is a place of overwhelming, magnificent complexity:

- It is a place within an infinitely larger Universe where marvelous, often poorly-understood natural forces interact and exchange energy at unimaginably large and small levels of scale.
- It is a place where global and microscopic events occurring over millennia and microseconds cause some creatures to evolve, while others unable to adapt perish.
- It is a place where societies bound together by common purposes and dreams sometimes become separated by conflicts that impact our lives, future and planet

111. NASA

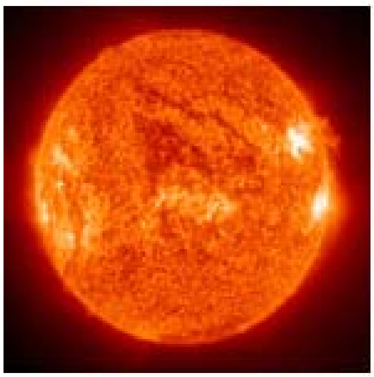
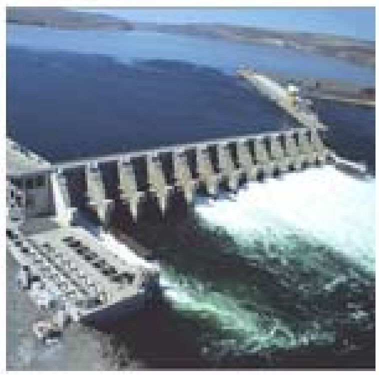
112. Candy Feuer

A resourceful world view recognizes that each and all of us are integral parts of Nature and that it constitutes what we are made of.

113. Texas A&M U, TAMMI
114. Sci/Tech
115. Seeds of Change



116. US DOE
117. US DOE-EERE
118. SKF Group


119. About Spas
120. Geothermal Energy Assn
121. US-DOE


PART TWO: ENERGY RESOURCES

CONSUMPTION, SUPPLIES, AND IMPORTANT ISSUES

End of the fossil energy era

Although it took only about 150 years to create our current fossil fuel-energized society where oil is the most widely-traded world commodity, this dependence upon finite Earth resources cannot continue much longer.

- Many leading geologists believe that most oil and natural gas reservoirs will be exhausted well before the end of this century, and coal will be depleted by the middle of the next one:
  - It is broadly predicted that oil production capacities are already peaking, and that new reservoirs will not be sufficient to offset declines in old fields, much less sustain continued consumption growth.
  - While oil will continue to flow for another 75 - 100 years, price increases and supply shortages will drive essential transitions to alternative, renewable energy sources at an accelerating rate.

122. Monash University Australia
123. Tony Boom
124. Looking Glass Productions Ltd
125. Chapel Electrics

Freeway Traffic

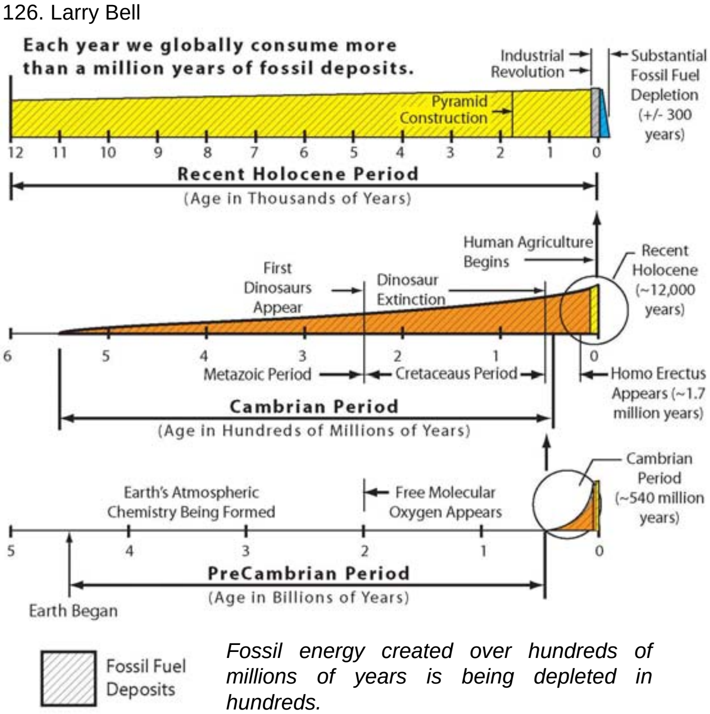
Electrical Power

Industry

Heating

A Looming Crisis

126. Larry Bell



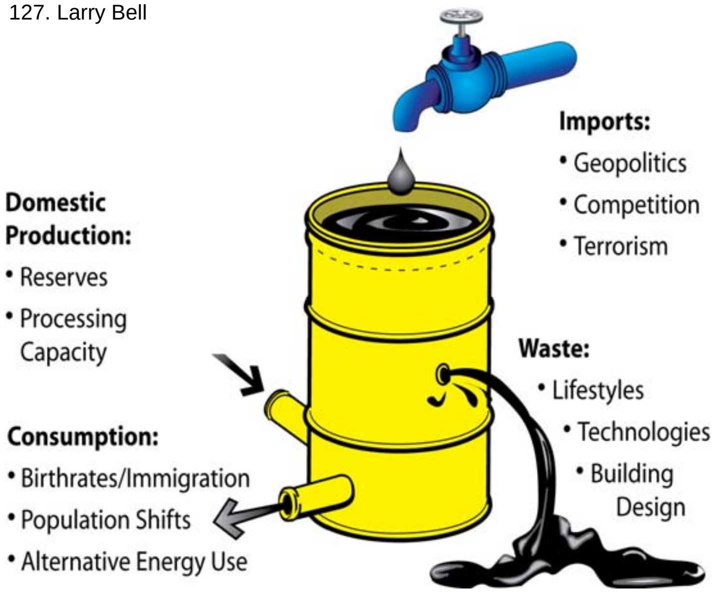
Fossil energy created over hundreds of millions of years is being depleted in hundreds.

Earth's Fossil History

Eliminating dependence upon fossil fuels is not a choice, but rather, is an imperative.

- These resources which now account for most of our energy needs are being depleted at an incredible rate, and deposits which accumulated over billions of years will have been largely consumed over hundreds:
  - Free molecular oxygen wasn't present until about 2 billion years ago, and photosynthetic plants later evolved over millions to billions of years.
  - The Cambrian period (most recent 540 million years or so) witnessed development of life forms which evolved and diversified rapidly, leading to our Homo Erectus ancestors who appeared about 1.7 million years ago.
  - The Recent Holocene period saw the beginnings of organized human agriculture about 12,000 years ago, exploding population growth, and the very recent Industrial Revolution which has produced large-scale global impacts.

127. Larry Bell



Influences and Impacts

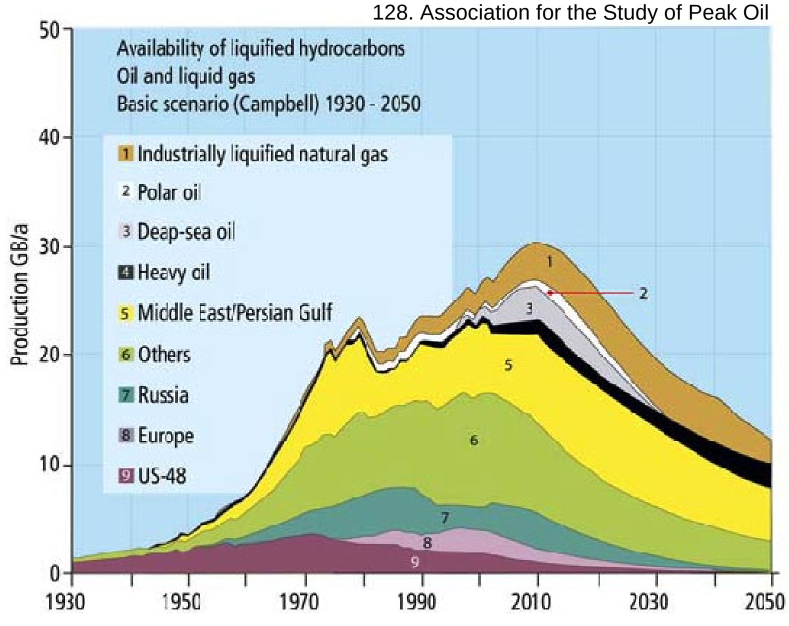
The very short residency of humankind on this planet has already produced broad influences which are continuing at an accelerating rate.

- While some dramatic changes occur naturally, others are undoubtedly influenced, or possibly even precipitated by our actions:
  - Fossil fuels that accumulated over millions of years will have been exhausted over a few centuries, leaving none for future generations.
  - Forces that drive and affect Earth's weather and climate are subjects of intense study to examine the nature and extent of human contributions to recent fluctuations and trends, and to determine causes and interventions.
  - While large areas of uncertainty remain, there is no doubt that our current human course is unsustainable, and that we must either alter our ways, or expect unacceptable consequences.

The trend over the last two centuries for world populations to have switched from biomass energy to depend predominantly upon fossils for heat and power is not a sustainable development.

- While prominent experts disagree about how long it will be before accessible fossil supplies will be exhausted, predictions typically vary at most tens of years for oil and gas, and hundreds for coal:
  - As liquid and gas reserves play out, increased dependence upon coal can be expected to drive consumption and cost rates higher.
  - Rising prices of all fossils will make alternatives more attractive, but will also increase global competition which is likely to produce shortages, crises and conflicts.

128. Association for the Study of Peak Oil



ASPO Oil and Liquid Gas Forecast

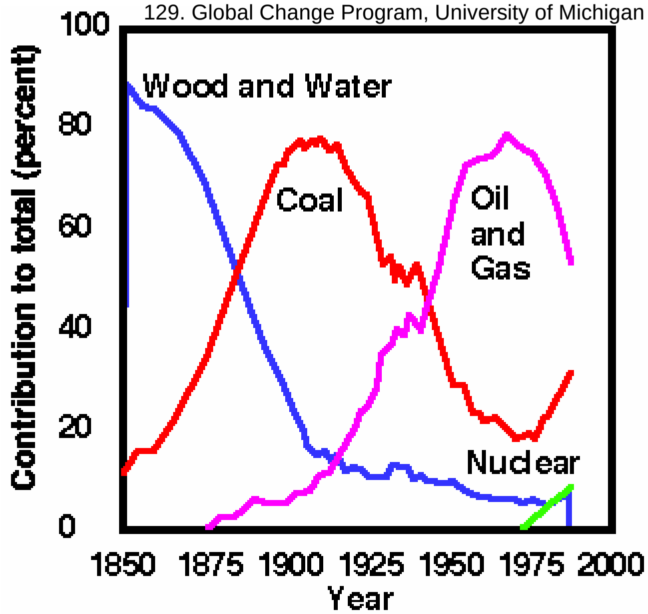
The Association for the Study of the Peak Oil and Gas (ASPO), a group of oil geologists, has forecast that oil production will increase roughly until 2010, and then production from new fuels will no longer be able to offset declines from old ones.

Major energy transition challenges

Global energy consumption continues to rise at a rapid rate, although this trend appears to be improving due to expanding conservation efforts in more developed countries.

- While continuing US shifts to coal and renewable fuel sources are predictable due to increasing oil and natural gas production costs and dwindling supplies, history shows that such transitions from one dominant source to another require substantial time:
  - Coal use decreased in relation to oil and gas over a 50 year period between about 1910 and 1940, and transitioning back is requiring about the same time.
  - We might imagine that transitioning to alternative renewable sources will also require many years, demanding that real progress will be needed soon to avoid economic and social turbulence.

129. Global Change Program, University of Michigan



Historical US Fuel Use by Percentage

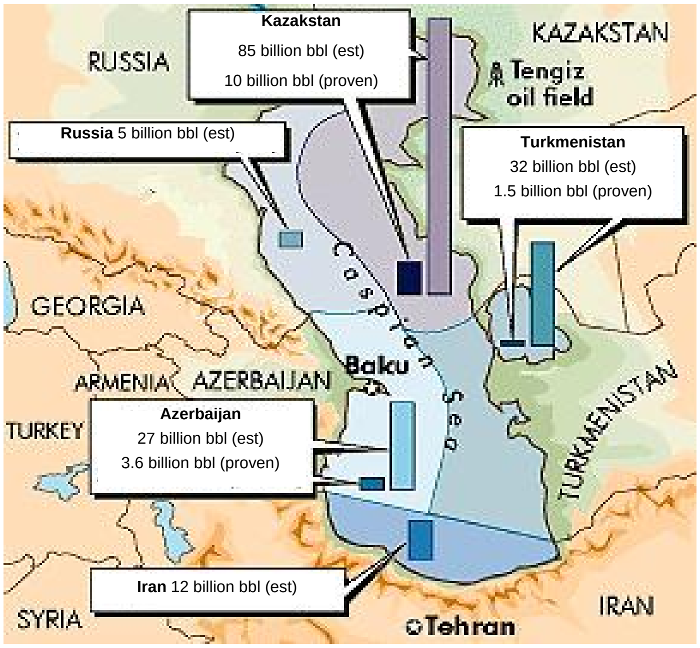
130. Brad DeLong

1970s Fuel Crisis

Fuel crises can provoke hasty stop-gap responses that are costly and ineffective.

- Prevention interventions will not be simple or easy, and must simultaneously address daunting issues at many levels of scale:
- International policies influence geopolitical cooperation associated with joint resource and technology development, imports/exports and responses to terrorist threats.
- Federal, state and local programs influence domestic production capacity and consumption through regulatory incentives related to technology investment and user costs.
- Industries, businesses and individuals influence lifestyles and demands that determine which technologies will succeed in the marketplace, and whether conservation will be broadly practiced.

131. The Dossier



Many countries in the Caspian Sea region have long histories of political instability, and terrorism presents a growing threat to oil and gas pipeline security.

Estimated Caspian Sea Region Oil Reserves

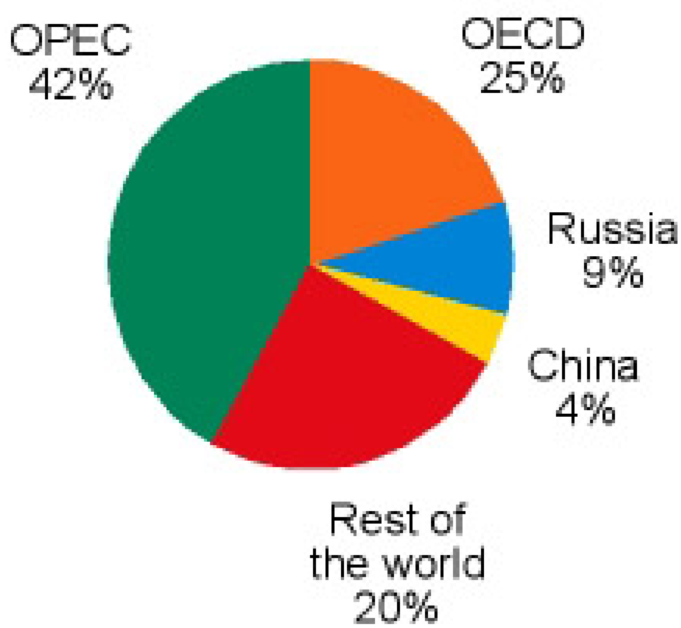
Decisions by OPEC in 1973 to tighten oil production created shock waves of alarm, causing long queues of vehicles at gasoline stations and motivating many nations and corporations to think about new ways to lessen reliance upon petroleum products.

- The ability of OPEC to exercise extensive influence over production and prices, in combination with exponential consumption growth in China, India and other countries, are reasons for great ongoing concern:
  - Many experts believe that global oil production has already peaked, or soon will, with demand rates permanently outpacing available supplies.
  - A real problem is that we may only become broadly aware of how serious this condition is after it is too late to implement remedies.

Oil continues to be a critical fuel and chemical resource, and continued US dependence upon imported oil is becoming increasingly problematic and unrealistic.

- Although before 1950 the US was a major world oil producer, the US Department of Energy estimates that this country currently has less than 3% of known oil reserves:
  - Members of the Organization of Petroleum Exporting Countries (OPEC) produce about 40% of the world's present oil supply, and nearly 25% comes from countries in the Persian Gulf.
  - The Caspian Sea region in a geologic basin of Central Asia is another substantial oil source which may eventually produce about 3.9 million barrels / day, but this region is landlocked and depends upon pipelines rather than tanker ships to move the product.

132. US DOE - EIA



Organization of Economic Development (OECD) countries include the US, European Union, Japan, and South Korea.

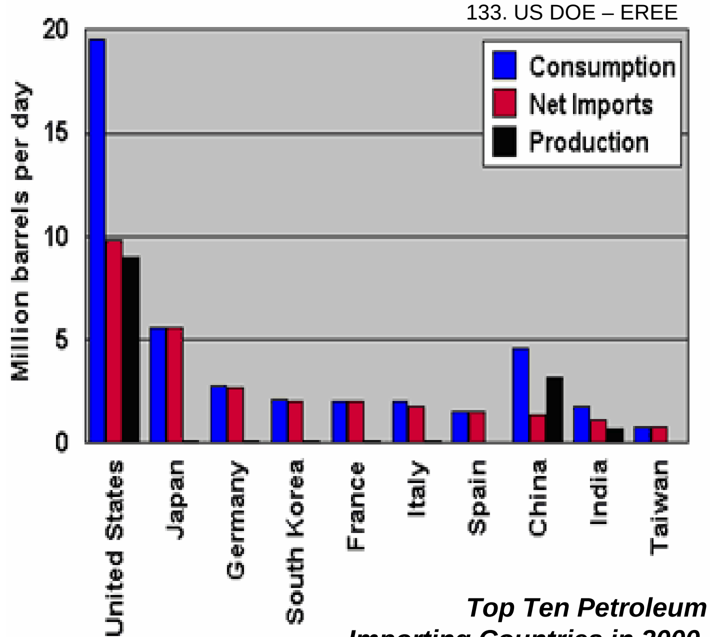
World Crude Oil Production

Petroleum and natural gas sources

Global competition for the world's rapidly dwindling oil resources makes transitions to non-fossil fuel alternatives inevitable and urgent.

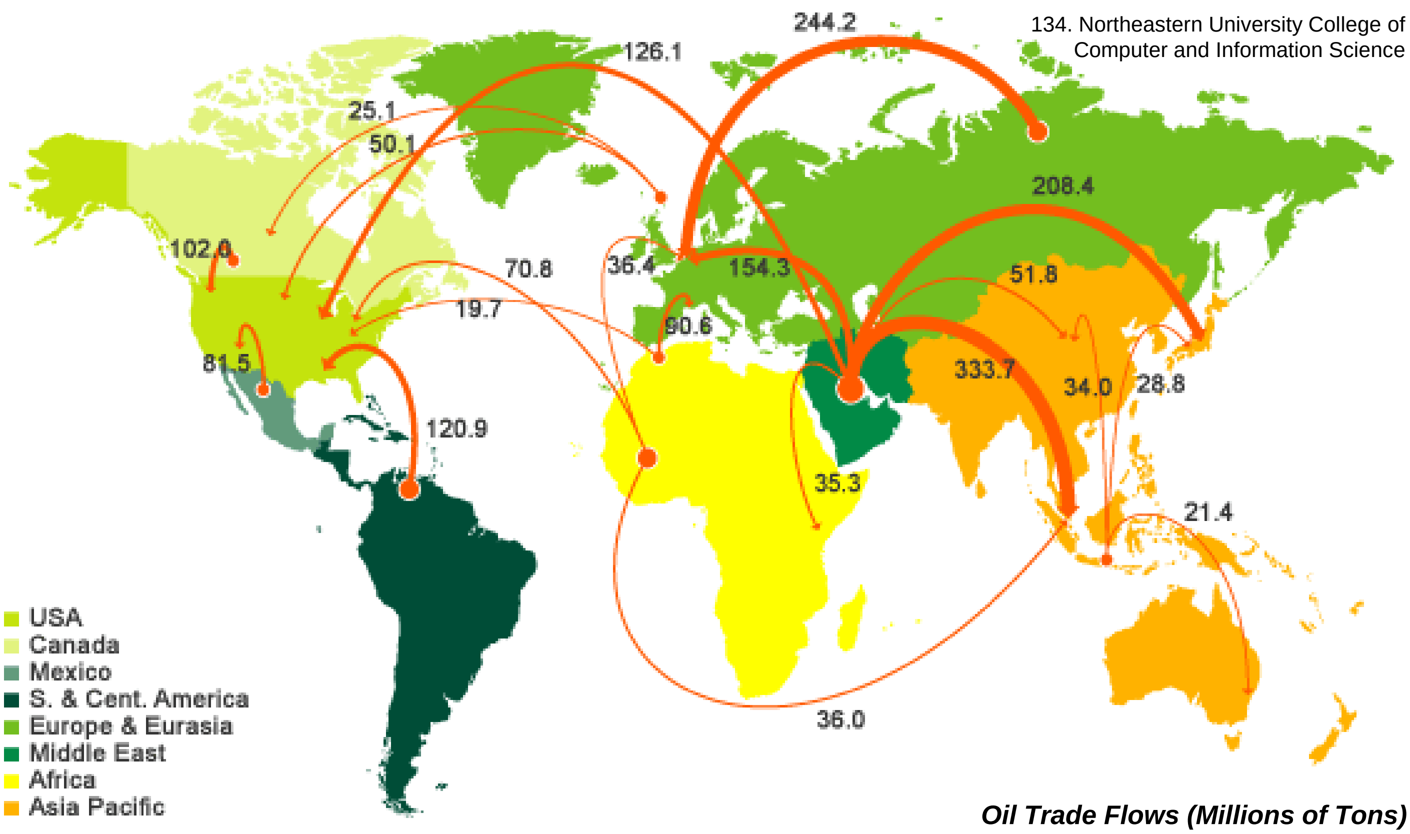
- This competition is certain to become more aggressive as developing nations continue to increase their consumption rates through industrial growth and economic prosperity:
  - According to the US DOE's Energy Information Administration (EIA), worldwide oil consumption is expected to grow by 60% over the next two decades, and demand in developing countries may grow by 115% during this period due in part to increasing automobile ownership.
  - The US currently imports more than half of the oil it consumes (about 10 million barrels/day), and these imports are expected to increase to an estimated 17.7 million barrels/day (about 50%) within the next two decades.

133. US DOE – EREE



Top Ten Petroleum Importing Countries in 2000.

134. Northeastern University College of Computer and Information Science



Oil Trade Flows (Millions of Tons)

135. Precast Consulting Services

LNG Port Restrictions

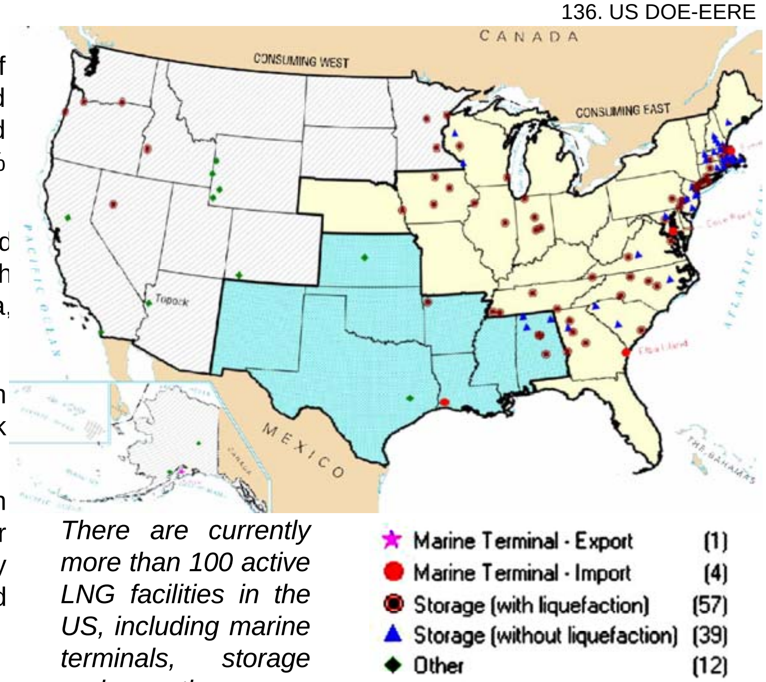
Many experts predict that known natural gas resources that provide about one-fourth of US energy and 20% worldwide will be exhausted by the end of this century.

- Continued dependence upon foreign imports to supplement domestic sources is unrealistic:
  - Global competition for all fossil fuels combined with geo-political uncertainties and conflicts have volatile influences upon supplies and costs.
  - Imports of LNG to the US are constrained by limited port terminal location options with adequately deep harbors sheltered from wind and waves.
  - New or expanded LNG terminal developments are inhibited by seaport congestion, right-of-way conflicts for pipelines, and problems in locating large LNG and end-use plants in high population density areas near ports.

Although the US currently obtains more than 99% of the natural gas it consumes from domestic and Canadian sources, the US DOE projects that liquid natural gas (LNG) imports will account for about 25% of total US consumption by 2021.

- Most present LNG imports come from Trinidad and Tobago, followed by Qatar and Algeria, with much smaller amounts from Nigeria, Oman, Australia, Indonesia and the United Arab Emirates:
  - As North American gas fields are depleted at an increasing rate, the US has little choice but look to foreign supplies.
  - This is particularly urgent for some states, such as California which relies upon natural gas for more than half of its electricity, produces only about 17% of what it consumes, and is at the end of the US pipeline grid.

136. US DOE-EERE



There are currently more than 100 active LNG facilities in the US, including marine terminals, storage and operations.

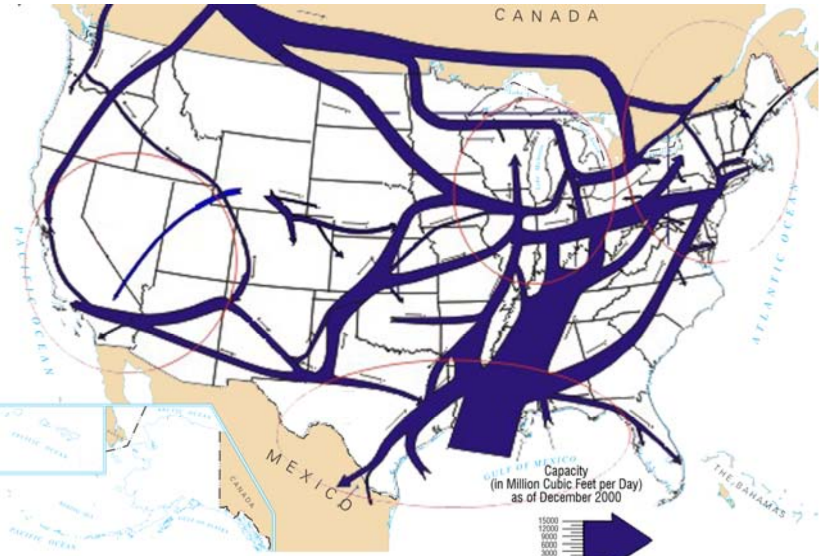
Active Liquid Natural Gas Facilities

Delivery, storage and processing capacities

The US natural gas infrastructure is well developed, including production, liquefaction or regasification of LNG, storage and transport (pipelines and tankers).

- Pipelines carry natural gas in both directions between Canada and the US, and between the US and Mexico (which imports more than it exports):
  - Canadian gas flows to and from the US through several large pipelines feeding markets in the Midwest, Northeast, Pacific Northwest and California (nearly 95% of US imports).
  - A major portion of pipeline capacity within the US connects key production areas of Texas and Louisiana to markets in Western, Northeastern and Midwestern regions.

137. US DOE-EIA Office of Oil and Gas/NRCAN



A large network of pipelines connects US producers and markets within the US, Canada and Mexico.

Natural Gas Pipelines

138. University of New Orleans

A substantial increase in deepwater and land-based terminal capacity will be required to meet projected needs for LNG imports. Although many new terminals are proposed, most face strong opposition from local communities and environmental groups. Of four deepwater LNG ports that presently exist, only the LOOP in Louisiana is in operation.

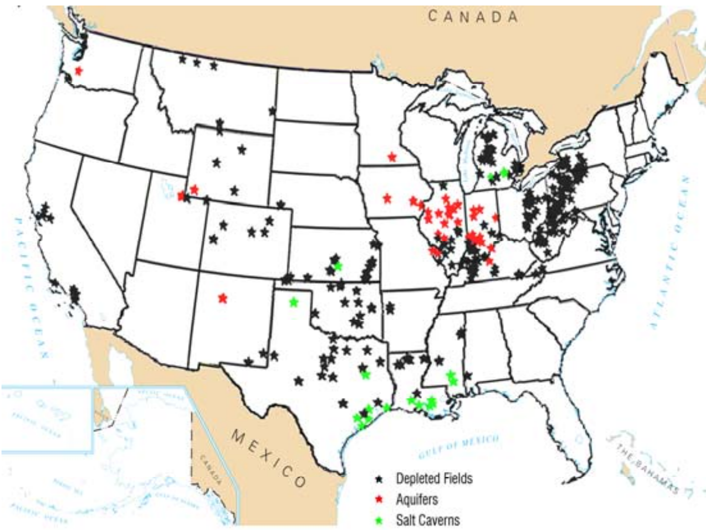
LNG Terminals

Increasing LNG import demands will require development of new and expanded terminals to meet national and regional needs.

- The EIA projects that by 2010, new terminals will be required to collect 812 billion cubic feet annually to accommodate an estimated 58% increase, with 60% of that increase served by enlarging existing facilities:
  - Two deepwater LNG ports are proposed to be built eight miles off the coast of Gloucester, Massachusetts, and nearly a dozen land-based terminals are proposed from Rhode Island to eastern Canada.
  - Development of new terminals is facing strong opposition by local communities due to safety and terrorism concerns, and many of at least two dozen current proposals are experiencing legal challenges. *

* **See Appendix: 21**

139. US DOE Fossil Energy Office



Most natural gas produced in the US requires long- distance transmission to users through the nation's 1.5 million miles of pipelines. Demographic shifts and predicted regional supply shortages are creating expanding needs to increase storage capacities that can accommodate periodic regional shortfalls.

Natural Gas Storage

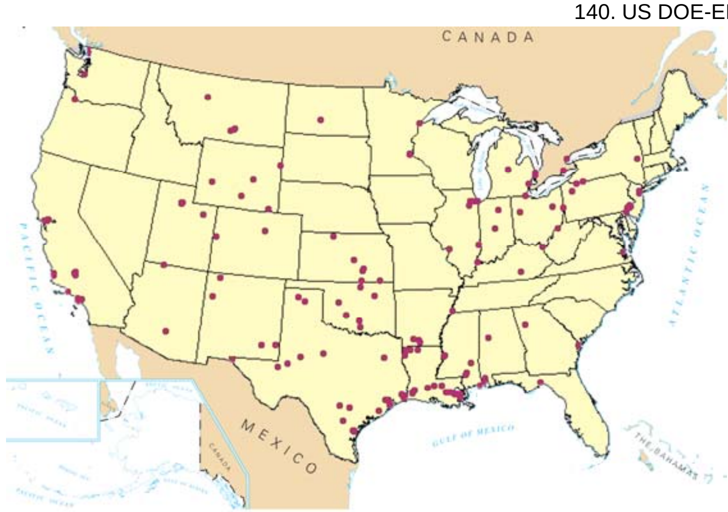
Unpredictable seasonal and periodic peak demands in regions remote from pipeline sources require means to store natural gas for emergencies.

- These storage needs are growing in many regions as a result of population and industry growth, and will continue to expand nationally as dwindling national gas supplies create chronic shortages.
  - Adequate storage is already lacking in New England and Middle Atlantic coastal areas where LNG is a critical part of the regions' heat and power supply during severe cold snaps.
  - The 2000-2001 California electricity crisis was exacerbated by deficient natural gas supplies that caused large energy price swings.

The US also faces a shortage of petroleum refineries since the last US one to be constructed was the Marathon-Ashland Garyville, Louisiana plant in 1976, and less than half the number that existed in the 1970s still remain.

- Although demand for refined products (transportation fuels in particular) continues to rise steadily, refineries are high on the list of least-wanted industries in many locales:
  - In California where 10 plants that represented 20% of the state's refining capacity were closed between 1985-1995, it is unlikely that more will be built due to concerns about smog, truck traffic carrying hazardous materials, and potential leaks in event of earthquakes.
  - High land costs and environmental restrictions along prime coastal areas of the Gulf of Mexico, Pacific, Northeast, and the Great Lakes also inhibit refinery development.

140. US DOE-EIA



Existing refineries are vulnerable to disruptions due to maintenance and breakdowns caused by accidents and natural disasters that can create supply shortfalls and price hikes. West Coast and Midwest regions are particularly at risk due to a lack of easy supply accessibility.

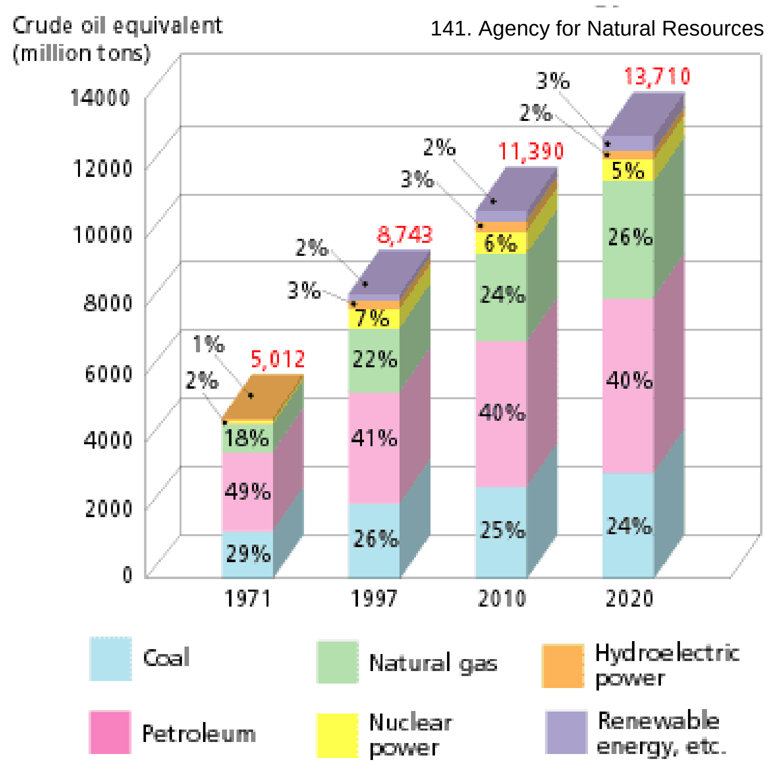
Petroleum Refineries

Global and US energy consumption

It is important to note that fossil fuels provide about 90% of all world energy.

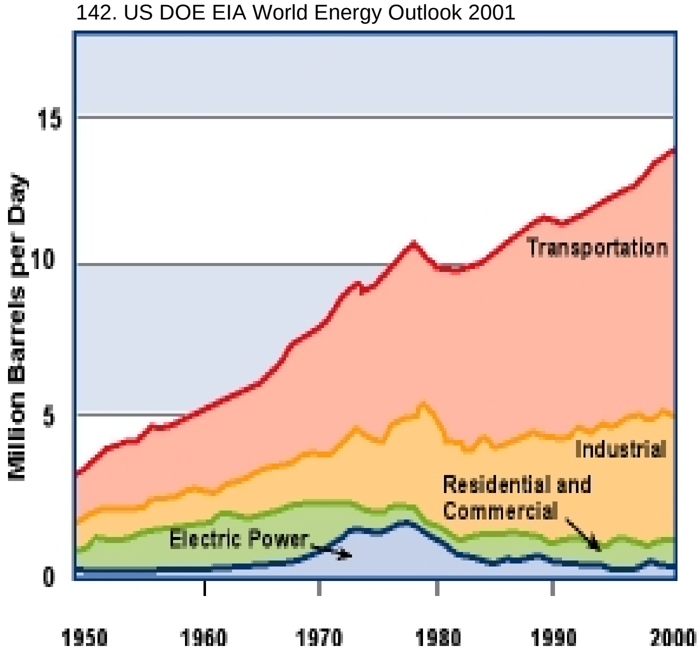
- Oil has been the largest single source, followed by coal and natural gas, but a consumption trend is shifting towards coal, particularly in North America:
  - Coal remains much more abundant than known deposits of oil and natural gas, with an estimated 250 year US reserve supply.
  - Most known oil reserves are projected to be exhausted within about 40-60 years, depending upon the rate of growth in global consumption, along with possible extraction from sandy tars that may provide some added time.
  - Most known natural gas reserves are also projected to be depleted within about 60 years.

141. Agency for Natural Resources



World Energy Demand Trends

142. US DOE EIA World Energy Outlook 2001

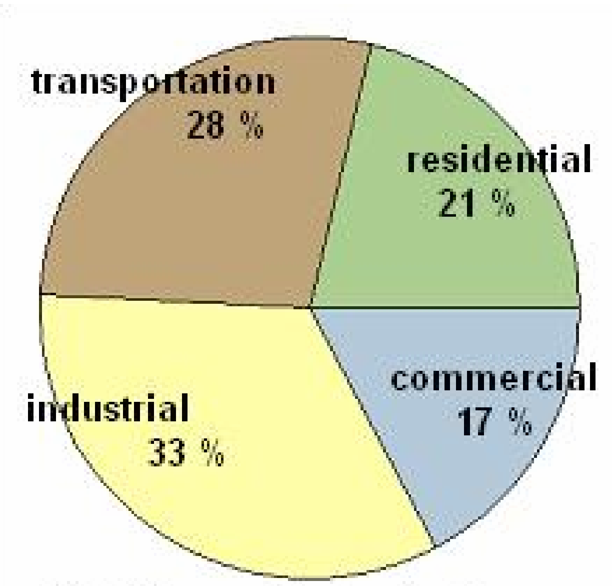


US Petroleum Consumption by Sector

Today, the US consumes more than one-fourth of the world's oil, and imports constitute about a quarter of this country's balance-of-trade deficit.

- More than two-thirds of US oil consumption is in the transportation sector, where energy demands are growing rapidly:
  - The US consumed about 384.7 million US liquid gallons of gasoline per day (1.36 gigaliters) in 2005.
  - US consumption levels are driven by high per capita ownership of automobiles, large vehicles, private vs. public transportation preferences and relatively low gasoline costs compared with many other countries.
  - US consumers, on average, spend a smaller fraction of their incomes on gasoline now than in previous decades.
  - Only about 55% of these gasoline costs are for crude oil, with 22% for refining, 19% for taxes, and 4% for distribution and marketing.

143. US DOE-EIA

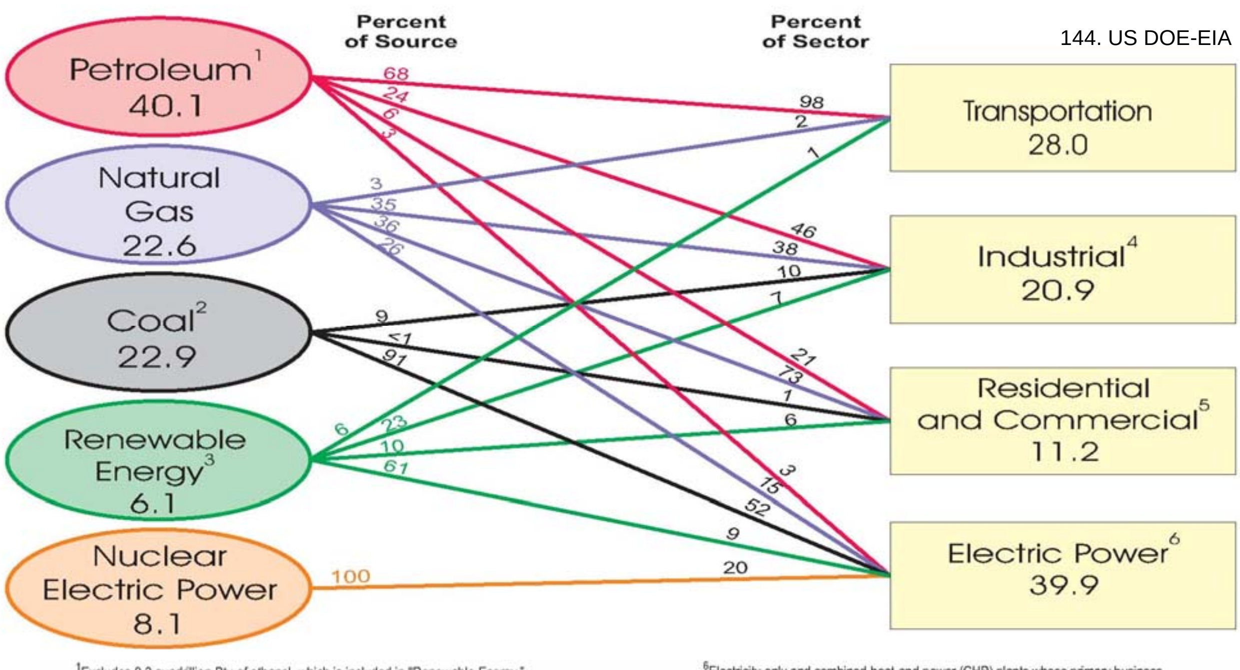


US Energy Consumption by Sector (2004)

The more wealthy nations use the most energy, and the US uses more per capita than other countries.

- About half of the US energy consumption is in transportation and residential sectors that are largely controlled by individual consumers, while the remaining industrial and commercial expenditures are mostly controlled by business, government entities and facility managers:
  - Approximately 65% of transportation energy is consumed by gasoline-powered vehicles (mostly personally-owned), 20% by diesel-powered trains, ships and trucks, and about 15% by aircraft.
  - Energy use in the residential sector varies across the country largely due to regional climate and regulation differences, with about half expended on space conditioning.
  - Space conditioning is also the biggest energy user in the commercial sector (about 30%), with lighting representing another 25%.

144. US DOE-EIA



[1]Excludes 0.3 quadrillion Btu of ethanol, which is included in "Renewable Energy."
[2]Includes coal coke net imports.
[3]Conventional hydroelectric power, wood, waste, alcohol, geothermal, solar, and wind.
[4]Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[5]Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[6]Electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.
Note: Sum of components may not equal 100 percent due to independent rounding.
Source: Energy Information Administration, *Annual Energy Review 2005*, Tables 1.3 and 2.1b-2.1f.

US Primary Energy Consumption by Source and Sector, 2005 (Quadrillion Btu)

Energy demand trends and influences

Based upon best estimates, it is realistic to expect that global oil and natural gas reservoirs will be substantially drained before children attending kindergarten today reach typical retirement ages.

- Given our current high level of dependence upon these resources, a full range of consequences is daunting to contemplate:
  - International relationships and commerce will most certainly be impacted in major ways, including shifts in trade and production, business travel and tourism, and geo-political tensions and alignments.
  - National fuel shortages will create competition between user sectors and groups, including military, manufacturing, agriculture and transportation.
  - Power and heating costs will accelerate relocations of business and households to warmer locales (particularly those with good access to energy), leaving many older and poorer residents behind.

145. U of Rochester
146. LA Review Journal
147. Clipmarks
148. Age Concern Cymru

International Trade

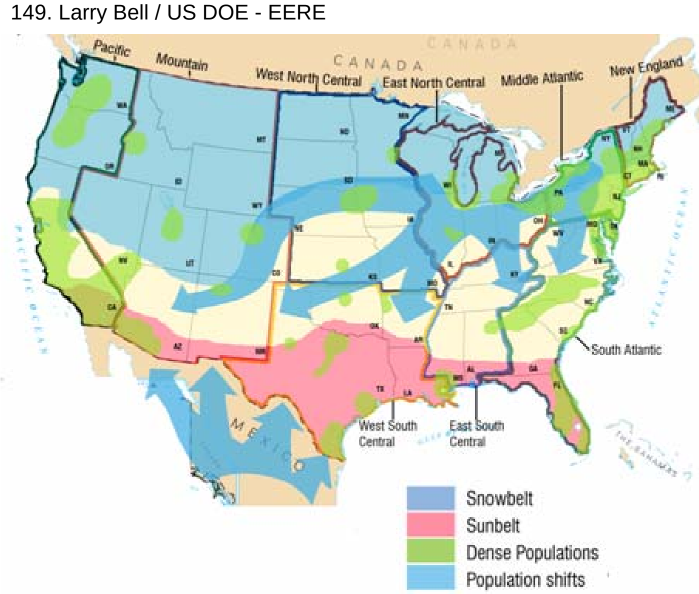
Travel and Tourism

Industries and Jobs

Health and Hardships

Future Impacts

149. Larry Bell / US DOE - EERE

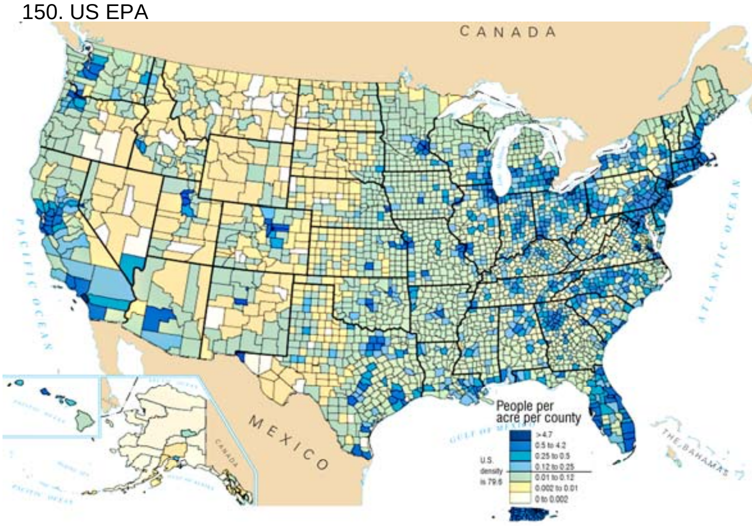


Population and Energy Trends

The US population more than tripled during the 20th century to reach 300 million in 2006, up from 200 million 39 years earlier, and is expected to grow to more than 390 million by 2050.

- Although this growth rate is nearly six times lower than many less developed countries, it continues to expand consumption of energy, food and natural resources, and removes land from agricultural production:
  - While population growth due to birth rates is relatively slow, people are tending to live longer, adding to costs for medical services that compete for energy and food budgets.
  - About 40% of US population growth is from immigration (legal and illegal), contributing more than 1 million people of all ages annually.
  - Rather than downsizing after children become adults, many parents are moving into larger homes, and retirees are purchasing vacation properties that consume fuel and space.

150. US EPA



The US population is heavily concentrated around large cities in the Northeast, and slightly more than half is clustered in coastal counties. Rapid shifts are occurring from central cities to suburbs, and from the Northeast and Midwest to Southern and Western states.

Population Density by Counties, 2000

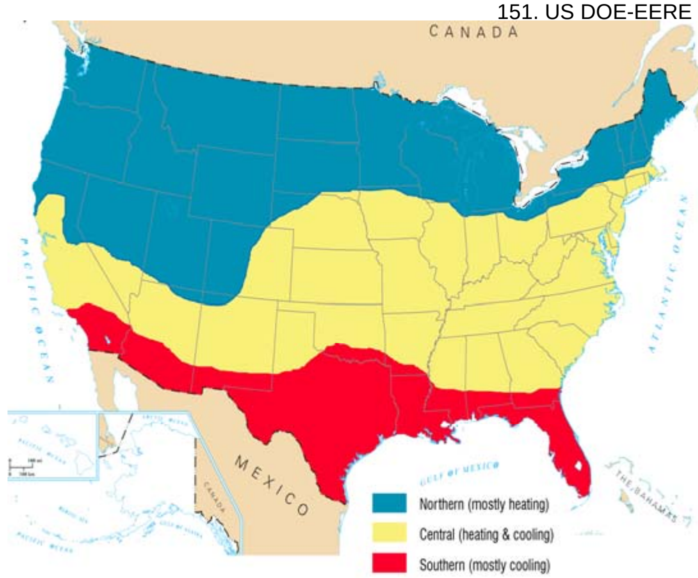
The US is largely an urban nation with more than 80% of its population living in and near cities.

- Households are becoming increasingly less densely concentrated in large metropolitan areas, and are shifting to more distant suburbs where real estate and services are less expensive, resulting in more energy use for travel and less efficient single-family dwellings:
  - Northeastern regions are by far the most densely populated, but also have the slowest growth (and in some instances are experiencing reductions) due to migrations to Sunbelt locations.
  - Southern and western states are realizing the highest influx of immigrants along with population gains from the Mideastern and Midwestern regions, often overtaking power and water supplies.

Population shifts from the Snowbelt to the Sunbelt create impacts upon regional energy demands, environments and economies.

- These changes present advantages and disadvantages for areas of gains and losses:
  - Shifts from energy use from fossil fuel heating in winter to more electricity for air conditioning makes better use of centralized power plants that are more efficient than stand-alone furnaces, and produce fewer CO_2 emissions.
  - On the other hand, relocations of people and industry from large metropolitan areas to rural locations create impacts upon aquifers and natural ecosystems, plus losses of prime farmlands and wetlands.
  - New households and businesses also contribute to greater energy consumption, while areas that lose them suffer job and tax base reductions.

151. US DOE-EERE



Population migrations from colder to warmer regions substitute fuel heating demands for increased electricity use.

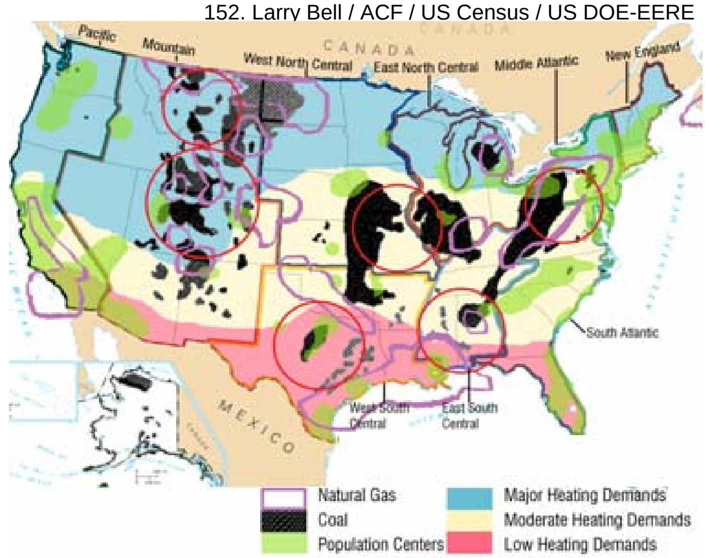
Energy Needs

Regional fossil fuel sources and demands

Cold weather space heating must compete with year-round power generation for fossil fuel use.

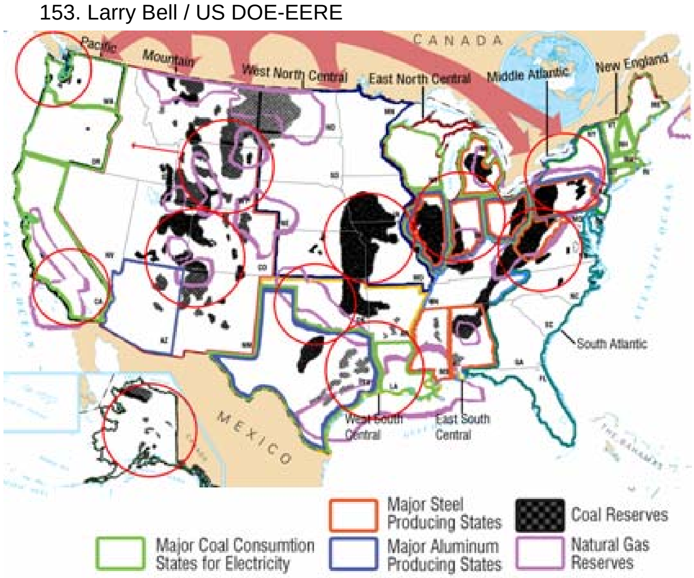
- Various US regions present different opportunities posed by climate conditions and concentrations of people and industries:
  - The Pacific Region contains high population densities, with some coal in northeastern Washington, and natural gas primarily in southern California.
  - Mountain and West North Central states have abundant coal and natural gas, with modest population clusters in central areas.
  - West and East South Central states have large coal and natural gas deposits and moderate climates.
  - South and Middle Atlantic states have large coal and natural gas resources in northern areas.
  - New England, with cold weather and very limited fossil supplies, must depend upon other regions.

152. Larry Bell / ACF / US Census / US DOE-EERE



Heating Demands and Fossil Sources

153. Larry Bell / US DOE-EERE



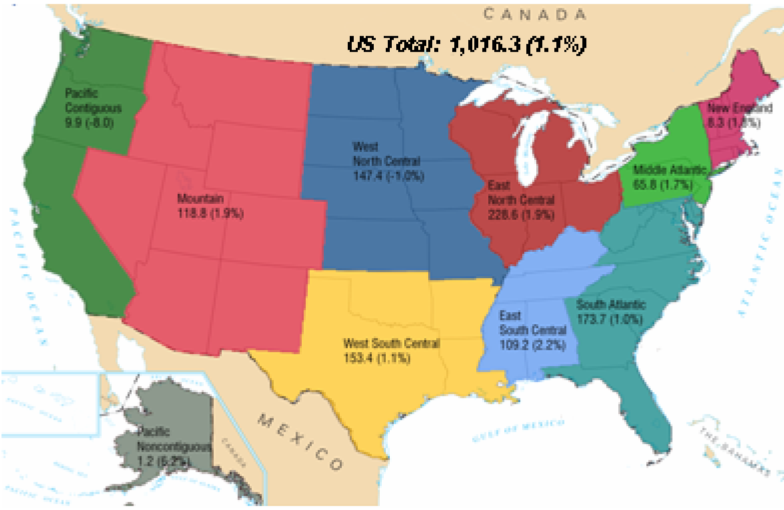
The three largest coal-producing states are Wyoming, West Virginia, and Kentucky, followed by Texas and Pennsylvania. Most primary aluminum producers are located in the Pacific Northwest, Ohio River Valley, Great Lakes Region and Southern California.

Fossil Fuel Energy Sources and Consumers

Large and small industrial plants place substantial demands upon fossil energy sources.

- Motors, steam, compressed air, pumps, process heating, combustion and combined heating and power account for about 80% of US industrial energy use:
  - The forestry industry is the largest user of energy from steam and CHP, and the petroleum industry is the largest user of fuel-fired heaters.
  - The metal industry is the third largest user of fired heaters, with major processing located in the West and East South Center, Middle Atlantic, East North Central and Mountain Regions.
  - Most primary aluminum producers are located in the Pacific Northwest, Ohio River Valley, Great Lakes, and Southern California.
  - Coal is a major source of industrial power, with leading consumer states located in the New England, West South Central, East North Central and Pacific Regions.

154. US DOE-EIA



In 2005, coal accounted for more than 70% of all electrical power generation in the East North Central Region, making it the largest coal consumer, and accounting for 23% of all electrical power. In Mountain and North Central Regions, coal provides more than 60% of the fuel mix for electrical power generation.

Coal Electric Utility Consumption by Census Region (Million Short Tons and Percent Change, 2004 – 2005)

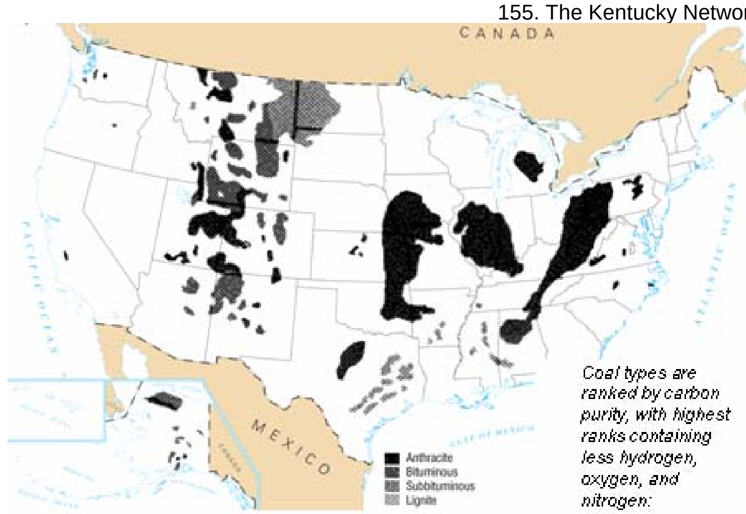
Coal is the largest single source of fuel for electricity generation world-wide, and coke from coal processing is a vital component in the reduction of iron ore.

- An expanding US economy and warmer-than-normal summer weather in 2005 drove up coal demand for electrical power by 2.1%, accounting for 92% of all coal consumption.
  - While coal was a minor part (less than 20%) of the fuel mix for two census regions (New England and Pacific), it was a major source (more than 50%) in five others (East North Central, West North Central, South Atlantic, East South Central and Atlantic).
  - Coal was one of the two main electric fuel sources in the other two regions; the Middle Atlantic (competing with nuclear), and the West South Central (competing with natural gas).

US coal is mined in 27 states and is most concentrated in 10, led by Montana (which contains about 25% of demonstrated recoverable reserves), followed by Illinois and Wyoming (with a combined amount of about 30% of the total balance).

- The US Geological Survey projects that the US has about 1.7 trillion tons of identified coal reserves, and many geologists believe that with future discoveries this estimate may more than double, although much of this coal cannot be mined now due to technology limitations, access costs and environmental restrictions:
  - Total recoverable reserves are estimated to be about 472 billion tons.
  - Since current mining techniques leave substantial amounts in place, near-term recoverable assets are estimated to be about 262 billion tons.

155. The Kentucky Network



- *Anthracite (95% purity and above) is primarily used for residential and commercial space heating.*
- *Bituminous (next in rank) is used for steam-electric generation, combined heat and power, and to make coke.*
- *Sub bituminous and lignite (in rank order) are principally used for steam-electric generation.*

Coal Reserves

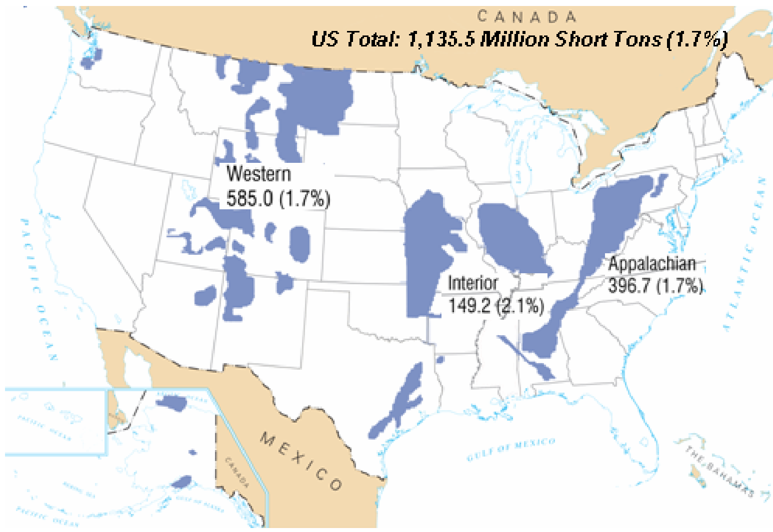
US Coal

Coal, oil shale and derivative resources

Coal production levels are impacted by influences of weather upon transportation (primarily rail and barge), mine accidents and safety conditions, and government permitting processes that can close or delay operations.

- Surface (or "open pit") mining which accounts for about 60% of total US recovery is used primarily in the Western Region where near-surface deposits can be up to 100 feet thick, presenting fewer safety problems than underground mining east of the Mississippi in Appalachian Mountain states:
  - The Western Region accounts for more than 51% of total production, with Wyoming (the largest US producer with 69% of the region's total) leading Montana.
  - The Interior Region is led by Texas (about one-third of regional production), followed by Indiana.
  - The Appalachian Region is led by West Virginia (largest producer in the region and second largest in the US) followed by Ohio.

156. US DOE-EIA



Production in the Appalachian Region in 2005 was hampered by problems associated with hurricanes and river flooding that impacted barge transport, lawsuits that halted or delayed mine permits, and safety problems (roof collapses and high methane gas levels).

Coal Production by Region, 2005 (Million Short Tons and Percent Change from 2004)

157. State of South Dakota

Reclaimed Mine Area

Open-pit coal operations are now typically required to post bonds for each acre of land surface to be mined, and later restore soils as nearly as possible to original contours with native vegetation and trees replaced. Since 1977, more than 2 million acres of coal land have been reclaimed in this manner.

Coal Mining Issues

Despite enormous dependence upon coal for electricity, heating and important byproducts, coal industries and utilities are broadly regarded as "dirty businesses."

- Public resistance to coal mining and burning relates to major environmental and safety concerns:
  - Coal-fired plants are the largest source of human CO_2 emissions, and although capture has been proposed, it is not yet commercially used.
  - Coal contains low levels of uranium, thorium and other radioactive isotopes, and coal burning also produces such wastes as fly ash, boiler slag, sulfur, and a variety of heavy metals (including arsenic and lead).
  - Coal harvesting and abandoned mines release methane that can explode and put workers at risk.
  - Surface mining has had destructive impacts upon local land areas, polluted waters and destroyed natural habitats.

158. Intertek Petroleum Industry Applications

Coal-derived fuels, including hydrogen, can potentially be processed in conventional petroleum refineries.

Coal-Derived Liquid Fuels

Processing of coal to create liquid synthetic fuels may significantly extend and eventually replace crude oil-derived petroleum products.

- Although this gas-to-liquid capability can be traced back to the Fischer-Tropsch process development of the 1920s, continuing research is revealing new possibilities:
  - Penn State University experiments that are yielding coal-derived jet fuel, a high-grade kerosene that remains stable at high temperatures, may prove essential to the future of commercial and military aviation.
  - Some coal-derived fuel processes can be accomplished in conventional petroleum refineries for production of gasoline, diesel, fuel oil, and even hydrogen for fuel cells.

Petroleum products can also be obtained from oil shale, rocks rich in an organic material called kerogen that yield oil when heated.

- Although oil shale can be mined through traditional surface or underground operations, more environmentally-friendly approaches avoid excavation:
  - The Shell Oil Company has implemented a new in-situ electrical heating extraction method in Colorado that lowers a heating element into a well for about four years to convert kerogen into oils and gases that are pumped to the surface.
  - Another "staged" approach gradually lowers an element that increases heat with depth to double as a refinery that causes oil components to separate through distillation, ranging from ethane and methane (higher up) and oils (at lower levels).

159. US DOES-EIA

The US has large reserves of kerogen-rich oil shale that can be used as a source of liquid and gas petroleum products. A major economic obstacle for capitalizing upon this resource is the large amount of electricity required for thermal extraction (approximately equivalent one barrel of oil used for every three obtained). Use of an alternative renewable power source can potentially reduce this disadvantage.

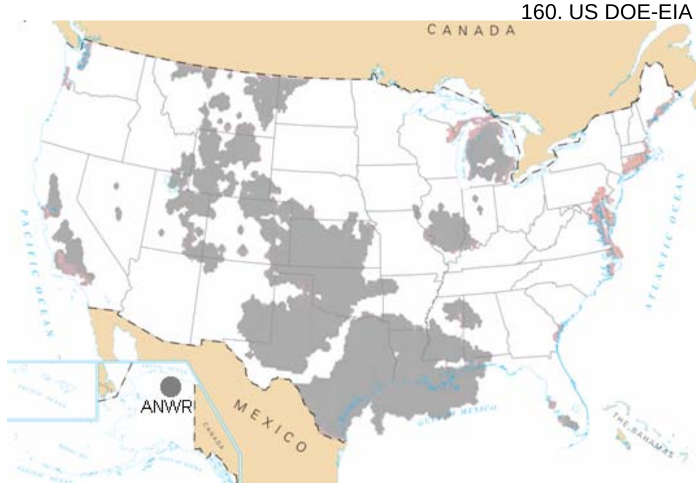
Oil Shale Fuel

Challenges to expanded oil and natural gas drilling

US crude oil reserves are located primarily in Texas, California, Louisiana, Oklahoma and Federal offshore locations, and oil infrastructures are most highly developed around these production centers.

- Canada and Mexico are key suppliers of crude oil to the US, where oil products flow back and forth between countries in trucks, pipelines and ships requiring large transportation and processing infrastructures:
  - The US transports oil over long distances from Alaska.
  - Canada's huge resources principally derive from oil sands that require major development and processing operations.
  - Mexico's heavy crude oils (Maya) also require significant development, transport and refinery adaptations to serve huge North American markets for lighter oils (gasoline, jet fuel and liquefied petroleum gases).

160. US DOE-EIA



Intense controversy exists over whether or not a government moratorium should be lifted that prevents drilling for oil in Alaska's Arctic National Wildlife Refuge (ANWR) which is estimated by the US Department of Interior to contain between 9-16 billion barrels of recoverable oil.

Crude Oil Deposits

161. MSNBC

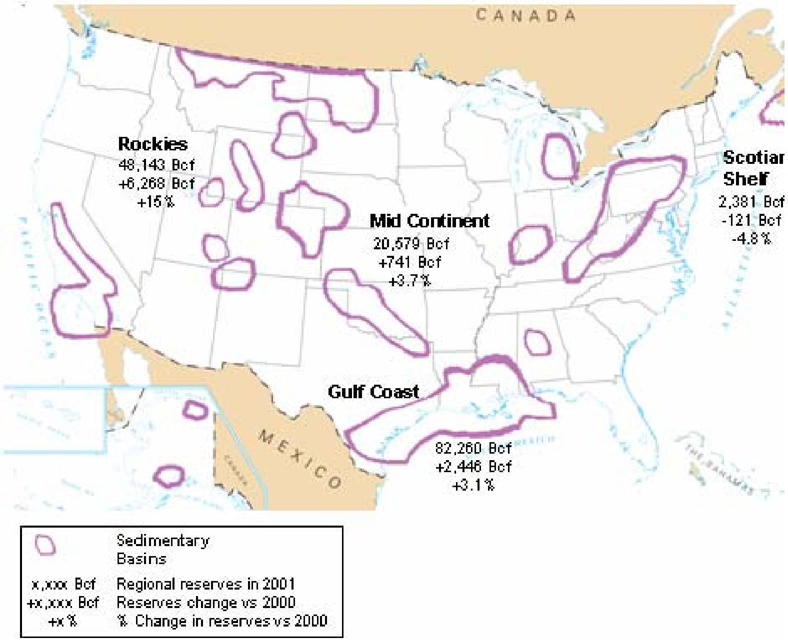
Chevron estimated that the 300 square mile region where its test well sits may hold between 3-15 billion barrels of oil and natural gas liquids.

2006 Oil Discovery in the Gulf of Mexico

In 2006 a trio of oil companies led by Chevron Corp tapped into an oil deposit about four miles deep into the Gulf of Mexico that may eventually produce between 3-15 billion barrels of crude and natural gas liquids.

- While this is potentially the largest domestic US discovery since the Alaskan Prudhoe Bay oil field a generation ago, it will have little overall effect upon reducing import requirements:
  - Oil companies estimate that it will require many years and tens of billions of dollars to bring the newly-tapped oil to market.
  - The extreme depth of the oil field adds significant challenges and costs to drilling operations.

162. US DOE EIA / CAPP / NRCan



North American Natural Gas Reserves (2001 Estimates)

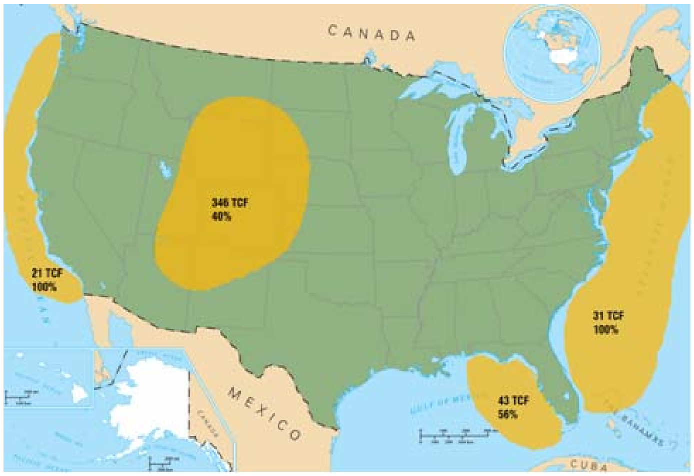
According to the US Department of Interior, about 85% of US natural gas comes from domestic onshore and offshore areas, and most of the rest comes from Canada.

- During 2003, total domestic land reserves were estimated to be about 107 trillion cubic feet (TCF), with about 76% owned by the Federal Government.
  - Approximately 73% of domestic reserves are concentrated in Texas, New Mexico, Wyoming, Oklahoma, Colorado and Gulf of Mexico offshore areas.
  - Proven reserves concentrated in the Gulf of Mexico off the coasts of Alabama and Louisiana total about 16.73 TCF, and off Texas, about 5.3 TCF.
  - Current economically-recoverable reserves for Federal Offshore Gulf of Mexico areas are estimated to be 100.3 TCF, mostly in deep water (more than 400 feet deep in western Gulf areas).

Conflicting concerns about near-term energy sufficiency, long-term sustainability and environmental priorities have caused raging disputes between proponents and opponents of natural gas and oil drilling in public onshore and offshore areas.

- Current federal and state government environmental policies make large natural resources in areas such as the Rocky Mountain basins, the Outer Continental Shelf of the eastern and western coasts and in the eastern Gulf of Mexico off limits or severely restricted:
  - Drilling proponents argue that drilling can be environmentally safe, and that prohibitions and restrictions cause continued dependence on foreign sources and price escalations.
  - Environmental groups believe that offshore pipelines harm marine life and salt marshes, while onshore development poses threats to wildlife habitats, fragile soils and archaeological resources.

163. Independent Petroleum Association of America



A recent US Department of Interior study indicates that 80% of domestic economically-recoverable natural gas reserves are now open for development with certain restrictive stipulations.

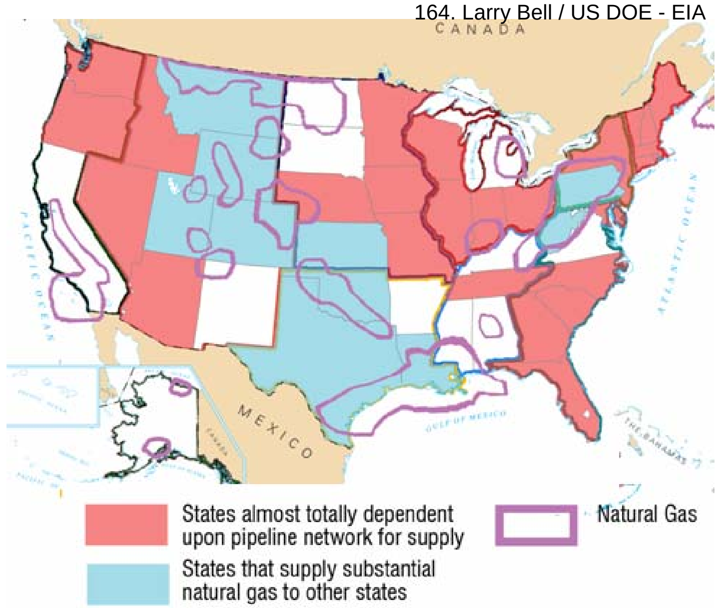
Natural Gas Restricted Reserves (Trillion Cubic Feet and Percentages)

Imperative transition to non fossil fuels

As natural gas demands continue to increase, it is unclear how future demands can be met.

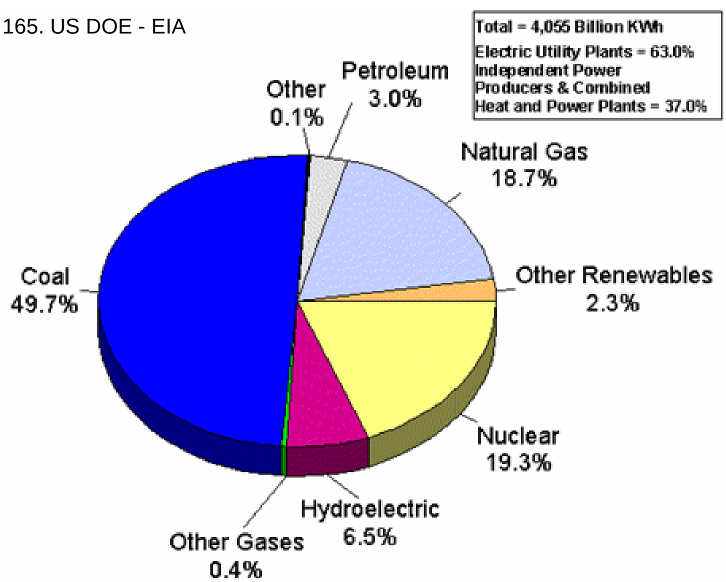
- Transport capacity is constantly being added, including expanded links with Canada and Mexico:
  - Substantial increases in western states (particularly California) responded to the 2000-2001 energy crisis, including supply connections with Canada, Mexico, Montana, Wyoming and Utah coal beds.
  - The Mountain Region, including Colorado coal beds, also supplies gas to meet rapidly-growing needs in Arizona and the Midwest.
  - The West South Central Region provides large amounts of gas from the Gulf area to central Florida, Alabama and Mississippi, and from northern Texas and southern Oklahoma to the North Central Region.
  - Northeastern, Southern Atlantic and adjacent Middle Atlantic Regions provide much of the gas needed to meet expanding northeastern and New England demands.

164. Larry Bell / US DOE - EIA



US Natural Gas Distribution

165. US DOE - EIA



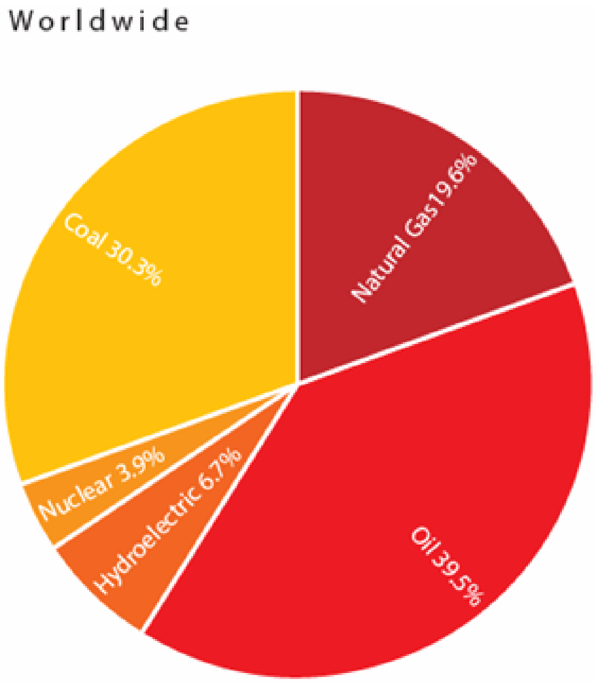
During 2005, more than 71% of all US electricity was produced from fossil fuels and more than 19% from nuclear plants, with less than 10% form hydroelectric and other renewable sources.

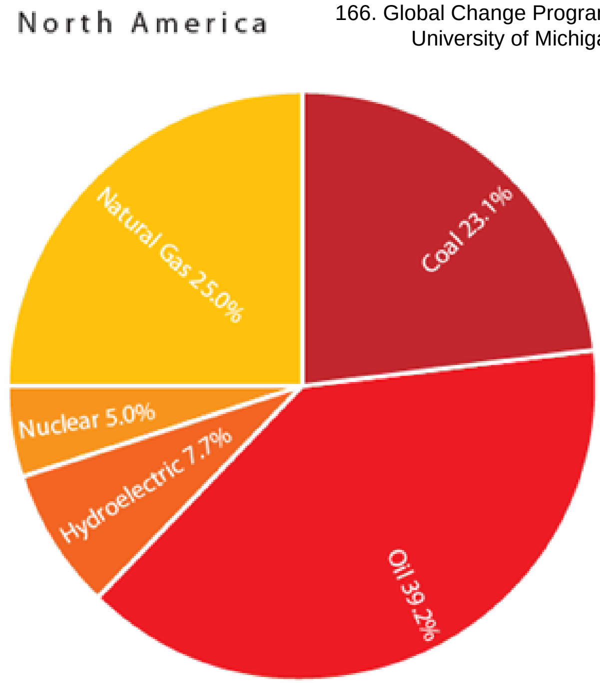
US Electrical Power Industry Net Generation, 2005

Most world oil and natural gas supplies are likely to be depleted within the lifetimes of many of today's children, making it imperative that transitions to primary use of other alternatives be expedited.

- Such substantial transitions will not occur easily or quickly:
  - In the US electrical power sector fossils account for more than 71% of all energy sources, of which coal provides about half and natural gas most of the fossil balance..
  - Nuclear energy provides more than 19% of all US electrical power as the leading alternative, followed by hydroelectric, currently the only significant renewable source.

The nuclear reality





166. Global Change Program, University of Michigan

From a total energy production standpoint (all uses), fossils supply about 90% of energy use worldwide, and more than 85% in North America, with hydroelectric and nuclear providing most of the rest.

World and North American Energy Use

Nuclear power uses heat from the radioactive decay of a fissile material such as uranium-235 (235U) to boil water into steam to generate electricity.

- The US produces the most nuclear energy, with nuclear power providing about 20% of its electricity, while France produces the highest percentage (80%) from nuclear reactors:
  - International construction of nuclear power plants declined following the 1979 Three Mile Island accident, and again after the 1986 Chernobyl disaster.
  - Renewed international government and public interest in nuclear energy is being motivated by increasing oil prices, improved plant safety designs, and fossil fuel greenhouse gas concerns along with stringent emission standards established by the Kyoto Protocol.

167. Flickr/Bill & Vicki Tracey

Non-radioactive water vapor rises from hyperboloid-shaped cooling towers. Nuclear reactors are located inside cylindrical containment buildings.

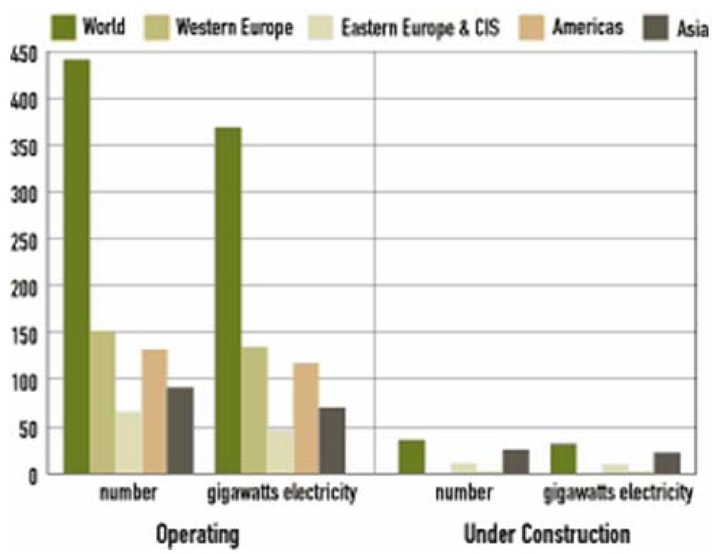
Renewed Global Interest

A Substantial Fossil Alternative

In 2005 there were 441 commercial nuclear reactors in the world, with a capacity of about 368 gigawatts.

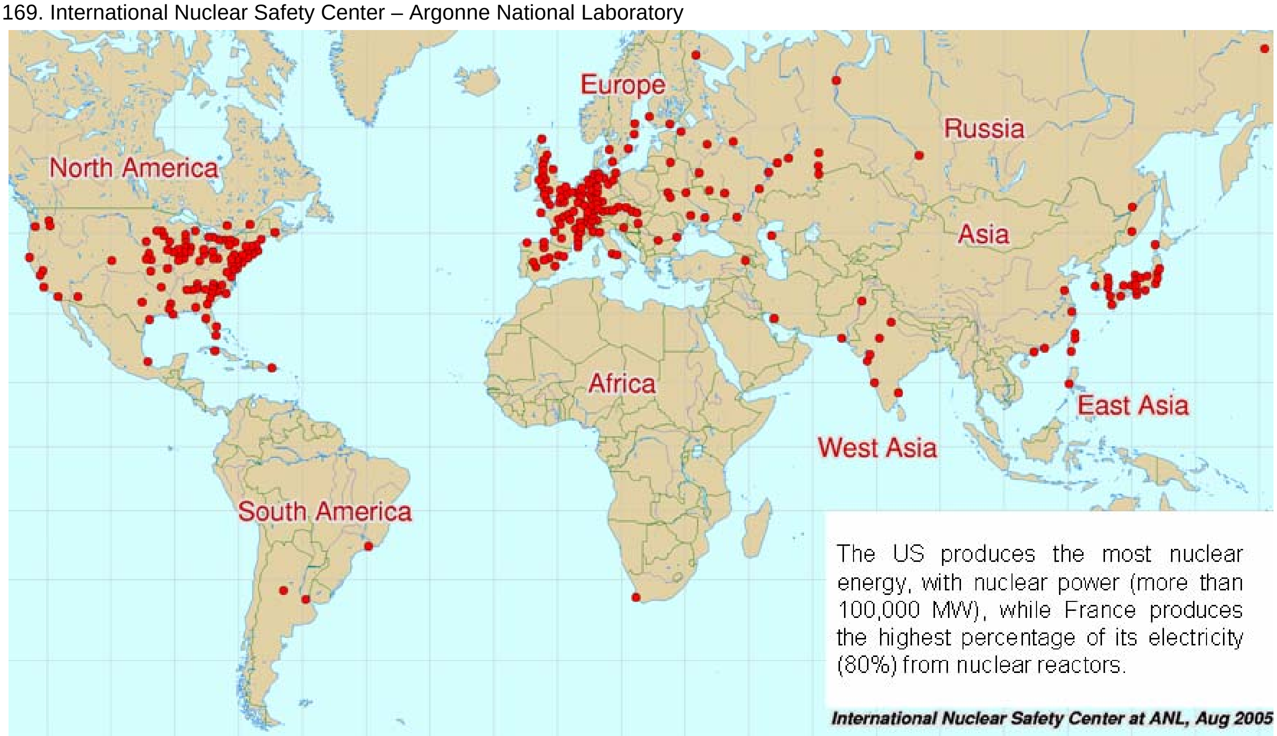
- Since 2005, 111 reactors have been shut down (36 GW), and 80% of those remaining are more than 15 years old:
  - Currently, about 337 plants are in operation overseas, and the United Nations' International Atomic Energy Agency (IAEA) projects at least 60 more within the next 15 years or so.*
  - Lithuania and France lead the world in percentages of nuclear power generated, and several other countries including Great Britain, Germany and China appear to moving towards nuclear plant expansion.
  - India is constructing at least 6 new nuclear power reactors (as of 2006, among the highest development rate in the world, along with China).
  - A planned 1,600 MW reactor scheduled for operation in Olkivoto, Finland in 2010 will be the world's largest.

168. Areva Resources Canada



Operating and Under-Construction Plants

169. International Nuclear Safety Center – Argonne National Laboratory

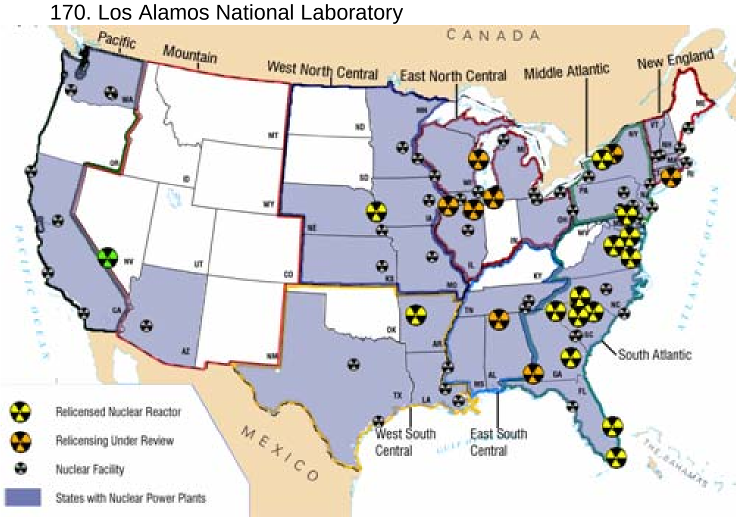


Countries with Nuclear Reactors

* **See Appendix: 22**

Current US nuclear energy capacity

170. Los Alamos National Laboratory



The US currently has 104 nuclear power plants located in 31 states that produce nearly 20% of the nation's electricity and about 8% of total energy. Although more expensive to build than fossil fuel plants, they release only water emissions, use much less expensive fuels, and may become significant sources of electricity to process hydrogen.

US Plant Locations

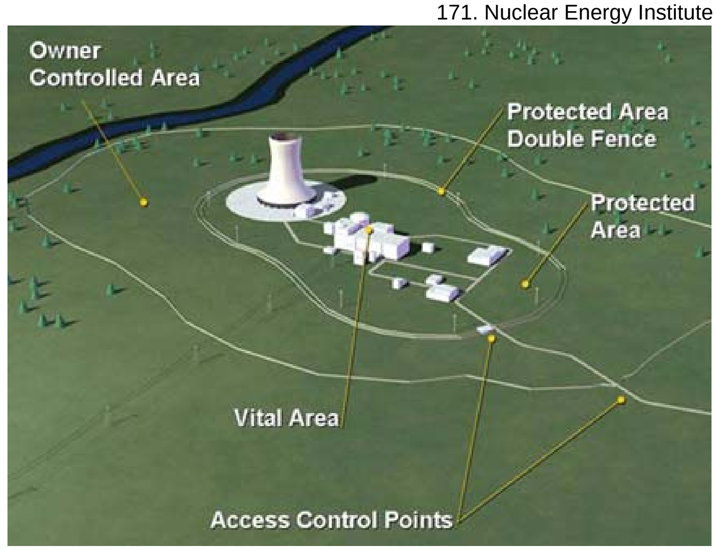
Nuclear power development is gaining public advocacy in the US and abroad because of growing concern about CO_2 released by coal-fired plants, rising natural gas costs, and increased confidence in nuclear plant safety.

- International construction of nuclear power plants declined following the 1979 Three Mile Island accident, and again after the 1986 Chernobyl disaster:
  - Renewed international government and public interest in nuclear energy is being motivated by increasing oil prices, improved plant safety design, and fossil fuel greenhouse gas concerns.
  - In the US there are 104 licensed commercial generating units, producing about 101,289 megawatts of electricity.
  - Supported by incentives provided by the US Energy Policy of 2005, two new sites have been selected, and utility companies are expected to finance more.

Although current US nuclear plants have demonstrated exceptional safety records that benefit from substantial technological advancements, until recently, no US nuclear power plant has been ordered without subsequent cancellation for more than 20 years.

- Nuclear power continues to be a controversial subject for several reasons:
  - Opponents cite problems and challenges of safely storing radioactive wastes for indefinite periods.
  - Public fears about possibilities of radioactive contamination by accidents or sabotage are reinforced by global terrorism trends.
  - Proliferation of nuclear weapons by rogue nations under the guise of peaceful energy programs poses a growing threat.
  - Some critics argue that nuclear power is uneconomical in comparison with fossil fuels (although escalating oil prices are changing this condition.)

171. Nuclear Energy Institute



Security at nuclear power plants is regulated and monitored by the US Nuclear Regulatory Commission (NRC). Physical barriers and high-tech surveillance devices control access, and reactors are protected by massive reinforced concrete containment buildings.

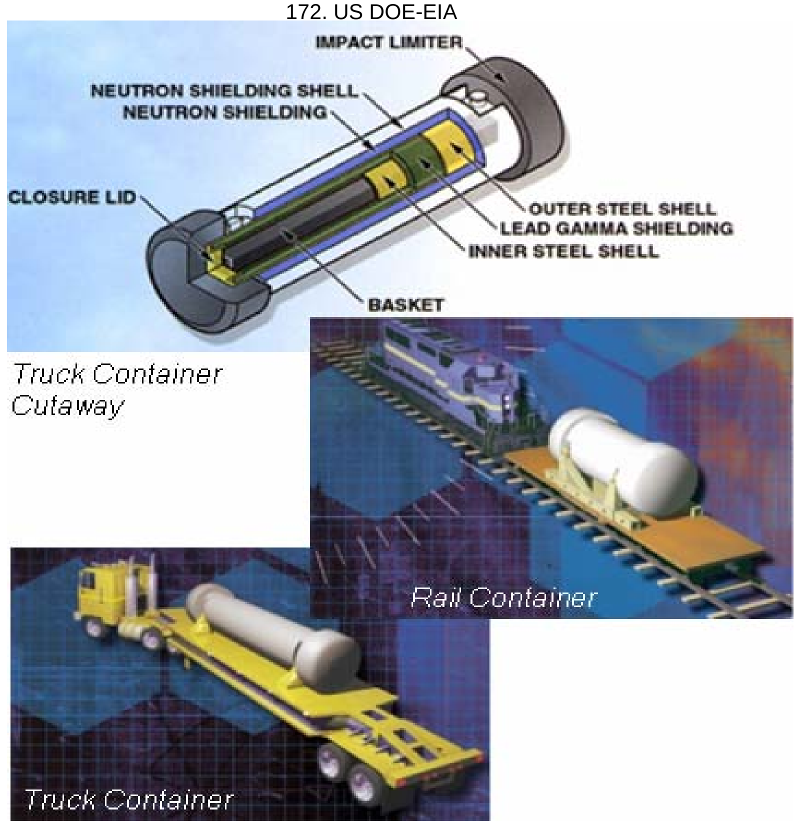
Plant Security

Nuclear waste containment and fuel recycling issues

Safe transportation and containment of spent nuclear fuels presents particularly difficult issues and controversies.

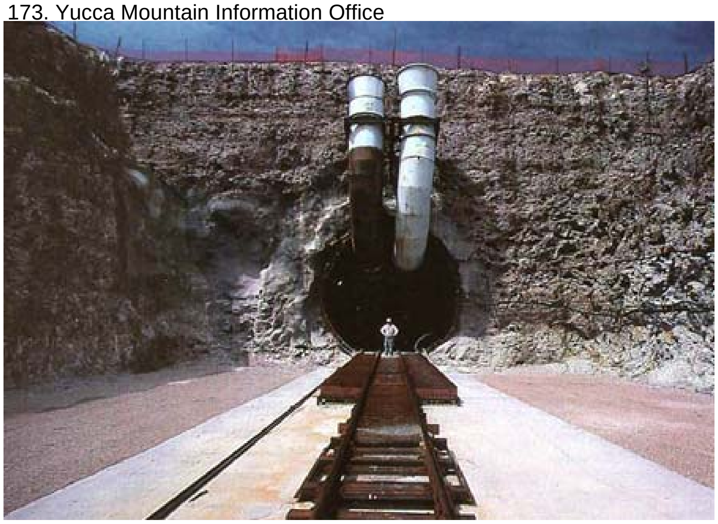
- Current radioactive waste is stored at temporary locations, including water basins in nuclear power plants and dry surface locations:
  - Although most nuclear waste is solid and relatively non-corrosive, a significant amount of old liquid waste still exists which can corrode metal storage tanks internally.
  - Interim storage using many older types of tanks has presented a troublesome leak history.
  - Continuing accumulations of spent materials are creating major disposal problems where former plant storage areas are no longer accepting additional materials.

172. US DOE-EIA



Waste Containment and Transport

173. Yucca Mountain Information Office



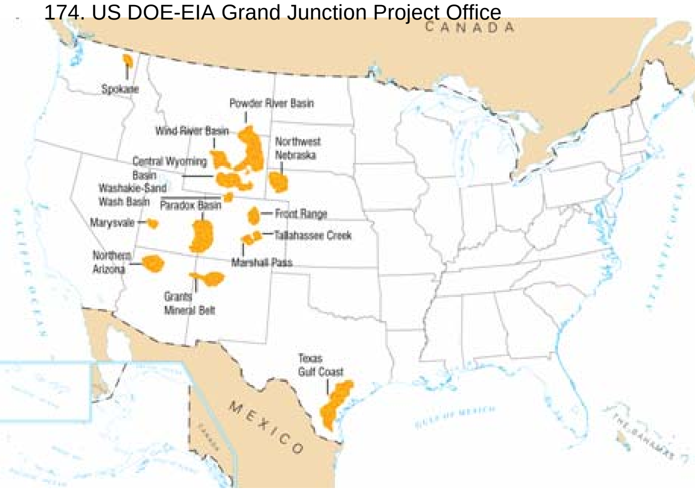
The proposed facility would ultimately contain up to 40,000 metric tons of spent nuclear material, and be licensed under renewable terms of 100 years.

Proposed Yucca Mountain Nuclear Waste Storage Facility

The US Department of Energy has proposed to create a centralized storage facility at Yucca Mountain in Eureka County, Nevada to provide long-term containment of spent nuclear fuels.

- Although the site was approved by the 105th Congress in October 1997, the plan has not yet been approved to proceed:
  - DOE's Office of Civilian Radioactive Waste Management has estimated that more than $20 billion (1998 dollars) will need to be spent over the next 100 years to develop, operate and close the Yucca Mountain project.
  - The waste would be contained in steel canisters buried 984 feet (300 meters) below the surface and designed to last at least 1,000 years, using the mountain to provide a natural shielding barrier.

174. US DOE-EIA Grand Junction Project Office



Most US uranium deposits are small and low-grade, but supply about 85% of the nation's production. Modern mining uses in-situ leach (ISL) methods that pump water into sub-surface hydrochemical "cells" to dissolve uranium minerals, leaving the ore where it was naturally formed. Surface processing of the leached solution produces "yellow cake".

Major US Uranium Reserves

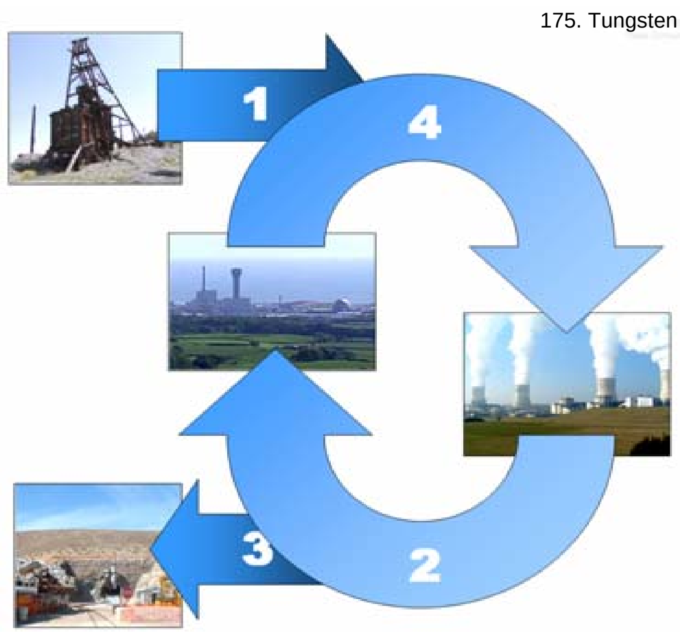
Although nuclear power isn't widely regarded as renewable energy, the fuel is readily available.

- Proponents of nuclear power argue that the amount of available recoverable uranium that can be reprocessed from standard reactors using breeder reactors will last hundreds of years:
  - Breeder reactors can reprocess as much as 95% of the original material, but have been banned in the US since the Carter Administration due to a risk of weapons-grade nuclear proliferation. *
  - A new US initiative, the "Global Nuclear Partnership" announced in 2006, will spearhead an international effort to reprocess fuel in a manner that will prevent proliferation, and make nuclear power available to developing countries.

Following a period of very limited uranium exploration and mining between 1996-2002, global production and prices are rapidly rising due to a resurgence of interest in nuclear power.

- Primary production of 36,042 tons at the end of 2002 provided only about half of the world's reactor requirements, with the remainder coming from utility inventories, downgrading of military weapons and spent fuel reprocessing:
  - In the US, only three in-situ leach (ISL) mines were operating, and by 2003, inventories were largely depleted.
  - New ISL mines are now being created or restarted, and about a dozen are now licensed in western Colorado, Wyoming, Nebraska and Texas.

175. Tungsten



Nuclear fuel can be used many times through reprocessing:

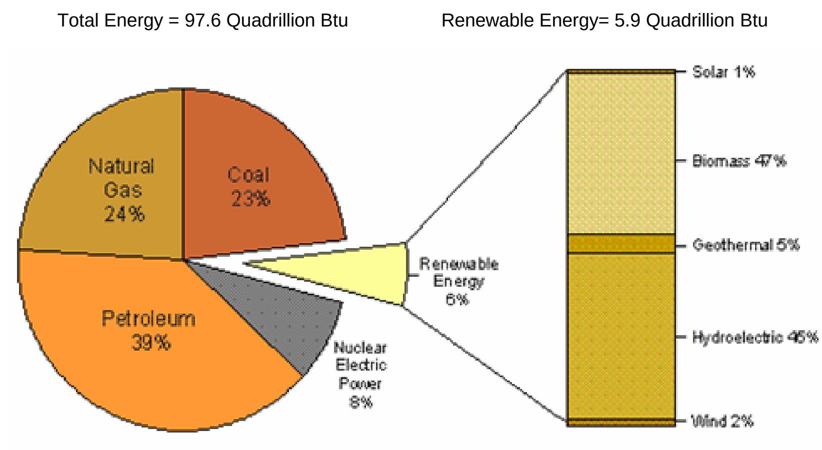
1. Uranium is mined, enriched and delivered to the plant; 2. spent fuel is reprocessed (or 3. stored in a final reposition for geological disposition) and then 4. reprocessed fuel is recycled and reused.

Fuel Recycling

* **See Appendix: 23**

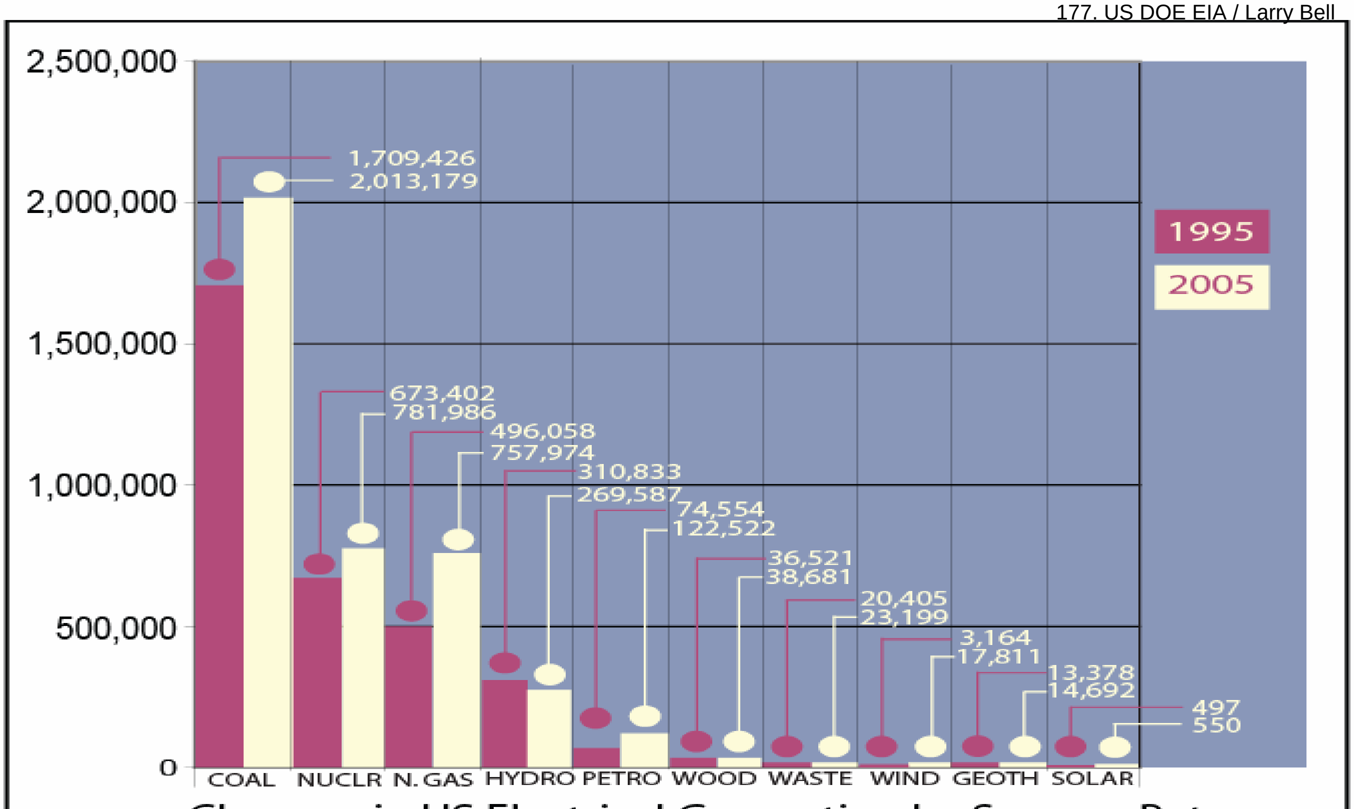
Renewable capacities in perspective

176. US DOE-EERE



Although renewable sources are receiving an enormous amount of public attention, they currently provide only about 6% of total US energy. All have expansion limitations, and most present environmental and economic controversies.

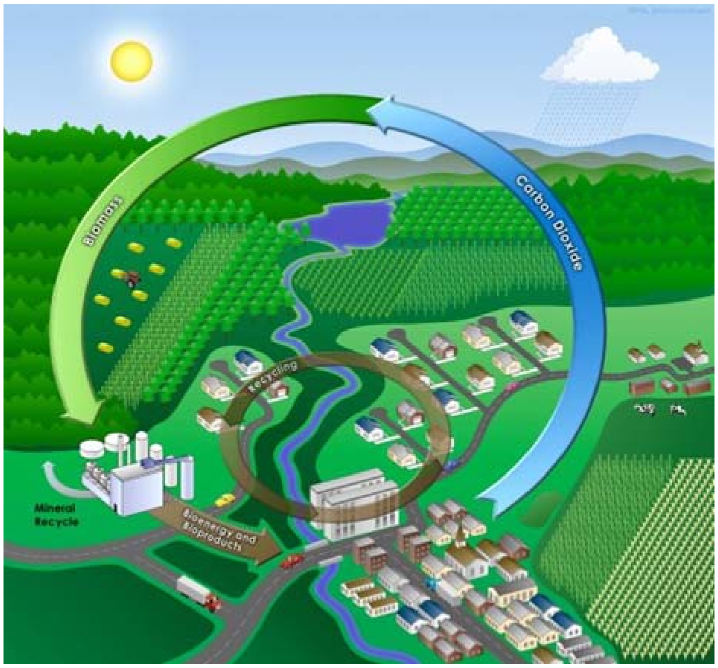
177. US DOE EIA / Larry Bell



Changes in US Electrical Generation by Sources Between 1995 and 2005 (thousands of megawatt-hours)*
Source: US DOE EIA

* See Appendix: 24

178. ITI Arturo Maligani



Biomass Conversion

Biomass residues from plant matter such as trees, grasses, agricultural crops, and other biological materials can be converted into useful gaseous hydrogen as well as liquid fuel forms.

- Government and industry organizations in the US, Europe, and many developing countries are actively cultivating energy crops specifically for renewable biomass fuel production: *
  - As fossil-based fuels become scarcer and more expensive, biomass conversion becomes more attractive and economical.
  - Bio-energy presently ranks comparably to hydropower as a renewable US energy source, and accounts for about 3% of primary US energy production.
  - Large agribusinesses and chemical corporations are moving aggressively into biofuel research and production activities in response to government incentives, long-term business opportunities and public relations benefits. **

Humans have used biomass energy ever since people began to burn wood to cook food and keep warm.

- Wood is still the largest bio-energy resource today, but it is only one among a great many others, including:
  - Food crops, such as corn stover, potatos, vegetable oils (rapseed, corn, safflower), and brewery waste.
  - Animal crops, such as switchgrass, wheat straw, and other grassy plants.
  - Residue from forestry and sawmills (sawdust, woodchips, and pallets/crates).
  - Animal and landfill wastes (methane in particular).

179. Seeds of Change
180. Fairfax Co. Pub. Schools
181. Flagstaffotos
182. US Fish and Wildlife Service

Bio-Energy Resources

* See Appendix: 25
** See Appendix: 26

Biofuels and long roads ahead

183. USDA-ARS
184. Stan Shebs

Bio-Energy Combustion

Although often publicly regarded to be "green energy", burning biomass releases about the same amount of carbon dioxide as burning fossil fuels produced by photosynthesis millions of years ago.

- Advocates argue that biomass burning releases carbon dioxide that is largely balanced by carbon dioxide captured by plant growth ("new" greenhouse gas vs. "old" greenhouse gas):
  - As with all fuels, true accounting of greenhouse emissions must also factor in pollutants released through fuel production and processing, including crop-growing and harvesting.

Useful biomass products can be obtained from many sources, including dedicated energy crops and trees, agricultural food and feed crops, crop wastes and residues, aquatic plants, and animal and municipal wastes.

- Conventional technologies convert those materials into diverse energy-related products:
  - Biopower technologies presently produce more than 10 gigawatts of US electricity.
  - Biofuel research and development is advancing production and product quality.
  - Biomass-derived materials are gradually replacing non-renewable traditional petrochemical-derived products, including chemicals, plastics, fibers, and structural substances.

185. Ian Smith
186. Minnesota Legislature
187. EESI
188. Marcello Movra

Biomass Products

189. RunningonAlcohol.com

Ethanol and biodiesel can supplement liquid fossil fuels in areas with large agricultural and forestry applications. Ethanol is also nationally-distributed as a gasoline additive to reduce CO_2 emissions.

US Ethanol Production Capacity (Millions of Gallons per Year, 2003).

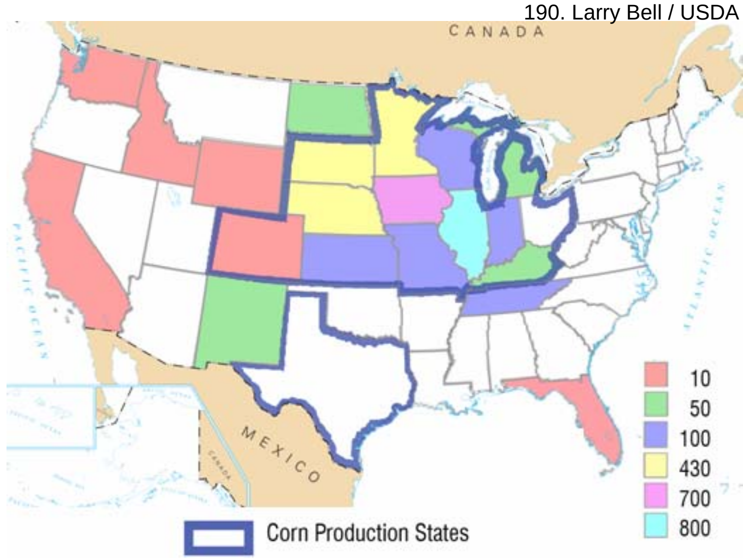
Ethanol and biodiesel production is often advocated as an important, cleaner-burning alternative to fossil fuels to reduce CO_2 emissions and dependence upon foreign oil.

- While at peak levels these alternatives might supply only 10%-14% of US transportation demands, many believe that they are a step in the right direction:
  - Corn-based ethanol can potentially pave the way for cellulosic ethanol constituted from switchgrass and various agricultural and forestry wastes that will be more substantial and sustainable.
  - Biodiesel made from processed vegetable oil, animal fat and recycled cooking grease can be useful either as a fuel additive (typically 20%) or in a pure form for diesel engines for agricultural fuel and local power generation, but is not generally envisioned as a primary national energy source.

Ethanol production and use is rapidly growing, in part, as a gasoline octane enhancer to replace methyl butyl ether (MTBE) which has been banned in many states for environmental and health reasons.

- More than 80 ethanol production facilities currently exist in the US (about one-half of these farmer-owned), primarily in North Central and West North Central states:
  - About 30% of all US gasoline is now blended with ethanol, a practice that may become universal as trends continue.
  - Iowa and Illinois are leading corn ethanol producers, followed by Nebraska, Minnesota and South Dakota.
  - South Dakota devotes about 30% of its total corn crop to ethanol production, more than any other state.

190. Larry Bell / USDA



Key Corn and Ethanol States

Ethanol produced from plant cellulose is the same product as corn ethanol but is created using different feedstocks and processes.

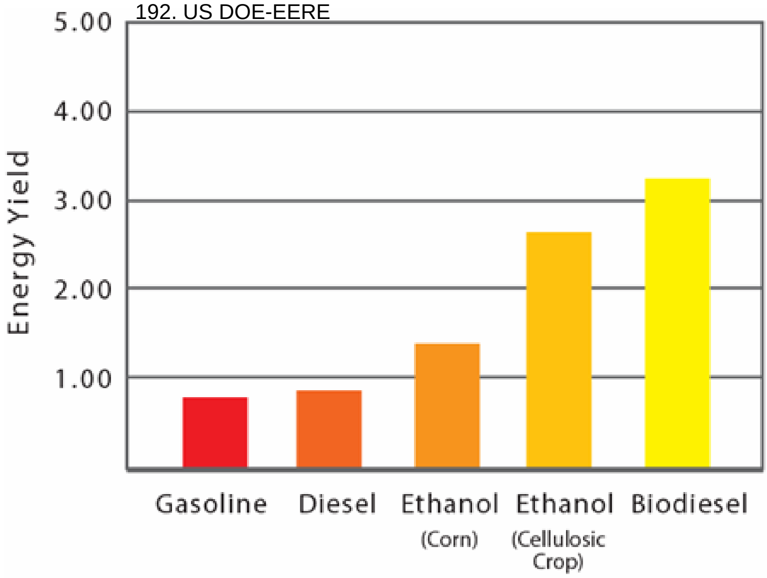
- Instead of using only starch from the plant kernel, the fuel yield is increased by using other parts more fully:
  - An important advantage is the ability to utilize a large variety of biowastes, including corn stover, cereal straws, sugarcane bagasse, saw dust and paper pulp, as well as fast-growth grasses.
  - The left-over lignin dry mass can be burned to create steam, or gasified to produce electricity.
  - Although process enzymes add substantial production costs, technology advancements and a variety of process byproducts are expected to improve economic factors.

191. Tyler Hamilton Foundation

Cellulose ethanol production is accomplished using a variety of biorefinery hydrolysis and fermentation processes to break down fibres into glucose fuel. Extensive use of the plant material increases energy yield over corn ethanol but also adds process costs.

Cellulosic Ethanol

192. US DOE-EERE



Energy Yield / Unit of Fossil Fuel Consumed On a Life Cycle Basis

Plant oil blended with petroleum diesel can reduce fossil fuel consumption along with fossil (old-source) CO_2 emissions per unit of engine work.

Biodiesel is often produced using oil from soybeans blended with petroleum diesel (typically a 15/85 mix), and is rapidly gaining popularity.

- This fuel can be used in standard diesel engines with comparable energy efficiencies to petrodiesel (about 80% vs. 83%):
  - Although efficiency yields are slightly lower due to energy required to convert soybean oil to fuel, biodiesel can dramatically increase the energy produced per unit of fossil fuel consumed (about 3.2 units vs. 0.83 for petrodiesel).
  - Biodiesel reduces fossil fuel life cycle consumption roughly proportionally to its concentration; an approximate 19%.reduction for a 20% biodiesel / petrodiesel blend (B20), and about 95% for 100% biodiesel (B100).

Biodiesel

Harnessing regional water energy resources

193. US Bureau of Reclamation

A Major Renewable Energy Source

Hydroelectric power currently constitutes nearly half of renewable energy in the US, almost 3% of total electrical power.

- Expansion of capacities from conventional approaches that harness falling water is not a major option in the US and developed countries because most primary sites are already being exploited or are unavailable for environmental reasons:
  - While construction of surface reservoirs has slowed considerably since about the 1980s, hydropower is the dominant electricity source in Idaho and Washington.
  - Since water can be stored as potential energy, an important role is to provide hour-to-hour peak load power adjustments in combination with other electrical sources.

Large-scale hydropower applications harness mechanical energy from major dams, ocean waves and tides, and tidal streams, using various types of turbines to produce electricity.

- Many of these technologies are quite new, and some exist only in prototype stages:
  - Large dams that produce massive amounts of hydroelectric power have proven to be important and effective energy sources in many countries.
  - Tidal power, including tidal streams, are relatively new hydropower approaches which are rapidly gaining international interest.
  - Wave power is a promising future source of energy for countries with long coastlines and rough sea conditions.

194. Philip Greenspun
196. Marine Current Turbines, Ltd.
195. Atlantisstrom Germany
197. Wave Dragon

Dam

Tidal Power

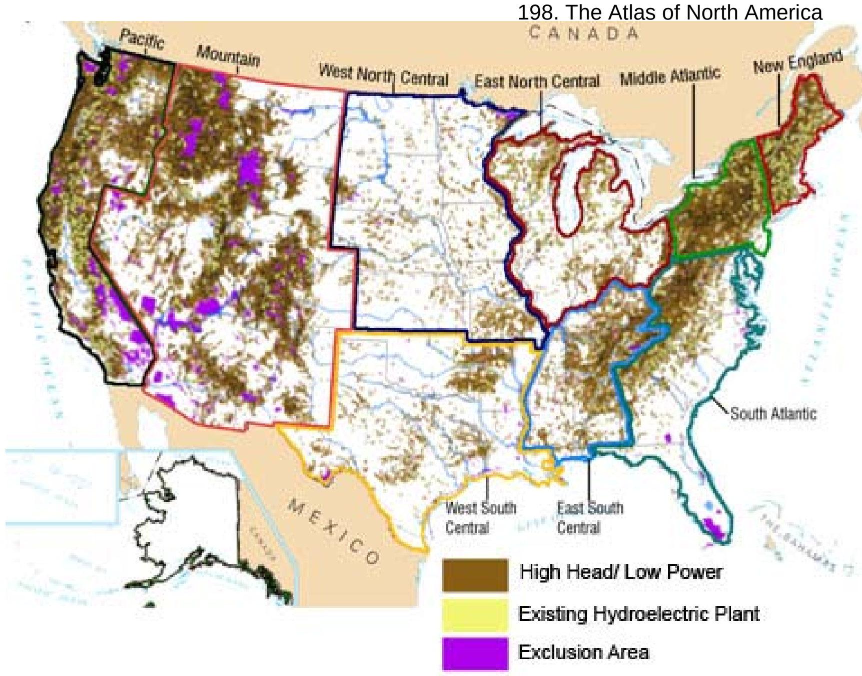
Tidal Stream

Wave Power

With approximately 80,000 MW of generating capacity in 2006, hydropower is the largest US renewable electricity source.

- While a 2004 Department of Energy Study estimated that total potential in the contiguous 48 states might possibly double that amount using energy from rivers and steams, no feasibility studies were conducted to determine real practicalities:
  - "Low head" (less than 30 feet) and "low power" (less than 1 MW) resources constituted about 19,000 MW of this new potential.
  - Micro-hydro sites (less than 100 kW) make up an additional 9,500 MW possibility.

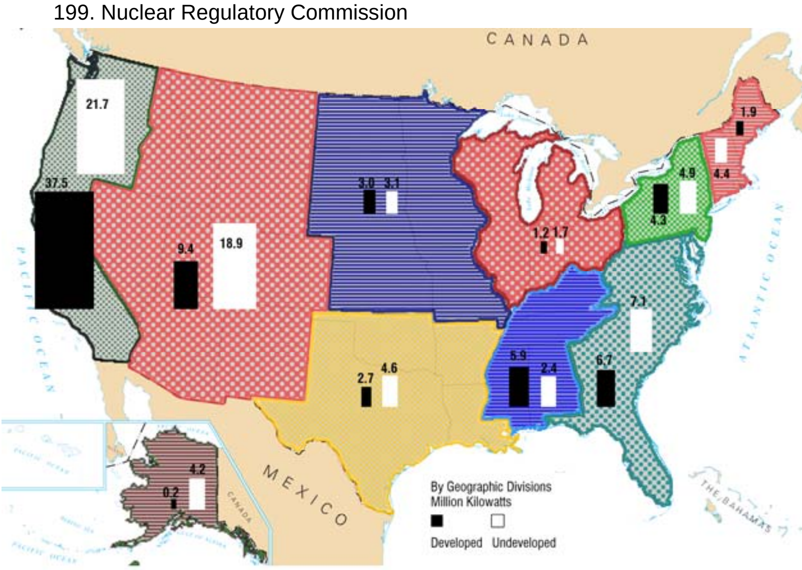
198. The Atlas of North America



While most sites for large dams are already used or restricted, there appears to be significant opportunities to expand small installations, particularly in western states.

Current and Future Hydropower Capacity

199. Nuclear Regulatory Commission



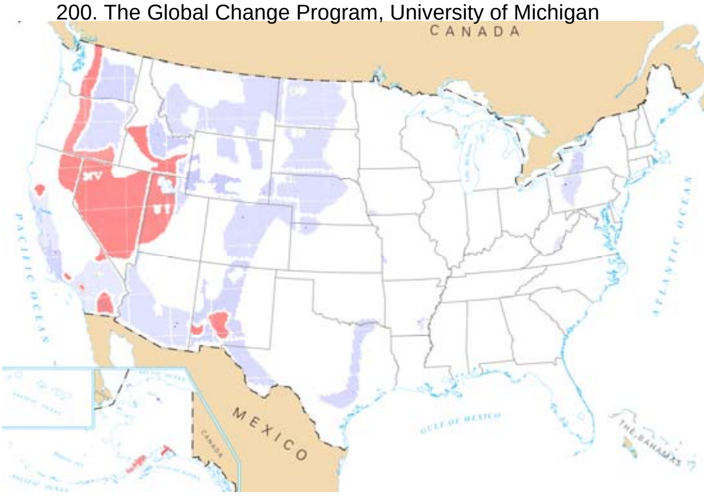
Hydropower Development Potentials

Hydropower generates about two-thirds of all electricity in the US Pacific Northwest Region, and the Idaho National Laboratory projects that there may be an underdeveloped capacity of 50% more on swift-flowing rivers and streams in western states.

- This potential might add small damless operations up to 30 MW, low-power installations and new powerhouses at existing dams, and expanded hydroelectric plant capacities, for a 30,000 MW increase:
  - Washington already has by far the highest generating capacity, and Alaska, California, Oregon and Montana have large new potentials.
  - It is also predicted that Hawaii can multiply its hydropower capacity many times

Capturing Earth’s heat for local benefits

200. The Global Change Program, University of Michigan



Economically-feasible geothermal resources are located mostly west of the Rocky Mountains, and only California, Hawaii, Nevada, and Utah currently have operating plants. The majority of thermal springs and other surface manifestations of underlying geothermal resources are also located in the West, including Montana, North Dakota, and Wyoming. Some low-temperature resources also exist in Central Texas.

Geothermal

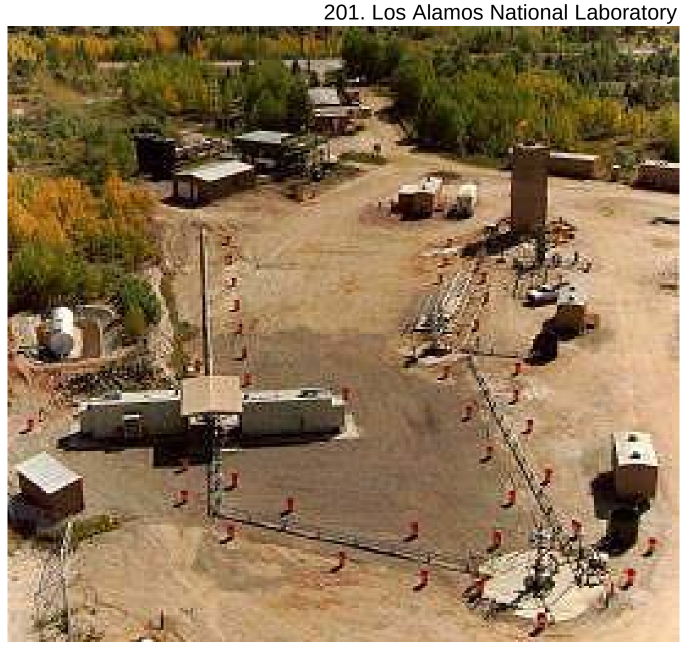
Geothermal power can be reliable and environment-friendly in certain parts of the US, but produces less than 1% of the nation’s electricity.

- Most of known geothermal resources and all presently known sites capable of electric power generation are located in the western half of the country, including Alaska and Hawaii:
  - Growth opportunities are much more constrained than wind or solar since plants must be located at the immediate and limited hot water sites.
  - Many of the potential sites are not located near large power demand centers, requiring long transmission lines to deliver electricity to customers.
  - Diminishing water temperatures and pressures from plant operations can also impact production capacities and efficiencies over time.

In addition to hot water and steam geothermal resources, possibilities also exist to tap deep underground “hot rocks” for power generation.

- The heat collection process pumps high pressure water into dry wells, breaking up rock formations to collect heat and return it to the surface, driving turbines:
  - One barrier to commercialization is that wells must be much deeper than those required for conventional geothermal plants.
  - Another drawback is that since heat flow through dry rocks is slow, heat removal is also slow.
  - An additional limitation is that the majority of promising sites are in dry areas of the West where process water is scarce.

201. Los Alamos National Laboratory



The Fenton Hill Hot Dry Rock site plant in New Mexico uses a 11,500 ft deep well drilled into rocks in a 430° F environment. Water pumped into the well at 80° F returns to the surface at 360° F, producing up to 5MW of electrical power.

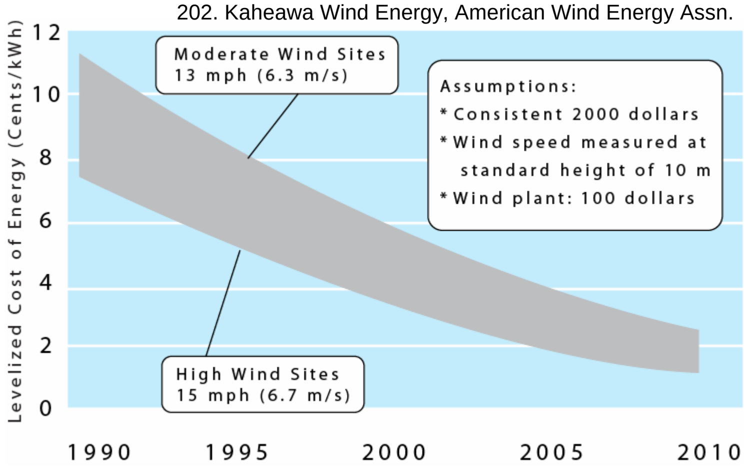
Geothermal Hot Dry Rock Plant

Wind capacities and constraints

Although wind provides only about 2% of US renewable energy (0.12% of total electricity), this source is growing at a rapid rate averaging about 30% per year (compared with dependable single-digit growth for fossil fuel power).

- Wind power is recently realizing cost reductions, and in some locations new wind farms are costing less than coal or nuclear-fueled plants with equivalent capacities:
  - Although current production costs per kWh appear to be leveling, rising fossil fuel costs are making wind more and more cost-competitive.
  - Growth is being supported by new state energy policies and the success of "green marketing" across the country.
  - Interest in small stand-alone systems is also growing (up 62% between 2004-2005).

202. Kaheawa Wind Energy, American Wind Energy Assn.



Wind power use is growing rapidly throughout many parts of the US due to lowering costs and environmental benefits. Small units can operate with wind speeds as low as 8 mph, and large ones at 13 mph.

Energy Production Costs for Large Commercial Wind Projects

203. Sandia National Laboratories

Offshore Wind Farm

The popularity of wind energy has always fluctuated with the prices of fossil fuels.

- Interest in wind turbines waned in the US and abroad when fuel prices fell after WW II:
  - Improvements in wind turbine technology along with oil embargoes of the 1970s promoted new interest and investment.
  - Wind farms connected to public utility grids have now become substantial alternative energy sources in the US and Europe.
  - Continuing R&D, along with investment growth, has made wind-generated electricity competitive with fossil fuel generators in some locations.
  - Wind is now the world's fastest-growing alternative energy source.

204. Iowa Energy Center

Theoretical Capacities

According to the American Wind Energy Association, wind provided about 0.4% of total US electricity in 2005, enough for 1.6 million households.

- World-wide capacity more than quadrupled between 1999-2005, with 90% of total installations in the US and Europe, with Germany representing 32% of this amount:
  - In theory, land and near-shore wind could supply current world electricity needs on about 4-10% of global land area (assuming an average of six 1.5 MW turbines with 253 ft [77 m] diameter blades for 0.38 square mile [1 square kilometer]).
  - Placing the same number of turbines offshore could contribute about seven times more wind energy due to power multiplying effects of 90% higher wind speeds.

Even though wind is characterized as a clean energy source, many new wind farm proposals face public resistance on environmental and aesthetic grounds.

- Numerous developments have been blocked by residents in prime coastal and hilly areas due to concerns about influences upon bird migration and nesting patterns and visual impacts upon picturesque vistas: *
  - Seashores tend to be popular recreation and high-value real estate locations which also have good wind energy features caused by differential cooling of land and water over the course of day and night.
  - Offshore turbines (typically 6 miles [10 kilometers] or more from land) encounter less opposition, but are more expensive due in part to harsh, corrosive conditions with less maintenance accessibility, and greater water-to-shore transmission challenges.

205. Research Institute for Sustainable
206. Energy Greenpeace

Environmental and Visual Objections

* **See Appendix: 27**

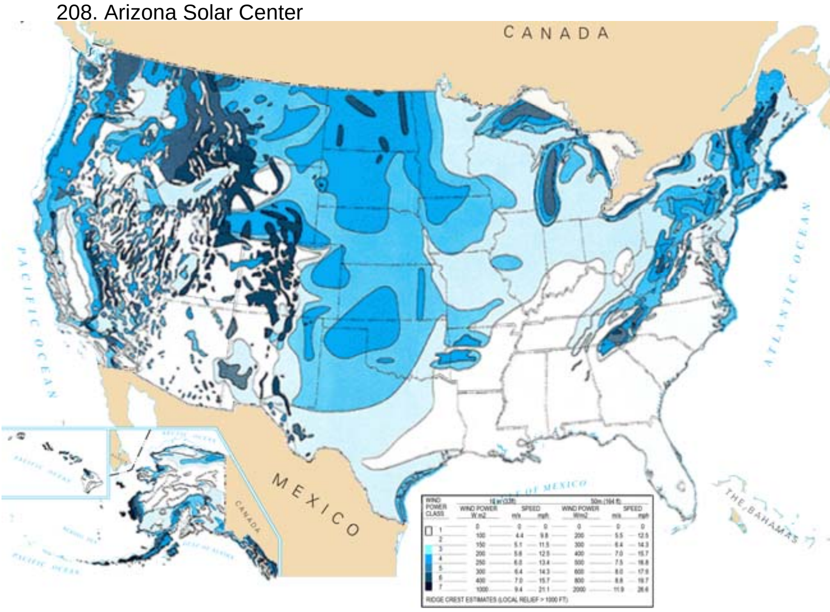
Unfortunately, practical amounts of wind energy are not always available where or when needed.

- Although annual power capacities are usually relatively constant, daily and seasonal levels can fluctuate considerably:
  - Regional and local power demand levels also fluctuate on a seasonal and daily basis, and may often be incompatible with wind conditions during those periods.
  - Since winter winds tends to be strongest, this energy source can be particularly helpful in northwestern states to capture mountain winds during periods of least sunlight to fill cold weather power gaps.
  - Allowing for intermittent fluctuations, a 1000 kW wind turbine might be expected to produce roughly the same annual energy as a 500kW coal-fired generator.

207. Bruce Center for Energy Research and Information

Wind Farms Tend to be Located Far from Power Demand Centers

208. Arizona Solar Center



Annual Wind Power Resources

In 2005, the US added 2,431 MW of new wind energy capacity, more than any other country, for a total 2006 capacity of more than 10,000 MW.

- It is estimated that American wind farms currently save more than half a billion cubic feet of natural gas per day, and the rate of expansion is predicted to grow:
  - More consistent wind resources are located in the Great Lakes Region, and from ocean breezes along the eastern, western and southern coasts.
  - Important inland areas are in the Great Plains from northeastern Texas and eastern New Mexico northward to North Dakota and western Montana, in ridge crests and mountains of Appalachia, and throughout western states, particularly in mountain wind corridors.

Advantages

- Wind is renewable, produced by solar heating of the atmosphere.
- It is an abundant US source of energy to reduce dependence on oil imports.
- Wind is one of the lowest-priced renewable technologies (4-6 cents/kilowatt hour).
- It is a clean source of energy – doesn't pollute like combustion processes.
- Wind turbines don't produce acid rain or greenhouse gases.
- Turbines can be installed on farms or ranches to provide income and local power.
- They can also be combined with other land uses such as livestock.

Disadvantages

- Depending upon site wind conditions, turbines are not always cost-competitive.
- Technology requires higher initial investment than fossil fuel generators.
- Since wind is intermittent, energy is not always available when needed.
- Good wind sites are often remote from areas where electricity demands are high.
- Wind sites can compete with other land uses such as agriculture.
- Noise from blades and visual impacts are sometimes considered to be objectionable.
- Birds are occasionally killed by flying into rotor blades.

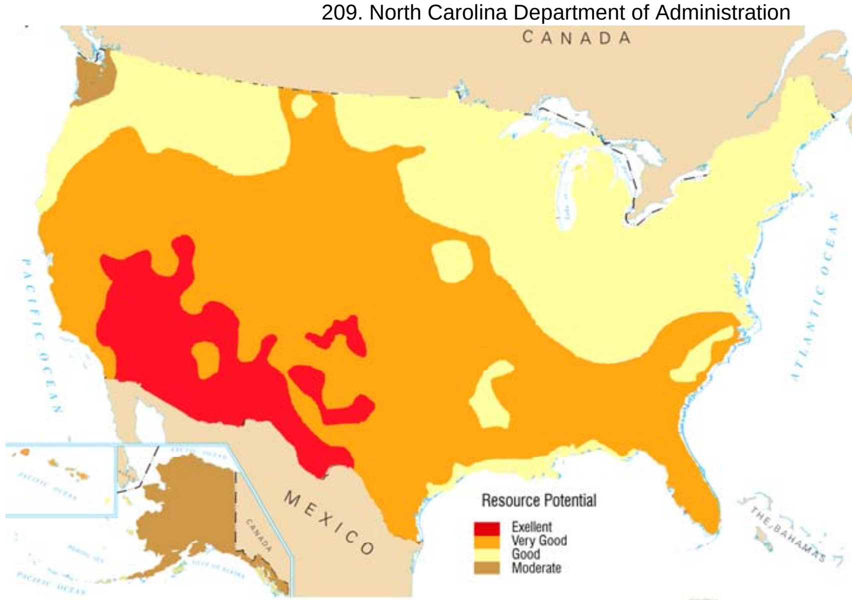
Wind Energy Advantages and Disadvantages

Solar energy: a growing but limited supplementary option

While solar power currently supplies far less than 1% of US energy, the potential for Photovoltaic (PV) expansion promises to be quite large.

- A report issued by the Western Governors Association Solar Task Force in 2006 projects that 4,000 MW of PV, 4,000 MW of concentrating power and 2,000 MW of solar hot water can be easily developed:
  - An estimated 105 MW of domestic photovoltaic (PV) capacity in 2005 was expected to grow 20% by 2006.
  - Concentrating solar power has realized contracts to build about 2,000 MW of new installations in sunny southwestern states over the next decade.
  - Domestic solar water and pool heating is growing even more rapidly, and increased by about 50% from 2006-2007.

209. North Carolina Department of Administration

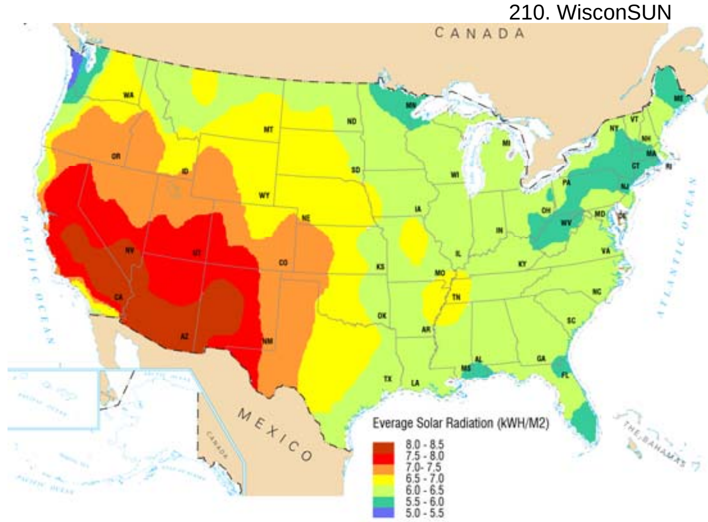


Solar Resource Potentials

Much of the solar power industry growth can be attributed to rising energy prices along with federal and state government incentive programs.

- The US 2005 Energy Policy Act (EPAct) established tax credits for solar installations with apparent effectiveness, and 39 states enable customers to sell excess electricity back to grids, with 36 providing state-wide programs to do this:
  - In 2005, grid-tied Photovoltaic installations (PV) surpassed off-grid installations, and this trend is likely to continue, the majority for homes and businesses.
  - California is dominant for grid-tied systems, with 73% of the nation's total.
  - New Jersey, second in the US for grid-tied PV, doubled its capacity in 2006 to 26 MW.

210. WisconSUN

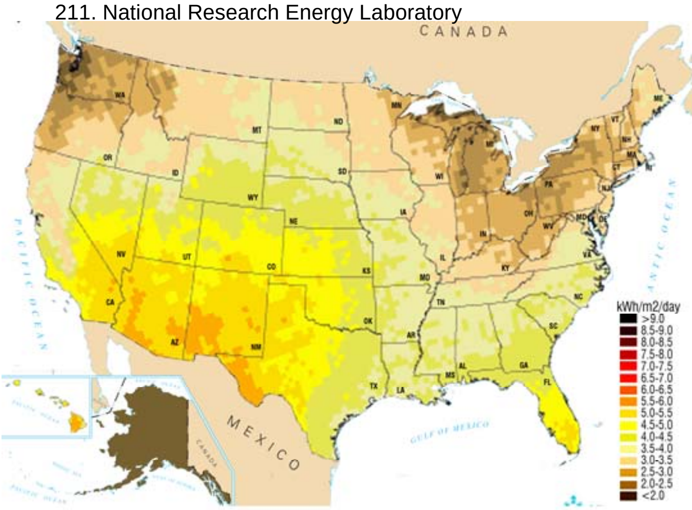


Solar Worst Case Month (June) Demands:

Average Solar Radiation Received by a Horizontal Surface (kilowatt hours per square meter)

In many parts of the US, highest PV outputs and demands are on hot sunny summer days.

211. National Research Energy Laboratory



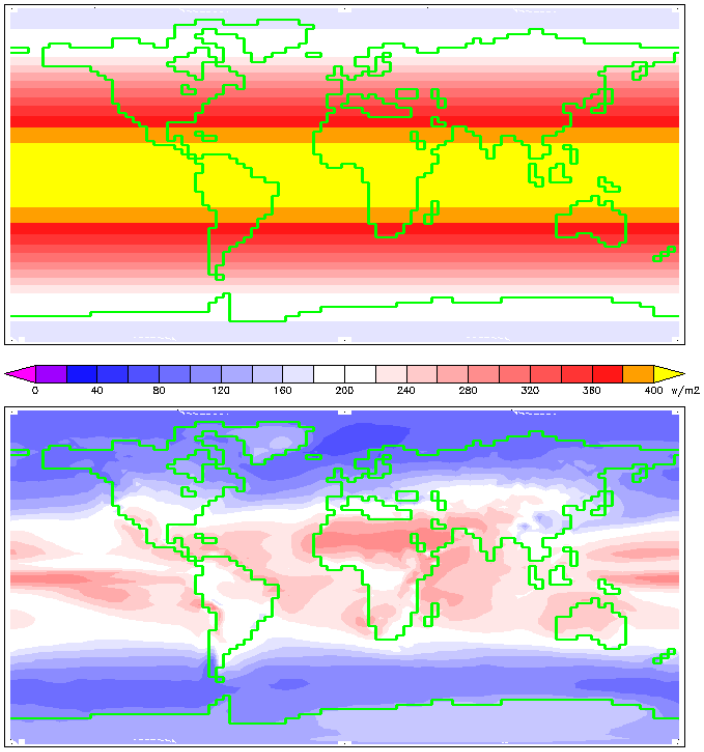
Solar Worst Case Month (January) - Supply
PV Solar Radiation, Flat Plate Facing South Latitude Tilt

This map shows the amount of solar energy in hours received each day on an optimally-tilted surface.

Solar power is broadly accepted as an environment-friendly energy supplement, with the only real impacts associated with collector production and disposal of battery storage devices

- Factors that inhibit expansion primarily relate to geographic limitations and economic returns on investments:
  - Sunlight availability varies considerably according to latitude and seasonal Sun angle influences, and devices only operate during daylight and under good weather, sky and atmospheric conditions.
  - System costs currently require several years for recovery (although increased PV cell production and planned expansion of polysilicon manufacturing combined with rising fossil fuel prices and solar tax incentives can greatly enhance economic benefits).

212. William M. Connolley, British Antarctic Survey



Theoretical annual mean insolation, at the top of Earth's atmosphere (top) and at the surface on a horizontal plane.

Solar Radiation: Atmosphere and Surface

Solar energy has come into widespread use, most particularly for low-power applications where other sources are not available:

- Solar radiation is converted into electricity or applied directly as a heat source for a variety of purposes which include:
  - Electricity generation using photovoltaic systems for roadside emergency telephones, off-grid home power, irrigation water pumps and other services.
  - Space heating, hot water and cooking using direct solar thermal radiation.
  - Solar thermal concentrators that produce steam or heat gases to drive engine-turbines that produce electricity.
  - Solar photovoltaic concentrators that convert radiant energy directly into electricity.

Geographic and power limitations pose significant constraints upon widespread PV utilization.

- Of the total 1,366 watts per square meter (W/m^2) of solar radiation that encounters the Earth's upper atmosphere, the average incoming amount (or "insolation") that reaches the surface in the contiguous US ranges between 125-375 W/m^2 (or 3.9 kWh/m^2/day):
  - While travelling through the atmosphere, about 6% of solar radiation is reflected back to space and about 16% is absorbed, resulting in a peak irradiance at the equator of slightly more than 1,020 W/m^2.
  - Average atmospheric conditions (clouds, dust and pollution) further reduce insolation by about 20% through reflection, and about 16% through absorption.
  - Atmospheric conditions also affect the quality of insolation reaching the surface by diffusing incoming light and altering the spectrum.

213. ePrairie, Inc.
215. Naional Renewable Energy Lab

214. Genersys ireland
216. US DOE-EERE

Off-Grid Electrical Power

Water and Space Heating

Solar-Thermal Power Plant

Solar Photovoltaic Power Plant

Small-Scale Commercial Applications

PV power applications have steadily expanded during recent years in response to environmental concerns in combination with rising costs of dwindling fossil fuel supplies.

- Between 2000-2004, worldwide solar energy capacities have increased at a rate of about 60% annually, although shortages of refined silicon for PV cells has slowed growth somewhat since that period:
  - PV popularity has benefited from reductions in manufacturing costs, where average lowest retail prices for large arrays have declined from $7.50 - $4.00 per watt between 1990 and 2005.
  - PV markets have also been boosted by many jurisdictions that provide customer tax and rebate incentives, often enabling system installations to recover costs in 5-10 years.

217. US DOE- EERE

This 6.5 kilowatt PV array supports an all-purpose general store, restaurant, gas station and public campground near Moab, Utah.

These two silicon modules are rated at 50 watts each, and generate power to illuminate a large entry sign.

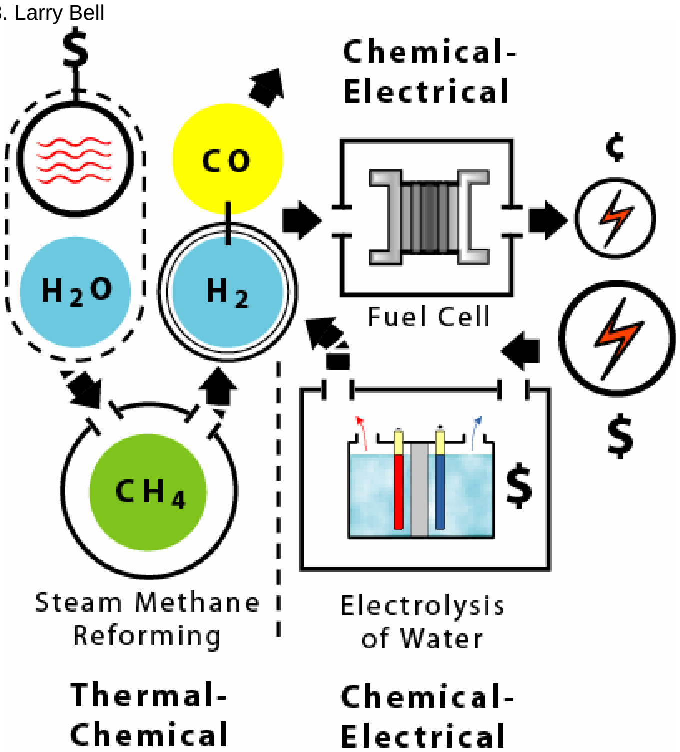
Small-Scale Commercial Applications

Advantages	Disadvantages
• Sunlight energy is free following initial PV installation costs, and is non-polluting.	• Installation and replacement costs may require several years to recover.
• Installations can operate with little maintenance after initial setup is accomplished.	• Solar panels have limited power density, ranging from only about 7%-17% efficiency.
• Systems are particularly beneficial in remote locations where public utility connections are not available.	• High-latitude regions and locations with frequent cloud cover and dust limit effectiveness.
• Grid-connected systems can displace highest-cost electricity during times of peak demand.	• Solar power is not available at night or during rainy/cloudy periods when electricity may be needed.
• Grid-connected systems can sometimes transfer excess electricity to the grid for energy credits.	• Batter power storage, if needed, imposes large energy penalties, costs and space requirements.
• PVs can often be combined with wind power and other energy sources to optimize power production.	• Inverters to convert DC to AC electricity also impose significant energy efficiency penalties.

PV Installation Advantages and Disadvantages

Hydrogen sources, applications and issues

218. Larry Bell



H_2 Production Economics

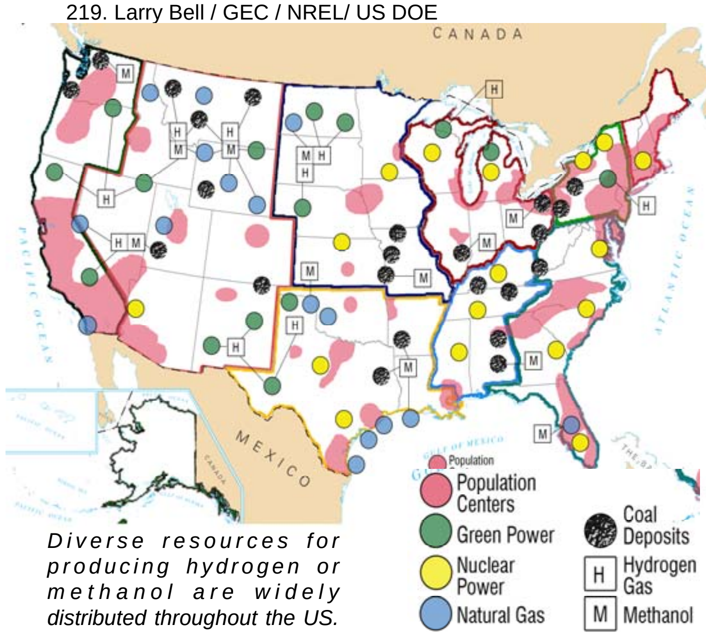
Hydrogen and methanol are generally characterized as renewable fuels because they can be derived from renewable sources (water electrolysis for hydrogen, and methane released from biomass for both).

- They are also produced as by-products of natural gas, crude oil and coal, in which cases they are not renewable derivatives:
  - Steam methane reforming (SMR) to produce hydrogen gas (H_2) imposes economic and energy costs for natural gas or methane recovery processes to provide the feedstock, along with the heat energy to create the steam.
  - Production of the H_2 using water electrolysis requires large amounts of electricity (more energy than it produces using fuel cells), competing with power for other uses.

Hydrogen and/or methanol processed from fossil and biomass feedstock may eventually gain significant roles as transportation fuels.

- Methanol offers advantages over hydrogen of easier and safer transport in liquid form, and can be used either in internal combustion engines or in direct methanol fuel cells (DMFCs):
  - Resources for hydrogen and methanol production are broadly distributed throughout the US, including green and nuclear power for hydrogen through electrolysis; and coal and natural gas for either or both.
  - Whereas hydrogen might be used near the production sources, methanol can be moved over much longer distances using existing fuel infrastructures.

219. Larry Bell / GEC / NREL/ US DOE



Diverse resources for producing hydrogen or methanol are widely distributed throughout the US.

Potential Hydrogen and Methanol Production Areas

220. Geocities

Hydrogen is regarded to be an energy carrier rather than a source because of net deficit power it produces relative to power needed to create and convert it to electricity.

Hydrogen

Hydrogen requires more energy to create than it yields, and imposes additional cost and efficiency penalties for compression, liquefaction, transport, bulk storage, transfer to vehicles and fuel cell inefficiencies.

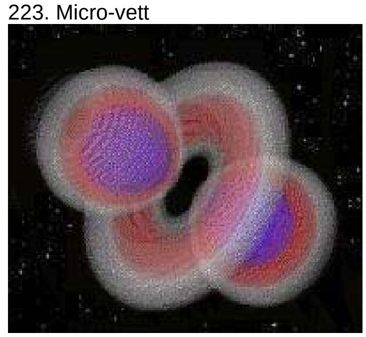
- When hydrogen is produced using fossil fuels, there are also pollution penalties:
  - Electricity produced by burning natural gas in a large unit produces CO_2 emissions just over 14oz/kWh (400g/kWh).
  - When hydrogen is produced by reforming natural gas, CO_2 emissions resulting from creating it are about 10oz/kWh (285g/kWh).
  - If the product hydrogen is then passed through a fuel cell to create electricity, CO_2 emissions are about doubled to 19.4oz/kWh (550g/kWh) since fuel cell efficiency is at best about 50%.

An offsetting advantage of hydrogen fuel cells is that they can provide electrical power plus heat for a variety of off-grid applications, but at high energy processing, containment and transportation costs.

- This fuel presents special challenges for several reasons:
  - H_2, the smallest molecule of all, tends to escape from gas pipelines, making transport by this means very problematic.
  - Increasing gas pressures to compensate for low energy/volume density using smaller containers requires stronger/heavier tanks and energy for compressors.
  - Liquid hydrogen (LH_2) imposes added energy costs for liquefaction and tank insulation to prevent boil-off.
  - Hydrogen is highly combustible and explosive, necessitating special safety precautions.

221. Purdue University
223. Micro-vett

222. E-Marine, Inc.
224. University of Birmingham

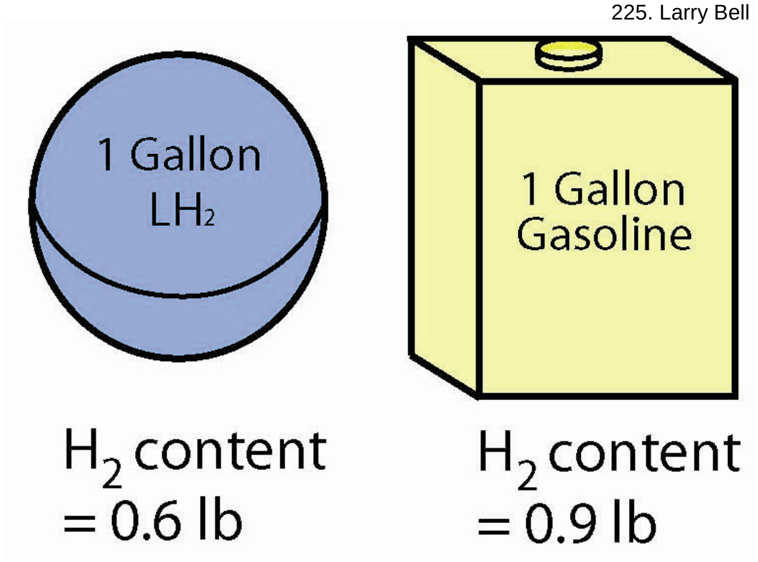


Hydrogen Transit and Containment

Although hydrogen has been mass produced for more than 50 years, it may be some time before it has a major place in the automotive energy economy.

- Key problems are associated with high costs of storage and transport with current technology:
  - Although gaseous H_2 can be pumped directly from production to consumption areas, the tiny molecular size causes costly leakage.
  - While H_2 has good energy density/weight, it has poor density/volume, requiring larger and heavier storage tanks than gasoline or diesel fuels.
  - Increasing gas pressure enables tanks to be smaller, but also makes them heavier and requires more energy to power the compressors.
  - Liquid hydrogen has higher volumetric energy than gaseous hydrogen, though cryogenic liquefaction imposes large energy and tank insulation costs.

225. Larry Bell



LH_2 has a worse energy density/volume than gasoline by a factor of about four. There is about 50% more H_2 in a gallon of gasoline weighing 0.9lb than in a gallon of hydrogen weighing 0.6lb.

Hydrogen Storage Considerations

Hydrogen Gas (H_2)

- Highly combustible, will burn in concentrations as low as 4% H_2 in air.
- Hydrogen explodes upon ignition when mixed with oxygen.
- Reacts violently in contact with chlorine and fluorine.
- Readily leaks due to small molecular size through porous materials, cracks or bad joints.
- Has good energy density per weight, but poor density per volume (compared with gasoline).

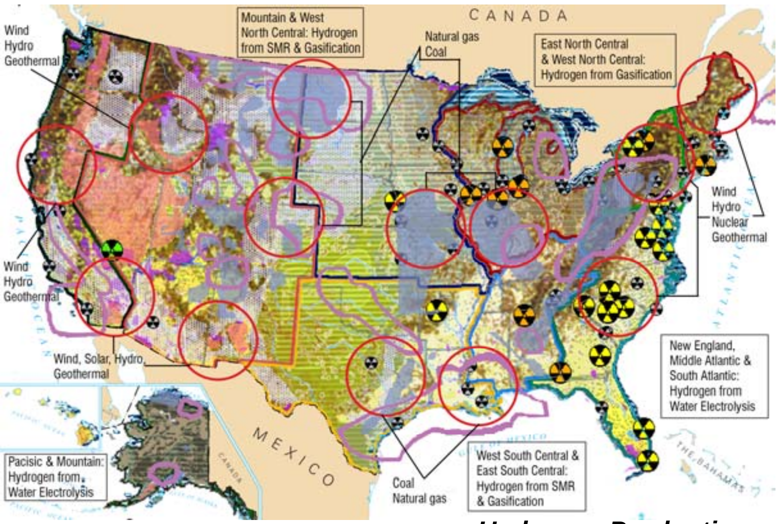
Liquid Hydrogen (H_2)

- Has higher volumetric energy density than gaseous H_2, but requires low temperature storage.
- Has much worse energy density per volume than gasoline.
- Expensive tank insulation is required to prevent boil-off (LH_2 boils at about -423°F [-253°C]).
- LH_2 is cold enough to freeze air, and can cause valves to plug up in automotive fuel applications.
- Production and transportation of LH_2 or H_2 can require more than twice the energy recovered.

Hydrogen Form Characteristics as Energy Carriers

Optimizing all alternatives

226. Larry Bell / GEC / NREL / AFC



Hydrogen Production

Practical benefits of hydrogen depend upon affordable processing energy and minimized transport.

- Renewable electricity in combination with local production from steam methane reforming or the process of coal gasification can help to achieve these needs:

  - Abundant renewable energy resources located in the Pacific and Mountain Regions and Atlantic states can help to supply hydrogen processing demands in highly-populated western and eastern coastal areas.
  - Coal and natural gas in Mountain, West North Central, East North Central, West South Central and East South Central Regions can be used to produce hydrogen from SMR and gasification.

227. National Renewable Energy Laboratories
228. National Renewable Energy Laboratories

Hydrogen might be provided inexpensively using wind and hydropower that offer "free" sources of renewable energy applying mechanical forces supplied by Nature, but only at the expense of other electrical power uses.

- Both of these sources are highly geographic-dependent, requiring that the kinetic power that is captured be used locally, stored or transferred in the form of electricity, or converted into a hydrogen carrier through water electrolysis with energy penalties:

  - Wind power development currently represents a very small but rapidly expanding segment of total renewable energy production.
  - While hydropower presently constitutes nearly half of all US renewable energy production, it is less likely to grow as dramatically due to limited major site options and environmental impacts upon water ecosystems.

Forces of Nature

229. US DOE / How Stuff Works

Computerized systems at each control area operations (CAO) center monitor power grid activity, balance supplies to meet demands, and prevent overloads. Population and industry shifts influence demand capacities that must be accommodated.

Electrical Power Grids and Control Centers

Power grids of different sizes connect together sets of large generating plants to provide sufficient amounts of electricity to meet predicted requirements.

- These networks work fine so long as demands are not exceeded, but are vulnerable to overloads leading to entire system failures if one or more plants must be disconnected due to an accident or possible act of sabotage:
  - If a failure occurs, other plants must be disconnected from the grid to protect them from overloads, in turn shifting increased loads to neighboring parts of the system and causing a cascading shutdown or "blackout" that can leave millions of users literally in the dark.
  - One solution is to provide significant amounts of excess capacity with more plants and transmission lines, an approach that requires major new investments as power demands grow.

Coal is the world's most abundant fossil fuel can be expected to be the primary source of electricity and heat for many years.

- The International Energy Agency (IEA) projects a 43% increase in coal use between 2000 and 2020:
  - This trend is causing escalating public concerns about CO_2 emissions into the atmosphere that are contributors to global warming.
  - In response, the US and many other countries are investing heavily to develop "clean coal" technologies that dramatically reduce CO_2 and other pollutant emissions.
  - Coal gasification is a leading approach to extract hydrogen and other useful energy forms from coal in the process of removing CO_2.

230. Oakridge National Laboratory

"Clean Coal" Gasification Plant

Gasification and other "clean coal" technologies are being developed and advanced to remove CO_2 and other pollutants such as sulfur and nitrogen that form droplets of weak sulfuric and nitric acid ("acid rain").

Coal

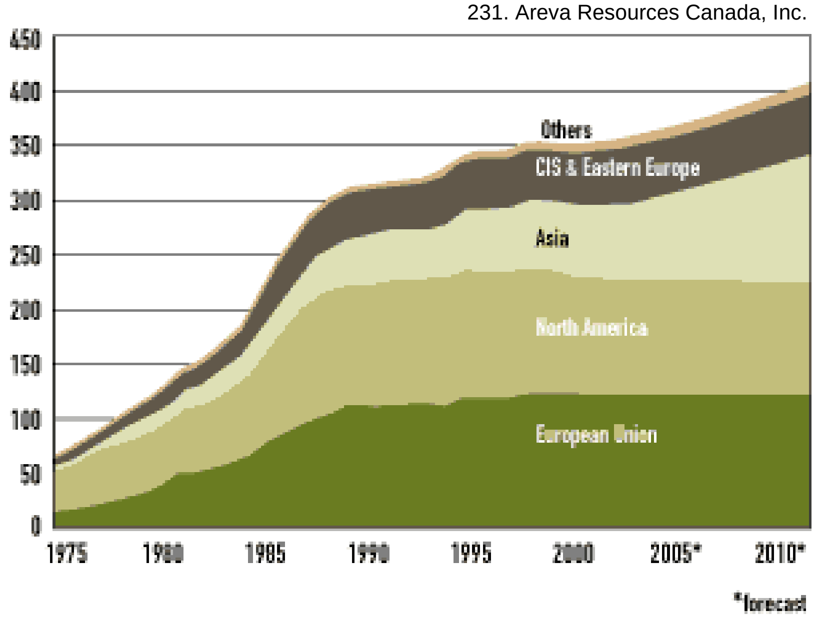
Power and Heat

Primary and secondary energy expansion priorities

Coal, nuclear power and wind are broadly considered to be the only realistic large-scale energy sources that can be expanded sufficiently to significantly reduce oil and natural gas dependence after production has peaked.

- Current nuclear reactors return about 40-60 times the investor energy needed to produce it, better than coal or natural gas, but less than hydropower:
  - Nuclear and wind power expansion offer advantages of not realising atmospheric pollutant emissions..
  - In addition, and contrary to popular belief, coal-burning actually releases more radioactive waste into the environment than nuclear power.

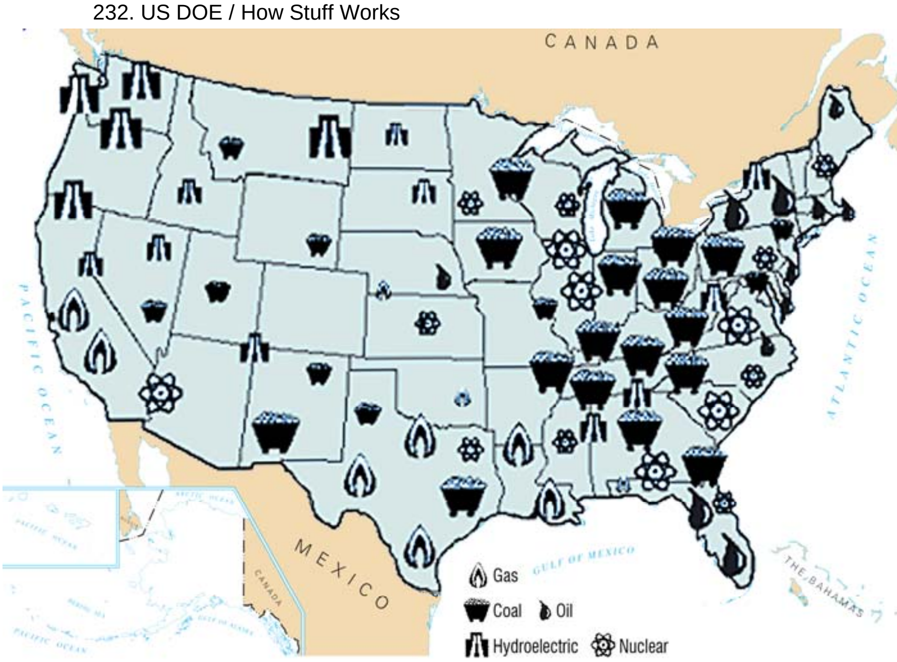
231. Areva Resources Canada, Inc.



Existing and Projected Nuclear Power Output

Gigawatts of Electricity

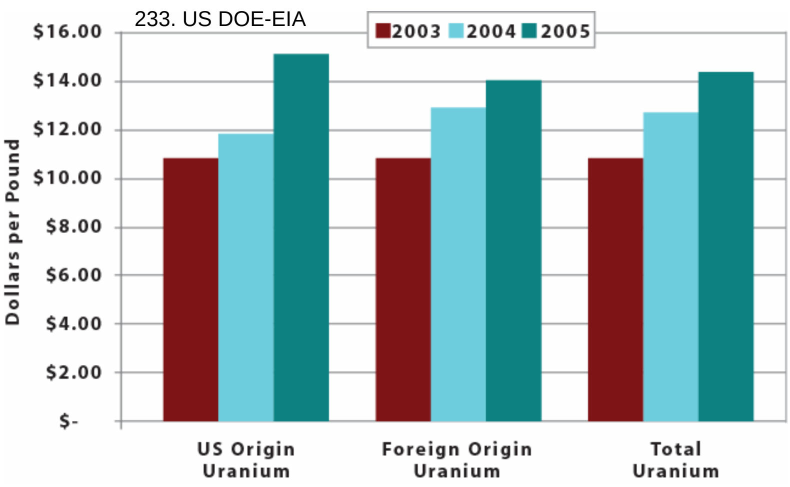
232. US DOE / How Stuff Works



Nuclear and Other Resource Locations

Followed by coal, nuclear plants are the second leading source of US electricity, providing nearly 20% of the nation's supply.

- Although broadly distributed throughout the country, nuclear energy is least prominent in the Mountain Region (only in Arizona), and most significant in seven Midwestern and Eastern states:
  - Coal and nuclear plants are both generally concentrated in the upper Midwest and Northeastern regions to support power-intensive industries and dense urban populations.
  - Illinois has six commercial reactors that produce nearly half of the state's electricity, and Pennsylvania ranks second with 5 plants.



Costs of Uranuim Purchased by Owners and Operators of US Civilian Nuclear Reactors by Origin and Delivery Year, 2003-2005.

While nuclear power plants are significantly more costly to build than coal or gas-fueled plants, coal is substantially more expensive than nuclear fuel, and natural gas is substantially more expensive than coal.

- Coal and nuclear plant operating and maintenance costs are comparable, but lower nuclear fuel costs have not yet offset higher investment costs:
  - In many countries, licensing, inspection and certification of nuclear plants add large additional construction costs and delays.
  - Streamlining and standardizing of regulatory processes for sighting, licensing and construction without compromising safety can offer strong development incentives.

Other general power production options offer important opportunities to reduce energy consumption from fossil, biofuel and nuclear sources, but are principally linked to local and off-grid applications.

- All of these "secondary options" are governed by geographic and site-specific conditions that constrain expansion capacities and utilization:
  - Mechanical energy from wind and hydropower is "free" and renewable, but is limited to locations with satisfactory seasonal climate and prevailing weather conditions.
  - Wind and solar are intermittent and somewhat unpredictable.
  - Hydroelectric and geothermal energy expansion is severely limited by a scarcity of practical and unexploited sites, along with environmental restrictions on new development.

234. SKF Group
235. EV World
236. How Stuff Works
237. ACRE


Mechanical and solar power is limited to sites with favorable weather conditions.


Hydroelectric and geothermal expansion is constrained by a scarcity of sites and environmental restrictions.

Expansion Limitations

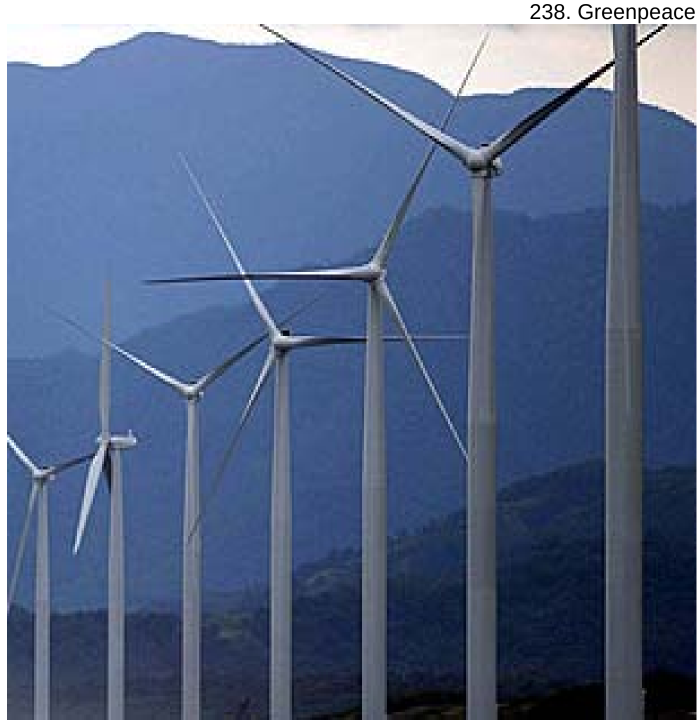
Capabilities and Costs

Moderating supply-side growth expectations

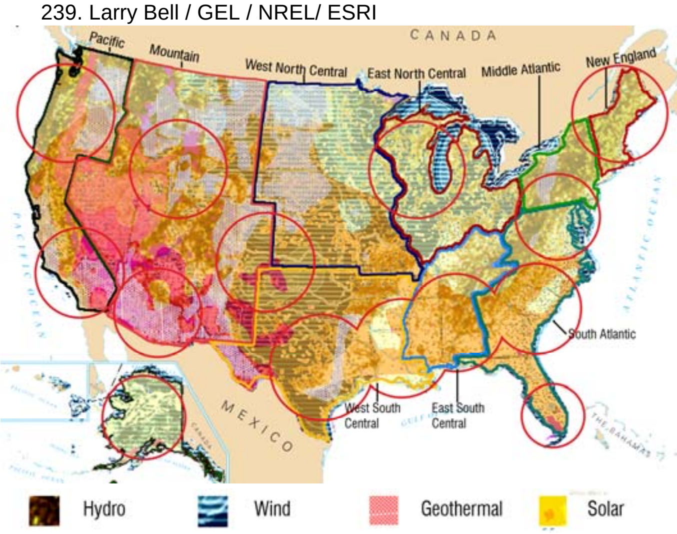
Wind energy currently represents only a small percent of US renewable energy capacity and total production, but is gaining rapid development.

- Passage of a Production Tax Credit (PTC) by the US Congress in 2004 has helped to boost corporate investment in this area:
  - US wind energy installations grew by more than 35% in 2005, adding about 2,500 megawatts (MW) of new capacity. (Each MW is enough to power 270-300 homes.)
  - Growth is occurring at a time when US customers are facing electricity and natural gas hikes due to fossil fuel shortages.
  - About 9,000 MW of wind energy (approximately the 2006 total) can potentially reduce natural gas consumption by 4%-5%.
  - Unlike large-scale drilling of natural gas fields and LNG terminal construction, wind plants can be rapidly built and permitted (requiring 1-2 years).

238. Greenpeace



239. Larry Bell / GEL / NREL/ ESRI



Clean renewable energy sources can support grid-connected and off-grid electrical needs. Circles show areas where multiple types converge to expand outputs and benefits.

Renewable Power

Renewable energy sources scattered throughout the US do offer important means to reduce fossil fuel consumption and provide primary power in certain locales.

- Unfortunately, some of the best sites are constrained from optimum use either by heavy residential development or by remoteness from population centers where power is most needed:
  - Wind energy is prevalent around the Great Lakes, along ocean coasts, in Appalachia, and throughout the Great Plains.
  - Geothermal energy is primarily found in the western half of the US, including Alaska and Hawaii.
  - Hydropower opportunities are most abundant throughout Pacific and Mountain Regions along with states bordering the Atlantic.
  - Solar power is most ideal in areas bordered by western Texas, most of Arizona, southern borders of Colorado and Utah, and the southern half of Nevada westward to California.

240. National Renewable Energy Laboratory

Utility-scale solar power systems are large, expensive, and are limited to regions with ideal Sun and weather conditions that tend to be remote from population centers.

While solar energy must be regarded as a very important resource to reduce fossil fuel energy consumption through home and business space and water heating economies, it is not likely to offer a major contribution in supplying national electrical power needs.

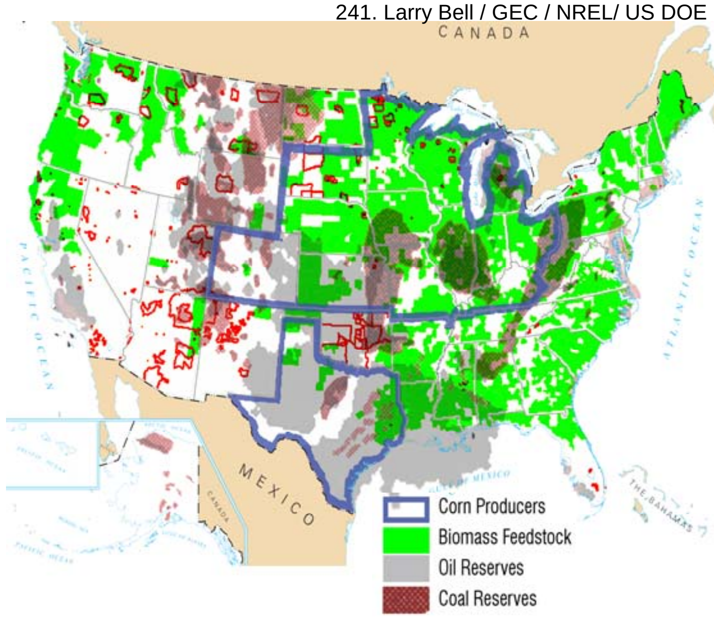
- The most effective and promising technologies, collecting solar power systems (CPSs); are limited due to a scarcity of suitable locations with adequate and dependable direct sunlight:
  - Optimal commercial PV systems require large, expensive arrays that require several years for investment cost recovery.
  - Many of the best sites are in remote areas distant from population centers where power is needed, requiring construction of distribution systems that add costs and cause transmission line losses.

Solar Power

Liquid biofuels and fossil fuels are likely to be dominant transportation energy sources for many future decades.

- Plant-derived ethanol and bio-oil produced throughout the US can extend diminishing fossil fuel supplies and benefit regional economies:
  - Corn ethanol opportunities are most prevalent throughout the West, and East North Central Regions, in north central Texas, and in Kentucky and Colorado.
  - Cellulosic ethanol possibilities are more broadly distributed in grassland and woodland areas found in most regions, and at all latitudes.
  - Crude oil reservoirs for petroleum refining are often associated with coal deposits in Mountain, and West South Central states, along the Pacific, Gulf Coast, and Alaska.
  - Additional opportunities for obtaining liquid fuels from coal gasification are present in Mountain states and Appalachian deposits.

241. Larry Bell / GEC / NREL/ US DOE



Liquid biofuel and fossil fuel resources are broadly distributed throughout the US.

Liquid Fuel Sources

242. Bob Swihart

Ethanol, mostly produced from corn in the US (and sugarcane in Brazil), is a key biofuel contender to extend fossil supplies.

- Although assessments of net corn ethanol life cycle yields vary considerably, prominent organizations and researchers project a net positive:
  - A study presented in the US Department of Agriculture *Agricultural Economic Report No. 813, 2002*, estimates that for every BTU needed to produce the fuel, there is a 34% energy gain.
  - The USDA report assumes that only about 17% of the production energy comes from fossil fuels (gasoline and diesel), so that for every 1 BTU of fossil fuel consumed, there is a 6.34 non-fossil BTU gain.*

It is much more economical to reduce fossil use than to replace excess consumption with bio fuels.

Corn Ethanol

243. USDA

Agricultural biofuels require substantial land and energy to grow and process the plants

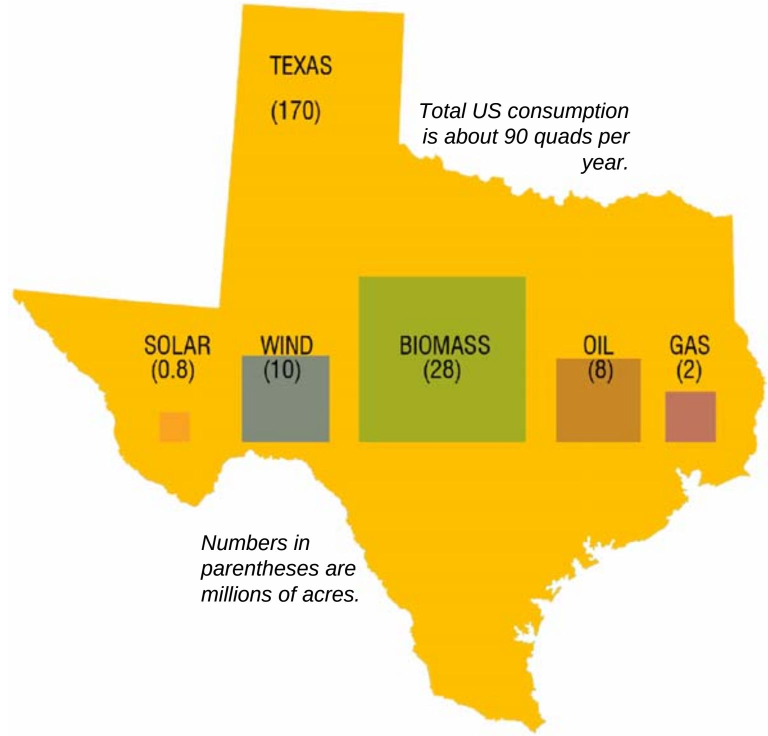
Independence from fossil fuels is not likely to occur any time soon.

- Replacing the vast majority of current US energy that comes from fossil fuel burning using agricultural plant biomass fuels, for example, will be difficult or impossible:
  - Croplands that provide essential food for livestock and humans would need to be multiplied many times and redirected to corn, sugarcane, soybeans and other biofuel feedstocks.
  - Most of that land and its yields would be needed to produce fuel required for the tractors and processing to create the fuel products.

Fuel Balances

* See Appendix: 28

244. Texas State Energy Conservation Office



One quad (or quadrillion BTUs) equals about 1 TCF of natural gas.

Land Areas Needed to Produce One Quad of Electricity

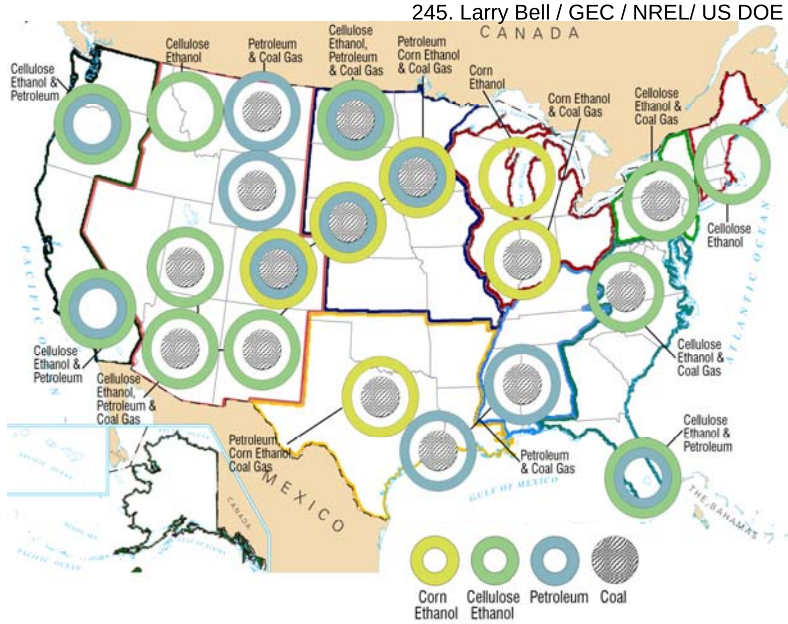
Since cultivation of corn for ethanol is very energy-intensive, ethanol produced from cellulosic plants such as switchgrass is gaining popular interest.

- Ignoring crop rotation requirements, an acre of switchgrass harvested 1-2 years after planting might produce 5-10 tons of biomass annually, with a yield of 50-100 gallons (190-380 liters) of ethanol per ton:
  - According to these estimates, approximately 25 million acres of land (39,000 square miles) would be needed to displace 1 million barrels of crude oil daily.
  - At this rate, about 3% of all available US crop, range and pasture lands would need to be utilized just to reduce projected 2050 oil imports by about 10%.

Possibilities exist to greatly expand small-scale ethanol production operations throughout the US.

- Ethanol plants can take advantage of area oil refineries and coalgas processing facilities to provide blends that are tailored to regional climate and regulatory requirements:
  - The northern Mountain Region, for example, can draw upon abundant cellulosic biomass and coal resources to create fuels for cold weather conditions.
  - Northern West and West North Central areas can utilize corn crops, stover and other agricultural biowastes combined with coal gas resources in nearby southern East South Central and northern Middle Atlantic Regions.

245. Larry Bell / GEC / NREL/ US DOE



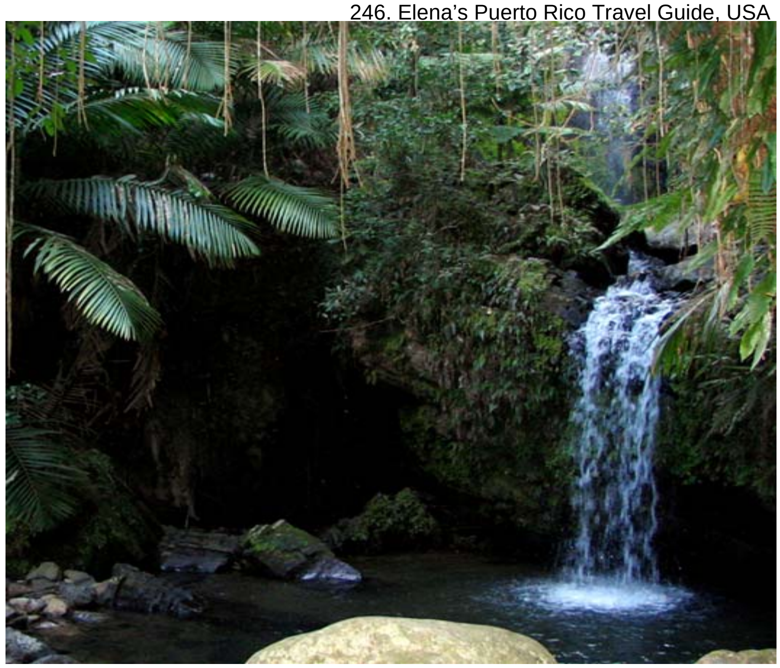
Combining Fuel Sources

Imperfect options and necessary actions

Regrettably, no renewable fuel or new technology option offers a panacea to fulfill expanding energy demands or to solve environmental problems associated with prevailing sources.

- All "alternatives" combine distinct disadvantages and limitation with benefits they afford:
  - Biofuels such as ethanol and biodiesel release CO_2 and other greenhouse gas emission just as fossil fuels do, they compete with food crops for agricultural land, and require energy to produce.
  - Hydrogen requires much more energy to produce than it yields through fuel cells, and is difficult to store and transport.
  - Geothermal, hydro, solar and wind power are vitally useful, but site limitations constrain nation-wide energy contributions.

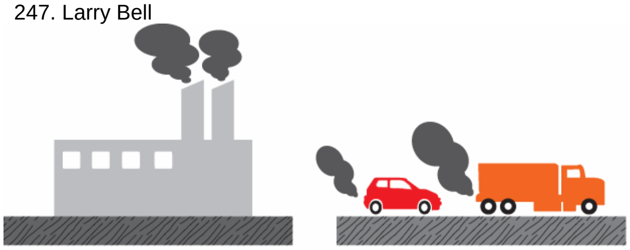
246. Elena's Puerto Rico Travel Guide, USA



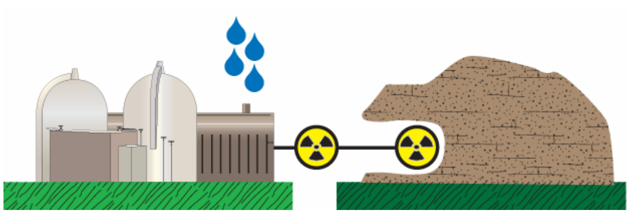
Nature uses a huge diversity of different mechanisms and organisms to produce energy for life using solar energy, biomass, recycled heat and other sources. It is clear that we must do the same.

A Need for Diversity

247. Larry Bell



Fossil and bio-fuels produce atmospheric combustion contaminates



Nuclear plants emit only water, but produce wastes that must be sequestered.

Pollution Tradeoffs

Available power production options that can supply substantial percentages of US requirements are few, each presenting advantages and disadvantages.

- Just as none offer a total solution, there are also none that can be excluded as a non-essential:
  - All fossil sources are non-renewable and release CO_2 and other atmospheric pollutants when combusted.
  - All biofuels also release combustion pollutants, and although often cleaner, only marginally extend rather than replace fossil fuels; require energy for production and processing that may release pollutants; and some compete with land use essential for livestock/food crops.
  - Nuclear power releases no atmospheric pollutants, but presents safety, security and waste storage concerns.
  - Hydrogen (fuel cells) are net power consumers, but provide the only fuel that can be created from electricity.

248. Larry Bell

Oil and Natural Gas **Advantages:** • High energy densities • Many derivative products • Easy to store and transport **Disadvantages:** • Dwindling global supplies • CO_2 and other emissions	**Coal** **Advantages:** • Good energy densities • Many derivative products • Presently relatively abundant • Cleaner technologies available **Disadvantages:** • Mining impacts upon land areas	**Biofuels** **Advantages:** • Resourceful use of biowastes • Can reduce fossil fuel use • Apply current technologies **Disadvantages:** • Compete for land with food crops • Produce CO_2 when burned
Nuclear Power **Advantages:** • Potentially a substantial source • Environmentally-clean energy • Relatively abundant / inexpensive **Disadvantages:** • Possible safety/security risks • Concerns about safe storage	**Hydrogen** **Advantages:** • Derived from multiple sources • Technologies being improved **Disadvantages:** • Low energy density / volume • High costs of production • Difficult to store/transport	**Solar Power** **Advantages:** • Excellent energy supplement • Free energy following installation • Concentrator techs promising **Disadvantages:** • Geographic/weather limitations • High implementation costs
Geothermal Power **Advantages:** • A free energy source • Environmentally-friendly energy **Disadvantages:** • Limited geographic sites • Few high temperature sources • Not currently cost-competitive	**Hydropower** **Advantages:** • Free energy after installation • New technologies developing **Disadvantages:** • Limited geographic sites • Environmental marine impacts • Large systems are costly	**Wind Power** **Advantages:** • Free following installation • Environmentally-friendly energy • Rapidly decreasing costs **Disadvantages:** • Weather-dependent operations • Substantial implementation costs

Key Advantages and Disadvantages of Various Sources

Energy alternatives and related needs, sources, environmental impacts and safety/security issues are subjects of hotly-contested disputes among groups with opposing viewpoints.

- Common aspects of these adversarial outlooks are that the passions expressed are justified, and the arguments are typically valid:
  - Public energy independence, environmental and health safety concerns associated with all options are clearly legitimate, and are shared by most development and operating companies that are proud of progress and achievements in these areas.
  - Yet, essential progress is hampered when strong lobbies favouring one particular energy solution as an ultimate answer work to block development of others that are also vital.

249. ORNL
250. Western Libraries
251. MYAA Site
252. The Livingroom

Meeting Demands

Safety and Security

Protecting Nature

Future Needs

253. Larry Bell

Advocates →		← Opponents
Is essential to reduce foreign dependence	Expansion of Oil & Natural Gas Drilling	Must protect limited existing supplies
New sources needed for economy / living		Limiting supplies promotes conservation
New development requires years		Improved conservation can solve the problem
Oil / natural gas are energy-efficient		Cleaner alternatives are available / essential
Essential to support growing import needs	New Ports, Terminals & Refineries	They all present major terrorist targets
Technologies are safer / cleaner than in the past		Offshore operations pollute marine life
Necessary to prevent regional power gaps		Don't put them in my region / backyard
Are vulnerable to disasters / breakdowns		Efficiency upgrades have kept pace with demands

Oil and Natural Gas Development

Advocates →		← Opponents
Coal is our most abundant fuel source	Coal Mining & Power	Cleaner alternatives are available / essential
Clean coal technologies are reducing emissions		Gasification requires large CO_2 containment
Coal is a source of important derivatives		We can obtain them from biomass / biofuels
Coal mining is vital to regional economies / jobs		Mining operations harm people / ecosystems
Nuclear power has large expansion potential	New Nuclear Power Plants	Don't produce it in my region / backyard
Plants produce no CO_2 emissions, only water		Radioactive waste is an environmental hazard
Advanced technologies have proven very safe		Breakdowns / terrorism present large threats
Fuel reprocessing can greatly extend supplies		Breeder reactors can proliferate weapons

Coal and Nuclear Power Development

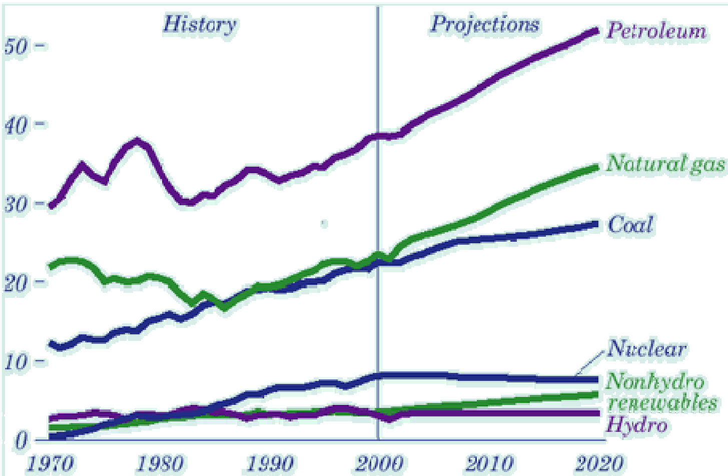
Advocates →		← Opponents
Produces clean power	Hydrogen Fuel Cells	Production can pollute
Has good power density		Is a net energy user
Usable in different forms		The gas is explosive
A renewable alternative		Is difficult to transport
Are renewable sources	Corn / Cell. Ethanol	Can compete with food
Can reduce fossil use		Reduction may be limited
Releases only "new" CO_2		CO_2 is CO_2,
Cellulose uses biowaste		Processing can be costly
A "free" energy source	Solar PV / Concentrat.	Devices are expensive
Solar Is broadly available		Not always optimum
Can reduce fossil use		Limited energy production
Offer versatile applications		Often requires storage

Hydrogen, Biofuel and Solar Power

Advocates →		← Opponents
A clean power source	Wind Power	Not in my backyard
An abundant source		Depends upon location
A "free" energy source		Requires large investment
Can reduce fossil use		Intermittant availability
A clean power source	Hydro Power	Can pose ecohazards
An abundant source		Very limited locations
A "free" energy source		Plants can be costly
Can reduce fossil use		Limited growth potential
A clean power source	Geothermal Power	Sites are often restricted
An abundant source		Can deplete heat/pressure
A "free" energy source		Plants can be costly
Can reduce fossil use		Often not very efficient

Wind, Hydropower and Geothermal

254. US DOE - EIA



Although we may see a continuing rise in use of non-fossil renewables, these fuels are predicted to represent only a small fraction of US energy over the next several years. Petroleum, natural gas and coal will remain to be primary sources.

US Fuel Consumption Projected, 1970 - 2020

Forward-looking energy strategies and developments will not occur without controversies and compromises.

- Growing needs and costs to fuel industry, domestic heating/cooling and power, transportation and other services are certain to prompt public policies that are not popular with everyone.
  - Nuclear power must be considered as an important option which can reduce CO_2 emissions on one hand, while also presenting legitimate safety and security concerns.
  - Biofuel development is a logical way to extend fossil resources, but can only do so at the expense of land for food crops and/or with modest net energy benefits.
  - Subsidies and tax incentives for renewable resource development and use will be disagreeable with many who challenge their real impacts and economic viability.

Fossil Fuels:

- Ease restrictions on oil and gas development on public lands.
- Ease permit processes for refinery expansion/construction.
- Offer tax breaks for clean coal technology use.

Power Plants:

- Speed licensing procedures for new hydroelectric/thermal plants.
- Streamline processes for power plant site approvals.
- Ease clean air regulations to make plants more efficient.

Nuclear Power:

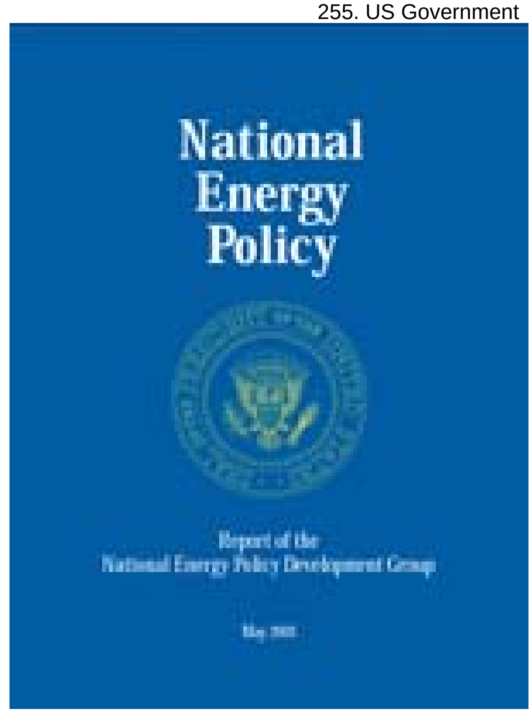
- Speed relicensing of reactors and licensing of new plants.
- Limit industry liabilities from accidents.
- Allow spent fuel to be reused (prohibited since the 1970s).

Renewable Energy:

- Tax credits for plants that use organic waste/biomass.
- Tax credits for wind energy and household solar panels.
- Tax incentives for alternative fuels and hybrid vehicles.

The Bush Administration has proposed to reduce gasoline use by 20% in the next 10 years through greatly expanded alternative fuel use and tougher vehicle economy standards.*

255. US Government



Representative Recommendations of the National Energy Policy Development Group Report, US National Energy Policy, 2001 Recognize the Importance of All Options

* **See Appendix: 29**

Regional strategies and cooperative initiatives

Rather than seeking universal solutions to national energy challenges, it may be much more productive to concentrate more upon developing nationally-integrated special-case regional strategies.

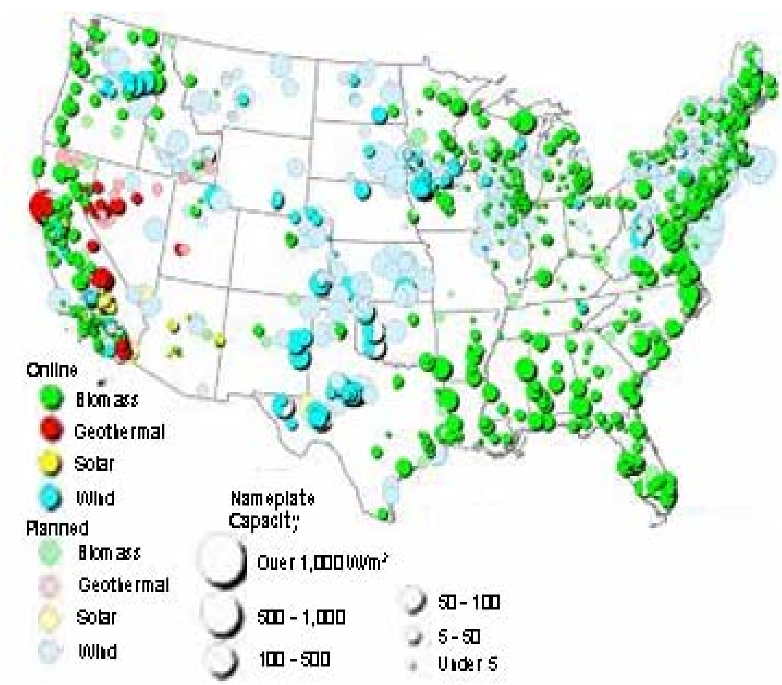
- Strong evidence of opportunities and trends in this direction are already apparent:
  - Energy industry deregulation is opening markets for smaller power utility companies that take advantage of more efficient CHP production to serve local district needs.
  - Emergence of regional "boutique" fuel mixtures tailored for seasonal weather and state regulatory restrictions offers new advantages for smaller specialty refiners.
  - State governments and regional alliances are taking more active roles to promote and develop energy resources most appropriate to their unique resources, needs and economic opportunities.

256. Larry Bell

Priorities	Strategies
Develop appropriate energy supplies and technologies	Provide incentives for energy investments
Create and expand efficient distribution infrastructures	Coordinate state / regional programs and networks
Concentrate supplies / services where needed most	Optimize CHP and other shared-use opportunities
Anticipate demographic trends and future needs	Plan / implement long-term development initiatives
Transition to cleaner / safer energy solutions	Promote / facilitate green energy co-op programs
Encourage conservation in homes and businesses	Establish public information and education programs

Representative Regional Priorities and Strategies

257. Renewable Energy Access



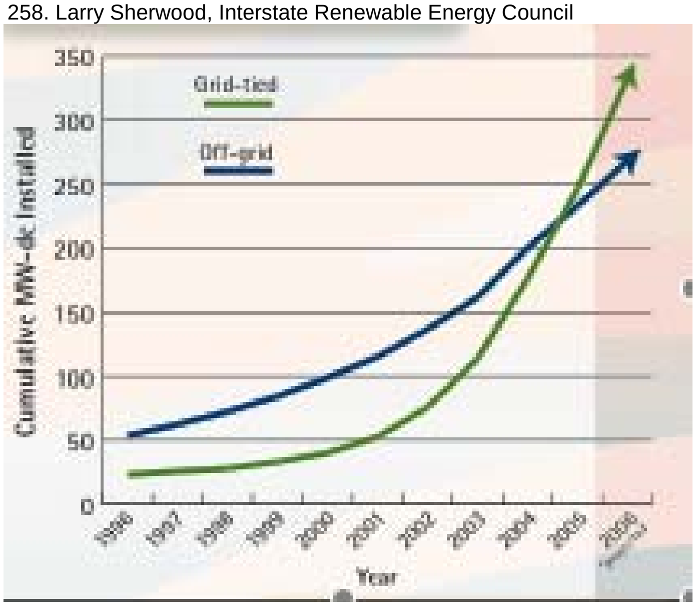
Current and Planned Renewable Energy Facility Locations

Availability of diverse regional resources and needs in combination with changing demands posed by population and business shifts, global geopolitical developments, and technology advancements make reliance upon any single answer both impractical and dangerous:

- Recognizing that while it is important that renewable energy sources be developed and utilized, this can not provide a near-term substitute for urgent expansion of clean coal and nuclear capacities as well:
  - True resourcefulness demands that all options be developed and optimized, including ways to make them more environmentally-friendly and efficient.
  - Efficiency includes means to consume less and put precious available resources to better use. *

* See Appendix: 30

258. Larry Sherwood, Interstate Renewable Energy Council



Cumulative US PV Installations by Year

Photovoltaic and other green power producers are supplying increasing amounts of excess electricity back to grids for energy credits.

State Government Initiatives

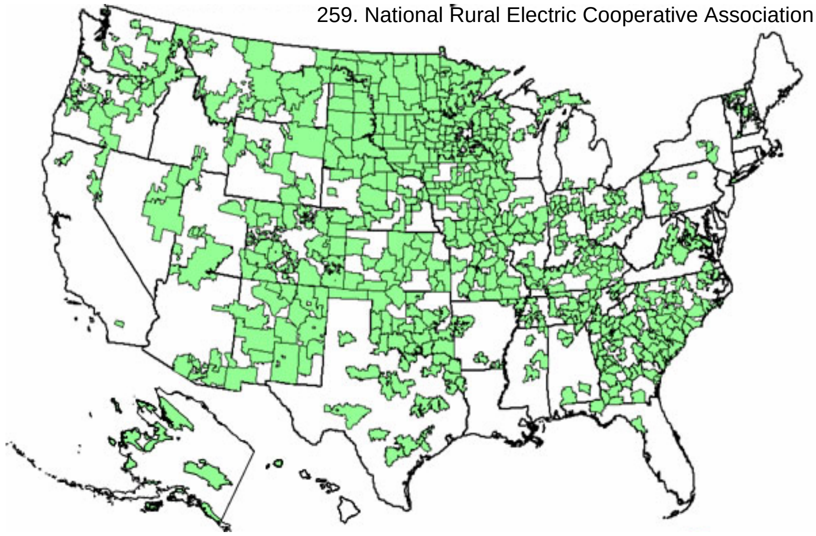
A growing number and variety of state and regional conservation programs are being enacted with popular public and industry support.

- Many of these initiatives provide economic incentives: *
  - Legislation establishing stricter environmental standards for equipment and building codes are realizing progress through tax credits and other benefits.
  - Many states are providing education and financial assistance for implementing efficient technologies and renewable energy solutions for farms, rural businesses, and agricultural and forest-thinning industries.
  - Thirty-nine states now allow green power homes and businesses to sell excess electricity back to grids, and 36 offer state-wide programs for this purpose.

"Green power co-ops" producing electricity from wind, photovoltaic and biomass are a popular trend in many parts of the country.

- *More than 550 rural electric systems offer green power through co-ops that supply energy to local grids. Member owners operating "backyard" systems receive revenue incentives.*
  - Typical home-sized solar power systems producing about 1kW and costing $13,000-$20,000 might return approximately $200-$250 per year to help make installations more cost-effective.
  - Wind cooperative members often run larger 10kW turbines and offer low-interest loans to finance installation costs.

259. National Rural Electric Cooperative Association



Rural Electric Systems

* **See Appendix: 31**

Development of regional energy resources can also potentially reduce national vulnerability to incapacitating acts of terrorism through decentralization of supplies.

- The health of the US economy is ultimately linked to its electricity and fuel infrastructure:
  - The country relies upon thousands of miles of power lines, pipelines and associated support facilities that are difficult to protect.
  - Large power generating stations such as dams and nuclear plants, along with ports and refineries, also present special risks.
  - Attacks on September 11, 2001 have prompted policymakers, state representatives, emergency management and law enforcement officials and energy leaders to more actively plan and coordinate energy security and independence programs.

260. Aachua County, Florida

Terrorist attacks on New York and Washington, DC, brought energy security and independence into the forefront of American consciousness.

Energy Security

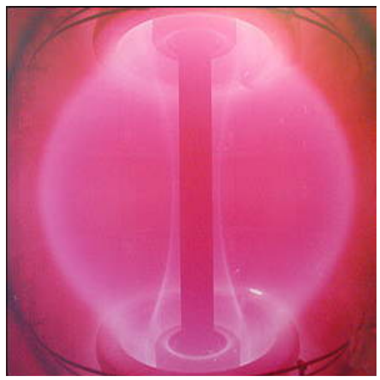
261. Larry Bell

Our Only Real Option is to Resourcefully Optimize All

262. Pacific Environment
263. Seagen System
264. Scienmet Group Russia
265. NASA
266. BBC News
267. All 4 Engineers
268. USDOE
269. U of Georgia
270. USDOE-EERE









PART THREE: FUEL & POWER TECHNOLOGIES

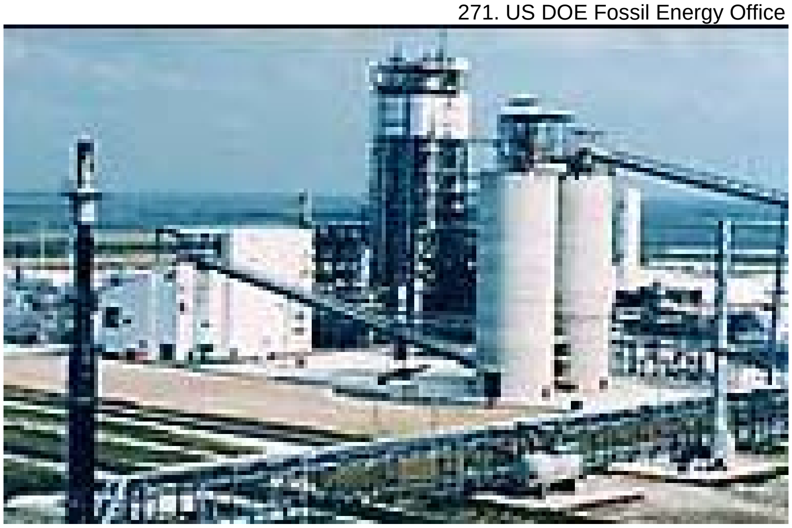
OUTPUTS, DELIVERY EFFICIENCES, AND NEW DEVELOPMENTS

Greener energy from coal

Gasification offers a versatile and clean way to convert coal into electricity, hydrogen, diesel and other energy products, such as aviation fuels.

- Rather than burning coal directly, the process breaks it down into its basic chemical constituents:
  - In modern gasifiers, the coal is exposed to hot steam and carefully controlled amounts of air or oxygen under high temperatures and pressures.
  - When carbon molecules break apart, they set off chemical reactions that produce a mixture of carbon monoxide, hydrogen and other gaseous compounds.
  - Coal gasification provides a capability to create fuels with extremely low sulphur and carbon dioxide content advantages.

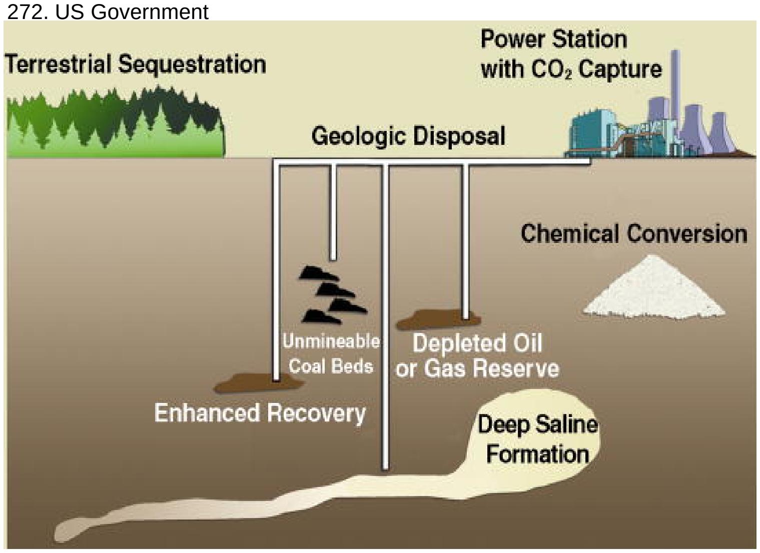
271. US DOE Fossil Energy Office



The clean coal technology field is moving rapidly towards gasification with CO_2 capture, offering 73% thermal efficiency. Using hydrogen produced in gas turbines for electricity may offer long-term potentials to achieve overall system efficiencies up to 60%

Coal Gasification Plants

272. US Government



Much of the CO_2 collected from current coal processing is sequestered in deep geological strata such as aquifers and depleted oil fields. This gas can be of increasing value for enhanced oil and natural gas (methane) recovery as these resources are depleted.

Carbon Sequestration Options

CO_2 produced by coal processing must be either stored (sequestered) or used.

- While the scale of need for CO_2 disposed far exceeds today's uses, the product does offer practical value:
  - Millions of tons of CO_2 are injected into oil fields for enhanced oil recovery each year.
  - CO_2 is also injected into deep, unmineable coal seams where it is absorbed to displace methane. (While this is currently not as economical as enhanced oil recovery, the future potential is large.)
  - CO_2 is used for a variety of commercial applications, including carbonation of soft drinks and soda water, as a leavening agent in baking, for fire extinguishers, and as an inexpensive atmosphere for welding.

273. Intertek Petroleum Industry Applications

Coal-derived fuels, including hydrogen, can potentially be processed in conventional petroleum refineries.

Processing of coal to create liquid synthetic fuels may significantly extend and eventually replace crude oil-derived petroleum products.

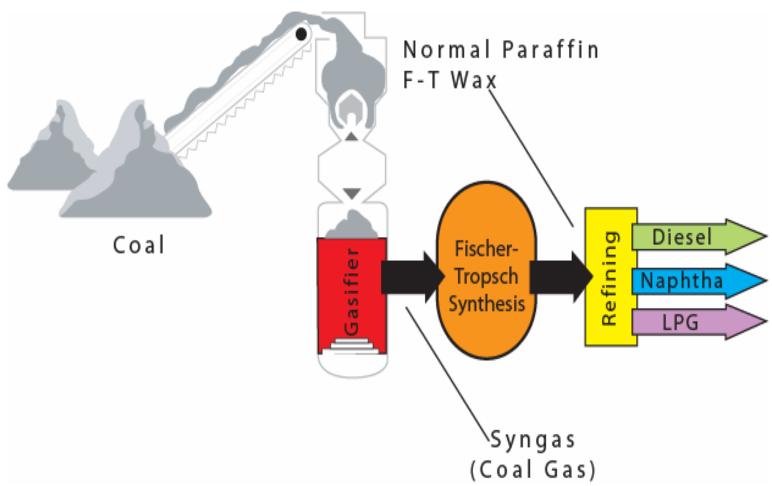
- Although this gas-to-liquid capability can be traced back to the Fischer-Tropsch process development of the 1920s, continuing research is revealing new possibilities:
  - Recent experiments are yielding coal-derived jet fuel, a high-grade kerosene that remains stable at high temperatures, which may prove essential to the future of commercial and military aviation.
  - Some coal-derived liquid fuel processes can be accomplished in conventional petroleum refineries for production of gasoline, diesel, fuel oil, and even hydrogen for fuel cells.

Coal-Derived Liquid Fuels

Researchers at the Penn State University Energy Institute have demonstrated that jet fuel for high-performance military and commercial aircrafts can be produced from coal.

- Two alternative methods have been successfully tested:
  - One uses a variant of a process used in petroleum refining where bituminous coal is combined with a byproduct petroleum oil and heated until the liquid portion distills off as jet fuel (leaving solid coke as a useful secondary product).
  - The second process mixes coal-derived chemical oil (a byproduct of the coke industry), with a light petroleum oil, and adds hydrogen to produce jet fuel as a distillate.

274. Missoula News



The original Fischer-Tropsch process to convert coal into liquid fuel was developed by German researchers during the 1920s and is still used to produce diesel fuel today in South Africa and China. Although currently more expensive than diesel from crude oil, this approach is likely to become more cost-competitive as petroleum sources are depleted and prices rise.

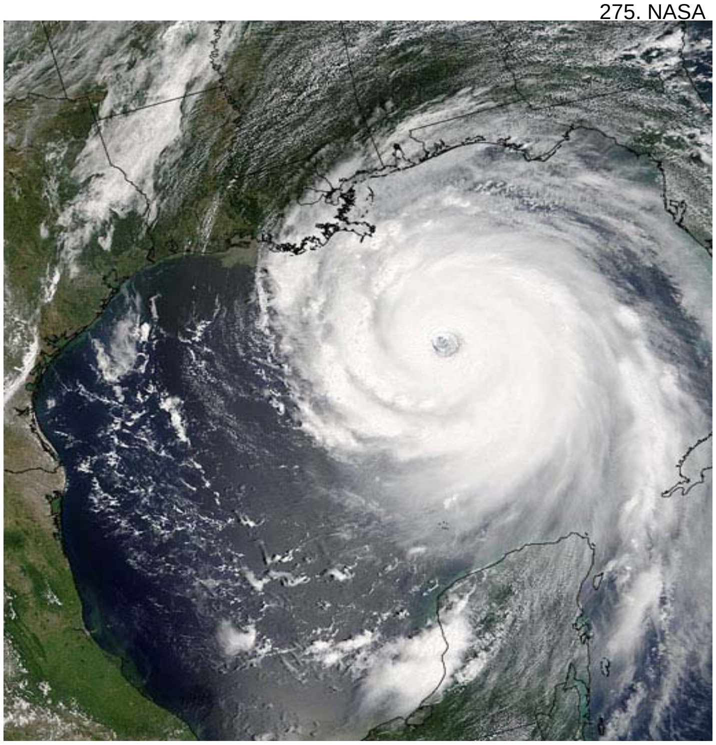
Coal-Liquid Fuel Process

Oil and natural gas production, processing and derivatives

Strong public concerns about air and wastewater contamination produced by oil refineries have led to US government regulatory restrictions that severely limit gasoline processing capacities.

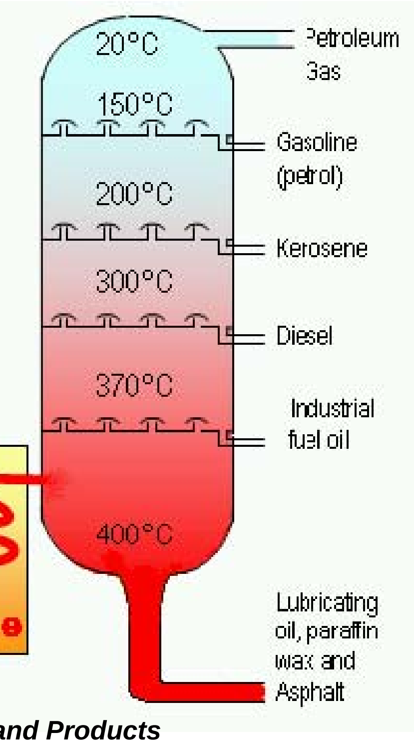
- No new major refineries have been built in the US since 1976, although many existing plants have been expanded:
  - Noxious odors in the vicinities of refineries, in combination with the risk of fires and explosions, contribute to public resistance to capacity expansion.
  - Such process limitations make US gasoline supply-demand balances particularly vulnerable due to crude oil supply interruptions caused by hurricanes impacting domestic sources, and international instabilities that disrupt imports and pose plant security threats.

275. NASA



Vulnerable US Petroleum Production

276. Chemistry Daily



Oil Refining and Products

Processing of gasoline is but one of many products that compete for crude oil use.

- Refineries separate the raw oil into a variety of solid, liquid, and gaseous parts using fractional distillation furnaces:
  - Oil contains hydrocarbon molecules of varying masses and lengths, each with special chemical properties and uses.
  - Fractional distillation uses different temperatures in fractionating columns to separate the molecules, where lighter ones rise to cooler regions on top, and heavier fractions emerge at lower levels.
  - The heavier molecule fractions can then be broken up (“cracked”) into lighter short chains to create other products.

277. *Automotive Handbook* (data), *4th Edition*, Robert Bosch GmbH, 1996

Fuel Type	MJ/l	BTU/US Gal
Naphthalene	47.14	169,100
Diesel	40.9	147,000
Gasoline	32.0	125,000
Gasohol (10% ethanol + 90% gasoline)	28.06	120,900
LPG	22.16	95,475
Ethanol	19.59	84,400
Methanol	14.57	62,800

Gasoline contains about 32 megajoules per liter (MJ/L) or 131 MJ/US gallon.
** Since diesel is not used in gasoline engines, a low octane rating is not an issue.*

Energy Density Content of Different Fuels

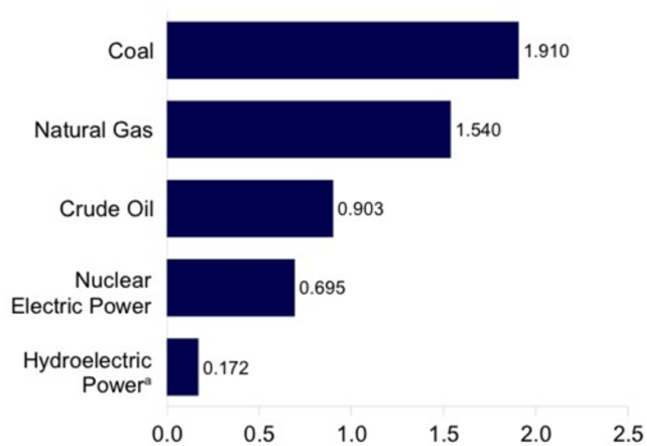
Octane ratings determine how resistant a particular gasoline mixture is to premature detonation in an engine, which causes knocking.

- Following fractional distillation and contaminant removal, different product streams can be recombined to meet specific octane requirements:
  - Octane can also be improved by catalytic reforming which strips hydrogen out of hydrocarbons to produce "aromatics" which have much higher ratings.
  - The final step in gasoline production is to blend fuels of different octane ratings, vapor pressures, and other properties.
  - Exact ratios depend upon the particular refinery (not all have the same processing units), the grade of crude oil available at a given time, and distributor demands.

Natural gas is a substantial source of US energy for industry, electricity and heating, and also an important feedstock for other fuels and chemicals.

- As a fuel, natural gas burns cleaner than other fossil types:
  - It produces about 30% less carbon dioxide than petroleum, and about 45% less than coal for equivalent heat.
  - It is often used to supplement other fuels (coal, wood and biomass) to improve combustion efficiency of low-grade materials (such as wet wood) and to reduce emissions.
  - Compressed natural gas (CNG) can offer a cleaner alternative to gasoline for automobiles with comparable energy efficiency, but does not work well in modern diesel engines.

278. US DOE-EIA, Monthly Energy Review, December 2006



Natural gas supplies about 23% of all US energy. This includes nearly 24% of all electrical power, about 38% of all energy for industry, 13% of all energy for commercial facilities, and heating and cooling for more than 60 million households.

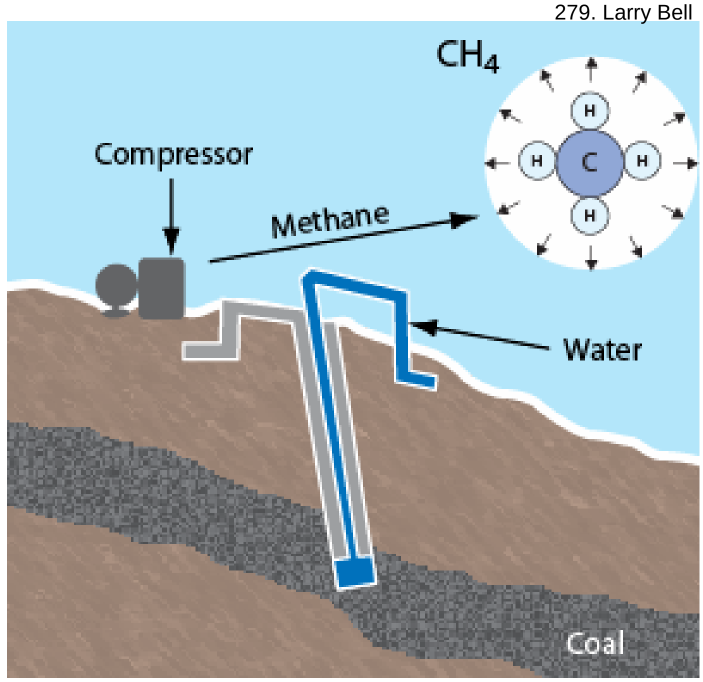
The US Energy Information Administration (EIA) projects that US natural gas consumption will increase by more than 40% over the next 2 decades.

Total US Consumption by Major Sources (2006)

Natural gas is collected from oil wells as “casinghead gas”, and is also obtained from gas fields and coal beds.

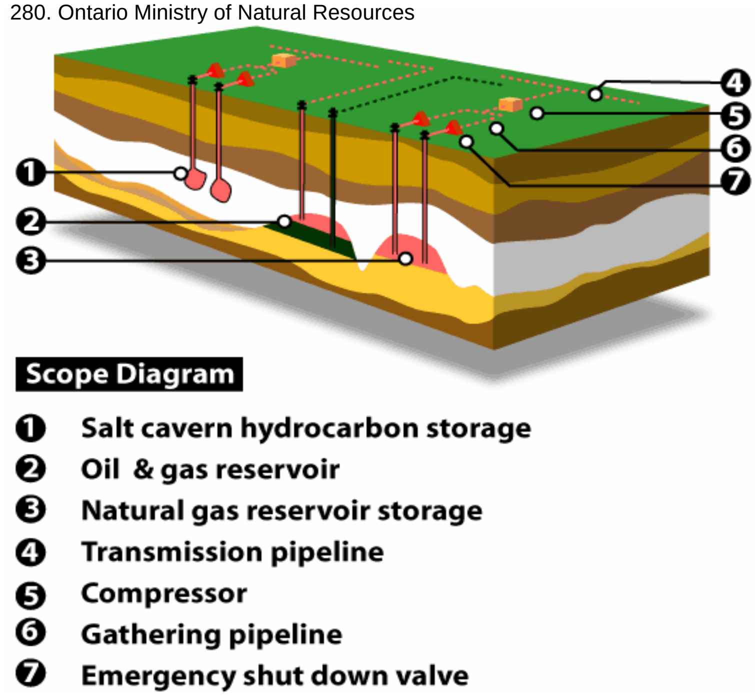
- Prior to use, the gas is cleansed of sulfur impurities such as hydrogen sulfide (H_2S):
  - The gas is a major source of electricity production through gas and steam turbines (often operated in combined cycles to optimize efficiency).
  - Compressed natural gas (CNG) is used as an alternative to liquid automotive fuel.
  - Although natural gas can be explosive when confined at concentrations of 5% - 15% of air, this is not a hazard with CNG used in vehicles.
  - Since processed gas is odorless, small amounts of thiol odorants are added to assist in leak detection.

279. Larry Bell



Natural Gas Collection and Processing

280. Ontario Ministry of Natural Resources

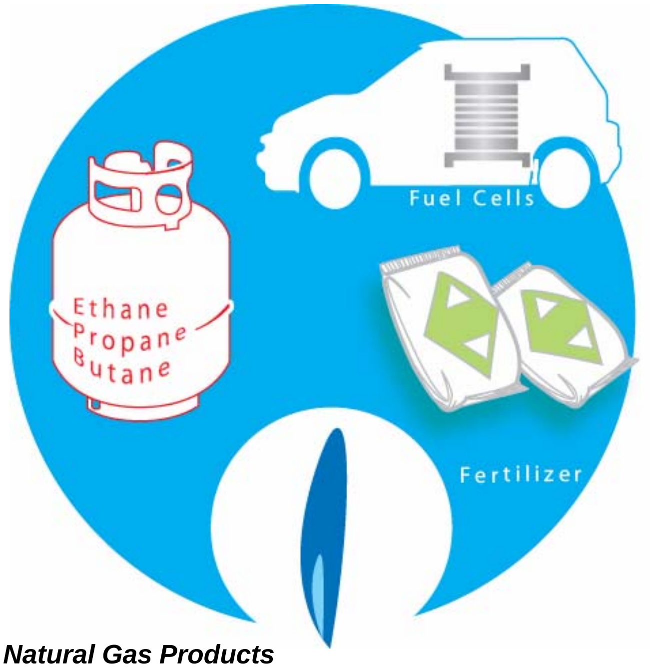


Natural Gas Storage Reservoirs

Although natural gas collected from oil field operations in recent years was not a commercially profitable product and was simply burned (“flared”), this circumstance no longer holds true.

- This gas is now recognized to be a very valuable, non-renewable resource:
  - Flaring is no longer practiced in the US because it pollutes the atmosphere.
  - Oilfield gas is now re-injected back into a formation, stored in underground caverns formed inside depleted gas wells, in salt domes, or in LNG tanks for later recovery during high demand periods.
  - Storage near ultimate end-users is most convenient to address highly volatile demands, but isn’t always possible due to land use restrictions associated with limited urban space and public safety concerns.

281. Larry Bell



Natural Gas Products

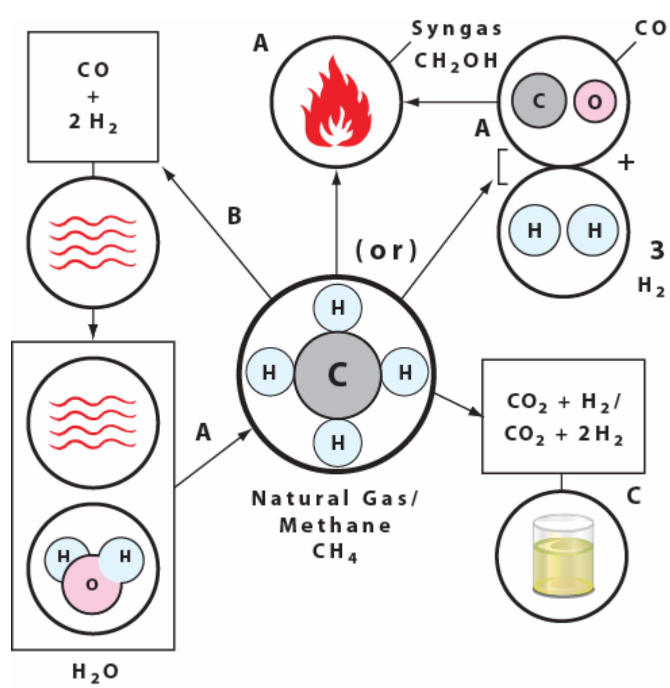
In addition to direct energy use, natural gas also serves a variety of other valuable purposes.

- Consisting mostly of methane (CH_4) it is a primary feedstock for producing secondary fuels, fertilizers and other chemicals:
  - Methane is a major source of hydrogen for industrial use and fuel cells, and also helium.
  - Steam methane reforming (SMR) is used to commercially produce syngas (CH_2OH) and methanol (CH_3OH).
  - Natural gas methane is an important feedstock for manufacturing butane, ethane, propane, and ammonia fertilizer.

Steam methane reforming (SMR) using natural gas is the most widely used method to produce hydrogen (and can also be used to produce methanol and syngas), but is an energy-costly use of this non-renewable fuel source.

- SMR uses steam and a nickel catalyst, applying three process options:
  - **Option A**: Methane reacts endothermically with steam to create carbon monoxide and hydrogen ($CH_4 + H_2O \rightarrow CO + 3H_2$) or syngas ($CH_2OH$).
  - **Option B**: Methane undergoes partial oxidation with oxygen to release heat to drive the SMR process as a precursor step to conserve energy in producing methanol ($CH_4 + 0.5O_2 \rightarrow CO + 2H_2$).
  - **Option C**: The ratio of CO and H_2 from option B is reacted with a second catalyst (copper, zinc oxide and alumina) to produce methanol ($CO + 2H_2 \rightarrow CH_3OH$).

282. Larry Bell



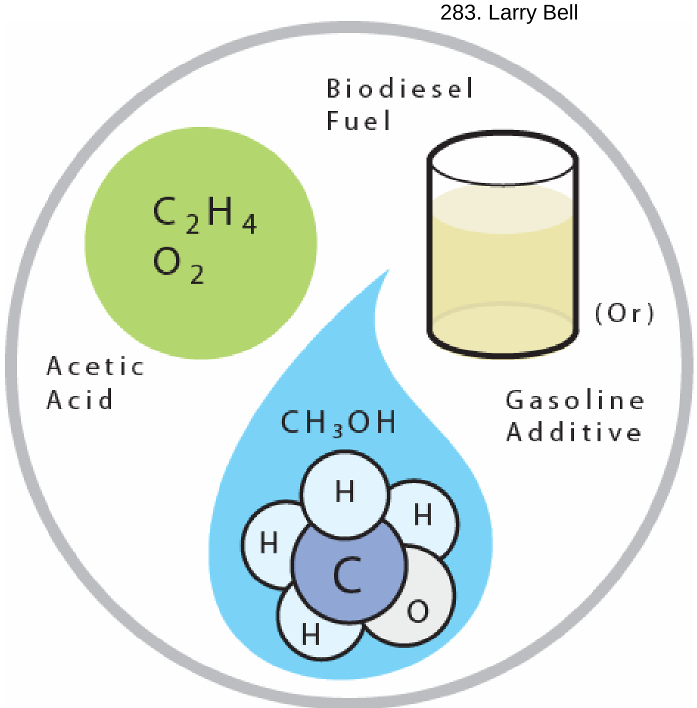
Hydrogen, Methanol and Syngas Production Using Steam Methane Reforming (SMR)

Methanol and biofuels from fossils and organic wastes

Methanol (or methyl alcohol) is most commonly produced from the methane component of natural gas or syngas, but is also a product of coal gasification.

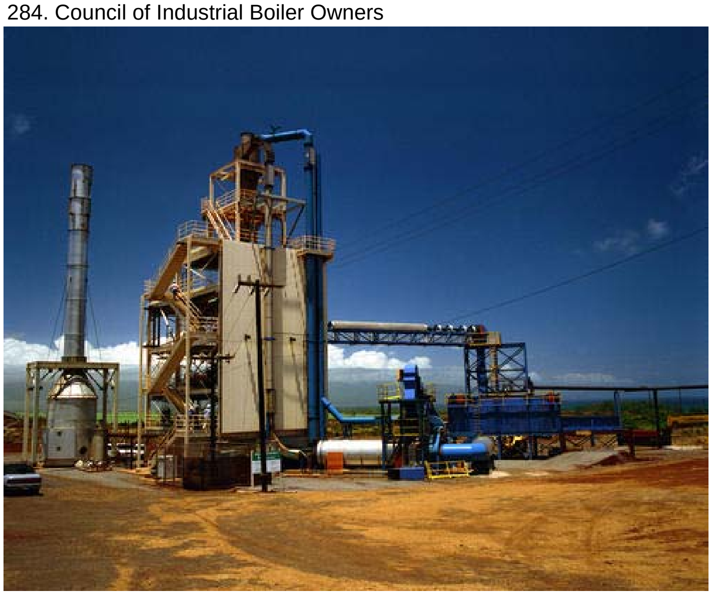
- The chemical compound (CH_3OH) is the simplest and cheapest alcohol created by anaerobic metabolism:
  - Methanol is used on a limited basis to fuel internal combustion engines, but is not nearly as flammable as gasoline.
  - It can be reacted with vegetable oils to produce biodiesel.
  - Methanol is often mixed with gasoline on an 85% methanol, 15% gasoline basis to boost energy performance ("methanol 85").
  - The drawback to its use as a fuel is its corrosive nature that degrades aluminum and other metals.
  - Its largest use by far is to obtain acetic acid to produce plastics, wood glue, paints, explosives and permanent-press textiles.

283. Larry Bell



Methanol

284. Council of Industrial Boiler Owners

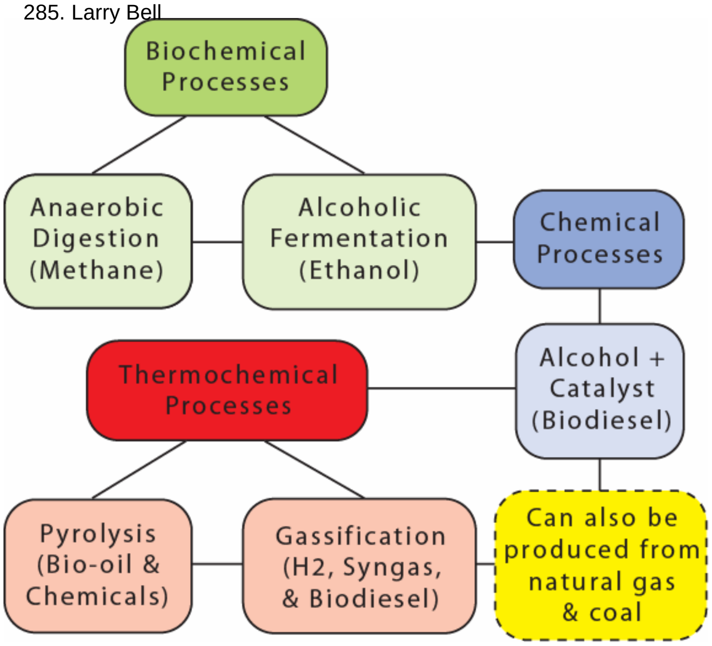


Direct Burning of Biomass

Biomass from renewable plant and animal wastes provides a fuel that can be burned directly to power steam-driven turbines.

- Some biomass industries use spent steam from biomass combustion to heat buildings as well as for manufacturing energy:
  - Combined heat and power CHP can greatly increase overall energy efficiency.
  - Paper mills are the largest current producers of biomass power, and typically use the generated electricity and process heat to support recovery of pulping chemicals.
  - Co-firing, which mixes biomass with fossil fuels such as coal, can significantly reduce process emissions (especially sulfur dioxide).

285. Larry Bell



Biofuel Conversion Methods

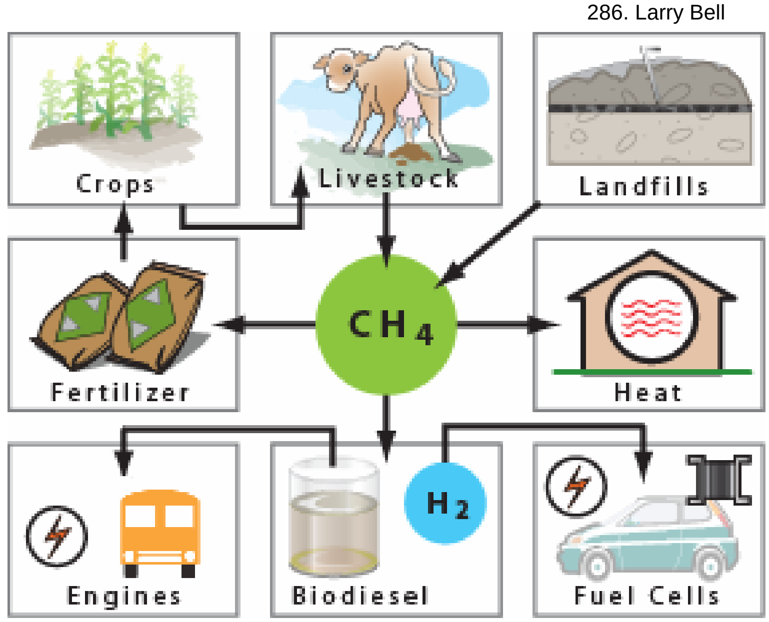
In addition to use as a direct fuel, biomass is converted to bio-oils, biogas and petroleum additives through various chemical means:

- Key among these are biochemical, chemical and thermochemical processes:
  - Biochemical (or organic) processes use natural decay methods (anaerobic digestion and fermentation) to produce methane and liquid fuels and feedstock.
  - Chemical processes mix biomass and other fuel products together into combined forms using catalysts to create liquid fuels.
  - Thermochemical processes (pyrolysis and gasification) use heat to convert biomass and fossil fuels into hydrogen, biogas and other energy and feedstock materials.

Methane gas is the simplest of all organic compounds, and is an important feedstock for other compounds and commercial hydrogen production.

- Large amounts are produced through digestion of carbonaceous biomass by microscopic methanogenic organisms in the stomachs of mammals, in swamp sediments, in landfills, and in other anaerobic environments.
  - Recycled methane-derived fertilizers are used to provide nutrients to support plant growth.
  - Plant oils, combined with methane-derived methanol, create biodiesel fuel for tractors and power generation.

286. Larry Bell



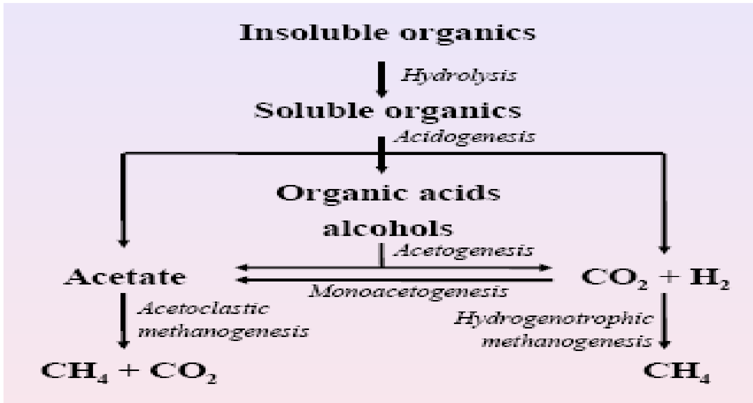
Methane Life Cycles

Landfills and waste treatment facilities as methane resources

"New" biomass gas is produced through a biochemical anaerobic digestion process which breaks down organic matter by microbiological activity in the absence of air.

- Three common man-made technologies are used:
  - Wells drilled into landfills release methane from decaying organic matter which is piped to central points where it is filtered and cleaned before burning.
  - Fermentation of human and/or animal wastes in specially-designed anaerobic digesters kills bacteria in the manure and produces methane.
  - Anaerobic treatment of municipal and industrial sludge, human and animal wastes, and municipal wastewaters can yield energy conservation, waste / odor removal and pathogen control benefits.

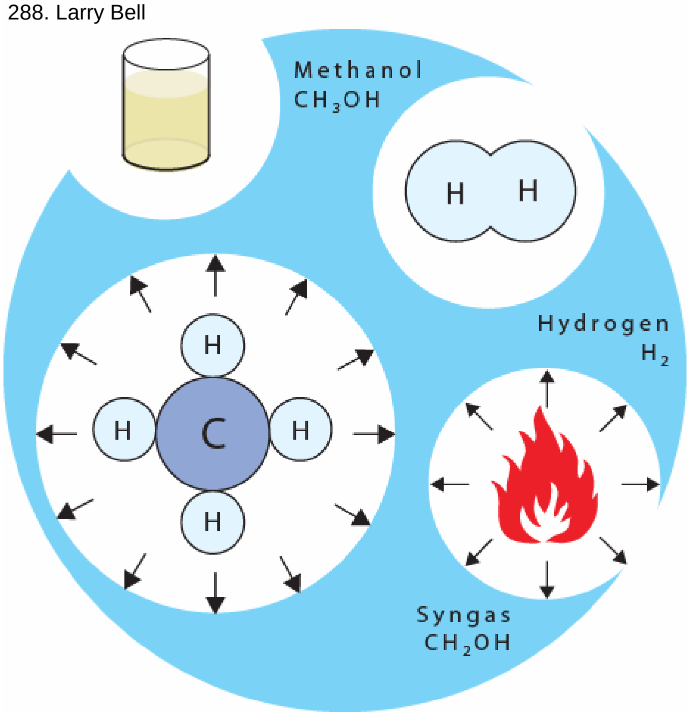
287. INRA Montpellier



Anaerobic digestion transforms organic materials under oxygen-free conditions into biogas, nutrients, salts and cell matter. The process involves an acidification (acid) phase, and a methanogenic (methane) phase.

Methane from Anaerobic Digestion

288. Larry Bell

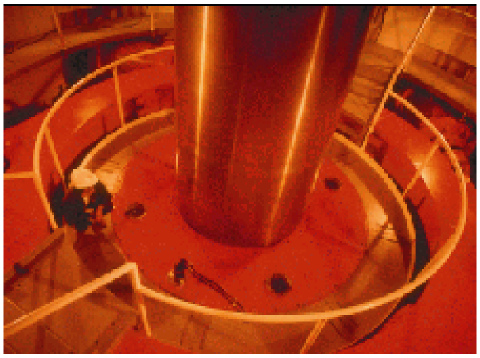


Methane Gas Products

Methane obtained from both fossil fuel sources and anaerobic digestion has a variety of direct and derivative energy uses.

- The gas can be burned directly, or used as a feedstock for a a variety of important industrial uses:
  - Methane combustion is a very efficient means to transfer heat for direct contact industrial water heaters.
  - Combined heat and power (CHP) systems can use methane for "cogeneration" that produces electricity and recycles excess heat and steam for space heaters, water heaters and industrial boilers.
  - Synthetic gas (syngas) produced from steam methane reforming (SMR) and other processes are used to produce hydrogen and methanol, along with ethane (C_2H_6), propane (C_3H_8), and butane (C_4H_{10}).

289. General Sources



Electrical Power

Heat

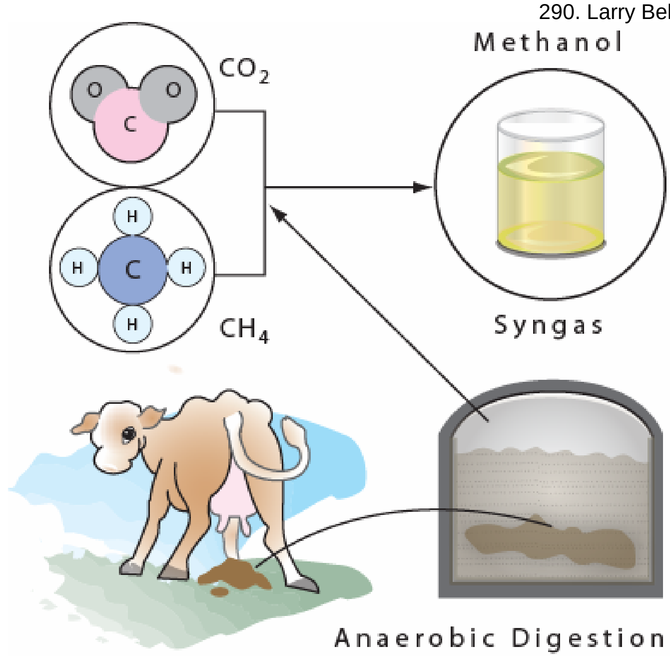
Chemicals and Plastics

Methane/Natural Gas Uses and Derivatives

Methanol can be blended with other liquid fuels to reduce pollutant emissions in internal combustion engines, and can serve as an ideally simple one-carbon molecule hydrogen carrier for fuel cells.

- It can be produced from fossil for biomass syngas in a variety of ways:
  - Carbon monoxide and hydrogen from coal gasification can be reacted with steam (currently a major source).
  - Hydrogen from electrolysis or steam methane reforming can be reacted with CO_2 to produce fuel.
  - Syngas from anaerobic digesters or landfills can be reacted with CO_2 to create methanol.
  - Syngas from heated biomass (pyrolysis) can also be reacted with CO_2 (one ton of biomass yields about 45 gallons of methanol).

290. Larry Bell



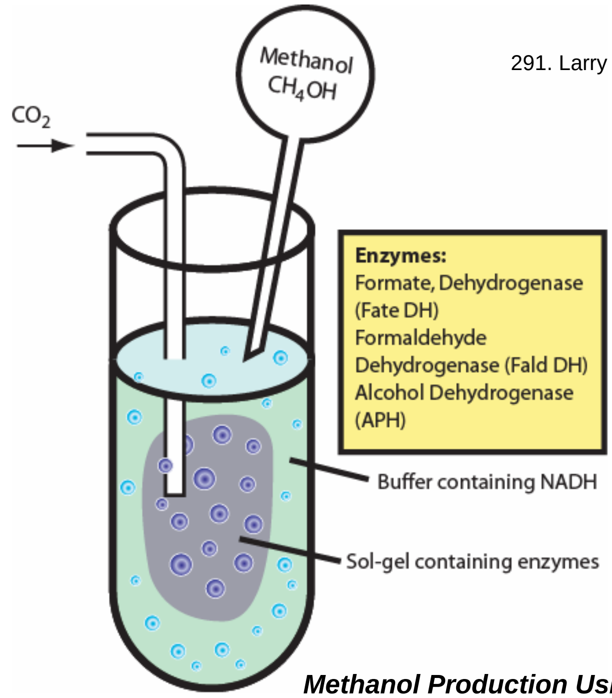
Methanol from Biodigesters

Harvesting methanol and methane from chemical and organic wastes

Many research organizations are pursuing ways to develop efficient and inexpensive ways to produce methanol directly from CO_2 using various enzyme reactions.

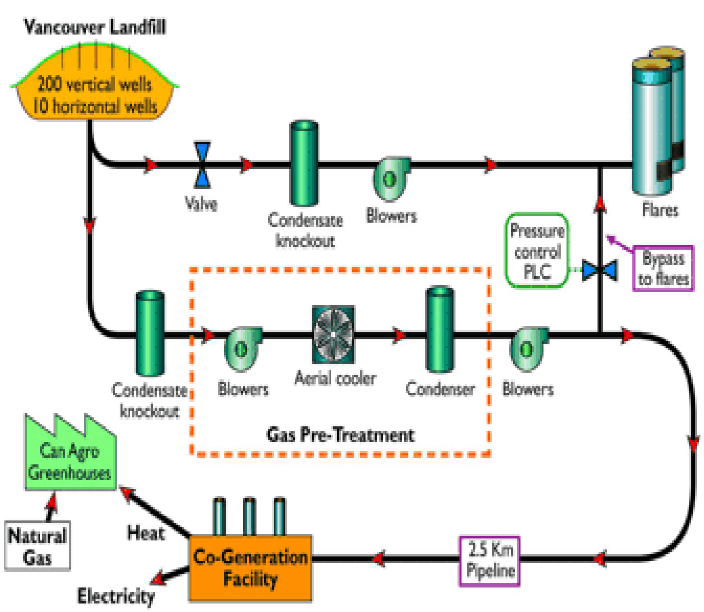
- One method being studied reduces CO_2 to methanol by coupling reactions of three enzymes using NADH from photosynthesis in linked conversion stages:
  - The enzymes are encapsulated into a porous silica sol-gen solution that solidifies into a gel within a buffer solution containing small amounts of NADH.
  - The NADH dehydrogenase serves as an electron donor for each of the three enzyme conversion stages.
  - After about two days to allow time for the NADH to diffuse into the gel, CO_2 is added, producing methanol through enzymatic reaction with a nearly 44% yield.

291. Larry Bell



Methanol Production Using NADH Enzymes to Reduce CO_2
(Southern Illinois U. Process)

292. Environmental Science and Engineering Magazine, March 2004, Vancouver Landfill Operation



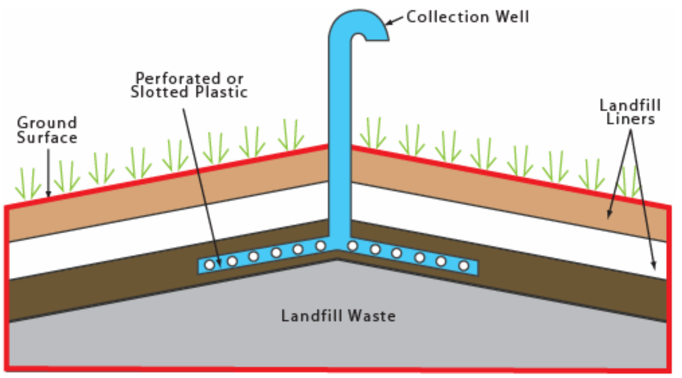
Landfill Gas Collection and Utilization

Municipalities and waste management organizations are realizing that they can convert garbage to revenues.

- Landfills produce substantial amounts of methane that can be captured to help meet growing demands:
  - Landfill gas is created by natural anaerobic decomposition of discarded organic wastes that must often be removed to prevent high pressures from damaging the landfill structure, produce unpleasant odors, cause vegetation die-off and present explosion hazards.
  - When water vapor is removed, about half of the gas is methane and half is CO_2, along with small amounts of nitrogen, oxygen, hydrogen, and sulfides.

293. ATSDR

Landfill gas collectors use “wells” made of perforated or slotted plastic tubing that provide pathways for gas migration.

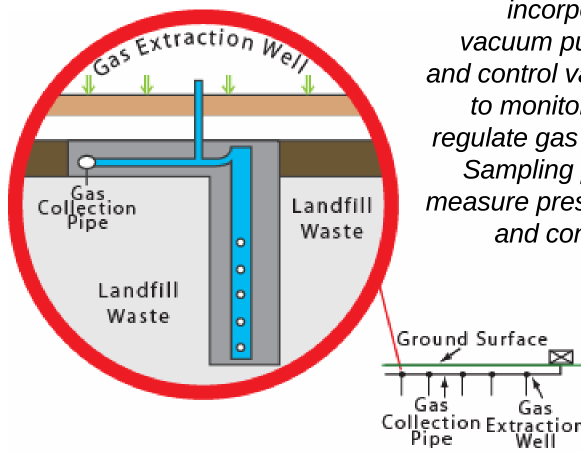


Passive systems are used in small recovery operations, and active systems provide for managed commercial capabilities.

Passive Landfill Gas Collector

Passive systems collect gas using impermeable liners on top, sides and bottom to limit venting into the atmosphere.

Active systems incorporate vacuum pumps and control valves to monitor and regulate gas flow. Sampling ports measure pressure and content.



Active Landfill Gas Collector

Landfills often face public resistance due to public concerns about objectionable odors, wind-blown litter, vermin and leach contamination of groundwater.

- Many operators are implementing safe guards to address these problems, and at the same time make methane more recoverable:
  - Separation and recycling programs are reducing necessary landfill sizes, and are also much more labor- and cost-effective when accomplished prior to disposal.
  - Groundseal barriers and modern gas extraction technologies are also making methane odor control and collection more efficient and productive.
  - Many landfills are being developed by operators into public parks and sports areas as added benefits.

294. Auckland City Council

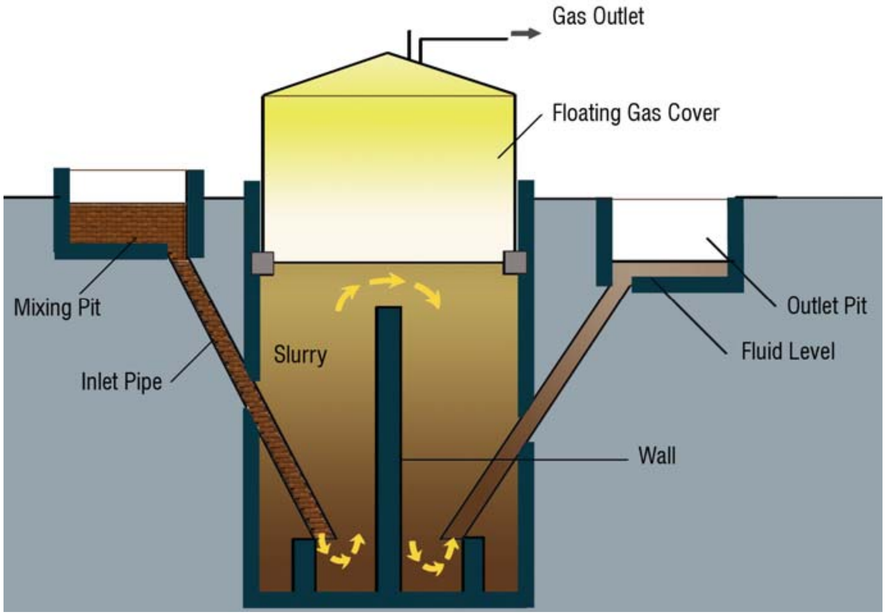
Former landfill converted into a public park in Auckland, New Zealand.

Landfill Methane Recovery

Agricultural operations are also collecting methane gas using digesters that duplicate a phenomenon that occurs naturally at the bottom of ponds and marshes to produce marsh gas.

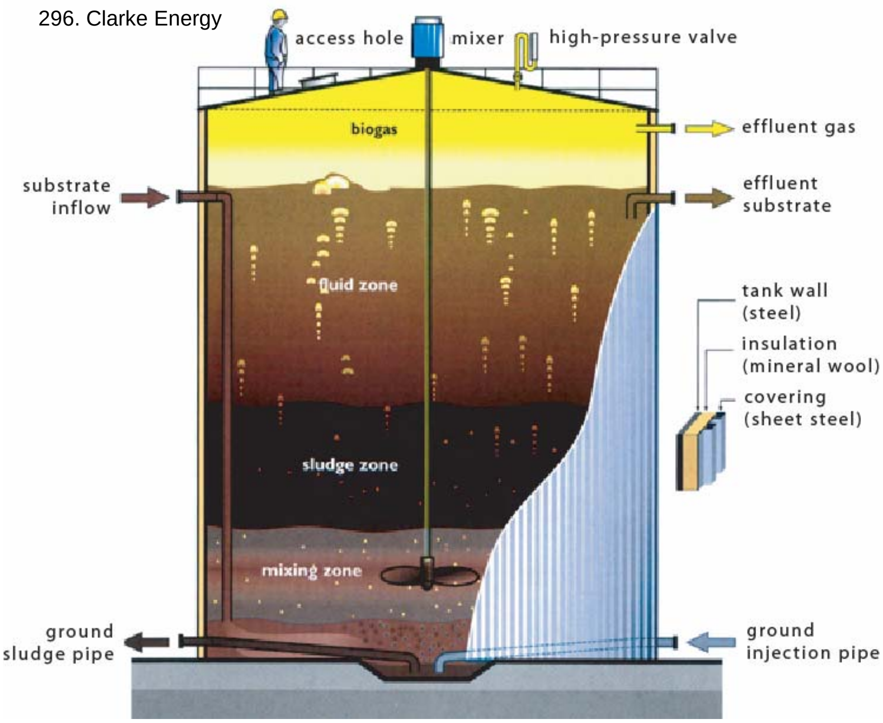
- Two similar types of biogas digester processes are popularly used to ferment animal wastes, each using a different gas collection method:
  - Floating-cover type digesters use water-sealed covers which rise as gas is produced to create expanding gas storage chambers with large capacities.
  - Fixed-top digesters feed a waste-slurry into a containment tank with a domed or conical top which collects the methane with somewhat limited gas storage capacity.

295. Larry Bell



Floating-Cover Anaerobic Biogas Digester

296. Clarke Energy



Fixed-Top Anaerobic Digester

Raw biogas typically consists of about 60% methane, 40% carbon dioxide, water vapor, and trace amounts of hydrogen sulfide.

- Production processes using floating- and fixed-top digesters are simple and similar:
  - Methane-producing bacteria that transform the wastes into component parts operate most efficiently at temperatures between 86°F - 172°F (requiring heat to be added in colder climates).
  - Digestion time ranges from weeks to months, depending upon feedstock and temperature.
  - Residual slurry removed at outlets can be used as a fertilizer.

Brewing alcohol from grain plants and cellulose

297. Larry Bell

1. Milling:

The corn (or other grain) is passed through hammer mills that grind it into a fine power called "meal".

2. Liquefaction:

The meal is mixed with water and alpha-amylase and passed through cookers to reduce bacteria levels.

3. Saccharification:

The mash from the cookers is cooled, and a second enzyme (gluco-amylase) is added to convert the liquefied starch to sugars.

4. Fermentation

Yeast is added to ferment sugars into ethanol and CO_2. Using several fermenters, the process continues until complete.

5. Distillation:

The fermented mash (or "beer") containing about 10% alcohol is pumped through a multi-column distillation system where alcohol is removed from unfermented solids, leaving about 96% strength.

6. Dehydration:

Alcohol passes through a dehydration column where water is removed. Most plants use a molecular sieve to capture any remaining water, and the anhydrous ethanol is now about 200 proof.

Typical Grain Ethanol Production Processes

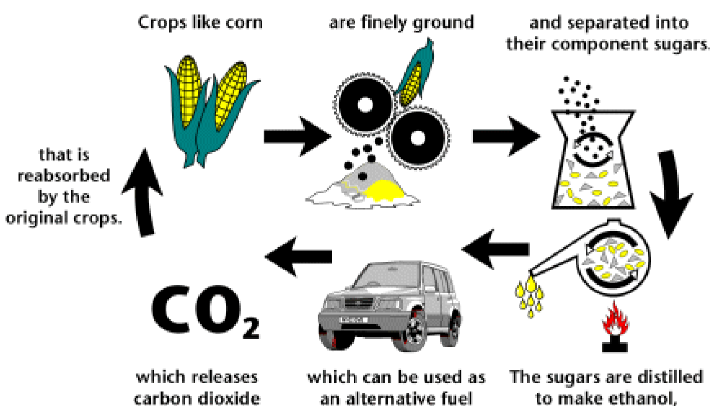
Ethanol (ethyl alcohol, grain alcohol or simply alcohol), another biofuel, is produced biologically by fermentation of sugars with yeast, much like brewing beer.

- Glucose for ethanol can be obtained either from biomass or from cellulosic wastes or from grain crops such as corn, switchgrass and sugarcane:
  - Ethanol obtained from corn and other grains requires energy to grow the plants and convert them into alcohol.
  - Closed-loop agricultural ethanol production can reduce energy costs by using fermenting energy from manure produced by livestock that are fed distillation byproducts, and by applying leftover manure for fertilizer to grow more grains.
  - Ethanol produced from cellulose requires hydrolyzing enzymes to digest the materials, adding substantial costs

Ethanol is the most widely used biofuel today.

- Like methanol, ethanol can be mixed with alkyl esters obtained from transesterication of abundant vegetable oils and animal fats.
  - Hydrous ethanol (45% by volume) containing some water can be used directly as a gasoline substitute in cars with modified engines.
  - Anhydrous ethanol (water-free) is at least 99% pure, and can be blended with conventional fuel in proportions between 5% and 85%.
  - As a 10% additive, it can be used in modern engines. (Higher blends require engine modifications such as found on "flexible-fuel" vehicles).

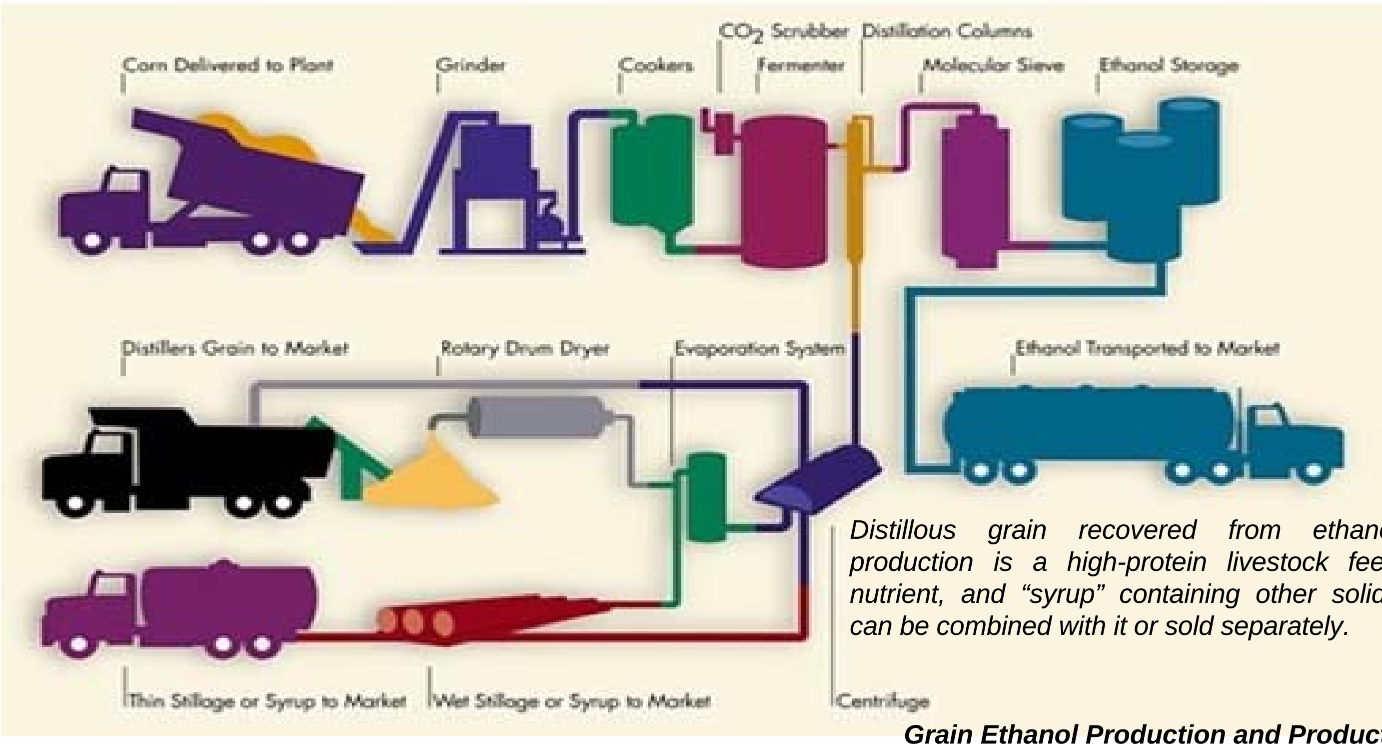
298. US DOE-EIA



Ethanol can be used as a fuel in internal combustion engines as a petroleum substitute, additive or blend. It is also used to manufacture ethyl-tertiary-butyl-ether (ETBE), a fuel enhancer for conventional petroleum.

Ethanol Production and Benefits

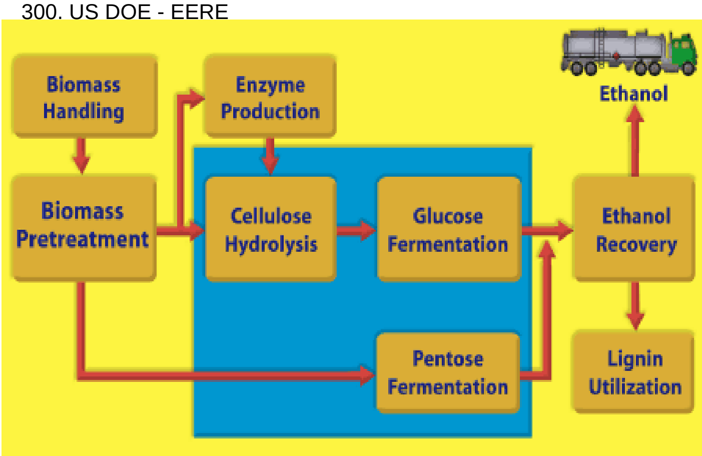
299. Big River Resources, LLC.



Distillous grain recovered from ethanol production is a high-protein livestock feed nutrient, and "syrup" containing other solids can be combined with it or sold separately.

Grain Ethanol Production and Products

300. US DOE - EERE



Biotech processing uses enzymes to break down difficult-to-digest feedstocks into simple sugars that can be fermented into alcohol and other biofuel products. The undigested lignin can be utilized as a combustion fuel for process heat to conserve energy.

Cellulosic Biofuel

While natural enzymes can readily break down food crop biomass into simple sugars and ferment the sugars into ethanol, cellulosic biomass materials are not easily digested.

- Many research organizations are exploring biotech approaches that may reduce the harsh pre-treatment required to dissolve solid cellulosic feedstock.
  - A key challenge is to genetically engineer microbes that produce enzymes capable of digesting cellulosic feedstock such as corn stalks and switchgrass into liquid biofuel in an efficient manner.
  - Possible breakthroughs may ultimately replace foodcrop-derived ethanol, conserving enormous amounts of land and energy for other purposes.

Biodiesel fuel from methanol or ethanol plus waste oils

301. National Renewable Energy Laboratory

Organic biodiesel can be produced by combining methanol with methyl esters obtained from three varieties of sources:

- *Rapeseed methyl ester (RME)*
- *Vegetable methyl ester (VME)*
- *Fat methyl ester (FME)*

It burns cleanly and fully in modern diesel engines, and works with catalysts, particulate traps and exhaust recirculation to eliminate most pollutants.

Biodiesel Production and Benefits

Either methanol or ethanol alcohol can be chemically mixed with alkyl ethers obtained from transesterification of vegetable oils and/or animal fats to create biodiesel fuel.

- The fuel can be readily used as a substitute for petroleum diesel, offering several advantages:
  - Biodiesel can be used straight, or can be blended with fossil fuels.
  - It has a higher octane rating than petrodiesel, causing it to ignite more rapidly in an engine.
  - Biodiesel is biodegradable and non-toxic.
  - Although it produces more nitrogen oxide (NOx) exhaust gas than petrodiesel, this pollutant can be reduced to levels lower than fossil fuel using catalytic converters.
  - The vegetable oils used are plentiful and replenishable as straight vegetable oil (SVO) and waste vegetable oils (WVO).

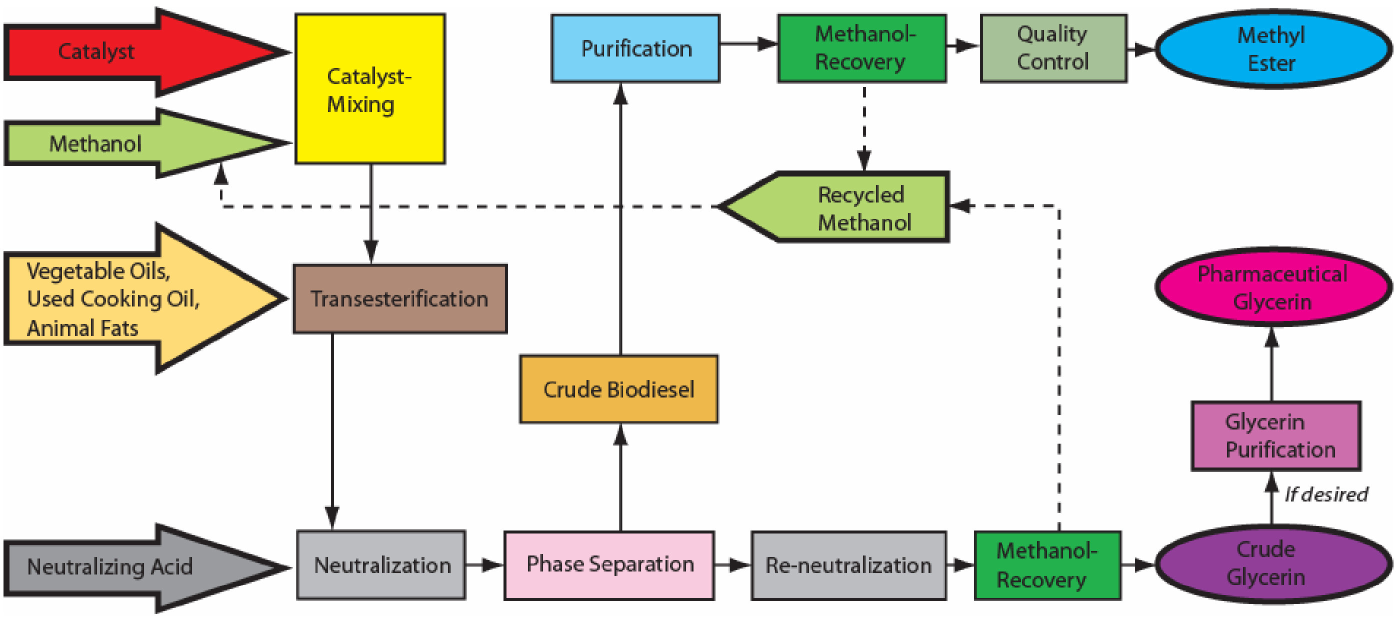
Biodiesel is produced through a process in which organically-derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester.

- Biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel or used in a 100% form:
  - Biodiesel can be made from a variety of fats and oils, including soybean or canola, animal fats, vegetables and microalgae.
  - The fats/oils are first degummed, and acid is removed.
  - Ethanol or methanol and a catalyst are then added for esterification prior to final washing and drying.

302. Risoe

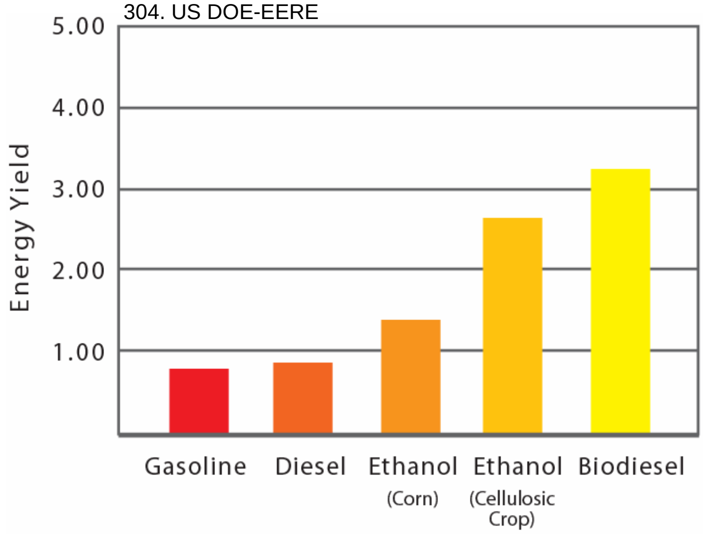
Biodiesel Production

303. Fleet Challenge Canada



Biodiesel Production Process

304. US DOE-EERE



Plant oil blended with petroleum diesel can reduce fossil fuel consumption along with fossil (old-source) CO_2 emissions per unit of engine work.

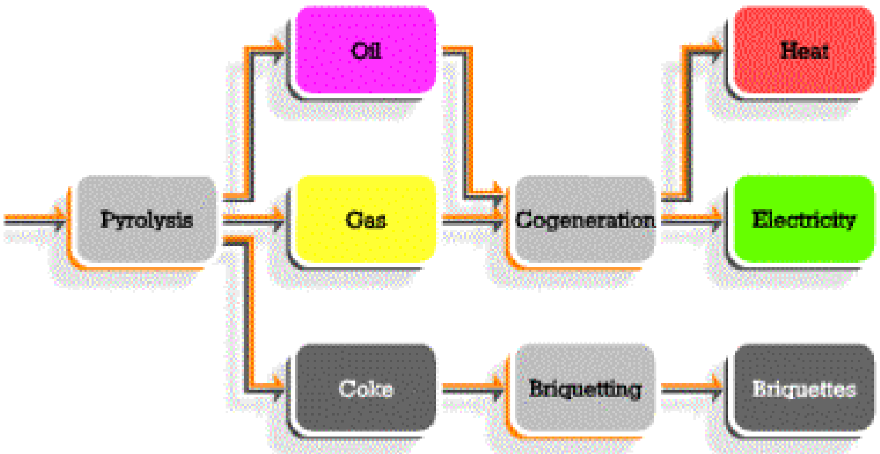
Energy Yield / Unit of Fossil Fuel Consumed on a Life Cycle Basis

Biodiesel is often produced using oil from soybeans blended with petroleum diesel (typically a 15/85 mix), and is rapidly gaining popularity.

- This fuel can be used in standard diesel engines with comparable energy efficiencies to petrodiesel (about 80% vs. 83%):
  - Although efficiency yields are slightly lower due to energy required to convert soybean oil to fuel, biodiesel can dramatically increase the energy produced per unit of fossil fuel consumed (about 3.2 units vs. 0.83 for petrodiesel).
  - Biodiesel reduces fossil fuel life cycle consumption roughly proportionally to its concentration; an approximate 19%.reduction for a 20% biodiesel / petrodiesel blend (B20), and about 95% for 100% biodiesel (B100).

Producing cleaner fuel and power from biomass

305. Alcyon Engineering



When biomass decomposes at elevated temperatures, three primary products are formed: gas, bio-oil and char. At high temperatures the bio-oil decomposes again into secondary gases and polymetric tar.

Ancient use of anhydrous pyrolysis produced charcoal, and the process is currently used on a massive scale to turn coal into coke for metallurgy (particularly steelmaking).

Pyrolysis Fuel and Power Products

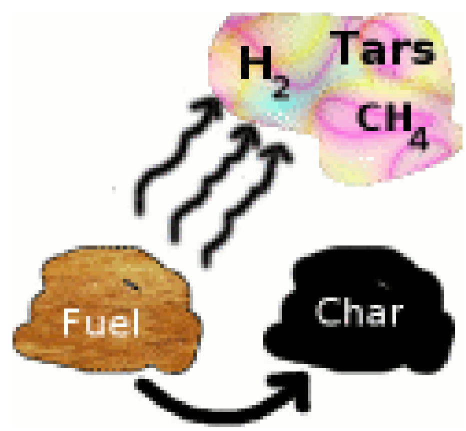
Pyrolysis is a phenomenon that commonly occurs whenever a solid organic material is sufficiently heated (e.g. when frying, roasting, baking and toasting) under normal atmospheric conditions.

- Pyrolysis is usually understood to be anhydrous (without water), although the term is sometimes used to encompass “thermolysis” in the presence of water (such as using steam to depolymerize organic waste into light crude oil):
  - Pyrolysis occurs when a solid fuel like wood or coal burns. (The flames are due to combustion of released gases, not of the actual wood.)

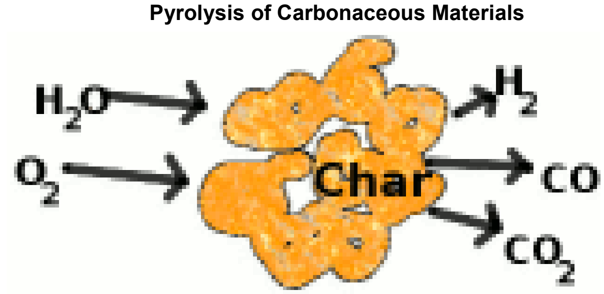
Pyrolysis and gasification are related forms of thermal treatment under limited oxygen conditions.

- These processes typically occur in sealed vessels under high temperature and pressure, and are more efficient than direct incineration with greater energy recovery for productive uses:
  - Pyrolysis chemically decomposes organic materials into solids, liquids, and gases.
  - Gasification decomposes organic materials into a synthetic gas composed largely of carbon monoxide, and converts inorganic waste into an inert vitrified gas.
  - Pyrolysis of biomass and other carbonaceous materials to release volatiles and char occurs at the initial process stage of gasification. (The char reacts with carbon dioxide and steam to produce carbon monoxide and hydrogen.)

306. Claus Hindsgaul



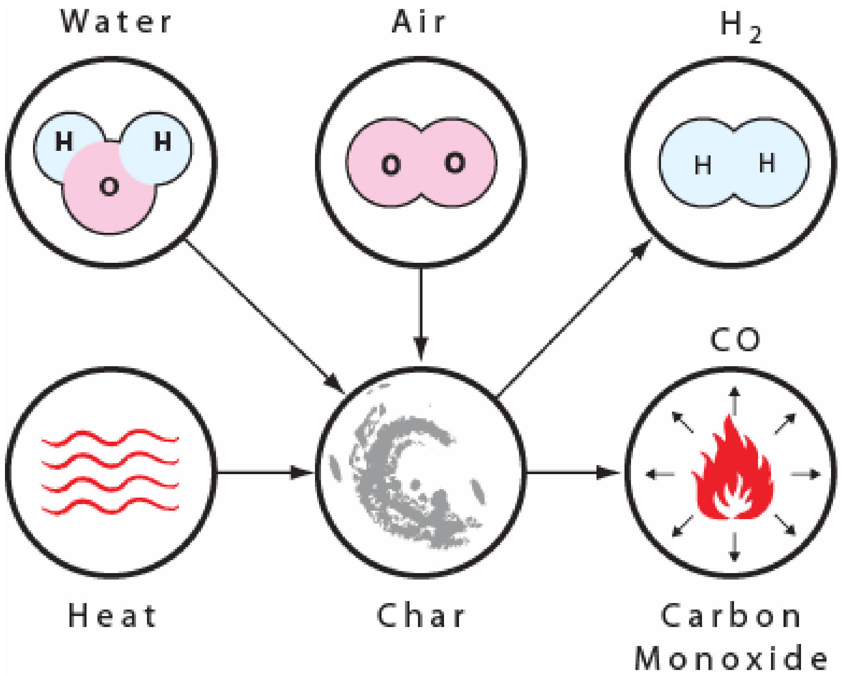
Pyrolysis of Carbonaceous Materials



Gasification of Char Product

Synthetic biomass fuels and lubricants

307. Larry Bell

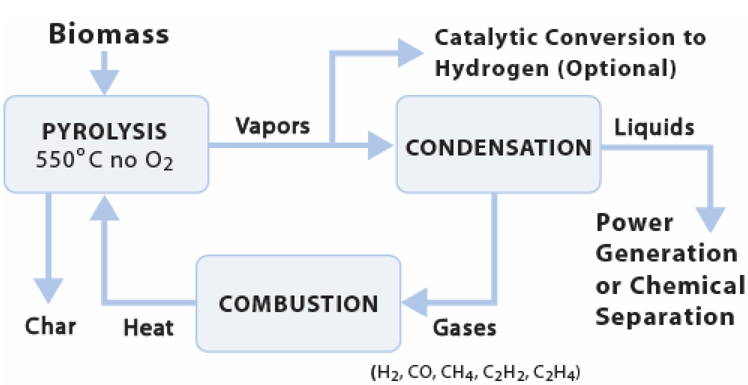


Gasification of Char

Biomass can be gasified to produce a synthesis gas composed primarily of hydrogen and carbon monoxide (also called "syngas" or "biosyngas").

- Gasification uses a thermochemical process similar to pyrolysis which exposes the stock material to even higher temperatures in an oxygenated environment causing it to decompose:
  - Syngas can also be converted using a "Fischer-Tropsch" process to create Fisher-Tropsch diesel fuel which is similar to petroleum diesel.
  - These same fuels can be produced from natural gas using a similar process.

308. US DOE-EERE



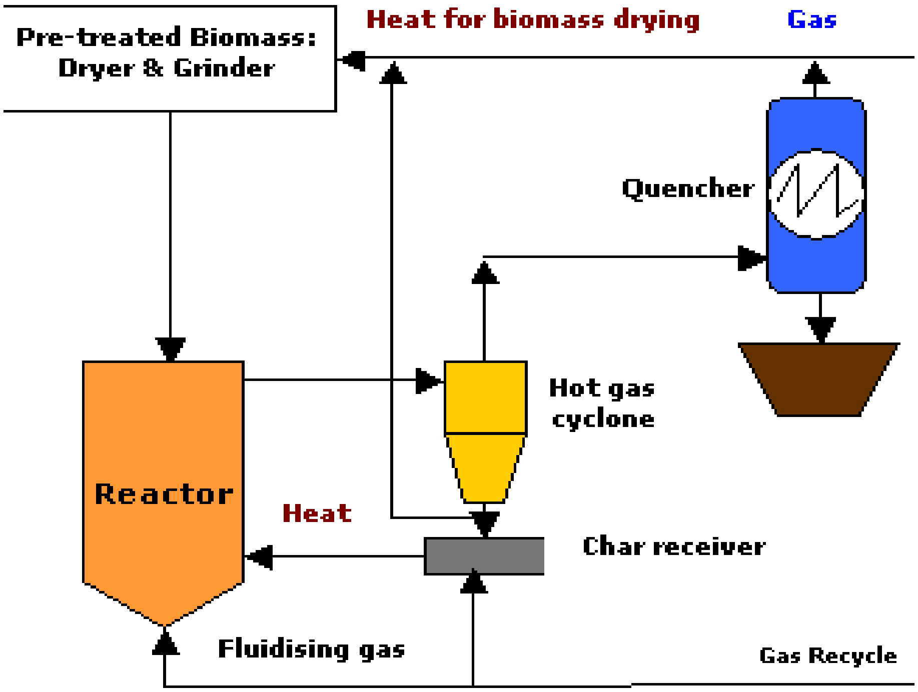
Fast pyrolysis of biomass is a thermal decomposition process that produces a liquid bio-oil that can be readily stored and transported. Pyrolysis oil has been successfully tested in engines, turbines and boilers, and has been upgraded to high- quality fuels, although presently, at uncompetitive energetic and financial costs.

Bio-Oil Production

Bio-oil is created using agricultural and "fast pyrolysis" to process biomass obtained from agricultural and municipal wastes, forestry residue, oil crops, and short-rotation herbaceous and woody plants.

- Up to 40% bio-oil has been used as a mixture with standard diesel fuel, and continuing developments may enable direct use in diesel engines for trucks, tractors and other equipment:
  - The fuel can be combusted directly in boilers, gas turbines and slow-medium speed diesels for heat and power applications.
  - Bio-oil has only about half of the heating value of light or heavy oil per volume, but is superior to heavy fuel oil for viscosity and cold weather properties.

309. European Commission, DG Research



Fast Pyrolysis Processing

Fast pyrolysis of biomass can yield liquid energy fuel and chemical products with yields up to 75% based upon starting biomass weight.

- Fast heating of biomass greatly reduces the amount of char – forming reactions to optimize liquid fuel product:
  - This process rapidly heats the biomass stock to temperatures of 750°F - 1110°F (400°-600°C).
  - Product yields are temperature-dependent. (Maximum oil yields are obtained at about 930°F [500°C].)

Pyrolysis oil can be used directly as fuel, and also as a feedstock for valuable chemicals and materials.

- This bio-oil is a renewable liquid fuel that can be easily stored and transported:
  - Fast pyrolysis has achieved commercial success as a method to produce oil for engines, turbines, and boilers.
  - Bio-oils can be upgraded to high-quality hydrocarbon fuels, although presently only at high energetic and financial costs.
  - The yields and products of bio-oil depend upon the feedstock, process type and conditions, and product collection efficiency.

310. Madur

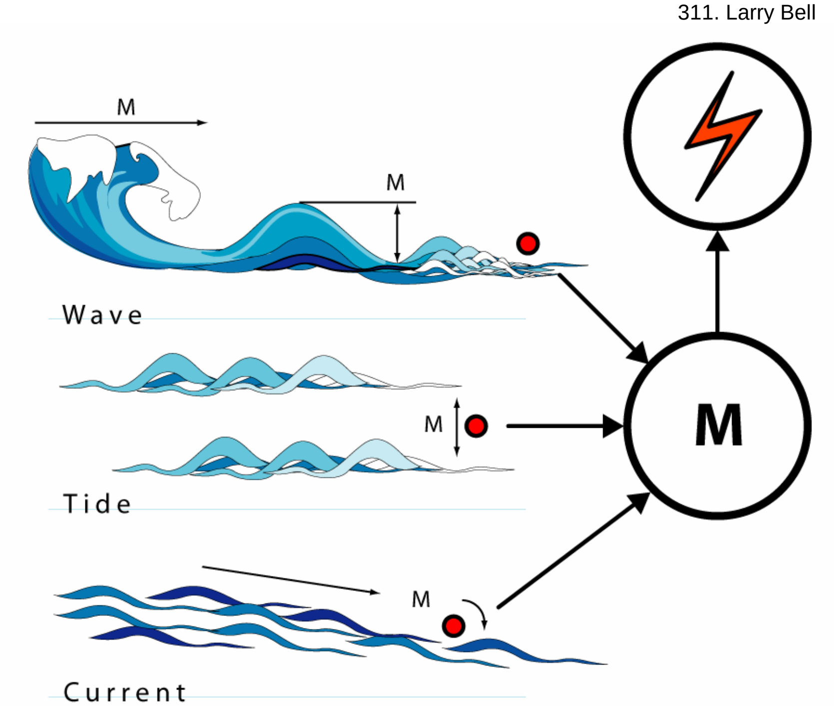
Pyrolysis Bio-Oil Production Facility

Hydropower principles and technologies

Hydropower systems convert mechanical energy from falling and flowing water by various means.

- The methods used to capture the energy for transfer to electrical power generators fall into two general categories:
  - Water turbines use the gravitational kinetic force of falling water or the kinetic energy of flowing currents to drive electrical generators.
  - Power take-off systems convert kinetic energy from wave or tidal motions into electricity using hydraulic pumps, air turbines and other devices to drive generators.

311. Larry Bell



Hydro-mechanical Sources

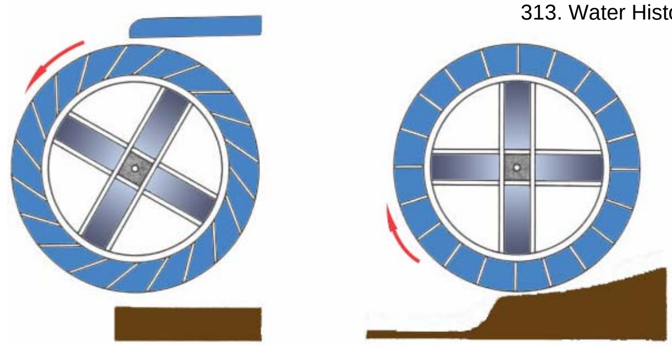
312. Water Wheel Factory

Waterwheel

Most current hydro systems apply very old and basic principles.

- Two main types of technologies are waterwheels and turbines:
  - Waterwheels are familiar variations of massive antique wooden wheels that move slowly, but with great torque as streams pour over or under them.
  - Turbine approaches collect water from upstream sources that provide kinetic energy through flowing currents or gravity pressure.
  - Very large and small turbines drive generators that produce electricity.

313. Water History



Many parts of the world continue to make use of water wheels for direct mechanical power.

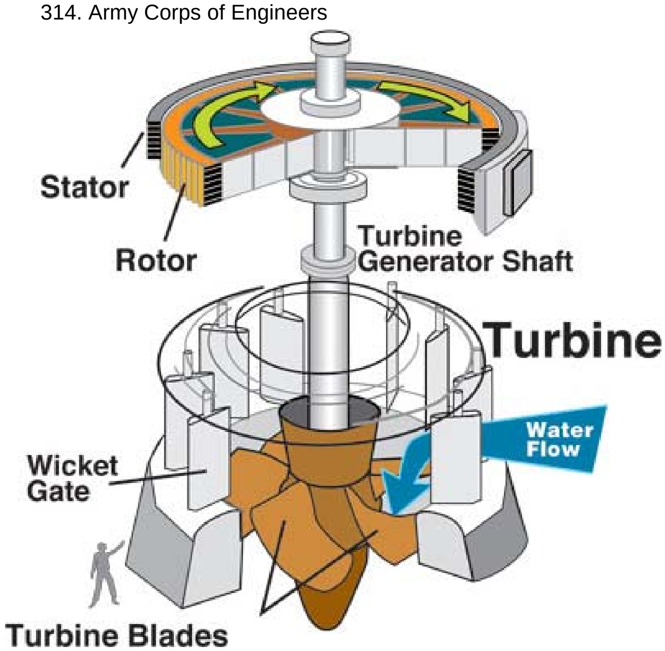
- The designs fall into three basic types:
  - Horizontally-oriented wheels are driven by a jet of water that turns a rotor much like air flowing through a pinwheel (a form of turbine).
  - Undershot wheels are oriented vertically as paddle wheels powered by a stream of water that flows underneath.
  - Overshot wheels are also oriented vertically, and receive water from above using gravity for power.
  - While the horizontal wheels (often called Norse wheels) apply mechanical torque directly to do work, the vertical types transfer mechanical force through gears.

***Overshot**: use an elevated stream and require gears.*

***Undershot**: are driven from below and require gears.*

***Norse**: apply power directly*

314. Army Corps of Engineers



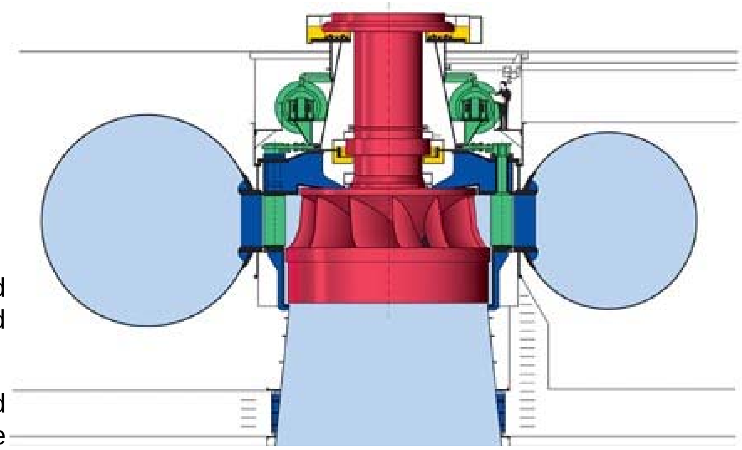
Commercial-Scale Water Turbine-Generator

Modern turbines are similar to waterwheels, but accelerate by water pressure force that is directed onto blades of a spinning “runner” to transfer energy that drives a generator.

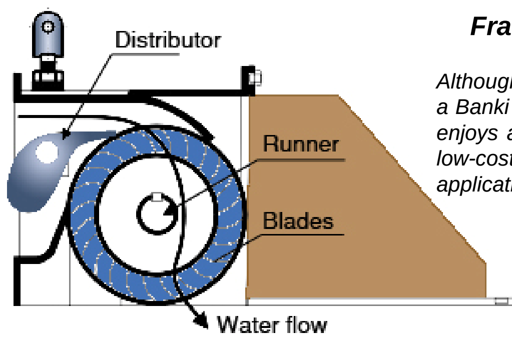
- The main difference between water turbines and waterwheels is the swirl component of water which passes energy to a spinning rotor:
  - Their principle advantage over waterwheels is the fact that they can be much smaller, yet produce substantial power.
  - Since they turn much faster than waterwheels, they can harness greater “heads” to process water more effectively.
  - Very small turbines are ideal to provide residential and supplementary power from streams at very low cost.

Small and large scale power applications

315. Voith Siemens; European Small Hydropower Association



Francis Turbine



Although the efficiency of a Banki turbine is lower, it enjoys a niche market for low-cost and home-made applications.

Banki Turbine

Very small turbines can provide residential and supplementary power from streams at low cost.

- Francis micro-hydro turbines can operate with as little as 10ft of water head:
  - Water circulates through the center (inward flow) and provides energy through combined radial and axial flow.
  - Water enters through a spiral-shaped inlet and acts upon vanes (or a wicket gate) causing the runner to spin.
- Banki micro-hydro turbines operate much like overshot waterwheels:
  - The middle is left open, causing the water to pass through and accelerate by a venturi effect.
  - Very inexpensive home-made Banki turbines can produce up to 2 amps at 12vDC with only 3ft (1m) of water head.

316. Forcefield

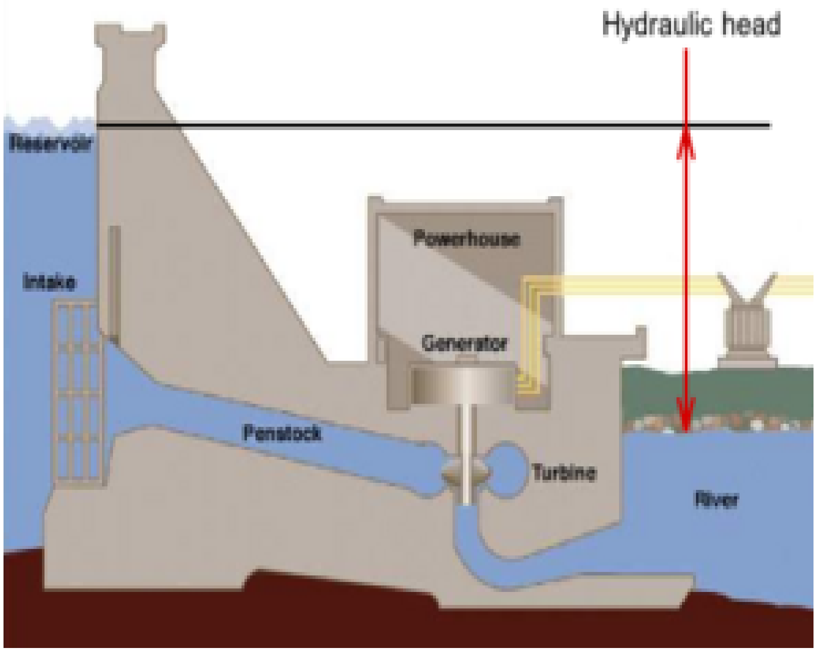
This home-made squirrel cage Banki turbine generator in a small stream produces a steady 1-2 amps of power 24 hours/day.

Small-Scale Hydro Applications

Small-scale hydro (including “mini-hydro” and “micro-hydro”) power is increasingly being used as an alternative energy source in remote regions.

- They can often be used in connection with existing dams created for river and lake water control or for irrigation, and can also be used without dams to generate home-scale power:
  - Small-scale systems can have generating capacities of up to 10 MW or more, enough to serve small communities and medium-sized industries.
  - Mini-hydro systems are generally characterized as less than 1,000 kW, and micro-hydro systems as less than 100 kW.
  - Mini and micro applications can be useful supplements to solar power to provide 24 hour/day capabilities.

317. Tennessee Valley Authority



Hydraulic Head in a Reservoir

As with other power sources, hydroelectric resources can be measured according to the amount of available power (or energy) that they can produce in a unit of time.

- In the case of energy produced by falling water, power is a function of "hydraulic head" and rate of flow:
  - For a reservoir, the hydraulic head is the height of the water level relative to the height after the water is evacuated.
  - Each unit of water can produce a quantity of work equal to its weight times the head, where:

    The amount of energy (E) released by lowering an "object" of mass (M) by a height (h) in a gravitational field is:

    E= mgh (where g is acceleration due to gravity)

Although hydropower produces no greenhouse emissions, dam, and barrage construction and operations can have significant environmental repercussions:

- Many sites are restricted from new development for a variety of reasons:
  - Vegetation along nearby riverbeds can decay in lakes created when dams are built, releasing large amounts of methane.
  - Water in dam lakes tends to be colder and oxygen poor at the bottom compared with the surface, and when rapidly released can kill fish and flood plant and wildlife habitats downstream.

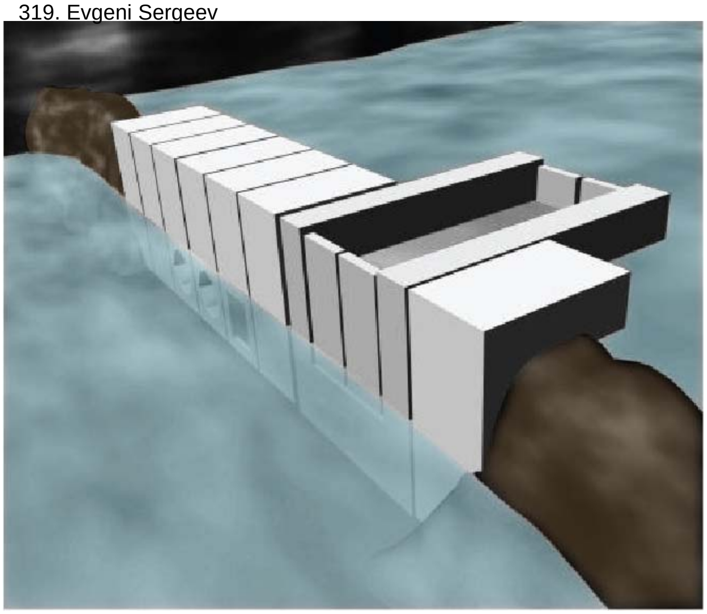
318. The Atlas of North America

Many young salmon in the Northwest are killed by turbine blades as they swim downstream towards the ocean, and adult fish attempting to swim upstream to reproduce are blocked by dams. After populations were dramatically reduced in the Northwest Columbia Basin, many fish ladders and side channels were built.

Fish and Natural Habitat Issues

Tidal generators

319. Evgeni Sergeev



Tidal Barrage

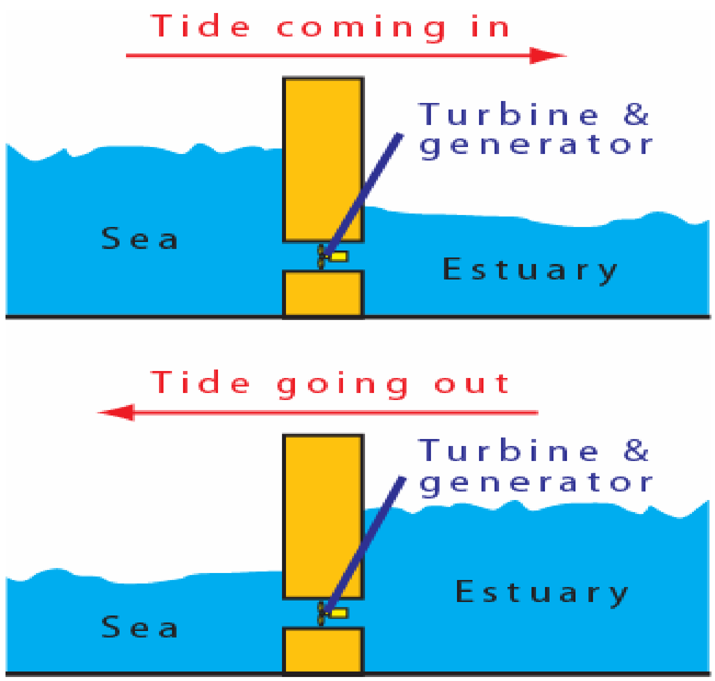
Tidal power is classified as a renewable energy source because it is driven by orbital mechanics of the Solar System and provides predictable and inexhaustible energy.

- Tidal barrage plant applications, however, impose certain limitations and consequences:
  - Tides can only generate power about 15 hours each day.
  - Estuaries often have high sediment volumes moving through them from rivers to seas that accumulate and impair barrage operations.
  - Sewage concentrations can lead to bacterial growth, impacting local ecologies.
  - As with dams, large fish populations are often sucked up through turbines, and fish lifts/ladders are typically not successful.

Barrages are similar to very large dams, built across river estuaries that flow into a sea, and are comprised of enclosed embankments constructed of massive concrete blocks that contain sluice gates, turbines and ship locks.

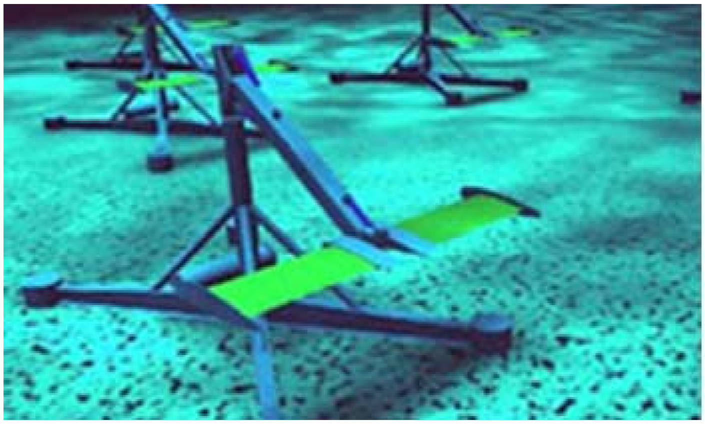
- Sluices and freewheeling turbines open to allow basins to fill during high tide, and close when the tide goes out so that water pressure drives the turbines until the cycle repeats:
  - Efficiency of tidal generation depends upon the amplitudes of tidal swell (to create heads) which can exceed 30 feet (10m) in some locations.
  - The selection of practical locations is limited to places where high-amplitude tides exist, including river and fjord estuaries in the former USSR, Canada, Australia, Korea, and the UK.

320. Andy Darvill



Barrage Operations

321. Engineering Business (EB)



The Stingray uses the flow of the tidal stream over a hydroplane to create an oscillating motion that operates hydraulic cylinders that drive motor generators. The devices are mounted to the seabed at depths of up to 330 ft (100m).

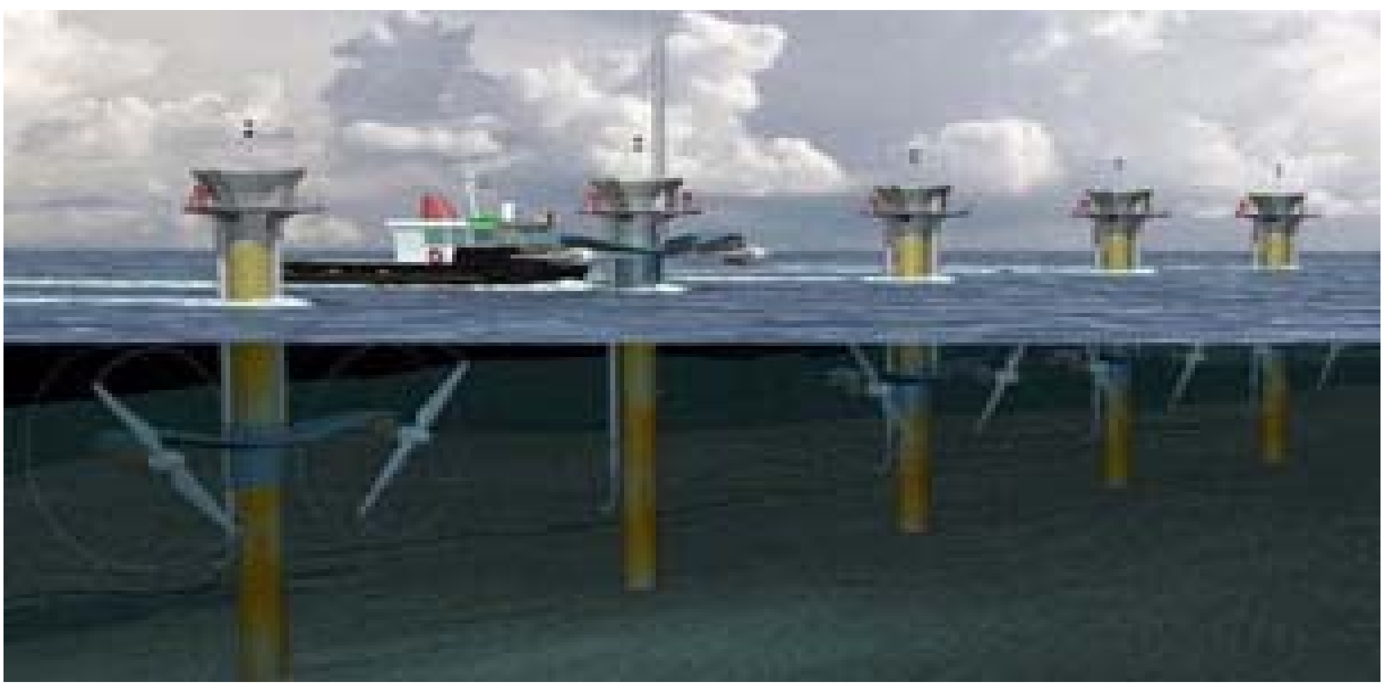
The Stingray Tidal Flow Generator

322. SMD Hydrovision

SMD Hydrovision's TidEL device consists of a pair of contra-rotating 500 kW turbines mounted together on a crossbeam. Mooring chains that tether the buoyant assembly to the seabed, allow the turbines to align to the prevailing tidal flow.

The TidEL Tidal Flow Generator

323. Seagen System

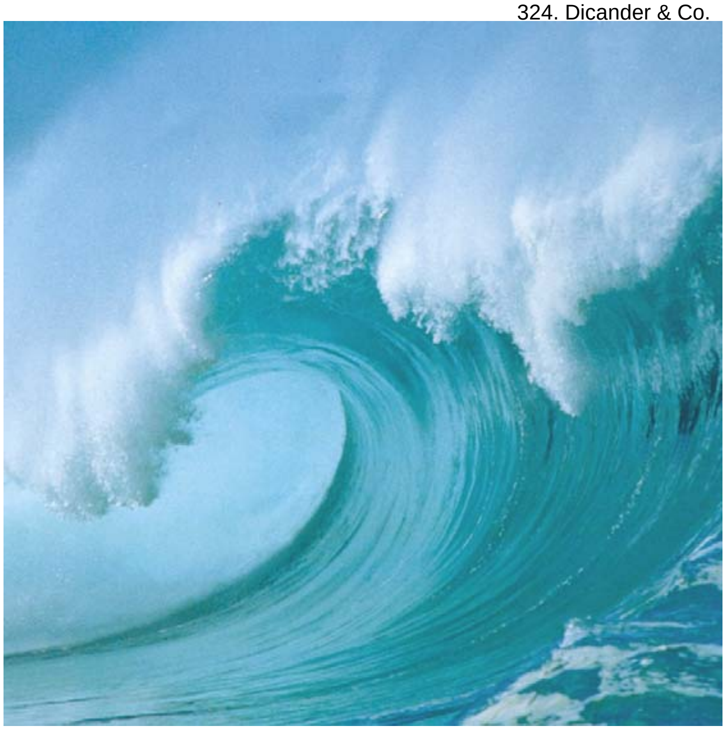


Relatively new technology uses tidal stream generators that draw energy from underwater currents in a manner similar to generators powered by wind. "Seagen" in Northern Ireland uses sets of rotor turbines rated at about 1 MW that can be raised above the surface for maintenance.

The Seagen Tidal Generator

Power from wave energy

324. Dicander & Co.

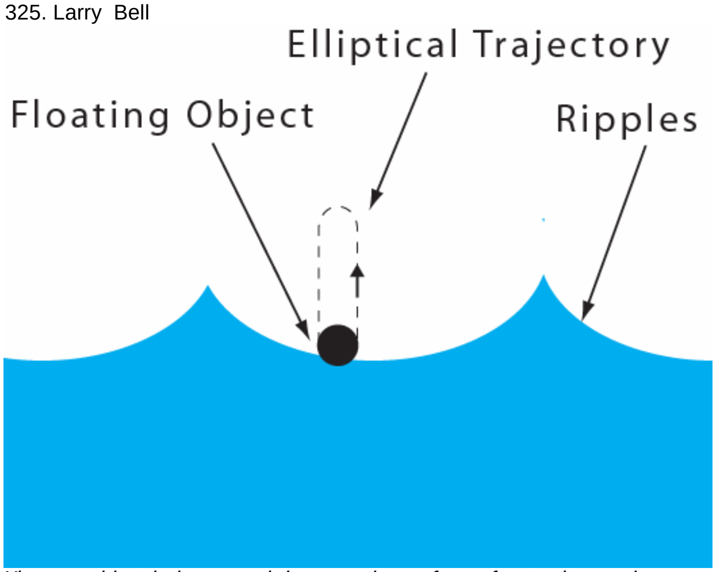


Wave Power

Harnessing power from wave motion may eventually yield more energy than tides.

- New technologies are being developed involving generators that can be either coupled to floating devices or turned by air displaced by waves:
  - Although sometimes co-mingled with tidal power, wave power is more continuous since it is produced by ocean currents.
  - Wave power is determined by wave height, wave speed, wavelength and water density.
  - Wave size is determined by wind speed, “fetch” (distance over which wind excites the water), and seafloor depth and topography.
  - A given wind speed has a practical limit over which time or distance will not produce larger waves (a limit called a “fully developed sea”).

325. Larry Bell



When an object bobs up and down on the surface of water it experiences an elliptical trajectory. The energy transferred to the object from the water’s movement can be harnessed to do useful work (such as to drive an electrical turbine generator).

Harnessing Wave Energy

North and south temperature zones offer the best wave power locations, with prevailing westerlies in winter blowing strongest.

- Wave motion is highest at the surface, and diminishes exponentially with depth, although wave energy is also present as pressure waves in deep water:
  - The potential energy of a set of waves is proportional to wave height squared times wave period (time between wave crests), and is equal to kinetic energy.
  - Wave power is expressed as kW/m, according to the formula:

    Power=$KH^2T \approx 0.5H^2T$, where:

    K=constant, **H**=height (m), and **T**=period (sec)

326. BWEA Marine
327. Wavegen

The Pelamis Wave Energy Converter is a point absorber that is flexibly moored near shore to swing head-on into incoming waves.

Wavegen's Land Installed Marine Powered Energy Transformer captures wave energy along a shoreline in Scotland.

Shoreline Wave Energy Converters

Although wave power generation is primarily in experimental stages of development and implementation, it can be accomplished by a variety of methods.

- Some representative system types are characterized according to the ways they capture wave energy, by their locations of use, and by the way energy is converted to power:
  - Wave energy capture methods include wave power point absorbers (small area devices), wave power attenuators (aligned parallel to wave propagation), and wave power terminators (aligned perpendicular to propagation).
  - Locations include shoreline, offshore and deep water applications.
  - Power conversion includes hydraulic rams, elastomeric hose pumps, pump-to-shore, and hydroelectric or air turbines.

328. Ocean Power Delivery

The Pelamis is a semi-submerged, articulated structure composed of cylindrical sections linked by hinged joints. Wave-induced motions of the joints are resisted by hydraulic rams that pump high-pressure oil through hydraulic motors that drive generators to produce electricity. Many sections can be tethered to the shore by a single cable.

The Pelamis Wave Energy Converter

329. Wave Dragon

Wave Dragon consists of collectors that channel waves towards a double-curved ramp structure to create a water storage reservoir. A set of propeller turbines convert water head in the reservoir into electricity. The design is unique among wave energy converters because it produces electricity through a one-step system using turbines.

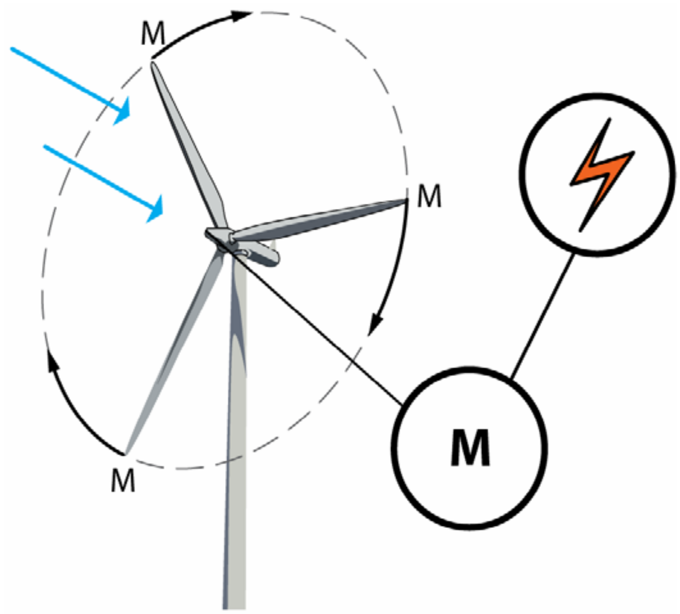
The Wave Dragon

The mechanics of wind energy

Wind turbines are devices that capture kinetic energy with propeller-like blades mounted on a rotor and convert it via generator devices into electrical power.

- The blades act much like airplane wings:
  - When the wind blows, low-pressure air forms on the downward side of the blades creating “lift”.
  - The lift force is actually much stronger than the wind’s force against the front of the blades (called “drag”).
  - The combination of lift and drag causes the rotor assembly to spin like a propeller, turning a generator shaft to create power.
  - The theoretical amount of energy generated is a function of the cube (third power) of wind speed, so that if wind speed is doubled, power increases by a factor of eight (although in actual practice it is less).

330. Larry Bell



Since the theoretical energy generated by a wind turbine equals the cube of wind speed, small increases in wind speed produce large increases in power.

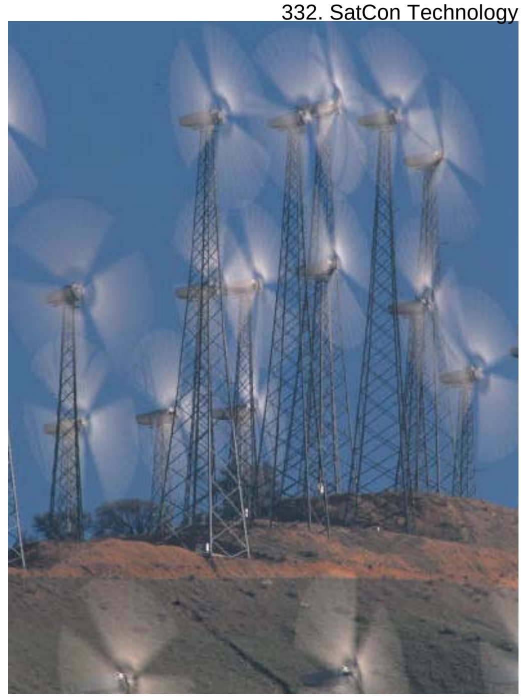
Wind Power

331. Derek Jensen

Contemporary wind turbines range in size from small ones used in rural areas to supplement electricity from public grids, to large units that are linked together for multi-megawatt, utility-scale applications.

Small Independent Unit

332. SatCon Technology

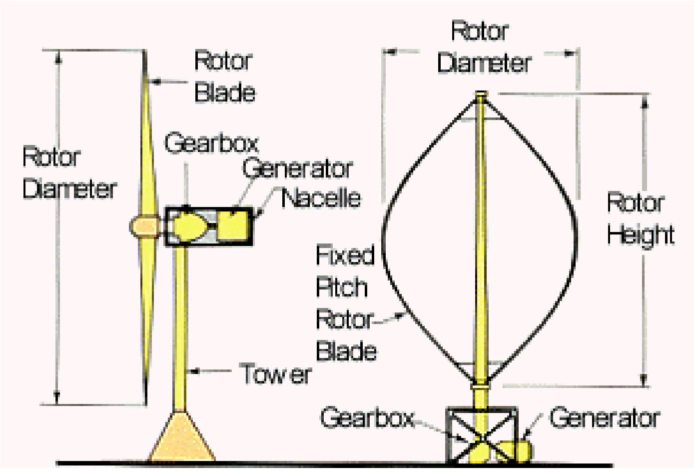


Wind Farm

Wind turbines come in different blade orientations and configurations.

- Modern systems generally fall into two basic types of groups:
  - Horizontal-axis types include three-bladed versions located upwind with blades facing into the wind, and two-bladed versions located downwind.
  - Vertical-axis turbines include an eggbeater-style Darrieus model (named after its French inventor).
  - Horizontal-axis types are commonly used today, and are the primary focus of current US Department of Energy (DOE) research and development.

333. American Wind Energy Association



Horizontal-Axis

Vertical-Axis

Wind Turbine Configurations

334. Tree Hugger

Familiar Horizontal-Axis Types

335. DOE-EERE

Vertical-Axis System

The theoretical amount of available wind power is determined by the equation **W = ½rAv³**, where:

W = power; **r** = air density; **A** = rotor area; **v** = wind speed**, and:**

Power = one-half times air density, times rotor area, times the cube of the wind speed:

- Air density varies according to elevation, temperature, and weather fronts
- The formula for air density (r) is:

r = (1.325 × P) / T, where:
T = temperature in Fahrenheit + 459.69
P = barometric pressure

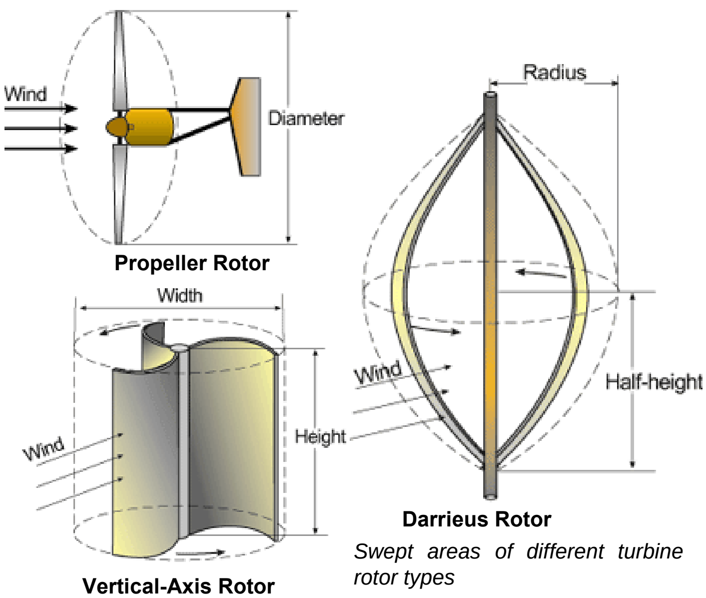
English Units	**Metric Units**
W = 0.0052Av³ where:	**W = 0.625Av³** where:
A = cross-sectional area in ft² swept by blades **V** = wind speed in miles/hr	**A** = cross-sectional area in m² swept by turbine blades **V** = wind speed in meters/sec

336. Scienmet Group Russia

Air density (the number of molecules in a unit volume of air) influences the mass that moves turbine blades. Density decreases slightly with humidity and altitude. Air is more dense in winter than in summer, producing more power with the same wind speeds. Density is also less at high mountain altitudes (lower air pressure), but wind speeds are higher

Influences on Rotor Power

337. Iowa Energy Center



Swept areas of different turbine rotor types

Wind Turbine Rotor Influences

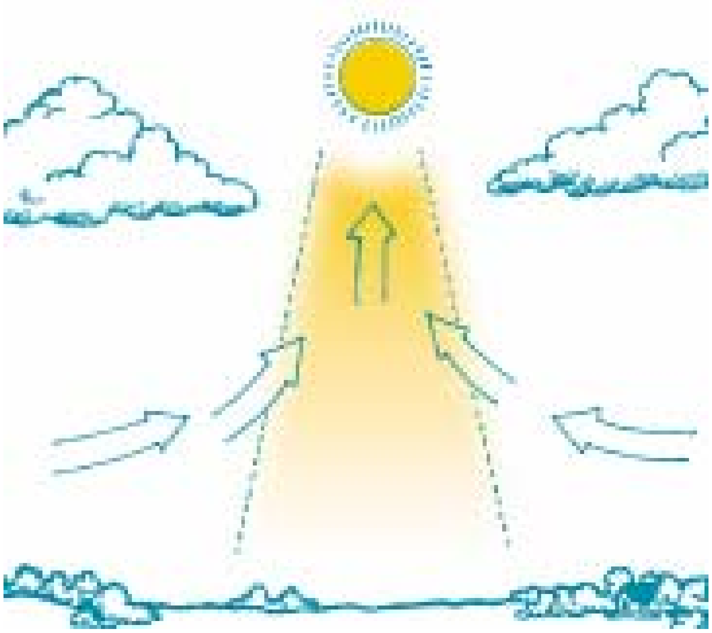
Although the power equation shows an exponential increase with wind speed, the actual power increase is more linear than predicted**.**

- Since turbines are not perfectly efficient, the power curve associated with each turbine is most significant:
  - Since the area swept by turbine blades is circular, **Swept rotor area A = πr².**
  - Assuming a wind speed of 15 mph, standard air density, and a rotor radius of 10 ft, the wind power (English units) is:

W = 0.0052Av³
W = 0.0052(314ft²)(15 mph)³
W = 0.0052(314)(3375)
W = 5,511 watts (5.511 kilowatts).

Wind site considerations

338. Natural Resources Canada



Upward Air Currents

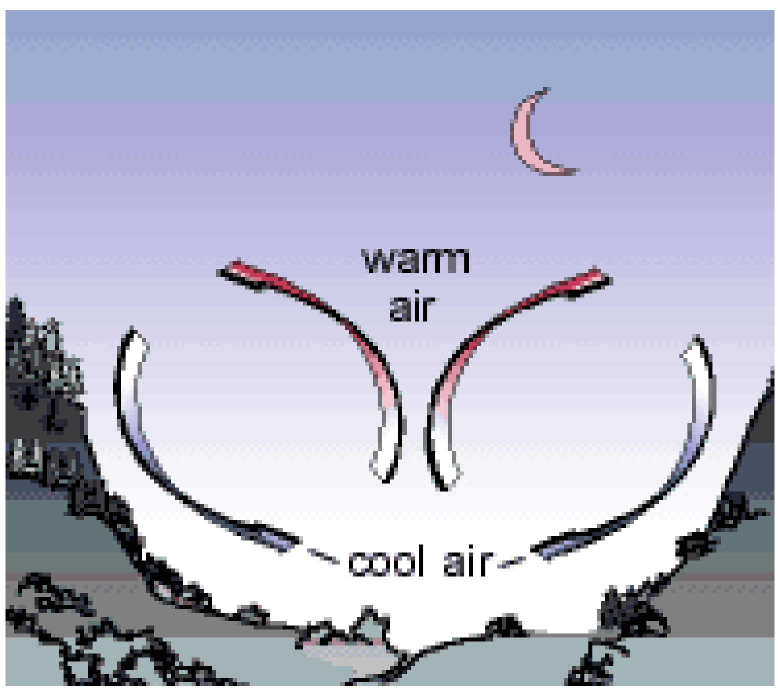
Approximately 2% of the Sun's energy reaching Earth is converted to wind energy (about 50 – 100 times more than the energy converted to biomass by all plants).

- The Earth's surface heats and cools unevenly, creating atmospheric pressure zones that cause air flow from the high- to low-pressure areas:
  - Daily and seasonal changes have important influences on wind conditions.
  - In Iowa (for example) seasonal winds are strongest in early spring and weakest in summer; daily winds are usually strongest in the afternoon and lightest in early morning.
  - Strongest winds generally prevail out of the southwest to northwest.

In selecting appropriate sites, hills, valleys, river bluffs, and lakes can produce highly variable wind regimes.

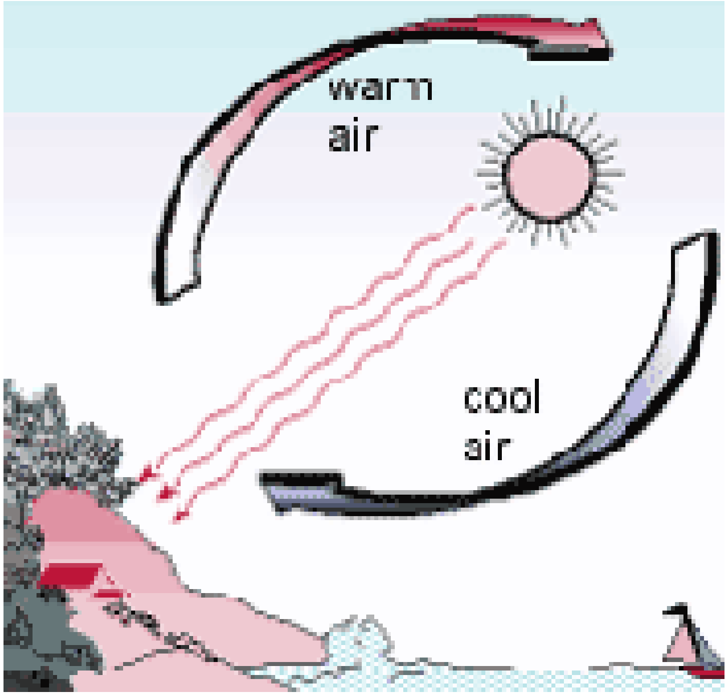
- Each geographical feature influences wind in certain ways:
  - Hills, plateaus, and bluffs provide high grounds which raise wind speeds, and can often produce power all night when turbines at lower elevations are idle.
  - Sheltered valleys often have lower wind speeds, but when oriented parallel to wind flow can channel and increase velocities.
  - Constrictions in valleys can further increase wind flow by funneling air into smaller areas.

339. Iowa Energy Center



Evening Wind Effects

340. Iowa Energy Center



Sites Near Water Bodies

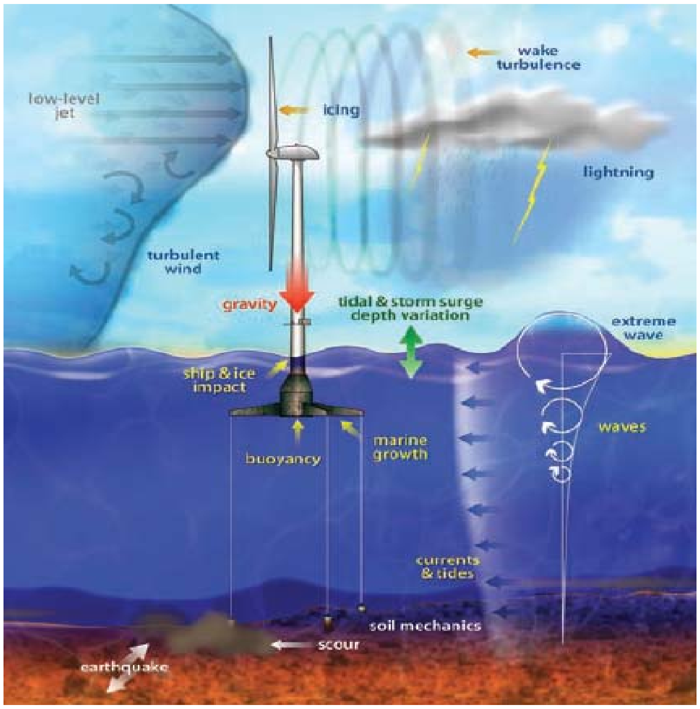
Land areas adjacent to large bodies of water can provide excellent wind turbine sites.

- Air flowing over flat water surfaces encounter little friction, and differential temperatures between land and water produce breezes:
  - The best shoreline sites are where the prevailing wind direction is "on-shore".
  - Local winds occur when warm rising air over land is replaced by cooler air over the water during the day, and when this condition is reversed at night as land cools more quickly.

Many large urban centers located along coastlines present major electricity demands.

- These areas are excellent candidates for offshore wind resources:
  - The DOE estimates that wind farms placed between 5 - 60 miles off coasts could provide as much as 900 GW of energy capacity.
  - Only 18 operating offshore wind projects currently exist in the world, constituting a total installed 804 MW capacity.
  - All installations are located in shallow coastal waters (less than 60 ft [18m] deep).
  - More than 11 GW of offshore wind projects are presently planned (mostly in Europe), with 600 MW in US undergoing permitting processes.

341. US DOE-EERE



Offshore Installations

Special off-grid benefits

342. The Organic College

Small-Scale Applications

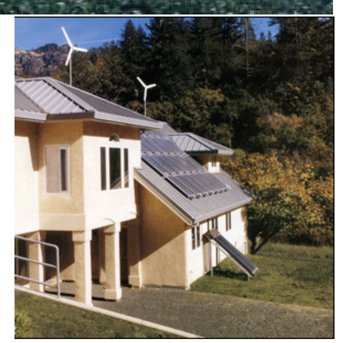
Wind has been an important source of energy for small-scale agriculture, industry and domestic applications for hundreds of years, and remains a valuable resource for electricity in many rural and remote sites.

- Wind can be particularly useful for off-grid circumstances, especially in combination with solar and other renewable sources:
  - Wind pumps for irrigation are viable options in some locations where breezes are constant and adequate for demands.
  - Wind can also be an excellent power source for telecommunication sites where height and exposure of antennas optimize conditions.
  - Since wind is not always present when needed, some means of electricity storage is often required, and use to electrolyze water into hydrogen for fuel cells represents one option.

Off-grid wind power can provide a renewable, environmentally-friendly, economical and low-maintenance small-scale energy source.

- Local applications are diverse:
  - Water pumping: “windmills” have been used for generations to supply water in rural and remote locations for livestock, irrigation, households, and even small communities.
  - Electricity: wind energy systems provide alternatives to fuel generators to power lights, electric fences, and a wide range of appliances.
  - Hybrid applications: wind turbines can be combined with other power sources such as photovoltaic systems, diesel generators and electric power grids to provide cost-effective, non-polluting backup energy.

343. US DOE-EERE
344. Treehugger
345. Enviro-Energy Technologies



Hybrid Wind/Solar Applications

Solar technologies and uses

346. US DOE-EERE

Solar Electric Conversion

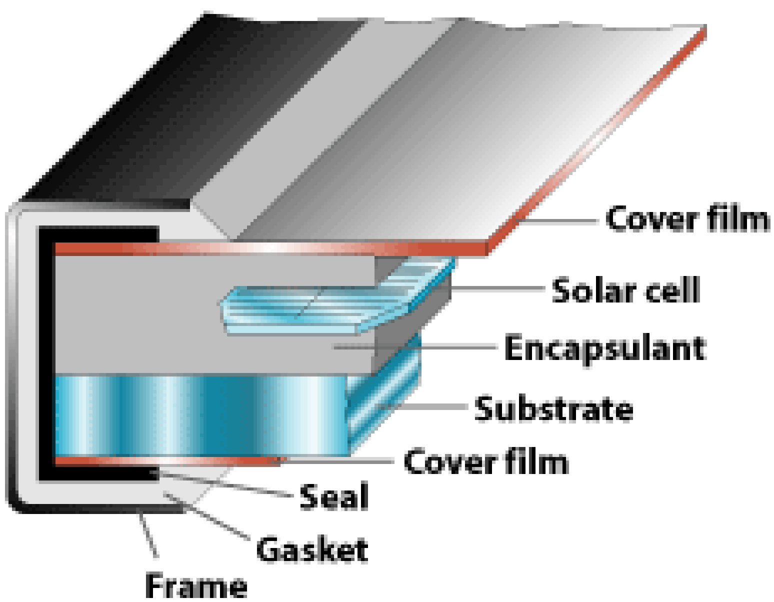
PV power systems produce electricity through solar electric conversion.

- When light photons of sufficient energy strike a solar cell, they knock electrons free in the silicon crystal structure, forcing them through an external circuit (battery or DC load) to then return to the cell and repeat the process.
  - The voltage output from a single cell is about 0.5 V with an average directly proportional to the surface area.
  - Typically about 30-36 cells are wired in series (+ to -) in each solar module.
  - A solar module with a 12 V nominal output (~17 V at peak power) can then be wired in series and/ or in parallel with other modules to form a complete solar array to charge a 12, 24 or 48 volt battery bank.

The most common PV array design uses flat plate modules (or panels) that can be either fixed in place or allowed to track the Sun.

- Fixed arrays are simplest because they lack moving parts and are relatively lightweight:
  - They are suitable for many locations, including most residential roofs.
  - While less efficient than tracking systems, they are also substantially less expensive
- Tracking arrays are useful when high efficiency is desired using smaller installations:
  - Optimal orientation to the Sun enables more energy to be captured with less surface area.

347. US DOE-EERE



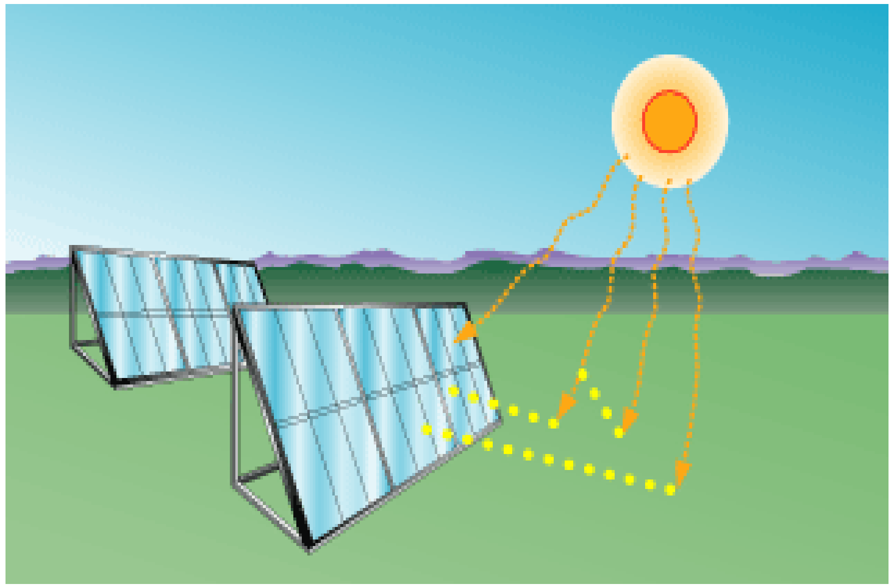
Typical flat plate module design uses a substrate of metal, glass or plastic to provide structural support on the back, an encapsulant material to protect the cells, and a transparent glass or plastic cover.

Flat Plate PV Design

Flat plate collectors draw a substantial amount of energy from diffuse sunlight.

- These systems containing a large number of cells mounted on a rigid, flat surface, and can use both direct sunlight and diffuse sunlight from clouds, the ground, and nearby objects.
  - In clear skies, the diffuse component of sunlight accounts for 10%-20% of the total solar radiation on a horizontal surface.
  - On partially sunny days, up to 50% of radiation is diffuse.
  - On cloudy days, 100% of the radiation is diffuse.

348. US DOE-EERE



PV arrays must be mounted on stable, durable structures that can withstand wind, rain, hail and other adverse conditions. Much solar energy is captured from diffuse radiation.

Diffuse Energy Collection

349. Sacred Power Corporation

PV-Wind Generator Hybrid System

PVs are commonly used for low-power off-grid applications using inverters to convert DC electricity to AC (resulting in a 4%-12% energy penalty).

- The effective marriage of solar power and inverters has opened up great opportunities for rural electrification in areas not served by public utilities:
  - Typical installations draw electricity from a co-located PV array, inverter, battery bank and switch gear system located in an outbuilding or other central distribution point.
  - Power from a wind generator or other source is often tied-in with PVs to provide hybrid system capabilities.

PV systems are becoming vitally important in threshold and developing nations where more than two billion people lack access to an electricity grid.

- Low population density regions with very limited energy consumption pose special problems due to large costs and efforts required to create public services:
  - Decentralized PV systems offer practical advantages for such areas as an alternative to kerosene lamps, disposable batteries or diesel generators.
  - Photovoltaics, in combination with wind turbines, motor generators or small hydropower plants, can offer sustainable, economical and socially acceptable solutions to energy needs.

350. German Energy Agency

Village PV System Installation

351. Fraunhofer Institute for Solar Energy Systems

Storage Batteries in Indonesian Village

A major requirement for off-grid PV applications is to provide means to supply or store power for use at night and on cloudy days.

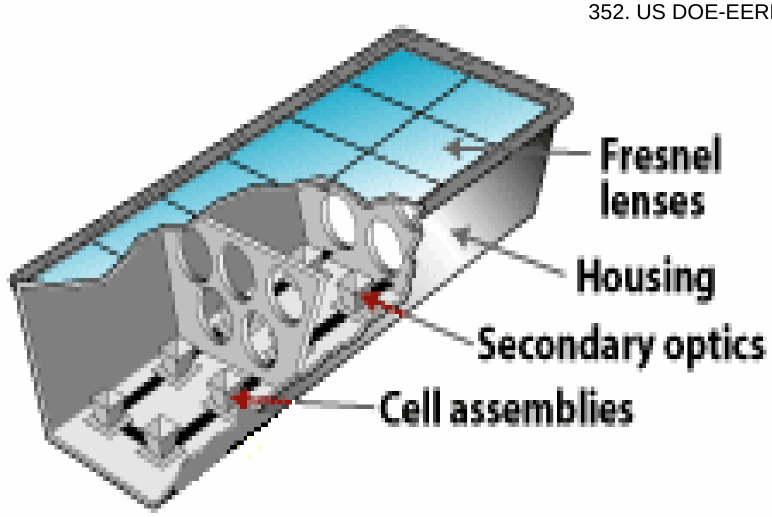
- Battery backup and storage systems are the common method, but present certain limitations and disadvantages:
  - Batteries lower the efficiency of a PV system because only about 80% of the energy that goes into them can be reclaimed.
  - Batteries usually need to be replaced every 5-10 years.
  - They also take up a considerable amount of floor space, have poor efficiency in cold weather, require periodic maintenance, and present potential safety problems.

Industrial power scale developments

Some new types of concentrating solar PV assemblies are offering higher power efficiencies, but are more expensive.

- These devices can be very effective for large-scale power generation, offering several advantages over flat plate approaches:
  - Both reflectors and lenses can be used in these units to concentrate light.
  - Fresnel lenses use a miniature "sawtooth" design to focus light.
  - While the best of the lenses can transmit 90%-95% of the direct incoming light, none can focus diffuse sunlight (20% of solar radiation available on clear days).

352. US DOE-EERE



A typical basic concentrator unit consists of a lens to focus sunlight, cell assemblies, a secondary concentrator to reflect off-center light, various electrical contacts, and support housings.

Typical Concentrator Design

353. Pyron Solar

The Pyron Solar Generator can produce 800 times more electricity than conventional non-concentrating cells of the same size.

Pyron Solar Generator

Spectrolab, Inc., a Boeing subsidiary company, has demonstrated the development of a new photovoltaic system with 40.7% solar energy conversion efficiency for space and terrestrial purposes.

- The device uses a special class of metamorphic semiconductor materials that are much more efficient than conventional silicon cells which are mounted in concentrator units:
  - The "Pyron Solar Generator," a platform 23 feet in diameter and 12 inches high can generate 6.6 kW of peak power (a record for its size).
  - Higher cell efficiency enables fewer cells to be used to achieve equivalent power, resulting in lower system and electricity costs.

354. US DOE-EERE

This high-performance solar power generator has been developed for the Arizona Public Service Company's Solar Test and Research (STAR) center.

Concentrator PV System

Although usually not suitable for small projects, solar concentrator PVs can make use of relatively inexpensive materials such as plastic lenses and special metal housings to focus more energy onto cells, thereby increasing output.

- These devices can be very effective for large-scale power generation, offering several advantages over standard PV approaches:
  - Fewer solar cells are needed to accomplish power objectives using concentrated light more efficiently.
  - Solar cells are more efficient using concentrated light.
  - Concentrators can use cells which are easier/cheaper to produce than large-area, high-efficiency PV cells.

Concentrating solar power (CSP) systems use lenses or mirrors that track the Sun to focus a small beam of radiation onto a thermal collector or PV cells to produce electricity.

- Within the US more than 350 MW of CSP capacity currently exists, and has been operating reliably for more than 15 years.
  - CSP systems range in size from as small as 10 kW (a typical US home can meet most energy needs with about 5-15 kW), to more than 100 MW for utility grid-connected applications.
  - Since the systems make use only of direct sunlight (not diffuse light), use is limited to sunbelt locations.
  - Many provide thermal storage for power during nighttime and cloudy periods.

355. James Fraser

Tracking Solar Power Concentrators

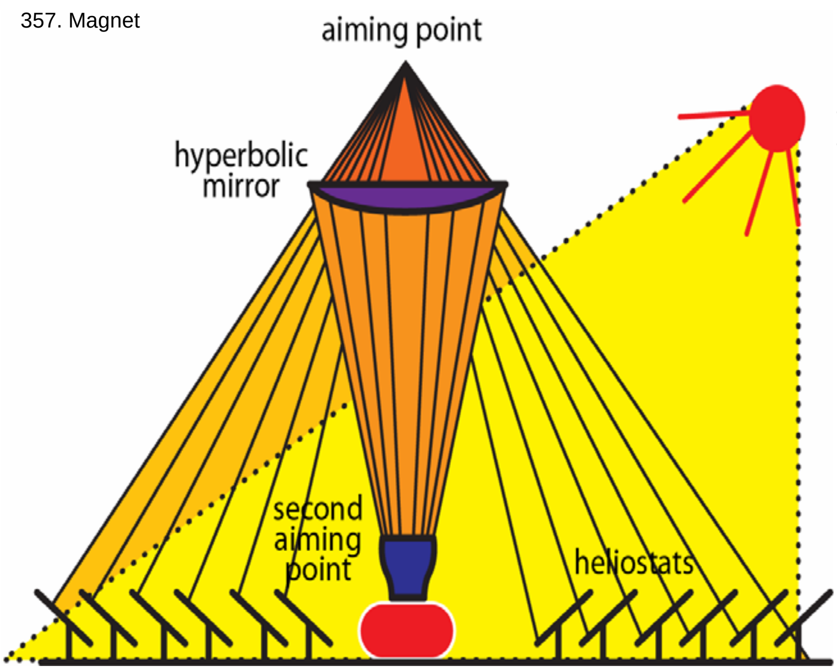
356. US Dept. of Labor - OSHA

Concentrating Solar Power Tower

Solar thermal power CSP systems heat fluids and gases to high temperatures that drive steam or gas engine-turbines.

- These systems use various types of mirrored sunlight collectors and concentrators that focus high-temperature radiation onto heating element targets:
  - Power towers (or "heliostat" power plants) use flat, moveable mirrors to focus energy upon a collector tower that reflects it back to an absorber to store heat for later use.
  - Dish and trough collectors track the Sun to concentrate and focus energy that drives steam or sealed-gas engine-turbines to produce electricity.

357. Magnet



Concentrating Solar Power Tower

Power tower CSP systems are comprised of numerous large sun-tracking heliostat mirrors that focus sunlight onto a hyperbolic receiver at the top of the tower which reflects it back to a second aiming point.

- The concentrated energy heats a transfer fluid or molten nitrate salt in the receiver to generate steam power or hot gas to drive sealed closed-cycle turbine-generators:
  - Power towers can typically produce between 600 KW - 34 MW of electricity, with an average 250 KW - 5 MW in continuous operation.
  - Thermal-electric efficiency may range from 25%-50%, and overall solar-electric conversion turbine-engine efficiency may range from 13%-25%.

358. US DOE-EERE

Concentrating Solar Dish-Engine

Solar dish-engine CSP systems are stand-alone electric generators that use a solar concentrator that reflects energy onto a receiver.

- The reflective concentrator surface is made of glass mirrors that reflect about 95% of the sunlight that strikes them:
  - The receiver transfers collected heat either to a bank of tubes containing a gas (usually hydrogen or helium) that serves as a transport medium, or to heat pipes that use an intermediate boiling fluid that condenses to transfer heat to an engine-turbine.
  - Although dish-engine systems are not yet commercially available, ongoing demonstrations indicate good potential to generate up to 35 kW of power.
  - Individual systems can be connected together to increase capacity, and can be combined with other systems for continuous hybrid power-generation.

359. US DOE - EERE

Concentrating Parabolic Troughs

Trough-type CSP systems use a collector field comprised of many parabolicly-curved trough-shaped reflectors that transmit thermal energy onto inside receiver pipes.

- Parallel rows of the troughs are aligned on a north-south axis to track the Sun from east to west during the day, requiring no mechanical pointing mechanisms:
  - Current systems can generate 80 MW or more of electricity.
  - Thermal storage can enable electricity generation to continue several hours into the evening in combination with other energy sources to supplement low solar radiation periods.
  - Trough systems are the simplest and least expensive of all CSP devices.

Converting heat to electricity

360. Geothermal Education Office
361. US DOE OCRWM

In addition to solar thermal concentrators heat energy is converted to electrical power from two other primary sources, geothermal and nuclear.

- Both sources typically heat a fluid to produce steam that drives a turbine generator to provide electricity, although geothermal energy is also frequently used for direct heat for buildings as well as for near-site applications:
  - Geothermal power is generally limited to use at or near the source locations and has relatively low heat / power conversion efficiencies.
  - Nuclear power is a substantial electricity generator source connecting to regional and national grids providing competitive commercial economies.

Geothermal sources currently produce about 5% of the renewable energy in the US, a total of only about 0.3% of the total of all energy produced.

- Future growth is severely limited by an extreme scarcity of sites with suitably high temperatures (225º - 600ºF [107° - 315°C]):
  - Of the approximately 2,700 MW of electricity produced in the US, about 1,000 MW is generated at The Geysers, a plant located about 90 miles north of San Francisco.
  - Other smaller plants are located or under development in California, Nevada, southeastern Oregon, southwestern Idaho, Arizona, and western Utah.
  - Geothermal electricity is presently not very competitive with fossil and nuclear-fueled power due to much lower temperatures and energy conversion efficiencies.

362. US DOE-EERE

Geothermal power is limited to certain western US locations, and is presently not cost-competitive with fossil or nuclear due to lower energy and conversion efficiencies.

Geothermal Energy

Geothermal power generation

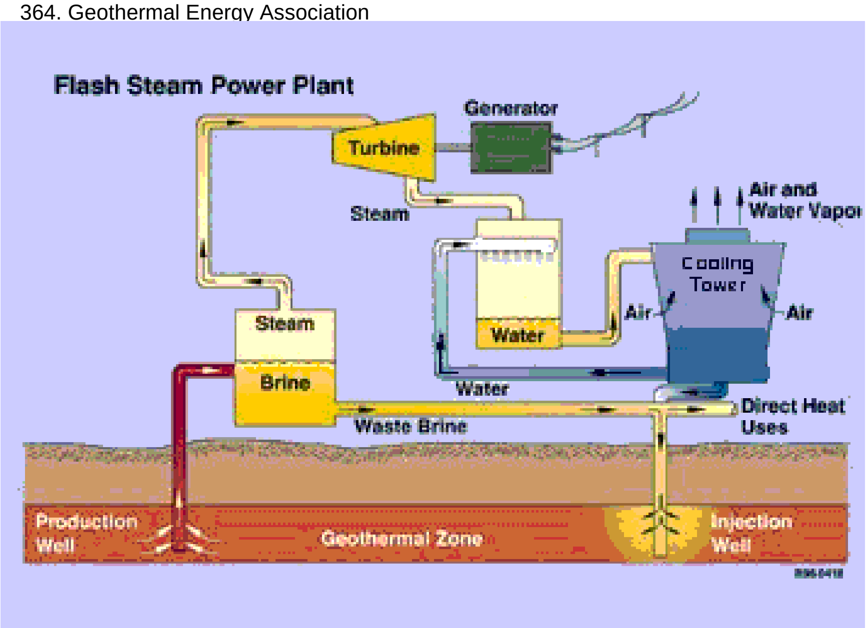
Natural geothermal reservoirs of low-to-moderate temperature water (68ºF – 302ºF [20°C - 150°C]) provides sources of heat for direct use or conversion to electrical power in many regions of the world.

- Geothermal electricity is produced by steam or binary-cycle water generators supplied by near-surface wells heated by Earth's magma and hot rock:
  - Because they are most abundant, moderate-temperature sites running binary-cycle power plants are most commonly considered as electricity producers.
  - Technology advancements will be necessary to make these sources of electricity more cost-competitive with traditional energy options before geothermal power becomes a key element of the US energy infrastructure.

363. Geothermal Energy Association

Harnessing the Earth's Heat

364. Geothermal Energy Association

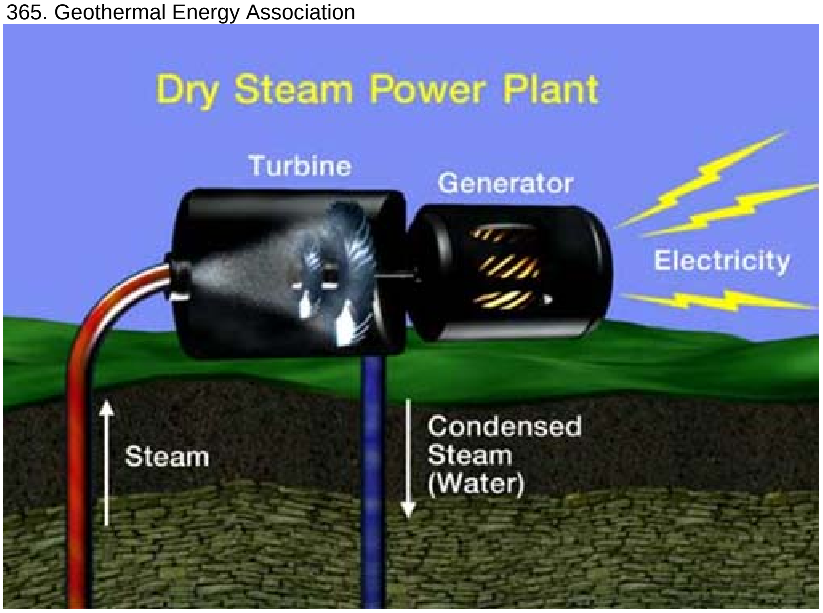


Flash Steam Power Plant

Some plants use high-temperature subterranean water to produce electricity.

- Flash steam power plants convert hydrothermal fluid above 360ºF (180ºC) to steam:
  - The fluid is sprayed into a tank held at a much lower pressure than the fluid, causing some of the fluid to vaporize ("flash").
  - The vapor drives a turbine, which, in turn, drives an electrical generator.
  - Any remaining liquid in the tank is flashed again to extract more energy for added efficiency.

365. Geothermal Energy Association



Dry Steam Power Plant

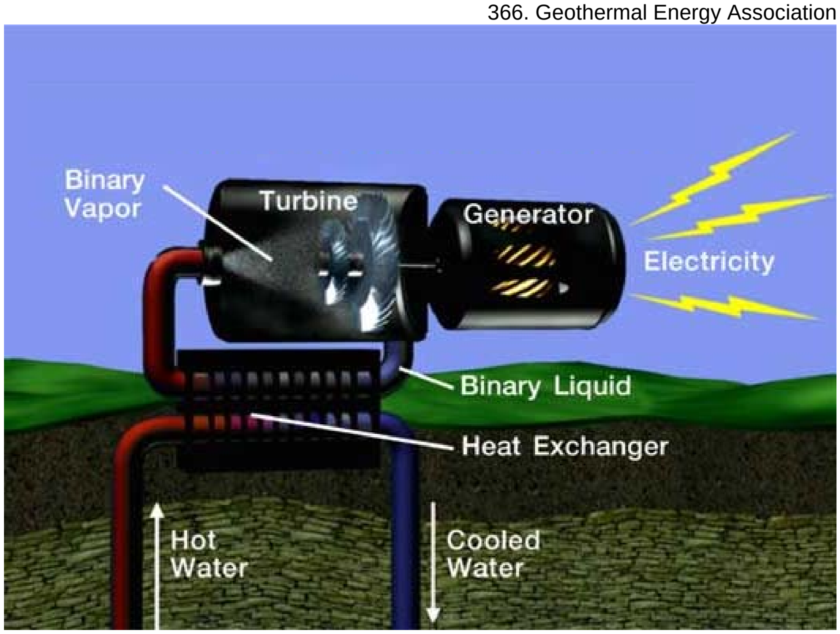
Dry steam power plants use hydrothermal fluids that are primarily steam.

- The steam goes directly into a turbine which drives a generator to produce electricity:
  - This is the oldest type of geothermal power plant, first used at Lardarello, Italy in 1904.
  - The technology remains to be effective, and is used today at The Geysers plant in northern California (the world's largest single source of geothermal power).
  - These plants emit only excess steam and very minor amounts of gases.

Binary-cycle power plants use moderate-temperature water (below 400ºF [200°C]).

- Energy is extracted from the fluid by a second ("binary") fluid with a much lower boiling point than water in a heat exchanger:
  - Heat from the geothermal fluid causes the secondary fluid to flash to vapor that drives a turbine.
  - Since this is a closed-loop system, nothing is emitted into the atmosphere.
  - Moderate-temperature water is by far the most common geothermal resource, and most future geothermal power plants will be binary-cycle types.

366. Geothermal Energy Association



Binary-Cycle Power Plant

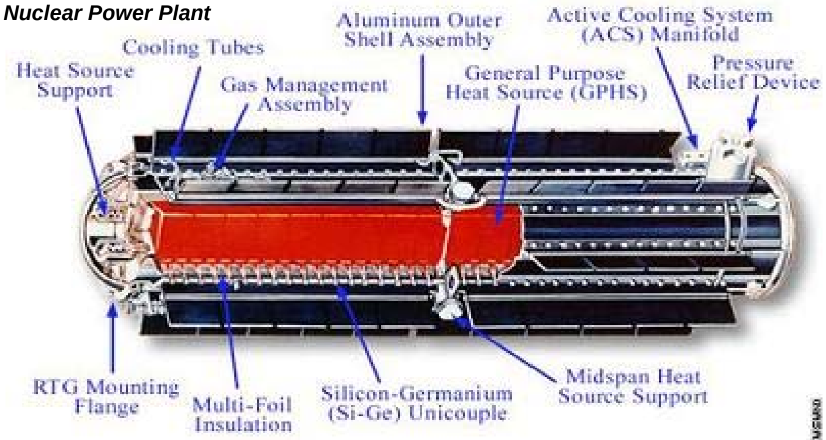
Utilizing heat and power from atomic transformations

367. Picture Newsletter
368. NASA

The radioactive decay of certain isotopes (or radio nuclides) releases heat energy through changes in the atomic nuclei that can be used to generate electricity or applied directly.

- Current applications of isotopic energy are used to produce electrical power at large and small levels of scale:
  - Nuclear fission reactors split nuclei of heavy atoms such as uranium to create large amounts of energy to boil water into steam that drives turbine generators that produce commercial quantities of electricity.
  - Radioisotope thermal generators (RTGs) use spontaneous decay of plutonium-238, a heavy radioactive metallic element, to produce much lower heat energy levels used primarily for small-scale space applications.

Nuclear Power Plant



Radioisotopic Thermal Generator

Isotopic Power

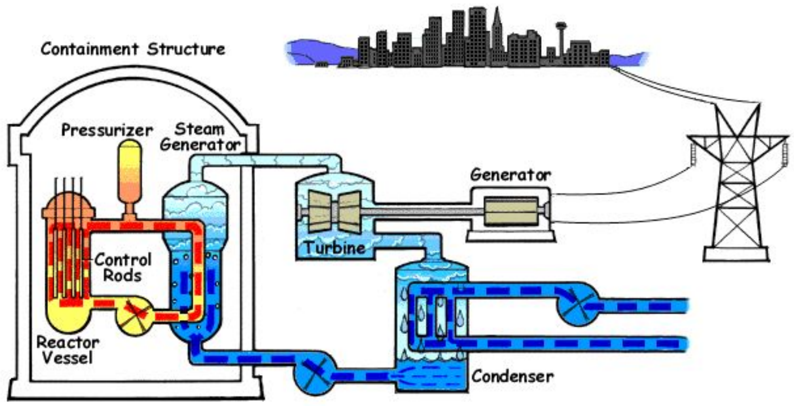
369. WP Clipart

Nuclear Reactors

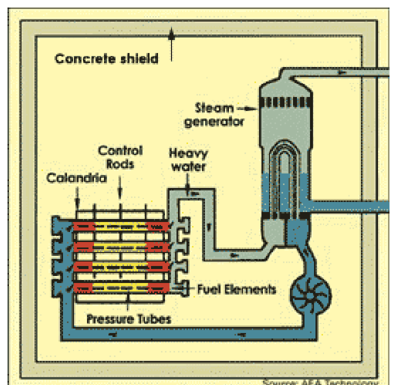
Nuclear power uses heat from the radioactive decay of a fissile material such as uranium-235 or plutonium-239 to boil water into steam that generates electricity.

- Renewed international government and public interest in nuclear energy is being motivated by increasing oil prices, improvements in plant safety design and concerns about fossil fuel greenhouse emissions:
  - Energy produced by one ton of uranium equals the energy produced by about 3 million tons of coal, or about 12 million barrels of oil.
  - Supplies of uranium and plutonium are abundant in Earth's crust, and are relatively inexpensive.
  - These advantages are offset because nuclear reactors are more expensive to build than coal-fired types, containment failures can be very hazardous, and spent wastes remain radioactive long after use.

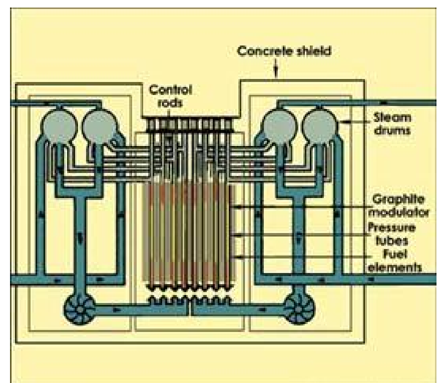
370. US Nuclear Regulatory Commission
371. AEA Technology



Light Water Reactor



Graphite Moderated Reactor



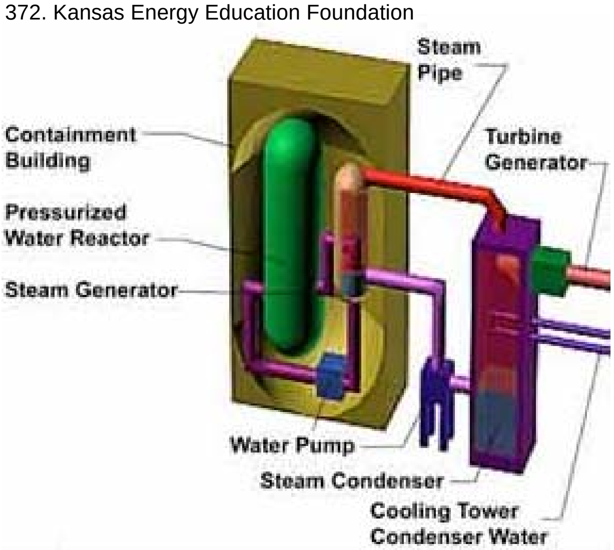
Heavy Water Reactor

Nuclear Reactor Types

While there are many types of nuclear fission reactors three are most conventionally used today.

- Light water moderated reactors (LWRs) use ordinary water to moderate and cool the reactions:
  - When the operating temperature of the water increases, its density drops, causing fewer neutrons passing through to be slowed enough to trigger reactions, thereby stabilizing the reaction rate.
- Graphite moderated reactors and heavy water reactors tend to be more thoroughly thermalized than LWRs, and can use natural uranium / unenriched fuels (about 0.72% uranium-235 and the rest uranium-238).

372. Kansas Energy Education Foundation



Nuclear Reactor Steam Supply Systems

Nuclear reactors are often located near rivers or lakes to enable steam they produce to be cooled, although this heat can warm the water bodies and be harmful to wildlife and plants. As a result, many have cooling towers that allow heat of water to pass into the atmosphere.

- Typical reactors use pressurized or boiling water steam systems:
  - Pressurized water reactors (PWRs) constitute the majority of types used today and are generally considered to be safest and most reliable (although the Three Mile Island reactor was of this type).
  - Boiling water reactors (BWRs) operate under slightly lower pressure, and while thermal efficiency can be higher, the boiling water can stress some components and increase risks of radioactive water leakages.

Advanced and experimental reactor developments

373. ESI Africa

Pebble Bed Nuclear Reactor

The pebble bed reactor (PBR) is an advanced technology that offers significantly higher safety and efficiency levels than conventional light water nuclear reactors.

- Instead of water, PBR uses pyrolytic graphite as the neutron moderator, and an inert or semi-inert gas such as helium, nitrogen or carbon dioxide as the coolant that directly drives a turbine:
  - Uranium, thorium or plutonium fuels are fixed in ceramic form within spherical graphite “pebbles” that function like complete mini-reactors that are combined together in quantities necessary to achieve desired power outputs.
  - The design is relatively simple and self-controlling, avoiding complex water cooling systems with piping that can become brittle over time and expensive backup safeguards.

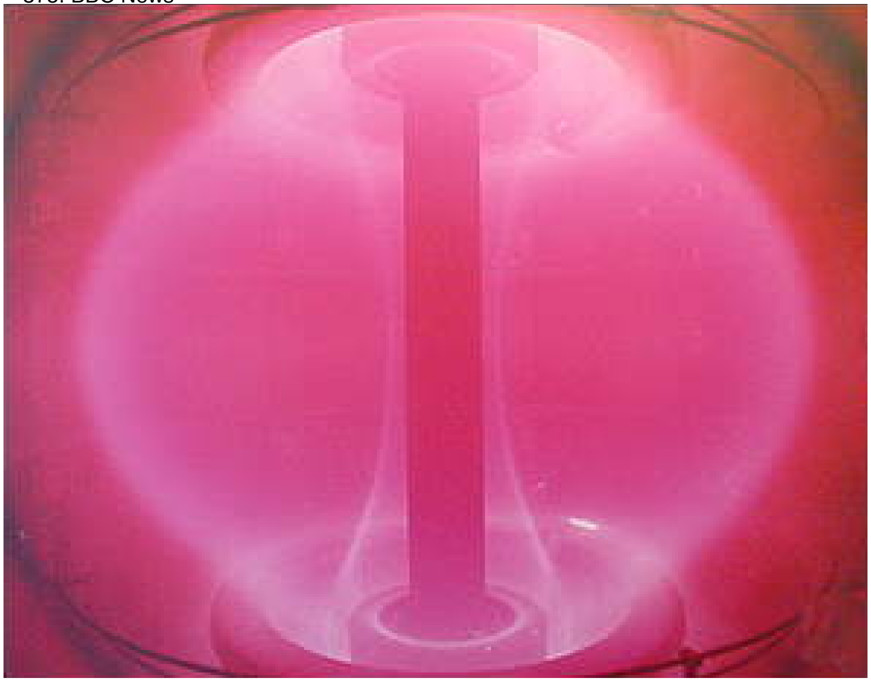
Pebble bed reactors contain nuclear fuel in small 0.02 inch diameter graphite spheres that limit any containment failure to this amount of material.

- As the fuel heats, the reaction rate automatically lowers the fuel temperature without mechanical aides.
  - South Africa is constructing an advanced pebble bed reactor demonstration plant near Pretoria.
  - China currently has the only operational plant of this type, an experimental model near Beijing, and plans to build several more.

374. Wikipedia Commons

Graphite Pebble

375. BBC News



Nuclear Fusion Experiment

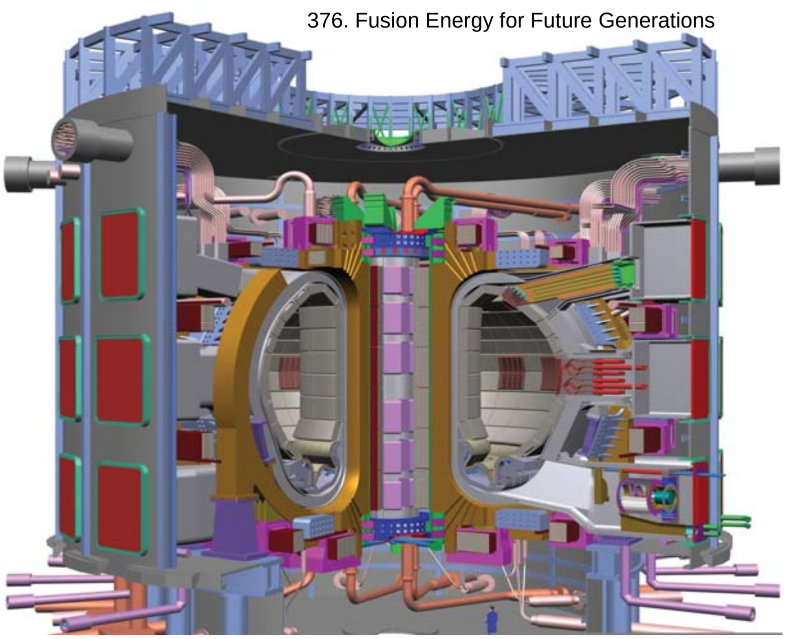
Nuclear fusion can potentially offer an advantage over nuclear fission because radioactive wastes would be safe to handle in 50-100 years compared with many thousands for fission wastes.

- This has proven to be an elusive goal due to incredible temperatures needed to produce the reaction, requiring high energy inputs and challenging containment means:
  - The largest previous experimental nuclear fusion device heated hydrogen isotopes suspended in a magnetic field to 300 million degrees.
  - The experiment produced an output of 16 MW for only a few seconds, consuming slightly more energy than it created.

An agreement was announced in June, 2005 to build an International Thermonuclear Experimental Reactor (ITER) at Cadarache in France through a partnership involving the EU, US, Japan, Russia and China. (India later joined the project.)

- The goal is to create the first nuclear fusion device to produce thermal energy at a conventional power plant scale to pave the way for commercial applications:
  - Construction is expected to take at least a decade, and there is no assurance that the venture will be successful due to technical uncertainties.
  - Whether or not fusion offers any potential economic advantages over other forms of power is unclear, and commercial opportunities, if any, are not expected for several decades.

376. Fusion Energy for Future Generations



Planned International Thermonuclear Experimental Reactor Fusion Device in Cadarache, France.

Small scale space and terrestrial radioisotopic applications

377. NASA

Apollo 12 Astronaut Alan Bean Loading an RTG Package Into an Ascent Vehicle.

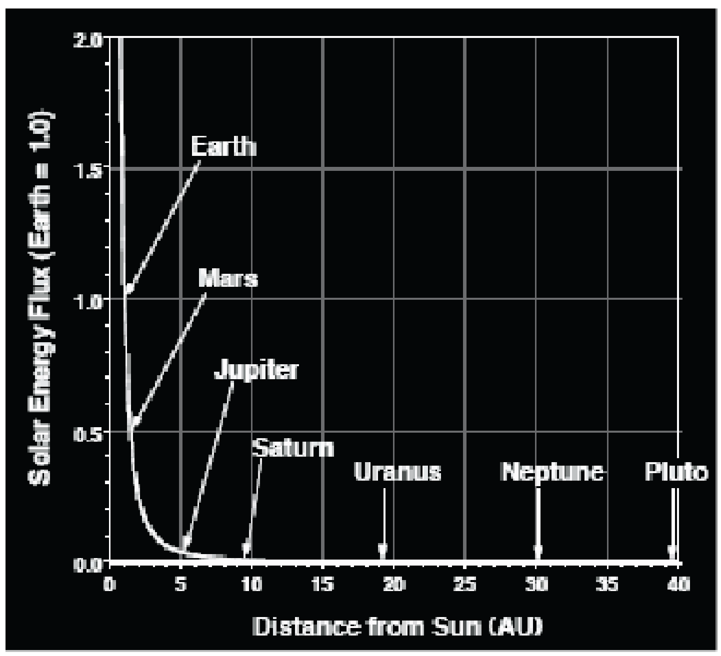
Heat produced from natural alpha particle decay of plutonium-238 is converted to electrical power through a passive thermoelectric or dynamic nuclear generator process.

- RTGs have been used on many manned and unmanned space missions to provide heat and power.
  - Heat produced from these processes can be useful for thermal control of subsystems in extremely cold space environments.
  - Astronauts on five Apollo missions left numerous RTGs behind to power a variety of "Apollo Lunar Surface Experiment Packages".
  - One produced 75 watts of electricity to power an experiment package for nearly 8 years.

RTGs afford a number of important advantages over photovoltaics, fuel cells and other available technologies for deep space and planetary surface applications.

- Unique features include:
  - Steady power delivery independent of distance and orientation with respect to the sun.
  - Operation in shadowed and heavily clouded regions and locations (craters and thick atmospheres).
  - Power generation in extreme environments (Venus and Titan).
  - Operation in high-radiation environments (Jovian space).
  - Long-duration operations (tens of years or more).
  - For human missions, alpha radiation produced by plutonium-238 will not penetrate the skin, but is harmful if dust is inhaled or ingested.

378. NASA / STAIF



Solar Energy Flux as a Function of Distance from the Sun (AU)

379. NASA

Cassini mission equipment included three RTGs providing a total of 850 watts of power.

Cassini RTG Inspection Before Launch

The most common application of RTGs is to provide power for unmanned spacecraft.

- Since 1961, “System Nuclear Auxiliary Power Program” (SNAP) units have been used for probes traveling far from the Sun where solar panels are ineffective:
  - Viking landers and scientific experiments were left on the Moon by the crews of Apollo 12 – 17.
  - Voyager 1 and 2 traveled beyond Uranus and Neptune, 70 times farther from the Sun than Earth, where it is very cold and there is little solar energy.
  - Pioneer 10 and 11 traveled past Jupiter, Saturn and ultimately, beyond Pluto.
  - The NASA/ESA Ulysses spacecraft flew by Jupiter in 1992, and went into orbit around the Sun.
  - Cassini explored Saturn’s rings and moons.
  - New Horizons launched in 2006 will visit Pluto and its moon Charon.

RTGs have also been used for a variety of terrestrial applications.

- Uses range dramatically in size and purpose:
  - One of the first terrestrial RTG uses was by the US Navy (1966 –1995) at the uninhabited Fairway Rock Island in Alaska.
  - Some very small plutonium-238 RTGs (plutonium “cells”) have been used in heart pacemakers to ensure long “battery life”.
  - The former Soviet Union constructed many unmanned lighthouses and navigation beacons power by Beta-M RTGs.
  - It is estimated that as many as 1,000 discarded RTGs that have exhausted their engineered life spans remain in Russia, imposing radioactive contamination risks.

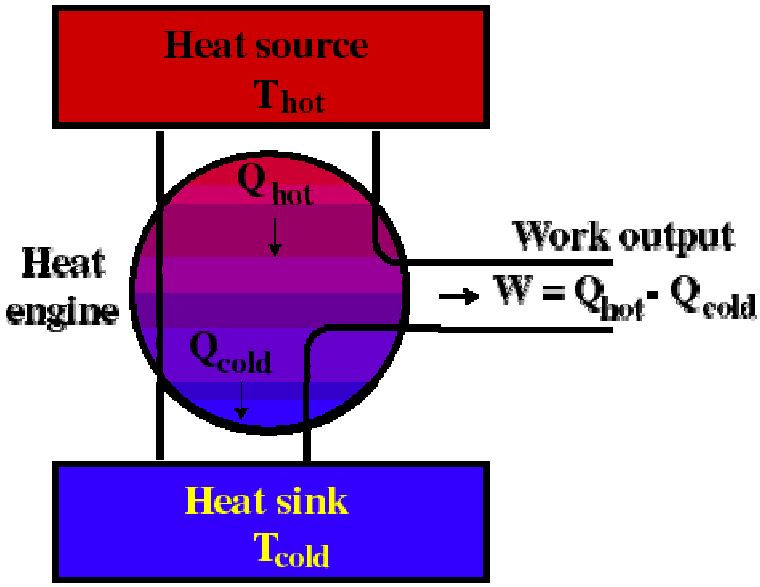
380. Finland Regional Government

Many former Soviet RTGs developed for various purposes are no longer functional and exist in hazardous dilapidated and vandalized conditions.

Discarded Soviet RTGs

Engines that convert heat to mechanical energy and back

381. University of Oregon



Heat Engine Efficiencies

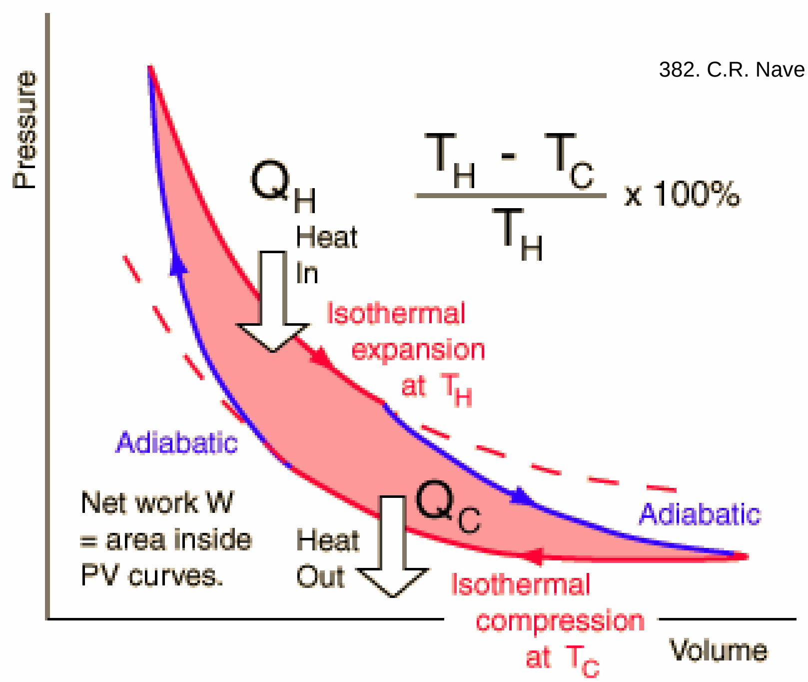
Heat engines, including steam, gasoline and diesel types, extract mechanical energy to do work from a temperature difference (or gradient) between a hot source and cold body (heat sink).

- As decreed by the Second Law of Thermodynamics, no heat engine can be 100% efficient, because not all of the source heat can be converted to do work:
  - In general, larger temperature gradients between the source and cold side produce greater potential engine efficiencies.
  - On Earth, the cold side is typically close to the ambient temperature of the environment, so most efforts to improve thermodynamic efficiency focus upon increasing the source temperature.

Heat engines operate on thermodynamic cycles that occur each time heat is converted to mechanical energy and back.

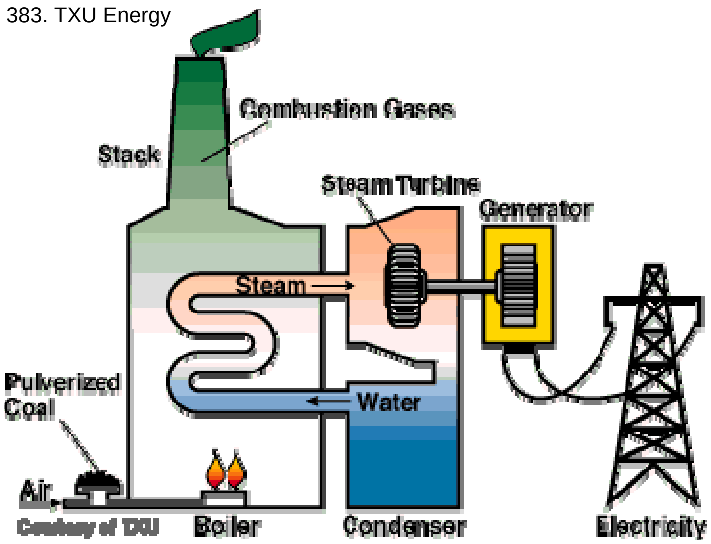
- This same general principle is applied to heat pumps such as refrigerators, but in reverse, where mechanical energy can be transferred from a colder body to a warmer one:
  - No heat engine can operate reversibly as a heat pump without putting more energy back into the system.
  - This rule can be demonstrated mathematically by an imaginary “Carnot engine” (a perfect but impossible device) that could only operate if a heat engine cycle was completely reversible.

382. C.R. Nave



The Carnot Cycle

383. TXU Energy



Steam turbines have replaced steam engines to drive generators that produce the majority of all US and world electricity.

Steam Turbines

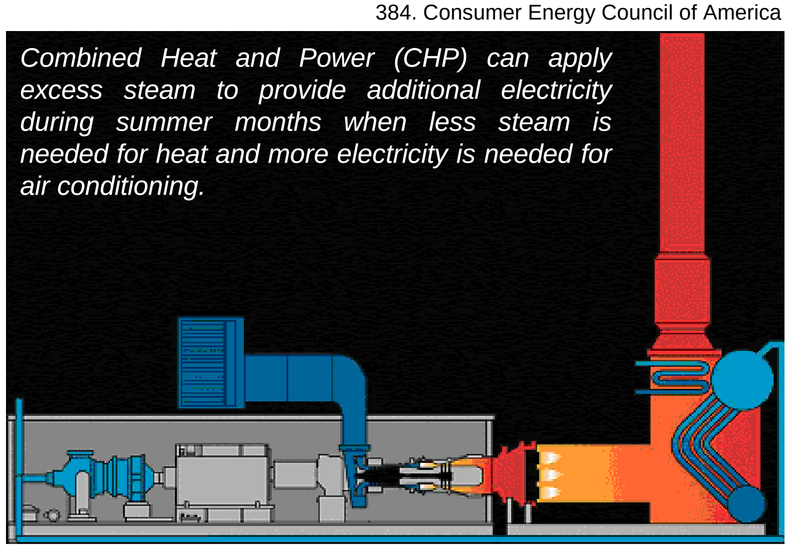
Steam turbines are a form of heat engine that operate somewhat like water turbines using thermodynamic force rather than water pressure to provide mechanical output that is converted to electrical power.

- These turbines range greatly in size, from 1 hp (0.75 kW) units to more than 2,000 hp (1,500 kW) for utility-scale electricity:
  - Steam turbines create rotary mechanical motion that is particularly useful for driving generators, produce more than 85% of all world electricity, and generate more than three-fourths of all US electricity.
  - Thermal conversion efficiencies range from 20%-90% depending upon types and applications, usually offering excellent power-to-weight ratios.

Steam turbines operate on a "Brayton" cycle, and are one of the oldest and most versatile technologies used to drive electrical generators and produce process heat for other applications.

- Steam turbines use stationary sets of blades, comprising impellers that are mounted on shafts to produce kinetic energy:
  - A high pressure maintained in front of an impeller, and a low temperature behind, provides a pressure and thermal gradient.
  - As steam shoots through the turbine to the rear, its energy is converted to blade velocity.
  - Exhaust heat can be recycled back to the burner to produce more power, or can be redirected for separate purposes.

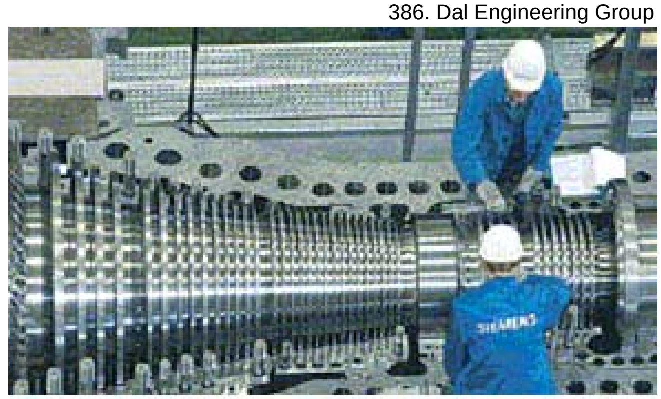
384. Consumer Energy Council of America



About 80% of all bulk utility-scale fossil fuel plants, and all nuclear plants, use turbines to produce electricity and apply waste exhaust heat for supplementary power, thermal processes and other applications.

Combined Cycle Heat and Power Turbines

385. Siemens
386. Dal Engineering Group

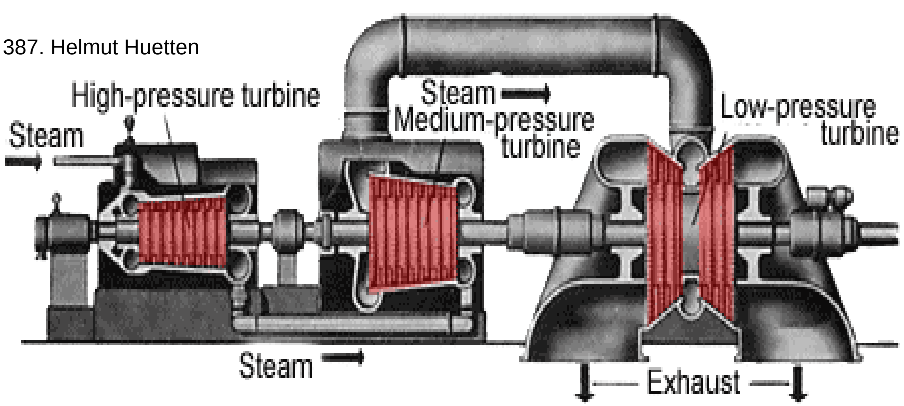


Condensing Steam Turbines

Steam turbines come in a variety of technical forms.

- Most that are used in large power plant applications are condensing-type turbines for primary power:
  - Used steam exhausted by each stage passes through a series of condensers to ensure that an optimum amount can be extracted to provide the most efficient thermal cycle.
  - Operators controlling the process can allow more steam to be used as desired, either for thermal applications, or to produce more electricity during periods of lower heat demands for other purposes.
  - The CHP waste heat is produced at no cost, although a separate Heat Recovery Steam Generator (HRSG) and associated equipment are required to convert hot exhaust gases into useful process steam.

387. Helmut Huetten



Steam cools and expands as it passes through each impeller, requiring larger, conical-shaped impellers in sequence. Coupled with a generator and fired by a nuclear reactor, they can produce large amounts of electricity, exceeding 1,000 MW.

After passage through the system, condensed water can be returned to a boiler by a pump (a special advantage in nuclear plants where radioactive thermal water is clearly separated from cooling water).

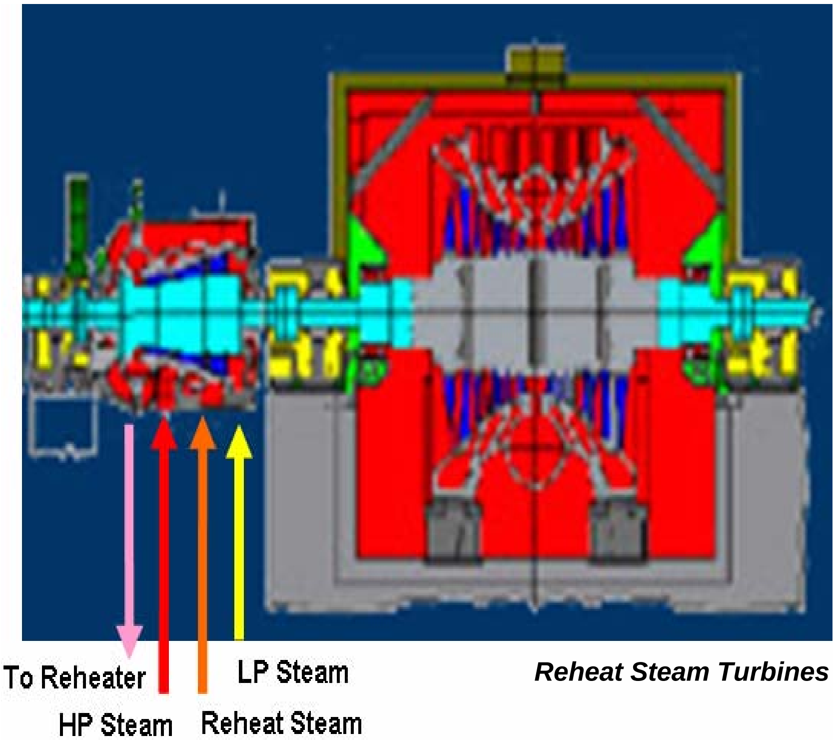
Coupling of Steam Turbines

Modern steam plants use multiple impellers configured in series that are referred to as “multi-level” systems.

- Between the impellers are idlers that don’t turn, where gas changes direction to be used in the next impeller:
  - Power plants typically use different turbine designs in series (e.g. one high-pressure, followed by 2 medium- and 4 low-pressure units).
  - This coupling leads to excellent efficiency (often more than 40%), which is superior to large diesel engines.

Steam powered turbines for primary and industrial applications

388. Ansaldo Energia



Reheat Steam Turbines

Turbine energy conversion is most efficient when the gradient between high and low pressures from input through output is as large as possible, an advantage for nuclear installations, and a frequent disadvantage for geothermal heat sources.

- In many utility-scale applications, the low-pressure steam at the outlet of a high-pressure chamber is returned to the boiler where additional superheat is added, which then goes to an intermediate pressure section of the turbine to continue its expansion:
  - Reheat is a form of energy recycling to provide higher efficiencies.
  - Reheat can also take advantage of afterburners to provide supplementary heating that greatly increases power, but markedly decreases efficiency.

Non-condensing (or back pressure) turbines are used in combination with condensing types or as separate units in refineries, distinct heating units, pulp and paper plants and desalination facilities where large amounts of low-pressure steam is available.

- These systems are typically smaller and less efficient than condensing types (about 15%-35% efficiency), but are also less expensive:
  - Higher pressure steam is used to drive the turbines, leaving lower pressure steam to be used for process or space heating.
  - They are often used in industrial and institutional settings which have limited power and heating needs and budgets.

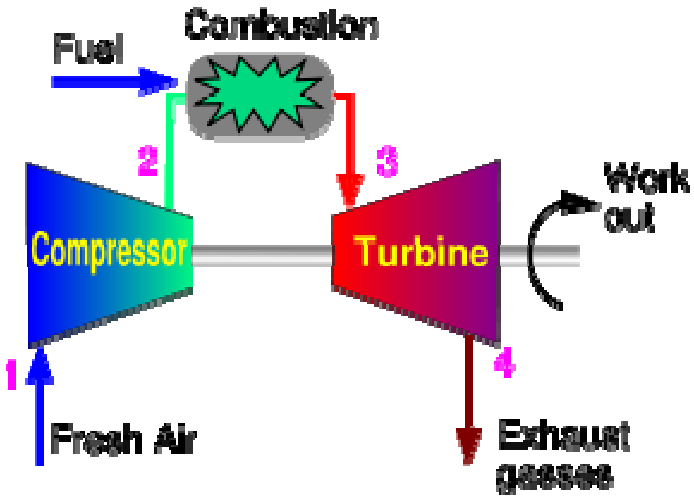
389. Global Power Resources

Back pressure steam turbines are often used in connection with industrial processes that have a need for low- or medium-pressure steam.

Back-Pressure Turbines

Gas – fueled turbines for varied uses

390. Duk



Gas Turbines

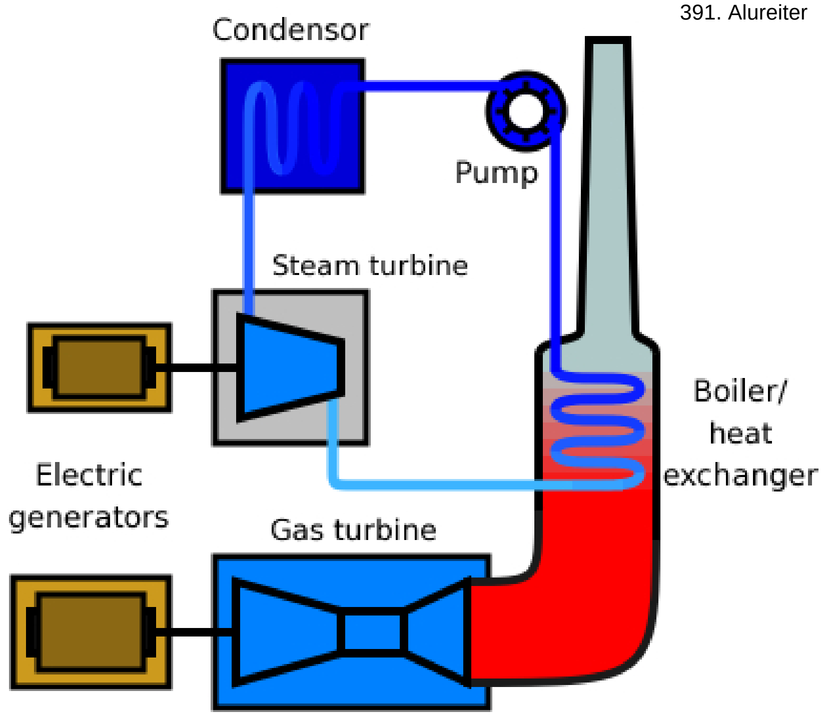
A gas turbine, also called a combustion turbine, is a rotary heat engine that extracts energy from a flow of gas.

- Gases (typically air) are compressed, heated, and then expanded to drive the turbine, with excess energy over that consumed by the compressor used for power generation:
  - Similar to a steam turbine, gases directed over turbine blades cause it to spin and power the compressor.
  - Gases then pass through a nozzle to generate additional thrust by accelerating hot exhaust through expansion back to atmospheric pressure.
  - Energy is extracted in the form of shaft power, compressed air and thrust, or any combination of these to power electric generators, aircraft, trains, ships, and even tanks.

Industrial gas turbines range in size from truck-mounted mobile plants to enormous complex systems for bulk utility-scale plant operations.

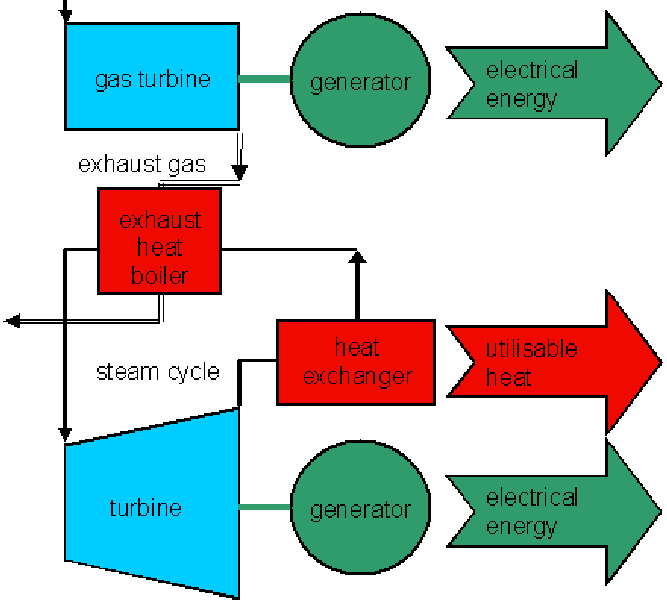
- Very large industrial turbines for electrical power generation operate at 3,000 rpm or 3,600 rpm to maintain AC grid frequency, and can produce large outputs:
  - They can be particularly efficient (up to 70%-80% electrical and useful thermal) when heat from a gas turbine is recovered by a steam turbine in a combined heat and power (CHP) installation.
  - Used in a simple-cycle operation where a single gas turbine is utilized for power only, their efficiencies approach about 40%.

391. Alureiter



Combined-Cycle Gas Turbines

392. Austrian Energy Agency



Gas turbines can provide power and heat in stand-alone applications, or can be combined with steam turbines for greater power and efficiencies.

Gas Turbine Applications

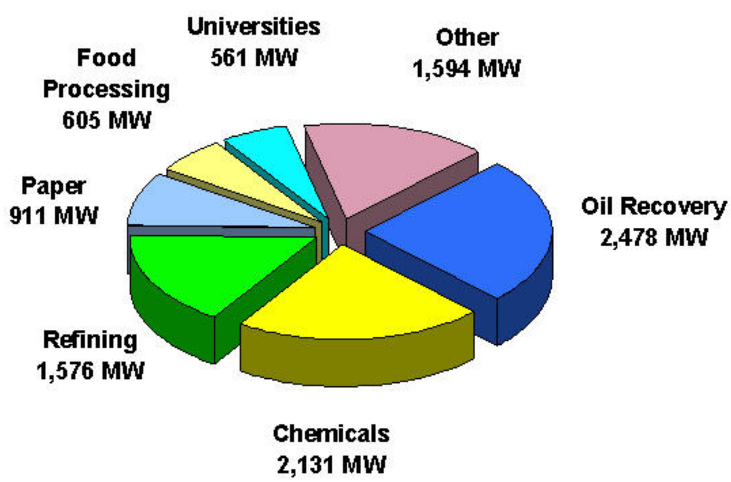
As with all heat engines, the overall efficiencies and pollutant emissions produced are influenced by the fuel sources used and their particular applications.

- Each type offers special advantages for specific circumstances:
  - Operations using a single simple-cycle gas turbine for power only require smaller capital investments than CHP systems that recover exhausts for auxiliary steam and hot water, and are most useful when small amounts of power are needed.
  - Combined-cycle gas turbines using single stand-alone units can be installed much more rapidly than more expensive and complex gas-steam turbine configurations.
  - Combination gas-steam turbine systems are most efficient and applicable for large-scale bulk utility cogeneration plants.

The portability and relative simplicity of stand-alone simple-cycle gas turbines offers versatility for a broad range of industrial, institutional and commercial uses.

- Larger units can be turned on and off in minutes to adjust to power demand loads with efficiencies approaching 40%, and small ones can be easily installed to support site-specific needs:
  - Steel industries use gas turbines to drive air compressors for blast furnaces, and process industries use them for chemical, paper and other material production.
  - Large commercial and institutional organizations use gas turbines for on-site CHP, including space/water heating and to drive absorption chillers for cooling and refrigeration.
  - Small turbines drive compressors for long-distance natural gas pipelines and petrochemical refinery processes.

393. Energy and Environmental Analysis, Inc.

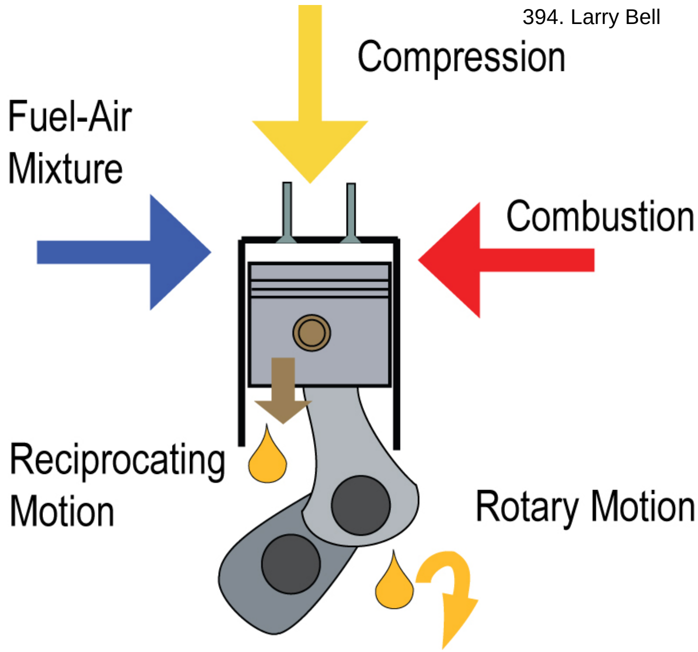


Simple-cycle gas turbine-based CHP systems are most prevalent in smaller installations (typically less than 40 MW).

Simple-Cycle Gas CHP Capacities at 359 US Sites

Features and performance comparisons of various internal combustion types

394. Larry Bell



Internal Combustion Engines

Although the term "internal combustion engine" can be applied to gas turbines, it is usually used in reference to reciprocating piston engines.

- Such engines are widely used for mobile applications due to relatively high power-to-weight ratios with good fuel energy density:
  - The most common fuels used today are derived from petroleum hydrocarbons, including diesel, gasoline and liquefied petroleum gas (LPG), although liquid and gaseous biofuels are gaining popularity.
  - Some engines can run on hydrogen, but this requires modifications to the conventional engine's cylinder block, head and head gasket to seal in the explosive gas (which can still leak out undetected).

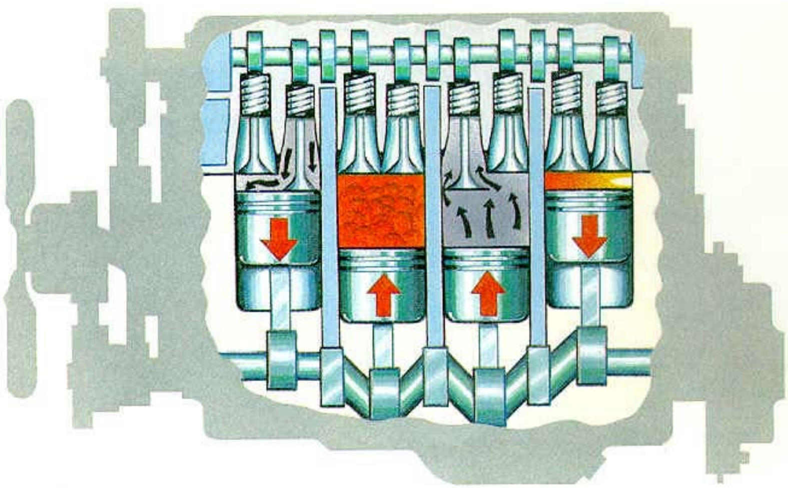
395. Matthia Sebulke
396. Madgasters Photos

Diesel and Gasoline Vehicles

Engines that use gases for fuel are properly called gas engines, and those that use liquid hydrocarbons are called oil engines, although gasoline engines are often colloquially referred to as "gas engines" also.

- Limitations on fuels used are their abilities to be easily transported through an engine's combustion chamber and release sufficient energy in the form of heat for practical benefits:
  - Diesel fuel engines are generally heavier, noisier and more powerful than gasoline, and are also more fuel-efficient in many instances.
  - Sophisticated, fuel-efficient diesel engine cars have become prevalent in Europe since the 1990s, and currently constitute about 40 percent of the market.

397. NCERT India



Diesel engines are similar to gasoline engines except that air alone enters on the intake stroke and the fuel is injected or sprayed into the cylinder at the end of the compression stroke to be ignited by heat rather than a spark.

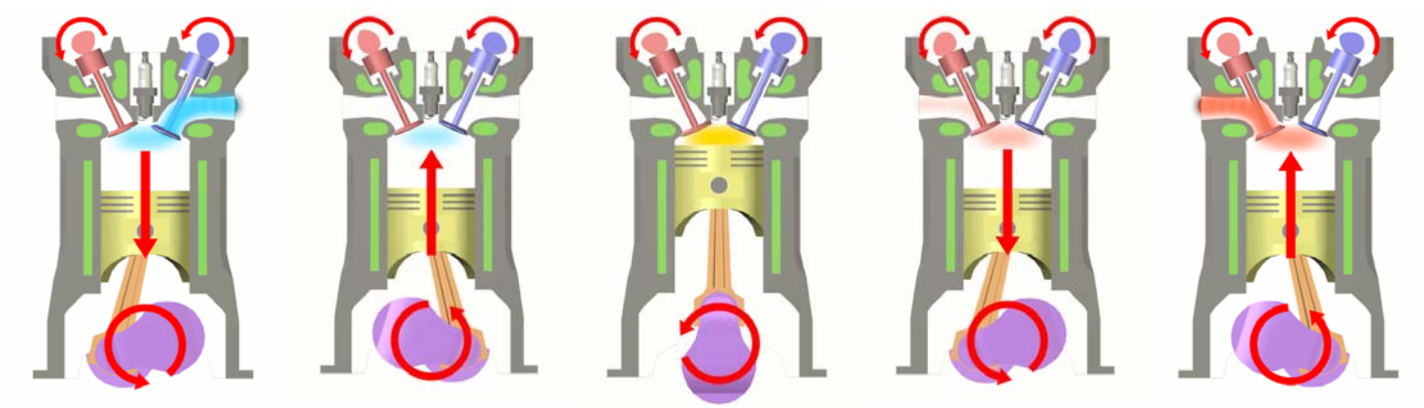
Diesel Engines

Most internal combustion engines use expanded gas in closed cylinders to drive pistons.

- Conventional diesel and gasoline engines used in modern vehicles operate on a four-stroke ("Otto") cycle that has one power stroke per cycle:

1. During the initial stroke, a valve opens to take air into the cylinder (in a diesel engine), or a mixture of air and fuel (gasoline engine) as the piston moves down.
2. Next, the piston moves up to compress the air (diesel) or air/fuel mixture (gasoline) to increase the pressure and temperature. (In a diesel, fuel is then sprayed into the cylinder.)
3. When the piston returns to the top of the cylinder, an electric spark (gasoline) or heat of the mixture (diesel) ignites the gases, forcing the piston down (power stroke).
4. At the bottom of the piston's travel, unburned gases are forced out through a port that then closes, and the cycle repeats.

398. Eric Pierce



Intake Stroke *Compression Stroke* *Ignition Occurs* *Power Stroke* *Exhaust Stroke*

Sequences in a Four-Stroke Gasoline Engine

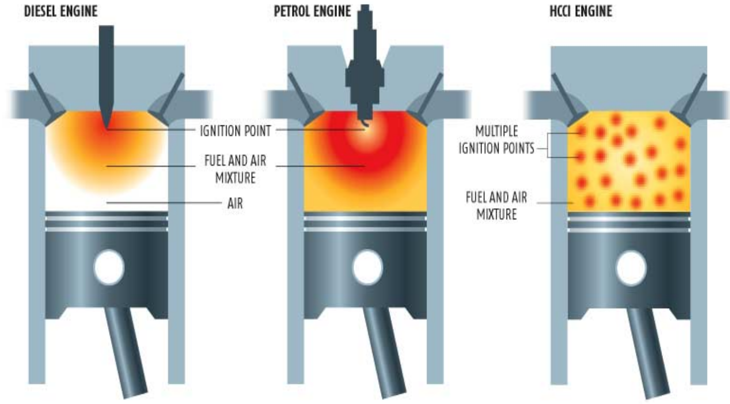
Gasoline Engines

Engine efficiency influences

All internal combustion engines require some means of ignition to promote combustion.

- Most use either electrical or compression heating for ignition systems:
  - Electrical ignition is used in gasoline engines, and generally relies upon a lead-acid battery and an induction coil to provide a high voltage electrical spark to ignite an air/fuel mix in the cylinders.
  - Compression ignition systems, such as diesel engines, rely upon heat created through compression of air in the cylinders to ignite fuel vapors.
  - Homogeneous charge compression ignition (HCCI) is an emerging new technology that combines features of electrical and compression types, where ignition occurs in several places at one time to cause the fuel/air mixture to burn nearly simultaneously.

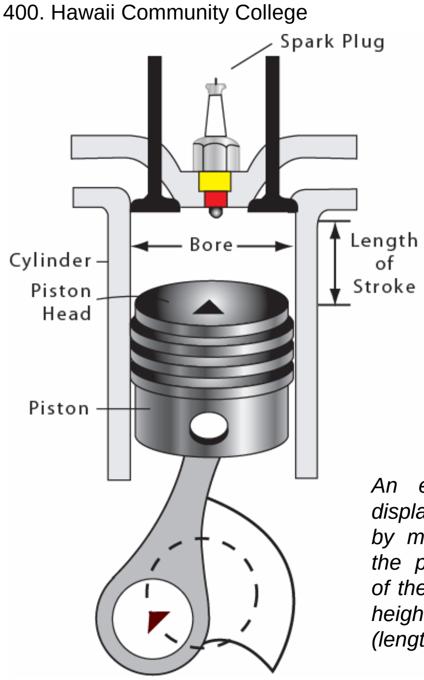
399. Popular Mechanics



In HCCI and petrol engines, fuel and air are mixed before combustion, preventing soot emissions associated with diesel engines. Only HCCI engines have multiple ignition points throughout the chamber which enable lean combustion at low temperatures to offer higher efficiency and avoid formation of nitrogen oxides (NOX). Ignition relies upon heat from compression rather than a spark.

Engine Ignition Systems

400. Hawaii Community College



An engine's total piston displacement is determined by multiplying the area of the piston head (diameter of the cylinder bore) by the height of the cylinder (length of stroke).

Total engine displacement (size) is the number of cylinders times the displacement of one of the pistons measured in liters or cubic inches.

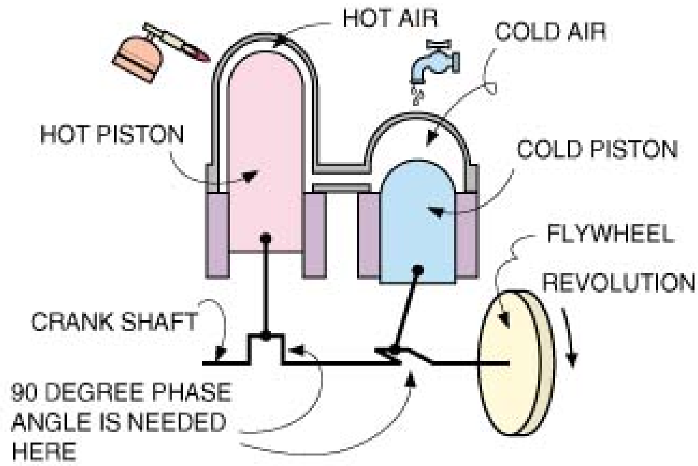
Engine Capacity / Volume

- Having more cylinders yields potential benefits along with disadvantages:
  - More cylinders can provide larger displacement of pistons in the power stroke with smaller reciprocating mass (the mass of each piston can be less), making an engine run smoother.
  - With larger displacement vs. mass, more fuel can be combusted, with more combustion events (more power strokes per given time) to produce more power.
  - Disadvantages of more cylinders are that they tend to weigh more and generate more friction as pistons rub against cylinders, reducing fuel efficiencies and taking away some power gains.
  - Engines can lose about 30% of power through exhaust heat, 6% through friction, and 36% through water heating (leaving about 20% to do work).

Sterling engines are piston-operated types that do not involve internal combustion, but instead use thermal expansion and contraction of a working gas caused by an external heat or cold source to produce mechanical energy.

- Low generating capacities (up to a few kilowatts) make them unsuitable for industrial applications, but they are gaining some interest for residential and small business-scale uses:
  - They offer high thermal efficiencies running on virtually any means to create heat, including fossil fuels, biomass, waste gases, and solar thermal.
  - They can also run on chemical processes that produce cold, such as sublimination of dry ice or boiling of liquid nitrogen.

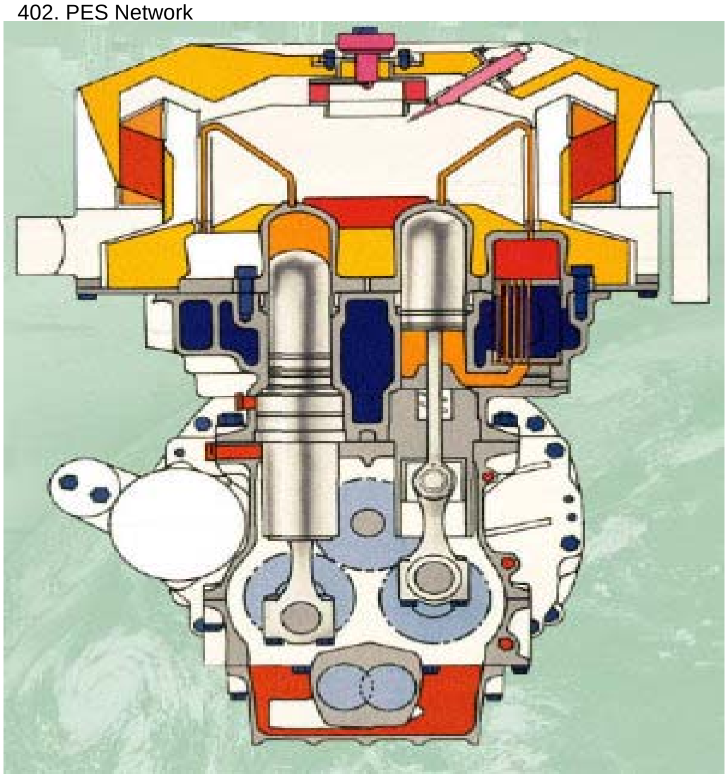
401. National Maritime Research Institute of Japan



This two-piston Alpha-type version incorporates a crankshaft and flywheel drive mechanism to convert thermal expansion and contraction of a working gas contained in the engine to mechanical energy. Other design approaches are also being developed.

Stirling Cycle Engine

402. PES Network



Alpha-Type Stirling Engine

Sterling engine designs represent a variety of configurations, engineering concepts and application sizes that are most often in experimental development stages.

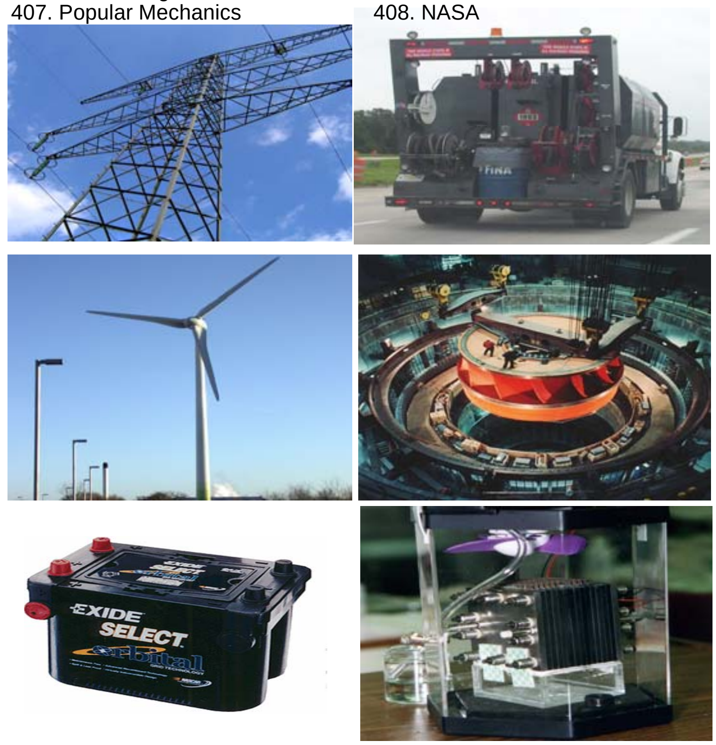
- Common features provide for use of a contained working gas (typically helium or hydrogen) which is repeatedly heated and cooled, causing expansion and contraction to drive one or more pistons:
  - A “regenerator”, consisting of a wire mesh positioned between cold and hot regions, stores much of the thermal energy contained in the working gas for use in the next cycle after each expansion stage.
  - The same basic processes can be applied in reverse to convert mechanical energy into heat or cold using Sterling heat pumps or refrigerators.

Assessing energy conversion and delivery economies

Energy sources often aren't located where we want them to be, in the form we desire, or available when we need them most.

- Substantial economic and efficiency costs usually occur when we move energy, transform it or store it for future use:
  - Energy conversion from one form to another imposes penalties that can be very expensive.
  - Energy storage using batteries, fuel cells and other devices imposes conversion penalties on both the input and output sides along with potential transport losses.
  - Delivering energy from one location to another invariably requires more energy to carry it or to compensate for losses along the way.

403. Jean-Pierre Daniel
404. Ben Ostrowsky
405. Adrian Pingstone
406. US Bureau of Reclamation
407. Popular Mechanics
408. NASA



Transportation, Conversion and Storage

Fuel Types	Heat Values			
	MJ/L	MJ/kg	BTU/Gal[2]	Octane[3]
Gasoline	32.90	45.00	125,000	97-98
Diesel	40.90	63.47	147,000	N/A[4]
Gasohol[1]	28.06	43.54	120,900	93-94
Ethanol	19.59	30.40	84,400	129
Methanol	14.57	22.61	62,800	123
LPG	22.16	34.39	95,475	115

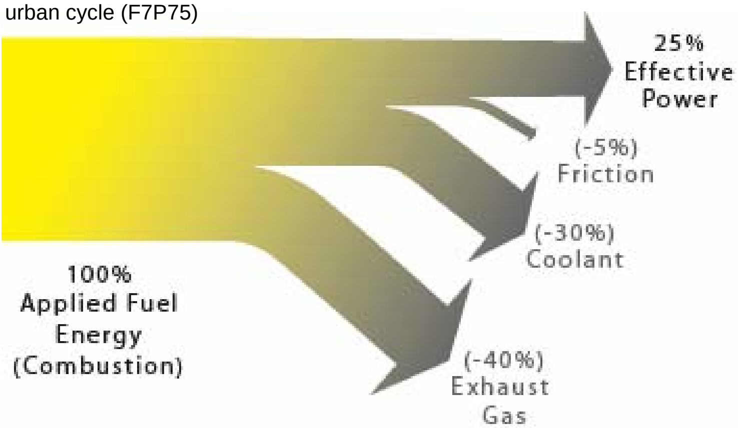
1. 10% ethanol / 90% gasoline
2. US gallon (0.833 x imperial gallon)
3. Research Octane Number (RON)
4. Applies to spark ignition engines only

Energy Contents of Various Fuels

In the case of internal combustion engines, the conversion energy content (or "heat of combustion") contained in a fuel is the amount of heat energy produced when it is burned.

- Relative efficiencies of energy content are measured in terms of either fuel or energy efficiency:
  - Fuel efficiency refers to either thermal or fuel energy available in a carrier fuel to that which can be converted to kinetic energy or other work on the basis of inputs vs. outputs per unit (such as miles per gallon).
  - Energy efficiency is similar to fuel efficiency, but input units are measured in heat terms (such as Mega Joules or BTUs), and input-output relationships (energy intensity) is measured in terms of work product (such as kWh for electricity).

409. Chevron: Fuels/ bulletin, fuel economy Passenger car in EPA urban cycle (F7P75)



The gasoline combustion engine is relatively inefficient in the actual driving cycle. It converts about 65% of the gasoline to heat, and only about 30% to mechanical energy. Of this, only about two-thirds of the mechanical energy reaches the wheels.

Typical Energy Split in Gasoline Internal Combustion Engines

Generally, diesel engines are about 40% more efficient than gasoline engines in terms of miles per gallon.

- Although diesel fuels weigh somewhat more than gasoline per volume, the fuel also contains about 10%-20% more energy per volume, particularly at low idle speeds that trucks usually have:
  - Higher diesel compression ratios offer an advantage.
  - Heat of combustion contained in diesel fuel also occurs at higher values than in gasoline engines, causing the liquid to give up more latent energy for more complete and efficient conversion.
  - All internal combustion engines are relatively inefficient, and reducing vehicle weight is a key improvement strategy.

Efficiencies of conversions from chemical to mechanical energy depend upon the types and numbers of processes used.

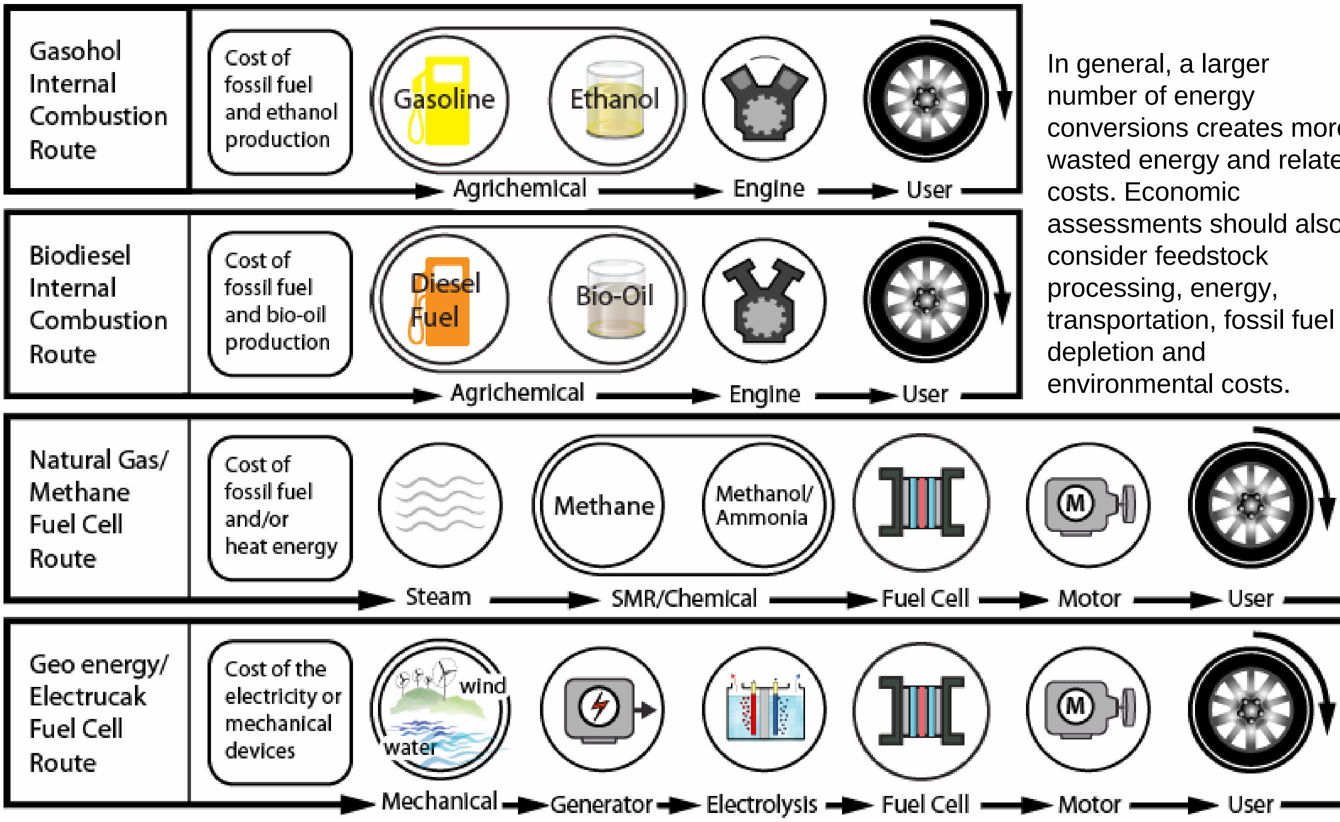
- Determinations of real power costs must take the energy and financial expenses of fuel sources into account:
  - Overall fuel cell efficiencies are impacted by costs of producing and transporting the hydrogen, the form of its use, and characteristics of the system that produces the electricity.
  - Internal combustion and steam engine efficiencies are determined by fossil fuel and/or biofuel costs along with engine type, design and application.
  - Although direct chemical conversions tend to be most efficient for producing electrical power, internal combustion engines are efficient for automotive purposes because they avoid an intermediate electric motor stage.

Conversion Devices	Conversion Processes	Wheel Efficiencies
Diesel Fuel Engines	Chemical-Mechanical	Approx. 33%
Gasoline Fuel Engines	Chemical-Mechanical	Approx. 25%
Generators/ Motors	Mechanical-Electrical	30%- 60%
Fuel Cells Compressed (CH_2)	Chemical-Electrical	Approx. 22%
Fuel Cells Liquid (LH_2)	Chemical-Electrical	Approx. 17%

Mechanical Wheel Power Efficiencies

Comparing energy conversion penalties and costs

410. Larry Bell



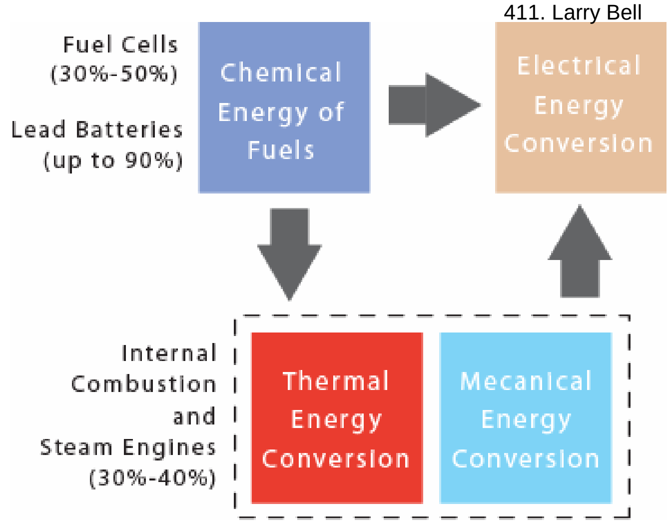
In general, a larger number of energy conversions creates more wasted energy and related costs. Economic assessments should also consider feedstock processing, energy, transportation, fossil fuel depletion and environmental costs.

Mechanical Power Conversion Efficiencies and Cost Penalties

Batteries and fuel cells are the most efficient ways to convert chemical energy into electricity because they bypass intermediate thermal and mechanical stages associated with internal combustion engines and thermionic (e.g. steam turbine) converters.

- Maximum efficiencies of all heat-driven engines are constrained by "Carnot" limits which typically reduce energy outputs vs. inputs by 30%-40%:
  - Since fuel cells convert chemical energy directly to electricity, their efficiencies can exceed Carnot maximums, even when operating at relatively low temperatures where thermal systems are most efficient.
  - Combined-cycle heat and power systems which recycle heat in electricity production operate at higher efficiencies than other engines (55%-60%), but are limited to high-power applications.

411. Larry Bell



Direct chemical-to-electrical conversions are more efficient because they avoid the need to convert from chemical-to-thermal- to mechanical-to-electrical.

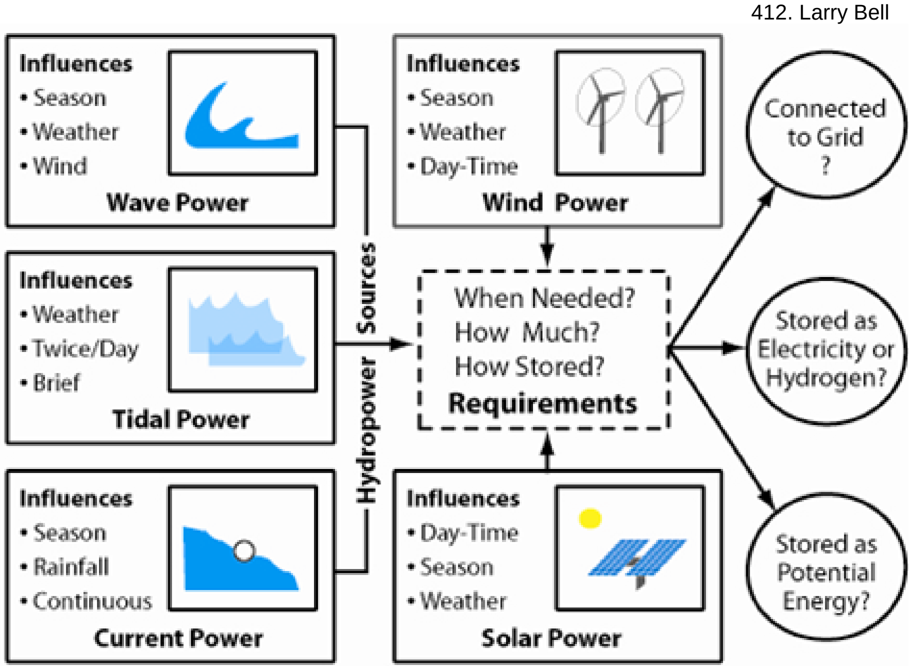
Electricity Conversion Efficiencies

Storing energy for availability when needed

Wind, solar and most types of hydropower are intermittent electricity sources.

- Different strategies can be applied to provide more continuous, useable power:
  - Two or more types can be combined together to increase power levels and continuity.
  - They can be connected to a two-way electron power grid, potentially being credited for supply contributions.
  - They can store energy for times needed in the form of electricity (batteries) or hydrogen (fuel cells).
  - They can also power pumps to raise water, storing potential energy that can be released to drive turbines.

412. Larry Bell

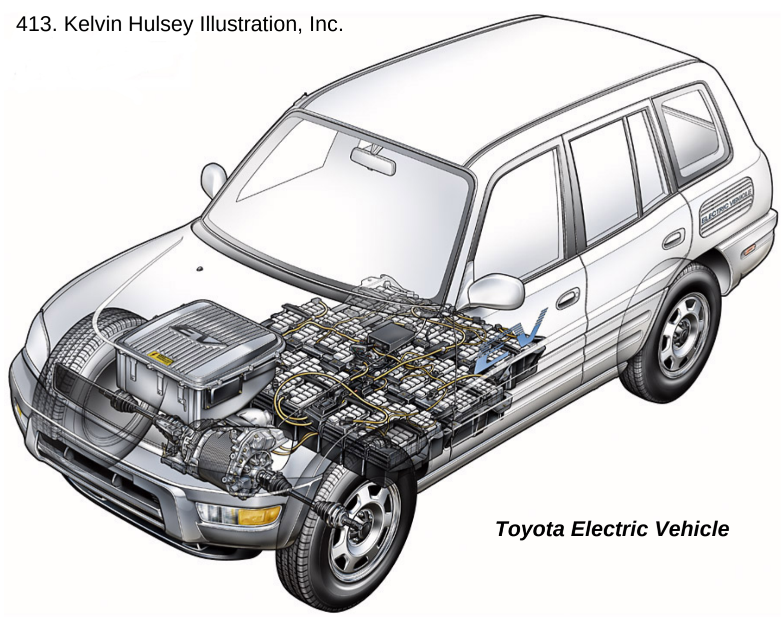


Energy Use/ Storage from Intermittent Sources

Energy can be stored in a variety of forms including electrochemically in batteries, electrostatically in supercapacitors, mechanically using flywheels, and chemically in the form of hydrogen and other fuels.

- Batteries play very diverse roles in low and moderate energy storage applications, and improved technologies are especially vital to advanced electric vehicle (EV) and hybrid electric vehicle (HEV) performance:
  - Electric vehicles currently have very constrained power and range due to limited battery capacities and added weight they impose.
  - Hybrid electric vehicles have much smaller electrical storage needs than EVs, but require batteries with higher power capacities and abilities to withstand many more charge/discharge cycles.

413. Kelvin Hulsey Illustration, Inc.

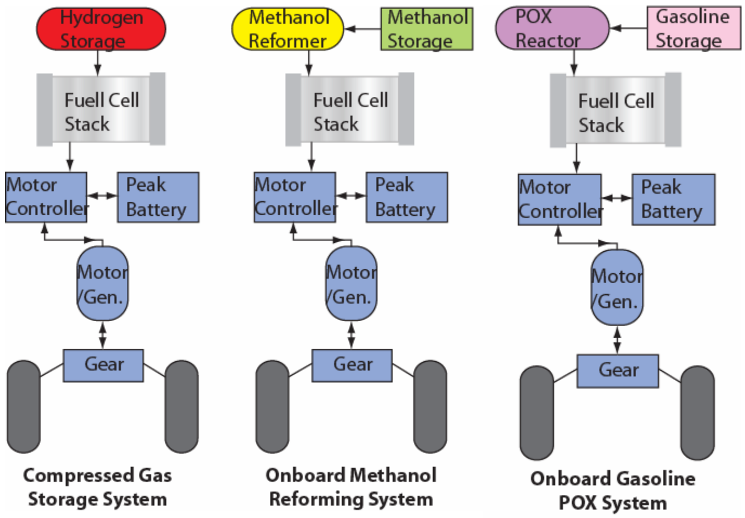


Toyota Electric Vehicle

Battery Storage

Hydrogen storage options for automotive fuel cell systems

414. JM Ogden et.al., Journal of Power Sources



Various automotive fuel cell systems store hydrogen in the form of compressed gas, or convert methanol or petroleum fuels to hydrogen onboard the vehicles.

Types of Automotive Fuel Cell Systems

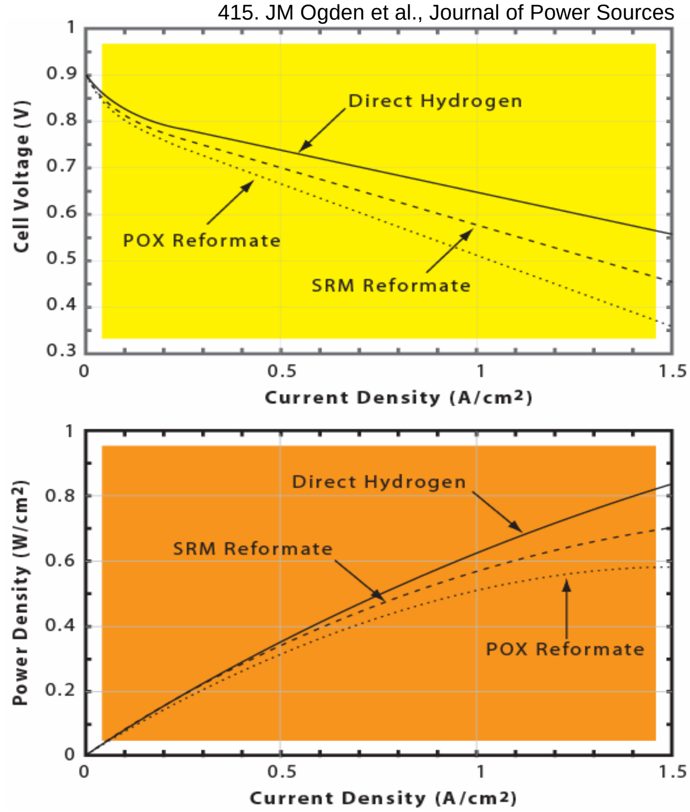
Various fuel cell systems use hydrogen that is stored in either gaseous or liquid forms.*

- Automotive fuel cells generally fall into three categories: those that use compressed hydrogen gas storage; those that reform methanol to obtain hydrogen onboard the vehicle; and those that use onboard systems that apply partial oxidation (POX) of hydrocarbons obtained from crude oil derivatives (gasoline, diesel fuel or middle distillates):
  - Generally speaking, the higher the hydrogen content by volume of the fuel source, the better the fuel cell performance due to greater power density.
  - Systems that use direct hydrogen storage tend to be the most simple in design, but entail more complexity in terms of fuel transport infrastructure requirements.

The output of common proton electron membrane (PEM) fuel cells varies with the concentration of hydrogen in the feed gas.

- The hydrogen density afforded by each of the three different automotive options determines the amount of fuel that must be carried for a given power capacity:
  - Since for compressed gas storage the feed gas is pure hydrogen, this system provides the highest peak power output per volume (about 22% plant-wheel efficiency vs. about 17% for liquid hydrogen).
  - For onboard methanol steam reforming, the hydrogen content is about 75% by volume, and about 35% for a gasoline POX system.
  - Large storage requirements add to vehicle weight and energy inefficiencies, both for fuel and for increased structure to carry the fuel.
  - Onboard methanol fuel cell cars may weigh about 10% more than compressed gas vehicles, and gasoline POX vehicles may weigh about 19% more.

415. JM Ogden et al., Journal of Power Sources



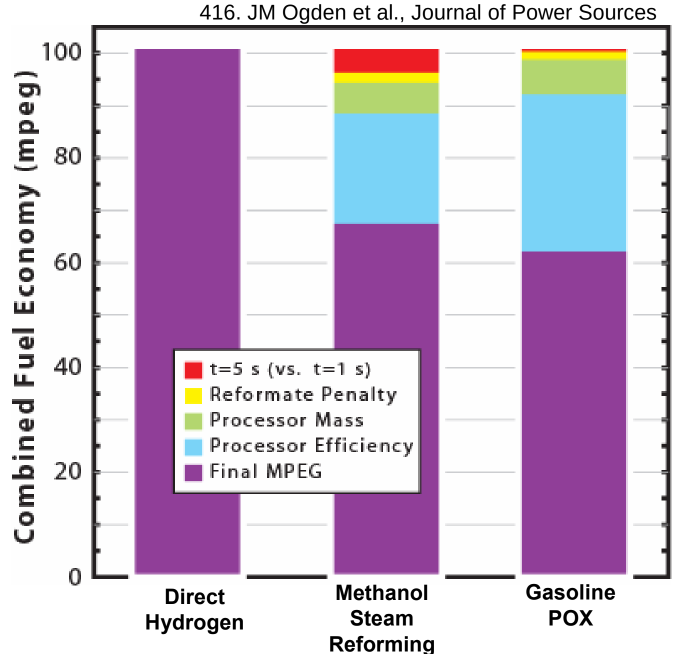
Comparison of Fuel Cell Performances

* See Appendix: 32

Fuel cell economies of different options are significantly impacted by energy conversion characteristics of fuel system types.*

- Compressed hydrogen systems are about one-third more efficient in converting energy than those that convert hydrogen from fuels onboard a vehicle:
  - Approximately 15%-25% of energy is lost in converting methanol or gasoline/diesel to hydrogen.
  - Although methanol and gasoline fuel cell cars offer about the same fuel economy, about twice as much methanol is needed due to a lower energy density, requiring larger storage tanks and weight.
  - Onboard steam reforming response times are typically 40%-50% slower than onboard POX systems, requiring more backup energy to be rerouted through a battery with resulting charging/discharging power losses.

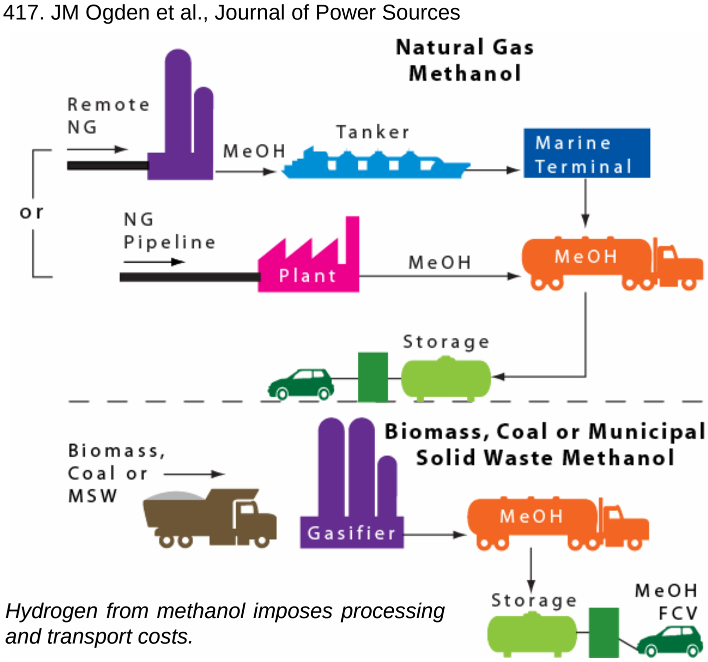
416. JM Ogden et al., Journal of Power Sources



● *T=5 s (time=5 seconds) factors a delay time allowed for fuel processing by steam reformers and POX systems to meet peak demands, requiring batteries to fill energy gaps. This adds recharge penalties.*

Fuel Cell System Economy Comparisons

417. JM Ogden et al., Journal of Power Sources



Hydrogen from methanol imposes processing and transport costs.

Fuel Cell Hydrogen from Methanol

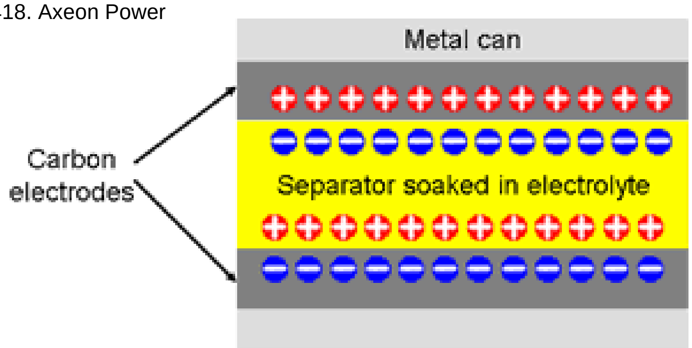
Assessments of alternative fuel cell options for automotive applications should also take broader energy conservation and environmental considerations into account.

- The sources of hydrogen fuel used by different system types is a key factor influencing relative benefits vs. downsides:
  - If compressed or liquefied hydrogen is obtained from natural gas/methane reforming, the depletion of these resources, combined with energy used for compression and transport, add real costs.
  - Hydrogen obtained from water electrolysis adds substantial costs for electricity that competes with other uses, and may produce greenhouse gases.
  - Hydrogen derived from methanol or gasoline/diesel consumes energy for processing and transportation, although transport can use conventional roadway and distribution infrastructures that reduce costs.

* See Appendix: 33

Special use electrical and kinetic storage devices

418. Axeon Power



Supercapacitors look much like batteries, but do not use chemical storage. They consist of two electrode plates of opposite polarity separated by an electrolyte. The capacitor is charged by applying voltage across terminals, causing current to migrate to the surface of the electrode of opposite polarity.

Capacitor / Battery Comparison

Device	Energy density Wh/L	Power density W/L	Cycle life Cycles	Discharge time Seconds
Batteries	50-250	150	$1 - 10^3$	> 1000
Capacitors	0.05 - 5	$10^5 - 10^8$	$10^5 - 10^6$	<1

Supercapacitor Electricity Storage

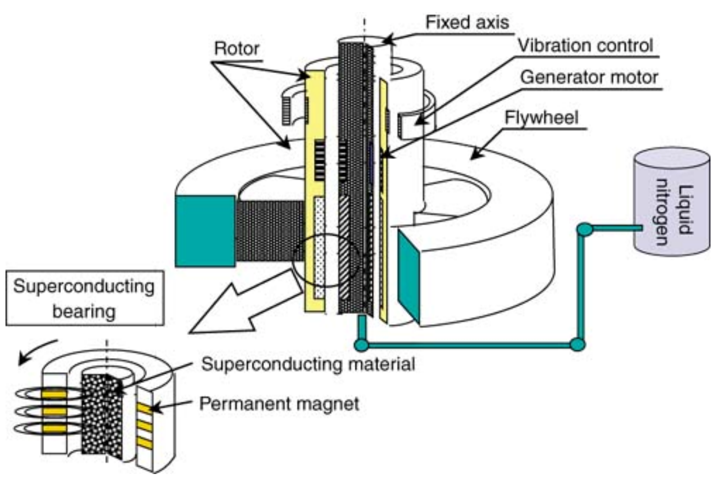
Supercapacitors, another energy storage technology, (sometimes also called “ultracapacitors” or “electric double-layer capacitors”) store energy in an electrostatic field rather than in a chemical state as batteries do.

- These devices have low energy densities (typically less than 15 Wh/kg), but can have very high power densities (4,000 W/kg or more):
  - Low energy densities render supercapacitors unsuitable as primary energy sources for EV and HEV applications, but they can offer excellent means to capture and store energy from regenerative braking and to boost power for sudden demands.
  - Used in conjunction with batteries for regenerative charging, they can avoid wasteful dumping of excess charges that batteries can’t accommodate in order to increase vehicle ranges.

Modern super flywheels store kinetic energy in high-speed rotating drums that form rotors of generators which provide short periods of electricity to fill power gaps in large power grids.

- When surplus energy is available it is used to add momentum to a drum/rotor for times when it is needed:
  - A super flywheel spinning at 100,000 rpm might deliver 100 kW for 15 seconds, then recharge at the same rate until backup generators can be brought back on line during a power outage (usually within 5-20 seconds).
  - Super flywheels have been proposed as power boosters for EVs, but this idea raises concerns about containment of high-speed rotors in case of accidents or mechanical failures, requiring massive and heavy enclosures that would offset power advantages.

419. NEDO Japan



Super flywheels must be very strong to avoid being torn apart by rotational forces at speeds of 100,000 rpm or more. A 1-foot diameter flywheel rotating at that speed would attain a rim surface speed of about 3,570 mph (4.8 times the speed of sound), with a centrifugal force on rim particles equal to 1.7 million Gs. Very strong materials such as fused silica are used along with extremely low-friction bearings.

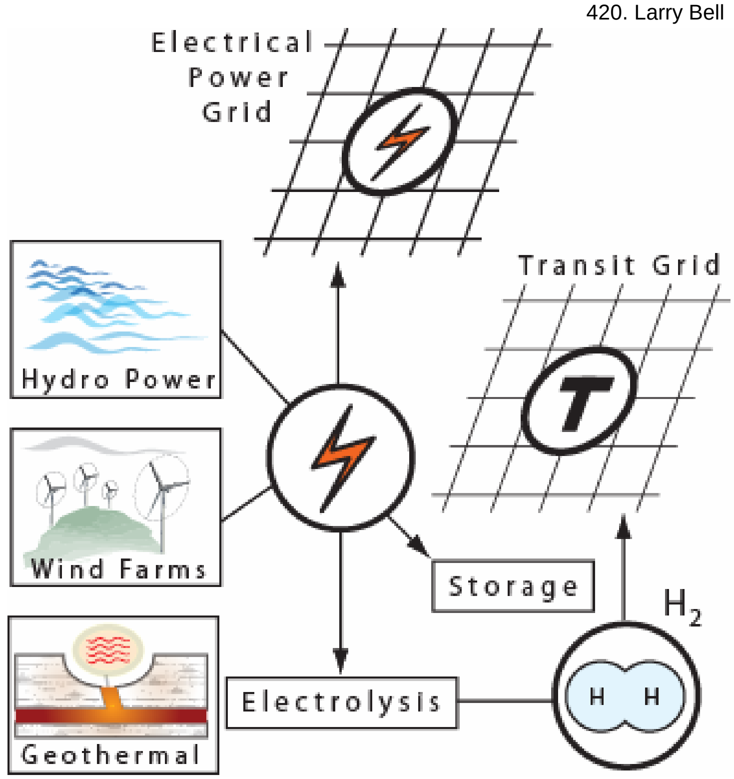
Super Flywheel Kinetic Energy Storage

Energy delivery options and costs

Energy costs per units of power delivered to consumers by each source are fundamentally influenced by the respective transportation, conversion and storage systems used.

- Electrical power economies associated with renewable sources are particularly sensitive to conversion and storage methods:
  - Wind and hydro efficiencies are determined by the way kinetic energy is captured and transformed, and whether the electricity is used directly, transferred to a power grid, or stored in batteries or as hydrogen.
  - Geothermal efficiency depends upon whether the heat will be used directly or converted to electricity.
  - Hydrogen efficiency depends upon the source and production method, the conversion form (electrical or chemical), and the conversion/use technologies (at source and end-use).

420. Larry Bell



Energy Transfer Grids

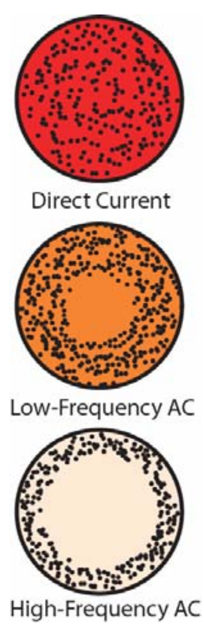
421. Larry Bell

DC Conductor

DC currents distribute electron flow throughout a conductor, causing more collisions with atoms (more heat).

AC Conductors

AC currents distribute electron flow towards the outer surfaces of conductors, producing less resistance (heat). Higher frequencies increase this benefit.



Heat Reduction Through AC

Heat losses in electrical power transmission devices caused by resistance drain energy away from intended purposes and can also impair or burden some equipment operating functions.

- The amount of resistance (“Joule heat” or “ohmic heat”) can be reduced by converting a direct current (DC) to an alternating current (AC) using an “inverter”:
  - Conversion to AC redistributes current density near the surface of the conductor rather than throughout its cross section so that fewer electrons collide as they pass through. (This is called the “skin effect.”)
  - When heat is desired as the output product, conductors are selected with high electric resistance and are often coiled to maximize heat transfer (release).

AC Systems	HVDC Systems
• Almost universally used by US commercial power distributors. • Lower costs / transmission losses for shorter applications than HVDC. • Can change voltage to respond to particular power needs. • Transformers are currently cheaper and more reliable than solid-state devices.	• Useful for long-haul bulk power transmission in remote areas. • Enable power transmission between unsynchronized AC distribution systems. • Reduce line costs due to use of 2 rather than 3 conductors. • Minimize power losses associated with corona discharge of ions/electrons.*

* *Both AC and DC transmission lines can produce coronas that cause significant power losses as their electric fields tear electrons from surrounding un-ionized air and positive ions, or electrons are attracted to the conductor while charged particles drift away. HVDC systems can experience about half the loss of AC lines of the same power.*

AC and HVDC Power Transmission System Features

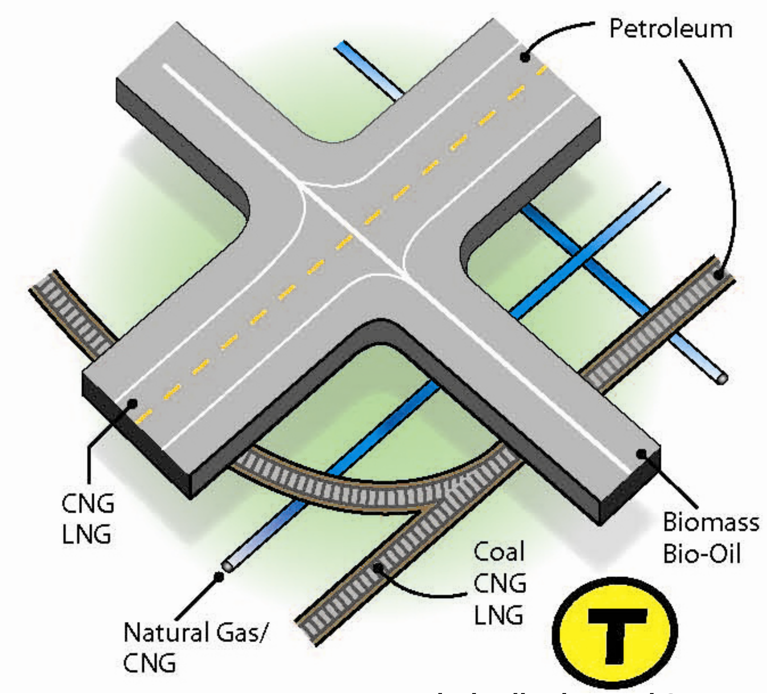
Electrical heat resistance in power transmission lines is a major source of energy losses, potentially accounting for efficiency penalties of about 7% of generated capacities in the US.

- Efforts to control these losses in transmitting bulk amounts of high-voltage power over commercial networks are accomplished using two general types of systems:
  - Alternating current systems use transformers to boost voltages to high levels that maximize transmission efficiencies in combination with the oscillating frequencies that reduce ohm resistance.
  - High-voltage direct current (HVDC) systems are often used to transmit bulk power over long distances between unsynchronized AC circuits using advanced solid-state inverters that convert to AC at connecting station interfaces.

Rising petroleum costs add expenses for transporting fuels and other materials to end-users, thereby compounding cost escalations.

- Transport economies to reduce energy consumption and costs can be realized in three basic ways:
  - Reduce public and commercial fuel and material consumption using more energy-efficient vehicles and conservation-minded living and travel practices.
  - Select the most energy-efficient transportation mode for bulk fuels and materials (pipeline, rail or truck).
  - Convert fuels to electricity at or near the supply sites to enable power transmission by wire.

422. Larry Bell



Fuel Distribution and Storage

Natural gas storage and distribution challenges

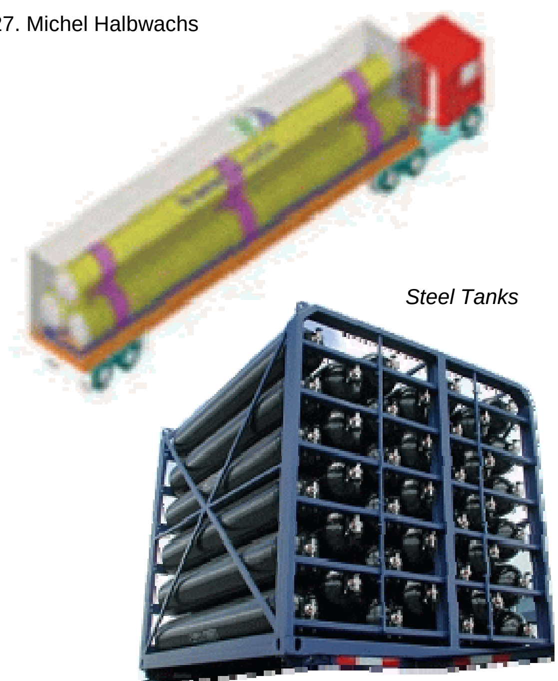
Storage and transportation add substantial cost and complexity to natural gas supplies

- No single approach can address all needs and conditions:
  - Pipelines are economical for moving gas on land, but are not practical across oceans.
  - Many existing pipelines in North America are operating near capacity, causing shortages in some regions (particularly colder locales).
  - Special tanker ships transport LNG across oceans, while tank trucks carry LNG and CNG over shorter distances to end-users or distribution points such as pipelines for further transport.
  - Additional facilities for liquefaction or compression at production points, and end-user facilities for gasification or decompression of the gas, expand the requirements and costs.

423. Pacific Summit Energy
424. Peker Construction, Inc.
425. Enter Stage Right
426. Kleenheat Gas Australia

Natural Gas Storage and Transportation

427. Michel Halbwachs



Natural Gas Containment

Natural gas is highly flammable and explosive, and must be handled carefully.

- Containment and transportation must take safety precautions into account:
  - Local production at the end-use site must provide proper ventilation to ensure that gas does not collect in hazardous concentrations that can present explosive risks or cause suffocation by displacing oxygen.
  - Since the gas is odorless and colorless, special leak detection means are essential.
  - Although the gas can be transported by pipeline over relatively short distances (9 miles [15 km] or less), broader distribution is usually accomplished in a compressed form (CNG).
  - Compressed gas is usually contained in robust, high-pressure tanks made of steel or composites, and is dehydrated to avoid water corrosion of metal parts.

The necessity of petroleum alternatives and fuel conservation

428. Nat. Sustain. Agri. Info. Svc.
429. GE Dolbear & Assoc.

Plant biowaste ethanol can offer a more land- and energy-efficient alternative to grain sources.

Coal-derived liquid fuels can be substituted for petroleum vehicles and aviation fuels.

As petroleum supplies continue to be depleted, it will be essential to transition to liquid transportation fuel substitutes derived from biomass and coal.

- Advancements in biowaste ethanol and coal-to-liquid fuel processing are becoming increasingly vital:
  - Corn and other grain ethanol and biodiesel fuel may become more economical provided ways can be found to reduce farming and processing energy budgets.
  - Cellulosic ethanol avoids large areas of cropland and amounts of energy required for cultivation of grain ethanol, but is more difficult to process, a problem that is being addressed through genetic engineering and other approaches.
  - Conversion of coal into diesel fuel, liquid petroleum and jet fuel is currently possible, but expensive, and many researchers are pursuing methods to reduce these costs for commercial production.

Petroleum Alternatives

430. Larry Bell

Energy Sources	Long-Term Supply	Utility Capacity	Energy Efficiency	Environment Issues
Fossil Fuels: • Natural Gas • Petroleum • Coal	Dwindling natural gas & petroleum reserves. Longer coal reserves.	Primary sources of electricity, heat, vehicle fuels and chemicals.	Relatively high compared with other fuel options (use-dependent).	CO_2 & other combustion emissions are greenhouse & health liabilities.
Biofuels: • Biomass burning • Bioenergy crops	Renewable energy sources, but may consume energy for production and transport.	Depends upon croplands & energy for acquisition, processing & distribution.	Depends upon biomass source, yields and process/ distribution costs.	May reduce greenhouse emissions, depending on production/ processing.
Nuclear Electric Plants	Can offer long-term potential using breeder reactors to process fuels.	Currently provides 19% of US electricity with large growth possible.	Comparable to fossil fuels in production and plant costs.	Clean emissions but requires storage/ protection of spent fuels.

Primary Sources

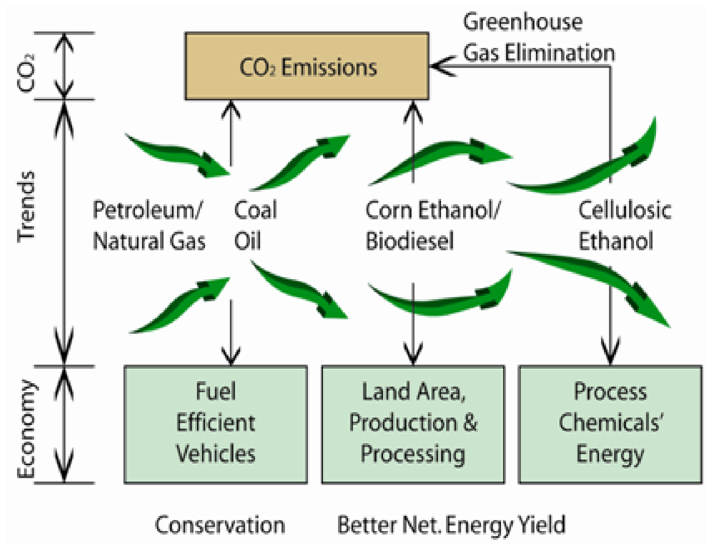
Energy Sources	Long-Term Supply	Utility Capacity	Energy Efficiency	Environment Issues
Mechanical Energy • Wind Turbines • Hydropower	Renewable sources with limited site applications for substantial benefits	Depends upon local site features & seasonal/ daily weather conditions	Can be very efficient, primarily for power grid balancing.	Wind is clean. Hydro can impact marine ecosystems.
Geothermal Power Plants	Renewable energy source, but very limited growth possibility	Depends upon limited sites with suitably high/ accessible temperatures.	Depends upon size/ temperature of heat reservoirs for power plants.	Clean, but can have potential adverse subterranean impacts.
Solar Power: • PV systems • Utility-scale concentrators	Renewable, but primarily a back-up or power-balancing supplement.	Depends upon geographic climate & daily site weather.	Influenced by atmosphere, weather & size/type of system used.	Clean energy with excellent conservation benefits.

Secondary Sources

Transitioning to organic and coal-derived liquid fuels to extend dwindling crude oil reserves appears to be a useful but limited longer-term solution.

- All current hydrocarbon combustion processes release CO_2 and other pollutant emissions and consume substantial amounts of production energy relative to outputs:
  - Corn and other grain ethanol and biodiesel fuel may become more economical provided that bioengineering developments can improve average yields, and ways can be found to reduce farming and processing energy budgets.
  - Cellulosic bioethanol may gain advantages if difficult chemical digestion and process energy problems can be solved.
  - Petroleum derived from coal can be expected to become increasingly attractive as oil costs continue to rise provided that current experimental technologies prove to be scalable and effective.

431. Larry Bell



Fuel Transition Challenges

432. Larry Bell / Candy Feuer

The Road to Renewables

Growing interest in renewable energy alternatives is spurring technological advancements.

- Improved performance can be expected to continually drive costs down and expand markets for many of these systems:
  - Although initial up-front expenses are often quite high, rising electricity costs and a variety of government incentives are making investments more attractive on a life cycle basis.
  - Photovoltaic systems for both utility and small-scale domestic applications have particularly promising potentials due to active development in this field.

Practical limitations upon renewable energy substitutes

433. SKF Group
434. EV World
435. How Stuff Works
436. ACRE

Mechanical and solar power is limited to sites with favorable weather conditions.

Hydroelectric and geothermal expansion is constrained by a scarcity of sites and environmental restrictions.

Expansion Limitations

Renewable types of electrical power production options offer important opportunities to reduce energy consumption from fossil sources, but are often linked to local and off-grid applications.

- All of these "secondary options" are governed by geographic and site-specific conditions that constrain expansion capacities and utilization:
  - Mechanical energy from wind is "free" and renewable, but is limited to locations with satisfactory seasonal climate and prevailing weather conditions.
  - Wind and solar are intermittent and somewhat unpredictable.
  - Hydroelectric and geothermal energy expansion is severely limited by a scarcity of practical and unexploited sites, along with environmental restrictions on new development.
  - All are potential sources of power for hydrogen production through electrolysis

A variety of methods are used to convert organic fossil and biomass materials into relatively clean gaseous and liquid fuels, nutrient fertilizers and valuable chemical feedstocks.

- Some of these methods apply natural biological processes and conventional waste treatment and industrial production technologies:
  - Methane alternatives to natural gas and associated byproducts can be produced using biochemical anaerobic digestion and fermentation of biowastes.
  - Chemical catalysts can convert plant wastes and grains into biodiesel fuel and other energy products.
  - Thermochemical pyrolysis and gasification are used in combination to release bio-oils, hydrogen and syngas from carbonaceous materials and realize "clean coal" benefits.
  - Steam methane reforming is used to produce hydrogen, methanol and syngas from natural gas, and can do the same from biodigested methane.

437. Larry Bell

Systems	Applications	Advantages	Disadvantages
Biochemical: • Anaerobic Digestion • Alcoholic Fermentation	Produces methane, liquid fuels, & chemical feedstocks through natural bacterial & chemical processes.	Can be applied using organic, municipal & agricultural wastes for resource recovery & bio-remediation.	Must be applied on a practical scale to realize practical development & operation benefits.
Chemical	Reacts bio-chemical, thermo-chemical & other materials to produce fuels and derivatives.	Can convert alcohols & sugars from organic sources into biodiesel and other energy products.	May require expensive catalysts that impose costs that reduce advantages.
Thermochemical: • Pyrolysis • Gasification	Use conventional industry processes to produce bio-oil, hydrogen, sugars & liquid fuels.	Extensively used to create "clean coal" (gasification) & may be a source of diesel and jet fuel.	Use of a natural gas as the heat source consumes a dwindling natural resource.
Steam Methane Reforming (SMR)	Is the most widely used process to produce hydrogen from natural gas/ methane	Is also used to produce methanol & syngas for local plant & commercial applications	Use of natural gas as a feedstock consumes a valuable & dwindling natural resource.

Biomass and Fossil Processing Methods

Hydrogen to power fuel cells is currently an economically-limited transportation option because more energy is always required to produce it than can be extracted.

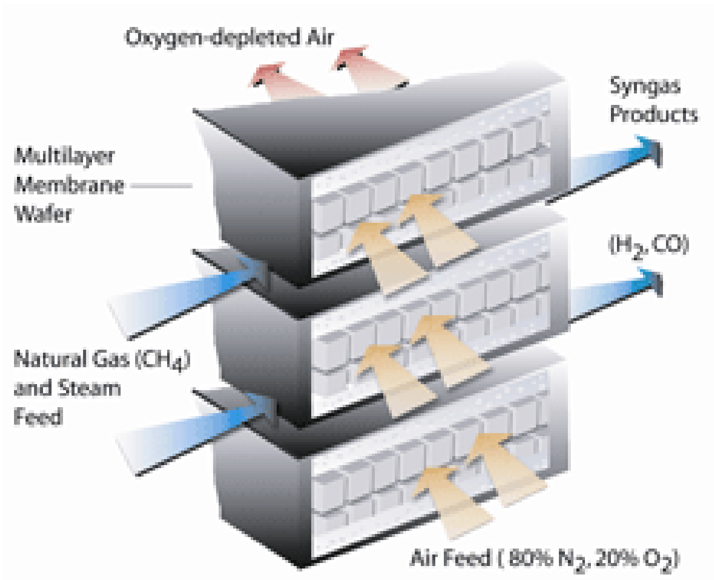
- Steam methane reforming which removes H_2 from natural gas is the most widely used extraction method, and requires substantial energy to produce the steam.

- A new, potentially more efficient method to extract H_2 from natural gas passes the methane along with oxygen-depleted air through non-porous ceramic membrane wafers under high-energy pressure and temperature (producing H_2 + CO).

- H_2 production using biological anaerobic methane reduction and all other processes requires energy to pressurize it into a contained gaseous form, or to refrigerate it into a cryogenic liquid (LH_2).

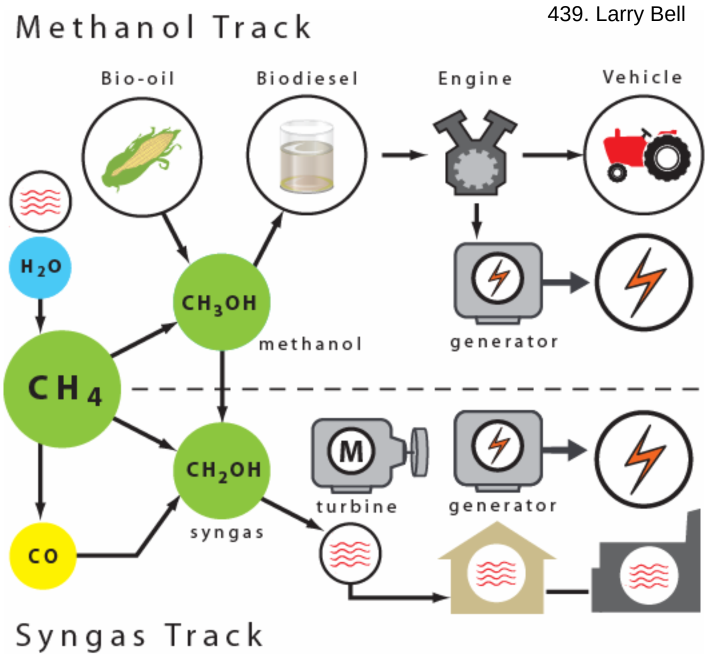
- Electrolysis generally involves very expensive materials (platinum and palladium) which don't scale up well for economic production.

438. US DOE, Office of Fossil Energy



Hydrogen Extraction Through Partial Combustion of Natural Gas

439. Larry Bell



Methane Reduction for Methanol and Syngas

The economics of producing hydrogen for fuel cells or direct fuel using "free" renewable electricity sources through water electrolysis vs. steam methane reduction (SMR) of fossil or biodigested methane must be assessed on a regional and ongoing basis.

- In addition to H_2, it should be considered that SMR can produce syngas for direct use, or as a feedstock for methanol:

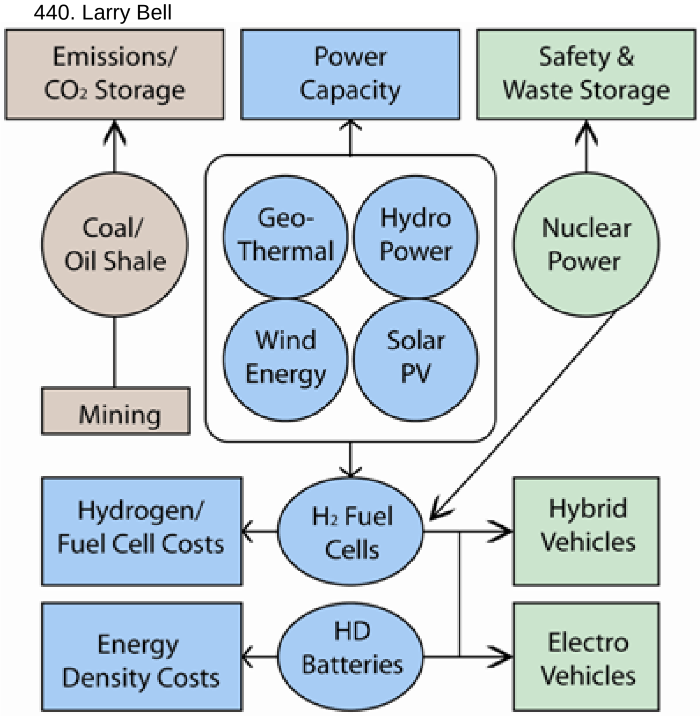
  - Methanol plus plant bio-oil produces biodiesel which can fuel engines to provide mechanical and electrical power, or the methanol can be converted into fertilizer to grow food and oil crops.

  - Syngas can be burned to provide heat for space and industrial processes, or can drive turbines and generators to provide mechanical and electrical power.

  - Syngas is also created as a product of coal gasification (coal gas).

Technology priorities, progress and uncertainties

440. Larry Bell



Power / Fuel Innovation Challenges

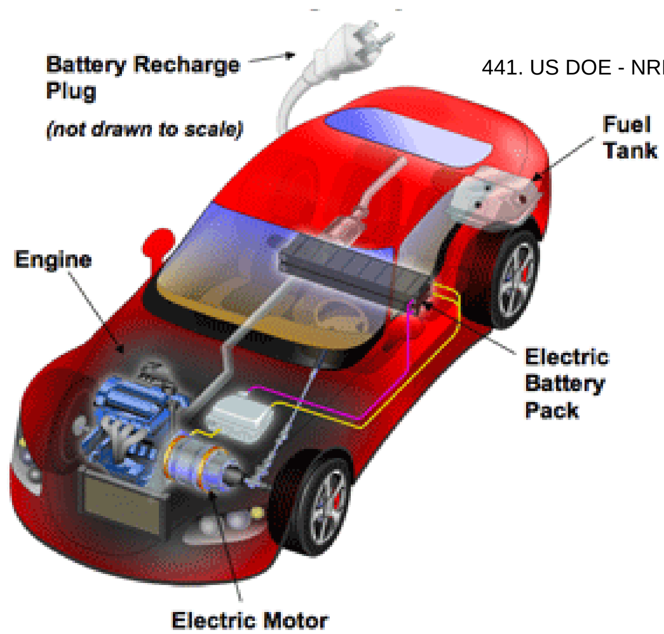
Recent and emerging technologies reflect progress in response to serious environment and resource depletion issues, but none yet offer perfect or complete solutions.

- Continued innovation will be needed to improve or replace many of these approaches:
  - More efficient and effective clean coal and CO_2 sequestration methods must be implemented, ultimately transitioning to non-combustion processes.
  - Nuclear energy is potentially a major energy source, but safety and hazardous waste storage concerns must be conclusively addressed.
  - "Alternative" geothermal, hydropower, wind and solar approaches can provide clean hydrogen processing for fuel cells (at the expense of other electricity uses), but fuel cell costs must also be reduced.
  - Development of more powerful, yet affordable high-density batteries is vital to improve performance and expanded use of clean electric vehicles.

While solely battery-powered electric vehicles have not gained broad market interest due to limited ranges between recharges, plug-in hybrids appear to be showing real promise.

- Plug-in hybrids that can be recharged from 110-volt, or even 220-volt outlets may be able to cut fuel consumption by more than 50%, particularly for drivers who travel relatively short distances each day:
  - Many of these experimental vehicles have onboard computers that determine when power can be most efficiently obtained from electricity or a fuel.
  - They typically have larger battery packs than standard hybrids, sometimes offering 30-35 mile (47-55km) ranges on electricity alone.
  - Future successes will be influenced by needed battery technology advancements to increase range with reduced weight and costs.

441. US DOE - NREL



Plug-in hybrids are applicable to vehicles with gasoline or diesel engines using either fossil or biofuels. Large batteries enable them to be powered totally by electricity over limited ranges. Improved battery technologies are key to expand utility and market interest.

Plug-In Hybrids

Coal and natural gas currently supply about 48% of all energy used by industry, and about 67% of all electrical power.

- Transitioning from these sources to nuclear which provides 19% of all US electricity can stretch these resources and reduce atmospheric pollutant emissions considerably.
  - Industry presently consumes about 35% of all natural gas, and constitutes about 38% of the energy used in this sector.
  - Coal, which is much more abundant, provides about half of all electrical power, presently consuming approximately 91% of all US electricity used.

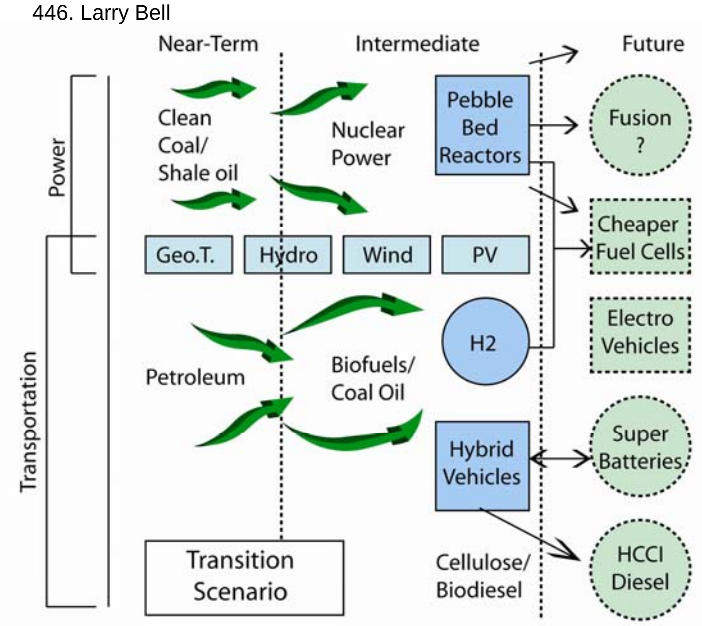
442. Texas A&M University
443. State of New York
444. US DOE-EERE
445. US DOE OCRWM

Industry and Electrical Sectors

Transitioning from current fossil fuel dependence to cleaner, more abundant and sustainable energy sources will require staged incremental developments.

- Large investments will be necessary to create new and expanded production and distribution infrastructures at each stage, and to support continuing technological innovations for more efficient energy utilization:
  - Improved nuclear safety through pebble bed reactors and other advancements including possible fusion power may ultimately replace most fossil combustion used for power generation.
  - More affordable fuel cell devices may lead to broader use for energy/heat cogeneration and transportation vehicle applications.
  - Future high-density battery technologies may make clean electric vehicles a growing option of choice for many users, and also boost hybrid performance.
  - Cleaner, more efficient engines, potentially including HCCI diesel, may make extensive use of biofuel production and processing advancements.

446. Larry Bell



Applying Alternatives

447. All 4 Engineers

Homogeneous Charge Compression Ignition Combustion Engine Systems

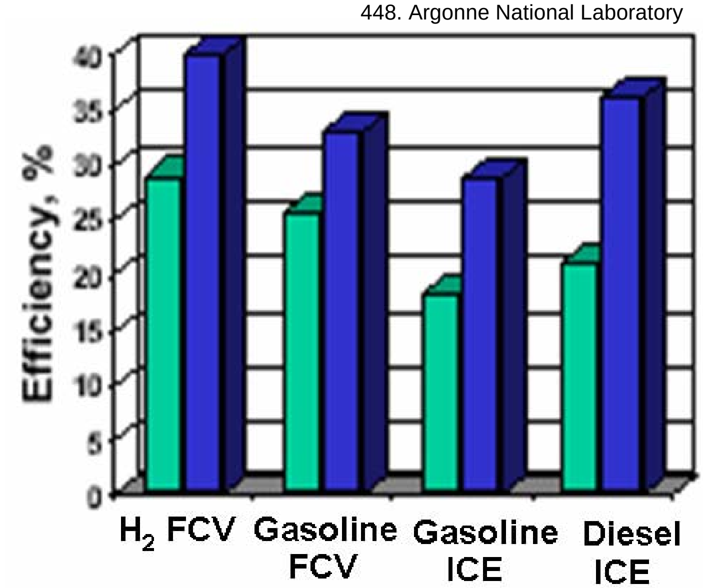
Diesel engines afford efficiency advantages over gasoline for cars, trucks and other uses, but emit higher levels of pollutant gases and particulates.

- Several automobile manufacturers, including General Motors, Ford, Nissan, Toyota and Volkswagen are pursuing development of homogeneous charge compression ignition (HCCI) engines that may be substantially more efficient than current diesel and gasoline engines, and eliminate most NOx and other pollutants:
  - This relatively recent technology uses a lean, diluted mixture of fuel and air that auto-ignites without spark plugs similar to a diesel, but using a pre-heated fuel mixture or warm combustion products reused in the cylinders.
  - Several obstacles remain to be overcome, such as difficulty in controlling the moment of auto-ignition and energy release rates, mechanical and chemical complexities, and costs.

Various types of engine and fuel combinations present different environmental impacts.

- Gasoline and diesel engines produce significant CO_2, sulfur and nitrogen oxide emissions due to incomplete combustion of hydrocarbon fuels:
  - Diesel engines produce a wide range of pollutants, including aerosols of many small particles that can lodge deep in lungs and present health hazards.
  - LPG burns much more cleanly and completely than gasoline and diesel fuels, and doesn't contain sulfur.
  - Hydrogen engines primarily release water, but when air is used as the oxidizer, nitrogen oxides are also produced.

448. Argonne National Laboratory



Engine Pollutant Emissions

Our only real alternatives

Costs of all energy alternatives should be weighed against penalties of continued dependence upon rapidly dwindling fossil reserves.

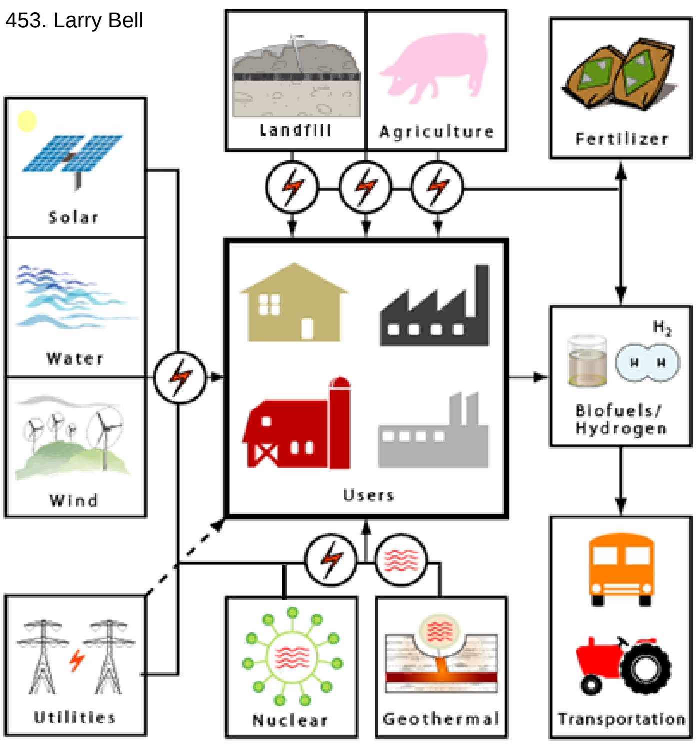
- While renewable source development will require substantial up-front investments, long-term lifecycle economies reinforced by escalating fossil fuel costs can offer large economic, environmental, and social rewards:
  - Nuclear, wind, hydropower, geothermal, and solar, along with clean coal, can greatly reduce use of natural gas and petroleum for electricity.
  - Natural organic processes can provide methane for biofuels, fertilizers and other derivatives.
  - Use of more efficient transportation technologies can conserve energy.

449. The Pasty
451. U of Warwick

450. Subiaco
452. MSNBC

Costs and Benefits

453. Larry Bell

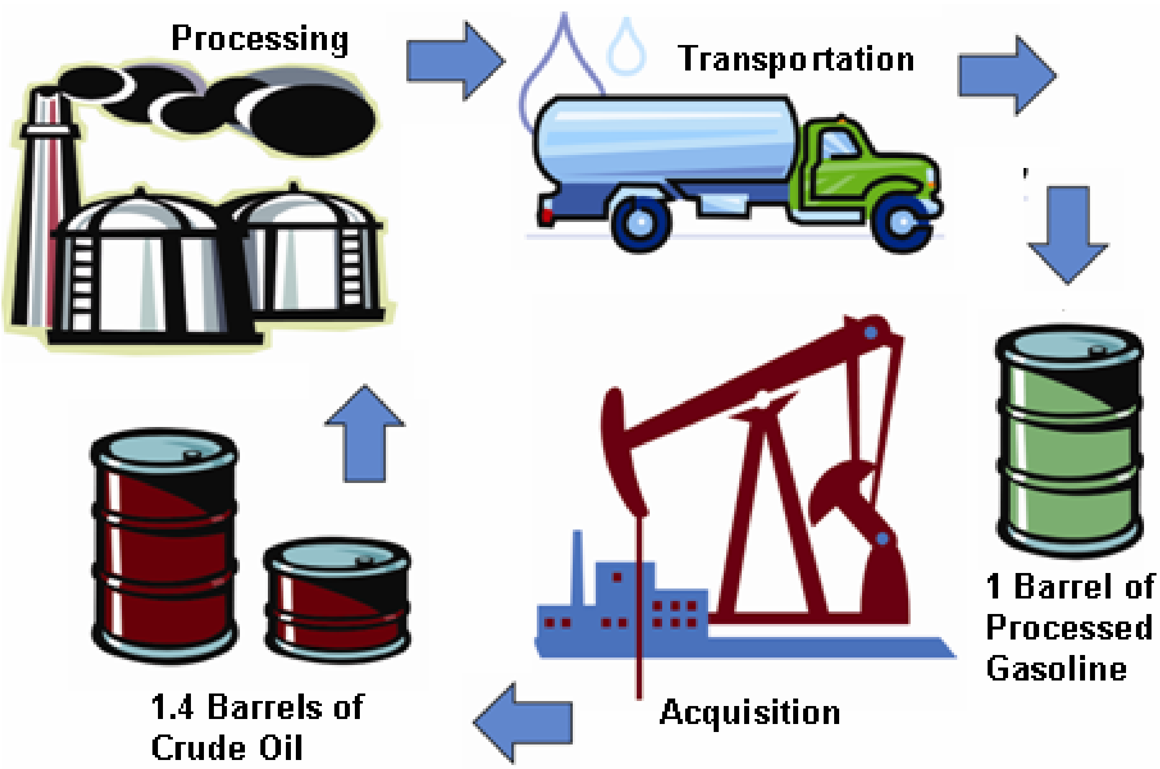


Combining Resources

While no current or emerging technology offers a perfect or total solution to pressing conservation challenges, we cannot afford to wait for an ideal panacea to materialize.

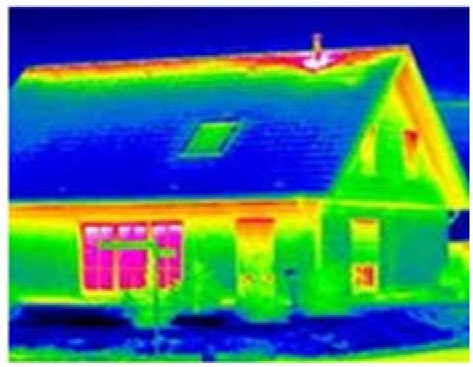
- Real progress towards energy conservation and pollution reduction can only be achieved through a combination of means:
  - Nuclear and renewable energy use must be greatly expanded.
  - Petroleum and natural gas must be shifted away from electrical power, and reserved for transportation and petrochemicals.
  - Wind, water, solar and geothermal development and use must be accelerated.
  - Biofuels and methane recovery must increasingly replace oil and natural gas for fuels and chemical feedstock.
  - All strategies require that we consume less and use resources more efficiently.

454. Larry Bell / Olga Bannova



In the long run, every unit of energy saved pays substantial dividends through avoided costs of production, conversion and distribution.

The EIA’s Texas Energy Office estimates that every barrel of oil saved equals 1.4 barrels earned.



PART FOUR: CONSERVATION PRACTICES

WATER, MATERIALS, ELECTRICAL POWER AND FUEL RESOURCES

Conservation and optimization of precious resources

World population growth, competition for dwindling energy reserves and environmental concerns are prompting general recognition that we must use precious resources more wisely.

- Diverse organizations are realizing that this is not only the right thing to do, but makes good practical economic sense as well:
  - More efficient, environmentally-responsible technologies are becoming standards in energy processing, industrial production, space conditioning, as well as other applications.
  - R&D programs are creating better alternatives to drive progress.
  - Government incentives are expanding investments and markets for conservation-oriented products and services.
  - Public and private recycling and adaptive reuse initiatives are converting wastes into needed energy and useful materials.

461. PBS
462. U of Strathclyde
463. Aero Ecology
464. FCIPT
465. Sower Project
466. Ymparisto

Energy and resource conservation is realized in many forms.

Source Reduction

Minimize consumption and waste through responsible technology selection and utilization.

Recycling

Recover, sort, and treat waste materials so that they can be reclaimed for useful purposes.

Reuse

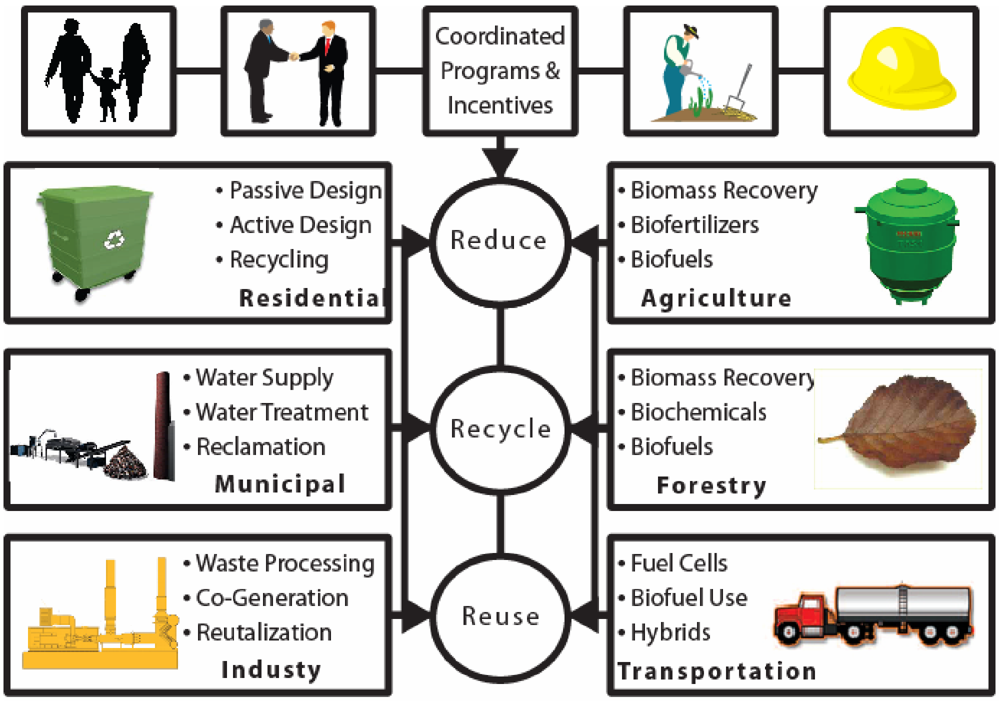
Reapply waste and discarded products in their current or in altered form.

Primary goals of responsible conservation practices are to extract maximum resource benefits while minimizing wastes and hazards.

While many new and emerging technologies are encouraging, it is evident that such innovations alone cannot resolve imminent energy shortages and environmental crises.

- Government and industry can provide incentives and tools, but real progress can only be realized through responsible choices involving large numbers of private citizens, business, and community stakeholders:
  - We must reduce consumption by choosing to purchase and apply efficient and environmentally-benign technologies, and avoid wasteful lifestyles.
  - We must choose to regard discarded by-products of daily activities as valuable resources that can be recycled.
  - We must exercise choices to support public legislation and programs that conserve, reprocess, and reuse resources in a safe and sustainable manner.

467. Larry Bell



Shared Responsibilities

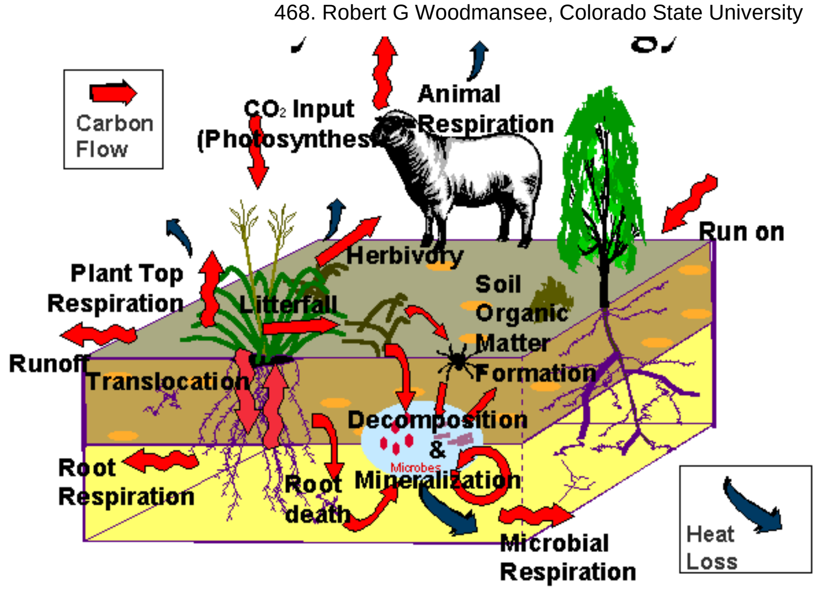
Conservation fundamentally entails doing more with less.

- Many municipalities, industries, businesses and households work to accomplish by applying three basic principles.
  - Reduce consumption through sensible economies.
  - Recycle rather than discard useful leftover products.
  - Reuse salvaged products, including biomass and heat.

We can learn much about conservation principles by observing the ways that natural systems work.

- In Nature's grand model, all parts are connected and synergetic, with complex forces and processes acting in concert:
  - Nature's model demonstrates the interdependency of large and small processes, where the product of each provides the energy and feedstock for others.
  - In this model all parts are used, and while transformable, can never be destroyed.
  - Conservation of energy and natural materials through human-assisted processed and innovated devices can be guided by these lessons

468. Robert G Woodmansee, Colorado State University



Carbon Cycle and Energy Flow

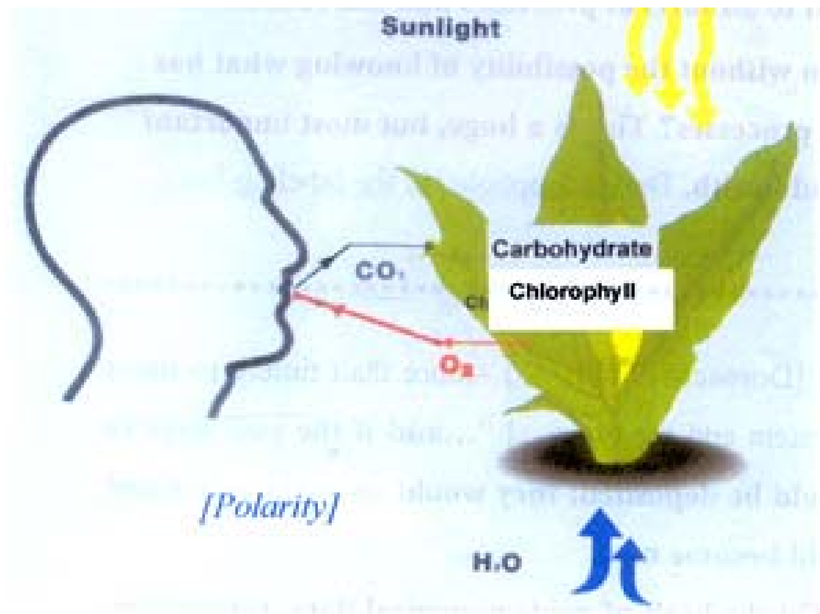
Applying Nature's Lessons

Learning from natural examples

Synergetic exchanges between plant and animal respiration processes are an example of the way Nature recycles energy and chemical materials.

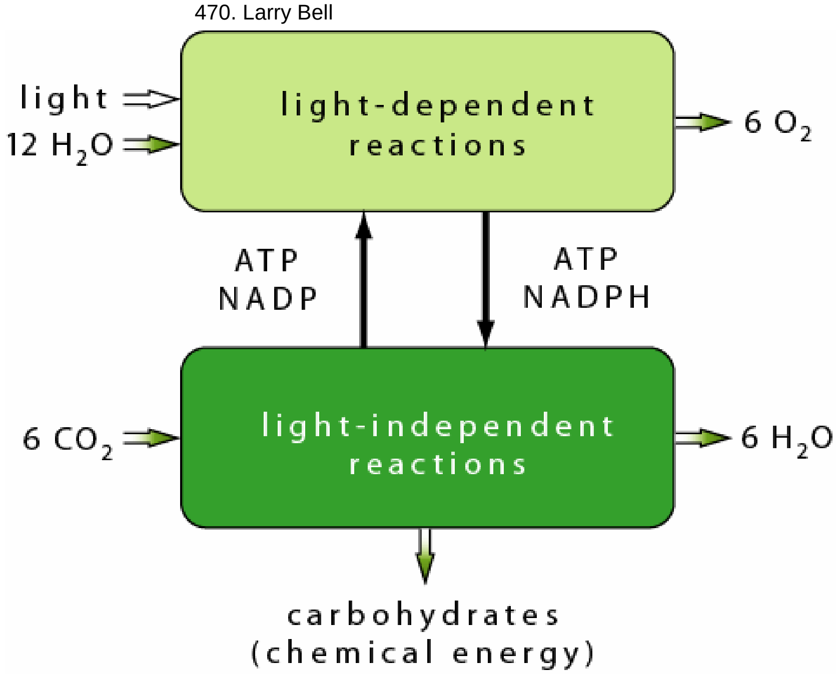
- Green plants use photon energy to convert water and carbon dioxide into glucose carbohydrates for growth energy, and periodically release excess oxygen that we and other creatures require to live:
  - During the growth seasons, plants take up more CO_2 than they expel from sources such as the decomposition of biomass, various ocean and atmospheric sources, and fossil fuel combustion.
  - Then, during the rest of the year, plants release more CO_2 than they use, causing regional atmospheric levels to rise.

469. Edu Care Do



Plant/Animal Respiration

470. Larry Bell

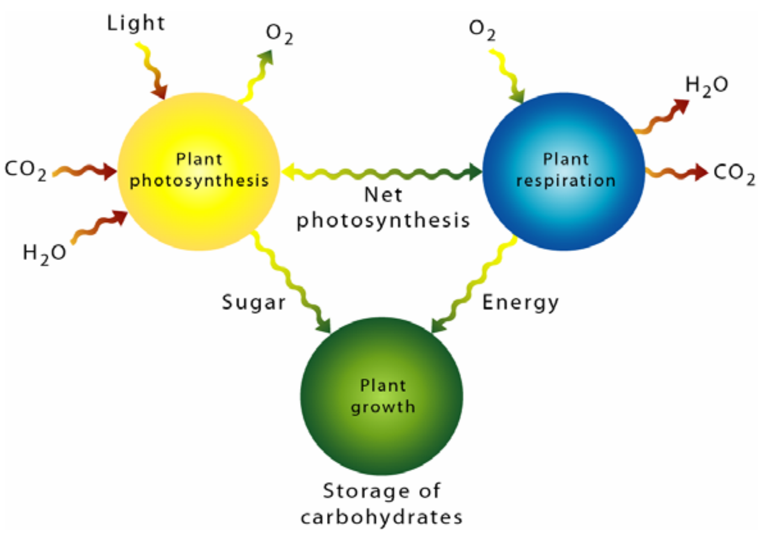


Plant Photosynthesis and Respiration

Viewed as synergetic systems from a human benefit perspective, we might regard plants as devices that process photonic and chemical energy into food and gaseous respiration products that we depend upon to exist.

- The processes of photosynthesis and plant respiration accomplish this in two stages that apply light-dependent and light-independent reactions:
  - During the day, chlorophyll mechanisms use stored ATP and NADP molecules to capture electrons and split water into oxygen and hydrogen components, producing NADPH in the reaction.
  - At night, light-independent (“dark”) reactions use ATP and NADPH to convert CO_2 into sugar glucose carbohydrates, the chemical energy that fuels plant metabolism.

471. Agri. Tech



A Natural Conservation Model

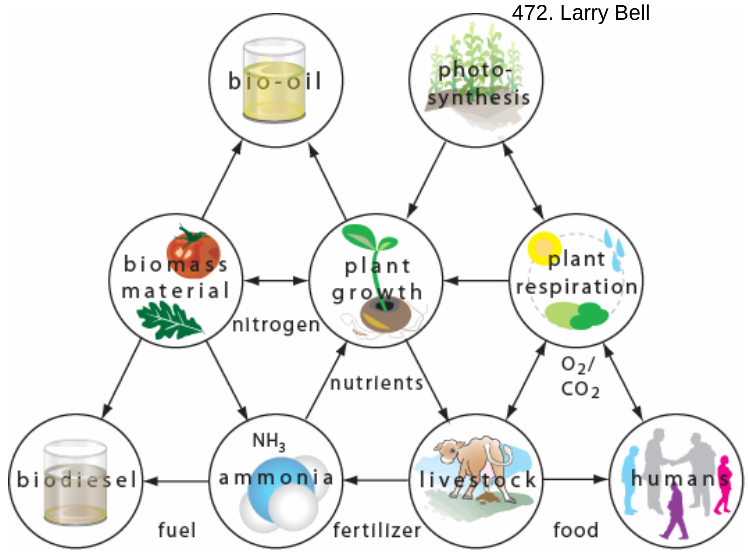
From a plant's point of view, the CO_2 that we and other natural sources produce, provide a feedstock along with water-derived oxygen, to enable it to grow and produce excess oxygen.

- Fortunately for us and other aerobically-supported life, that excess ("waste"), oxygen, is recycled for other useful purposes:
  - Oxygen released into the atmosphere combines with hydrogen to be recycled back to leaves and soil in forms of humidity and rain.
  - Other plants grow, die and decompose, providing CO_2 that is recycled back for photorespiration by new plant life to perpetuate the cycles.
  - This time-tested model proven over many millions of years is one that we can apply in many ways.

Conservation principles we can apply using Nature's connected and synergetic lessons are not limited to certain technical categories, industry sectors or geographic scale boundaries, but extend across broad aspects of life and enterprise.

- By observing the workings of Nature, we can become more aware of larger potentials, and more fully foresee natural consequences of our choices and actions:
  - We can consider ways that processes and products of different industry and business sectors can be beneficially coordinated.
  - We can recognize possibilities for managing resources and production infrastructures more effectively at national, regional and local levels.
  - And we can examine opportunities for applying sensible and rewarding conservation practices in our everyday lives.

472. Larry Bell



Outgrowths of Photosynthesis

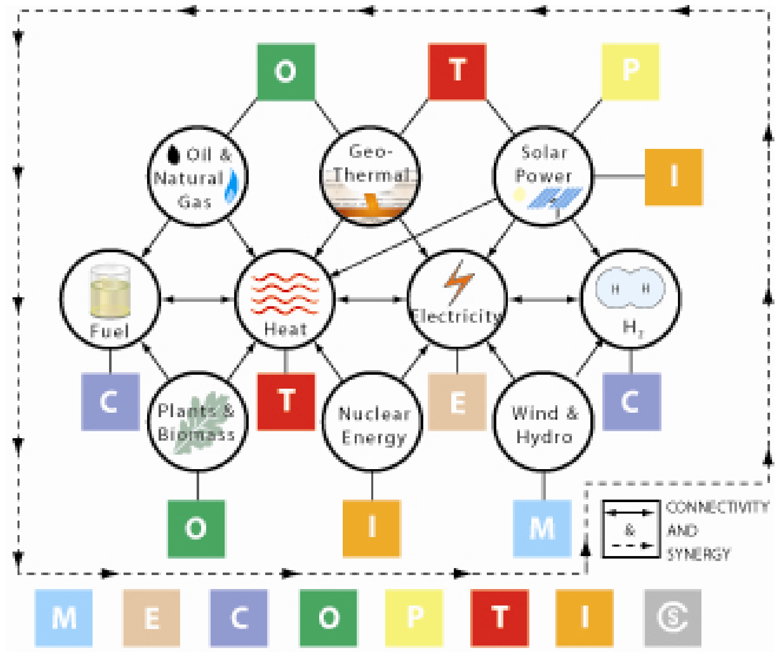
Connected, Synergetic Processes

Connected and synergetic elements

473. Larry Bell

A reference model called “MECOPTICS” offers to help illustrate natural conservation principles that are applied to human technologies and practices.

- The MECOPTICS framework is intended as a reference for considering basic ways that “waste” outputs of certain processes and devices can be recycled to provide energy or feedstocks for others:
  - These connections and synergies often occur within a single operating system such as within a plant facility, building, or transportation vehicle.
  - They can also occur between activities and entities that share national, regional, and local networks and comprise a variety of business and industry sectors.



In Nature, and in natural conservation, everything is important, everything connects, and everything works together.

474. Larry Bell

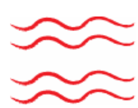
M= Mechanical
These systems collect or produce kinetic energy that can be converted to electrical power.

E= Electrical
These systems generate, store and/or transfer electricity for power and heating.

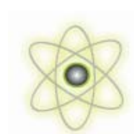
C= Chemical
These systems process organic and inorganic materials into other forms through molecular and atom reactions.

O= Organic
These systems use microorganisms to combine or breakdown molecules and compounds into derivative products.

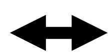
P= Photonic
These systems convert solar radiation into electricity, heat or means to create photosynthetic products.



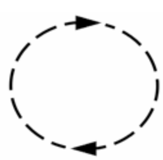
T= Thermal
These systems use heat energy to produce chemical reactions and to drive turbines and engines.



I= Isotopic
These systems produce heat energy through the natural decay of radionuclides, atoms that can be converted to electricity.



C= Connectivity
Refers to ways various systems functionally relate to one another.

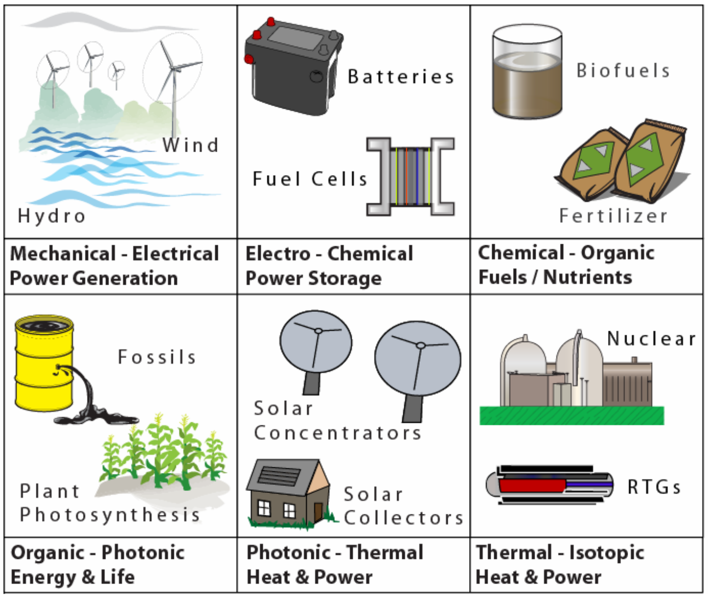


S= Synergy
Characterizes shared or interdependent relationships between two or more systems

MECOPTICS Terms

The term MECOPTICS incorporates initials of seven general categories of processes that create and convert natural resources

475. Larry Bell

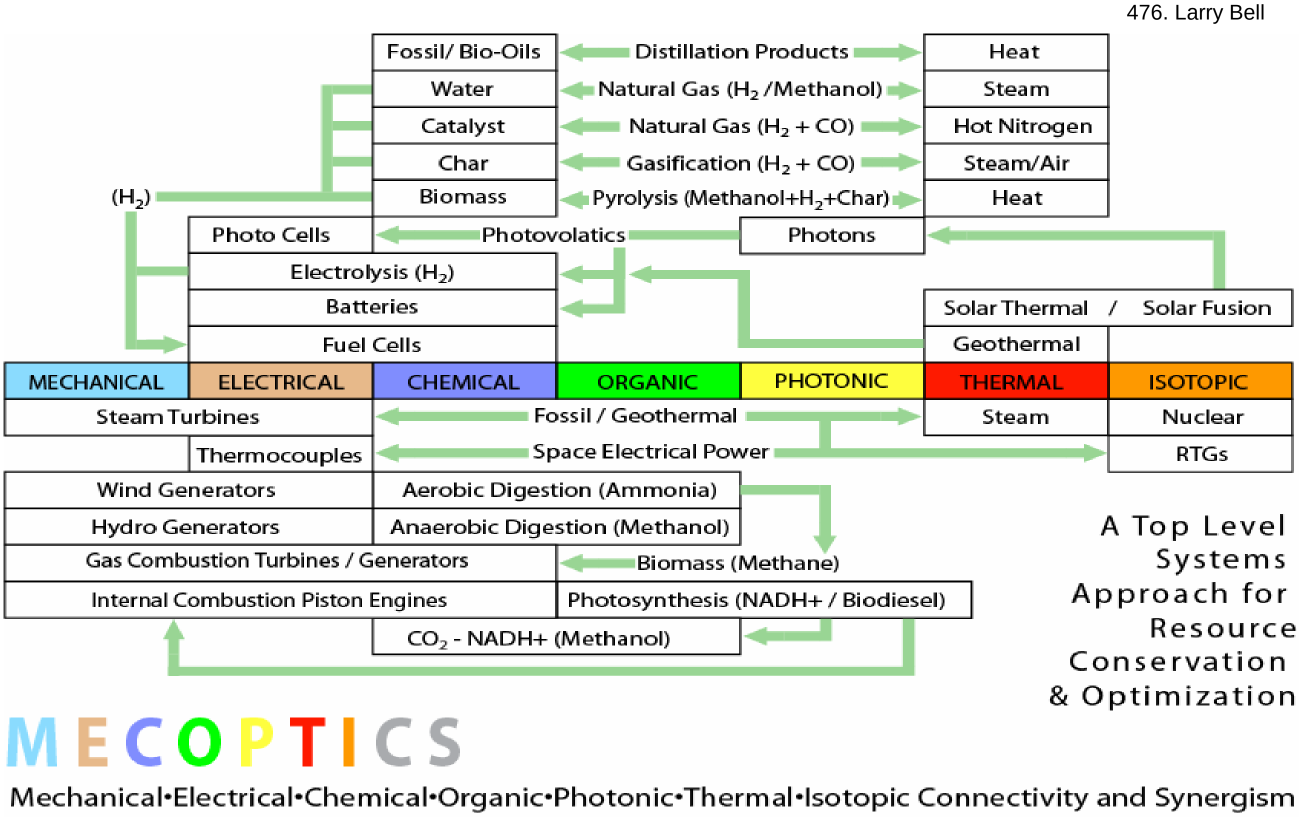


Applied Processes and Devices

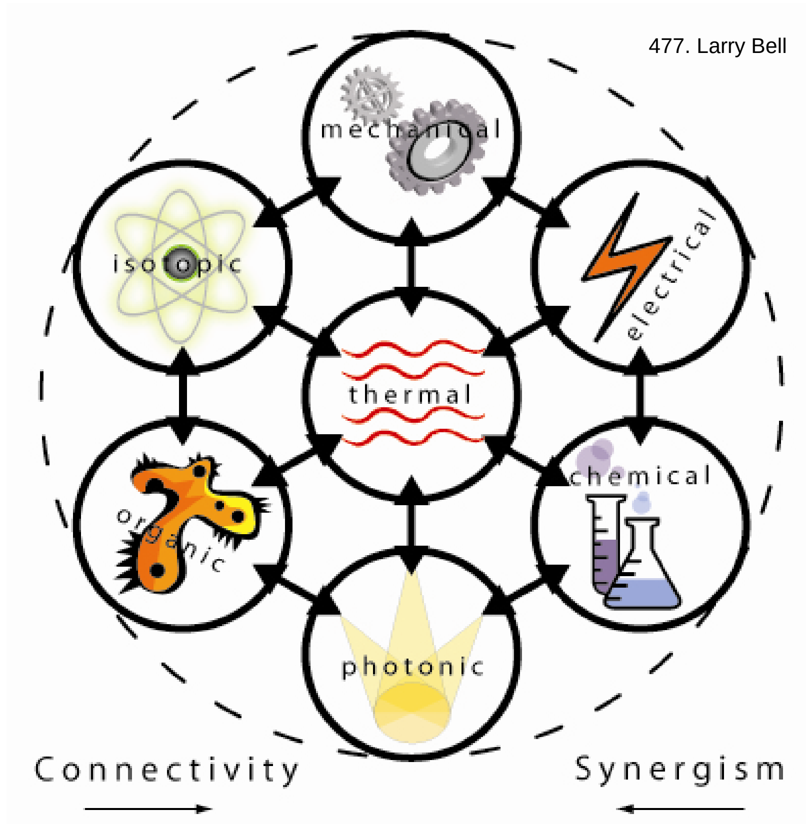
Man-made processes and devices typically combine natural elements into systems in a nearly endless variety of forms:

- Mechanical-electrical devices convert kinetic energy to a transmittable / storable form and back again.
- Electro-chemical devices enable energy to be stored and transported in electrical and gas or liquid forms when and where needed.
- Chemical-organic forms convert natural fossil and plant / animal materials into foods and nutrients.
- Organic-photonic processes convert photon energy into hydrocarbon life, food, fuels and other resources.
- Photonic-thermal devices convert photon energy through conversion processes into heat and power.
- Thermal-Isotopic devices convert the natural decay of radioisotopes into heat and power.

476. Larry Bell



Heat as a fundamental resource



Central Importance of Heat Energy

Just like in nature, efficient man-made processes and devices are planned to work together so that energy and material inputs and outputs share beneficial relationships.

- As illustrated in the diagram, thermal inputs and outputs often have central roles and interactions with other elements:
  - Heat is energy in its purest form that originates from a variety of sources, including solar fusion radiation, the natural decay of radioisotopes, chemical reactions associated with molecular transformations, and electro-mechanical phenomena.
  - This fundamental and versatile resource can be used directly, stored in other forms, and converted to provide mechanical and electrical power.

Heat energy is a fundamental resource that enables mechanical and electrical processes to do work, and is measured in a variety of ways:

- **Joule** (**J**): the amount of force required to move a certain weight a certain distance (1 J= 0.737 foot pounds)
- **Watt** (**W**): the power or rate of work accomplished (1 W= 1 J/second)
- **Horsepower** (**hp**): a measure of power needed to lift 550 pounds off the ground for one second (1 hp= 746 W)
- **British thermal unit** (**Btu**): the heat energy needed to raise the temperature of one pound of water one degree Fahrenheit (1 Btu = 1,055 J)

Measuring Heat Energy Products

Heat is the universal medium of exchange that forms the basis of energy economics.

- This “thermodynamic” energy transfers the capacity to do work or raise temperatures back and forth between all of the other MECOPTICS processes and devices by exciting molecules and atoms to move more rapidly and become hotter:
  - Each of these transfers (or conversions) causes some heat energy to be dissipated into the surroundings, often reducing availability to do what we desire.
  - Some types of conversions are much more “expensive” then others, and all add to costs.

478. UT Environmental Sciences Institute

Fire is an exothermic chemical chain reaction that produces heat and light when a combustible fuel is rapidly combined with a reactant (oxygen).

All matter is composed of molecules made of atoms which are connected together by attractions between electrons around the atoms.

- When molecules break apart to create other molecules, a change in the motion of their bonding electrons cause them to either absorb stored heat from the chemical reaction, or to release some of their stored energy to the product molecule:
  - When a molecule contains more energy than its product molecule can absorb, the reaction is "exothermic", and excess heat is released out into its surroundings.
  - When the product molecule requires more heat than the original molecule can provide, the process is "endothermic" and outside heat must be added for the process to occur.

Heat as an Exothermic Chemical Output

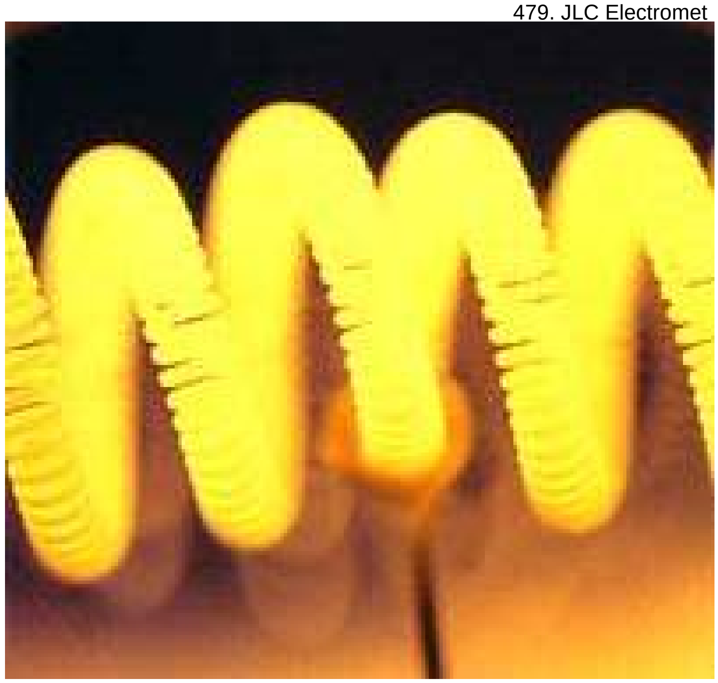
Electrical systems produce large amounts of by-product heat through electrical resistance of the conductor (ohms) that oppose passage of an electric current (amperes) in a circuit:

- Electron collisions in the conductor (ohm resistance) cause the atoms to vibrate more violently about their respective equilibrium positions. The resulting agitation releases energy (heat) proportional to the square of current strength times the conductor resistance as stated in Joule's law:

  $\mathbf{Q = I^2 \cdot R \cdot t}$ where:
  Q = heat by constant current (I)
  R = resistance
  t = time

  - This heat is a "good" product when applied for a useful purpose (such as in a space conditioner or cooking unit), and "bad" when it produces power losses (such as in transmission lines or overheating of spaces or equipment).

479. JLC Electromet



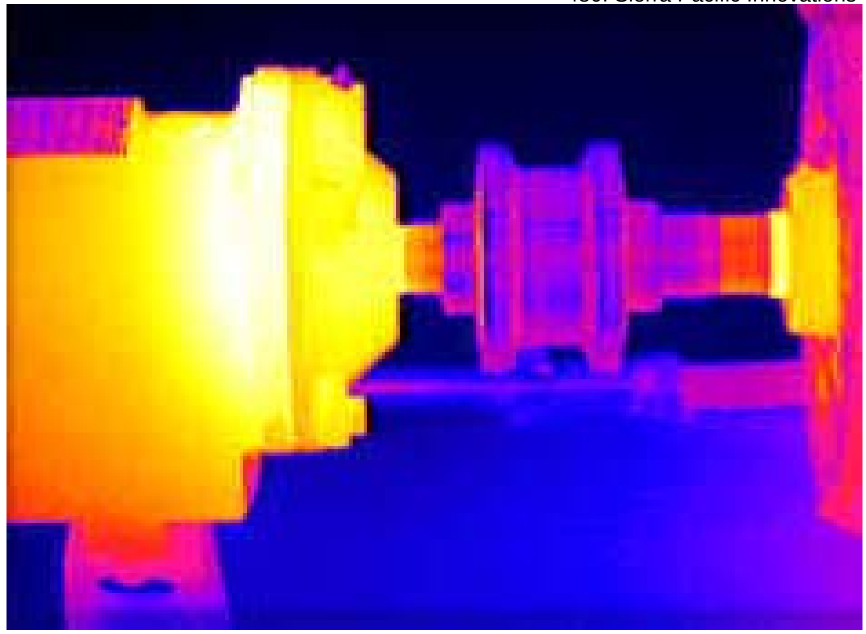
Electric current passing through a conductor transfer kinetic energy that agitates atoms and convert the kinetic energy to ohmic (resistance) heat.

Heat conversion and transfer

Mechanical systems always convert some amount of their kinetic energy through friction to heat, and electrical devices release kinetic energy of electron collisions with atoms for heat.

- Conversion of kinetic energy to heat, and transport of electricity from a source to a use-destination both present efficiency penalties that can be reduced, but never eliminated in the form of "waste heat".
  - Waste heat is the energy created by a machine or technical process for which no useful application is utilized after "free energy" has been extracted.
  - Free energy is the amount of mechanical or other energy that is extracted from a process to do useful work.

480. Sierra Pacific Innovations



Thermal Image of an Electric Motor

Energy conservation reduces waste heat by making conversions and transfers as efficient as possible, and reinvesting product heat energy to do other work.

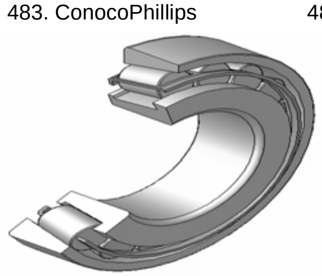
Mechanical Heat Losses

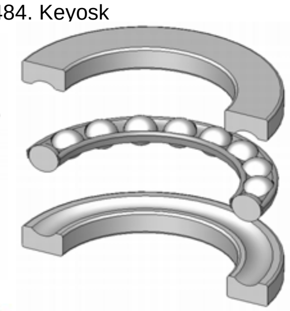
481. Silberwolf

482. Silberwolf

483. ConocoPhillips

484. Keyosk



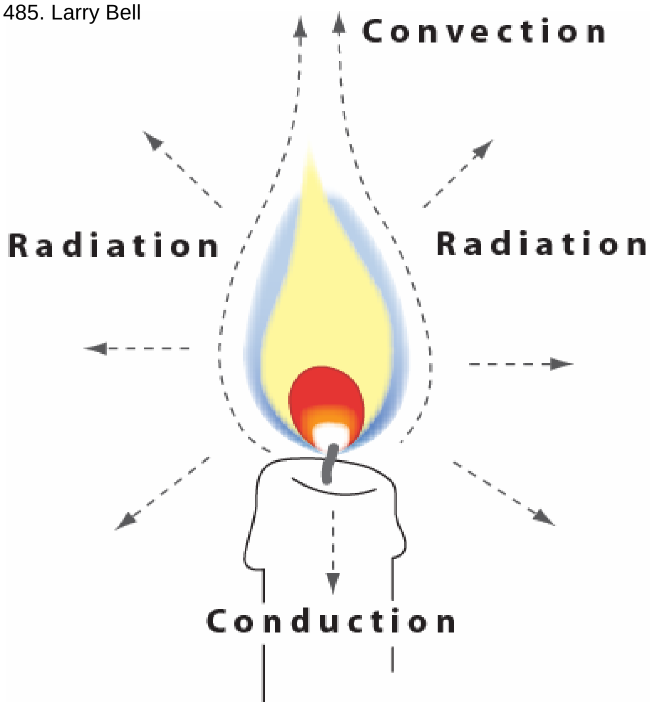


Reducing Frictional Heat Losses

Friction caused by relative motion between two contacting surfaces excites atomic vibrations (electromagnetic forces) that convert kinetic energy into heat, causing particularly costly efficiency penalties in transportation vehicles and large power devices.

- Frictional heat energy losses can be reduced by minimizing contact surfaces and making them slippery, but can not be entirely eliminated:
  - Roller bearings and ball bearings are used to convert sliding friction into smaller rolling friction.
  - Lubricants such as oil, graphite or Teflon convert "solid friction" into "liquid friction".
  - Replacement energy must always be put back in to perpetuate the mechanical process.

485. Larry Bell



Conduction, Radiation and Convection

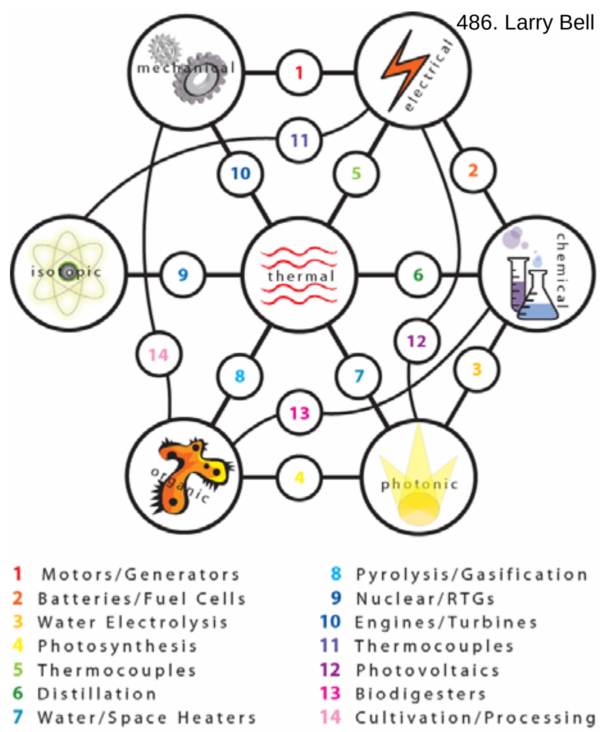
Bodies lose or gain heat energy through conduction, radiation and convection, a fundamental consideration in planning energy-efficient buildings and industrial processes:

- Conduction transfers heat from a hot to a cold body through free electron diffusion as adjacent atoms vibrate against each other or are exchanged:
  - This mostly occurs in solids, such as metals, where atoms are densely packed and are in constant contact to increase collisions.
- Radiation occurs through electromagnetic atom vibrations in the heat spectrum:
  - All objects radiate heat unless they are at absolute zero (virtually impossible), and insulators and reflectors are used to keep heat in or out.
- Convection transfers thermal energy through circulation of a heated medium (typically from or to fluids or gases):
  - A heated, less dense fluid receives heat, causing a cooler, denser fluid to move in and replace it.

Effective thermal energy utilization and conservation are of fundamental importance in extending precious fuel resources.

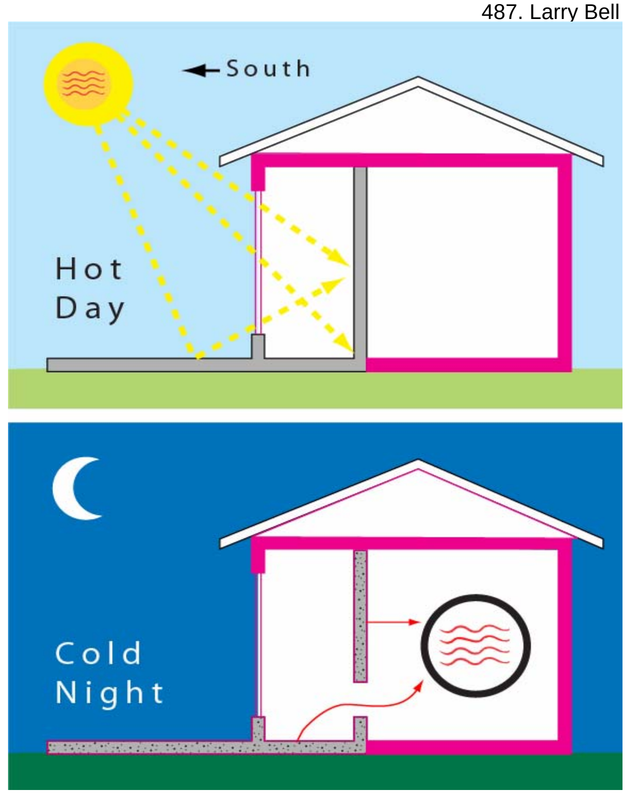
- This is true for a variety of reasons:
  - Thermal energy provides most of the global electrical power, driving steam turbines and chemically-fuelled generators
  - Heat powers all internal combustion engine vehicles, and efficiencies in utilizing this energy have substantial influences upon fuel consumption.
  - Heat is both an input and output of chemical and mechanical industrial processes, and technologies that recycle this energy for combined heat and power producing major economies.
  - Building space and water heating/cooling impose large energy requirements that can be greatly reduced through simple planning measures.

486. Larry Bell



Energy storage and recycling devices

487. Larry Bell

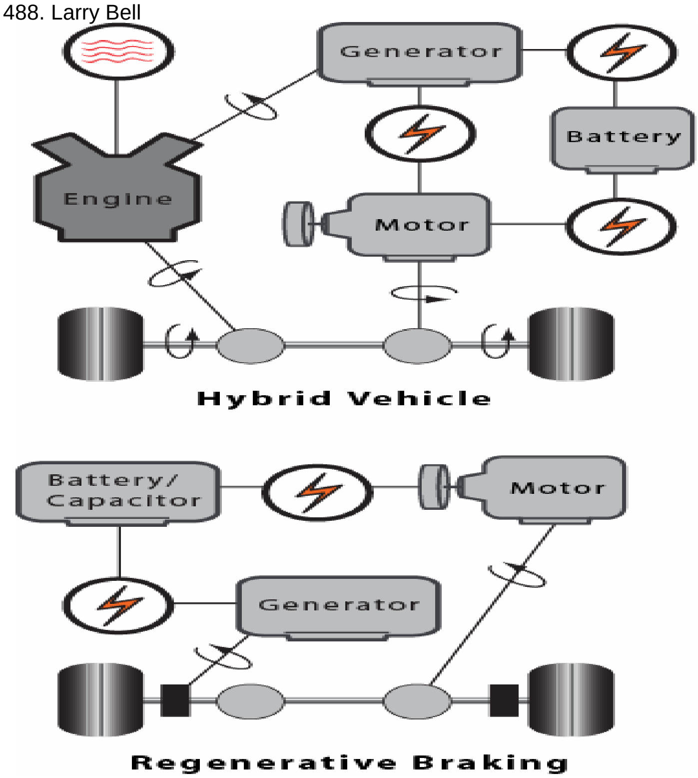


Storing Heat in Structures

Energy-conscious building design uses a variety of simple natural principles to block solar heat from interior living quarters when it is not desired and store it for colder evening periods when it is needed.

- "Passive" solar design strategies consider a number of location and seasonal climate conditions and use a variety of devices including appropriate window orientations to Sun angles, shading elements, natural ventilation and thermal insulation barriers:
  - Use of Sun spaces and heat-absorbing material mass is one effective way to collect radiant energy during the day and gradually release it at night similar to the way growing plants do.
  - Passive design techniques represent large opportunities to reduce energy consumption and user costs.

488. Larry Bell

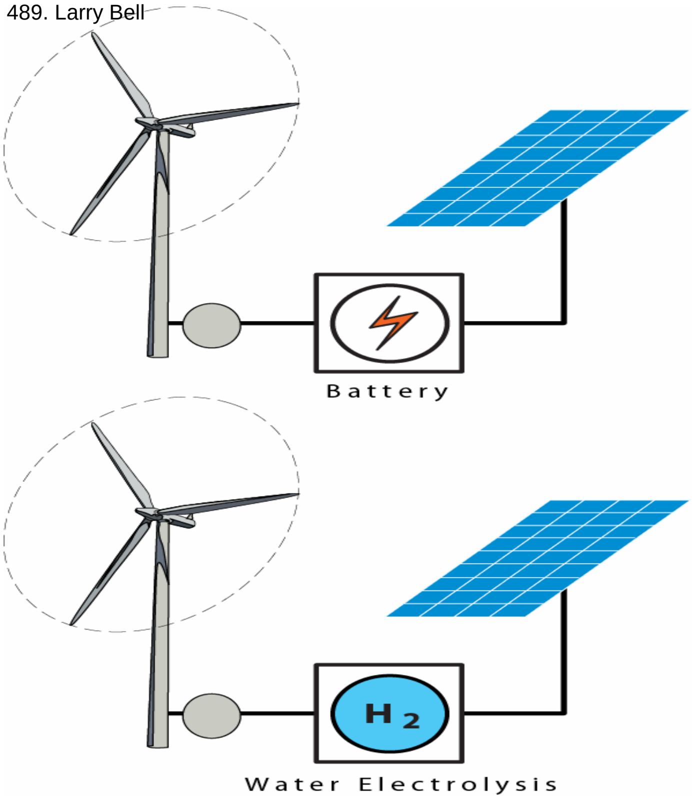


Source Optimization in Vehicles

Hybrid vehicles conserve energy by selective optimization of their combined engine and motor power sources.

- Engines provide the power at higher speeds when they operate most efficiently, and motors take over under slower conditions and for shorter range/duration travel:
  - Engines offer an additional source of power to recharge batteries to extend electrical motor use.
  - Regenerative braking, another conservation device, can convert mechanical energy via a generator to also recharge a battery or electrical storage capacitor to power a drive motor and extend vehicle range, and economy.

489. Larry Bell



Supply / Demand Balancing

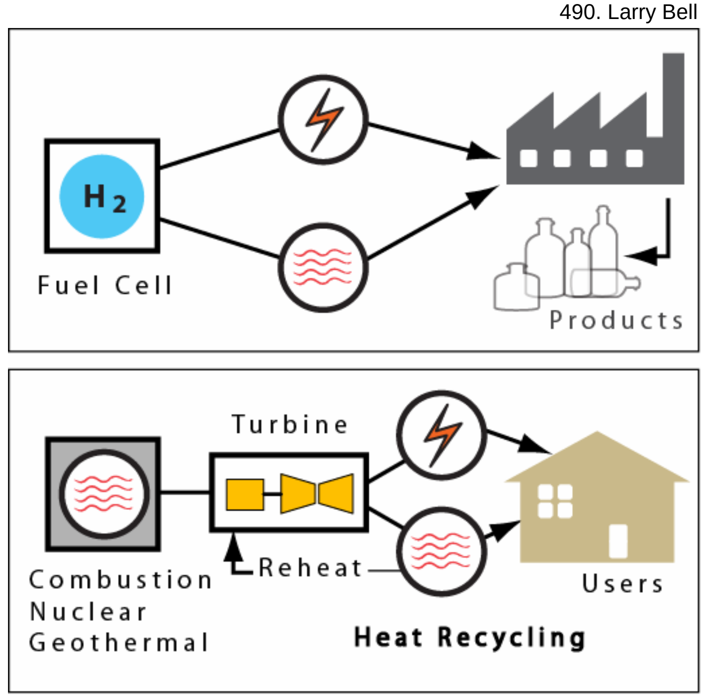
Selective energy optimization through a hybrid approach can also be accomplished using combined power generating and storage devices that balance electrical supply and demand cycles.

- An example is use of wind and photovoltaic devices that store energy in batteries or in the form of hydrogen for fuel cells:
  - Availability of solar photovoltaic power depends upon seasonal and daily weather conditions, including periods of daylight and clear skies.
  - Wind power is often most plentiful under contrasting conditions during evening / night time periods, and winter seasons with shortest days and strongest, most frequent breezes.

Combined heat and power (CHP) or "cogeneration" technologies represent a simple and highly effective energy conservation example that applies logical natural recycling principles.

- CHP is primarily used in large power production settings, but is also applicable to moderate size industrial facilities and potentially even residential environments:
  - Some systems use fuel cells as electricity-generating sources and harness the heat which is created as a product for secondary purposes.
  - Other systems use heat from fuel combustion, nuclear or geothermal sources to drive steam turbines for electricity and either recycle product heat back into turbines or use it for other benefits.

490. Larry Bell



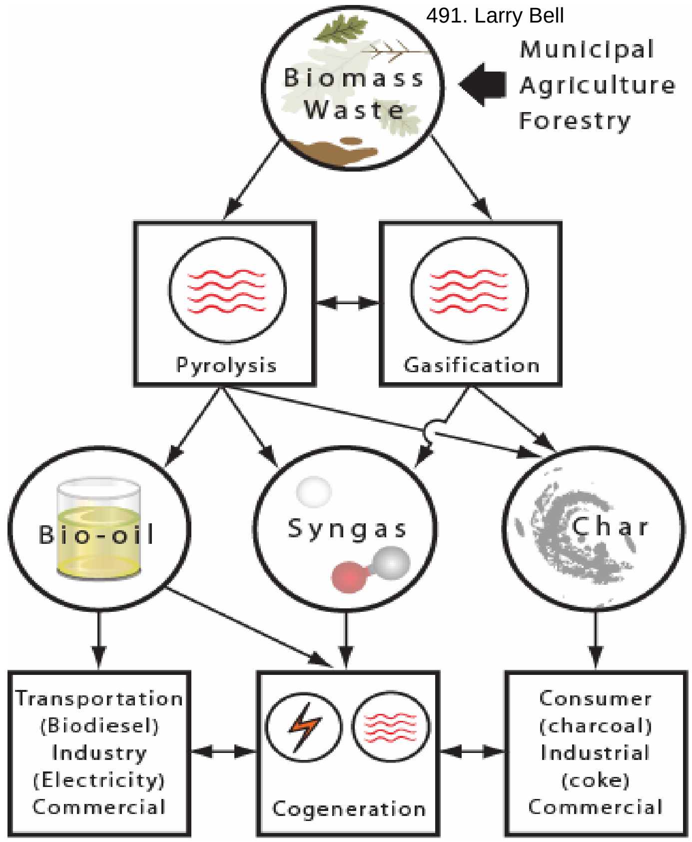
Recycling Heat through Cogeneration

Recycling waste to energy

Cogeneration can be used in combination with other available and emerging technologies to convert and recycle a wide variety of organic municipal, agricultural and forestry wastes into valuable fuels and electrical power.

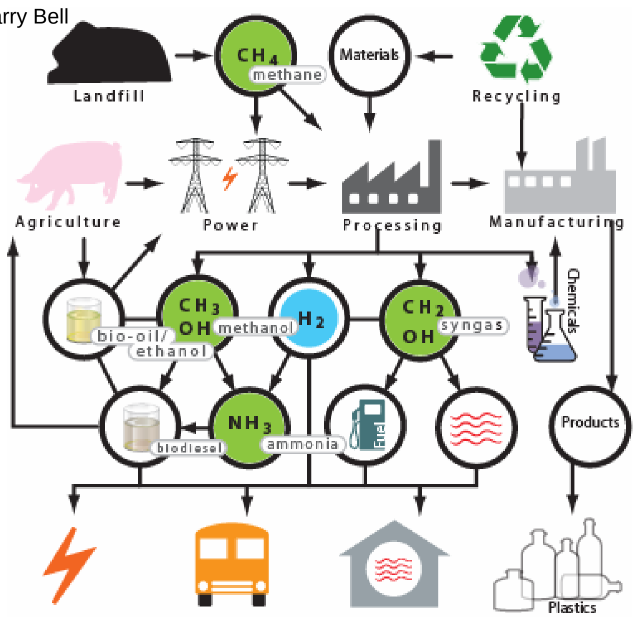
- The most prevalent processes used for these purposes today are pyrolysis and gasification which are often combined in the same plants:
  - Pyrolysis heats the carbon-rich materials under pressure in the absence of oxygen, producing liquid oil residues, syngas (along with feedstock for carbon char) that can be used to cogenerate heat and electricity in the facility, or exported to commercial customers.
  - Gasification heats pyrolysis products at higher temperatures in an oxygenated environment to also produce syngas that can be used for cogeneration, along with charcoal and coke which can be exported.

491. Larry Bell



Recycling Waste to Energy

492. Larry Bell



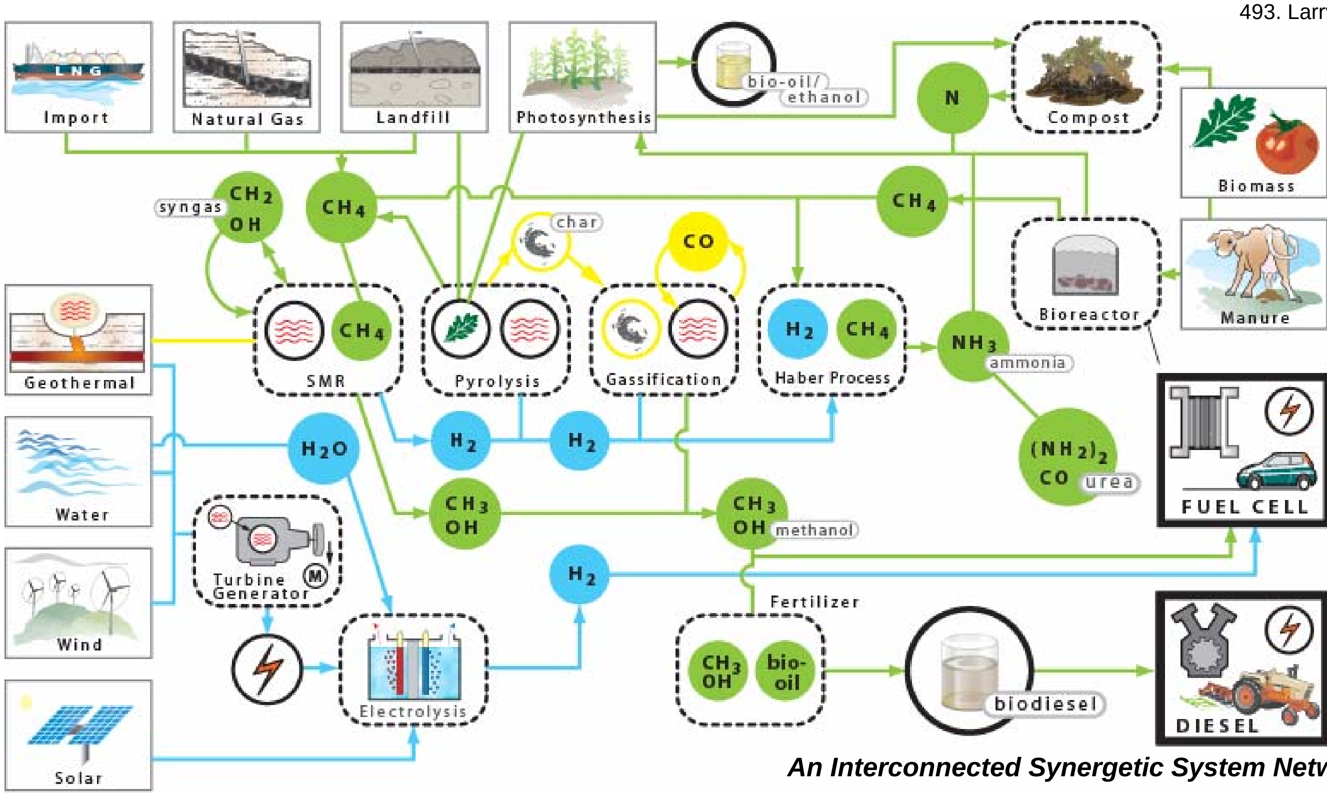
Methane from Landfills and Agriculture

Capturing methane from municipal landfills and constructed anaerobic digestion systems is a natural means to reduce natural gas consumption for energy, fertilizers and other products.

- As with all processes, the economic benefits relative to input costs vs. yields depend upon the scale and particular nature of applications:
  - Commercial waste companies are increasingly realizing that the large investments necessary for landfill site purchases, development and operations are providing dividends that can be expected to grow as natural gas prices continue to rise.
  - Agriculture businesses are converting plant biowastes and manure into fuel for space- heating and biodiesel-production to power equipment and, along with nitrogen from composting, into fertilizers.

Conservation networks

493. Larry Bell

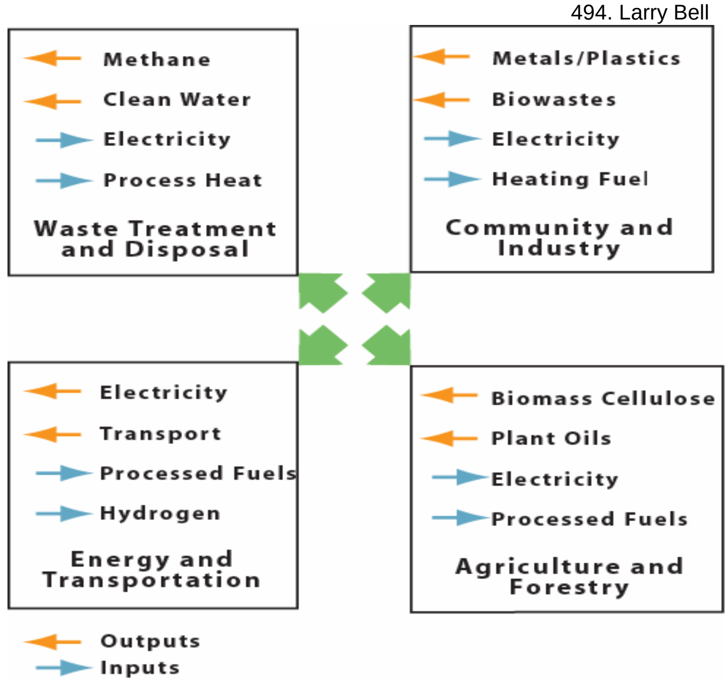


An Interconnected Synergetic System Network

All public and business sectors have important stakeholder interests in clean resource development, use and conservation.

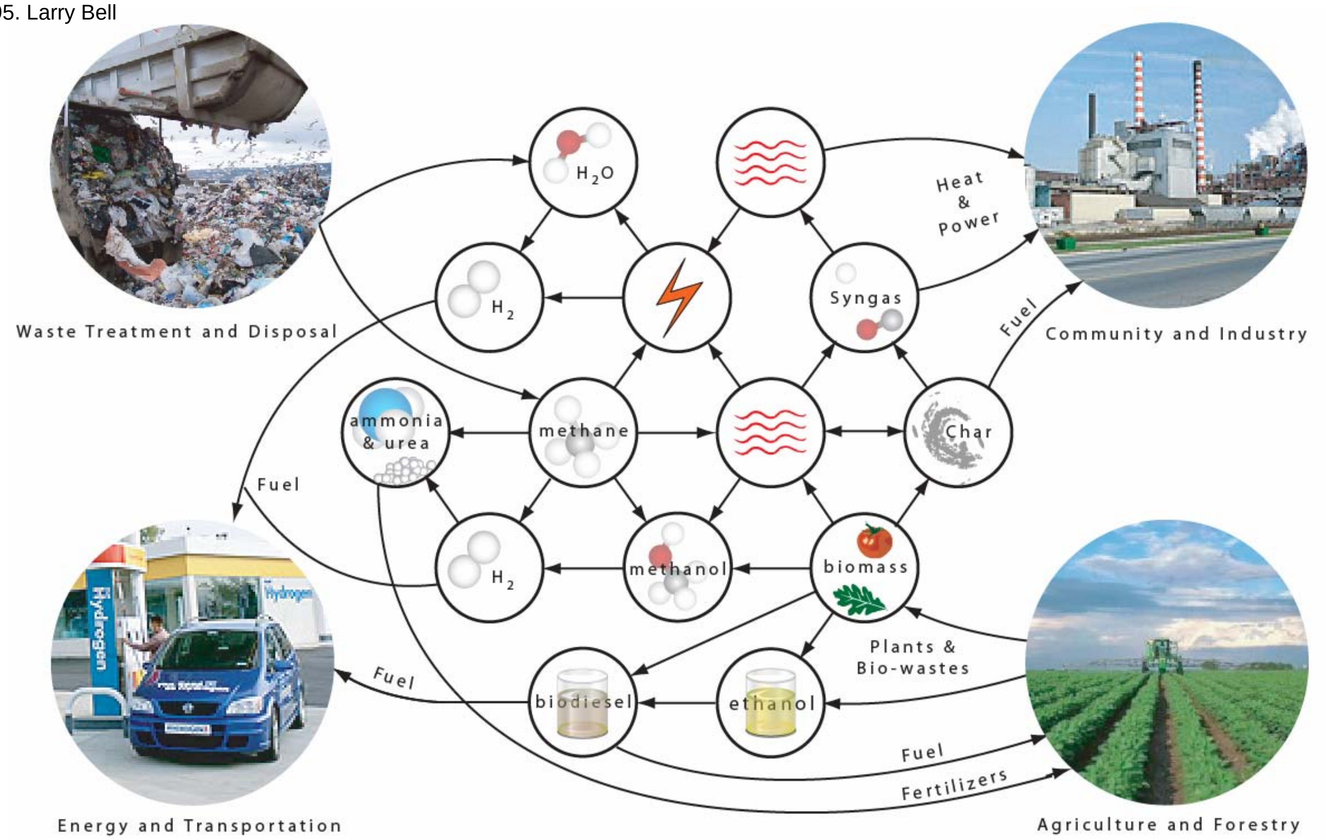
- Coordinated networks connecting these sectors afford opportunities to combine capabilities and exchange services for mutual and far-reaching benefits:
  - Various organizations and activities generate waste outputs that can be used as input feedstock for others.
  - Private and corporate energy consumers can create markets for vehicles and heating systems that use cleaner, more efficient and sustainable fuel sources.
  - Transportation and utility industries can respond to consumer demands with energy-saving products and distribution infrastructures.

494. Larry Bell



Conservation Stakeholders

495. Larry Bell



A Natural Resource Network

496. Rec. Travel USA-Canada
498. Petr Amadek

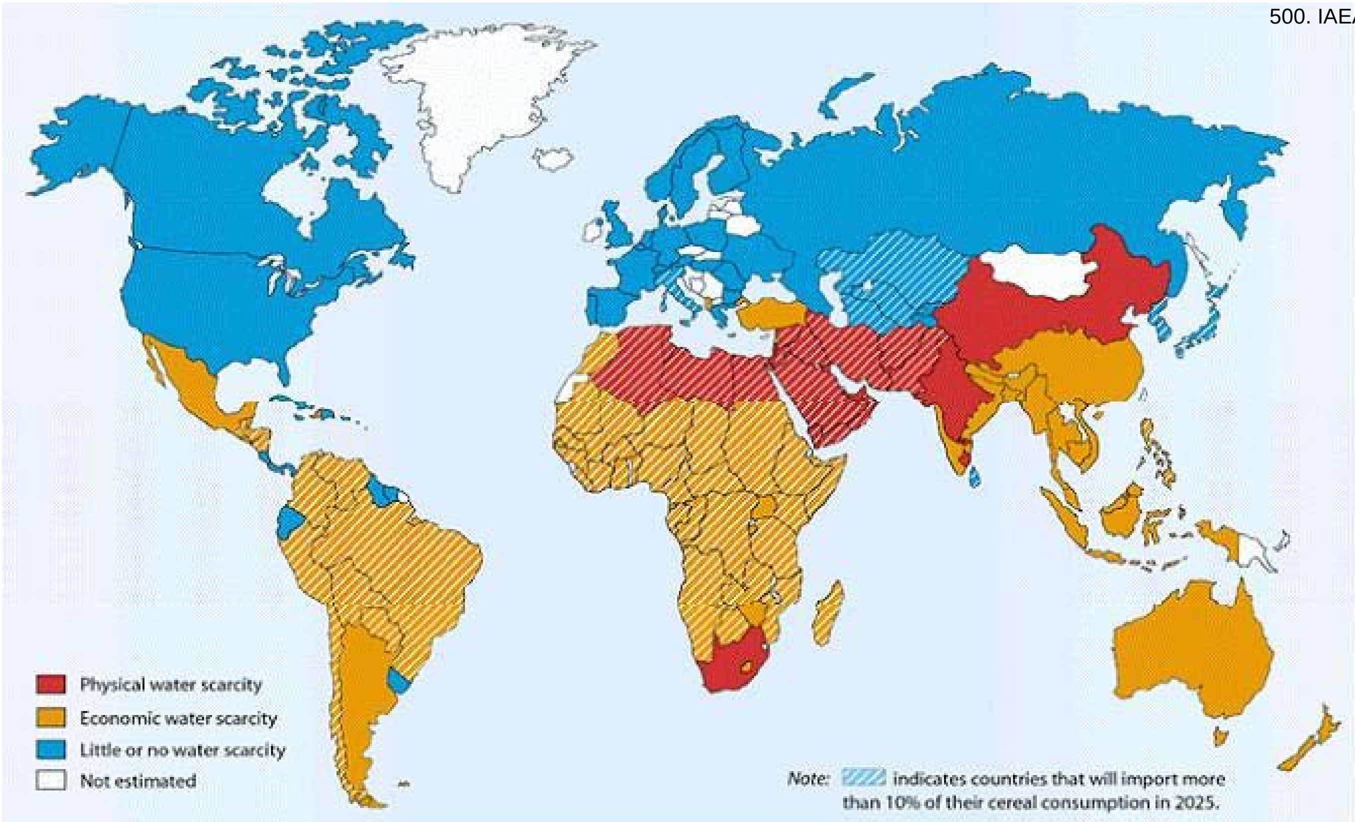
497. The Pasty
499. Carla Perrotti

Water is a precious resource that is essential to sustain life.

- According to the International Atomic Energy Agency (IAEA), while approximately 70% of the planet is covered with water, only about 2.5% is freshwater:
  - Nearly 70% of this freshwater is frozen in icecaps of Antarctica and Greenland.
  - Most of the rest is in the form of soil moisture, or in deep, inaccessible aquifers or falls in precipitation at the wrong times and places to meet needs (monsoons and floods).
  - Less than 0.08% of the world's water is readily accessible for direct human use, and even that amount is very unevenly distributed.

The global water crisis

500. IAEA



Global Water Scarcities

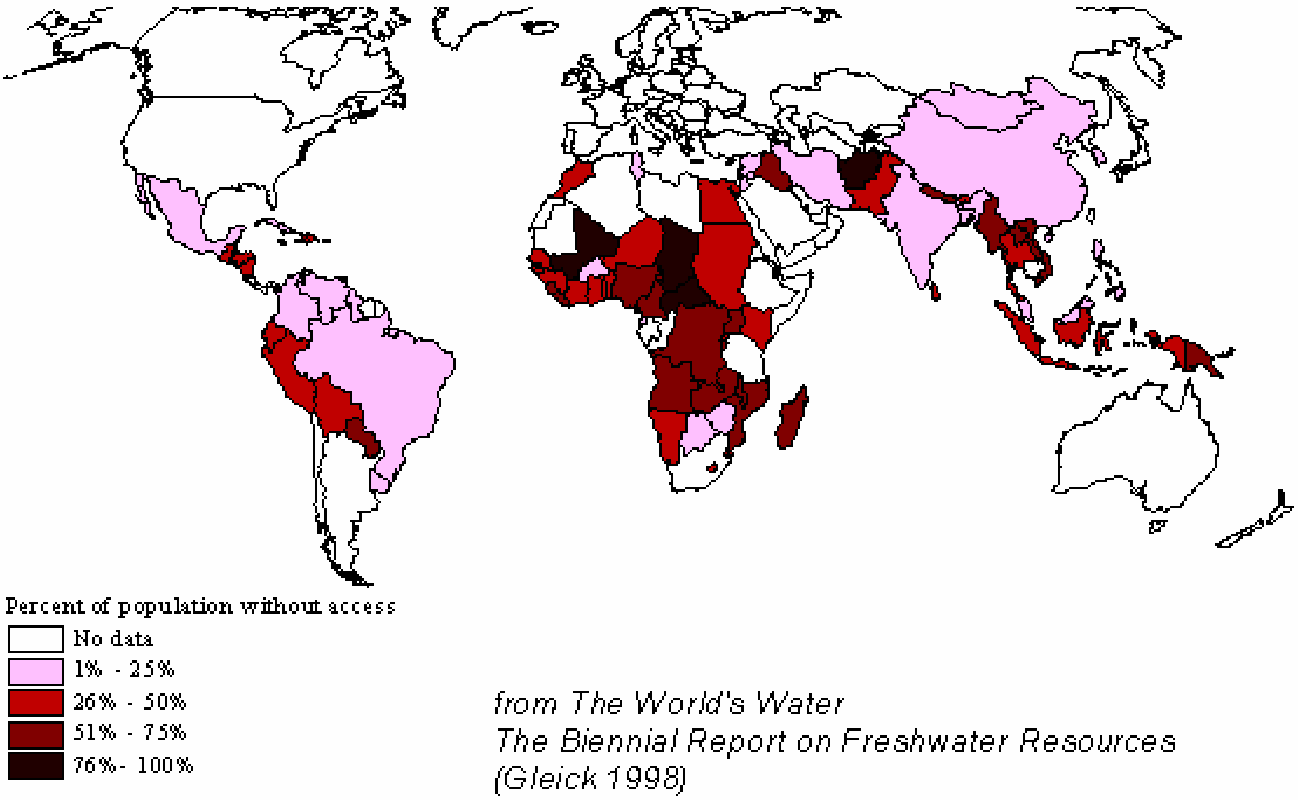
The IAEA estimates that an estimated 1.1 billion people currently lack safe water, resulting in huge death tolls and numbers of illnesses each year.

- According to some "business-as-usual" consumption forecasts, about two-thirds of the worlds population may face clean freshwater shortages by 2050:
  - As global populations continue to grow, limited easily accessible freshwater resources in lakes and shallow groundwater aquifers will dwindle even more rapidly due to over-exploitation and water quality degradation.
  - Water conservation along with improved and expanded wastewater treatment and use is vital everywhere.

501. Leia

A Precious Resource

502. The World's Water



Populations Without Access to Safe Drinking Water

503. Georgie Sharp

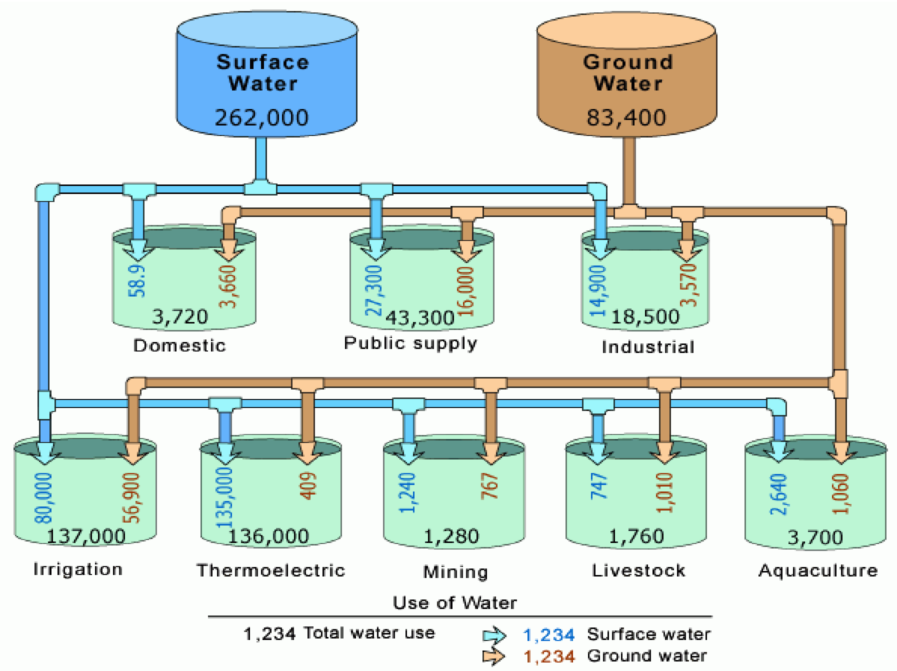
Freshwater Consumption

About four thousand cubic kilometers of water are used by global populations each year for domestic, agricultural, and industrial purposes (not including non-consumptive uses such as energy-generation, mining, and recreation)

- Some countries use far more of this resource than others:
    - On average, people living in Central Africa use only about 2% of the water consumed by each person in North America.
    - China, India, and the US use the most, but the amount consumed per capita in the US is about three times higher than in either India or China.

Natural and processed freshwater supplies

504. USGS Circular 1268



Sources/ Uses of Freshwater in the US (2000) Millions of Gallons / Day

It is estimated that each American uses about 60 gallons of water per day, more per capita than any other developed country.

- More than two-thirds of the freshwater is supplied from surface sources (the balance from groundwater
  - Irrigation is a major user of water from both sources, of which much is released to the atmosphere through evaporation.
  - Domestic consumption is primarily supplied from groundwater, while surface water provides most of the industrial water.

505. Treehugger

Seawater Desalination

Global freshwater output from desalination is very small (less than 0.1% of all drinking water), and about two-thirds of this is produced in Saudi Arabia, Kuwait, and North Africa. *

- The most common process uses reverse osmosis (RO) which pushes salt water through a semi-permeable membrane at high pressures (about 1000 lb/in^2):
  - About 35% - 50% of seawater volume is recoverable freshwater, and the rest is a soupy brine that presents large discharge disposal problems due to toxic impacts upon aquatic life.
  - Energy for desalination adds substantial cost over conventional water treatment, often making recycling a preferred option wherever possible.
  - Water conservation is always the best way to preserve water and reduce energy and costs.

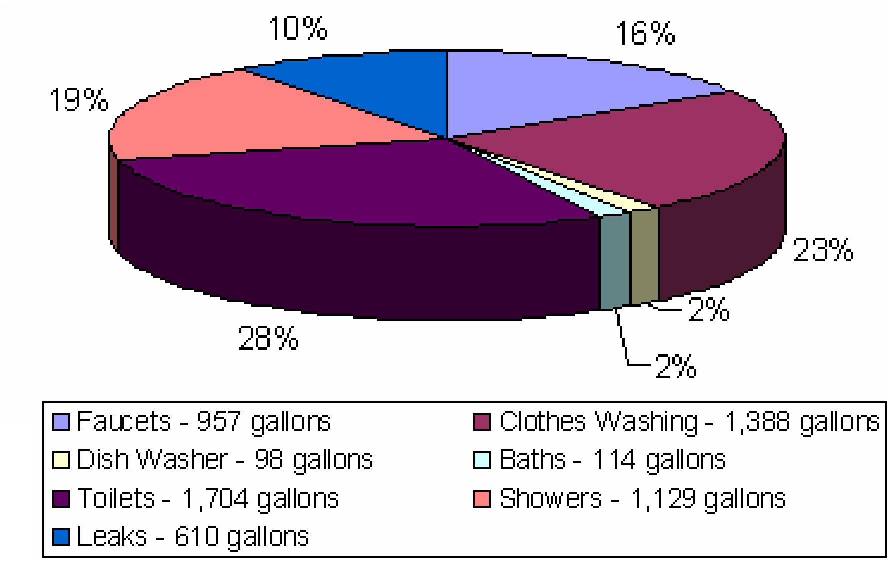
* See Appendix: 34

Water conservation strategies

The US Green Building Council (USBC) sponsors a *Leadership in Green Energy and Environmental Design* (LEED) program that offers a rating certification system to recognize conservation in building architecture

- The certification program includes up to five credits for water-efficient design:
  - Two for reducing potable water use for irrigation.
  - One for reducing potable water use for sewage conveyance.
  - Two for reducing potable water use inside a building.

506. City of Santa Rosa, California



Average Monthly Indoor Residential Water Use (6,000 gallons Without Conservation)

Outdoor	Indoor
• Cover pools and spas to reduce evaporation.	• Replace older toilets with ultra low flush system types.
• Plant hardy, water-saving plants (particularly native species).	• Don't use toilets as trash cans for facial tissues, etc (flush less often).
• Plant grass only where practical and functional to reduce watering.	• Test toilets periodically for leaks to prevent wastes/expenses.
• Minimize evaporation by watering in early morning or evening.	• Purchase *Energy Star* model washing machines and dishwashers.
• Install drip irrigation systems with automatic timers.	• Run full loads of clothes/dishes to optimize use.
• Mulch to retain water (create/use compost if possible).	• Program washers to eliminate additional rinse cycles when possible.
• Mow less frequently during dry times to retain moisture.	• Use less shower and bathtub water (shorter showers/less full bathtubs).
• Use a shut-off nozzle when washing cars (don't run water continuously).	• Install low-flow showerheads with aerators.

Household Conservation Tips

507. Biolet

Composting Toilets

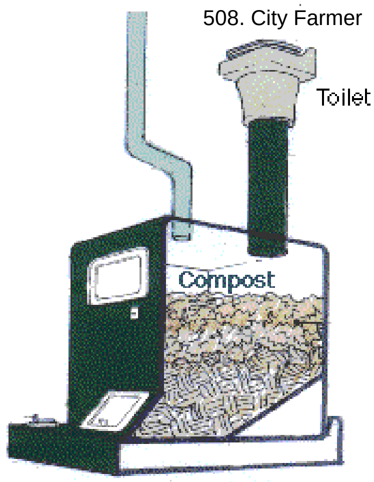
Composting toilets offer an alternative to standard types to conserve water, and are most often used where public water and sewage isn't available.

- These "dry sanitation systems" offer minimum-energy on-site solutions that avoid "transporting the problem downstream" or pollution problems often associated with septic tanks:
  - They operate through the same natural decomposition process that occurs in a garden compost heap.
  - Properly functioning compost toilets do not produce objectionable odors or health-safety problems.
  - In some applications the systems can convert human wastes into useful solid and liquid fertilizers.

Composting toilets use aerobic decomposition to convert human wastes into organic compost.

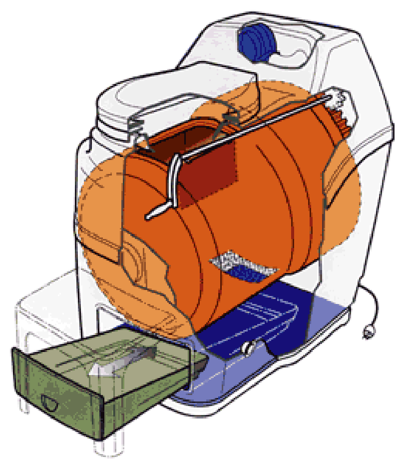
- There are two basic types of these toilets:
  - "In-situ" toilets are emptied directly into composting containers which are eventually purged of solid products after process completion.
  - The "bucket and chuck it" approach empties toilets into remote compost piles that are kept separate from other composting materials such as kitchen and garden wastes.
  - Some composting toilets of each type have electrical fan systems to exhaust air and increase microbial activity.
  - Other toilets require a user to rotate a composting drum or otherwise stir the wastes from time to time.

508. City Farmer



In-Situ System

509. Sun-Mar Biodrum



Removable Tray System

Composting toilets are technically quite simple, but require more attention than flush-type WCs. They must be operated separately from grey water collection systems and often need special installation and operation accommodations. The composted material must be removed when sufficiently decomposed (frequently dependent upon container size, amount of use, and climate conditions).

Compost Toilet Types

510. Envirolet

Many people in the "developed world" regard composting toilets to be unappealing due to perceived hygiene and health issues.

- These concerns can be minimized provided that the systems are properly maintained:
  - Odors can be controlled using natural air ventilation or low voltage extractor fans, by separating urine and feces, or by adding a high carbon-content peat mix to absorb liquid.
  - Toilet design should allow waste material to remain aerated to prevent compost from becoming anaerobic (again avoiding odors).
  - Feces should either be heated to destroy pathogens, or allowed up to a year to break down and disappear naturally.

Special Compost Toilet Considerations

511. Wikipedia Commons

Public Compost Toilet Installation Along a Highway in Sweden.

Growing Public Acceptance

Waterless compost toilets have been used in Scandinavia for many decades, and tens of thousands of units have been installed throughout Europe, the USA, and Canada.

- Safety and performance standards established by the National Sanitation Foundation (NSF) International and recognized laboratories have advanced public confidence in the US:
  - The toilets can operate in an odor-free fashion.
  - As waterless systems, they conserve water, and enable use in drought areas where water is not available for long periods of time.
  - Human wastes can be converted into fertilizer that can be legally used for horticultural and agricultural after a specified amount of time.
  - Some systems are inexpensive to install and require little maintenance.

Incineration can afford another useful waterless process for eliminating human fecal wastes in small-scale applications.

- Incinerating toilets can offer advantages over flush-type WCs in a variety of circumstances:
  - They are often used in places where septic systems are impractical due to shallow soils, high groundwater, or extremely cold weather.
  - They are used in remote areas where piped sanitation systems are not available.
  - Marine vessels use them due to prohibitions upon discharge of untreated wastes into water bodies.
  - The waterless devices are often attractive in drought areas and other locales that demand particularly stringent water conservation.

512. Wikipedia Commons

Incinerating Toilets

Incinerating toilets are relatively simple in design and operation, consisting of traditional commode-type seats connected to holding tanks with electric or gas-fired heating/combustion systems.

- General features of both incineration types are similar:
  - The incineration products are mostly water and sterile fine ash that can be easily and safely disposed of.
  - The product ash is space-saving (about one tablespoon per average toilet use).
  - The units are portable and simple to install in remote areas, in unheated shelters, and in locales with freezing temperatures.
  - Incinerating toilets are relatively odorless, particularly in comparison with more commonly used "storage-in-disinfectant" portable toilets.

513. Incinolet

The Incinolet usually incinerates waste after each use but can accept a maximum of 2-4 "flushes" before incineration is necessary

Incolet Electric System

514. Starburn

The Starburn toilet can be used up to 60 times before incineration. It can meet the needs of 8-10 people in an average 8-10 hour workday, or about 6-8 people over a 16 hour period. It cannot be used during the 4.5 hour burning cycle.

Starburn Gas-Fired System

Incinerating Toilet Types

Wastewater treatment

In addition to problems of water scarcity, the United Nations estimated that in 2000, about 2.64 billion people (about 44% of the global population) had inadequate sewage treatment and/or disposal, and about half of the people in Africa and Asia had no access to wastewater treatment at all.

- The result of inadequate sewage treatment has significantly contributed to high mortality levels from preventable diseases, impacting children and elderly in underdeveloped countries in particular:
  - Even very low levels of certain contaminants in wastewater can produce health hazards, including bacteria that feed upon organic wastes, hormones from animal husbandry, pesticides and herbicides, and industrial chemical wastes.
  - Modern wastewater treatment processes can eliminate human and environmental hazards.

515. US Army

New Water Treatment Plant in a Small Iraqi Village, Created by the USA

516. USGS

Natural Water Sources

Purification to produce water that is safe and pleasing to drink from original natural and wastewater reclamation sources is essential.

- These requirements are influenced by water supply sources:
  - Deep groundwater from rainfall is often naturally filtered through soil and rock layers to a high degree of clarity before entering a treatment plant or well.
  - Shallow groundwater wells or boreholes often contain bacteria and dissolved toxic materials including zinc, copper, and arsenic.
  - Upland lakes and reservoirs may contain excrement contaminants from livestock and industrial effluents.
  - Rivers, canals and lowland reservoirs may contain high levels of bacteria, algae, and surface runoff pesticides.

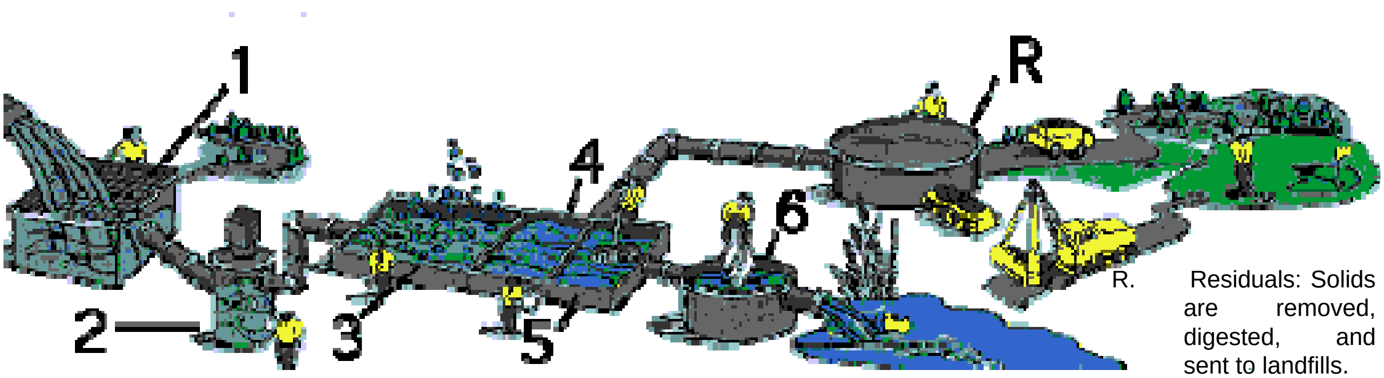
517. Walkerton
518. US Fire Administration
519. Clean Water Centre
520. Matt Kingston

Protecting Public Safety

Wastewater treatment facilities process ground and surface water and/or sewage to produce potable or “industrial water”.

- Potable water purification must remove bacteria, algae, viruses, fungi, and man-made pollutants to eliminate health hazards, pungent odors and unpleasant tastes.
  - Primary treatment collects, screens, and stores water from the original sources.
  - Secondary treatment removes fine solids and the majority of contaminants using filters, coagulation, flocculation and membranes.
  - Tertiary treatment polishes the water, adjusts the pH, removes bad tastes and smells, and disinfects the water to kill remaining organisms.

521. United States Geological Service



R. Residuals: Solids are removed, digested, and sent to landfills.

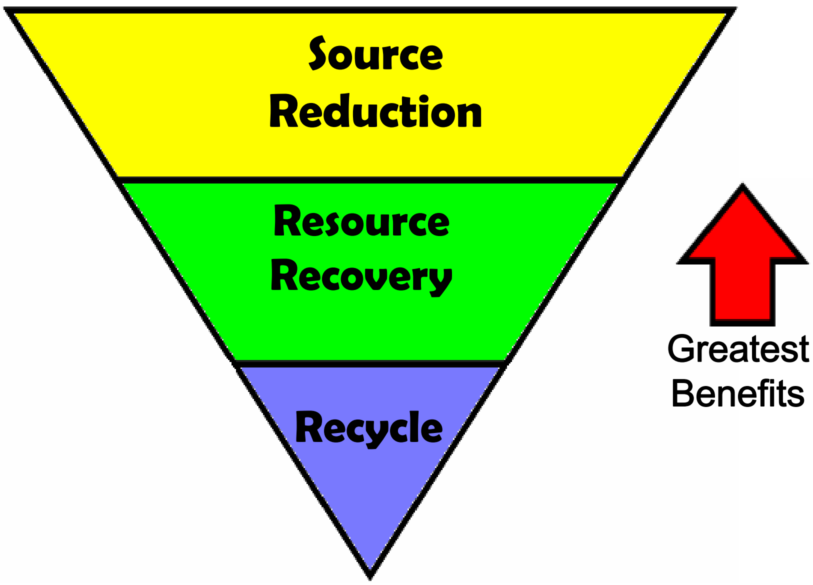
1. Screening: Debris such as wood, rocks and even dead animals are removed and disposed of.
2. Pumping: If the plant is above ground level, wastewater must be pumped up to aeration tanks for processing.
3. Aerating: Sewage enters long concrete tanks where air is pumped through to replenish oxygen and suspend organics.
4. Sludge Removal: Wastewater enters sedimentation tanks (digesters) where organic materials are removed.
5. Scum Removal: Grease, oils, plastics, soaps, and other floating scum is skimmed off and digested.
6. Bacteria Destruction: The wastewater flows into a chlorine tank where bacteria are killed.

Wastewater Treatment Steps

Eliminating Health and Environmental Hazards

Waste reduction, recovery and recycling

522. Ian Bell



Waste management involves the collection, transport, processing, recycling, and disposal of materials produced by human activities, along with efforts to minimize their production.

Basic Approaches

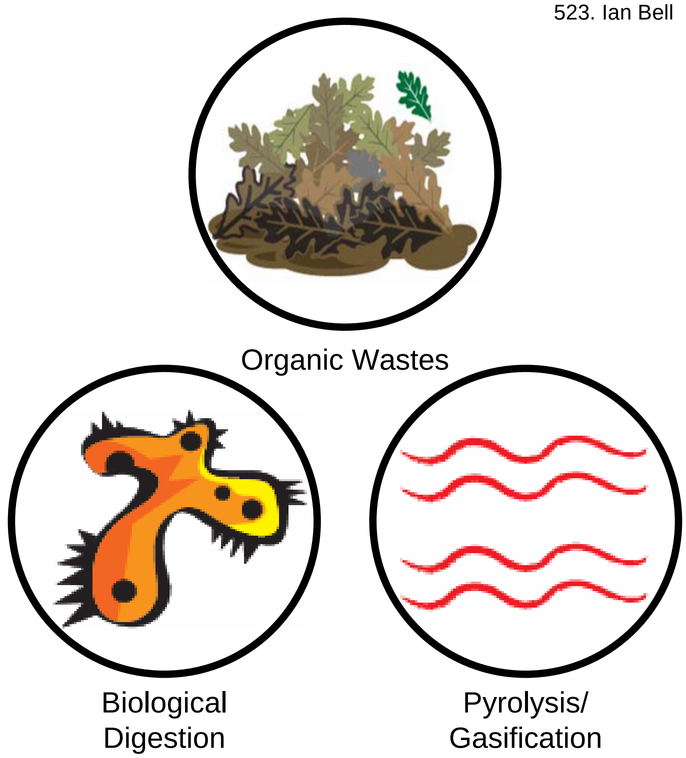
Responsible management views waste products as resources to be conserved rather than as a disposal problem.

- A primary aim of responsible policy must be to extract the maximum benefits from these products, and also to generate the minimum amount of waste, through three basic priorities:
  - Source reduction: for example to reduce hazardous waste and other material consumption by modifying industrial production.
  - Resource recovery: to collect and treat waste materials so that they do not pose hazards and can be reclaimed for useful purposes.
  - Recycling: to reuse waste materials and discarded products in their current or an altered form.

Organic waste materials can be made safe and converted into useful components through a variety of biological and thermal/chemical source reduction recycling processes.

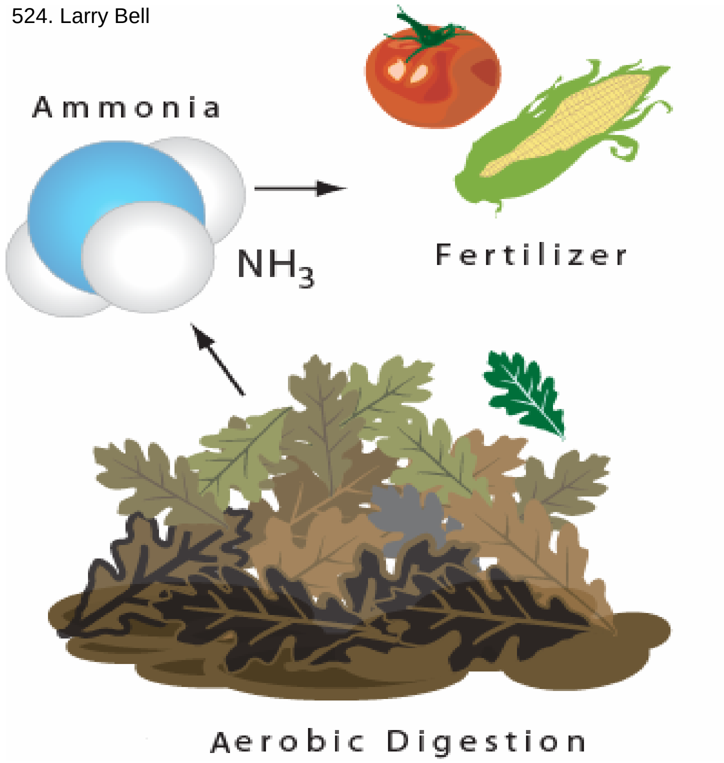
- Biological processes broadly include composting and anaerobic digestion, and thermal/chemical processes include pyrolysis and gasification:
  - Basic biological processes decompose organic matter to kill pathogens and stabilize the materials to be recycled as mulch or compost for plant growth.
- Thermal/chemical processes primarily involve pyrolysis and gasification methods that convert organic materials into useful solid, liquid and gas products.
  - Pyrolysis and gasification can convert municipal wastes into fuels to produce heat and power.

523. Ian Bell



Biological and Thermal/Chemical Processes

524. Larry Bell



Recycling Waste into Nutrients

Organic materials such as plants, food scraps and paper products are increasingly being recycled through composting.

- Composting is the aerobic decomposition of organic wastes by bacteria, fungi, worms, and other organisms under controlled conditions where oxygen is available:
  - Early Greeks and Romans practiced composting, although the process has occurred in Nature since the life on land.
  - Tree leaves and other plant materials that carpet surfaces of forests and meadows break down and decompose to produce a nitrogen-rich, slow-release fertilizer.
  - The same processes are employed in environmentally-sound gardening practices.

Composting of very small and large scales can substantially reduce municipal waste management costs and yield product benefits

- The process can eliminate up to 20%-50% of curbside garbage comprised of landscape and kitchen wastes:
  - This waste source reduction approach diverts large amounts of material away from landfills and saves transportation and other disposal expenses.
  - The product is a valuable soil amendment to provide nutrients, assist moisture retention, and provide mulch for landscaping.
  - A composting facility operated by the City of Edmonton, Alberta, Canada is about equivalent in size to 8 football fields, producing approximately 80,000 tons of compost annually.

525. TAMU

Important Composting Benefits

Converting waste to energy

Source reduction through anaerobic digestion breaks down organic matter using organisms that operate in environments lacking oxygen.

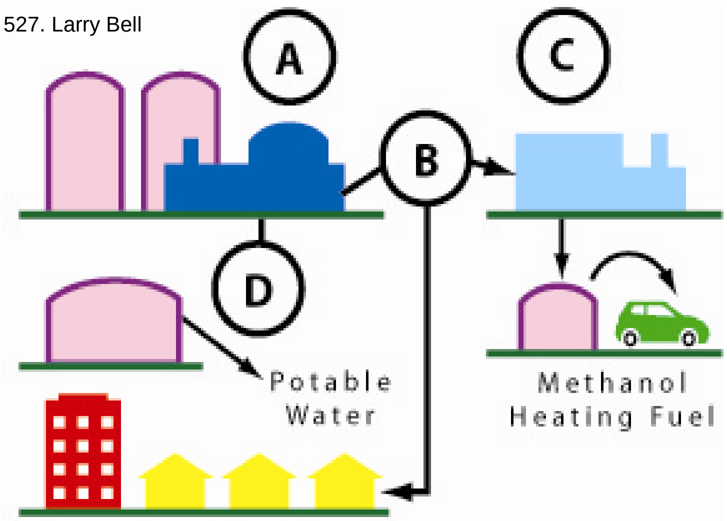
- Digesters are used to produce heating fuel, electrical power, or both:
  - They have been commonly used for sewage treatment and managing animal waste for many years.
  - The process is gaining widespread utilization in response to environmental pressures to reduce waste volumes and to generate byproducts.
  - Anaerobic digestion can greatly reduce the amount of organic material that would otherwise end up in landfills and incinerators.
  - Nearly all biodegradable materials can be processed, including paper, leftover food, and sewage.

526. Arrow Bio Israel

Large Twin-Stage Biodigesters for Waste and Wastewater Treatment

Anaerobic Digestion

527. Larry Bell



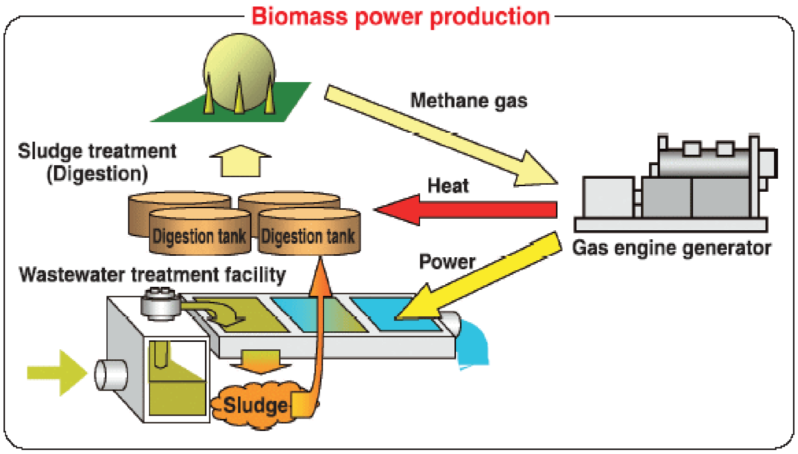
A - Wastewater Treatment
B - Methane Gas
C - Methane Plant
D - Water Purification

Municipal Waste Application

Some energy co-ops focus upon biomass waste sources for electricity, including farm by-products, wood wastes, aquatic plants and landfill methane.

- More than 105 co-ops in 22 states are now using biomass in their power supplies:
  - Landfill programs that convert gas to energy offer opportunities for large metropolitan centers, rural communities and agricultural businesses to supplement other power sources and realize revenues while practicing responsible conservation practices.
  - Conventional municipal wastewater treatment processes can capture valuable methane for heating and methanol production, in combination with standard water purification for community use.

528. Bureau of Sewage, Tokyo Metropolitan Government



Biodigestion of wastewater sludge can produce methane fuel for district power and heat. The heat can also be used to carbonize sludge as a low-ash emission fuel source for power through incineration.

Municipal Waste Conversion

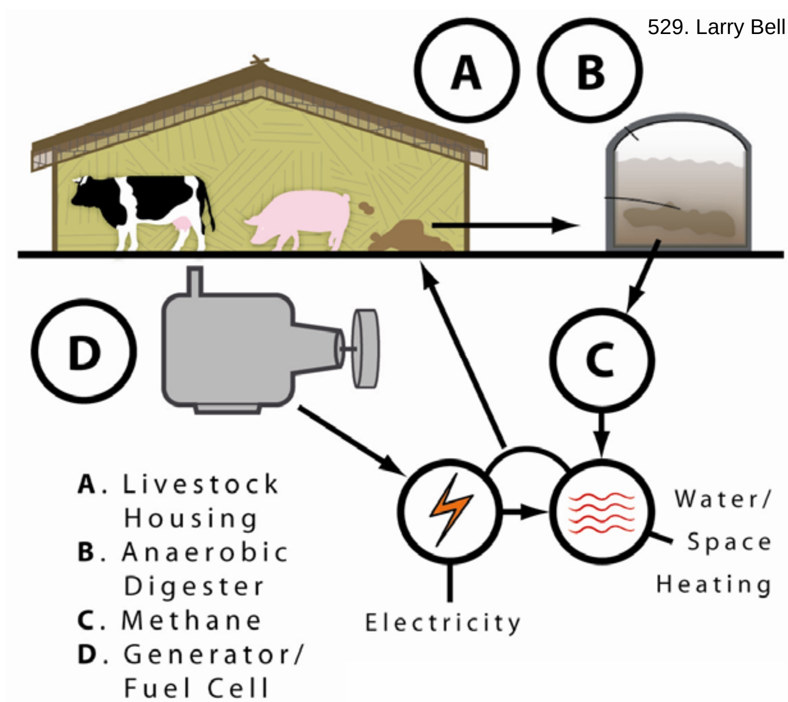
The Tokyo Bureau of Sewage (Japan) has developed plans to reduce greenhouse gases emitted during wastewater treatment and use sludge as a district power and heating fuel source.

- The biomass power production will capture and store methane from sludge biodigestion which is sent to a gas engine generator to create heat and electricity:
- During nighttime hours when electricity demand is relatively low the power will be stored in sodium-sulfur (NaS) batteries for daytime use.
- Heat produced from the power generating process will be fed back into sludge digestion tanks to accelerate methane production.
- Sludge incineration at high temperatures will create additional power with about 70% lower nitrous oxide (N_2O) emissions due to carbonization of the material.

Just as in municipal water and sewage treatment systems, farm-scale biodigesters can provide heat as well as power.

- Combined heat and power can be applied using either engine generators or fuel cells that operate on methane:
- Fuel cells offer the advantage of reduced CO_2, N_2O and CO emissions, and can provide higher efficiencies.
- For each 100 pounds (45.4 kg) of manure fed into a digester, about 4 pounds (1.8 kg) is converted into methane and the rest leaves as effluent, a process that requires about 20-25 days, with fresh manure added and effluent removed daily.
- Process heat can be used for space and water heating, and electricity can be used for milk coolers, vacuum pumps, lighting and other purposes.

529. Larry Bell



Municipal and Agricultural Materials

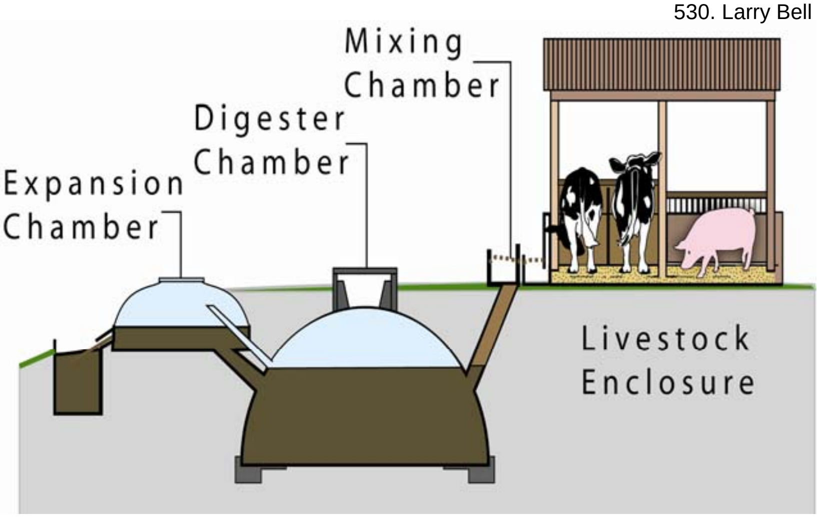
Agricultural bioreactors

Bioreactors for small-scale farm applications are relatively simple to construct, operate and maintain.

- Typically, small-scale fixed dome types are buried underground, and have three main connecting parts:

- **Mixing chamber**: Animal excrement is first mixed with water before it is poured into a digester chamber.
- **Digester chamber**: As the wet excrement ferments, methane and other gases push the manure and slurry that settle to the bottom into an expansion chamber.
- **Expansion chamber**: excess manure and slurry are collected and flow back into the digester chamber to push biogas up for use.

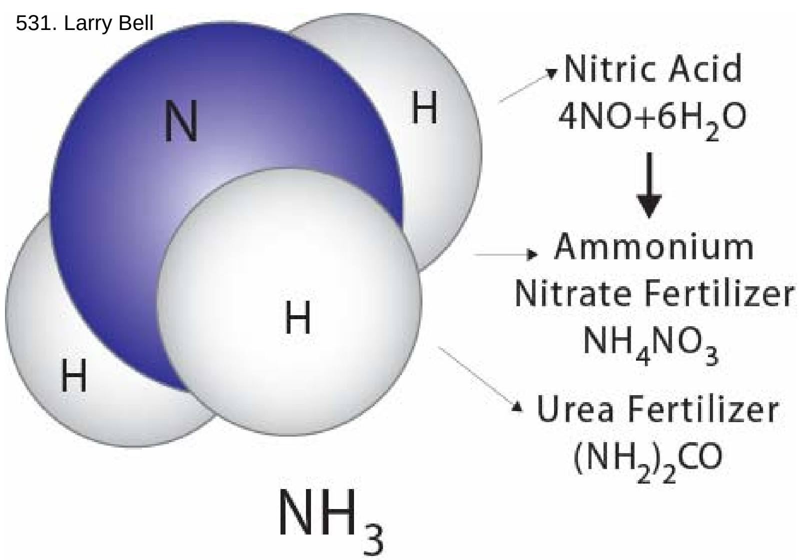
530. Larry Bell



- *Must have a minimum of three cows or ten breeding pigs to sustain operations*
- *Livestock enclosure must be within 65 ft (20 meters) of the bioreactor*
- *Animals must be in the enclosure all night (a minimum of 12 hours)*
- *Requires year-round access to ground water within 65 ft (20 meters).*
- *Biogas should be used within 330 ft (100 meters) of the reactor*

Manure Bioreactors

531. Larry Bell



Ammonia fertilizer is a source of nitrogen required for the synthesis of amino acids, the building blocks of protein in most living creatures.

Ammonia Fertilizer

Bioreactors are also used to maximize benefits of agricultural resources in rural areas by producing plant nutrients and water (along with methane fuel) that recycles animal and plant waste.

- Integration of energy, fertilizer, and water recycling processes applies practical conservation practices:
  - Livestock manure is a good source of nitrogen-rich ammonia, which can be used to create urea fertilizer, or can be mixed with irrigation water for growing nitrogen-dependent crops such as corn.
  - The anaerobic digestion process can greatly reduce fecal coli and salmonella bacteria levels, enabling water recovery for safe irrigation purposes.

Landfills and incineration

532. Utah State Univ
533. Penn State
534. US DOE
535. AP


Landfills


Incineration

Huge amounts of solid wastes are produced and disposed of in all regions of the world each year.

- Disposal of solid wastes is usually accomplished by two general methods: landfills and incineration, each presenting special controversies and problems:
  - Countries and regions with large land areas and low population densities (e.g. Australia) typically use landfills as the method of choice.
  - More densely populated places with limited adjacent space are likely to incinerate most of their solid wastes.
  - While older, poorly managed landfill sites present a variety of problems, these adversities can be reduced by applying modern improvements.
  - Incineration can be a largely wasteful and polluting approach, but if managed properly, can be accomplished using pyrolysis to produce syngas with beneficial results.

Although incineration is sometimes termed “Energy-from-Waste” (EfW), there are better ways to recover energy from waste than burning it.

- While still widely practiced in many areas, incineration is controversial for many reasons:
  - Burning not only destroys the raw material, but also all the energy, water, and other natural resources used to produce it.
  - The amount of energy that can be converted through combustion to produce steam for electricity represents only a small fraction of the fuel’s caloric content.
  - Incineration of municipal solid wastes releases dioxin and furan emissions into the atmosphere that present serious health hazards.
  - Incinerated ash can leach into the ground and contaminate subsurface aquifers.

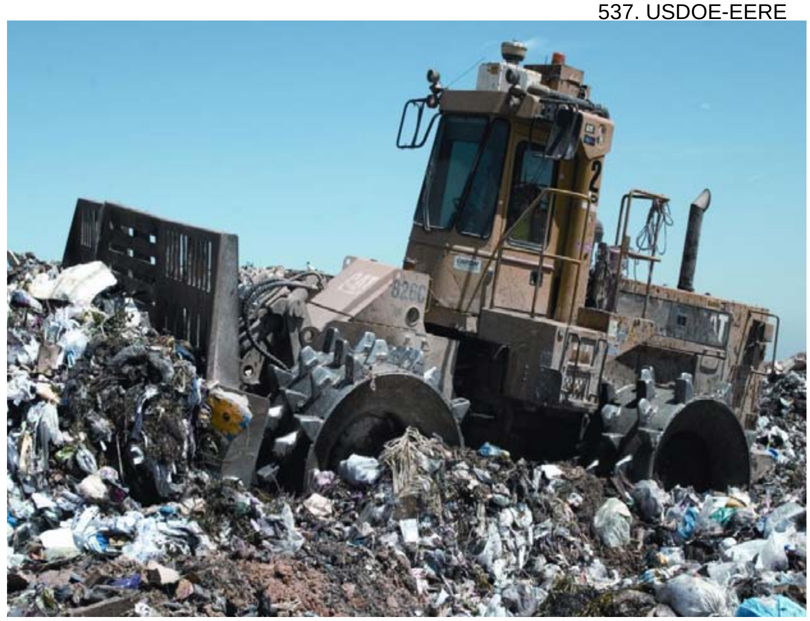
536. USDOE-EERE

Incineration

Landfills are the most traditional world-wide method of solid waste disposal.

- Raw garbage and sorted material landfill sites often use abandoned quarries, mining pits and other containment voids:
  - Many urban authorities find it difficult to establish new landfills due to opposition from nearby landowners and residents.
  - Public concerns include odors, wind-blown litter, vermin, and pollutants such as leachate which can contaminate groundwater and rivers.
  - Efforts to minimize uses include taxes on waste sent to landfills, recycling, converting materials into energy, and legislation making manufacturers responsible for disposal costs.

537. USDOE-EERE



Landfills

538. Hot Air Zone

540. Bottles and Cans

539. RRT

541. University of Oklahoma

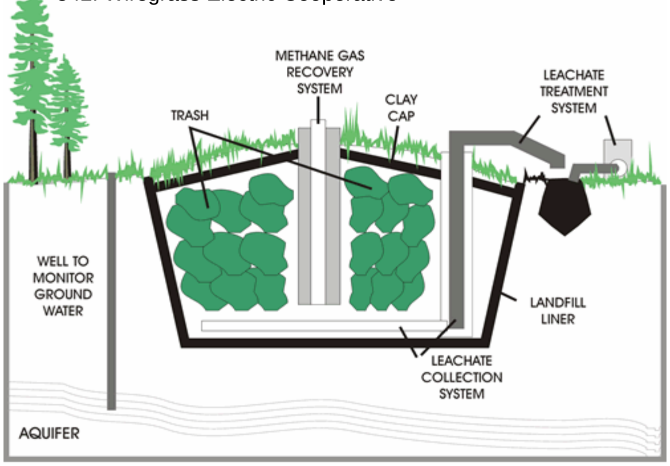
Landfill Problems and Opportunities

Public resistance to landfills coupled with economic resource recovery incentives are producing beneficial changes.

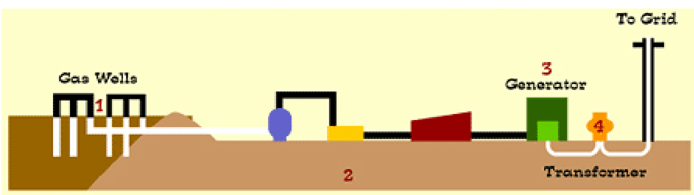
- Some optimists believe that today's landfills will be "mines of the future" as resources continue to become ever scarcer:
  - Improved Landfill gas extraction technologies are reducing odors, capturing methane more effectively and providing leachate collection and ground barriers.
  - Aluminum and other metals are being recovered and recycled for reuse rather than being put into landfills (it is much more labor and cost-effective to separate these materials prior to disposal).
  - As new disposal sites become fewer, farther and more expensive to operate, these economic factors will make recovery and recycling more essential.

Recovery and recycling programs

542. Wiregrass Electric Cooperative



Methane



Landfill Methane Recovery

The Wiregrass Electric Cooperative, a rural co-op serving customers in southeast Alabama, offers a Green Power Choice Program that enables users a voluntary option to purchase 100kW blocks of power from renewable sources for about $2.00 per month.

- Some of the electricity is generated from landfill waste, along with solar, wind, geothermal and hydro sources:
  - Landfill methane is used to fuel a gas-to-energy power station that generates about 4.8 MW of electricity.
  - The organization estimates that each 400kWhs of electricity generated prevents 3.6 tons of CO_2 emissions each year, the equivalent of planting 1.2 acres (0.48 hectares) of trees, or not driving 9,600 miles (15,000 km) in a family car.

Recycling fundamentally involves recovery of discarded products and materials that would otherwise be considered waste.

- "Secondary resource recovery" is increasingly being practiced in metropolitan areas world-wide, particularly where space for new landfills is becoming scarce:
  - There is a growing public awareness that simply disposing of waste materials such as metals is unsustainable, short-sighted, and irresponsible.
  - New recovery methods and technologies are constantly being developed, creating economical business opportunities for equipment developers and product reclaimers.

543. Earth Works Recycling, Inc. 544. Truman State U
545. Rochester Environment 546. State of South Dakota

Secondary Resource Recovery

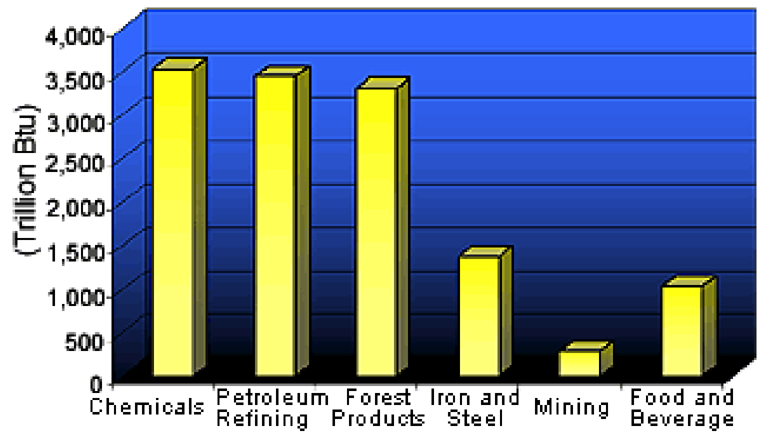
Waste Recovery Resources

Energy use and conservation in industry

The industrial sector, including manufacturing, construction, agriculture, mining, waste treatment and other organizations, consumes about one-third of all US energy.

- Increasing costs have forced many of the more energy-intensive industries to implement significant improvements during recent decades:
  - Unlike other sectors, total industrial energy use in the US has actually declined during the last decade due to conservation efforts and growing trends to move manufacturing operations offshore.
  - Energy used to produce steel and paper products has been reduced about 40% during the past 30 years, and petroleum/aluminum refining and cement production have reduced usage by about 25%.
  - Energy required for fresh water treatment and distribution often consumes a large amount of electricity and natural gas.

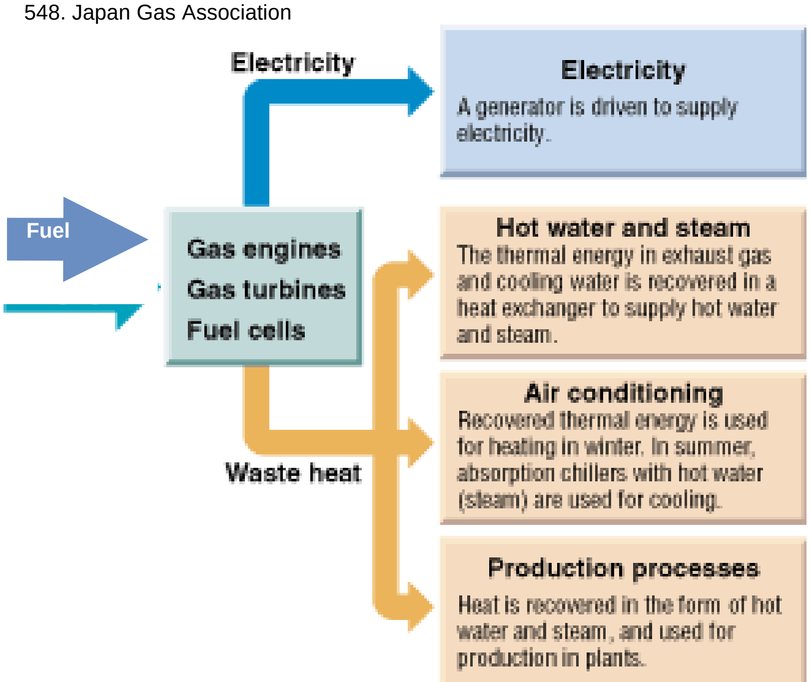
547. Agency for Natural Resources



Forest product processing is the largest user of steam and combined heat-power systems; while petroleum refining is the largest user of fired heating systems (iron and steel are third). Chemicals are the largest users of electrical motors, and motors also represent about 25% of mining energy use.

Top Six US Energy System Users (Trillion BTU)

548. Japan Gas Association



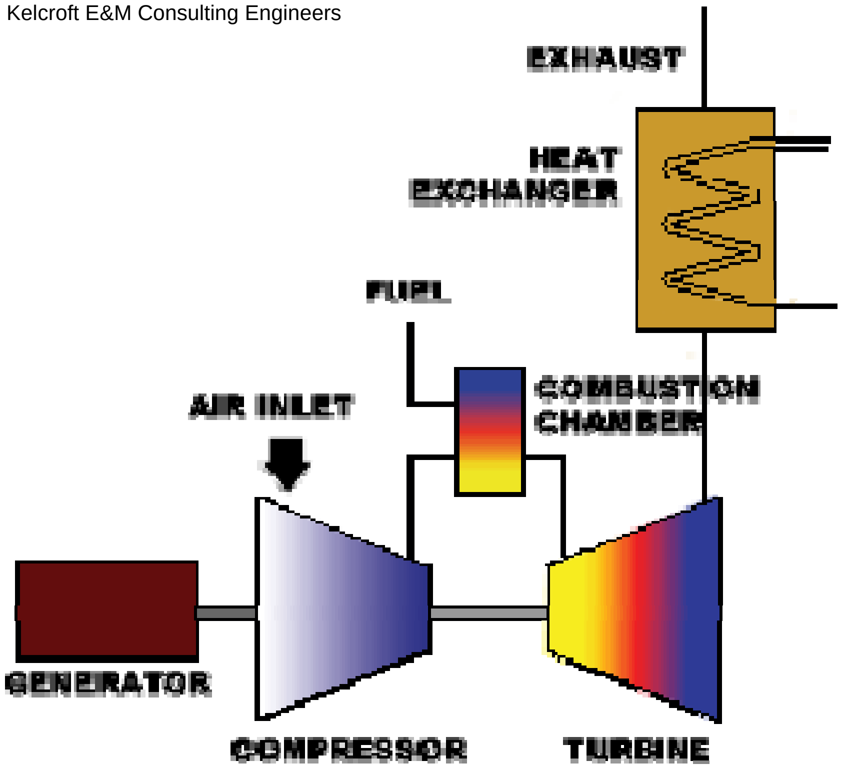
CHP Energy Recycling

Expanding use of combined heat and power (CHP) is contributing to large energy economy gains for power generation and industrial applications.

- CHP is becoming commonly used to generate electricity and heat from a single fuel source, and to capture waste heat for a variety of other uses:
  - In some cases the “waste” output heat is recycled to reduce energy required to sustain the electricity-generating process.
  - In other instances the excess heat is captured and used to provide hot water and steam, to drive air conditioning systems, or is exported for other production processes.

Cogeneration power and heat systems

549. Kelcroft E&M Consulting Engineers



Cogeneration Using Combustion

Cogeneration plants can yield efficiencies of 85% or more and can be powered by a variety of different fuels.

- By recycling large amounts of heat energy that conventional fossil fuel plants produce, CO_2 and other combustion products are minimized.
  - Cleaner operation enables these systems to meet stringent environmental standards.
  - Cleaner operations also enable the plants to be located closer to population centers where power is needed, resulting in shorter transmission distances with reduced line resistance losses.

A recent combined heat and power fuel cell technology is emerging to generate electricity and produce hot air and water for family residences, office buildings and factories.

- The new system typically uses phosphoric acid fuel cells (PAFCs) which comprise the largest segment of existing CHP products worldwide:
  - The largest manufacturer of PAFC fuel cells is UTC Power, a division of United Technology Corporation.
  - Combined PAFC systems can potentially provide efficiencies of nearly 80% (45% - 50% electricity, the remainder as thermal).
  - Molten-carbonate fuel cells are also used for CHP applications, and solid-oxide prototypes exist.

550. Wisconsin Distributed Resources Collaborative

Fuel cells generate efficient heat and power continually without use of generators. CHP applications emit significantly less CO_2 than reciprocating engines per unit output, and operate at lower noise levels that enable plants to be located nearer to users to reduce electricity transmission losses. Presently high implementation costs are a disadvantage.

Combined Heat and Power Fuel Cell Use

Combined Heat and Power

Phosphoric acid and other fuel cells are similar to proton electrolyte membrane types except for the electrolyte transfer chemistry.

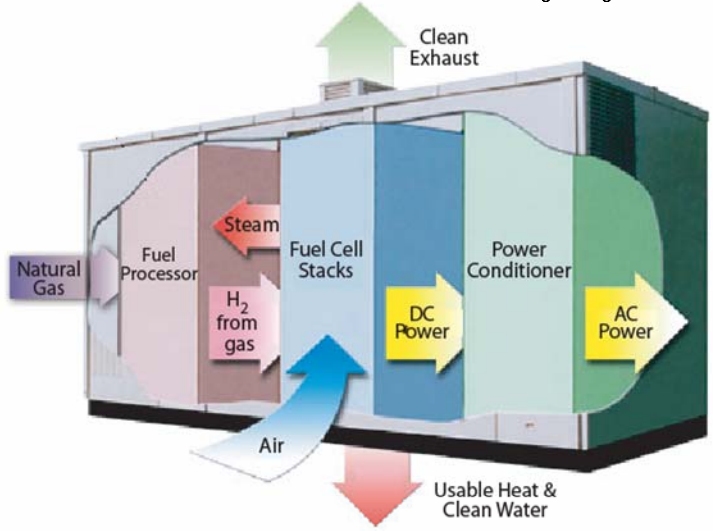
- Although PAFCs are typically used for stationary power generation, they have also found applications in large vehicles such as city buses:

- These cells are less susceptible to damage due to some impurities from reformed fossil fuels than PEMs (such as carbon monoxide that binds with platinum catalysts at anodes to reduce efficiency).

- PAFCs are, however, sensitive to "poisoning" from sulfur, which must be removed from gasoline fuels.

- Other disadvantages are that PAFCs are less powerful than other types of fuel cells of the same weight and volume, generally causing them to be larger, heavier and more expensive due to platinum anode catalyst costs.

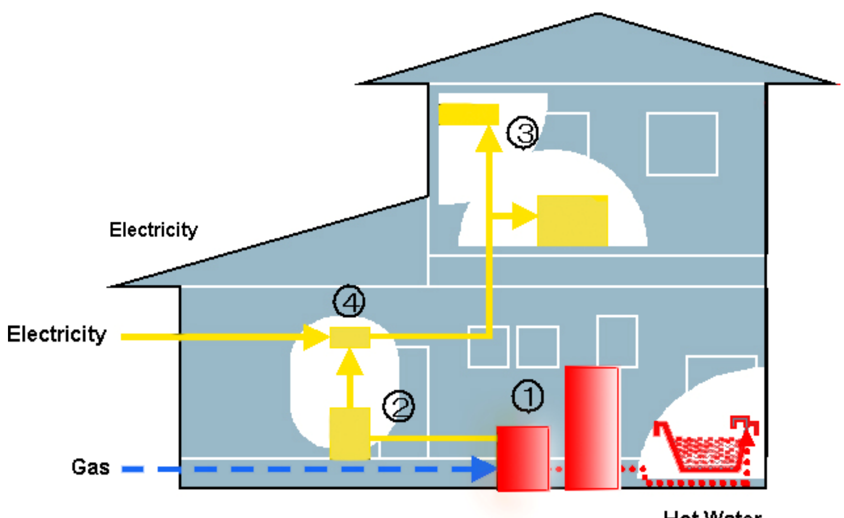
551. Whole Building Design Guide



Fuel cell power plants are typically comprised of three primary system elements:
1. ***A fuel processor** (or reformer) extracts hydrogen from natural gas or other fuel.*
2. ***A power section** containing fuel cell stacks produces electricity and releases water and heat byproducts.*
3. ***A power conditioner** converts DC to AC current.*

Typical Fuel Cell Power Plant

552. Panasonic



1. *Fuel cell cogeneration system*
2. *Commercial power splitter (for connection to a system-linked inverter.*
3. *Electrical appliances (such as air conditioners)*
4. *Electrical distribution panel*

Matsushita Home CHP Fuel Cell System

A recent combined heating and power fuel cell application is for family home, office and factory combined heating and power use which might obtain hydrogen from PV or other renewable sources.

- Matsushita Electric (Panasonic) in Osaka, Japan has developed a compact CHP system that can generate enough electricity and heat to supply an average household, with backup power provided from a public utility grid:

- The system's membrane-electrode assembly (MEA) structures offer an industry-level power-generating efficiency of about 35%, along with substantial thermal benefits.

- Operating noise levels are comparable to a typical air conditioner, acceptable for use in densely populated areas and at night.

Small scale PV applications and benefits

553. NASA
555. Europ. Solar Ener. School

554. IEA PV
556. Energy Supermarket

Photovoltaics

Millions of PV systems have been installed world-wide, ranging in size from a fraction of a watt to multi-megawatts:

- Mass production has driven cost down, and for many applications they offer the most economical and practical power option:

- PV systems are ideally suited for many remote locations ranging from recreational cottages to orbital and planetary space environments.

- Recreational vehicles, boats and scientific expeditions use PVs for direct power and to recharge batteries.

- PVs are used in agriculture to pump water for livestock and to power electric fences.

- PVs can be adapted for very small and large equipment, including calculators and watches, telecommunications, highway construction signs and navigational warning lights.

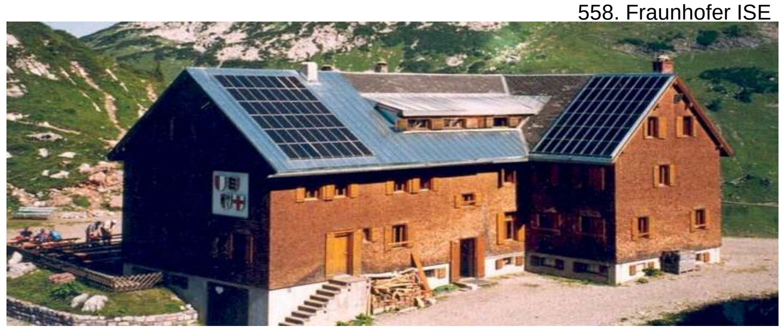
Large populations throughout the world depend upon off-grid autonomous and hybrid "island" PV systems to power their homes, farms and other businesses:

- Residents of southern Europe make extensive use of autonomous PV-battery systems due to a relatively warm climate and frequent access to sunshine.

- Residents of central Europe often use hybrid systems which pair PV with wind or other generators to accommodate the "solar gap" in winter. (In Germany, the amount of solar energy is six times lower in December than in June.)

- Off-grid stand-alone and hybrid systems are also used world-wide to provide electricity for public and private areas such as parks and campgrounds, emergency facilities, and communications.

557. Fraunhofer ISE
558. Fraunhofer ISE



Roof-Mounted PV Installation

Two-Array Ground-Mounted Installation

Off-Grid PV Applications

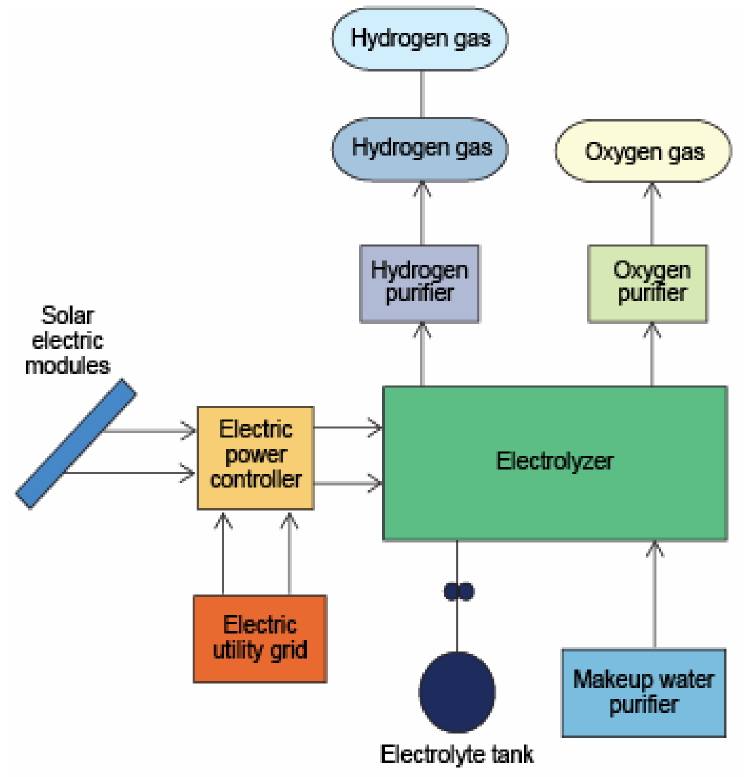
Combined renewable approaches

PV systems have been used to electrolyze water to produce hydrogen for hybrid solar/fuel cell applications along with electrical power to compress or liquefy the hydrogen gas.

- Although electricity delivered directly from one or more renewable sources to an end use would be much more efficient than using the power to electrolyze water for hydrogen fuel cell conversion back to electricity, this approach can sometimes be very beneficial:

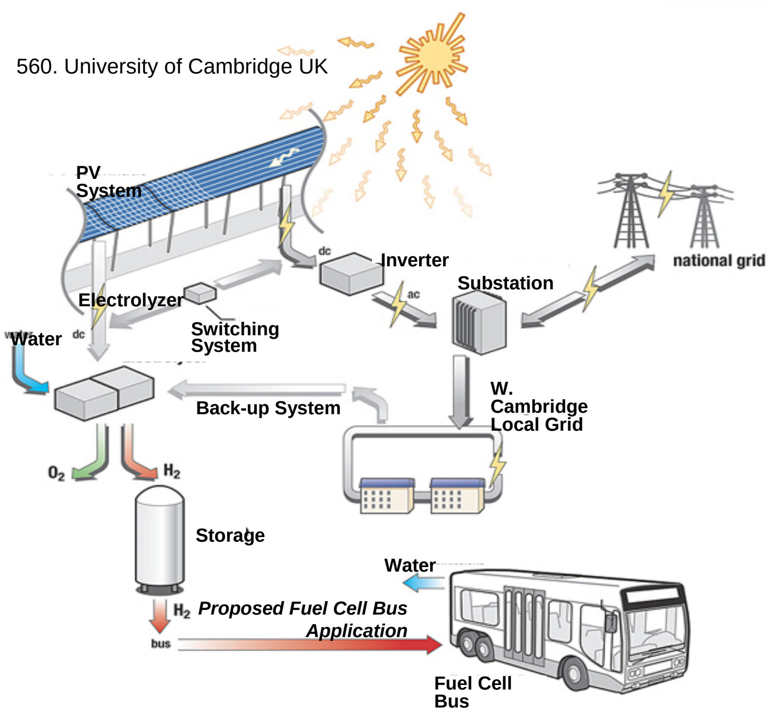
- Unlike battery storage of electricity when power is not available or needed, fuel cells do not run down or require recharging, offer much higher energy densities plus CHP cogeneration opportunities, and can respond to changing loads by adding more hydrogen fuel.
- Use of multiple renewable sources for hydrogen production can provide larger and often more continuous product outputs for local consumption or commercial export than wind or solar alone.

559. Watt Pyle, et al., Home Power



Solar Hydrogen Production

560. University of Cambridge UK



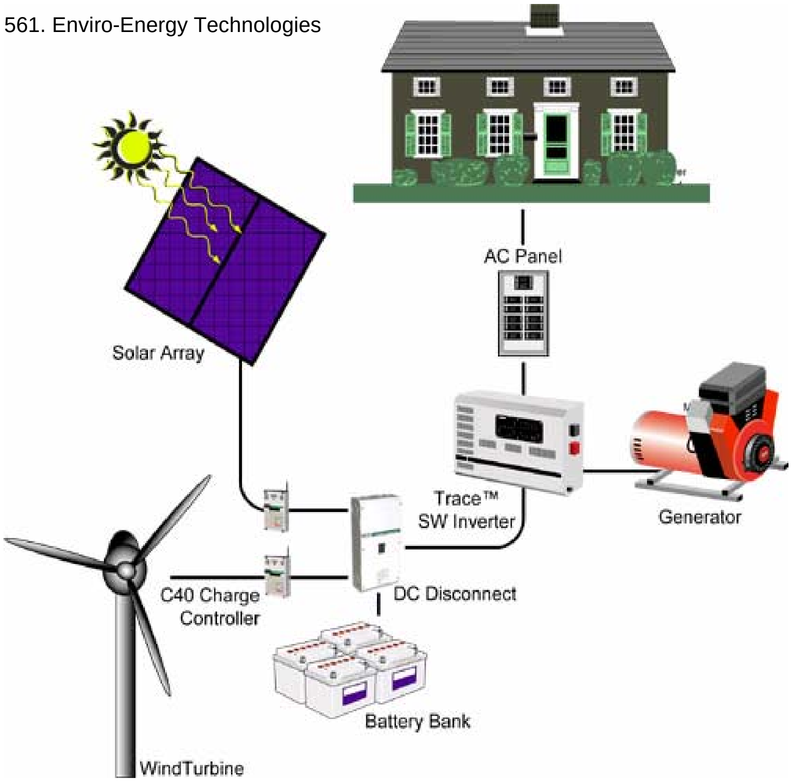
Solar Hydrogen Production Application

Solar (or wind) energy can provide an inexpensive source of power to produce hydrogen through electrolysis.

- An example is a proposal to supply hydrogen for fuel cell buses in Cambridge, England:

- A PV system integrated into a colonnade roof at the site would connect with national and local power grids.
- DC electricity would power both the hydrogen electrolyzer processing and cryogenic storage equipment, with DC-AC conversion of excess power to the grids.
- Backup grid power can also be sent directly to the electrolyzer and storage system.

561. Enviro-Energy Technologies



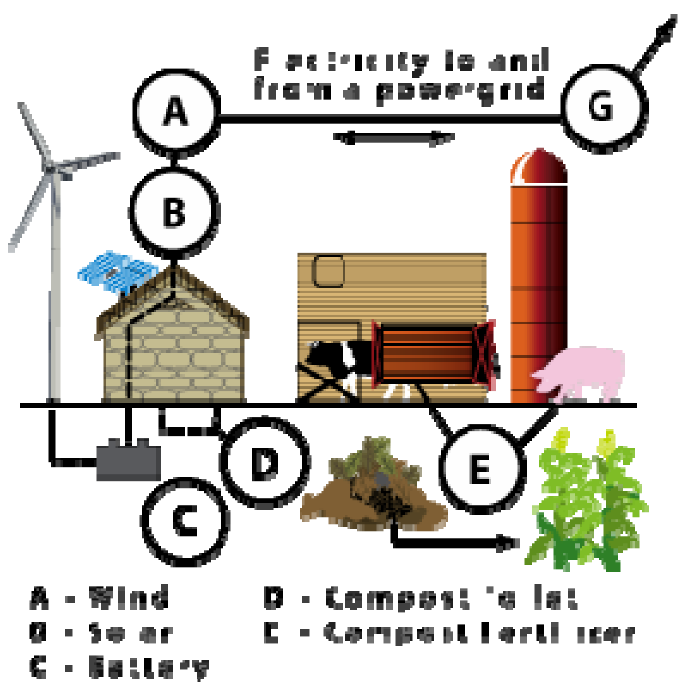
Off-Grid Solar-Wind Application

Off-grid hybrid PV/wind installations provide continuous electrical power to thousands of consumers who live and work far beyond the reach of power lines.

- Since wind and sunlight are not always present when needed, battery banks to store electricity are vital to these systems:
  - DC power that is generated and stored is usually converted to AC for general use.
  - PV systems and wind turbines are often combined in off-grid applications to realize benefits of both technologies.
  - Batteries can be viewed as “buckets of electricity” that are emptied and re-filled by inverter/charger devices, with capacities measured in Amp Hours.

Optimal selection and use of renewable resources depends upon a variety of circumstance and needs that are specific to each site and application, including geographic location, topography, and the nature and scale of end use.

- A small family farm in an area with favorable wind and Sun conditions, for example, may combine turbines and solar PV panels with battery storage for electricity, along with composting for waste reduction and fertilizer:
  - Wind and solar energy may reduce or avoid utility power use for domestic services, water pumping, milk cooling and other purposes, potentially releasing excess electricity back to a grid for credit.
  - Composting can convert waste biomass into safe plant nutrient supplements.



Private Farm Example

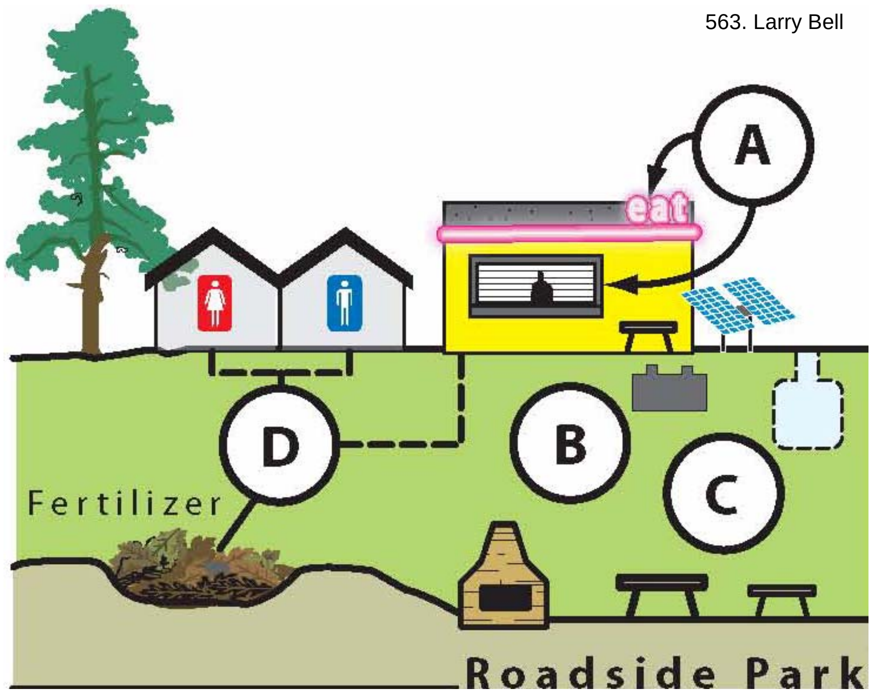
Hybrid Applications

Public parks, rest areas and other facilities in locations unserved by power and water lines can combine renewable resources for electrical and sanitary purposes.

- Such green applications make practical sense and demonstrate good examples of environmental consciousness:

- Photovoltaic systems, potentially supplemented by fuel cells or gas generators, can provide clean power for signage, lighting, food vending machines, water well pumps and other uses.
- Odorless compost toilets can convert human and food wastes into fertilizer that can be used for horticulture to beautify the sites as an alternative to conventional types that consume water and require septic leaching fields and sludge removal.

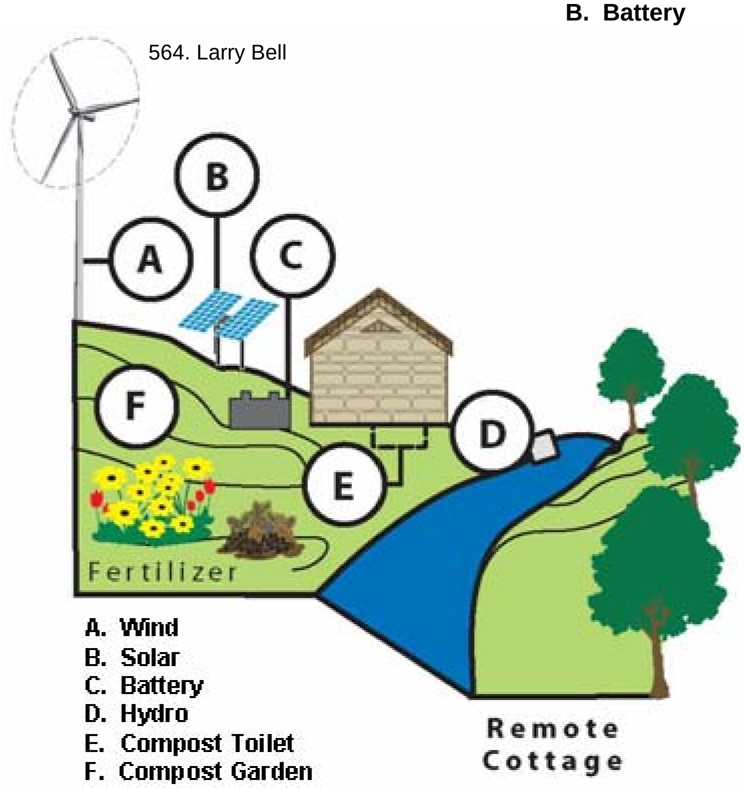
563. Larry Bell



A. Solar Signage / Service
B. Battery
C. Water Pump
D. Compost Toilet / Waste

Public Facility Example

564. Larry Bell



Vacation Residence Example

Selecting the most appropriate conservation options involves determining which can be best adapted and scaled to local conditions and needs.

- A variety of considerations must guide these decisions:

- Times and periods of use may influence if and when wind and solar resources will be adequate, taking seasonal climate variations into account.
- Use of hydropower from local water resources must be correlated with potential impacts of conversion devices upon surrounding ecosystems, including streams, marshes and drainage diversions.
- Incineration-type toilets may work best where composting and septic systems are impractical due to shallow soils, high groundwater or extremely cold weather.

Energy conservation in the residential and commercial sectors

565. Derek Jensen
566. Enoch Lau
567. US Coast Guard
568. Dennis Mojido




Energy Uses and Sources

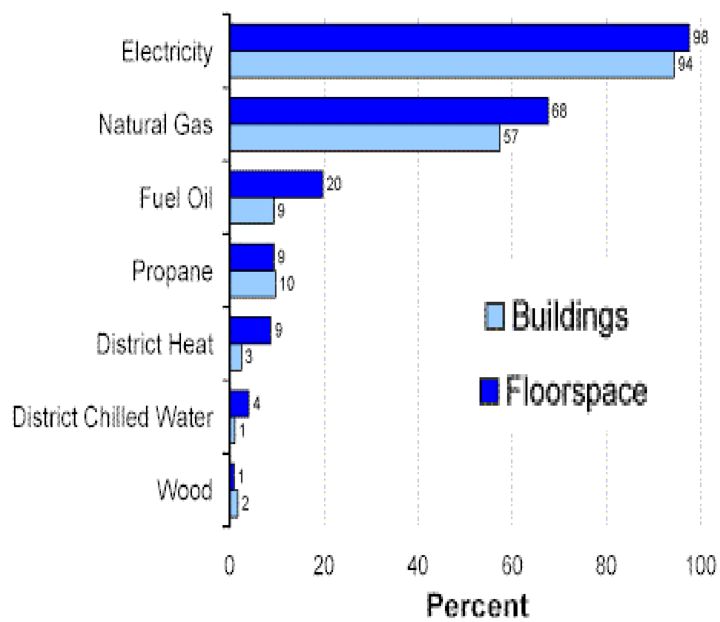
Residential and commercial energy uses for heat and power constituted about 11.2% of all US energy consumed in 2005, totaling approximately 36% of all natural gas, and 6% of all petroleum.

- These sectors represent important conservation opportunities through more efficient use of solar energy for space and water heating, along with wind power and biofuels:
  - Natural gas provided about 73% of all heating energy in this sector, which will become hard hit as supplies dwindle and prices continue to rise.
  - Most of the remaining residential and commercial heating energy (about 21%) was supplied by petroleum, competing with supplies needed for transportation and petrochemical production.

The commercial sector, including retail stores, business and government buildings, schools and other facilities, consumes a substantial amount of energy for space heating and lighting.

- Lighting, comprising about 25% of this energy, is the most wasteful component, often resulting from excessive illumination and use of incandescent sources that also add to space cooling loads:
  - Buildings with professional management and centralized control of energy conservation tend to perform much more economically than others.
  - Fluorescent lighting (about four times more efficient than incandescent fixtures) has become a commercial standard, but produces certain adverse health effects.
  - Consistent hours of operation, programmed thermostats and lighting controls, and good solar planning can produce substantial benefits.

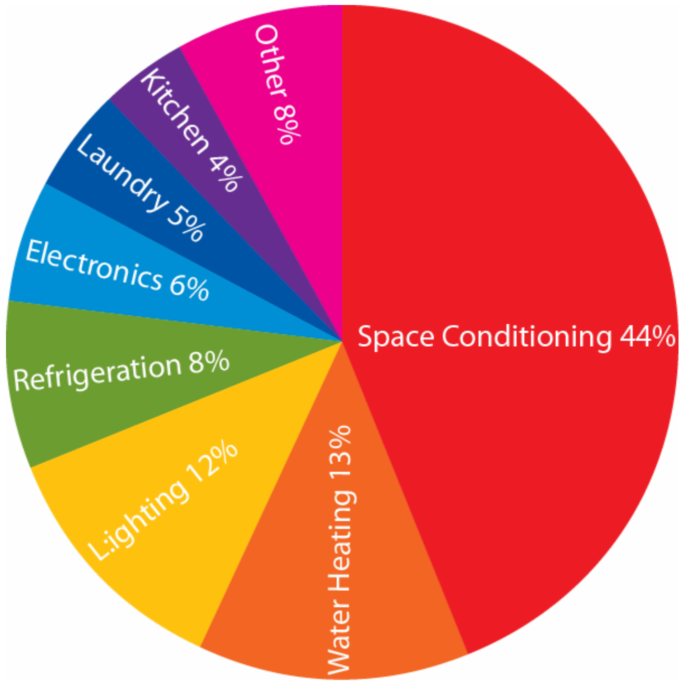
569. US DOE EIA



Energy Sources Used in Commercial Buildings

Active and passive conservation strategies

570. US DOE - EERE

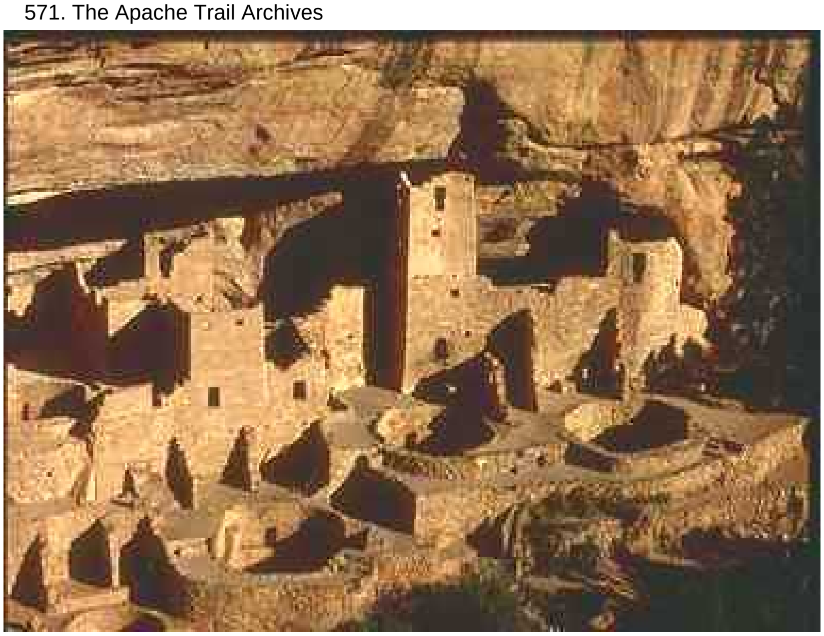


US Home Energy Consumption Averages

Although the efficiencies of furnaces and air conditioners have increased steadily since the energy crises in the 1970s, domestic energy demands continue to rise.

- A substantial portion of these growing demands is attributable to American lifestyle changes:
  - Average US home sizes have increased significantly, from about 1,500ft² (140m²) in 1970, to 2,300ft² (214m²) by 2005.
  - Single-person households have become more common.
  - The number of homes with central air conditioners increased from 23% in 1978 to 55% by 2001.
  - Lighting and water heating represent about 25% of average energy budgets, and lighting alone can consume 40% or more of the total energy in milder climates.

571. The Apache Trail Archives



Anasazi Indians of Colorado applied effective solar design principles to cliff dwellings thousands of years ago.

Applying Natural Principles

Vitally important resource conservation benefits are realized through simple methods that reduce energy required to heat and cool buildings and water, often with little or no added up-front expenses.

- As energy costs continue to rise, it is only logical to expect that the desirability and market value of energy-efficient buildings will be dramatically enhanced:
  - Prudent planning to effectively utilize and control direct solar gain can provide major results for diverse building types, large and small, in all climate regions.
  - While some approaches apply "active" technology devices, basic natural principles proven over many centuries by world-wide civilizations universally apply.

572. National Renewable Energy Lab

Solar thermal radiation is broadly used in small-scale active and passive applications to reduce water and space heating costs.

Active Solar Collectors

Active systems tend to be somewhat technologically-dependent and use-specific, often using pumps and fans to circulate heat transfer fluids and air.

573. Powered Living

Active vs. passive uses are generally characterized according to the degree to which they depend upon technology to function:

Passive Solar Design

Passive solar systems rely primarily or entirely upon direct solar gain through natural conduction, convection and radiation.

The major economic application of solar energy is to heat buildings and to provide hot water, often using rooftop solar collectors along with backup systems for supplementary power.

- Used directly as a thermal source or combined with PV cells for electricity, solar energy can significantly reduce heating bills and conserve costly resources:

- During summer, most locations between northern latitudes of 20°-58° can use passive solar panels to meet some electrical needs, and most hot water requirements.
- Advanced technology and production economies are continually reducing system costs, with residential swimming pool heating applications constituting an important market.

574. European Solar Thermal Industry Federation

Solar systems and effective passive planning can significantly reduce energy costs for home water and space heating, air-conditioning, and electricity consumption for power.

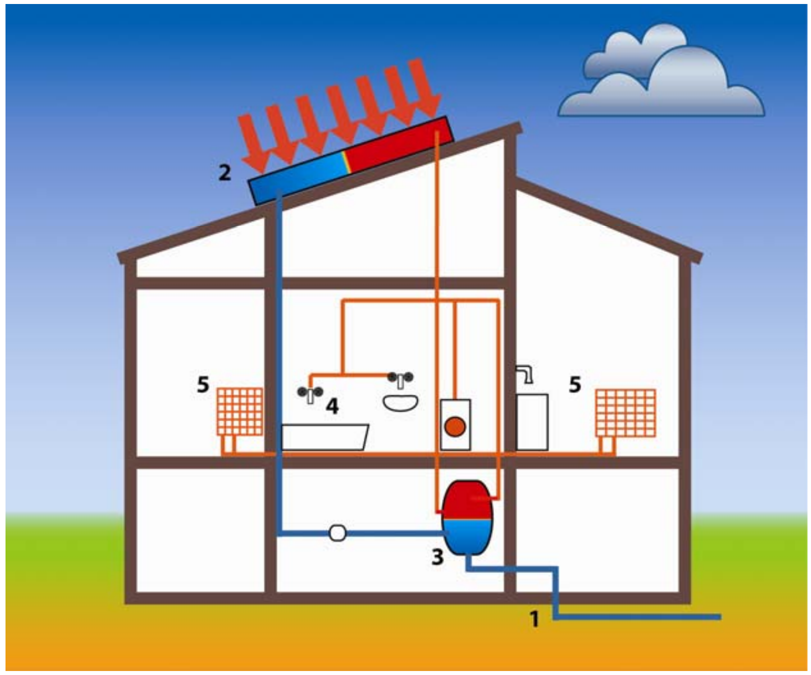
Active solar thermal space and water heating

Active solar systems are the most efficient way to heat water and air, producing low-grade thermal energy of a low temperature (less than boiling) direct from the Sun.

- Typical basic components are:

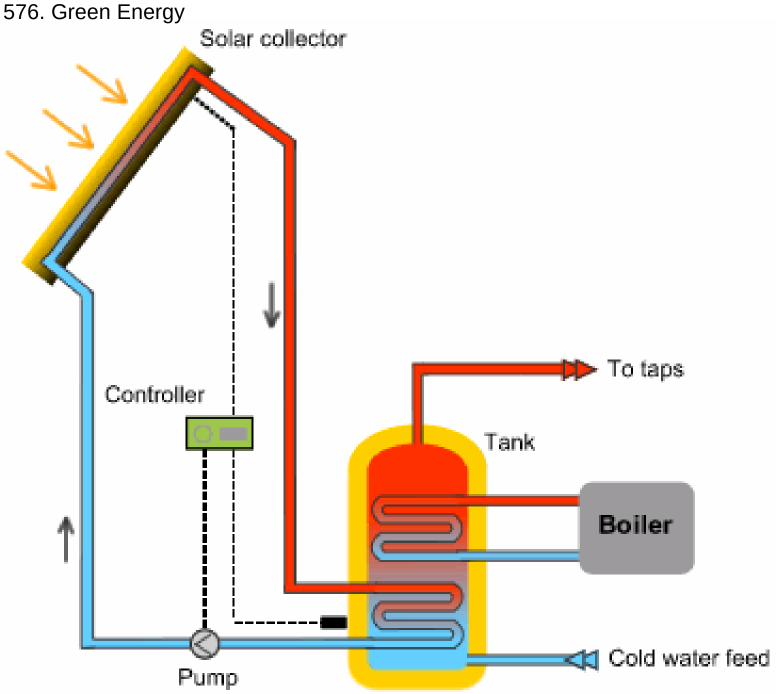
1. **Water supply**: potable water from a utility source or well.
2. **Flat plate collectors**: use radiant energy to heat water.
3. **Heat transfer and storage**: transfers hot water from collectors to a storage tank.
4. **Domestic hot water**: for kitchen, bathroom, washing machines, etc.
5. **Space heating**: hydronic heating systems (radiators).

575. Larry Bell/Olga Bannova



Active Residential System

576. Green Energy



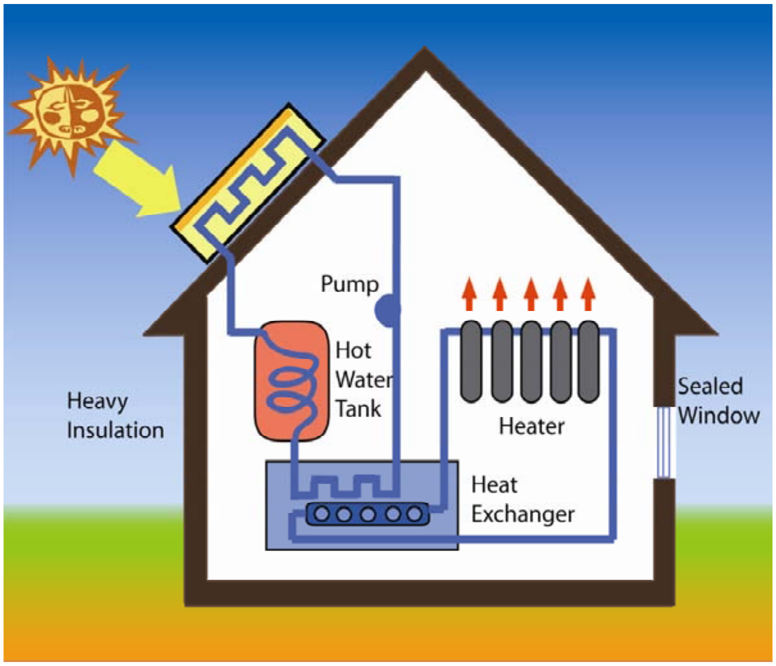
Active Hot Water Circulation

Active solar heating systems are used as a sustainable alternative to typical household water heaters.

- Utilizing a minimal amount of components, the system layout remains relatively simple:

- A controller constantly compares the temperature of the solar collectors with the temperature of the water in a tank cylinder.
- A circulating pump is switched on by the controller whenever the temperature of the collectors rises above that of the tank.
- A water/ antifreeze mixture is then circulated through the collectors and heat exchanger to heat the tank.

577. Larry Bell / Olga Bannova



Active Air-Based Heating System

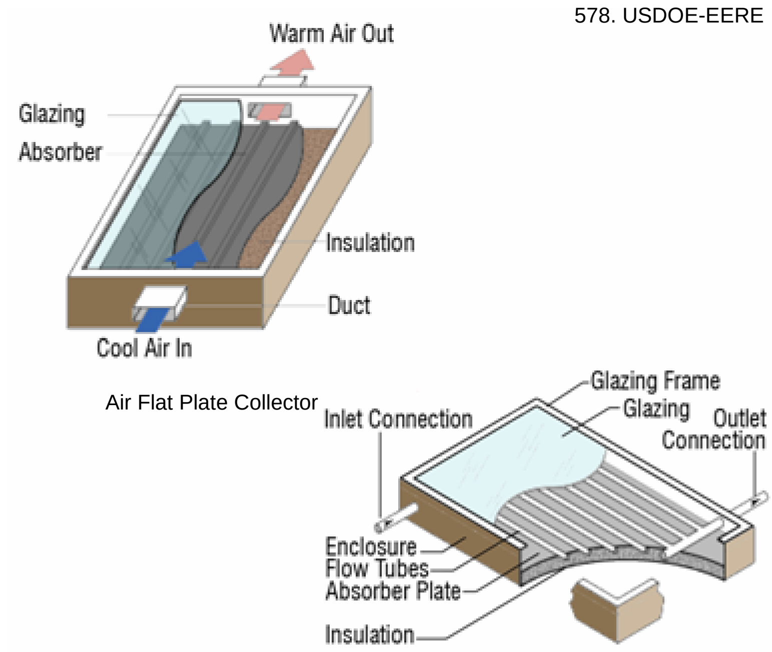
Space heating can also be accomplished using solar-heated water.

- This approach is similar to a conventional domestic hot water system, but uses a large flat plate collector array:
  - Such a system requires a large hot water storage capacity, and usually employs an air-to-water heat exchanger to supply the hot water during sunny periods.
  - Heat from the storage tank is typically transferred to a radiant floor heating system, baseboard radiation heating system or through a fan coil to a forced-air system.
  - Solar systems are often combined with supplementary gas or electrical water heaters to accommodate times of highest demands.

Flat plate collectors are the most commonly used types for solar water and space heating in homes.

- A typical collector is an insulated box with a glass cover and dark-colored absorber plate which can heat air or liquid to temperatures less than 180°F (82°C):
  - Air flat plate collectors primarily used for solar space heating are typically made of metal sheets, layers of screen or non-metallic materials that circulate heat by natural convection.
  - Liquid flat plate collectors heat fluid (often water) as it flows through tubes in or adjacent to an absorber plate, and are frequently used for potable water and swimming pools.

578. USDOE-EERE

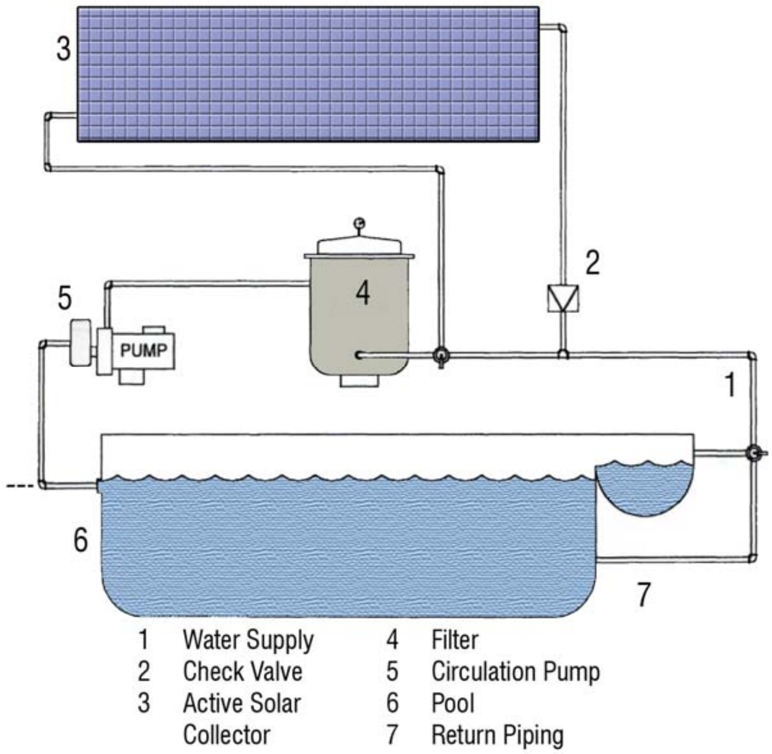


Liquid Flat Plate Collector

Active Space Heating Collectors

External water heating and heat retention devices

579. Norbert Lechner, Heating, Cooling, Lighting



Swimming Pool Heating

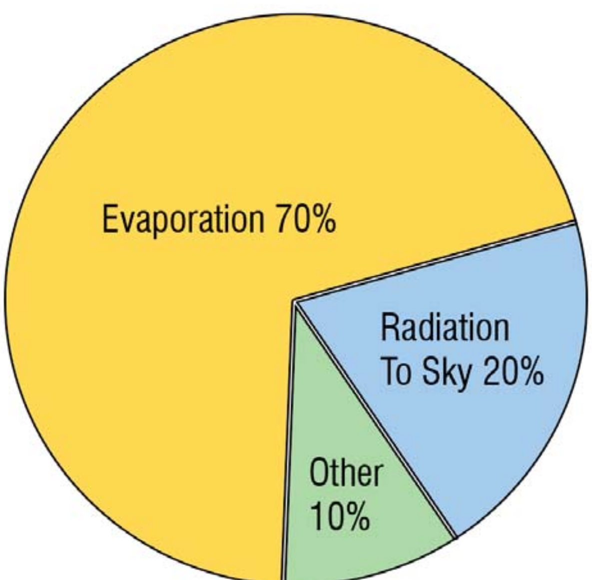
Swimming pool heating can account for 50% or more of a household's summer power consumption, often more than the energy required for home winter heating.

- Active solar heaters offer an effective way to dramatically reduce electricity use in many locations:

- Typical collectors are plastic or rubber panels or mats comprised of small tubes that connect to the pool's water supply and recirculation pump and filter system.

- The collector area needed depends upon climate, and wind conditions, shading, desired water temperature and other factors, but is usually at least half as large as the pool size and sometimes equal.

580. US DOE-EERE



Heat Losses

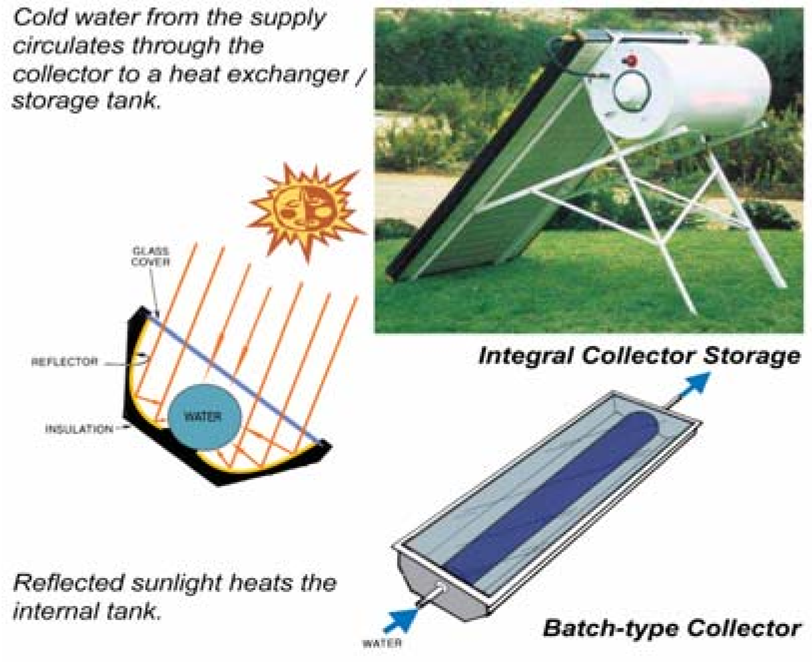
Swimming Pool Heat Retention

581. US DOE-EERE

An inexpensive translucent pool cover is another way to dramatically increase energy conservation by reducing evaporative cooling while permitting radiant heating.

Swimming Pool Covers

582. Norbert Lechner, Heating, Cooling, Lighting



Active Stand-Alone Water Heaters

Solar hot water systems are also available as stand-alone units that can be used for external building and outdoor applications.

- Some systems use conventional flat plate collectors, while others concentrate heat using reflectors:

- The integral collector storage (ICS) is a flat plate type that incorporates a hot water storage tank for outdoor use such as an external sauna.

- A batch-type solar concentrator system provides a collector water tank and reflector in the same glass-covered and insulated unit, and multiple units can be connected in series to increase throughput capacity.

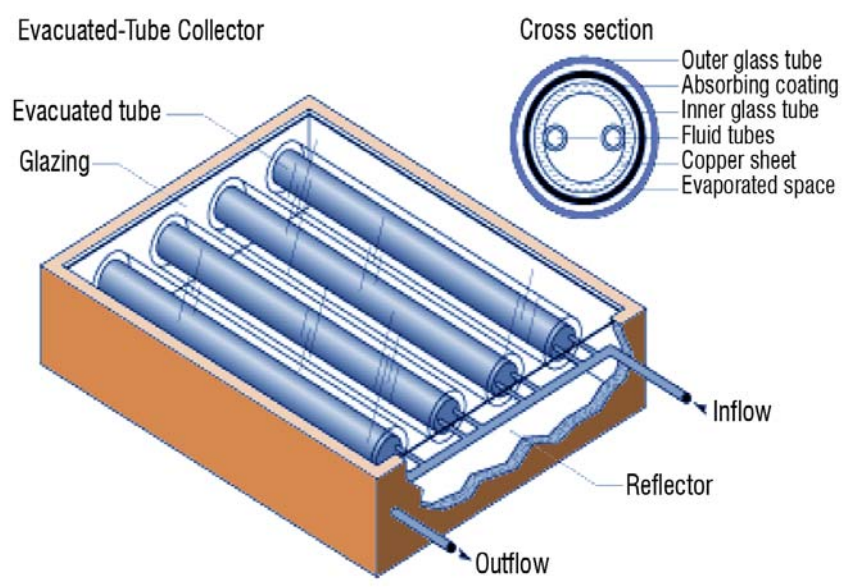
Some active solar heating systems are designed to provide large quantities of hot water for commercial and industrial uses.

- Evacuated-tube collectors are efficient at high temperatures (170°-350°F or 77°-177°C), but can be about twice as expensive as flat plate types:

- Collectors are shallow boxes full of many glass, double-walled tubes and reflectors that heat a fluid inside.

- A vacuum between outer tube walls with absorbing coatings and inner fluid tubes covered with a copper sheet provides insulation that holds in the heat.

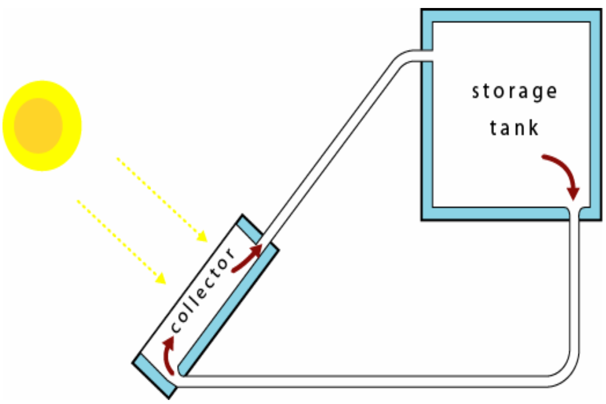
583. US DOE-EERE



Evacuated-Tube Collector for Commercial/Industrial Use

Solar furnaces and sun spaces

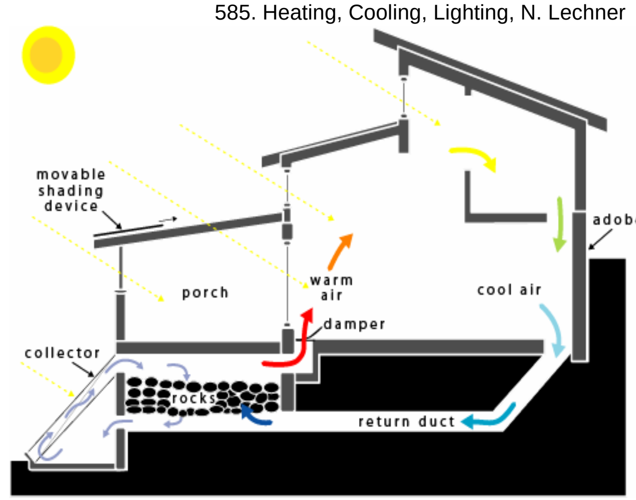
584. Heating, Cooling, Lighting, N. Lechner



Sunspaces can be augmented by "solar furnaces" that eliminate or reduce energy required for water and space heating. South-facing collectors heat water or air that is circulated through storage tanks or rockbeds.

Solar Furnace Hot Water System

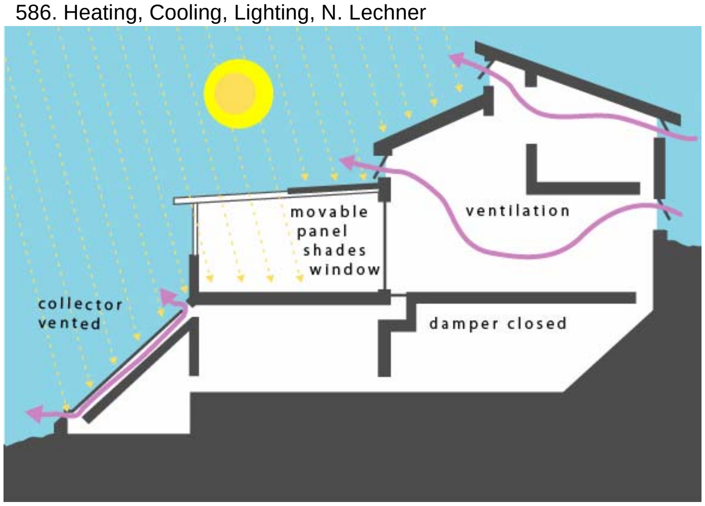
585. Heating, Cooling, Lighting, N. Lechner



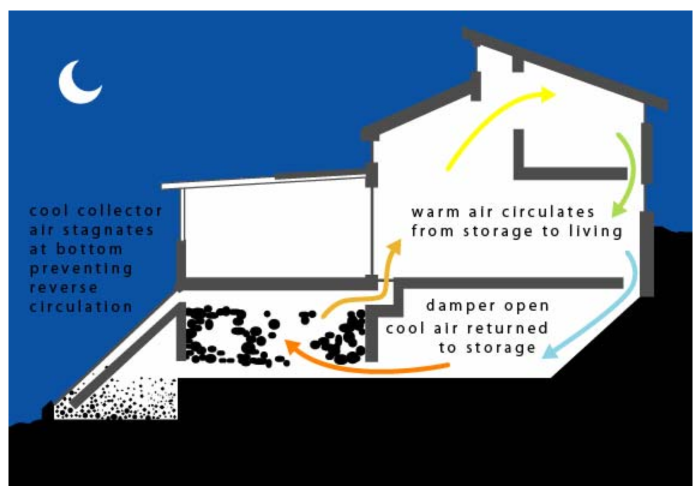
Hot air rises up from a storage bed to provide warm air at night, and cooled return air flows back to the collector in a loop. An operable vent on a north wall exhausts hot air and allows cross-ventilation.

Solar Furnace Space Heating System

586. Heating, Cooling, Lighting, N. Lechner



Summer Day



Winter Night

During the summer day, the sunspace is opened to the interior spaces.

- The rock storage vent is closed, causing the furnace to act as a thermal flue.

- Hot air is exhausted from the furnace and cool air from the north side circulates through interior spaces by natural cross-ventilation.

During the winter night, the sunspace is closed from interior spaces.

- Rocks provide the heat collector:

- The rock storage vent is opened, allowing warm air to circulate from this area throughout interior spaces by natural convection.

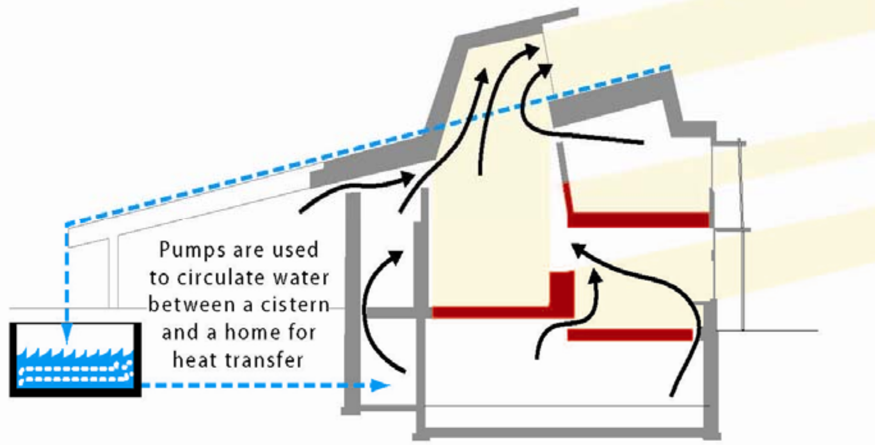
Combining natural heating and cooling features

Since heat is fundamentally an energy source, solar thermal energy can also be used to cool building spaces much like a familiar home air-conditioner uses electricity to accomplish this purpose.

- Solar thermal air-conditioning techniques can be very basic, using direct evaporative processes to cool water or air, or can be more complicated, applying mechanical refrigeration systems with special heat transfer fluids:

- An example of a simple approach is to pump water from a cistern that serves as a cooling medium for a home during hot summer months, and a source of heat from solar gain during colder seasons.

587. Norbert Lechner, Heating, Cooling, Lighting

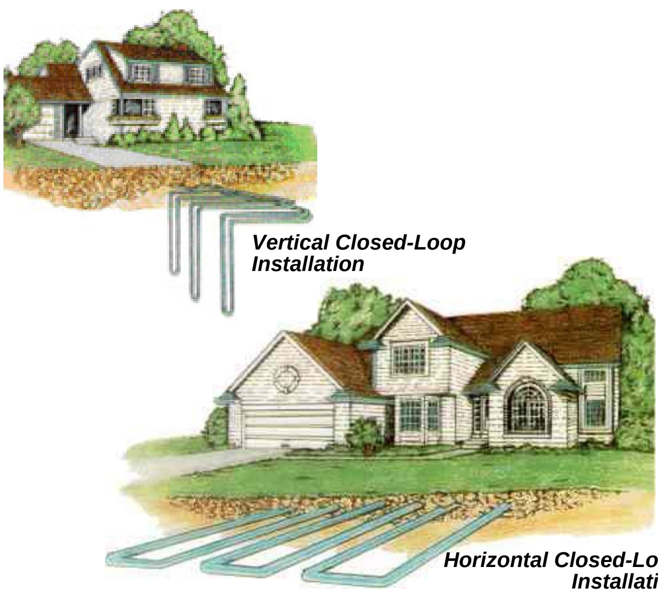


This clearstory scheme uses ambient water from a cistern along with roof evaporation for summer cooling, and direct solar gain from winter Sun for heating. Natural convection distributes the conditioned air.

Chilled water from a roof evaporator reservoir can supplement cooling effects to further reduce summer air-conditioning energy loads.

Active / Passive Hybrid Approach with Water Transport from a Cistern

588. Lewis County Rural Electric Cooperative



Geothermal heating and cooling can be more efficient than electric resistance, gas, or oil-fired systems, and can save homeowners 30% - 70% of heating and 20% - 50% of cooling costs according to EIA estimates.

Geothermal Heating and Cooling

Although relatively few places have suitable geological characteristics for major geothermal power production, abundant opportunities exist to use this resource type for small-scale building heating, cooling and hot water applications.

- Hot springs and wells can provide heat for greenhouses, fish farms and other facilities, and relatively constant year-round near-surface ground sinks can afford economical space heating and air conditioning benefits:

- Some cities such as Klamath Falls, Oregon and Boise, Idaho have used geothermal water to heat homes and other buildings for more than a century, and new housing developments in Reno, Nevada are using geothermal wells.
- Subsurface land heat approaches can be applied in many areas of the US with high energy-saving efficiencies.

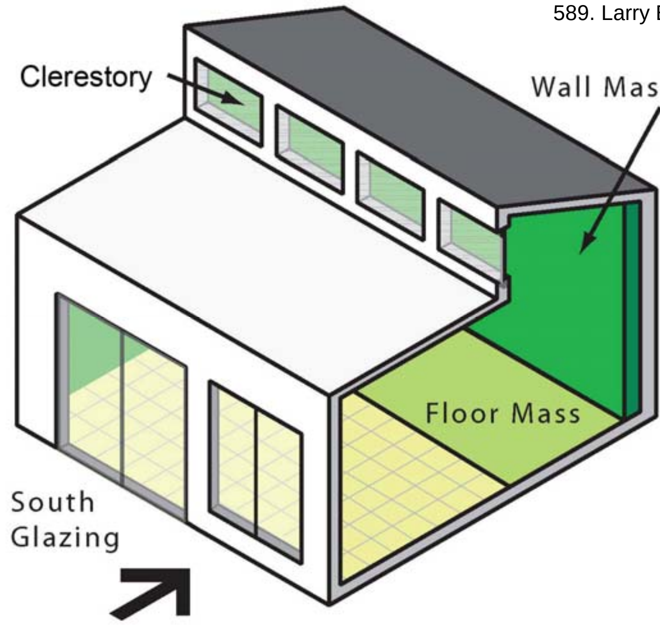
Passive planning principles

Enormous space heating and cooling energy economies can be achieved through sensible passive planning practices that require no mechanical devices and often impose no added construction costs.

- Proper design optimizes direct solar heat gain and retention under cold conditions, and reduces and exhausts heat for comfort and cost-efficiency under hot circumstances:

- Basic principles can be applied virtually anywhere, balancing energy requirements for each site location and building type with special climate conditions and user needs.
- Appropriate design and placement of windows and shading elements, provisions for natural convection and ventilation, and effective thermal insulation, are key influencing factors.

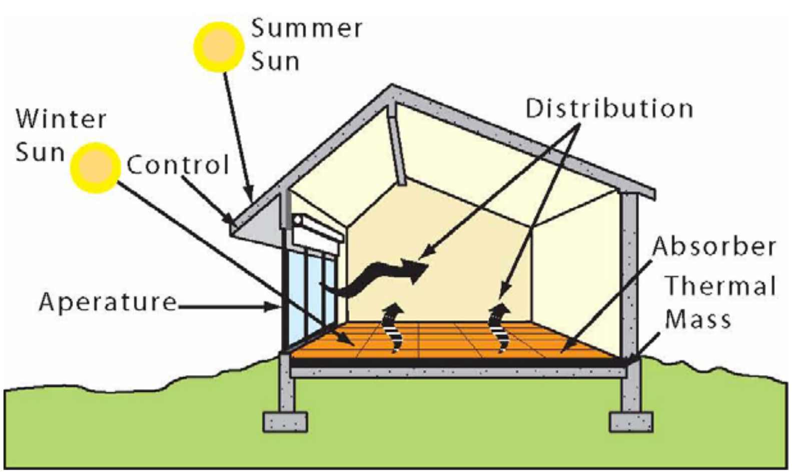
589. Larry Bell



Direct solar gain utilizes sunlight that shines directly into a building to heat interior materials which release energy at night.

Direct Solar Gain

590. Norbert Lechner, Heating, Cooling, Lighting



Distribution of solar heat throughout a building uses three different transfer modes: radiation, conduction, and convection.

- *Solar radiation is admitted by windows and is also stored in thermal mass.*
- *Thermal mass conducts heat to absorbers, which radiate it when needed.*
- *Convection circulates the warm air.*

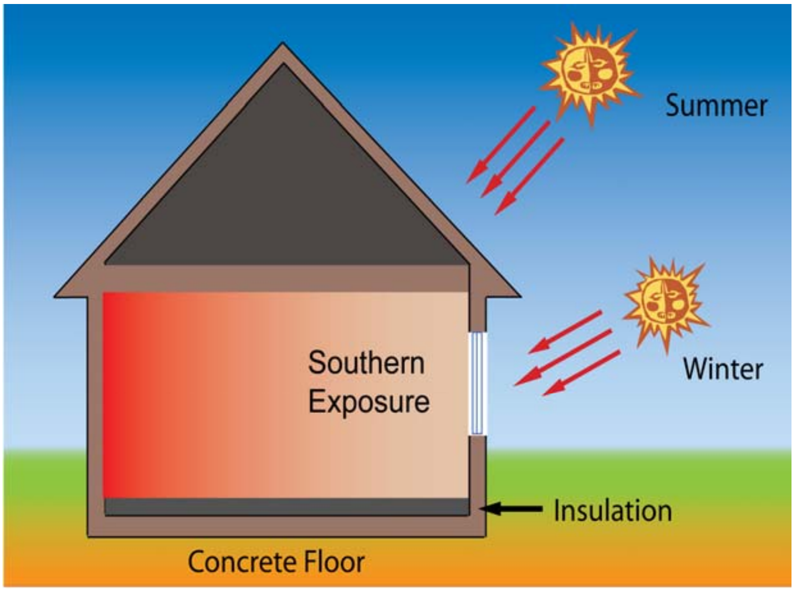
Moderating Solar Gain

Passive solar design approaches can produce substantial building space heating and cooling economies by storing direct energy from sunlight for use when it is needed, and preventing unwanted solar gain during warm periods through shading devices and controlled convection to minimize cooling requirements.

- Solar gain is moderated by a variety of means:

- Windows are placed, sized and designed to collect sunlight in winter, and restrict it in summer.
- Absorbers such as masonry walls and concrete floors are placed in the Sun's path to collect winter heat.
- Material mass placed behind the absorbers stores heat during the day, and slowly releases it when the Sun is not acting upon the surfaces.
- Roof overhangs and other shading devices prevent overheating during hot periods.

591. Larry Bell



Large window areas oriented to the south will allow low winter solar angles to heat interior floors and walls. Good insulation and well-sealed building envelopes hold heat inside.

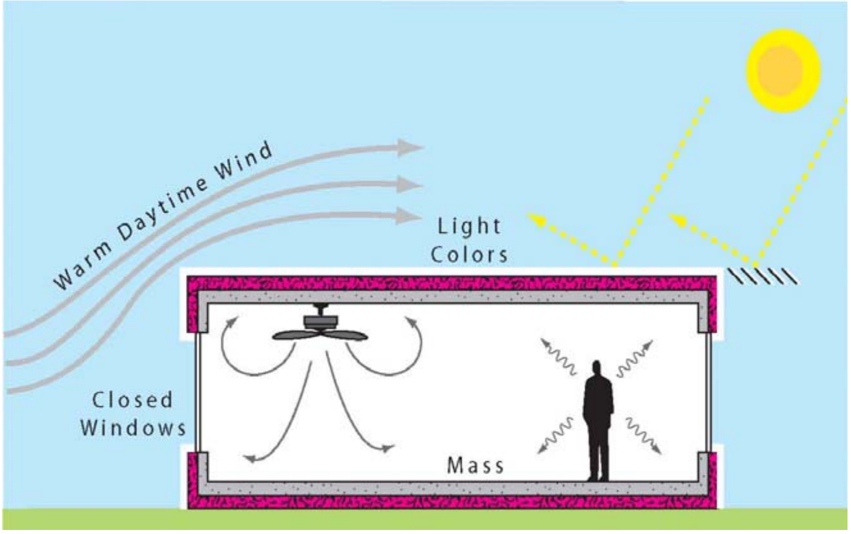
Space Heating

In cold latitude locations where winter heating creates high energy demands it is important to take advantage of direct solar gain through windows.

- The most efficient heat orientation in the Northern Hemisphere places windows due south, although any orientation within 30º of due south is generally considered acceptable:

- To admit sunlight, a ratio of about 8% window to floor area is usually recommended for south walls to enable heat to be absorbed by floors and walls.
- Latent heat produced by lighting, appliances and people can also provide some benefits.
- Well-insulated, air-tight building envelopes can substantially reduce heat loss through exchanges with colder outside air to conserve energy.

592. Norbert Lechner, Heating, Cooling, Lighting



Good insulation, shading, closed windows, and light reflective colors can minimize heat gain. Fans can enhance comfort and reduce condensation, but do not save energy except through reduced air-conditioning use by residents.

Space Cooling

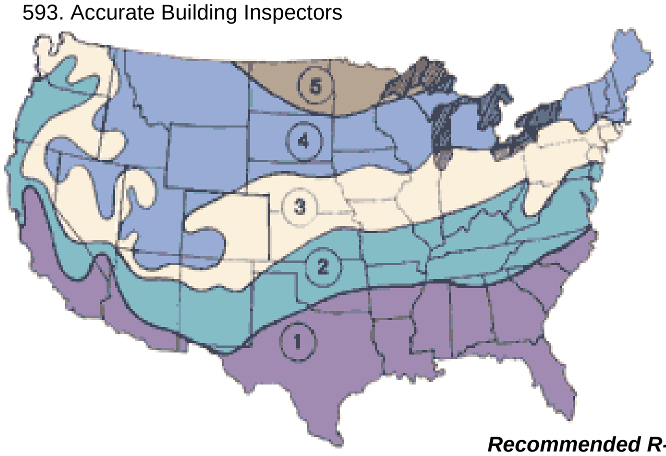
In hot regions where space cooling is most essential, the building envelope and floor mass provide a useful cooling strategy only for dry climates because mass does not “insulate” in the same sense that thermal insulation materials do.

- Here it is most important to provide high heat insulating materials in roof and wall structures to delay heat entry until cooler evening hours, and delay the impacts of cold nights until hot afternoons:

- A time lag between heat gain and heat release affords combined warming and cooling benefits.
- Light colors, shading and closed windows also minimize heat gain.

Thermal insulating barriers

593. Accurate Building Inspectors



Recommended R-Values

Heating Zone	Crawlspace or Basement Ceiling	Attic Floors	Exterior Walls
1	R-11	R-26	R-Value of full wall insulation, which is 3 1/2" thick, will depend on material used. Range is R-11 to R-13
2	R-13	R-26	
3	R-19	R-30	
4	R-22	R-33	
5	R-22	R-38	

R-Values rate the minimum recommended total thermal resistance for insulating materials (higher numbers have better resistance).

Heat Zones

Good insulation with radiant barriers and vapor barriers is very important for building energy conservation:

- Different heating zones present special requirements for each of these components:

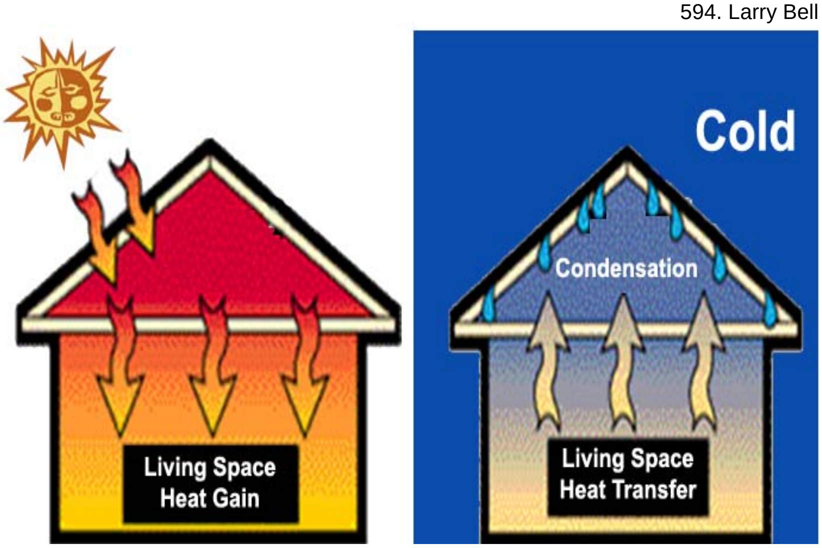
- Minimum insulation thermal resistance R-Values are influenced primarily by temperature characteristics of various heating zones.
- Radiant barriers (often reflecting foil) placed under attic insulation in hot climates can reduce heat transfer through a roof by 40%.
- Vapor barriers placed on the inside of insulation in cold climates and on the exterior side in hot regions can help seal buildings from moisture and air, and prevent condensation.

R-Values for various insulating materials are based upon their resistance to thermal transfer by conduction through solids, thermal radiation across attic and other spaces, and convection by the motion of air across surfaces.

- Common insulation types are flexible sheets, non-structural rigid boards and spray - or blow-in products:

- Flexible sheets include glass fiber and rock wool batts ranging from about 3.2-3.6 R per inch (per 2.54 cm) thickness.
- Rigid boards include expanded bead and extruded foam polystyrene, isocyanate and glass fiber board, and fiberglass wall sheathing ranging from about 3.5-5 R per inch (per 2.54 cm).
- Spray and loose-fill insulation includes polyurethane foam (5.5-6 R per inch [2.54 cm]), and cellulose and mineral fiber (about 3.1-3.7 R per inch [2.54 cm]).

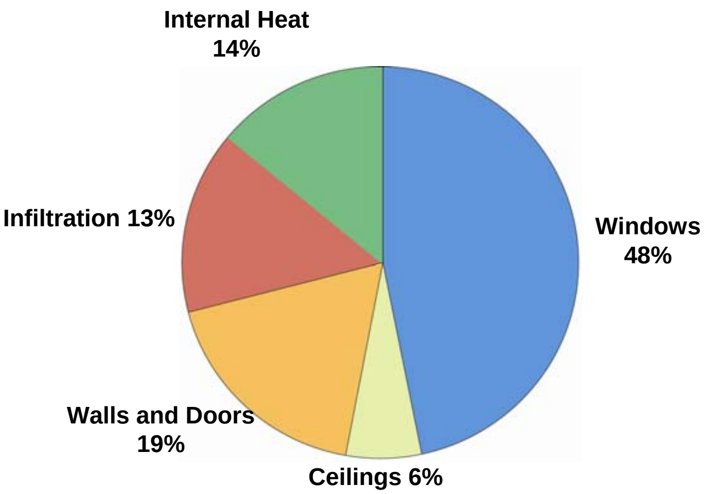
594. Larry Bell



Hot weather conditions demand thermal barriers to prevent attic heat transfer to lower levels, and cold weather barriers must prevent condensation from rising heat.

Thermal Insulation

595. US Department of Housing and Urban Development



Window design, orientation to summer and winter solar conditions, and proper shading are important energy conservation considerations.

Sources of Summer Heat Gain in Homes

A fundamental measure to avoid indoor overheating and to control energy costs is to prevent solar radiation from entering a building during summer, and allowing it to enter during the winter.

- Solar radiation control devices associated with window treatments and shading can go a long way to bring about large economies:

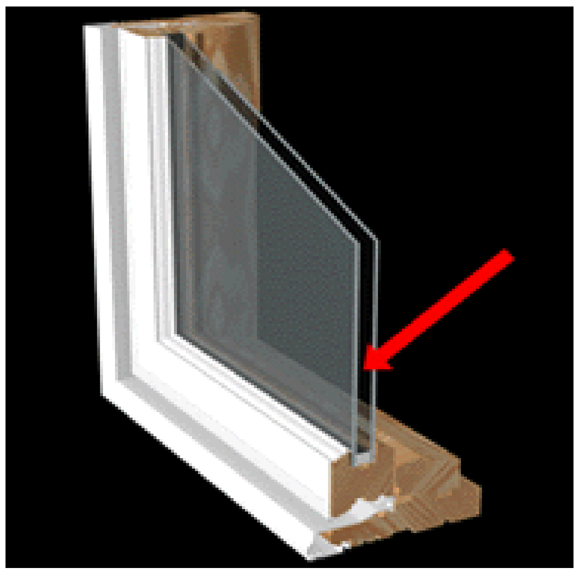
- Generally speaking, summer heat gains through windows account for nearly half of the total thermal load.
- Internal and external shading devices can block additional solar radiation using fixed and movable approaches.
- Special window selection and treatments can dramatically reduce solar radiation penetration into interior spaces, while also allowing good day lighting conditions.

Heat transfer through windows can be minimized through the use of coverings such as outside shutters or transparent sheets, or using multiple-pane installations with insulating air spaces between glass panels.

- In addition to energy efficiency, insulated windows offer excellent means to avoid outside noise and dust intrusion, and are comfortably warm to touch in cold weather:

- Since conventional single-pane windows have thermal resistance values that are typically much lower than surrounding insulated walls, adding a second pane can make a large difference.
- Triple glazing is generally used only in severe climates where higher costs are justified.
- Some insulated window units contain gases such as argon or krypton within spaces to further reduce heat transfer through conduction between panes.

596. The Worlds of David Darling



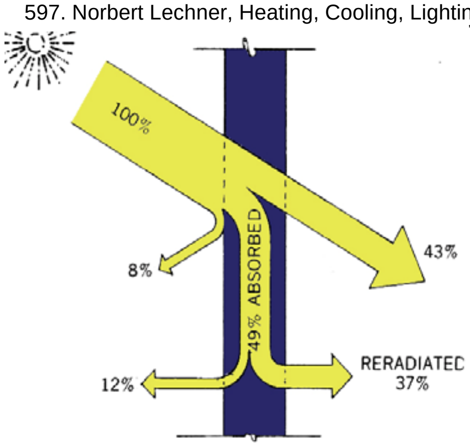
Multiple-pane window units have insulating air spaces between glass panels which are sometimes filled with special gases to further reduce heat transfer through conductance between panes and convection within the spaces.

Insulating Windows

Thermal Barriers

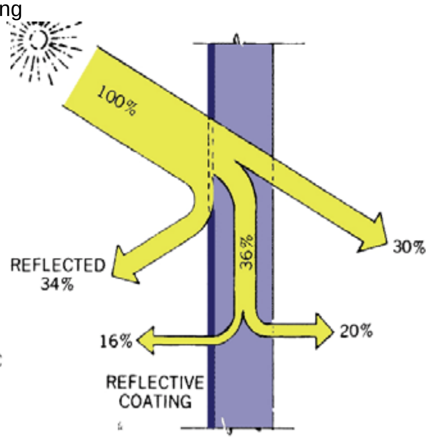
Conserving lighting energy

597. Norbert Lechner, Heating, Cooling, Lighting



Tinted Glass

Tinted glazing reduces light transmission, but doesn't significantly decrease heat gain because much solar radiation absorbed is re-radiated indoors. Tinted curtain wall glass became popular in the 1960s for efficiency and appearance.



Reflective Glass

A glazing surface covered with a thin metallic coating can significantly increase the amount of solar radiation that is reflected while allowing outside viewing. This can be combined with tinted glazing to improve efficiency.

Window Glazing Treatments

Much solar radiation can be blocked to reduce heat gain by using tinted glazing and reflective films.

- Ordinary window glass is transparent for shortwave radiation emitted by the Sun, but is opaque to longwave radiation emitted by objects in a room so that once it passes through and enters the space, it becomes trapped:

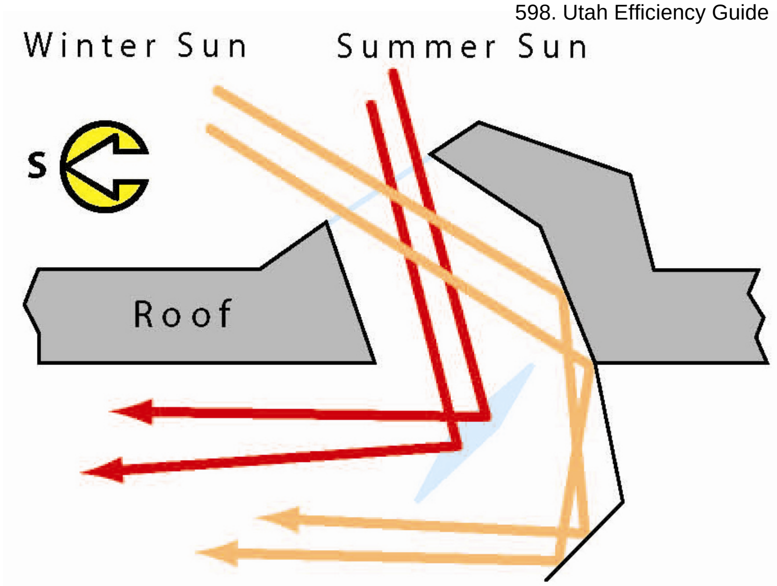
- Tinted glazing (green, grey, brown, blue, and browns tones) can reject 66% - 75% of solar heat, and reflective film applied directly to the inside of windows can be as effective for blocking heat as solar shade screens.
- Tinted glass and reflective films work best on east and west windows, but such treatments are not recommended for south-facing windows because they prevent passive solar gain in winter.

A variety of design strategies can be incorporated into buildings to substantially improve natural and artificial lighting efficacy and efficiency.

- Many of these approaches apply simple and inexpensive methods:

- Industrial facilities often incorporate vertical or angled "saw tooth" windows to supply natural lighting and enhance ventilation, and can be provided with operable louvers to avoid unwanted glare and harsh shadows.
- Skylights can be designed to redirect light onto light-colored ceilings and walls to diffuse illumination into spaces.
- Automated controls can turn lights and other equipment off when people aren't present and also adjust thermostats accordingly.

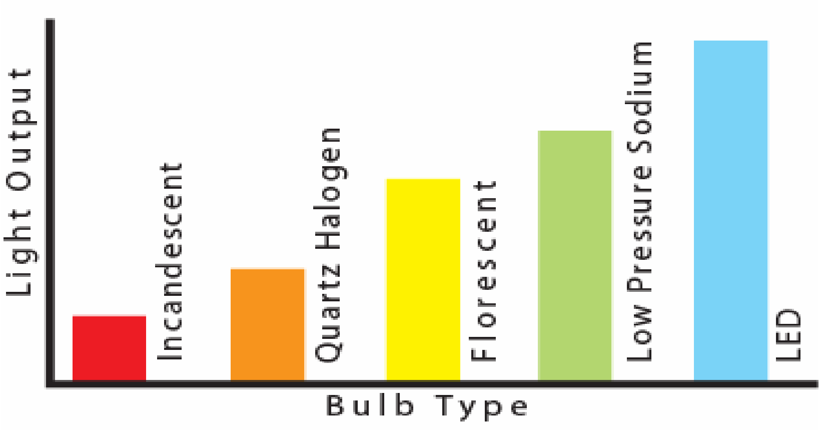
598. Utah Efficiency Guide



Rooftop windows can be designed to enhance natural interior illumination and avoid glare by redirecting sunlight. High-angle summer light can be dispersed using specular reflectors, and low-angle winter light can be redirected by solid reflectors for seasonal adaptation.

Rooftop Illumination Device

599. SpS Energy Solutions



Energy Efficiencies of Various Lighting Technologies

Lighting systems often account for large portions of total building power budgets. Fluorescent fixtures are rapidly replacing incandescent lighting for interior applications due to much higher efficiencies, longer life, and pleasing warm color illumination.

Quartz halogen, low-pressure sodium, and LEDs are primarily used for outdoor applications.

Lighting systems operate on the same resistance principles that electrical heating units do and consequently release a lot of thermal energy along with illumination.

- Most often this heating poses a considerable conservation detriment because it uses costly power to inefficiently benefit space cooling objectives and imposes large AC power and heat loads during hot periods:

- Incandescent lights are particularly inefficient, with approximately 95% of power emitted as heat rather than as visible light.
- Fluorescent lights use only about one-fourth as much power as incandescent (about 20% efficiency), and the tubes can last 10 times or more longer with approximately the same cost.

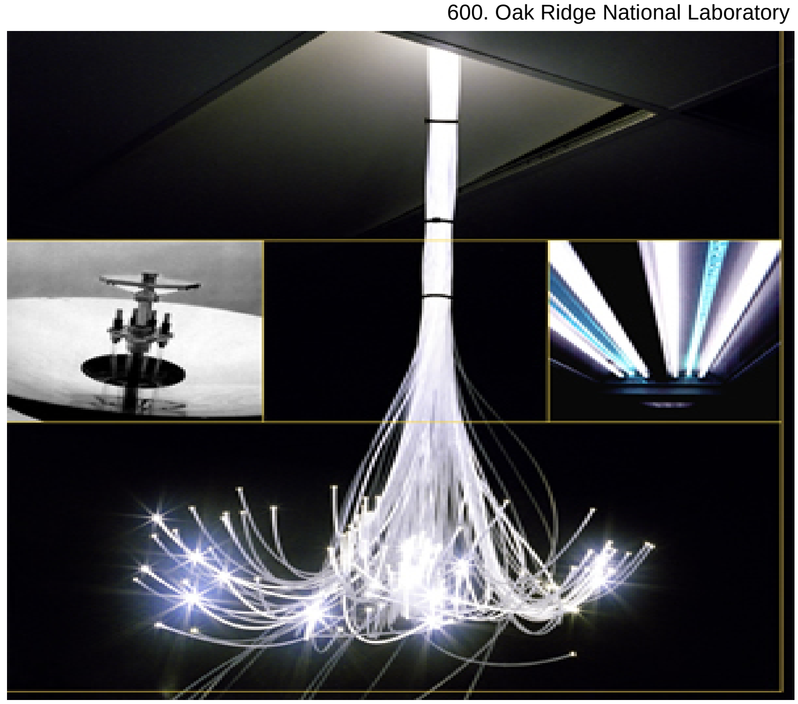
Lighting Systems

Hybrid solar lighting (HSL) which combines direct fiberoptic distribution of sunlight within a fixture also containing fluorescent tubes can reduce power costs as well as heat loads.

- A recent system developed at the Oak Ridge National Laboratory primarily consists of a rooftop-mounted collector and secondary mirror that tracks the Sun throughout the day, focusing optical light frequencies onto bundles of optical fibers equipped with diffusion rods:

- Originally developed for commercial buildings, HSL may also have residential applications if high current costs can be adequately reduced.
- Use is limited to spaces immediately below a roof and to sunny periods, with fluorescent lighting offering a backup.

600. Oak Ridge National Laboratory



Hybrid solar lighting distributes natural sunlight through fiberoptic bundles to reduce electrical power consumption and heat loads. The full-spectrum light energy exactly matches sunlight red shifts that occur during the day.

Hybrid Solar Lighting

Illumination Devices

Optimizing transportation economies

Public, commercial, and personal transport accounted for 28% of 2005 US primary energy consumption.

- Most (98%) of this energy was provided by petroleum, constituting more than half (68%) of the source use:
  - Increases in vehicle efficiencies and their utilization can substantially reduce petroleum consumption, and biofuels can extend supplies even more.
  - Fuel cell-powered vehicles can only reduce petroleum and natural gas consumption if non-fossil fuel sources are used to produce the hydrogen, and without major depletions of electricity for other purposes.

601. Carplus UK
603. Phoenix International

602. Ntnl Railway Historical Society
604. Mobile Review

The Transportation Sector

605. Fair-PR
607. APTA

606. Mitsui – Bussan
608. Direct News

Public Systems

Use of public transportation can be an effective way to reduce energy consumption and vehicle maintenance expenses:

- Buses, commuter trains and commercial airlines can offer good efficiencies provided that they operate at high average capacities:
  - While diesel-powered metropolitan buses produce substantial pollution levels, they replace large numbers of low-occupancy cars which are cumulatively dirtier and consume more fuel, particularly under city driving conditions.
  - Electric surface, elevated and subway trains offer cleaner, more efficient and often more expeditious travel options than other urban systems.
  - Passenger airplanes can realize average capacities of 50 passenger miles per gallon or more with 80% occupancy levels, but unfortunately spew NOx pollution directly into the stratosphere where ozone layer destruction is most problematic.

In the transportation sector, the oil supply crisis of the1970s prompted creation of a US Federal Corporate Average Fuel Economy (CAFE) program in 1975 that imposed fuel economy standards upon automobile manufactures.

- Automotive economy improvements and a "gas guzzler" tax assessed upon manufacturers since 1978 had positive effects that were offset after 1990 by the growing popularity of utility vehicles, pickup trucks and minivans that fell under more lenient truck standards:

- Many state and local governments work to reduce vehicle energy consumption through subsidized public transportation, carpooling, "kiss-'n-ride" programs, and high-occupancy vehicle lanes.

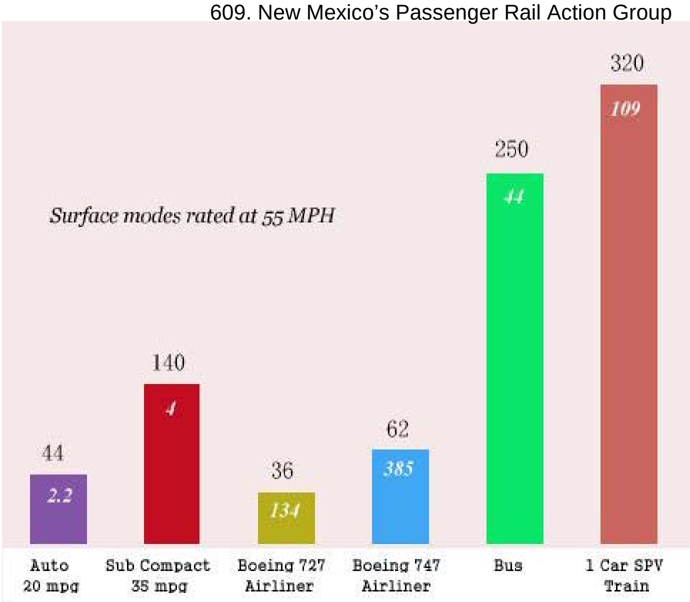
- Speed limits also work to improve vehicle operating economy, where a reduction from 65 mph to 55 mph can provide 15% more efficiency.

610. National Alternative Fuels Training Coalition

Flex-fuel vehicles and supplies provide a means to transition to renewables and offers the public opportunities to take advantage of the least expensive options.

Flex-Fuel Vehicles

609. New Mexico's Passenger Rail Action Group



Unit = passenger miles per gallon of fuel (italicized number denotes passenger loads)

Fuel Efficiency of Various Transportation Modes

US interests in progressing towards greater independence from oil imports are driving legislation to promote biofuels through rapid transition to flex-fuel vehicles.

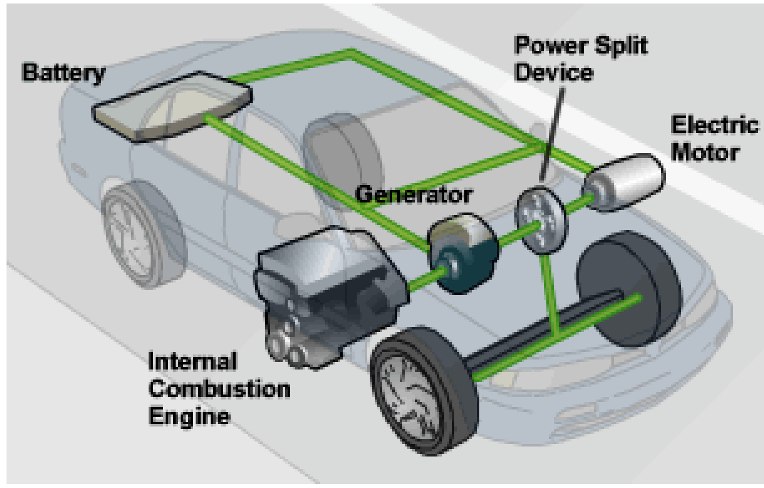
- A new Clean Energy Development for a Growing Economy bill (the Clean EDGE Act) introduced in the US Senate in May, 2006 will require many alternative refueling pumps to be installed across the nation:
  - The Act provides bond-issuing authority to states and local governments for projects to reduce fuel consumption and greenhouse gas emissions, to develop non-petroleum fuels, to produce more efficient vehicles, and to expand alternative fuel infrastructures and transit.
  - Ford, GM and other companies strongly support these measures, and have already introduced vehicles that will run on ethanol along with standard fuels.

Encouraging technology developments

Hybrid electric vehicles that use regenerative braking to recycle product energy back into power are another example of natural economy.

- Hybrids use two separate power systems, usually an internal combustion engine in combination with a generator/motor unit that converts energy back and forth between kinetic and electro-chemical forms:
  - When a vehicle receives power from the engine, some of that kinetic energy can be transferred to generate electricity to recharge batteries that power the vehicle when the engine is less efficient.
  - The generator/motor unit also helps slow the vehicle when desired, again transferring the kinetic braking energy to a storable electrical form.

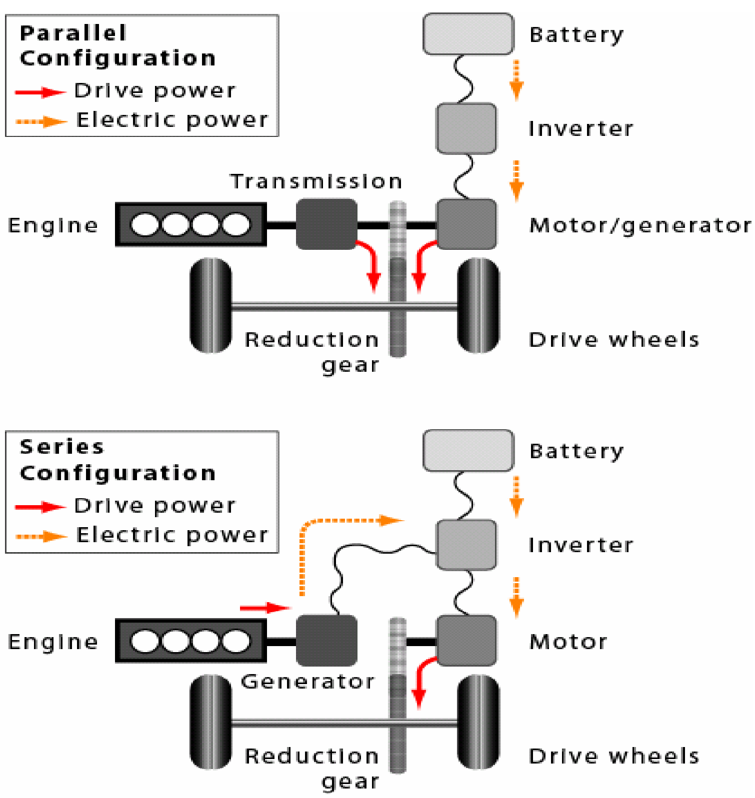
611. DIME C, University of Salerno



Hybrid electric vehicles configured with engines and electric motors connected in parallel can use regenerative braking to slow the vehicle and convert kinetic energy that would otherwise be wasted in the form of heat into storable electricity.

Recycling Kinetic Energy

612. University of Salerno

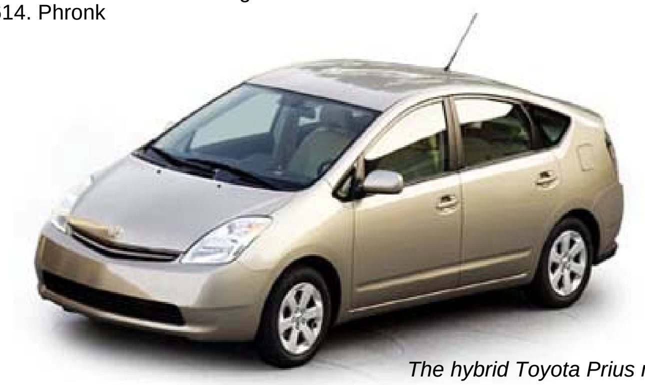


Hybrid Electric Vehicles

In addition to regenerative braking economies, hybrid electric vehicles typically use smaller engines than conventional types, and run them at more energy-efficient speeds, causing them to consume less fuel and produce less pollution.

- Although hybrids can be powered by fuel cells, and can even use “plug-in” all-battery systems for very light-weight, short-range applications, most currently use petroleum or diesel engines in a “parallel configuration”:
  - Parallel arrangements separate the engine and electrical systems so that a vehicle can run entirely on battery power under slow urban conditions when an engine is not very efficient.
  - An alternate “series configuration” uses an engine only to recharge an electrical drive system, eliminating a regenerative braking option.

613. Direct Vehicle Leasing
614. Phronk



Economy of Motion

The hybrid Toyota Prius mid-sized hatchback can achieve up to 55 mpg using either an internal combustion engine, an electric motor or both.

The "Smart For Two" microcar produced by Daimler Chrysler can achieve more than 70 mpg using a turbocharged 3-cylinder internal combustion engine.

Economy of Scale

For many, however, life without personal automobiles is unthinkable, and though a variety of compact, fuel-efficient cars are gaining markets, larger conventional vehicles continue to dominate US streets and highways.

- Significant vehicle fuel economy improvements are being achieved using hybrid alternatives and scaled-down, lighter vehicles which are gaining popularity, but continue to face US market challenges:

- Relatively low petroleum prices and high costs of hybrid alternatives have caused some consumers to question whether the miles per gallon savings warrant the substantial up-front investments.
- Such assessments may not take greater future resale value into account, particularly if fuel prices continue to dramatically rise as predicted.
- Many US consumers also question collision safety and utility volume penalties of small vehicle options.

The recent development and exploding popularity of personal computers and internet-based telecommunications may eventually have large impacts upon American commuting and long-range transportation habits.

- Telecommuting and teleconferencing offer potentials to often make much travel unnecessary altogether:

- Telecommuting has already become a viable alternative to driving or public transit for some jobs, and although not extensively practiced yet in America, hundreds of thousands of US and European employees have already been replaced by Indian workers that telecommute over thousands of miles.
- Teleconferencing with electronic data transfer holds large potential to minimize national and global business travel, saving time, money and energy in the process.

615. U of Illinois College of Veterinary Medicine

Technological developments in certain fields can have influences upon others that may appear unrelated.

Computer and Internet Impacts on Travel and Business

Technology Opportunities

Owning responsibility for the future

It is clear that the short era of abundant fossil and freshwater resources is nearing an end and that environmental impacts of current activity trends are unsustainable.

- Government, industry and academic organizations along with citizens that support them recognize that solutions to these urgent problems are essential for many reasons:

- Because they care about our children, grandchildren and the future of all generations who will follow.
- Because they are concerned about the quality of the natural environment and fragile ecosystems that are endangered.
- Because new and better solutions make good economic sense to create markets, provide employment and produce operating economies and profits needed for progress.
- Because change, whether forced or elective, is a necessity, not an option.

616. Children's Research Center
617. National Park Service
618. US Dept. of State
619. Salem Cnty. AVA Center




Incentives for Progress

620. Missouri Secretary of State
621. URFAN
622. Star Bulletin
623. City of Cambridge



Personal Choices and Influences

Each of us affects courses of human and natural events through our choices and actions.

- Individually and collectively, we change the world for better or worse through daily decisions:

- We exercise influence in determining who we will trust to lead us and implement policies we believe are important.
- We determine which businesses will be influential and which products will be successful in the marketplace through our purchasing power.
- We decide how many resources we will consume, how much waste will be created, and where it will go based upon values that guide how we live.
- We influence our children and others around us through our conservation outlooks and examples we put into practice.

Government programs can and do promote energy conservation in a variety of ways through representatives we help to elect and though the policies we influence.

- The Natural Resources Defense Council (NRDC), an independent environmental action organization, advocates a number of initiatives the Federal Government can sponsor to advance these objectives:

- Some of these actions involve accelerating and extending energy efficiency incentives of the 2005 EPAct such as the Energy Star Program which provides tax credits for home builders, appliance manufacturers, commercial buildings and consumers of qualified products.

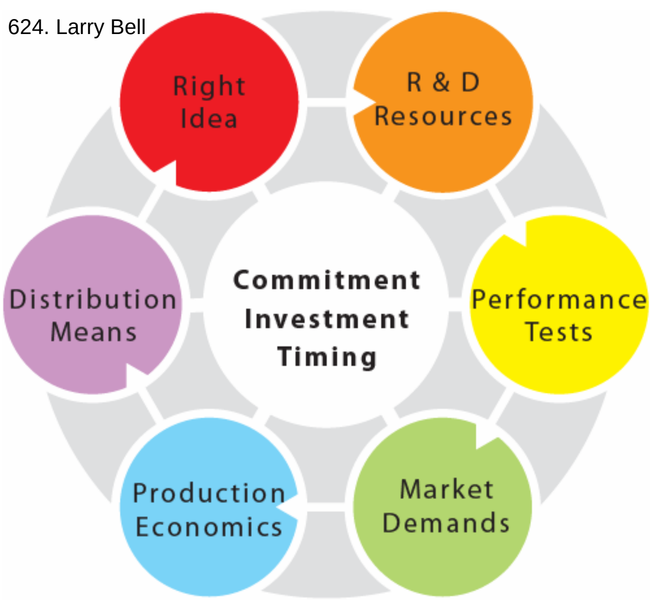
- Other programs encourage states to consider energy efficiency regulation reforms, including requirements and incentives to prompt electric utility companies to increase use of renewable energy sources.

- *Expand information programs to promote energy efficiency in development and purchases of buildings and manufactured products.*
- *Provide additional performance-based incentives for existing home retrofits and Energy Star provisions of the EPAct.*
- *Fund the Low Income Home Energy Assistance Program (LIHEAP) and Westernization Assistance Program (WAP) already authorized.*
- *Enact a national renewable portfolio standard advocated by EIA requiring major utility companies to increase power from renewable sources.*
- *Extend production tax credits for electricity produced from wind and geothermal energy that are soon scheduled to expire.*
- *Issue minimum energy efficiency standards for certain appliances, equipment products and federal buildings through the Department of Energy.*

NRDC Recommendations

Federal Government Initiatives

624. Larry Bell

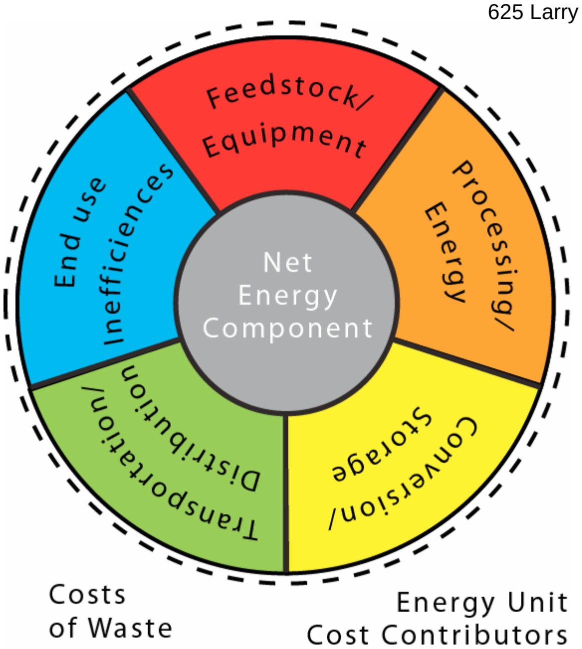


New ideas must compete with existing products that have established manufacturing capabilities, market demands, and distribution and service networks which offer advantages.

Academic and private industry programs are demonstrating encouraging supply-side and conservation advancements.

- Better, more efficient technologies and processes typically encounter major hurdles:
- New alternatives must compete with existing products and services that benefit from established manufacturing capabilities, distribution infrastructure and markets
- Inevitably, public interest in forms of essential investment support and purchasing demand determines which new developments will ultimately succeed

625 Larry Bell



Each unit of energy conserved saves costs in the form of energy, money and pollution to create it.

It is essential to realize that no single energy source, technology advancement or combination will satisfy needs of escalating consumption.

- The future we experience and introduce to those who follow will depend upon full use of our human resources of vision, intellect and discipline:

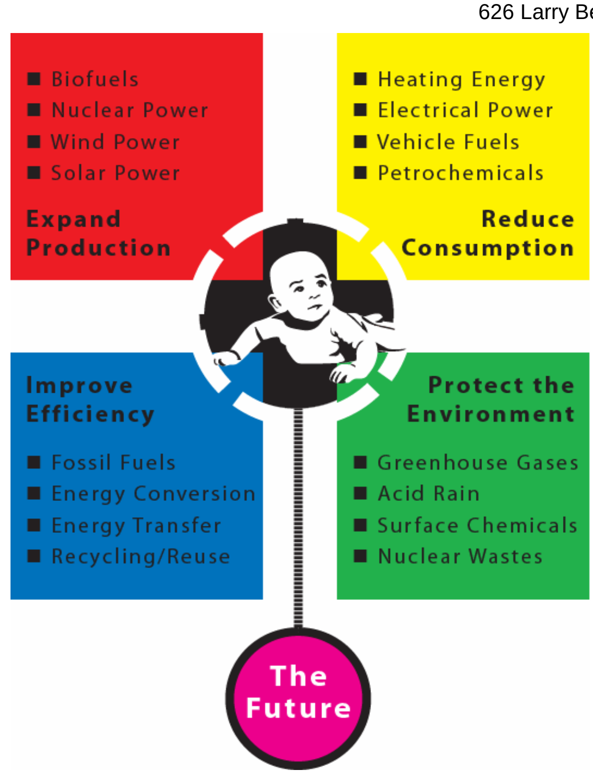
- We must apply all available means to expand energy production using renewable sources, yet recognize realistic limitations.
- We must strive to develop and utilize more efficient processes and systems that minimize, recycle and reuse wastes.
- We must adapt our lifestyles and habitats to apply responsible conservation principles that reduce energy and water consumption.
- Above all, we must recognize responsibilities to protect natural ecosystems that sustain all life.

Source reduction, the most important conservation strategy of all, can be practiced by everyone to minimize the amount of energy and material used and the quantity of waste created.

- Doing more with less makes good economic and moral sense, and can often be accomplished without serious lifestyle compromises. For example:

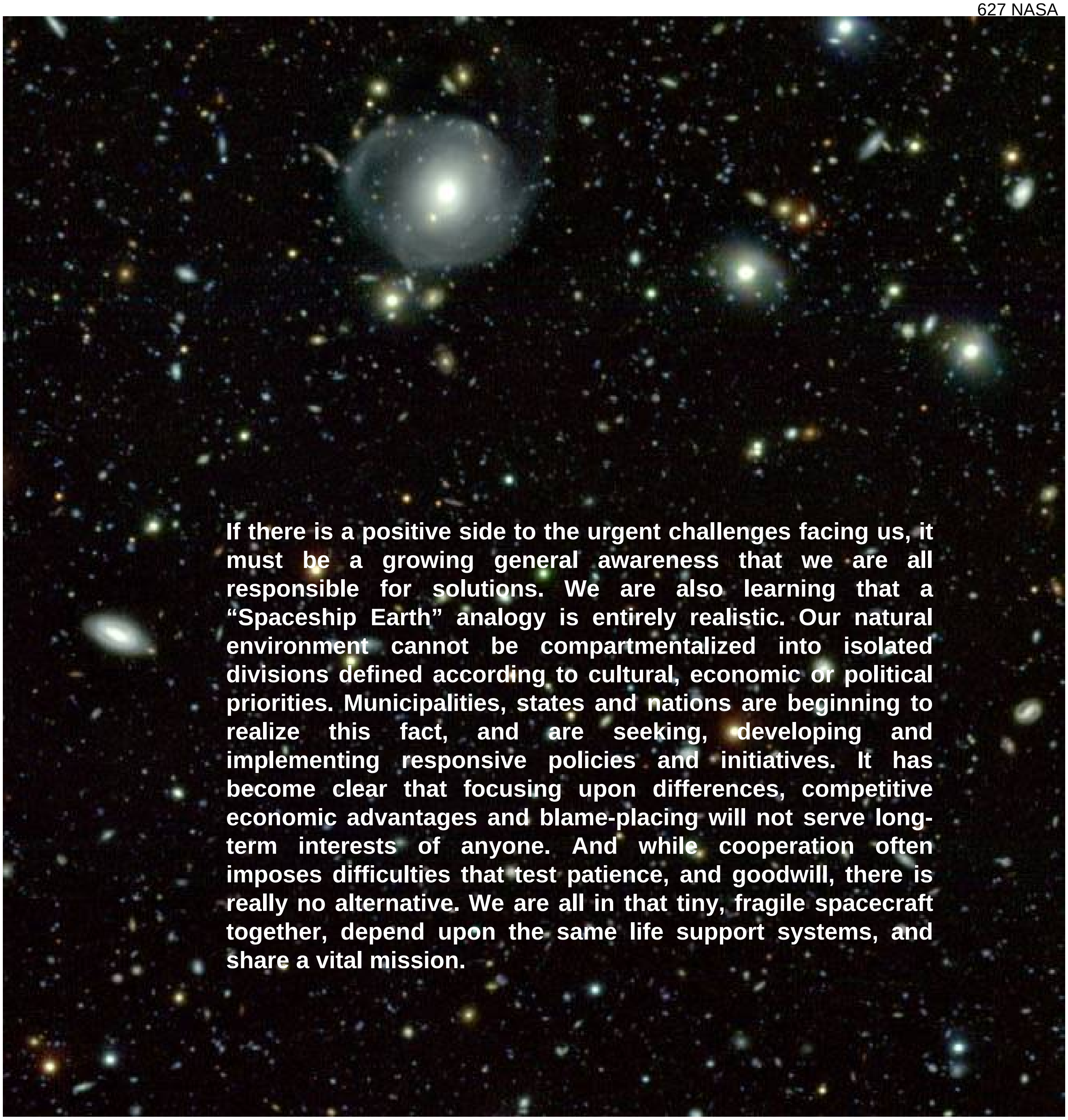
- Passive solar building design is a simple and effective example that when properly applied, can greatly reduce energy consumption and pollution impacts.
- Purchasing energy-efficient cars and use of public transportation expands market and service demands that drive costs down even more.
- Combined heat and power-generating systems and inexpensive solar water and space heating devices, can save money and fuel.

626 Larry Bell



Our only real options are to expand more environmentally-friendly alternatives to fossil fuels, to make more effective use of all resources, and above all, to apply aggressive conservation practices.

627 NASA



If there is a positive side to the urgent challenges facing us, it must be a growing general awareness that we are all responsible for solutions. We are also learning that a “Spaceship Earth” analogy is entirely realistic. Our natural environment cannot be compartmentalized into isolated divisions defined according to cultural, economic or political priorities. Municipalities, states and nations are beginning to realize this fact, and are seeking, developing and implementing responsive policies and initiatives. It has become clear that focusing upon differences, competitive economic advantages and blame-placing will not serve long-term interests of anyone. And while cooperation often imposes difficulties that test patience, and goodwill, there is really no alternative. We are all in that tiny, fragile spacecraft together, depend upon the same life support systems, and share a vital mission.

1. “Greenhouse Effect”

This “greenhouse effect” is a term applied to warming that occurs when the atmosphere traps heat radiating from Earth towards space. The analogy is to certain gases in the atmosphere that act roughly similar to a glass greenhouse structure that allows sunlight to pass inside, but blocks Earth’s heat from escaping into space. As a result, on average, the Earth becomes warmer, with some regions welcoming this change, and others not. The warmer conditions generally lead to more evaporation and precipitation overall, but individual regions vary, with some becoming wetter, and others dryer.

Although water vapor is by far the most abundant atmospheric greenhouse gas, CO_2 is cited by many as an important contributor also. Some crops respond favorably to increased CO_2, growing more vigorously and using water more efficiently. Shifting climate patterns that result may also change areas where certain crops grow best.

Source:

NASA Goddard, 1993. “Facts on Line.”
http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/green.htm

Sources:

NASA Goddard, 1993. “Facts on Line.”
http://www.gsfc.nasa.gov/gsfc/service/gallery/fact_sheets/earthsci/green.htm

NASA Marshall Space Flight Center, 1997.
“Global Climate Monitoring: The Accuracy of Satellite Data.”
http://www.ghcc.msfc.nasa.gov/MSU/hl_sat_accuracy.html

NASA Marshall Space Flight Center, 1997.
“Accurate Thermometers in Space: The State of Climate Measurement Science.”
http://science.nasa.gov/newhome/headlines/essd06Oct97_1.html

NASA Marshall Space Flight Center, 1997.
“The Answer Lies Partly in a Better Understanding of Water’s Role.”
http://science.nasa.gov/newhome/headlines/essd06Oct97_1.html

Lanzante, J., et al. 1997.
“An improved 40-year atmospheric temperature database”, NOAA Air Resources Laboratory.
http://www.arl.noaa.gov/milestn/mile7.html

2. Atmospheric CO_2 Influences/Models (NASA Goddard/NASA Facts On Line)

Based upon satellite measurements, it appears that atmospheric sensitivity to greenhouse gases is less than most climate models predict. Some scientists also believe that even if small warming increases are occurring, for example 1ºF (0.5ºC) over 140 years, they may not be outside the range of natural climate variability. It is broadly recognized that more comprehensive and sophisticated climate models are needed, although scientists have little choice but use present ones until better ones are developed.

One of the most challenging needs in creating more reliable climate models is to understand detailed physical processes associated with clouds to determine the extent and nature of water vapor feedback into Earth’s temperature. As stated by the IPCC: “*Feedback from the redistribution of water vapor remains a substantial uncertainty in climate models… Much of the current debate has been addressing feedback from the tropical upper troposphere, where the feedback appears likely to be positive. However, this is not yet convincingly established; much further evaluation of climate models with regard to observed processes is needed.*” (Climate Change 1995, IPCC Second Assessment).

3. Seasonal CO_2 Concentration at Mauna Loa Observatory, Hawaii

Measurements of atmospheric CO_2 concentration measured monthly over past decades at the Mauna Loa Observatory in Hawaii, a fairly remote and non-polluted area, show overall exponential increases with peaks and troughs that appear to correspond with plant growth influences. Peaks correlate with winter seasons (less photosynthesis and rising concentrations), and troughs occur during spring and summer plant cycles that remove CO_2. Anomalies in atmospheric circulation flow patterns associated with the El Niño/Southern Oscillation (ENSO) events also showed significant, though seasonally-variable roles, and it has been suggested that such atmospheric transport variations influencing CO_2 measurements warrant further study. This may account for indications of a decadal shift in the origin of air masses arriving at the observatory during the April-June period that favors lower CO_2 concentrations.

Source:

Linter, et al., 2006. “Seasonal Circulation and Mauna Loa CO_2 Variability”, American Geophysical Union,
http://www.agu.org/pubs/crossref/2006/2005JD006535.shtml

4. Water Vapor as a Greenhouse Gas (Feedback Observations)

A NASA-funded study found that some climate models may be overestimating the amount of water vapor entering the atmosphere as the Earth warms to trap greenhouse gases. The study was conducted by Ken Minchwaner, a physicist at the New Mexico Institute of Mining and Technology and Andrew Dressler at the University of Maryland and the NASA Goddard Space Flight Center in Greenbelt, Maryland. The study was published in the March 15, 2004 issue of the American Meteorological Society's *Journal of Climate*. It used data on water vapor in the upper atmosphere at a 6-9 mile altitude from NASA's Upper Atmosphere Research Satellite (UARS). This data measured specific humidity (actual amount of water vapor in the air) and relative humidity (amount of water vapor divided by the amount of water air is capable of handling at a given temperature).

As the Earth warms, more water evaporates from oceans to increase water vapor (the primary greenhouse gas) leading to an increase in surface temperatures (a "positive feedback"). The existence and size of this feedback has been argued for many years. The study confirmed that water vapor does increase with surface warming, but not as much as many climate-forecasting models had previously assumed.

Source:

NASA Goddard, 2004. "Satellite Finds Warming Relative to Humidity." www.nasa.gov/centers/goddard/news/topstory/2004/0315humidity.html.

5. Global Precipitation Trends

A Global Precipitation Climatology Project (GPCP) established by the World Climate Research Programme (WCRP) in 1986 has mapped patterns of precipitation around the world using data collected from satellite and in- situ measurements between 1979-2004. These monthly-averaged estimates do not yet show any evidence that atmospheric water vapor concentrations have increased over this period. While periodic variations occur, such as relatively brief changes associated with El Niño/Southern Oscillation (ENSO) episodes, the global positive/negative average is near zero.

The assessments also indicated that totals from land and ocean measurements tend to average out, which suggests that precipitation tends to migrate between the two rather than operate independently (both monthly and annually).

Source:

Huffman, G., et al., 2006. "Monthly GPCP Version 2 Satellite-Gauge Combined Precipitation Product." NOAA National Climate Data Center (NCDC), ftp://www.precip.gsfc.nasa.gov/pub/gpcp-v2/doc/V2_doc

6. Aerosols
(Real Climate: Guest Commentary, Ron Miller & Dorothy Koch, NASA GISS)

Estimates of effects of human-made aerosols vary considerably, often with conflicting model results and conclusions. Better understanding of this topic is of particular interest because their concentrations are enhanced by the same fossil combustion processes that create atmospheric greenhouse gases.

According to the 2001 IPCC report, direct radiative forcing by anthropogenic aerosols cools the planet, although the forcing magnitude is highly uncertain. The effects at the top of the atmosphere are even less clear, partly because they fall out or are washed out by rainfall, lasting only a few days or weeks, which does not allow enough time to be mixed uniformly throughout the globe. For sulfate aerosols it is also very difficult to distinguish droplets from industrial vs. biogenic sources because key modeling parameters are not well understood.

Aerosol levels are anticipated to drop faster during the 21st century than greenhouse gases due to more aggressive emission regulations. Although they tend to oppose rather than cause global warming, other problems such as respiratory health problems and acid rain have been of great public concern.

Source:

Miller, R. and Koch, D., 2006. "An Aerosol Tour de Forcing". Real Climate Guest Commentary. http://www.realclimate.org/index.php/archives/2006/02an-aerosol-tour-de-forcing/

Bellouin, et al., 2005. "Global Estimate of Aerosol Direct Radiative Forcing from Satellite Measurements", *Nature*. Vol 438. pp. 1138 – 1141 (22 December 2005).

7. Land Use Influences upon Weather/Climate

Agriculture has significantly transformed the face of the planet. Croplands have now replaced natural vegetation over about 18 million square kilometers of land surface with possible feedbacks that have altered the suitability of many regions for growing crops.

Although global changes in suitability are not yet established, regional effects may have occurred, particularly in Canada, Eastern Europe, the former Soviet Union, India and China.

The Great Plains of North America experienced significant overturning of land from natural grassland to irrigated land use during the 20th century. Research results show notably cooler temperatures during the growing season over irrigated areas, with more than 1ºC more cooling since 1945.

Interactions between various land use affects upon climate are complex and are currently poorly understood. This is particularly true on a global level.

Source:

US Global Change Research Program, 2006. "Land Use / Land Cover Change", USGCRP Program Element, http://www.usgcrp.gov/usgcrp/ProgramElements/land.htm

Kleidon, A. 2006. "Climate Change Forcings and Feedbacks". (Abstract) Science: Roger Pielke Sr. Research Group Weblog, http://climatesci.atmos.colostate.edu/2006/08/31/new-paper-on-the-importance-of-land-useland-cover-change-on-climate/

8. Global Warming/Cooling Trends

Although there are not enough records available to confidently reconstruct global, or even hemispheric temperature records prior to about 600 years ago, records that do exist do not reveal any multi-century periods when global or hemispheric periods were quite as warm as or warmer than the 20th century. Temperatures during the Medieval Warm Period and the Little Ice Age that followed have been estimated based upon a variety of measurement types and models, including analyses of ice core oxygen isotopes and CO_2 in air bubbles dating from these times. These studies indicate that CO_2 levels (reflecting warm and cold conditions) between AD1530-1810 remained relatively constant (about 280 ppm). After this period the concentrations began to rise abruptly and smoothly.

Source:

NOAA. National Climatic Data Center, 2006. "A Paleo-Perspective on Global Warming: The Medieval Warm Period". http://ncdc.noaa.gov/paleo/globalwarming/medieval.html

American Geophysical Union, 1995. "The Little Ice Age and Medieval Warm Period", US National Report to IUGG, 1991 – 1994. *Rev. Geophys*. Vol 33 Suppl. http://www.agu.org/revgeohys/mayews01/node5.html

9. Cosmological Influences on Climate

An emerging scientific field called "cosmoclimatology" is examining natural cosmological influences of Earth's Solar System upon climate changes. Special attention is directed to magnitudes of cosmic rays penetrating Earth's atmosphere determined by cyclical fluctuations of the Sun's magnetic field and Solar System migration over the Milky Way. The cosmic rays ionize air molecules in Earth's atmosphere, influencing formations of clouds that block solar irradiance from penetrating the troposphere. During times of low solar activity (and in some parts of the Milky Way) more clouds are formed, producing a cooling effect.(1)

It is widely believed that variations in solar activity and cosmic flux have significant impacts upon relatively short interglacial warming and cooling periods. During the Little Ice Age (about 1350-1850) an exceptionally weak solar magnetic field of the Sun (a low sunspot number between 1645 and 1715) coincided with its coldest phase.

The Medieval Warm Period and our current one also match times of low cosmic ray intensities (high solar activity levels) governed by solar cycles. This pattern appears to apply over 10,000s to 6,000 years ago, corresponding well with solar activity and cosmic ray flux levels during the Holocene warming period.(2)

Many researchers have concluded that climate changes are primarily driven by naturally occurring cosmological events rather than by variations in trace amounts of atmospheric CO_2 which lag behind temperature changes.(2) Over long intervals these galactic influences have had dramatic consequences, including "Snowball Earth" episodes (2,300 million and 700 million years ago) when the entire Earth was frozen. These periodic climate changes can be characterized according to five categories: 1) super-long fluctuations (about 150 million years); 2) long fluctuations (a few to 15 million years) 3) middle fluctuations (about 1-10 million years); 4) short fluctuations (10s to hundreds of thousands of years); and 5) ultra-short fluctuations (thousands to hundreds of years and less).(3)

Long and expansive glaciation periods occurred twice between 353 and 444 million years ago when atmospheric CO_2 levels were 7 to 17 times higher than today.(3) This observation conflicts with theories that CO_2 which contributes only about 2% of total greenhouse warming has had a significant climatological influence.(4) Of this total, atmospheric CO_2, anthropogenic contributions are estimated to account for less than 0.00022% throughout human history, and less than 0.01^{o}C of warming during the past century.(5)

The UN's Intergovernmental Panel on Climate Change (IPCC) conclusion that the reason why the last 50 years are the warmest in the past 1,300 years is primarily due to fossil fuel burning does not take the fact that the last 70 years has witnessed the highest solar activity in more than 8,000 years.(6) Russian astronomers at the Institute of Solar-Terrestrial Physics in Irkutsk who have analyzed sunspot cycles for the period 1882-2000 predict that a minimum of solar cycle activity will occur in 2021-2026, reducing the global temperature of surface air. (The peak of the current 22 year cycle was in 2002-2003, and it is now in a declining phase).(7) Observations and conclusions announced by researchers at the Pulkovo Observatory near St. Petersburg agree with this assessment, and predict a gradual decrease in global temperatures beginning in 2012-1215, leading to much colder conditions around 2050-2060.(8) This period is expected to last about 50 years, with cooling comparable to the Little Ice Age when temperatures decreased about 1-2^{o}C.(9)

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10. CO_2 Contributions to Global Warming

Atmospheric CO_2 has increased about 25% since the early 1800s, and climatologists at NASA's Goddard Space Flight Center, Green Belt, MD estimate that the increase since 1958 has been about 10%. The level is currently increasing at a rate of about 0.4% per year. Humans add CO_2 to the atmosphere mainly by burning fossil fuels, although other activities such as deforestation and burning/decaying felled timber are also contributors.

Predictions of actual CO_2 impacts are complicated, and most take other greenhouse gases into account such as methane and nitrous oxide. Scientists recognize the importance of understanding these concerns, but cannot yet produce good estimates of future regional climate changes because forecast tools are not sufficiently sophisticated.

The fact that there has been little observed increase in atmospheric CO_2 during the past 50 years raises questions about whether we are really experiencing significant effects from this, or whether other more important factors may be influencing climate. Some believe that a 1ºF (0.5ºC) change over 140 years may not be out of the range of natural climate variability. Others point out that the weight of carbon emissions by humans differs from that of carbon dioxide, because CO_2 is 3.7 times heavier than carbon alone.

Scientists estimate that about half of the present human carbon emissions are absorbed by the environment, and the half absorbed account for only half of where that goes (the "mystery of the missing carbon") amounting to about 1.8G ton/year. Based upon projections, the 270G tons of human carbon emissions over the past 200 years would have increased CO_2 concentrations from 280 to 415ppm if all had stayed in the atmosphere. But since present CO_2 is about 360ppm, 41% of cumulative emissions have been absorbed by the environment if the carbon source was entirely human, differing from a present 50% estimate.

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11. Stratospheric Ozone Depletion

Ozone (O_3) in the Earth's stratosphere between about 11-50 km altitude is essential to life because it absorbs a portion of incoming ultraviolet solar radiation with wavelengths between 210-310mm. Excessive UV radiation can damage immune systems, and cause genetic mutations and skin cancers in humans. It can also reduce photosynthetic capabilities in plants, including marine algae and phytoplankton which are at the base of the ocean food chain.

Ozone exists in a delicate balance with stratospheric oxygen. UV from the Sun breaks down molecules of O_2 into separate atoms which are free to combine with other O_2 to create O_3 (again absorbing UV). This balance can be disrupted by compounds such as chlorofluorocarbons (CFCs) released by human activities. The CFCs are broken down by UV, releasing chlorine (Cl) which so aggressively destroys ozone molecules that it is estimated that one Cl atom can affect 100,000 ozone molecules before being removed from the stratosphere by other chemical reactions. Although ozone is constantly being created, many believe that the rate of destruction currently exceeds the rate of production, possibly by as much as 1% every 3 years over the Northern Hemisphere.

Source:

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12. The IPCC

The IPCC Panel is composed of representatives appointed by governments and organizations led by government "scientists." It is encouraged that the delegates have appropriate expertise. The IPCC does not actually carry out research or monitor climate-related data or other relevant parameters. Instead, it bases its assessments mainly upon peer-reviewed and published scientific/technical literature. The Panel is a corporate entity that meets about once each year and controls the organization's structure and procedures.

Much of the actual Panel activity is conducted by Working Groups and a Task Force:

- Working Group I assesses scientific aspects of the climate system and climate change.
- Working Group II assesses vulnerabilities of socio-economic and natural systems to climate change, convergences and adaptation options.
- Working Group III assesses options for limiting greenhouse gas emissions and otherwise mitigating climate change.
- The Task Force studies/conducts National Greenhouse Gas Inventories.

Each of the Working Groups has two Co-Chairs, one from a developed country, and one from the developing world, along with a technical support unit. It supports these activities from funds it receives from the United Nations Environment Program (UNEP), the World Meteorological Organization (WMO), and its own Trust Fund it solicits from government contributions. Its activities concentrate on tasks allotted to it by WMO Executive Council and UNEP Governing Council resolutions and decisions along with priorities that support the UN Framework Convention Climate Change Process.

The Third Assessment Report's TAR Summary for Policymakers produced a great deal of media headline material. Included were many conclusions that remain to be subjects of continuing scientific debate. For example:

- There is new and stronger evidence that most of the warming observed over the past 50 years is attributable to human activities.
- Confidence in ability of models to predict future climate has increased.
- Human influences will continue to change atmospheric composition throughout the 21st Century, and global temperatures and sea levels are projected to rise under all scenarios.

The IPCC reports are widely cited in government, media and blog discussions as authoritative information regarding climate issues and predictions. The summary reports (Summary for Policymakers) are clearly most influential and draw primary attention because they are directed to non-technical readers and provide "sound-bite" conclusions that media organizations tend to favor (particularly if they are exciting and alarming). Four Major Assessment Reports have been produced to date: the first, in 1990; a second (SAR) in 1995; a third (TAR) in 2001; and the last (AR4) released in 2007. Each report is in three volumes, corresponding with Working Groups I, II, and III.

The Fourth Assessment Report contains many of the observations presented in others, including one that is facing strong scrutiny due to an extremely controversial graph, the "hockey stick" that many scientists believe exaggerates recent warming relative to pre-industrial and earlier periods, before smokestacks and automobiles. The methodology behind this graph has been called into question before the US Congress and scientific investigatory groups. (The graph appeared 6 times [full color] in the TAR report.)

13. Atmospheric vs. Surface Measurements and Assessments

In-situ radiosonde balloon sensors have been measuring lower atmosphere temperatures since 1958, and satellite Microwave Sounding Units (MSUs) have been sensing tropospheric temperatures (up to about 5 km above the surface) since 1979. While satellite measurements have the advantage of global coverage, they have been recorded over too short a period to provide a good basis for trend predictions. Radiosonde balloon measurements have occurred longer, but extensive instrumentation changes over their period of use may also account for possible errors in assessing temperature changes over time.

The MSUs on NOAA polar-orbiting platforms have measured the intensity of upwelling microwave radiation from atmospheric oxygen at different frequencies that sample “weighted ranges” associated with different altitudes. Records have been merged from nine different MSUs, each with special “peculiarities” calculated and removed to correct for errors (e.g., time drift of the spacecraft relative to local solar time).

The process of constructing temperature records from satellite data is complex. For some time, measurements analyzed at the University of Alabama Huntsville (UAH) have appeared to contradict surface measurement data at ground

stations that have indicated a warming rate estimated by climate models. These earlier atmospheric measurements seemed to suggest that warming was not occurring, or was occurring at rates below model forecasts. Subsequent corrections for possible errors in the analyses of satellite data have brought these two datasets more closely in line with each other and with the general conclusions of the UN Intergovernmental Panel on Climate Change (IPCC).

During the late 1990s the National Research Council observed that earlier record assessments contradicted predictions that temperatures should increase in the upper air as well as on the surface if increased GHG concentrations were the cause of the warming. Still, even at that time their report concluded that “*the warming trend in global-mean surface temperature observations during the past 20 years is undoubtedly real and is substantially greater than the average rate of warming during the 20th century. The disparity between surface and upper air trends in no way invalidates the conclusion that surface temperatures have been rising*.”

General theories suggest that the stratosphere should cool while the troposphere warms. Lower observed stratospheric records may be explained by other influences, such as effects of ozone depletion which may have cooled this region.

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14. Sea Level Changes

The IPCC has made dire predictions of coastal flooding that will be caused by rising ocean levels due to Arctic and Antarctic ice melts. However, satellite radar altimeter measurements of polar ice sheets along with records of results of previous warming period influences indicate less reason for alarm.

Decades of Satellite data recordings of ice mass changes in Greenland (more than 10 years) and Antarctica (9 years) have been conducted by the NASA Goddard Space Flight Center. These studies reveal that while the Greenland ice sheet is thinning at the margins (about -42 Gt of water mass per year), mass is growing inland at a rate of about +53 Gt per year (an estimated sea level decrease of -0.03 Gt per year). The western Antarctica Ice Shelf changed its mass at a rate of about -47 Gt per year, and the Eastern Ice Shelf increased by about +16 Gt per year for a net change of about -31 Gt (corresponding with a + 0.08 mm per year sea level rise). Combined together, the Greenland and Antarctica water mass changes yield a net sea level increase of about + 0.05 mm per year. This data can be compared with actual sea level rises measured by satellite of 2.8 mm per year. At this rate it will require about 1,000 years to raise global sea level by only 5 cm, and 20,000 years to raise it one meter.1

Inhabitants of the Maldives, a group of 1,200 very low-elevation islands in the central Indian Ocean, have survived sea levels at least 50-60 cm higher than now that occurred during the Medieval Warm Period. Various geomorphological and sedimentological records indicate that about 2,700 years ago the surrounding sea level was about 1 meter higher than at present, 1,000 years ago about 0.05 meter higher, and from 1900-1970, about 0.2-0.3 meters higher. During the last 30 years, the sea level dropped about 30 cm as measured by satellite altimeter and direct gauge records.2

<u>Sources</u>

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15. Greenland Ice Sheet

Researchers now have more than a decade's worth of data since 1992 from radar altimeters on European Space Agency EPS satellites that provide detailed information about thickness changes in the Greenland Ice Sheet. The measurements (accurate to approximately 2 centimeters) indicate a recent thickness growth of about 6.4 cm/year in interior areas above 1,500 meters, with a minus 2 cm/year below that elevation (broadly matching reported thinning in ice sheet margins). Spatially averaged, this represents a net increase of 5.4 cm/year. These findings contrast with previous estimates of high-elevation mass balances.

The satellite measurements provide records of Earth's oceans and land, as well as ice fields, and offer important data for assessments of whether ice sheets are growing or shrinking. While there is still no consensus regarding Greenland's overall ice sheet mass balance, there is evidence of melting and thinning in coastal marginal areas in recent years, and indications that outlet glaciers can surge, possibly in response to climate variations.

Many researchers attribute Greenland's interior elevation growth to increased snowfall linked to variability in regional atmospheric circulation known as the North Atlantic Oscillation (NAO) first discovered in the 1920s. This acts in a way similar to the El Niño phenomenon in the Pacific that contributes to climate fluctuations across the North Atlantic and Europe. There appears to be a direct ice sheet elevation change with strong positive and negative NAO phases during winter which largely controls temperature and precipitation patterns across Greenland.

The year 2002 witnessed a higher-than-average melt that coincided with unusually rare stationary low-pressure areas in the Arctic, contributing to a combination of higher temperatures and altered, stormy wind fields that tend to break up ice cover. 1992 had a less-than-average melt attributed in large part to a Mt. Pinatubo volcano eruption that sent cooling aerosols into the atmosphere.

Researcher caution that the altimeter survey data does not necessarily reflect a long-term or future trend because the recording period is too short. Arctic temperatures appear to fluctuate on a timescale of 60-80 years, which means that Arctic cooling may occur again soon, rather than warming. Current models also suggest that temperature increases up to about 3ºC may lead to positive mass balance changes at high elevations due to snow accumulations, and negative at low elevations due to snow melts. However after that threshold is reached (possibly within the next hundred years), the mass balance may begin to reverse.

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16. Greenhouse Modeling Problems

The actual mechanisms that determine “greenhouse” warming are much more complicated and less well understood than simple explanations would imply. These descriptions typically focus upon radiative balances of incoming solar radiation in ultraviolet wave lengths and thermal radiation absorbed and emitted by the surface and atmosphere. The main infrared absorbers in the atmosphere are water vapor and clouds, with minor contributions from trace gases such as CO_2 and methane. This emphasis does not adequately recognize important influences of convection (heat transport by air molecules) which bypasses much of the radiative absorption effects.

A fuller understanding of Earth cooling and warming most account for influences of air currents, including those in deep clouds that carry heat upward and towards the poles. A consequence of this convection is that greenhouse gases including water vapor high above the surface have particularly strong influences since the molecular density decreases by a factor of about 1,000 between the surface and a ten kilometer altitude. Accordingly, models that cannot accurately reproduce motions of the atmosphere are unable to accurately calculate average Earth temperatures or temperature ranges between the equator and poles, introducing large errors. A common modeling practice is to “tune” the results to get approximate estimates with large ranges of uncertainty.

In reality, climate is an extremely complex system which is currently impossible to predict with accuracy. Internal processes within the climate system change in response to warming in a manner that can amplify responses (characterized as “positive feedbacks”) or produce cooling responses (“negative feedbacks”). The most important positive feedback predicted in current models is attributed to water vapor measured in the upper troposphere (5-12 km altitude), which increases as temperatures rise. Such models do not have the ability to determine influences of convection on clouds and water vapor. Even small cloud cover changes can strongly affect responses to feedbacks associated with CO_2 levels, a condition that is further complicated by influences of clouds at higher levels, which may produce cooling effects (negative feedbacks).

Influences of reflective contributions of snow cover relative to increased atmospheric CO_2 levels are also not well understood. It has been generally assumed that warmer climates are associated with less snow cover (less reflectivity) to amplify warming. Yet clouds also shield the Earth’s surface from the Sun to minimize responses to snow cover with a cooling influence, and there is growing evidence that clouds may accompany diminishing snow cover to the extent that feedback factors can actually become negative. Even current models predict that warmer climates will produce increased humidity at all levels, yet do not incorporate necessary understanding of physics or numerical accuracy to address water vapor feedbacks. Recent studies of the physics of ways deep clouds moisturize the atmosphere indicate that what were assumed to be positive feedbacks may not only be negative, but very strongly negative contributions.

Source

Linzen, R.* 1992. “Global warming: The origin and nature of the alleged scientific consensus”. Regulation, the Cato Institute, vol. 15, no. 2, Spring 1992.
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* Richard Linzen is the Alfred P. Sloan Professor of Meteorology at the Massachusetts Institute of Technology and is a prominent critic of IPCC processes and conclusions.

17. Problems with Current Model Predictions

There are major reasons to believe that climate models exaggerate effects of increasing carbon dioxide levels and overestimate magnitudes of warming in general. Average global temperature records over the past century are irregular, but show an increase of about .45 degree centigrade (plus or minus .15^{o}C), with most of that increase occurring before 1940. Some cooling then occurred through the 1970s, followed by a rapid but modest increase in the late 1970s. Given a 50% increase in CO_2 since 1880, the models, if accurate, should have shown warming of about 2^{o}C already (rather than .30^{o}C-.60^{o}C). If a delay had been imposed to account for the ocean’s heat capacity, we might expect about one degree centigrade of warming to have occurred, about twice what has been observed. In addition, most of the warming happened before the bulk of minor greenhouse gases were added to the atmosphere.

There is nothing in the observed temperature records over this period that can be distinguished from natural climate variability. (The global mean temperature has risen no more than .5^{o}C in the past 27 years, almost identical to the rise between 1910-1945 when CO_2 emissions are accepted to be too small to be influential.)

There is evidence that the average equatorial sea surface temperature has remained quite constant, within plus or minus one degree centigrade of the present, over billions of years. This has held true during much of the Earth’s history when atmospheric CO_2 levels have been much higher than now.

Source

Linzen R.*, 1992. “Global warming: the origin and nature of the alleged scientific consensus”. Regulation, The Cato Institute, vol. 15, no. 2, Spring 1992.
http://cato.org/pubs/regulation/regv15n2g.html

* Richard Linzen is the Alfred P. Sloan Professor of Meteorology at the Massachusetts Institute of Technology and is a prominent critic of IPCC processes and conclusions.

18. Arguments Against Kyoto Protocol Provisions

Harvard scientists and economists, among others who study climate change, have voiced nearly universal criticism of the Kyoto Protocol which was faulted as economically inefficient, unobjective, inequitable and ineffective. One of the major failures cited is the exclusion of China, the largest future source of CO_2 emissions. They also argue that the agreement gave Europeans a massive advantage over other countries in reducing CO_2 emissions below 1990 levels. The reunification of Germany since that time has led to the elimination of many dirty, polluting East German industries, and the discovery of large natural gas fields in the North Sea enabled the UK to phase out large segments of its coal industry. Protocol terms allow the EU to apportion carbon credits not needed by Britain and Germany to other big EU polluters (awarding large net increases in some cases), providing flexibility that single individual nations like the US lack. Yet since 1990 the US has experienced unprecedented economic growth.

The 2008 completion date mandated by the Protocol would also present major problems for the US. Economists argue that the typical lifetime of a power plant is approximately 30 years, and an average US automobile is on the road for 11-12 years. Changing the energy economy too rapidly by retiring equipment would be economically unproductive.

Other disagreements with the Protocol argue against claimed environmental advantages. For example, it gives credit for planting forests to sequester carbon, but does so in a way that provides economic incentives to destroy wetlands, potentially creating net excess CO_2 releases. It also doesn't set long-term goals for reductions in atmospheric CO_2 concentrations. Some believe that real effects upon climate change would be virtually nonexistent in any case since an estimated 2%-3% emission reduction by 2050 would be well within the margin of error, and trivial compared with natural carbon sequestration by the marine and terrestrial biosphere.

Source:

Harvard Magazine, 2002. "Problems with the Protocol." http://harvardmagazine.com/on-line/1102199.html

19. US Kyoto Protocol Positions

On February 16, 2005, the Kyoto Protocol was brought into force (90 days after Russia ratified the treaty which was strongly advocated by the EU, and potentially influenced by their offer to support Russia for admission into the World Trade Organization). The US, a signatory, has neither ratified nor withdrawn. The US signature by then Vice President Al Gore was symbolic and non-binding unless ratified by the Senate, which was well understood by the Clinton Administration to be unrealistic so long as participation by developing nations was exempted. Since then, however, several states, and more than 180 mayors from US towns and cities have pledged to adopt Kyoto-style limits on greenhouse gas emissions. On August 31, 2006, the California Legislature and Governor Arnold Schwarzenegger agreed to reduce that state's GHG emissions (12th largest in the world) by 25% by the year 2020 through a "Global Warming Solutions Act".

President George Bush had indicated that he has no intention to submit the treaty for ratification, not because he doesn't support Kyoto principles, but rather because of its China and India exemptions, strains it would put on the US economy, and uncertainties regarding actual climate change benefits.

Sources:

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Pravda, 2004. "Russia Forced to Ratify Kyoto Protocol to Become WTO Member." http://www.english.pravda.ru/main/18/188/354/14495_kyoto.html

The White House, 2001. "President Bush Discusses Global Climate Change." http:/www.whitehouse.gov/news/releases/2001/06/20010611-2.html

Ackerman, D., 2002. "Global Climate Change – Selected Legal Questions about the Kyoto Protocol." Congressional Research Service. http://www.opencrs.com/getfile.php?rid=33856.

Full Text of the Kyoto Protocol (HTML Version). http://unfcc.int/resource/docs/convkp/kpeng.html

20. Abrupt Climate Change

Up until the 1990s the general view of climate change was one of the gradual responses to natural and human-induced influences. Observations of more rapid changes during the past few decades suggest that developments can occur much more abruptly as records of past events reveal. Such climate shifts may persist for years or longer, involving marked average temperature changes and altered storm, flood and drought patterns over an entire country or continent. In the context of past abrupt events these changes can occur within a single decade.

Severe droughts and other abrupt climate changes in the past have brought hardships upon societies which have had little time to adapt. The Natural Research Council emphasizes that while it is important not to be fatalistic about these threats, downplaying their significance can be costly. They conclude that "*Increased knowledge is the best way to improve the effectiveness of response; research into cases, patterns, and likelihood of abrupt climate change can help reduce vulnerabilities and increase our abilities to adapt.*"

Source:

National Academy of Sciences, 2007. "Abrupt Climate Change: Inevitable Surprises." Report from the Oceans Studies Board and the Board on Atmospheric Sciences and Climate of the National Research Council. http://dels.nas.edu/abr_clim/

21. Terrorist Threats to LNG Terminals

Proposals to build new liquid natural gas (LNG) ports usually face stiff opposition resulting from public safety concerns regarding accidental explosions and terrorism. The Federal Energy Regulatory Commission has estimated that if terrorists were to blow a hole in a tanker coming into a port or tied at a dock, it could threaten people three-fourths of a mile away, creating enormous vapor clouds and fires. (LNG tankers were temporarily banned from Boston Harbor and the Everett, Massachusetts facility following the September 11 attacks on New York and Washington, DC.)

22. Russia Advances Towards Nuclear Power Dominance

Russia is moving rapidly and aggressively to establish itself as a world nuclear power leader with major control over global uranium supplies. One example of this goal is its current initiative to construct the first in a series of floating nuclear power plants to provide combined process heat and electricity for its own use. Russia also plans to export plants and technologies to many other countries.

The initial floating ship-mounted plant containing a pair of 35 MW units is scheduled for completion in 2010. Modeled after units in operation for Russian nuclear-powered submarines and ice breakers, the reactors will supply power to the Sevmash shipyards that build nuclear-powered submarines, and where the plant vessel is being constructed.

The first seven of the floating nuclear plants are being designated for remote Russian sites that are chronically short of power. The Russian natural gas giant Gazprom is considering some units for Arctic oil extraction operations. But at an April 15, 2007 ceremony attended by the head of Russia's Federal Atomic Energy Agency (Rosatom) it was announced that the real promise of this "new Russian technology wonder" is the introduction of nuclear power to developing nations. Russian nuclear officials reported that a dozen nations in Asia and Africa have expressed interests in obtaining floating plants, and Russia has offered to provide the technology to many countries, including China, Malaysia, Algeria, Argentina and Namibia. Russia is negotiating with Namibia to secure uranium fuel from them.

According to plans, Russia will own and be responsible for the facilities that operate in other countries, and they would be returned to Russia for defueling and maintenance. Each plant would have the capacity to supply power needs for a city of 200,000 people, or when used for desalination, produce 240,000 cubic meters of fresh water daily. It is estimated that one floating nuclear power plant will replace up to 200,000 tons of coal, or 100,000 tons of petroleum each year.

Russia has been working to rebuild and modernize its nuclear power industry since the late 1990s, but hadn't really gained strong progress until President Putin reasserted national sovereignty and initiative. Although they are building new conventional nuclear power plants in Iran, China and India, they are also providing modern technology available for export.

Russia plans to commission two new nuclear reactors per year for its own use beginning in 2010, with 40 plants on-line by 2030. In November, 2006, Russia merged its state nuclear fuel producer, TVEL, with nuclear materials and services exporter Teksnabexport to form a new Uranium Mining Company that will prospect for and mine uranium in Russia and abroad. **(1)**

Russia produces less than half of its own nuclear fuel, and has obtained most of the rest through partnerships involving uranium mining and fuel processing with the Ukraine and Kazakhstan. Fuel fabrication occurs in Russia, and some is then sold back to the Ukraine for its nuclear plants. Kazakhstan has the world's second largest proven uranium reserves (17%) and is the third largest producer. In July, 2006, Russia's Rosatom signed joint venture agreements with them to establish joint ventures to explore an estimated 19,000 ton uranium deposit located near the border of neighboring Uzbekistan and Kyrgyzstan. Kazakhstan also wants to build its first nuclear plant and to participate with Russia in plans to produce fuel for other countries. A joint Russia-Kazak uranium center is planned to be built at the Angarsk Electrolysis Chemical Plant in Eastern Siberia to enrich Kazak uranium, and both countries will celebrate production of the first ton of uranium at the Zarechnoye mine through a joint venture that was initiated in 2004. Kas Atom Prom announced it will increase uranium mining fourfold to 15,000 tons by 2010.

Russia's Rosatom and Uzbekistan are discussing a joint venture that may produce 300 tons of uranium per year, and Russia expects to build nuclear plants throughout Eastern Europe along with a fuel infrastructure to support them. At the end of October, 2006, Russia's nuclear export company, Atomstroiexport, won a tender to build two new 1,000 MW plants outside of Sofia, Bulgaria, and their Uranium Mining Company is exploring a possible joint mining project with Bulgaria.

In February 2007, Rosatom announced a joint venture agreement with the African nation of Namibia which holds the world's largest uranium reserves (more than 280,000 tons) and is the fifth largest uranium producer (7%). During a September, 2006 trip to South Africa, Russian President Vladimir Putin invited South African engineers to study at Russia's Nuclear Research Institute at the Academy of Sciences and proposed that the two countries cooperate in peaceful use of atomic energy and uranium enrichment. In February, 2007, Russia's Renova Group and South Africa's Harmony Gold Mining signed a memorandum of understanding expressing joint interests in developing South African gold and uranium deposits. Both Russia and South Africa plan large-scale nuclear power development over the next two decades, and it has been proposed that Russia can supply South Africa with floating nuclear plants. South Africa is presently developing a "next-generation" high temperature gas-cooled pebble bed nuclear reactor.

Other African nations are also pursuing international nuclear power joint ventures. In October, 2006, China's *People's Daily* reported that the Zambian government had established a team of experts to explore ways to exploit its uranium reserves and develop a national policy. Chinese nuclear officials have been touring Africa to secure joint agreements for development of uranium resources.

Russia is engaging in active negotiations involving nuclear power ventures with the US strategic allies Saudi Arabia and Japan. At a February 13, 2007 press conference in Riyadh (during a Putin visit), Saudi Foreign Minister Prince Saud al-Faisal stated that six Gulf states are interested in nuclear energy with Russia's help. Given that the US has been working for the past ten years to prevent Iran from completing its Bushehr nuclear power plant which is under the International Atomic Energy Agency (IAEA) inspection regime, it appears unlikely that any Gulf country will turn to the US for similar assistance.

Russia is exploring cooperative nuclear power development relationships with Japan that can potentially include joint projects using fast nuclear reactors and use of a Russian center for the storage and processing of spent fuel. In 2005 at a round table on Russian-Japanese cooperation, Viktor Pavlyalenko from the Russian Academy of Sciences reported that "*Russia and Japan will cooperate to ensure the energy security in Northeast Asia as a whole*", which will include nuclear energy.

Japan produces nearly 30% of its electricity using nuclear energy and is looking to secure long-term fuel supplies from uranium-rich Central Asian nations. Japan and Kazakhstan agreed to cooperatively develop Kazak uranium resources in November 2005. China and South Korea are also aggressively pursuing Kazak uranium supplies, presenting competition for Japan.

In January, 2007, the Japanese press reported that the Russian state-run nuclear power company had approached Japan's Toshiba Corp (which purchased the Westinghouse Electric Company in 2006) and Ishikawajima-Harima Heavy Industries Company (IHI) to explore cooperation in the manufacture of nuclear plants. The Japanese companies might supply steam turbines and generators to Russia. One month later Japanese Trade Minister Akira Amari announced at a press conference that Japan will begin talks with Russian companies to enrich spent nuclear fuel from Japanese plants, stating that "*Russia can be an important option for Japan for spent fuel enrichment, given that there's a limited number of providers*." (About 6,400 tons of uranium recovered from spent Japanese fuel rods are presently being stored in the UK and France which the Russians might help enrich and recover for use.) Russia now provides about 10% - 12% of Japan's needs for low-enriched uranium through unofficial intermediary arrangements and side schemes.

Electric utilities that operate nuclear power plants in the US are concerned about global uranium competition, and have begun to pressure the government in Washington to negotiate long-term enriched uranium deals with Russia. It is clear that the world map for nuclear fuel is rapidly being configured in Russia's favor. **(2)**

Sources

1. Executive Intelligence Review, Marsha Freeman, April 27, 2007. "Russia building first floating nuclear power plant."
2. Executive Intelligence Review, Marsha Freeman, March 23, 2007. "Changing world map for nuclear fuel."

23. The Case for Nuclear Breeder Reactors

When former President Jimmy Carter put a stop to plans for breeder reactors to reprocess spent nuclear fuel in the interest of discouraging global nuclear weapon proliferation it was expected that other countries would follow the US's lead. This has not been the case however. Prototype "fast-neutron-breeder reactor" plants have existed in France since 1974, and in Russia since 1981. Japan plans to incorporate closed-cycle plants with breeder reactors systematically during this century, and India and China have similar plans. Technology currently exists for recycling spent nuclear fuel, and fast neutron sodium-cooled reactors have been operating for many years.

Nuclear fuel recycling offers two important advantages. One is to greatly extend uranium supplies which may otherwise soon become depleted as many other countries continue to add nuclear capacity to accommodate growing power needs. The other is to reduce hazardous nuclear waste accumulations. It is estimated at the present rate of production there will be enough spent nuclear fuel waiting by 2010 to fill the 70,000 metric ton capacity at the Yucca Mountain Repository in Nevada if that facility ever opens. This has been blocked by arguments over storage regulations for years, and no license is expected to be granted soon. A previous requirement for 10,000 years of safe storage has recently been extended to millions of years, and intense bureaucratic infighting over safety and security needs continues.

Advocates for breeder reactors argue that there is much public confusion about protracted times for safe storage due to failure to recognize differences between direct products of uranium fission and the "transuranics" contained in spent fuel. Transuranics are the isotopes that build up in the fuel when a uranium atom captures one or more neutrons without fission which decay into various elements. Plutonium-241, for example, decays into americum-241, which can then also capture neutrons. Several of these isotopes do have lifetimes of thousands and even tens of thousands of years, and some can generate enough heat to present storage problems.

Existing and emerging recycling processes offer ways to reduce these hazards. One that is in use abroad applies three chemical steps to separate some of the uranium, plutonium, other transuranics and fission products to drastically reduce volumes of contaminated liquid wastes. The recovered plutonium can then be used in thermal neutron reactors for two more cycles before higher isotopes of plutonium stop the fission process.

Another method under development called "pyrometallurgical recycling" or "electro refining" removes the fission products from the uranium, plutonium and other transuranics to leave only small waste volumes consisting almost entirely of fission products. These products have much shorter half-lives than transuranics, reducing necessary storage times from thousands to hundreds of years. Although the remainder, consisting of plutonium mixed with other transuranics represent a potential theft target, they offer an acceptable fuel for fast-neutron breeder reactors.

Breeder reactors offer the final step in development of modern nuclear reactor technology using a closed fuel cycle. Experimental Breeder Reactor No. 1 developed after World War II was the first to generate electricity from nuclear energy (1951), and its successor, ERB-2 operated successfully for 30 years from the early 1960s.

<u>Source</u>

William R. Stratton and Donald F. Peterson*, Editorial Commentary. <u>Barron's</u>. November 20, 2006. Vol. 86, Issue 47; pg 46. "Needed for nuclear power, fuel recycling mitigates waste worries and is key to new plant construction."

*The authors are nuclear scientists retired from the Los Alamos National Laboratory and members of the Los Alamos Education Group, a non-profit organization advocating increased use and development of nuclear energy.

24. Electric Power Industry Sources, 1994-2005

Coal, natural gas and nuclear (in combination) have consistently provided about 85%-88% of total net electricity generation between 1994 and 2005, although trends for each of these major sources have differed:

- Coal generation grew 1.7% in 2005 over 2004 (less than overall generation growth), and its part of the total has continued to show a slow decline (from 52.1% in 1994 to 49.7% in 2005).
- Natural gas had highest growth of the three from 2004-2005 (6.9%), accounting for 14.2% of the total in 1994, increasing to 18.7% in 2005. (This reflects a large increase in natural gas-fired capacity since 2000.)

  Natural gas growth has occurred in spite of rapidly rising fuel costs. Average costs of natural gas to power electricity generation increased from a previous record high of $5.96 per million Btu (MMBtu) in 2004, to a new record high of $8.21/MMBtu in 2005, representing a double-digit percentage increase for the third year in a row. This was due in part to high demands for heating and petroleum in combination with natural gas supply disruptions in and around the Gulf of Mexico caused by Hurricanes Katrina, Rita, and Wilma during the second half of 2005.

- Nuclear power generation has essentially maintained an approximate 20% share of total net electricity from 1994-2005 (although no new plants have been constructed, improved plant operations have expanded generating capacities). Fuel component costs are relatively small, with most uranium purchased through long-term rather than spot markets.

Petroleum-fired generation grew only about 1.6% between 1994 and 2005, accounting for about 3% of total electricity from all sources. Renewable sources (not including hydroelectric) grew about 5% during this period, accounting for approximately 2.3% of total generation. (Biomass provided the majority of all non-hydro renewable generation.) However wind showed strong 25.9% growth over the 2004-2005 period, with a record 17.8 billion kWh out of a total 94.9 billion kWh for biomass, wind, geothermal and solar combined.

Net generation for hydro plants increased slightly over 2004, but the level was still lower than the peak year (1997). During the 1999-2004 period, the US West experienced one of the most severe droughts in its history, but precipitation improved in the Northwest beginning in Spring, 2005.

<u>Source</u>

Electric power Industry 2005: Year in Review, US DOE, Energy Information Administration/Electric Power Annual 2005.

25. Oil Company Issues and Positions

Large oil companies are coming under government and public pressure to address environmental and global warming concerns. The US Department of Transportation's Pipeline and Hazardous Materials Safety Administration, which enforces oil pipeline regulations, amended a corrective action order against London-based BP, initially issued in March, 2006, requiring the company to improve safety of its North Slope Alaska pipelines for the third time. Oil spills attributed to corrosion led to a partial shutdown of their Prudhoe Bay operation, the largest US oil field, in 2006. **(1)**

Many companies are publicly "going green", both to improve their public images and to cash in on large government incentives to develop alternative energy programs. BP announced in 2005 that it plans to earmark $8 billion through 2015 to develop wind, solar, and hydrogen power. Houston-based Conoco Phillips has committed $100 million to a project with Tyson Foods to convert beef, pork, and chicken fat wastes into biodiesel fuel (which will account for about 3% of their total diesel output). **(2)**

San Ramon, California-based Chevron Corp, has pledged to spend nearly $5 billion for alternative and renewable energy technologies from 2002 to 2009, and currently owns a stake in a biodiesel plant under construction along the Houston Ship Channel. Hague-based Royal Dutch Shell has already spent more than $1 billion on biofuels, wind, solar, and hydrogen since 2000, and distributed about 100 million gallons of biofuels in 2006. Paris-based Total has committed more than $673 million for renewable projects between 2005 and 2010.

Not all large oil companies are jumping on the alternatives bandwagon yet. Irving, Texas-based Exxon Mobil Corp. has repeatedly stated that it isn't inclined to invest in anything that lacks profitability without subsidies, and until then, will stick with oil and gas. Exxon has, however, given $100 million to support a Global Climate and Energy Project at Stanford University that is working to develop cleaner energy technologies, and other oil majors have also provided large grants for similar initiatives. Exxon has cited unprofitable solar and nuclear initiatives of the past that require subsidies to work.

The National Biodiesel Board doesn't agree with successful efforts of companies to push through and gain access to federal US Treasury tax incentives aimed at encouraging emerging biodiesel technologies. Conoco Phillips can use changes in the tax credit law to get the same $1 per gallon allowance for renewable diesel processed at their existing refinery that biodiesel companies get for processing the fuel at new plants. They regard it to be bad public policy for taxpayers who are paying about $3 per gallon for gasoline to have their taxes pay another dollar so that companies like Conoco Phillips can break even or move toward profitability. **(2)**

Sources:

1. Houston Chronicle Business Section/Bloomberg News, May 8, 2007. "BP told to upgrade anti-corrosion efforts".

2. Houston Chronicle Business Section, Kristen Hays, May 14, 2007. "Big oil slowly, but surely, going green". Kristen.hays@chron.com

26. Biofuels

Many firms are flocking to biofuels, at least in part, because of a US White House energy plan announced in 2005 that is intended to reduce dependence upon foreign oil. The President's Energy Policy Act aims to double the use of ethanol and biodiesel by 2012. Important agribusiness powerhouses that are getting heavily involved include Archer Daniels Midland, Royal Dutch Shell, Siemans and Cargill. Large chemical producers such as Du Pont, Monsanto, and Dow Chemical are also advancing projects to develop biofuel opportunities, including new crop and seed technologies to boost production per acre, and finding ways to convert cellulosic plant fibers to fuels.

Biofuels currently constitute about 3% of all energy used in the US, but their share of the total is expected by many to become substantially larger. US Energy and Agriculture departments estimate that the country can produce 500 million tons of biofuels annually, the energy equivalent of about 1 billion barrels of oil. The Renewable Fuels Association (RFA), a Washington, DC trade organization, states that 40% of all US gasoline already contains ethanol.

Archer Daniels now produces about 1.1 billion gallons of ethanol per year from corn, and plans to build two new dry corn milling plants that will increase production by 500 million gallons/year. Du Pont is seeking ways to overcome hurdles in efficiently producing ethanol from corn stover and other cellulosic plant wastes, and has teamed with Broin, a biotech firm, to develop microbes that can digest the tough materials.

Kevin Coats, an energy policy consultant in Bethesda, Maryland, points to unresolved cost factors associated with energy required to harvest and process crops into fuel. He has expressed his opinion that "I still don't see biofuels as being the end-all as a gasoline substitute". **(1)**

Canadian companies are also getting involved in the rapidly accelerating biofuel trend. For example, ALCOA Canada has recently used bio-oil in place of regular oil to heat a furnace at one of its smelting plants, potentially setting the stage for other Canadian operations. Erie Flooring and Wood Products in Ontario is converting wood wastes into bio-oil using a special pyrolysis processing facility for this purpose. **(2)**

There can be no doubt that biofuel growth is already having huge impacts upon global food prices. US corn prices doubled during 2006, thanks largely to artificial ethanol markets mandated by Congress, which consumed 20% of that food crop, yet displaced only 3% of gasoline use. Consumers from the US to China are paying more for eggs and milk because cows, pigs, sheep, and chickens all eat corn. Mexicans are paying more for tortillas, and German beer prices have risen as well.

High subsidized corn prices are motivating farmers to move away from other food crops, such as soybeans, to plant as much corn as possible, often using expensive genetically-modified seeds and liberal applications of fertilizers to boost production. This greatly benefits large agricultural-chemical businesses which receive most of the subsidies, but offers limited rewards to small family farms. **(3)** As some have commented, America's breadbasket appears to becoming the nation's fuel tank.

<u>Sources</u>

1. Investors Business Daily, Doug Tsuruoka. October 16, 2006. "Crops, leaves, wood scraps = fuel: Biofuel push getting into gear". A-6, Internet & Technology, Investors.com
2. Investors Business Daily, Doug Tsuruoka. October 16, 2006. "A firm's patented pyrolysis converts waste into bio-oil". A-6, Internet & Technology, Investors.com
3. Barron's, Thomas G. Donlan, July 23, 2007. "Where the tall corn grows: Capital Hill's cure for problems caused by spending is… more spending". Editorial Commentary. http://tg.donlan@barrons.com.

27. Objections to Wind Farms

Public opposition to wind farms is not limited to residents and landowners of urban locations and coastal resort areas, but is also found in ranchlands, most particularly in Texas. In 2006, Texas pushed past California as the leading US wind energy producer, and wind farm developers are hoping to greatly expand this capacity. One company wanted to build about 100 turbines across an area about nine miles long and two miles wide in an "unspoiled" part of North Texas near Squaw Mountain Ranch, including at least a dozen of the 250 ft tall towers on the property. The ranch manager, Dan Stephenson, declined to lease land for the project, stating "I'm not interested in having blinking red lights causing the Milky Way not to be as bright or to hear them when I now hear nothing up here but the sounds of nature… Wind farm, that's a spin term… I call them wind turbine industrial zones."

According to the American Wind Association, Texas wind farms accounted for almost one-third of those installed in the US. The state also has the largest operating wind farm, the Horse Hollow Wind Energy Center in Nolan and Taylor Counties. Dale Rankin, who owns a horse ranch in Tuscola, Texas, about 20 miles south of Abilene, is not happy about this. "When they put 1,000 of these next to your property, you're not living out in the country anymore."

Jack Hunt, president of the Legendary King Ranch in South Texas, doesn't want them on or near his property either, and has been fighting a proposal to locate 267 turbines on a neighboring ranch near the coast in Kennedy County. He believes the development is likely to have a major impact upon a so-called "river of birds," the flyway from Canada to Mexico that funnels numerous migrating bird species through the area. He compares the result to "erecting a 10 mile wall".

Hunt and other critics argue that wind power doesn't merit major tax subsidies that drive such developments. Since wind is variable, the Electric Reliability Council of Texas, which controls most of the state's power grid, calculates that it can depend upon only 2.6% of wind power capacity being available during peak summer demand periods. Hunt commented that "we're destroying so much scenery for so little power."

<u>Source</u>

Houston Chronicle, Thomas Korosec, February 5, 2007. "Fight over wind farms: turbines generate opposition".

28. Ethanol Net Energy Efficiency

Various studies by different organizations present ranging estimates of the "net energy" gain of ethanol produced from corn and other feedstocks after energy required for planting, harvesting, and processing are accounted for. Most studies appear to suggest that net energy yields for corn are "positive", potentially as high as 35% or more.

A US Department of Agriculture study published by the Office of Energy Policy in 1995 concluded that ethanol produced from corn provides 34% more energy than is needed to grow and harvest the corn and to distill it into alcohol. According to the report written by Husein Shapouri and others, "studies conducted since the late 1970s have estimated the net energy value of corn ethanol. However, variations in data and assumptions used among the studies have resulted in a range of estimates. This study identifies the factors causing this wide variation and develops a more consistent estimate. We show that corn ethanol is energy-efficient as indicated by an energy ratio of 1.24". **(1)**

An update of that report published in 2002 by Husein Shapouri and James Duffield of USDA along with Michael Wang of the Center for Transportation Research, Energy Systems Division at the Argonne National Laboratory states that "For every Btu dedicated to producing ethanol, this is a 34% energy gain… only about 17% of the energy used to produce ethanol comes from liquid fuels, such as gasoline and diesel fuel. For every 1 Btu of liquid fuel used to produce ethanol, there is a 6.34 Btu gain." **(2)**

An even more recent 2005 report by Michael Wang concludes that ethanol generates 35% more energy than it takes to produce it. This estimate supports earlier research conducted at USDA, Michigan State University, the Colorado School of Mines, the Institute for Self-Reliance, and other public and private entities that indicate a positive net benefit. **(3)(4).**

Sources

1. Shapouri, S. et al., 1995. "Estimating the net energy balance of corn ethanol". USDA Economic Research Service, Office of Energy and New Uses, Agricultural Economic Report no. 721. July, 1995. www.ethanol-gec.org/corn_eth.htm.
2. Shapouri, S. et al., 2002. "The energy balance of corn ethanol: An update". USDA Economic Research Service, Office of Energy and New Uses, Agricultural Economic Report no. 813. 2002. www.usda.gov/oce/oepnu/aer_814.pdf.
3. Michael Wang. www.ncga.com/public_policy/pdf/03_28_05ArgonneNatlLab EthanolStudy.pdf
4. Journey to Forever, Keith Addison. "Is ethanol efficient". http://journeytoforever.org.

29. Bush Administration Energy Proposal

On January 23, 2007 the Bush Administration set a goal of cutting US gasoline use by 20% in 10 years, with a four-fold increase in alternative fuels and tougher fuel economy standards. The new energy plan would require the use of 35 billion gallons of ethanol and other alternative fuels (including hydrogen) by 2017, raising the share of such fuels to 15% from 3% in 2006. The other 5% reduction in gasoline use would come from raising the fuel efficiency standards for cars, light trucks, and SUVs by 4%/year starting with the 2010 model year for cars, and 2012 for trucks. This is projected to reduce gasoline use by 8.5 million gallons/year by 2017. Another goal of the plan is to stop the growth of CO_2 emissions from passenger vehicles within 10 years.

As an additional step towards energy security, the White House proposes to double the capacity of the Strategic Petroleum Reserve to 1.5 billion barrels by 2027. Following this announcement, crude oil surged between $2.46 and $55.04 per barrel, and ethanol stocks also soared.

Kevin Brook, an analyst with Friedman Billings Ramsey noted that the targets set may represent minimums acceptable to Democrat leaders in Congress, and that despite greenhouse gas reductions in the plan, "we still see growing Hill support for a cap-and-trade scheme" that sets limits on CO_2 emissions.

Cato Institute senior fellow Jerry Taylor commented that renewable fuels aren't widely used because they are not cost-efficient, and that Bush wants to change this through "mandates and subsidies and R&D." He believes that the alternative fuels goals could "skyrocket energy costs." Taylor also sees a strong inclination in Congress for making promises "that purport to address global warming," but not "much appetite to impose costs."

Source

Investor's Business Daily, January 24, 2007. "Bush favors cutting gasoline use 20% via renewable fuels".

30. Regional Energy Strategies

A rapid trend in North America to deregulate electric power production offers benefits to small distributed plants which are most viable on a deregulated basis since large utilities don't like to maintain many small sites. Local plants that provide combined heat and power (CHP) offer particular advantages because thermal energy can't be piped efficiently over long distances, and very small plants can offer strong economic advantages. **(1)**

Development of more small, regional gasoline refineries will make it easier to supply special "boutique" mixture demands in different parts of the country. Various blends can be formulated for hot and cold seasonal conditions and state regulatory requirements. This might open up competition among new refiners which can reduce costs to consumers. Refiners in California, the state with the most stringent regulations, tend to enjoy the highest profit margins. **(2)**

Sources

1. Ben Wiens, 2002. "The Future of Energy"http//:benwiens.com/energy3.html.
2. RAND Study. "New forces at work in refining: Industry views of critical business and operations trends" ISBN: 0-8330-3436-7, 2003.

31. States and Cities "Doing Battle on Global Warming"

Thirty-one states representing about 70% of the US population announced on May 8, 2007 that they have signed onto a new Climate Registry to measure, track, verify and publicly report greenhouse gas emissions by major industries (an emphasis upon CO_2). Six days later, New York mayor Michael Bloomberg hosted a Large Cities Climate Summit of mayors from about 30 major global cities. "It is in cities that the battle to tackle climate change will be won or lost," stated London mayor Ken Livingston. A variety of measures were discussed, including development/use of advanced biofuels to recycle more solid waste, setting high energy efficiency standards for new buildings, and creating new parks with large numbers of trees.

Former President Bill Clinton stated at the Summit that his personal foundation had arranged for $5 billion in energy-efficiency loan commitments from five major banks to be lent to city governments and landlords in 16 world cities including Houston, Bangkok, Berlin, Chicago, New York, Sao Paulo, Tokyo, and Mumbai. Representative purposes would be to pay for replacing inefficient heating, cooling, and lighting systems, sealing and upgrading windows, and sensors to make lighting and air-conditioning more efficient. The proposed plan would provide essentially cost-free financing, with energy efficiency savings used to pay back initial investments.

Another organization, the US Climate Action Partnership, announced that it now had 27 large corporate and private members that are advocating a CO_2 "cap-and-trade" system through government lobby activities. The members include General Motors, Environmental Defense, Du Pont, BP America, and Shell.

<u>Source:</u>

Houston Chronicle, Neal Peirce, May 29, 2007. Viewpoints, Outlook, "Cities are warriors in coming global warming battles".

32. Hydrogen Production, Storage Forms and Use

Hydrogen for combustion or fuel cells can be produced by applying a direct current to water (electrolysis) or steam methane reforming (SMR) of natural gas or other hydrocarbons. The electrolysis process is the opposite reverse reaction to what occurs in fuel cells, and in both cases, the energy conversion efficiency is typically less than 50%. Only about 4% of hydrogen worldwide is produced using electrolysis, most often for on-site purposes.

Pure hydrogen (H_2) can be stored in gaseous or liquid form (LH_2). In a gaseous form, it is highly combustible, and will burn in concentrations as low as 4% H_2 in air. The gas explodes upon ignition when mixed with oxygen, reacts violently in contact with chlorine and fluorine, and is difficult to contain, due to small molecular size that leaks through porous materials, cracks, or bad joints. H_2 has good energy density per weight, but very poor density per volume (compared with gasoline).

LH_2 has higher volumetric energy density than gaseous H_2, but requires low temperature storage, and still has much worse energy density per volume than gasoline. Since LH_2 boils at about -423°F (-253°C), expensive tank insulation is required. It is cold enough to freeze air, and can cause valves to plug up in automotive fuel applications. Production and transportation of LH_2 or H_2 can require more than twice the energy recovered.

Different ways to transport hydrogen from production through distribution are being pursued within the energy industry. One approach is to store it within ammonia (NH_3) for later release using a catalytic converter at the destination. Since ammonia is the second most commonly produced chemical in the world, a large production, transportation, and distribution infrastructure already exists. Although ammonia burns poorly at atmospheric pressures, under compression in conventional engines with slight modifications, it is a reasonable fuel that burns efficiently. Disadvantages of ammonia are that it is very energy-expensive to produce, and it is a toxic gas with a potent odor at ambient temperatures.

Metal hydrides can be used to store hydrogen as liquids or solids, and sodium borohydride, lithium aluminum hydride, and ammonia burane are among leading candidates. Sodium borohydride and ammonia burane can be stored as liquids when mixed with water, but must have very high concentrations for desirable H_2 densities, requiring complicated water recycling fuel cells. Sodium borohydride will enable less expensive fuel cells (without platinum contacts) to be used, but is energy-expensive and will require recycling plants. Both liquid and solid metal hydrides afford good energy density/volume, but much worse energy density/weight than gasoline tanks with the same energy. This adds greatly to weight in fuel cell vehicle applications, reducing efficiencies and ranges. Hydrides also present safety hazards for H_2 storage densities above 10% of total weight, and hydrides must be recharged with H_2, either onboard a vehicle, or at a recycling plant.

While solid metal hydride storage is probably most promising for automotive applications, it is likely to require lithium storage vessels that are much larger and more expensive than gasoline tanks for standard cars. A lithium metal hydride tank with the same energy content as a 15 gallon gasoline tank will require about three times the volume (45 gallons), and the metal hydride fuel will weigh about four times more (600 lbs vs. 150 lbs). The lithium tank material will also cost much more (about $40/lb vs. $1/lb for a steel gasoline tank.

An alternative to metal hydrides is to use regular hydrocarbon fuels, such as methanol or gasoline, as hydrogen carriers with a small reformer onboard a vehicle to extract H_2 as needed by a fuel cell. The reformers first break down long hydrocarbon molecule chains into simpler molecules (i.e. hydrogen, water, and carbon), then purify the gas until it is suitable for fuel cell use. The reformate emerges with about 40% H_2, 100 ppm CO, and the rest carbon dioxide and nitrogen. Advantages are that liquid hydrocarbon fuels avoid storage problems and complexities associated with high-pressure H_2 and LH_2 approaches and can use currently established energy production and distribution networks. Direct methane fuel cells can also be used, which do not require reformers to operate, but have lower energy densities than conventional fuel cells. On the other hand, reformers can add costs and complexities, along with associated system maintenance and longevity problems, and also tend to be slow, limiting power generation. Present fuel cells are less energy-efficient than internal combustion engines.

33. Automotive Fuel Cell Problems and Challenges

While a potential advantage of hydrogen is that it can be produced using solar, wind, and nuclear power for electrolysis, this yields much lower efficiencies than applying that electricity directly, potentially for other purposes. When hydrogen is produced in the more conventional way through SMR of hydrocarbons, the process consumes valuable fuels and ultimately creates high levels of CO2 emissions than current internal combustion engines due to the emissions released in creating it. **(1)**

When hydrogen is used in automotive fuel cells, other problems arise that present technology challenges which require attention. Key obstacles limiting popular use are costs and maintenance. Many designs require rare and expensive substances, such as platinum, to work properly and can readily become contaminated by impurities in the hydrogen supply. A nickel-tin catalyst under development may lower costs. More robust fuel cells are also needed that can survive bumps and vibrations that vehicular uses impose. Service life is an important cost factor, which must be comparable to existing engines that last well in excess of 5,000 hours. This represents a major research and development challenge.

Fuel cells also tend to be sensitive to freezing conditions because they produce water and utilize moist air with varying moisture content. Many fuel cell designs can't survive well in cold environments, and present special limitations during power start-up periods of operation, although progress is being made in this area. **(2)**

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34. Ocean Desalination

About two-thirds of the world's desalinated water is produced in Saudi Arabia, Kuwait, and North Africa, and other countries are also developing projects to recover drinkable water from salty oceans and seas. Perth, Australia hopes to provide for one-third of its fresh water needs in this way. Israel has opened a plant at the Mediterranean port of Ashkelon that can process 87 million gallons of water per day, and Singapore opened a sea water desalination plant in 2005 aimed at meeting at least 10% of its needs. General Electric announced a $220 million contract in 2007 to build a plant in South Africa.

Although desalination currently provides less than 0.1% of the world's drinking water, the Global Water Intelligence expects the industry to grow as much as 140% over the next decade through $25 billion in capital investment by 2010, and $56 billion by 2015. The US has hundreds of plants to purify brackish ground water, and is just getting started in processing saltier sea water. A $158 million sea water plant opened in the Tampa Bay, Florida area following years of delays, and California hopes to obtain about one-half a million acre feet per year of water according to their Department of Water Resources. A small $2.2 million pilot plant has been constructed in Brownsville, Texas on a one-acre site on a ship channel in preparation for a full-scale $150 million facility planned for implementation in 2010. Texas Governor Rick Perry began pushing for Gulf of Mexico desalination in 2002 after state officials projected that hundreds of communities may face water shortages in the next 50 years.

Desalination of sea water is expensive due to large amounts of energy required, along with high land costs in some areas. Yet Genoveva Gomez, the Brownsville project lead engineer, believes that in spite of the high costs, desalination projects will continue to expand. "If that's the only solution we have, you get water from the sea or you don't have any, then the cost wouldn't matter." She pointed out that people already pay a dollar or more for a quart of bottled water.

<u>Source</u>

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