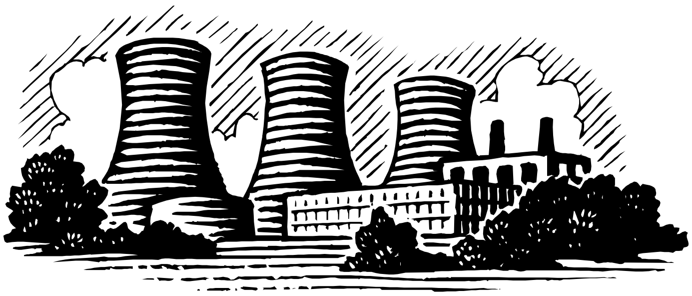
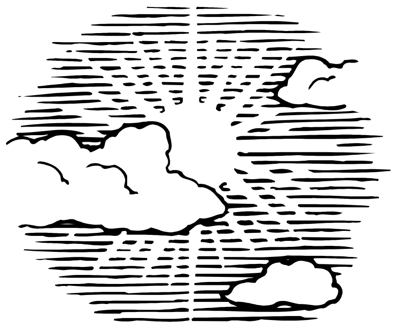
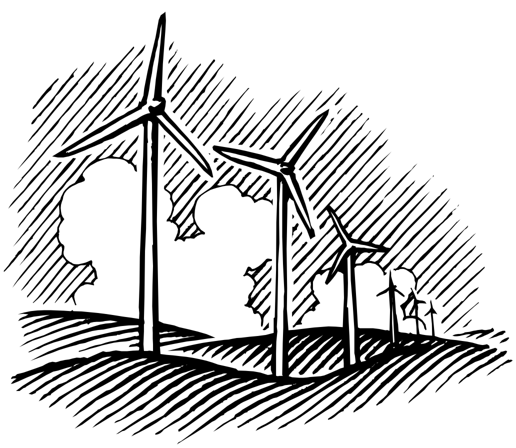
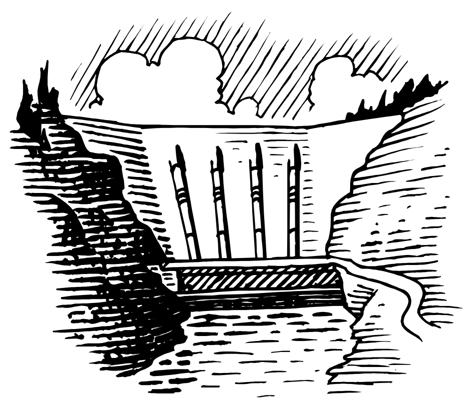
ENERGY AND CARBON









A public interest report on U.S. energy use, pros and cons of existing and proposed energy sources, and considerations and pitfalls of carbon credits and offsets.

Center for Earth Leadership

April 2010

The Center for Earth Leadership is a non-profit organization that trains and motivates
Northwest citizens to assume a leadership role in forging a sustainable culture.
This work is funded by contributions from interested individuals.
See www.earthleaders.org for more information.

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U.S. ENERGY OVERVIEW

ENERGY USE

Although the United States contains less than 5% of the world's population, it consumes 25% of the world's energy. The majority of energy consumed in the U.S. is for electricity and transportation, as can be seen in Table 1 below. However, if electric power is reallocated among the remaining sectors, residential and commercial becomes the number one use of energy in the U.S. (third column below).

Table 1. U.S. Primary and Total Energy Consumption by Sector, 2008

Use of Energy in U.S.	Percent of Primary	Percent of Total
Electric power	40%	
Transportation	28%	28%
Industrial	21%	31%
Residential and commercial	11%	41%
	100%	100%

For a more detailed analysis of the use of energy in the U.S., see Diagram 1, "U.S. Primary Energy Consumption by Source and Sector" on page 2 and Diagram 2, "Electricity Flow" on page 3.

In addition to energy consumed within the U.S., energy is required for the production and transportation of imported goods into the country. For example, an automobile imported into the U.S. from Asia requires energy to produce the automobile in Asia and transport the finished product to the U.S.

ENERGY SOURCES

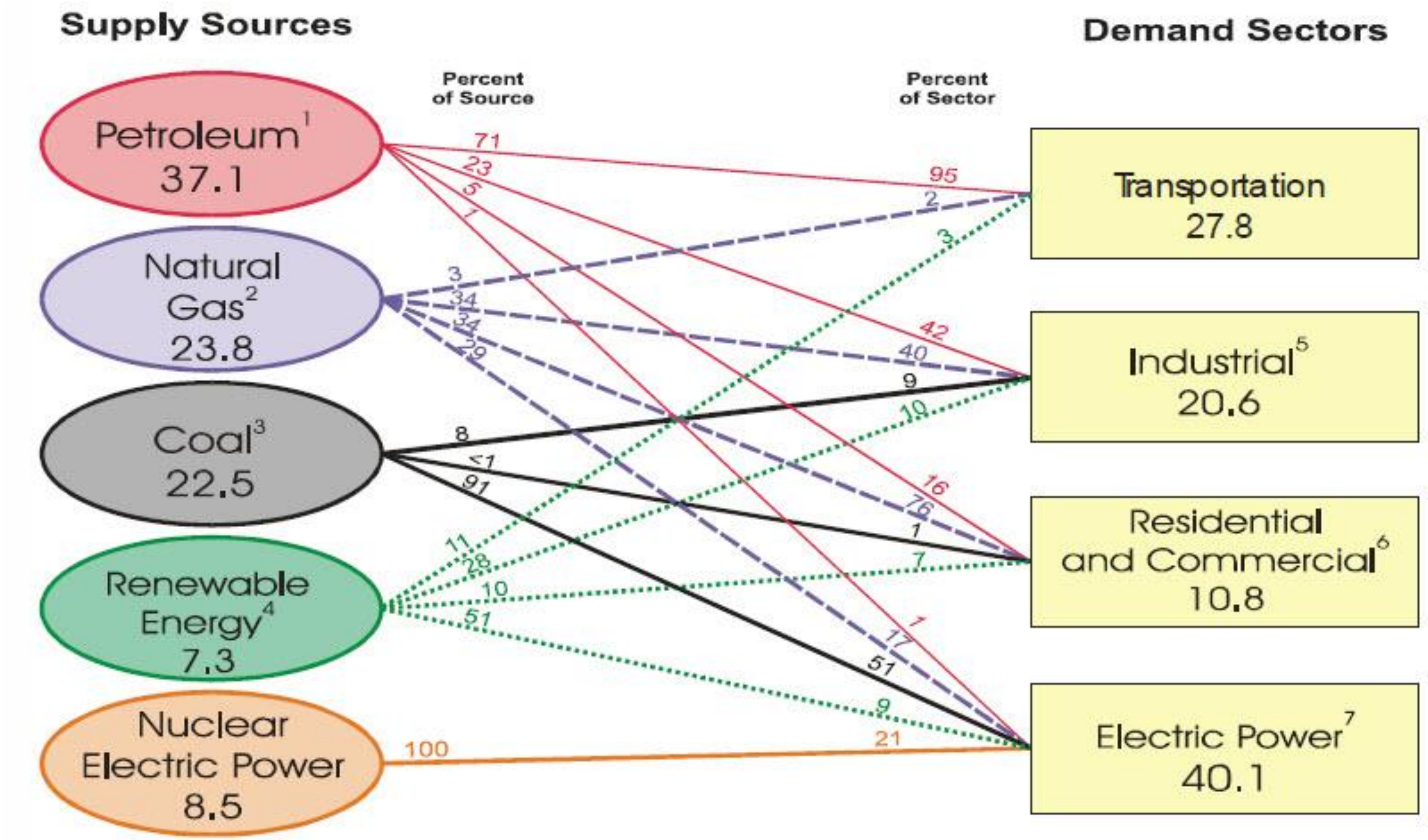
The energy used in the U.S. comes from a variety of sources. However, 84% is derived from fossil fuels. Of the remainder, 9% comes from nuclear, 4% from biomass, and 2% from hydroelectric. Other sources each contribute less than 1%. See Table 2 listing energy consumed by source in 2008.

Table 2. Primary Energy Consumption by Source (2008)

	Quadrillion BTUs*	% of Total
Petroleum	37.137	37.46
Natural Gas	23.838	24.04
Coal	22.421	22.61
Nuclear	8.455	8.53
Biomass	3.884	3.92
Hydroelectric	2.452	2.47
Geothermal	.358	.36
Wind	.514	.52
Solar PV	.091	.09
	99.150	100.00

*A British Thermal Unit (BTU) is the amount of energy required to raise the temperature of one pound of water by one degree F. A quadrillion BTUs is equal to one thousand times one trillion BTUs or 1,000,000,000,000,000.

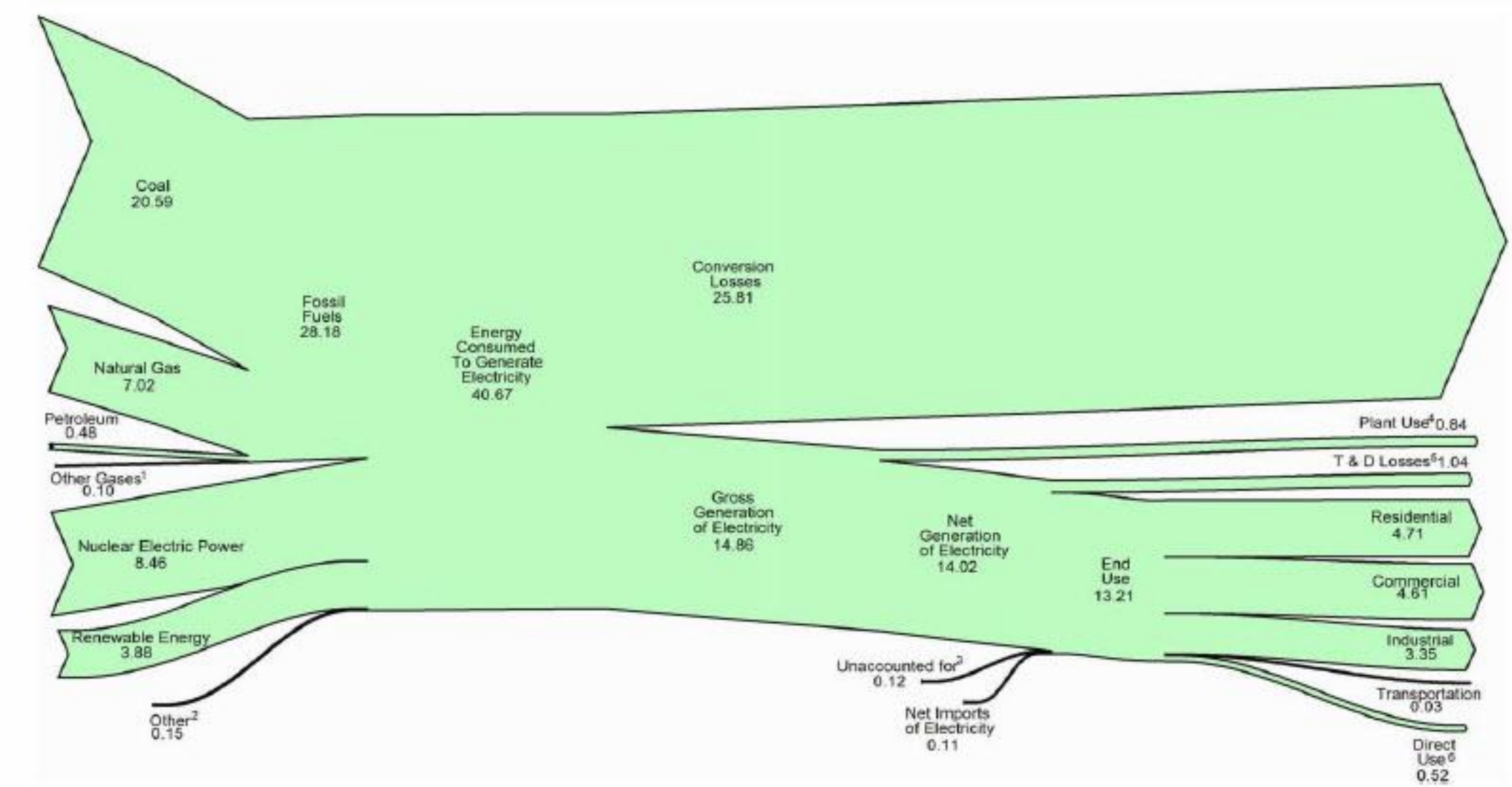
U.S. Primary Energy Consumption by Source and Sector, 2008
(Quadrillion Btu)



[1]Does not include the fuel ethanol portion of motor gasoline—fuel ethanol is included in "Renewable Energy."
[2]Excludes supplemental gaseous fuels.
[3]Includes less than 0.1 quadrillion Btu of coal coke net imports.
[4]Conventional hydroelectric power, geothermal, solar/PV, wind, and biomass.
[5]Includes industrial combined-heat-and-power (CHP) and industrial electricity-only plants.
[6] Includes commercial combined-heat-and-power (CHP) and commercial electricity-only plants.
[7]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: U.S. Energy Information Administration, *Annual Energy Review 2008*, Tables 1.3, 2.1b-2.1f , 10.3, and 10.4.

Electricity Flow, 2008 (Quadrillion Btu)



[1] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.

[2] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, miscellaneous technologies, and non-renewable waste (municipal solid waste from non-biogenic sources, and tire-derived fuels).

[3] Data collection frame differences and nonsampling error. Derived for the diagram by subtracting the “T & D Losses” estimate from “T & D Losses and Unaccounted for” derived from Table 8.1.

[4] Electric energy used in the operation of power plants.

[5] Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer) are estimated as 7 percent of gross generation.

[6] Use of electricity that is 1) self-generated, 2) produced by either the same entity that consumes the power or an affiliate, and 3) used in direct support of a service or industrial process located within the same facility or group of facilities that house the generating equipment. Direct use is exclusive of station use.

Notes: • Data are preliminary. • See Note, “Electrical System Energy Losses,” at the end of Section 2. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

Sources: Tables 8.1, 8.4a, 8.9, A6 (column 4), and Energy Information Administration, Form EIA-923, "Power Plant Operations Report."

Hydrocarbon Fuels

As a group, fossil fuels comprise an energy source sometimes referred to as *ancient sunlight*. Oil, natural gas, and coal formed from plant material over millions of years. Because the energy in these hydrocarbons is so concentrated, their discovery and use by industry has transformed human society. The transformation includes accelerated exploitation of the earth's natural resources, a worldwide population explosion, a highly productive industrial system, and a high level of material well being.

Our nation's reliance on hydrocarbons poses five notable problems: (1) global warming, (2) declining fossil fuel availability, (3) decreasing energy return on investment (EROI), (4) negative ecological impact, and (5) negative geopolitical and economic repercussions.

1. Global warming. Burning hydrocarbon fuels releases carbon dioxide (CO_2) into the atmosphere. When humans began digging up coal to fuel the industrial revolution, the level of atmospheric CO_2 rose slowly at first, then more rapidly in the late 19th century with the discovery of oil. The pre-industrial revolution level of CO_2 in the atmosphere was about 280 parts per million (ppm). Today, the level is 387 ppm, a concentration unseen on the planet in 650,000 years. Temperatures have warmed roughly 1.33°F over the last century, and more than half of this warming has occurred since 1979. Temperature rise occurs more slowly than the increase in CO_2 levels, which means additional warming will continue to occur, even if the CO_2 level were stabilized today.

To avoid catastrophic climate impacts, the Intergovernmental Panel on Climate Change (IPCC) says that we must keep temperature increases within 3.6°F of pre-industrial levels. Researchers from the IPCC, the European Union, and California have determined that meeting this goal will require an 80% reduction from 1990 CO_2 emission levels by 2050. Achieving such a large reduction will require a corresponding massive reduction in the use of fossil fuels, especially coal.

Fossil fuel sources vary in their release of CO_2 per unit of energy. Table 3 provides estimates by fuel source for (1) emissions per unit of energy and (2) the percent of total U.S. emissions, which reflects the higher total usage of oil, for example, over coal.

Table 3. Comparison of Carbon Emissions from Fossil Fuels

Fuel	Metric Tons of Carbon/ Billion BTUs	Total U.S. Emissions from Fossil Fuels
Coal	26	36%
Oil	20	44%
Natural Gas	16	20%

2. Declining fossil fuel availability. Oil is a finite resource. Production in the lower 48 states peaked around 1970 and began falling. Geologists predict that worldwide production will peak around 2011 and begin a decline of 50–60 years. Within 15 years, total oil supplies available to the U.S. may be about two-thirds of what they are today. Natural gas is expected to follow a similar pattern. Worldwide production of both conventional and non-conventional natural gas sources is expected to peak before mid-century. Coal is still plentiful in the United States, but if we attempt to use it to replace oil and natural gas, it will last only about 60 years. Additionally, coal's contribution to global warming and air pollution is a source of national concern. Our inheritance of concentrated fossil fuel is no longer a dependable source of energy.

3. Energy return on energy invested (EROI). EROI is the ratio of the usable energy obtained from a particular source to the total energy required to extract it. When oil was easy to find, pump, and refine, its EROI was as high as 100:1. Naturally we exploited the highest quality resource first. By 1970, the EROI for domestic oil had dropped to 30:1. Today, EROI for domestic oil is less than 14:1. Globally, new fields are rare, located at deeper levels, and smaller in size, and they produce lower quality oil. Even though oil is still available, it requires more energy to extract and process, and it is more expensive.

To mitigate global warming and declining fossil fuels, governments, utilities, and private companies are promoting a massive shift to alternative energy sources. However, these sources cannot make up for the energy embodied in ancient sunlight. The EROI for most alternative energy is lower than we have grown accustomed to, particularly for liquid fuels like biodiesel or corn ethanol. At the high end, the EROI for wind is 18:1; at the low end, some studies have concluded that corn ethanol may be less than 1:1—a negative EROI. Unconventional fossil fuel sources have the same problem. The EROI of oil from tar sands is estimated to be about 5:1. See Table 4 below:

.

Table 4. Energy Return on Energy Investment

Domestic Oil – 1930	100
Domestic Oil – 1970	30
Imported Oil – 2005	20
Domestic Oil – 2005	14
Coal	50
Hydro	>100
Wind	18
Natural Gas	10
Geothermal	8
Nuclear	7
Solar PV	7
Tar sands	5.5
Oil shale	3
Concentrating Solar	1.6
Corn Ethanol	1.2

4. Ecological considerations. As fossil fuels become more difficult to extract, they tend to cause more ecological damage. For example, mountain-top removal for coal has more severe effects than traditional strip or underground mining. Producing oil from tar sands releases up to three times more greenhouse gases than conventional oil and has more severe effects on forests, wildlife, fresh water resources, and air pollution.

5. Geopolitical and economic considerations. Deposits of fossil fuels are dispersed around the world based on random geological prerequisites. As such, fossil fuel that must be sourced from other countries presents an array of geopolitical considerations.

In 1950, our country was the world's largest exporter of oil, and most of the world's goods were manufactured here. By 2005, the tables had turned, with the U.S. being the world's foremost importer of both oil and manufactured goods. This shift has affected our national debt and our trade deficit. Between 1998 and 2008, our gross federal debt rose from $5.5 trillion to almost $10 trillion, and the annual trade deficit rose from $166 billion to $695 billion. World oil prices of $100 or more per barrel are likely before 2020.

Assessing Energy Sources

This report analyzes the existing and proposed energy sources for the United States—how they are used, their potential, their benefits, and concerns arising from their use. Fossil fuel sources are included because they are needed in the immediate future. In fact, some developers and policy makers are actually considering expanding the use of coal through gasification of the fuel and sequestration of CO_2, oil through tar sands and oil shale, and natural gas through shale deposits, coal-beds, and liquefied imports.

Carbon Credits, Carbon Trading, and Carbon Offsets

The second part of this report examines attempts to reduce greenhouse gas emissions through regulatory frameworks, such as the Kyoto Protocol, as well as voluntary offset programs.

ENERGY SOURCES

FOSSIL FUEL: COAL

WHAT IS IT?

Coal is a sedimentary rock that contains between 40–90 percent carbon. Coal was formed millions of years ago when dead plants accumulated in swamps or bogs and formed deep peat mats. As the peat mats were compressed by thousands of feet of sediment, they were converted into brown coal (lignite), and after many millions of years into black, "soft" coal (bituminous), the most widespread form in the United States. The oldest and hardest black coal is called anthracite.

In the U.S., coal is present under about 13% of the land area. Eastern coal, which has the highest energy value, is bituminous. Western coal, found primarily in Wyoming, is subbituminous (between lignite and bituminous). U.S. sources of anthracite have been nearly exhausted.

Traditionally underground mines provided most of America's Eastern coal. Today, surface mining accounts for 60% of production, particularly in the Western U.S., where seams are located closer to the surface. The earth and rock above the seam is removed; the coal is blasted into bits and extracted. As concentrated veins near the surface have been exhausted in Appalachia, operators are now dynamiting mountain tops and bulldozing them into valleys to reach deeper seams.

HOW IS IT USED?

Ninety percent of coal in the U.S. is used for electricity. To produce electricity, coal is usually pulverized and then burned to heat a boiler, producing steam, which powers turbines. Coal accounts for about half the electricity consumed in the U.S. and is the largest category of fuel used to generate electricity worldwide.

ENERGY POTENTIAL

The U.S. has the world's largest known coal reserves. At our current rate of use, domestic coal will not be depleted for 265 years. If we increase our use of coal by 2% per year, it is projected to last 93 years. In part due to clean air regulations, coal production has shifted to Western coal because of its lower sulfur content. Western coal also contains fewer BTUs of energy: power plants must burn 50% more Western coal to match the power output of Eastern coal.

Coal can be converted into synthetic oil or natural gas, called synfuels. In coal-to-liquid plants, developers hope to directly fill the needs now filled by oil.

In another technology, integrated gasification-combined cycle (IGCC) plants use the syngas and waste heat from coal gasification to generate electricity. IGCC plants would also make possible carbon capture and sequestration. Two demonstration IGCC plants have been constructed in the US, but the technology is not yet economical.

BENEFITS:

- Use of U.S. coal reduces our reliance on foreign nations for energy production. One quarter of the world's coal reserves are found within the U.S., and their energy content exceeds that of all the world's known recoverable oil.
- Power from existing coal-fired plants is less expensive than electricity from natural gas-fired plants. The lower fuel costs result in coal-fired generation being operated as a baseload resource (24 hours a day during most days of the year).

- IGCC plants have the potential to significantly reduce air pollutants compared to conventional coal plants. They also reduce carbon dioxide (CO_2) emissions because they are more efficient.
- Proponents of coal foresee capturing CO_2 from IGCC plants or synfuel plants and sequestering it underground in saline aquifers, basalt formations, or depleted oil and gas wells.

CONCERNS:

- Of all energy sources, coal may be the most damaging to the environment and human health.
- Coal-fired power plants contribute more CO_2 to the atmosphere than any other source.
- Coal is the leading source of sulfur dioxide (SO_2), causing acid rain that damages forests and lakes. In the U.S. about 1,200 lakes have become so acidified that fish and many other organisms cannot live in them. At the same time, control devices are capable of removing up to 90% of the SO_2.
- Coal plants also emit significant amounts of nitrogen dioxide, small particulates, hydrocarbons, mercury, arsenic, radon, lead, and cadmium, all of which are harmful to human health. Coal combustion is the largest U.S. source of mercury emissions.
- Transportation of coal also contributes to air pollution. Trains, barges, and trucks all run on diesel, and coal transportation accounts for approximately 50% of U.S. freight train traffic.
- The amount of ash, slag, and sludge generated from burning coal is roughly equivalent to the total amount of municipal solid waste buried in landfills. These wastes are often disposed of in unlined landfills and reservoirs. Toxic metals can leach out, or the reservoirs can be breached, contaminating drinking water supplies and harming local ecosystems. This happened in Tennessee in 2008.
- Plants with once-through cooling can raise the temperature of rivers or lakes by an average of 16 degrees, harming aquatic life.
- Strip mining destroys habitat and creates tons of hazardous and acidic waste, which often contaminates ground water or surface water, killing aquatic life. The mines continue to leach toxic substances long after they are closed. Mountaintop mining in Appalachia has buried more than 700 miles of biologically diverse streams.
- Underground coal mining is the most dangerous major occupation in the U.S. today.
- The net energy return for U.S. coal is falling because the BTU per ton content is declining.
- If coal were to be converted into a liquid fuel (synfuel), the process would almost double releases of CO_2 compared to the production of petroleum fuels unless the CO_2 is captured and sequestered underground.
- Large-scale sequestration of CO_2 has not been scientifically tested. It is unknown whether large amounts of CO_2 can be safely and permanently stored underground. It may take thousands of years for the stored CO_2 to become mineralized into carbonates, risking leakage to the surface during that time.
- Capture and sequestration of CO_2 won't be commercialized until around 2025 and may raise capital costs by 40–50%.

Fossil Fuel: Oil

What is it?

Petroleum, or crude oil, is a naturally occurring, flammable liquid consisting of 50–90% hydrocarbons. Oil was formed when organic material such as zooplankton and algae settled on the sea floor along continental shelves or on lake beds, mixing with sedimentary rock about 500 million years ago. Over the years, tectonic plate movements and volcanic activity buried them under heavy layers of sediment, resulting in high levels of heat and pressure. With no oxygen present, bacteria broke down the organic matter into oil and natural gas.

Oil deposits are found underground at depths varying from several hundred feet to several miles, held within porous rocks and capped by impervious rock. Where oil fields are found, wells are drilled. The primary pumping method usually only recovers about 20% of available oil, leaving 80% unrecovered. To get as much oil as possible in the later phases of pumping, several secondary and tertiary methods are used. These include the injection of water, chemicals, carbon dioxide, and hot steam into the wells. The oil is separated from the gas and water that generally come up with it and piped to ships or refineries. In a refinery, the oil is distilled into gasoline (about 45% of the output), kerosene, diesel, fuel oil (primarily for heating), lubricating oil, and coke.

Oil shale and tar sands contain oil that is not in a liquid state. After the shale or sand is mined, the oil is extracted using a more energy- and water-intensive process than oil drilling. In the U.S., rich oil shale deposits are found in Colorado, Utah, and Wyoming. The largest deposits of tar sands are in Alberta, Canada, which has the second largest proven oil reserve in the world behind Saudi Arabia.

How is it used?

Oil is used primarily for gasoline, diesel, and fuel oil. In the U.S., 70% is consumed for transportation purposes.

Energy potential

Domestic oil production in the lower 48 states peaked around 1970, and many experts say the global production peak is occurring now. We may be on an undulating plateau before the decline begins. The history of oil production suggests that by the middle of the century, worldwide oil production will be at 10% of current levels. The U.S. currently imports about 60% of the oil it uses (Canada is the largest supplier). Any increases in domestic oil are expected to come from offshore, very deep wells, or oil shale.

Benefits:

- Oil has a high energy density: a large amount of energy can be obtained from a relatively small volume of fuel.
- Oil is easily transported and distributed to consumers.
- When refined into gasoline, oil is ideal for powering transportation vehicles.

Concerns:

- The most notorious environmental impact of oil is marine pollution from spills. Between 1963 and 1993, there were over 200,000 oil spills in U.S. waters, dumping over 230 million gallons of oil. Such spills have killed hundreds of thousands of birds, sea otters, and shell fish. (Government regulations have had some effect in reducing spills in recent years.)
- About 85% of oil pollution in North American coastal waters is not from tankers and barges but from dispersed sources such as road runoff, leaky storage tanks and pipes, and boaters.

- Perhaps the worst impact is air pollution from the combustion of oil in transportation and the resulting impact on climate change. Transportation is responsible for one-third of U.S. CO_2 emissions.
- Transportation accounts for 50% of nitrogen oxide emissions in the U.S., leading to acid rain, which damages crops, forests, and buildings, and to health problems from smog. Other emissions include carbon monoxide, ozone, sulfur oxides, particulates, VOCs (volatile organic compounds), and toxic metals, which are hazardous to humans and other species.
- Exploration of coastal reserves using seismic waves can result in whale beaching. Installation of infrastructure in pristine areas such as the Arctic can be harmful to wildlife, such as polar bears and caribou.
- Extracting oil from oil shale and tar sands has more severe environmental impacts than conventional drilling: up to three times the greenhouse gases, destruction of critical habitat for birds and mammals (including virgin forests in Alberta), water withdrawals that threaten fish, and vast ponds of contaminated waste water.

Fossil Fuel: Natural Gas

What is it?

Natural gas is a mixture of hydrocarbon gases, primarily methane. It is a product of ancient plants and animals that were trapped under water or in bogs and decayed without the presence of oxygen. The organic materials were then covered with sediment. Like oil, natural gas is held in porous rocks, such as sandstone, under a cap of impermeable rock. Gas may be found floating atop oil reservoirs or alone in natural gas fields. To reach the gas, holes are bored in a field, gas and oil are extracted, and the gas is separated from the oil.

After extraction, the gas is piped to a processing plant to remove hydrogen sulfide, butane, and propane from the methane. Natural gas is then stored in large tanks or underground in old gas wells until it is transported by pipeline to the end user.

Gas from unconventional sources—tight sands, coal beds, and shale—is released from the ground through fracturing. Fluids are forced into the underground rock at high pressure, fracturing the rock and allowing the gas to flow. In coalbed mining, water associated with the methane must also be pumped out before the gas is released.

How is it used?

Natural gas is used by industry for heat or for combined heat and electricity (called cogeneration); by homes for space heating, water heating, and cooking; and by utilities to produce electricity. Natural gas supplies about 17% of electricity in the U.S. A small proportion is used in its compressed form as a transportation fuel because it is cleaner burning than gasoline.

Energy potential

Natural gas reserves in the U.S. are small compared to coal reserves, but are expected to supply the nation for at least 60 years. North American production may have peaked in 2001. Future domestic sources are likely to be shale, gasses in coal beds, and "tight sands" in the Rocky Mountains. Already, improved horizontal drilling and fracturing technologies are increasing the production of natural gas from U.S. shale. Companies are also attempting to build terminals to receive liquefied natural gas (LNG) from overseas. LNG is natural gas that is cooled and compressed for transport. At its destination, the LNG is re-gasified and sent through a pipeline to market.

Benefits:

- Natural gas produces 43% fewer carbon emissions than coal and 30% fewer than oil.
- Natural gas produces no solid waste and very little sulfur dioxide and particulate emissions.
- Unlike oil, the U.S. can meet a large portion of its natural gas supplies from sources in North America. In fact, after the Middle East and Russia, North America has the largest proven natural gas reserves in the world.
- Natural gas plants are less expensive and have shorter construction times than coal plants.
- Natural gas turbines provide better backup power for intermittent wind and solar power because they can ramp up and down faster than coal or nuclear plants.

Concerns:

- Small amounts of methane enter the atmosphere from leaks from natural gas wells, storage tanks, and pipelines. As a greenhouse gas, methane is 25 times more potent than carbon dioxide. Natural gas use, therefore, accounts for about 10% of all greenhouse gas emissions.
- Combustion of natural gas produces nitrogen oxides, a cause of smog and acid rain.

- Imported LNG, because of the energy used to liquefy, ship, and re-gasify it, has 30% more impact on climate change over its life-cycle than domestic natural gas. LNG imports would increase our reliance on foreign resources. Also, U.S. LNG terminals have been difficult to site because of the risk of catastrophic fire due to a tanker accident or terrorist attack.
- Large-scale drilling of oil and gas wells and the accompanying access roads, pipelines, and waste pits, in areas like the Rocky Mountains, fragment wildlife habitat, displace species—such as elk, pronghorn antelope, and sage grouse—and disrupt breeding and migratory patterns.
- Extraction from non-conventional sources such as tight sands, coal beds, and shale tend to have greater environmental impacts than conventional sources. The fluids used in fracturing underground rock to extract natural gas contain toxic chemicals that threaten groundwater. Also, the water pumped from coal beds during gas extraction can be high in dissolved salts, which can make nearby soils unsuitable for plant growth and be a hazard to aquatic life in streams.

NUCLEAR

WHAT IS IT?

Nuclear power is created by a reactor fueled by enriched uranium. In a fission reactor, nuclei of uranium and its daughter products are split, emitting neutrons that cause other nuclei to split, producing a chain reaction. In a light-water pressurized or boiling water reactor, the most common types in the U.S., the energy from the reactions heats coolant, usually water, which is sent to a heat-exchanger to produce steam and power a turbine.

Uranium ore is mined either in open pits or underground. Mines are located in Canada, Russia, Australia, and the Rocky Mountains. The uranium is chemically extracted from raw ore, converted to uranium oxide (yellow cake), and enriched through gaseous diffusion. (Natural uranium does not include enough of the isotope 235, the key ingredient that starts a nuclear reaction and keeps it going. Enrichment increases its concentration.) Enriched uranium is then sent to a fuel fabrication plant and made into fuel rods for the reactors.

HOW IS IT USED?

Nuclear power is used to produce electricity.

ENERGY POTENTIAL

In 2007, the U.S. had 104 nuclear power plants supplying about 20% of U.S. electricity. No new reactors have been ordered in the U.S. since 1979 because of cost overruns, long delays, problems in quality control, low capacity factors (which have since been resolved), and concerns about safety. Because many U.S. nuclear plants are near the end of their 40-year licenses, owners are getting renewals for up to 20 years. Some analysts expect few, if any, new reactors to come on line in the near future due to their high cost. Other analysts predict a renewal of nuclear plant construction because of the concern about global warming and the heavy federal subsidies that neutralize the cost issue. According to the Nuclear Regulatory Commission, 21 companies intend to seek permission to build 34 power plants.

The U.S. currently possesses enough uranium to fuel existing reactors for the next 40 years. The peak of world uranium production is likely to occur between 2040 and 2050. The industry may begin to reprocess reactor fuel, yielding plutonium and uranium, build breeder reactors that use plutonium as a fuel, or develop reactors that use thorium as a fuel. The U.S. has historically prohibited reprocessing, and breeder development has had a rocky history. Thorium reactors seem promising but will require many years and expensive research and development to commercialize.

In addition to fission, fusion (the combining of two small nuclei to form a larger nucleus) is theoretically possible but has never been successfully converted into useable energy. Billions of dollars have been spent since World War II trying to achieve controlled fusion.

BENEFITS:

- Except for relatively small emissions in constructing the plants and processing the fuel, nuclear plants do not produce greenhouse gases or other air pollutants.
- Nuclear plants provide base-load electricity: they generate power continuously.
- Nuclear plants produce a large amount of energy per unit of fuel, thereby reducing transportation impacts.
- As with renewable resources, nuclear plants have low variable costs, which reduce the risks from fossil fuel price escalation.

CONCERNS:

- The disposition of high-level radioactive waste (spent fuel rods) that won't be safe for thousands of years is the biggest concern. Spent fuel stored in pools on site are vulnerable to terrorist attacks. The problems related to permanent storage of spent fuel have been studied for 30 years but have not been resolved. In 1987, Yucca Mountain, Nevada, was selected as the site for a geologic repository, but it was never proven that radioactive materials would not escape into the ground water, and it has now been canceled.
- Radioactivity may escape from the reactor in a meltdown or rupture of the containment vessel. Major accidents occurred in 1979 at Three Mile Island in Pennsylvania and in 1986 at Chernobyl in Russia, where an estimated 9,000 people will die prematurely from cancer. There have also been close calls or threats of a meltdown.
- Radioactive uranium or plutonium may get into the hands of terrorists or rogue countries, which could use it to produce dirty bombs or nuclear weapons. If the U.S. were to reprocess spent fuel and ship plutonium to plants around the country, the risk would be magnified.
- Uranium mining increases the risk of lung cancer among workers, and the mining waste and mill tailings may contaminate air and water, threatening public health.
- Most nuclear plants use large amount of water to cool the reactors, making them vulnerable in times of water shortages.
- Among the current major options for power production, new nuclear plants are likely to be the most expensive, and most of the cost comes upfront in construction of the facility. Nuclear plants are also expensive for taxpayers because of tax credits, loan guarantees, and insurance caps.
- The nuclear plant permitting and construction process takes about 10 years, which increases risk for investors. This lag time also means that nuclear power cannot contribute to global warming reductions in the near term.
- Proposed new plants generally would be much larger than other sources of power (1500–1700 MW), creating a reliability risk for the region in the event of an unforeseen shutdown.

Hydro: Hydroelectric

What is it?
Hydroelectric power is energy produced by moving water.

How is it used?
Hydroelectric power is used primarily for electricity. Power plants with dams allow water to fall from a reservoir at a controlled rate. The dam creates height differential: as the water flows from a higher elevation to a lower elevation through a pipeline, the flow turns a turbine connected to a generator. On fast-flowing rivers with a constant year-round flow, hydroelectric generation can work without dams by diverting a portion of the water, often near a waterfall, through a pipe to a turbine and then back to the river.

Energy potential
In the U.S., hydropower generates about 6% of our electricity supply. This amount could be increased by improving efficiency at existing projects, retrofitting dams that currently do not produce electricity, and developing small-hydro diversion projects between 1–30 megawatts (MW). According to a 2004 U.S. Department of Energy survey, if sources under 1 MW are counted, only 40% of total hydropower potential has been developed. Despite substantial undeveloped resources, the U.S. Department of Energy forecasts very little increase in power capacity from hydro in the next 20 years because of environmental issues and the complex, costly permitting process.

Benefits:
- Hydroelectric power produces essentially no carbon dioxide or other air emissions once dam building is complete (concrete production and dam construction do contribute significant emissions).
- Hydroelectric facilities, especially large projects built from the 1930s to the 1960s, are commonly the least expensive source of electricity.
- An advantage of hydroelectric dams is their ability to handle seasonal and daily power demand fluctuations because water can be stored when it is not needed and directed to the turbines when power is needed.
- Hydroelectric facilities can be built to meet environmental standards developed by the Low Impact Hydropower Institute. To be certified, a facility must adequately protect or mitigate its impacts on water quality, aquatic species, and the watershed.

Concerns:
- Dams usually contribute to the loss of fish. For example, the number of salmon traveling upstream in the lower Snake River has decreased 90% since the construction of four dams. Numerous species have been listed as threatened or endangered on dammed rivers.
- Dam reservoirs flood large areas. This often displaces people, eliminates wildlife habitat, inundates historic treasures, and affects adjacent ecosystems. If water levels fluctuate significantly, fish and other organisms can be left stranded in shallow waters.
- Dams prevent the flow of sediment and nutrients downstream, negatively affecting aquatic life that depends on those nutrients.
- There is some risk of catastrophic failure of dams due to earthquakes or tsunamis. China barely escaped this risk after an earthquake in 2008.

OCEAN HYDRO: WAVES AND TIDES

WHAT IS IT?

Wave power and tidal power capture the energy produced by ocean waves or tides. Wave energy devices use the linear movement of waves to spin generators. The devices range in size from 30 feet in diameter to 500 feet long, are made of steel or a composite material, and are in the form of buoys, long tubes, vertical columns, or stationary platforms. Current regulations allow projects to be located within 3 miles of land with devices moored to the ocean floor. Energy is transported through cables to the shore. Traditional tidal power facilities operate like hydropower dams and are powered by tides in large bays with narrow inlets. Newer devices, still in the demonstration phase in Europe, operate like underwater windmills offshore, but with rotors driven by tidal currents rather than the wind.

HOW IS IT USED?

Wave power and tidal power are used to generate electricity.

ENERGY POTENTIAL

The Electric Power Research Institute estimates that wave and tidal power could eventually meet 10% of U.S. electricity demand. The Oregon Wave Energy Trust predicts 500 MW will be generated in Oregon by 2025. However, wave energy is still in the research and development stage. Although many tidal turbines are being tested, including one in the East River in New York, there is only one commercial facility (in France), and there are just a few wave facilities (most off the coast of Europe) actively delivering electricity to the grid. A demonstration wave project in Reedsport, Oregon, is attempting to become the first grid-connected project in the U.S. The prime sites in the U.S. are in Oregon, California, and Hawaii, where there are good waves created by steady, strong winds.

BENEFITS:

- Wave power reduces U.S. reliance on imported fuels.
- Wave power is infinitely renewable; it cannot be depleted.
- Except for emissions in the manufacture of power devices, wave and tidal power release no carbon dioxide or other pollutants.
- Unlike wind and solar, wave power is available around the clock. Wave and tidal power are also more consistent and predictable—patterns, height, and strength can be predicted days in advance—allowing grid managers to plan accordingly.
- Wave power can be generated relatively near most energy consumers.
- Well-sited tidal turbines may have very little environmental impact.

CONCERNS:

- The environmental impacts of wave power facilities are not yet known. Underwater transmission cables may entangle debris, and anchors that secure the buoys and transmission cables could damage bedrock structures that are critical to fish. Large projects could disrupt nutrient circulation patterns in the ocean.
- There are limited sites for tidal generators, and the ones like dams that obstruct tidal flow damage the ecology of tidal regions.
- Finding the right technology at a reasonable cost that can survive the storms and salt water is a challenge. Unplanned outages and maintenance could increase costs significantly.
- Wave energy fluctuates seasonally as well as daily, making it an intermittent source.

Biomass

What is it?

Biomass, as an energy source, is organic matter such as wood waste, agricultural crops and their residue, municipal solid waste, and animal waste.

How is it used?

Biomass is either burned in boilers to create steam or heat, or it is processed to create gaseous or liquid fuels, such as methane, ethanol, or diesel (see Ethanol and Biodiesel).

In the U.S. about 70% of biomass energy is produced from burning wood for electricity and industrial process heat, primarily onsite at lumber, pulp, and paper plants. Some wood is burned for residential space heating.

Approximately 20% of biomass energy comes from mixed solid waste, mainly municipal solid waste burned in incinerators, or from methane that is recovered from landfills.

About 10% of biomass energy comes from liquid fuels like ethanol and biodiesel, which are derived from agricultural crops and are used primarily for transportation.

Energy potential.

Biomass currently supplies about 4% of total energy consumed in the U.S. (1.5% of electricity) and about half of the nation's renewable energy. The U.S. Department of Energy estimates that biomass could provide as much as 14% of the electric power consumed in the U.S. in the future.

Benefits:

- Biomass combustion produces less sulfur dioxide and toxic metals than the combustion of coal. For this reason, wood or agricultural waste is sometimes used in co-fired coal plants.
- Except for the fuel and fertilizers used for harvest and replanting, burning biomass does not increase total CO_2 emissions because growing plants remove CO_2 from the atmosphere.
- Biomass energy can also provide additional environmental benefits by making use of organic waste products. For example, capturing methane from landfills reduces a potent global warming gas.

Concerns:

- The most significant environmental impact of burning biomass is particulate emissions. Emissions from wood stoves and fireplaces are of particular concern because they are concentrated where people live.
- Municipal waste incinerators are especially dangerous because they emit dioxin, cadmium, lead, and mercury, all of which are toxic, persist in the environment, and bioaccumulate.
- Raw biomass cannot be shipped cost effectively more than about 50 miles from its source.
- Forestry and agricultural wastes cannot be completely removed from the land without depriving the soil of necessary nutrients and adversely affecting wildlife habitat.

BIOFUEL: BIODIESEL

WHAT IS IT?

Biodiesel is a liquid fuel derived from vegetable oil or animal fat. Currently, chemically converted soybean oil provides about 90% of the biodiesel consumed in the U.S.

HOW IS IT USED?

Biodiesel is used primarily as a transportation fuel, but it can also be used for home heating. In the U.S. it is most commonly blended with conventional diesel fuel at rates of either 2% (B2) or 20% (B20). A growing number of transport fleets are using these blends. Some home brewers of biodiesel modify their vehicles to use pure biodiesel derived from restaurant grease.

ENERGY POTENTIAL

In 2007, biodiesel comprised less than 1% of total U.S. highway diesel fuel use and is expected to remain a small contributor to transportation fuels. If *all* current U.S. soy production were devoted to making biodiesel, it would displace about 6% of all diesel consumed in the US.

BENEFITS:

- A University of Minnesota study showed that biodiesel from soybeans reduced greenhouse gas emissions by 41% when compared to diesel. Other analyses have estimated an even higher reduction.
- Greenhouse gas emission benefits would be (1) higher for biodiesel derived from rapeseed and (2) even higher from algae, if it becomes commercially available, because less fossil fuel is needed to produce the feedstocks.
- Compared to petroleum diesel, pure 100% biodiesel has other significant air quality benefits. It reduces sulfur dioxide, particulates, and hydrocarbons, although it does increase nitrogen oxide emissions (a source of smog).
- Biodiesel has the potential to be produced from a variety of locally grown crops and processed in local facilities.

CONCERNS:

- Because plants and the soil contain so much carbon, converting rainforests or grasslands to the production of biofuels releases at least 17 times more CO_2 than is saved by replacing oil with the resulting biofuel.
- Large-scale, conventional soybean farming destroys biodiversity by converting native habitats to monoculture crops, contributes to water pollution through runoff, causes increased soil erosion, and harms natural ecosystems through the use of pesticides and herbicides. Clearing of tropical rain forests in Brazil, Indonesia, and Malaysia is of particular concern. (Brazil is now the world's largest soy exporter.)
- Genetically modified soybeans pose a risk to ecosystems: modified genes have escaped to wild plants, creating herbicide-resistant "super weeds." In the U.S., 87% of soy is currently genetically-engineered.
- If consumers shift to diesel vehicles manufactured earlier than 2009 because of anticipated environmental benefits, air quality could actually suffer. Before that year, advanced exhaust controls were not required. Compared to gasoline, biodiesel produces more toxic particulates, thereby risking human health.

BIOFUEL: ETHANOL

WHAT IS IT?
Ethanol is a liquid fuel refined from grains, such as corn, and plant fibers. The typical refining process converts plant starch into sugars, ferments the sugars, and then employs distillation to remove ethanol from the solids and water produced by fermentation.

HOW IS IT USED?
Ethanol is primarily used as a ground transportation fuel. Much of the gasoline sold in the U.S. includes 10% ethanol (E10). In the Midwest, a blend with 85% ethanol (E85) is sometimes found and can be used in flex-fuel vehicles.

ENERGY POTENTIAL
If all U.S. corn production were used to make ethanol, it would displace about 12% of all gasoline consumed in the U.S. In 2007, ethanol comprised about 3% of all gasoline sold. By 2030 it is expected to represent about 20% of gasoline consumption.

BENEFITS:
- Using domestically grown plants as feedstock can reduce dependence on foreign fuel sources.
- Ethanol appears to reduce greenhouse gases by about 12% compared to gasoline under certain conditions (where land for crops was already in production, when credit is given for byproducts like distillers' dried grain, and when natural gas rather than coal is used for processing).
- Cellulosic ethanol from switchgrass and other material, which could be commercially available in ten years, would contain about six times more energy than the fossil fuels required to produce it and may reduce greenhouse gases by 88%.
- Switchgrass requires less land, water, and fertilizers than corn ethanol and can prevent soil erosion. As a perennial, it only has to be replanted every ten years.

CONCERNS:
- Corn ethanol energy return on energy invested (EROI) is quite low, estimates ranging from 0.7:1 to 1.3:1. This is due to large energy inputs for fertilizers, pesticides, farm machinery, transportation, and processing. If coal is used in the distillation process instead of natural gas, there is no net return on energy invested. Converting biomass to electricity for electric vehicles may be a more climate-friendly option than using biomass to produce ethanol.
- The EROI studies above did not account for conversion of virgin lands to croplands, a phenomenon that is now occurring due to higher corn prices. Studies in 2008 found that when land use changes are taken into consideration, greenhouse gas emissions from corn-based ethanol nearly double compared to gasoline. If U.S. corn lands were converted to switchgrass, one of these studies projects that the resulting ethanol would increase greenhouse gas emissions by 50%.
- Conventional methods for growing corn have significant environmental impacts: (1) heavy use of chemical fertilizers and pesticides, contributing to the dead zone in the Gulf of Mexico, and (2) soil erosion.
- Producing ethanol converts productive farmland for food into land for fuel. In 2008, nearly 25% of corn grown in the U.S. was used for ethanol.
- Ethanol crops consume large amounts of water—about 1000 tons of water for each ton of biomass. This contributes to the draw-down of water tables.
- Because ethanol releases more smog-forming gases than gasoline, the use of ethanol is expected to increase smog in many urban areas.
- If crop or forest residues are used for cellulose ethanol, soil fertility could suffer.

Wind

What is it?
Wind spins blades on the tower of a wind turbine. The blades are attached to a generator that converts the wind's kinetic energy into electrical energy. Wind turbines can be small (30 feet tall) or enormous (325-foot-diameter blades on a 400-foot tower). Most large turbines are located in clusters called wind farms, where electricity is aggregated and connected onto the transmission grid. Small wind-powered electric systems sized for homes, farms, and small businesses can be connected to the distribution grid or remain off-grid. In a grid-connected system, electricity moves onto the grid when wind is abundant and is drawn from the grid when the wind is not blowing.

How is it used?
Commercial turbines in the U.S. generate electricity, primarily for utilities. Where a transmission grid has multiple electricity sources, if wind provides more power than is needed at that time, thermal or hydroelectric power plants can ramp down their generation. Thus, wind power, although variable, can cut costs and pollution.

Energy potential
The U.S. is now the world leader in wind energy production. Yet, wind energy makes up only 0.5% of total energy supply and 1% of electricity supply in this country. By contrast, in Denmark wind accounts for 19% of power needs, and in Spain and Germany, 6–9% of total power needs. The U.S. Department of Energy projected a scenario whereby wind could supply 20% of U.S. electricity by 2030. According to current estimates, North Dakota, Texas, and Kansas have the combined potential to supply enough wind power to meet the electricity needs of the country. The main problem with wind energy in these areas is that the wind farms are not located near sufficient transmission capacity to reach major population centers. The industry is exploring offshore sites, where wind speeds are high, to make wind energy more accessible.

Benefits:
- Wind power generation emits no greenhouse gases or other pollutants except in the manufacture, transport, and installation of the turbines. After considering embedded energy, wind farms emit only about 1% of the emissions from coal plants over their lifecycle.
- Wind power also avoids other negative impacts of fossil fuels: mining, transportation of fuel, and waste.
- Because of their rural location, wind farms can stimulate local economies. Farmers and timber owners may lease their land for turbines, providing them with extra income, and the added improvements increase property tax revenues for the county.
- The cost of wind energy is on par with coal and natural gas and less than nuclear.
- Wind turbines may be a variety of sizes and designs, allowing them to be placed almost anywhere with high average wind speeds. A single, small turbine can be erected adjacent to a building.
- Wind is one of the few energy sources that can be brought online quickly.
- Wind is a renewable resource; it cannot be depleted.
- If plug-in electric cars become mainstream, they could become an energy bank for wind energy, which often is produced at night.

Concerns:
- Wind power opponents usually focus on visual impact and noise. Because sites with the highest energy potential are often located in vast open areas, along ridge lines, or offshore, potential visual impact can be significant. Critics are concerned that pristine areas would be disturbed. Noise is a

concern where turbines are close to residences. Some homeowners have complained of sleep disorders, headaches, and irritability due to the low-frequency sound.

- Wind turbines can kill nocturnal-flying birds and bats. Turbines sited away from areas of high bird utilization are reducing this impact.
- Transmission of electricity from wind farms to customer load centers is a challenge because of high costs to upgrade the network, long lead times, and chicken-and-egg issues. Electric transmission lines are also visually obtrusive.
- Wind is a variable resource and may not be available during peak demand. Therefore it needs a companion source of power that can be turned on and off, such as hydroelectric or natural gas. Storage of wind energy is not yet available at a reasonable cost. Siting farms in different wind regimes can mitigate the reliability issue but may require more transmission investment.
- About 1000 turbines are required to equal one large power plant.

SOLAR

WHAT IS IT?

Solar power is a renewable source of energy from the sun's radiation. It is captured in four different ways: passive solar, solar heat collectors, photovoltaic systems, and solar thermal concentrating systems.

HOW IS IT USED?

Solar energy can be used for electricity, space heating, and water heating.

- Passive solar design captures the sun's heat in the winter and cool spring and fall days to warm buildings and minimizes entry of heat from the sun on warm summer days.
- Solar heat collectors, generally on rooftops, are flat boxes with pipes that transfer heated liquid—usually a water-alcohol or antifreeze mixture—to a storage tank in the building for hot water or space heating. In sunny climates, air can also be used as the transfer medium for space heating.
- Photovoltaic (PV) panels, also typically on rooftops, convert sunlight directly to electricity by freeing up electrons in the semiconductor materials within a solar cell. The materials are typically silicon crystals with added boron and phosphorus, and the cells are encased in glass or plastic. Large PV arrays can be amassed to form utility-scale power generation.
- Solar thermal concentrating systems focus sunlight with mirrors, or parabolic reflectors, to create a high-intensity heat source, which then produces steam to generate electricity. They are usually located on large parcels of desert land.

ENERGY POTENTIAL

Currently, solar electric systems supply only 0.09% of our nation's energy and 0.2% of our electricity. States are increasingly providing incentives, and several new solar thermal plants are under development. The industry predicts that solar photovoltaic and solar concentrating systems will contribute 10% to the U.S. electrical energy supply by 2030. A group of researchers have proposed a "Solar Grand Plan," a massive switch from fossil fuels and nuclear power to solar plants that could supply 69% of U.S. electricity and 35% of total domestic energy by 2050.

BENEFITS:

- During operation, solar technologies produce no noise, greenhouse gases, or other forms of air pollution. A widespread shift to solar would produce an enormous reduction in release of nitrogen oxide, sulfur dioxide, carbon dioxide (CO_2), and toxic metal emissions.
- Even when solar cell manufacturing is considered, PV generation produces less than 15% of the CO_2 that is emitted from a conventional coal-fired plant.
- Solar PV and heat collectors generate energy where it is consumed, avoiding transmission costs. Being small-scale and decentralized, they also promote community self-reliance.
- Passive solar, heat collectors, and PV panels generally do not require any additional land area. Utility-scale systems do require large amounts of land, but not as much as coal-fired plants when land needed for mining is taken into account.
- Large PV arrays and solar thermal concentrating systems can be constructed in 1–2 years compared to a minimum of 5–8 years for fossil fuel plants and 10 for nuclear plants.
- PV systems produce electricity at peak times (summer afternoons) when utilities pay the highest prices for electricity.

CONCERNS:

- Solar power is a variable resource. Solar PV generates electricity 17–38% of the time during the course of a year. Some solar-thermal concentrating systems are able to continue generating electricity several hours after sunset because heat remains in the heat transfer fluid, and developers are close to commercializing the storage of captured heat in molten salt.

- The generation cost of solar thermal and PV power is high relative to other new sources of electricity, currently 15–30 cents per kilowatt hour compared to around 5–10 cents for hydro, gas, coal, wind, and geothermal power.
- Many of the thin-film cells contain metals that are rare, such as tellurium and indium. Indium could be used up in ten years if there were an explosion in the manufacture of indium-containing cells.
- PV cells contain metals, such as silver and lead for silicon-based cells and arsenic and cadmium for thin-film cells, that could be a threat to the environment when cells are disposed.
- Solar thermal concentrating systems, when built in virgin desert areas, destroy native habitat, and (like most conventional power plants) they require cooling water, which is likely to be scarce in the desert. Air cooling is possible, but it reduces efficiency.

GEOTHERMAL

WHAT IS IT?

Heat exists under Earth's crust, partly left over from the planet's formation and partly from decay of radioactive elements. Geothermal power extracts this heat, particularly where hot spots occur, for example where plates of the earth's crust collide and hot water either rises to the surface or becomes trapped in permeable rocks under a layer of impermeable rocks.

HOW IS IT USED?

Low- and medium-temperature water can heat homes and buildings directly, and high-temperature resources can be converted into electricity. Geothermal power plants drill holes into the rock, generally a mile or two below the surface, to capture steam or water, use it to power turbines, and then return it underground. Most commonly, this hot water is circulated in a closed loop, passing through a heat exchanger where a second liquid is converted to the steam that drives the turbine.

On a smaller scale, geothermal energy is also tapped by using ground-source heat pumps to provide heat and cooling to buildings. The pumps take advantage of the constant year-round temperature of about 50°F just 5–10 feet underground. Typically, an antifreeze liquid is pumped through pipes buried underground and then used by a heat pump to provide pre-warmed or cooled air to the heating or cooling system of the building.

ENERGY POTENTIAL

Geothermal power currently supplies .8 % of U.S. electricity, and geothermal plants are competitive with new fossil fuel plants. New geothermal plants now under development in western states are expected to double geothermal generating capacity. Yet their contribution to energy supply will remain small. The conditions that make water circulate to the surface are found in less than 10% of Earth's land area.

Hot dry-rock sources at depths of 13,000 feet or more beneath the earth's surface offer enormous potential for the future, but the technology to use this resource is not yet commercially developed and could be quite costly. The rocks at this depth must first be broken up by pumping high-pressure water through them. Water would be circulated through the broken hot rocks, brought to the surface to turn turbines, cooled and then recycled again and again.

BENEFITS:

- Closed loop geothermal plants produce no air emissions. Even open systems emit less than fossil fuel combustion—no nitrogen oxides, almost no sulfur dioxide, and about 95% less carbon dioxide.
- Geothermal power does not impact much land area compared to other fuel sources. A geothermal field uses 1–8 acres per megawatt versus 5–10 acres per megawatt for nuclear plants and 19 for coal. Geothermal plants can be sited in farmland and forests and can share land with cattle and wildlife with no negative repercussions.
- Geothermal power creates virtually no water pollution. Production wells are lined with steel casing and cement to isolate fluids from the environment. Spent hot water is injected back into the reservoirs.
- Geothermal is cost competitive with wind power and significantly cheaper than solar; and unlike either of those sources, it provides a constant supply of energy.

CONCERNS:

- Geothermal sites generally have water or steam of only moderate temperature, are sparsely distributed, and are usually located some distance from markets needing energy.
- In open systems, the hot water and steam may emit carbon dioxide and hydrogen sulfide (a toxic gas that smells like rotten eggs) and small amounts of ammonia, methane, mercury, and radon. Sludge from air pollution control devices and from the condensation of steam contains toxic metals that are difficult to dispose of safely.
- As with coal and nuclear plants, most geothermal power plants require a large amount of cooling water. They can be operated with dry cooling towers but at higher costs.
- Many geothermal reservoirs are located in areas of great natural beauty, arousing intense opposition to development.
- Geothermal drilling is much more difficult and expensive than conventional oil drilling because of the high temperature and corrosive nature of geothermal fluids and the abrasive nature of reservoir rocks. Drilling can account for 30–50% of a geothermal project's total cost.
- Geothermal is not renewable in the same way as solar or wind because a local source is generally depleted in 40–100 years.
- Deep hot-dry rock fracturing can lead to earthquakes.

HYDROGEN

WHAT IS IT?
Hydrogen is an atom and the first element in the chemical periodic table. Pure hydrogen gas does not occur in nature in concentrated amounts. It is generally produced by a high-temperature process that separates it from natural gas (or another organic compound) or by electrolysis of water, which requires electric power to split water into its constituent elements.

HOW IS IT USED?
Hydrogen is an energy transfer medium rather than a primary source of energy. All the energy to be obtained by burning hydrogen must be supplied by the primary source. Therefore, the use of hydrogen as an intermediate is justified when there is some reason not to use the primary source directly.

Hydrogen is most commonly used in a fuel cell, where it is separated into protons and electrons, and the electrons are forced to pass through a circuit. The electricity produced can power an electric motor to propel vehicles. Fuel cell cars are similar to battery electric cars but do not have to be recharged. Instead, they have onboard storage tanks that could be filled at hydrogen filling stations.

Thousands of stationary fuel cells have been installed worldwide, often as backup power sources for critical applications such as hospitals. Fuel cells could be used for micro combined-heat-and-power generation for homes, office buildings, and factories. The waste heat generated by the fuel cell can be used for space heating or hot water, or, if hot enough, it can be run through a turbine to generate additional electricity.

ENERGY POTENTIAL
Fuel cell vehicles today are mostly produced as prototypes or in very small quantities. However, there is great interest among auto makers worldwide in the technology. Several major automakers stated their intention to begin selling fuel-cell cars by 2015, and Honda is currently testing a car in Southern California. However, some major companies are discontinuing their hydrogen programs to concentrate research on plug-in electric vehicles.

BENEFITS:
- A car operated by a hydrogen fuel cell could be twice as efficient as an internal combustion engine. All-electric cars using batteries may be equally efficient.
- Once produced, hydrogen is a clean-burning fuel, producing only water as a by-product and no carbon dioxide or other air pollutants. As such, it can be used in areas of high population density, such as cities.
- Hydrogen could enable the storage and transport of a virtually limitless quantity of wind or solar power.

CONCERNS:
- Producing usable hydrogen uses more energy than the resulting product will yield.
- The cost of installing hydrogen fuel stations is high. Without infrastructure and higher hydrogen production, the cost of hydrogen fuel will remain high as well.
- Hydrogen is bulky and difficult to store. It would take 21 tanker trucks to move the same amount of energy in hydrogen as one tanker of gasoline.
- Another challenge for hydrogen fuel cells is their durability and cost. Platinum, currently used as a catalyst in hydrogen fuel cells, is very expensive and rare.

- A challenge for developers is making fuel cells and fuel tanks small enough so that they do not take up too much space on a vehicle. Hydrogen, even when highly compressed, requires more space than gasoline or natural gas.
- The storage of hydrogen presents a risk because its flames are invisible, unlike gasoline. This increases the dangers from hydrogen fires.

CONSERVATION

WHAT IS IT?

Energy conservation is the practice of decreasing the quantity of energy used for services such as heating, lighting, industry, etc. It can be accomplished by (1) increasing efficiency (reducing energy inputs for a given level of service or output) or (2) reducing total consumption of energy. Greater efficiency is usually accomplished by building design or technology, such as redesigning a furnace to use less natural gas. Reducing consumption usually requires a business or lifestyle change, such as turning down the thermostat or turning off equipment when not in use.

HOW IS ENERGY CONSERVED?

To be considered an energy resource, conservation is typically achieved through public policy or a utility program. Government can play a big role in encouraging conservation through (1) tax policy; (2) regulation, such as setting standards, upgrading codes, or regulating utilities; (3) incentive payments for efficient equipment; and (4) leadership in marketing, training, research, and development. The oil crisis of the 1970s spurred the creation of conservation measures, including the following:

- Corporate Average Fuel Economy (CAFÉ) standards, which required auto manufacturers to progressively increase fuel efficiency, achieved dramatic results in its first ten years.
- Local governments, and by 1987 the federal government, set minimum efficiency standards for many household appliances.
- Federal and local governments subsidized public transportation and carpooling to reduce vehicle commuting miles.

ENERGY POTENTIAL

It is estimated that increased efficiency could reduce energy consumption in the U.S. from 20–33% by 2020. California has already demonstrated how state policy can produce substantial results. Over thirty years, efficiency programs in California saved enough electricity to prevent the building of twenty-four 500-megawatt power plants. Examples of how energy consumption and related carbon dioxide emissions could be reduced include the following:

- More efficient cars and trucks could save more oil in ten years than the potential supply in the Arctic National Wildlife Refuge. Currently, the U.S. requires cars to average 35.5 MPG by 2016, whereas the European fleet already averages 44 MPG and Japanese cars already average more than 45 MPG. Plug-in hybrids could reduce gas consumption by more than 60%.
- Energy codes could be strengthened to require more efficient building design, lighting, and heating/cooing systems. California's new mandate for green building techniques in all new construction is expected to make new homes 50% more energy efficient than homes built to existing national energy standards. Widespread construction of net zero-fossil-fuel homes (accomplished by reducing energy use by 70% and fulfilling remaining needs through renewables) could be achieved in 10–15 years, everywhere except hot, humid climates where air conditioning consumes larger amounts of energy.
- The majority of residential dwellings are still under-insulated. Low-income weatherization could be subsidized, or current programs could be expanded. Many local governments are encouraging upgrades with new financing mechanisms such as PACE (Property Assessed Clean Energy) whereby the proceeds of a bond are lent to home owners to finance their retrofits. The home owners repay their loans through an annual assessment on their property tax bill.
- A carbon tax and/or cap and trade system, by raising prices, would cause industry to reduce waste, install more efficient equipment, and capture waste heat, especially if supplemented by programs that offer specialized knowledge of how to achieve these results, increased access to capital, and

targeted subsidies. For example, the EPA suggests that combined heat and power systems could provide ten times the amount of electricity that they currently do.

- More sustainable farming techniques could dramatically cut energy-intensive fertilizer use.
- Utilities are testing a variety of devices in homes that provide feedback to consumers on energy use. One version tells the consumer how quickly they are consuming electricity and money. These devices have produced an average 6% to 15% drop in electricity consumption.
- A smart grid could reduce peak load demand by using two-way digital technology between a utility and its customers. For example, a utility might pay a customer to give it the flexibility of cutting the customer's air conditioning for 15 minutes during a peak time.
- The potential for use of waste heat from electricity generation, such as district heating systems, presents a significant opportunity for energy savings. Currently, 69% of the primary energy is lost before reaching the end user.

BENEFITS:

- The cost of conservation measures is, on average, less than half the cost of building new power plants and transmission systems and often as low as 20% of the cost.
- Many conservation measures can be implemented immediately while society adjusts to reduced supply and develops alternative energy sources.
- Conservation measures can save natural resources and avoid pollution.
- Most efficiency measures save consumers money by reducing energy bills. For example, the federal appliance standards have saved the average household $40–$60 per year.
- Conservation requirements and incentives encourage technological innovation, enabling U.S. companies to be leaders in competitive global markets.

CONCERNS:

- Except through taxes and utility programs, consumption levels are difficult for governments to address. It is difficult to legislate behavior, and many businesses and citizens object to government regulating their choices or raising utility rates.
- The initial cost of energy efficient equipment is often higher than the cost of less efficient items. It takes time to pay back the up-front cost.
- Building developers and owners are not often the same people who pay for utilities (i.e., tenants). In these cases, a monetary incentive for reducing energy is lacking.
- When improving efficiency holds energy prices down, society finds new uses for the saved energy.
- Operating efficiency often requires a level of quality management and attention that is difficult for homeowners and business owners to achieve. Specialized outside help is not always available.

CARBON CREDITS, CARBON TRADING, AND CARBON OFFSETS

INTRODUCTION

For the earth to retain a stable average annual temperature, it must maintain a balance of two heat transfers: (1) solar heat from the sun, which heats the earth and its atmosphere, and (2) the heat from the earth that radiates back into space. The problem today is that human development is disturbing the natural balance of heat transfer by discharging greenhouse gases into the atmosphere at a rate that is causing climate change. Six gases emitted from anthropogenic sources are of greatest concern, and each gas is measured in terms of its global warming potential as a function of carbon dioxide over 100 years.

Name	**Common Sources**	**Global Warming Potential**
1. Carbon Dioxide	Fossil fuel combustion, forest clearing	1
2. Methane	Landfills, natural gas systems, cattle	23
3. Nitrous Oxide	Fossil fuel combustion, fertilizers, manure	296
4. Hydrofluorocarbons	Refrigeration gases, aluminum smelting	120 – 12,000
5. Perfluorocarbons	Aluminum production, semiconductor industry	5,700 – 11,900
6. Sulfur Hexafluoride	Electrical transmissions and distribution systems	22,200

Over the past 20 years, climate change and greenhouse gas reduction have become the focus of international treaties, national policy debates in many nations, state laws and regulations in the United States, as well as voluntary efforts to reduce or mitigate the impact of greenhouse gas emissions. There are currently four major ways of achieving emission reductions that policy makers are discussing and, to varying degrees, implementing: (1) a carbon tax; (2) mandatory energy efficiency standards, such as California's plan for higher automobile fuel efficiency standards; (3) mandatory reduction programs via cap-and-trade schemes; and (4) voluntary reductions. This section will discuss the major issues and concepts in the latter two strategies.

CAP-AND-TRADE PROGRAMS: CARBON CREDITS AND CARBON TRADING

KYOTO PROTOCOL AND THE EUROPEAN UNION EMISSIONS TRADING SCHEME

To address greenhouse gas emissions, the United Nations Framework Convention on Climate Change was held in 1992, resulting in the Kyoto Protocol. This international agreement, signed in 1997 and effective in 2005, sets binding targets for reducing greenhouse gas emissions in 37 industrialized countries and the European community. (The U.S. did not ratify the Kyoto Protocol; Australia did not ratify it until December 2007.)

The Kyoto Protocol established a goal for industrialized nations to reduce greenhouse gas emissions to less than 95% of 1990 levels. To achieve that overall goal, each participating country was assigned a corresponding reduction target ranging from an 8% reduction in the European Union to an increase of 10% in Iceland. The target for each country was an average to be met during the phase-in period between 2008 and 2012. Countries that ratified Kyoto and committed to reductions saw their emissions remain relatively stable between 1990 and 2004. Globally, however, emissions continued to rise, especially in China and the U.S. In the U.S., emissions rose 16% during those years.

Each participating country decides how to allocate its allowance among the country's major emitters each year. The allowance takes the form of "carbon credits," with one credit equaling one ton of carbon dioxide. Because carbon dioxide is the gas of greatest concern, all greenhouse gases are converted into carbon dioxide equivalents, or CO_2e.

To comply with the Kyoto Protocol, in 2004 the European countries established the European Union Emissions Trading Scheme. Under the Scheme, all 25 EU nations are allocated allowances based on historical emissions, and each country, in turn, allocates its allowances among its major emitters, such as plants producing electricity, glass, steel, cement, and paper. The industrial participants that receive allowances are allowed to trade them. For example, if a steel plant in Germany reduces its emissions 25% below its allowances, the German plant can sell the excess allowances to a plant in Sweden that is unable to meet its emissions quota. While direct trades are possible, most buying and selling of carbon credits occurs through financial intermediaries. At the end of each year, each industrial participant must surrender to the government enough carbon credits to account for all of its plant emissions. If the plant emits more greenhouse gases than it has allowances, it must pay a fine. The fine creates the economic incentive to either reduce emissions or buy carbon credits, and trading of credits allows for an economically efficient reduction in emissions.

Non-Kyoto Cap-and-Trade Programs

In the U.S., which has no federal regulations to control greenhouse gas emissions, regional programs have been introduced. Three regions in the U.S. and Canada are in various stages of developing their own cap-and-trade systems. The Regional Greenhouse Gas Initiative is an effort by ten northeastern and mid-Atlantic states to cap CO_2 emissions from major power plants and then reduce those emissions by 10% by 2018. In 2008, the Initiative began auctioning allowances and intends to use the funds to promote energy conservation and renewable energy. The Western Climate Initiative by seven states and four Canadian provinces is designing a cap-and-trade proposal to reduce greenhouse gas emissions by 2020 to 85% of 2005 levels. The Initiative will start by setting caps for electric utilities and major industrial emitters in 2012 and for gas utilities and transportation sources in 2015. The Midwestern Greenhouse Gas Accord by nine states and two provinces also intends to develop a cap-and-trade system.

Carbon Offsets within Cap-and-Trade Systems

Because greenhouse gas emissions are a global problem, a reduction in one part of the world is considered as beneficial as a reduction anywhere else. For this reason, both the Kyoto Protocol and the European Trading Scheme recognize "carbon offsets"—specific reductions of greenhouse gases outside the boundary of the cap. A single offset equals one metric ton of CO_2, or its equivalent in other greenhouse gases (CO_2e).

The Kyoto Protocol and the European Trading Scheme allow the purchase and trading of offsets as a means to substitute for an allowance. The Regional Greenhouse Gas Initiative allows, in a very limited fashion, for emitters to use offsets to satisfy up to 3.3% of the emitter's allowance obligations. In the Western Climate Initiative, each jurisdiction may use offsets for no more than 49% of its total emission reductions from 2012 to the 2020s.

The European Trading Scheme offsets, called Certified Emission Reductions (CERs), are generated by emission reduction projects in developing countries and are certified pursuant to the Clean Development Mechanism (CDM), an element of the Kyoto agreement. Because developing nations are not part of the Kyoto Protocol's capped system, such projects achieve emission reductions that otherwise might not have happened. One CER is equivalent to one metric ton of CO2e.

As an illustration, assume the steel plant in Germany wishes to expand production, and thereby increase emissions by 50%, but cannot find carbon credits at an acceptable price from other emitters within the European system. The German steel plant could increase its allowance by purchasing CERs created by a project in a developing nation, such as installation of a biomass generator to replace a fossil-fuel generator. In this manner, the German company increases its allowable emissions from the steel plant in Germany while reducing a comparable amount of emissions in a developing nation, and the developing country gains foreign investment and infrastructure support.

Problems With the European Union Emissions Trading Scheme and the CDM

Under the pilot phase of the European Union Emissions Trading Scheme from 2005 to 2007, some countries allocated too many trading allowances, allowing their price to fall artificially low. Carbon emissions from the industrial participants did not fall because it was cheaper to buy allowances than to reduce emissions. In short, the cap was not low enough to result in reduced emissions. The EU made substantial adjustments (including partial auction of allowances) for the next phase. Environmentalists have a concern about over-reliance on the CDM, which, they fear, can undermine the caps.

The efficacy of CERs has also been called into question. CDM projects must go through an in-depth review and verification, meet objective standards, and have the carbon reductions verified by a third-party entity. Yet, critics claim that some CDM projects would have been constructed even without the extra payment for CERs, and others produced windfalls for those who arranged the transaction. The BBC World Service investigated projects in India where this was true. For example, a senior manager of a biomass plant said the plant would have been installed even without the extra money. A chemical company received carbon credits worth tens of millions of dollars even though the cost of installing an incinerator to burn off hydrofluorocarbons was only about $2 million. A Stanford researcher said, "China has been building about 10 gigawatts of hydropower every year for a long time. Last year, suddenly all of the development was claimed as carbon credits." As the world's first large offset provider, the CDM is learning from its experiences and making necessary changes. For example, many Chinese renewable energy projects that applied for CERs recently were turned down because they would have likely been built without the credits.

Voluntary Offset Programs

In addition to the market for offsets created by mandatory reductions within cap-and-trade programs, a voluntary market has emerged. By voluntarily purchasing offsets, an individual, business or organization can, in theory, become totally or partially "carbon neutral." After assessing the carbon emissions used to produce energy for operations, transportation, and other practices, a business or individual may purchase offsets to cover all or some portion of those emissions.

In its current phase of development, some say the voluntary carbon-offset market is like the Wild West because there is no clearly accepted definition of an offset. According to Mark Trexler, Director of Climate Strategies and Markets for Det Norske Veritas, the quality of offsets generated by some projects is suspect because the market lacks a "clear quality standard, a provider certification process, or effective disclosure and verification protocols."

Quality of Carbon Offsets

A key question for carbon offset markets—both in the voluntary market and in the cap-and-trade mandatory reduction schemes—is whether a project that purportedly generates offsets is, in fact, "additional." The concept of additionality dictates that projects are only eligible as carbon offsets to the extent the resulting emission reductions would not have happened without the carbon offset incentive.

For example, an offset may be claimed for the capture of methane gas from a landfill. If that project would have been completed without the carbon offset incentive, there is no "additional" environmental benefit.

Although simple in concept, the additionality test is often very difficult to apply. Several tests have been created to evaluate a project's additionality, though the process is inevitably somewhat subjective. Tests may include the following questions: Is the project legally required? Is the project financially viable without offset revenues? Does the project include innovations that go beyond common business practice? Are there significant non-financial barriers the project needs to overcome, such as reliance on non-proven technology or lack of information about the technology?

Beyond additionality, a *quality* offset must satisfy several other requirements as shown in the box below.

Requirements for Quality Offsets

- The emission reductions must be *additional*, meaning they occurred because of the presence of the offset incentive and would not have happened otherwise.
- The offset should be *verifiable*. For example, a solar cooking stove project in India had difficulty quantifying how many of the stoves would actually be used and how much wood burning they would replace.
- A credible emission's *baseline* should be in place so reductions from the baseline can be measured over time.
- *Leakage*, where reductions in one location are simply shifted to another location, must be taken into account. For example, one forest that is preserved may increase pressure on another forest to be logged. Or a cement plant in the U.S. is dismantled, but a new one is constructed in China to replace the gap in production.
- The reduction must be *permanent*. Trees may be planted to sequester carbon, but forests can burn down.
- Each offset should be *registered* on a publicly accessible registry to assure it is not used more than once.
- Offset projects should be *monitored and verified* over their lifetime to assure that their goals are being met.
- Offsets should not be *forward sold*—counted and used before the emissions reduction or sequestration actually occurs.

TYPES OF CARBON OFFSET PROJECTS

Carbon offset projects are generally placed in two categories:

1. **Greenhouse gas capture projects,** such as projects to capture methane from landfills or manure or to capture hydrofluorocarbons emitted by industrial facilities.

2. **Biosequestration projects,** such as planting trees that will capture CO_2 from the air or implementing no-till or other agricultural practices that keep carbon in the soil.

Tree planting carbon-credit projects are more difficult to assess than other types of projects. In certain types of forests, much of the carbon is stored in the soil and can be released when disturbed by harvesting and replanting. In an ironic twist, one study has suggested that trees planted in high-latitude areas could have the unintended effect of replacing the snow and ice that reflects sunlight, leading to a net increase in global warming, even as the trees capture carbon.

The permanence and ecological impact of forest projects are also issues. The efficacy of a credit may be reduced if the forest is altered by fire, disease, or future logging. Additionally, new tree plantations—usually monocultures—can have adverse environmental consequences that counteract the carbon benefits. They often use synthetic herbicides and fertilizers and do not provide niches for wildlife that natural forests do.

RENEWABLE ENERGY CERTIFICATES

Certificates for renewable energy projects can also be bought and sold. A Renewable Energy Certificate (REC)—also known as a green tag—is issued when one megawatt-hour of electricity is generated and delivered to the grid from a qualifying renewable energy source, such as wind, solar, or biomass. Green tags were created in the late 1990s to provide a financial incentive for development of renewable energy. The company generating renewable energy sells both (1) the electricity on the open market to be commingled with electricity from all other sources and (2) the detached green tags to a distributor that markets them to consumers.

About Green Tags

- Green tags can be sold in both mandatory and voluntary markets. In the late 1990s, states began passing Renewable Portfolio Standards, laws requiring electric utilities to derive a minimum percentage of their power from renewable sources by a particular date. To meet these requirements, some states allow the utilities to purchase green tags from other sources rather than generating all the renewable power themselves. In fact, the first green tags were traded among utility companies.

- Beginning in 2000, a retail market in green tags emerged. Green tags for new facilities benefit investors in renewable energy by creating additional revenue. And they allow individuals and companies to support renewable energy, such as wind or biomass, even if their local utility does not generate renewable energy.

- In 2002, when the market for green tags was just beginning, San Francisco's Center for Resource Solutions, working with stakeholders in the power industry and environmental community, developed a certification program, Green-e Climate, to set standards and to audit producers and sellers. Under these standards, only projects developed after January 1, 1997 and not otherwise mandated (e.g., counted toward compliance with renewable portfolio standards) would qualify to sell green tags.

- Since 2002, green tags have also been converted into carbon offsets, using a formula that determines the avoided carbon emissions. As a result, they can be sold in voluntary carbon offset markets. However, this practice has been controversial. Complaints revolve around issues of double counting, additionality, low cost, and purchases from existing, rather than new, facilities.

Mark Trexler, author of *A Consumer's Guide to Retail Offset Providers,* and the Offset Quality Initiative say that green tags and greenhouse gas offsets are subject to different qualification criteria that prevent them from being "mixed and matched." Trexler worries that cheap green tags might undercut the market for more expensive offsets and points out that the real drivers of new wind power are the federal tax credits and the Renewable Portfolio Standards. The strongest complaint about green tags being used as carbon offsets is the assertion that they don't ensure additionality.

Even though green tags cannot always demonstrate to a potential purchaser that a particular project would not have been built absent incentives, proponents say that consumers are sending a market signal that makes it more likely for investors to fund wind projects in the future and that green tags help shift a fossil-fueled economy to a renewable-energy one.

Third-Party Verification of Carbon Offsets

Some third-party certification protocols have been developed for the voluntary market (i.e., the market for offsets outside of the mandatory cap-and-trade systems). The international Voluntary Carbon Standard was established in 2007 by The Climate Group, the International Emissions Trading Association, and the World Business Council for Sustainable Development. The Voluntary Carbon Standard seeks to assure users that Voluntary Carbon Units represent real, additional, permanent, and independently verified emission reductions. A registry managed by the Bank of New York is used to record the registration, transfer, and retirement of Voluntary Carbon Units.

In 2006, WWF-UK launched The Voluntary Gold Standard, endorsed by 38 non-profit organizations and widely considered to be the highest standard in the world. The Gold Standard makes the same assurances as the Voluntary Carbon Standard but also seeks to meet other goals, including the use of technologies that will be part of the long term solution to global warming (renewable sources and energy efficiency) and make a positive contribution to sustainable development in the host country, as assessed by local stakeholders.

Effect of Carbon Offsets

Assuming that the quality and efficacy of offsets can be assured, are they a good idea? Critics argue that offsets simply provide a license for people to continue living their carbon-filled lives, guilt free, rather than changing their behavior. Even advocates of carbon offsets agree that every effort should be made to reduce energy use before resorting to offsets. Joel Makower, author of GreenBiz.com, expresses the concern that the trend for businesses to claim carbon neutrality might be seen as a cover up for failure to maximize their energy efficiency and use renewable sources.

International carbon trading in carbon offsets has raised the issue of fairness and social equity. If industrial countries have been largely responsible for the buildup of CO_2 in the atmosphere over the years, is it fair for them to purchase cheap offsets in developing countries rather than reducing their own use of fossil fuel? In 2004, human rights and environmental non-profits signed The Durban Declaration, rejecting the claim that carbon trading will halt the climate crisis. The Durban Declaration asserted that the cap-and-trade scheme commoditizes and privatizes air, soil, and water; encourages industrialized countries to finance cheap carbon dumps, such as large-scale tree plantations in the South; and promotes military conflict around the world because it does not reduce use of fossil fuels. Yet other observers see offset projects alleviating poverty and spurring development. An example is a biomass power project in India where local farmers were involved in decision-making and received ash from the plant to use as fertilizer.