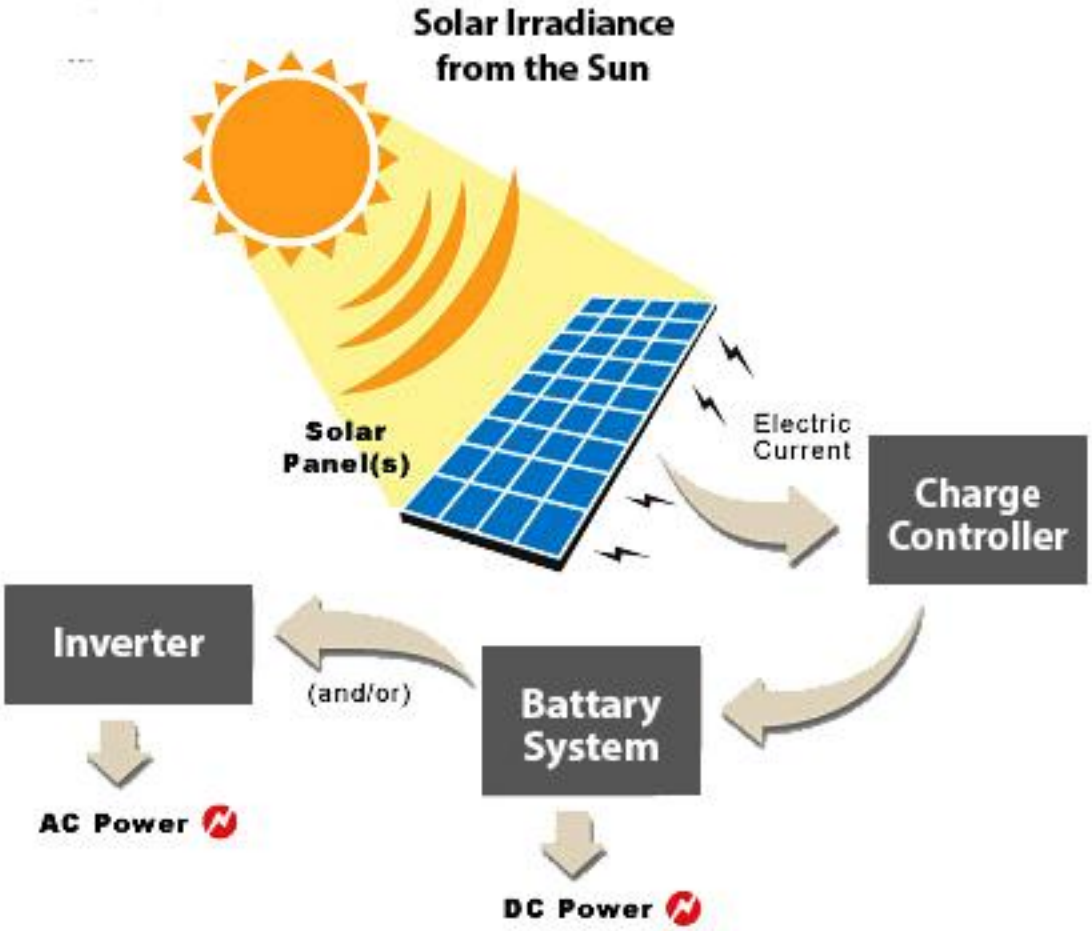
Lecture-2 Introduction to renewable energy sources

Renewable energy sources derive their energy from existing flows of energy from on-going natural processes, such as sunshine, wind, flowing water, biological processes, and geothermal heat flows. A general definition of renewable energy sources is that renewable energy is captured from an energy resource that is replaced rapidly by a natural process such as power generated from the sun or from the wind. Currently, the most promising (aka economically most feasible) alternative energy sources include wind power, solar power, and hydroelectric power. Other renewable sources include geothermal and ocean energies, as well as biomass and ethanol as renewable fuels.

Solar

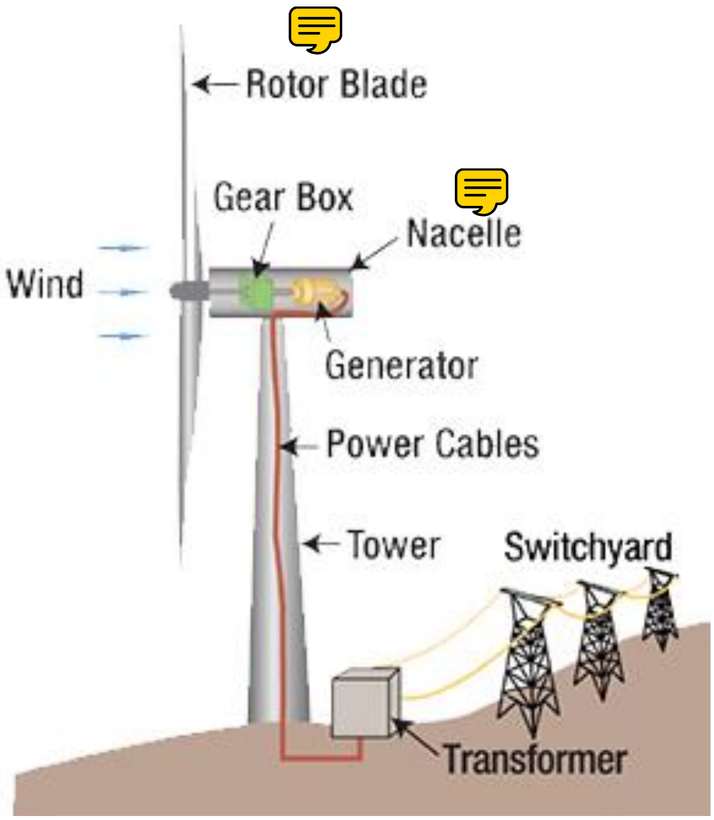
The recent disasters in the southeastern United States highlighted the decline in the world's oil supply, forcing us to begin considering other energy options. One promising technology, solar power is worth considering for its sustainable, renewable and emissions reducing qualities. Modern residential solar power systems use photovoltaic (PV) to collect the sun's energy. "Photo" means "produced by light," and "voltaic" is "electricity produced by a chemical reaction." PV cells use solar energy to generate a chemical reaction that produces electricity. Each cell contains a semiconductor; most commonly silicon in one of several forms (single-crystalline, multi-crystalline, or thin-layer), with impurities (either boron or phosphorus) diffused throughout, and is covered with a silk screen. Cells are joined together by a circuit and frame into a module. Semiconductors allow the electrons freed from impurities by the sun's rays to move rapidly and into the circuit, generating electricity. Commercial residential PV modules range in power output from 10 watts to 300 watts, in a direct current. A PV module must have an inverter to change the DC electricity into alternating current energy in order to be usable by electrical devices and compatible with the electric grid. PV modules can also be used en masse to create large-scale power plants.



Using PV modules to generate electricity can significantly reduce pollution. The most energy used in creating solar panels is used to purify and crystallize the semiconductor material. No official numbers are available on the exact amount of energy used to create solar panels because there is no industry standard for making the crystals. A number of researchers have done work in attempt to address concerns about energy payback for PV systems. Assuming 12% conversion efficiency and 1,700 kWh/m2 of sunlight per year, the estimates range between 2 and 4 years for rooftop PV systems to generate the energy it took to make them.44 The average United States household uses 830 kWh of electricity per month. Over twenty years, a 100-megawatt solar thermal electric power plant can avoid producing over three million tons of carbon dioxide. Estimates regarding pollution prevention suggest that producing 1,000 kWh of electricity through solar power can reduce emissions by 8 pounds of sulfur dioxide, 5 pounds of nitrogen oxide, and 1,400 pounds of carbon dioxide. Lifetime estimates (over a projected 28 years) average in the thousands of pounds of prevented emissions. Installing a PV system is a hefty investment for homeowners. 5-kW systems can cost up to $40,000. PV system power can cost as much as $9 per watt, and small systems will not produce enough power to offset electricity costs and save the homeowner any substantial money. As a result, over 30 states offer incentives (mostly in the form of tax rebates) to help encourage homeowners to purchase and install PV systems. California is one of the key states, receiving a huge amount of radiation, with the better part of the industry located there, and high-energy costs. The state of California offers a number of incentives under the Emerging Renewables Program passed by the state legislature. The California Energy Commission offers a rebate of $4 per watt to help homeowners affordably install PV systems. However, the mortgage financing required to purchase a realistic PV system is still quite substantial. As PV technology advances, more efficient, easily affordable, standardized, reliable and longer-lasting modules will become available. PV systems' value to the energy sector especially in residential capacities, is increasingly apparent. However, the continued high cost means that many homeowners will be deterred from purchasing and installing PV systems. The only way to encourage further growth in this sector is for consumers to purchase such systems. The energy emissions reductions are substantial enough to be worth the consideration of the federal government. In order to encourage consumers' interest in PV systems and growth in the renewable energy sector at a faster rate, the federal government should create an incentive program to help homeowners and businesses purchase and install PV systems, especially on new constructions.

Wind

Wind energy is one of the most promising alternative energy technologies of the future. Throughout recent years, the amount of energy produced by wind-driven turbines has increased exponentially due to significant breakthroughs in turbine technologies, making wind power economically compatible with conventional sources of energy. Wind energy is a clean and renewable source of power. The use of windmills to generate energy has been utilized as early as 5000 B.C., but the development of wind energy to produce electricity was sparked by the industrialization. The new windmills, also known as wind turbines, appeared in Denmark as early as 1890. The popularity of wind energy however has always depended on the price of fossil



fuels. For example, after World War II, when oil prices were low, there was hardly any interest in wind power.

However, when the oil prices increased dramatically in the 1970s, so did worldwide interest in the development of commercial use of electrical wind turbines. Today, the wind-generated electricity is very close in cost to the power from conventional utility generation in some locations.

Where does wind come from? Wind is a form of solar energy and is caused by the uneven heating of the atmosphere by the Sun, the irregularities of the Earth's surface, and rotation of the Earth. The amount and speed of wind depends on the Earth's terrain and other factors. The wind turbines use the kinetic energy of the wind and convert that energy into mechanical energy, which in turn can be converted into electricity by means of a generator. 2

There are essentially two types of wind turbines: The horizontal-axis variety, and the vertical-axis design. The horizontal-axis design is used more commonly and looks like an Old Dutch windmill, whereas the vertical-axis design looks like and eggbeater. These wind turbines generally have either two or three blades, called rotors, which are angled at a pitch to maximize the rotation of the rotors. The horizontal-axis design is slightly more efficient and dependable than the vertical-axis windmill. Most of the windmill models that are currently in production are thus horizontal-axis windmills.

Utility scale turbines can produce anywhere from 50 kilowatts to several megawatts of energy. These large windmills are generally grouped together in a windy area in what is called a wind farm. The proximity of the windmills in a wind farm makes it easier to feed the produced electricity into the power grid. Wind energy offers many advantages compared to fossil based power and even some other types of alternative energy, which explains why it is the fastest growing energy source in the world. The two main reasons are cleanliness and abundance. The fact that wind is a renewable resource gives it a major advantage over oil and the nonrenewable resources. Considering that environmental pollution is being linked to several global problems that might eventually threaten the existence or at the very least worsen human living conditions, the fact that windmills do not produce any emissions whatsoever is another reason to increase the use of wind turbines. Increasing the percentage of wind power used by the United States would not be unreasonable, seeing that the price of wind power is between 4 and 6 cents.

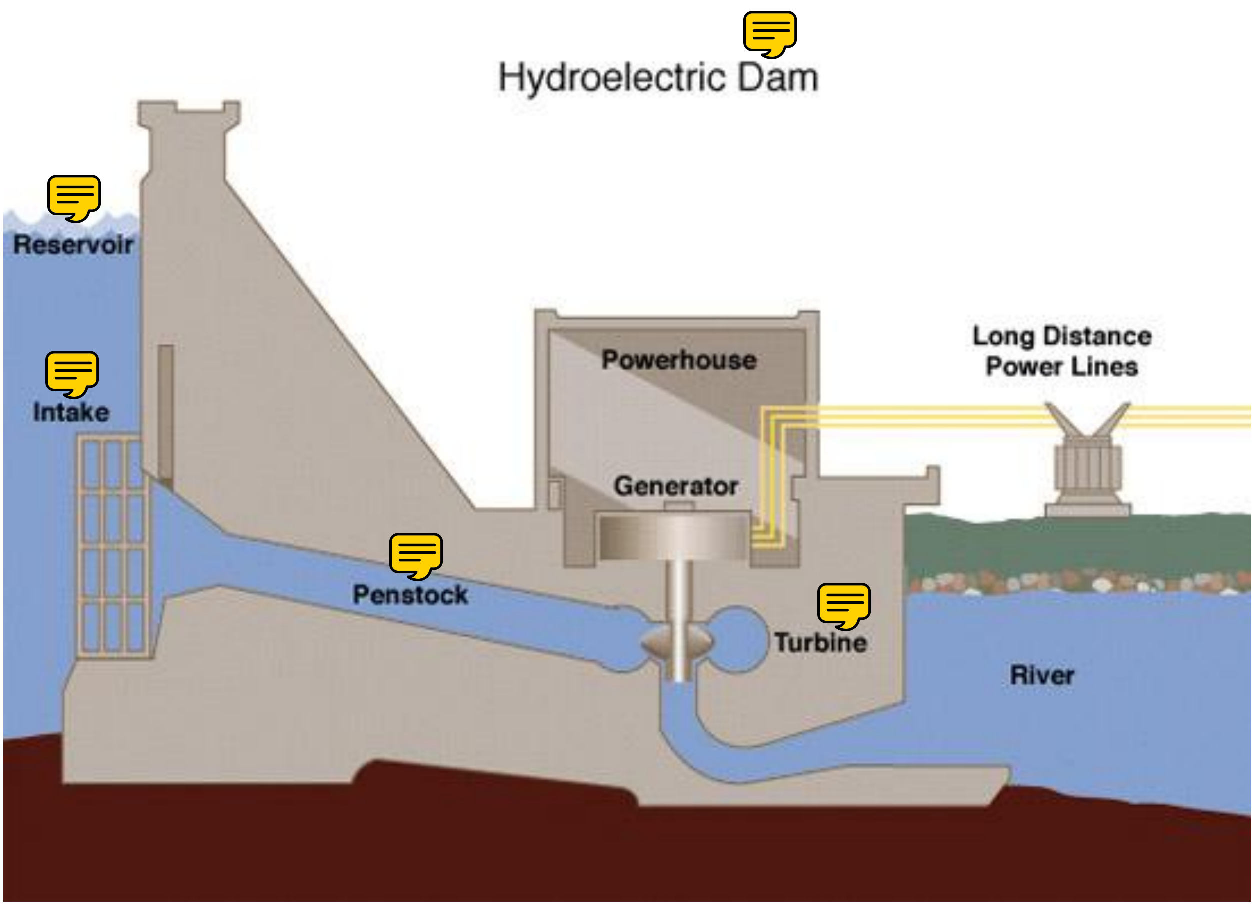
Even though wind energy has many environmental and supply advantages, there are several disadvantages that limit the usability of wind power. The main disadvantage to wind power is that it is unreliable. Wind does not blow at a constant rate, and it does not always blow when energy is needed. Furthermore, the windiest locations are often in remote locations, far away from big cities where the electricity is needed. Just like with any other energy plant, people oppose it because of aesthetic reasons. The rotor noise produced by the rotor blades is another reason for opposition.

Wind seems to be a very good source of alternative energy. Its biggest setback is its unreliability, but in combination with other, more reliable sources, wind energy should be used extensively to supplement the demand for energy.

Hydroelectric Power

Hydropower is America's leading renewable energy resource. This notable success can be attributed to the fact that out of all the renewable power sources, hydropower the most reliable, efficient, and economical. Furthermore, the concept behind hydroelectric power is fairly simple and has been in use for a significant span of time.

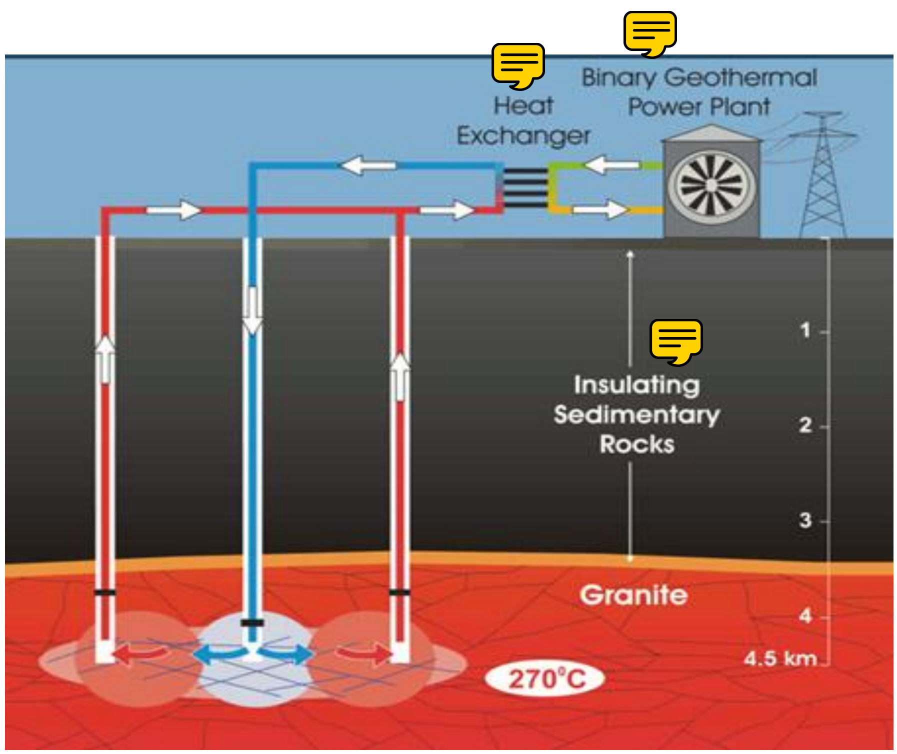
The earliest reference to the use of the energy of falling water is found in the work of the Greek poet Antipater in the 4th century BC. Indeed, the word "hydro" comes from the Greek language meaning "water." Several centuries later, the Romans were the first to utilize the waterwheel. Due to the Romans' powerful influence on Europe through conquest, the waterwheel was soon commonly found throughout that continent, and by 1800, tens of thousands of waterwheels had been built. These early waterwheels were of course not used for power generation, but mostly for grinding crops. Water energy was first converted into electricity on Sept. 30, 1882 near Appleton, Wisconsin.8 By 1980 hydroelectric power accounted for about 25% of global electricity and 5% of total world energy use, which amounted to approximately 2,044 billion kilowatt hours (kW h).



Harvesting energy from water is possible due to the gravitational potential energy stored in water. As water flows from a high potential energy (high ground) to lower potential energy (lower ground), the potential energy difference thereby created can be partially converted into kinetic, and in this case electric, energy through the use of a generator. There are essentially two major designs in use that utilize water to produce electricity: the hydroelectric dam, and the pumped-storage plant. The waterwheel discussed at the beginning of this paper is currently no longer in use and has been replaced by the far more economical and efficient dam. Both the waterwheel and the dam work on the same general principle, but the dam has the advantage of being more reliable due to the reservoir behind it. The principle is simple: the force of the water being released from the reservoir through the penstock of the dam spins the blades of a turbine. The turbine is connected to the generator that produces electricity. After passing through the turbine, the water reenters the river on the downstream side of the dam. A pumped-storage plant is very similar to the hydroelectric dam, the main difference being that the pumped-storage plant uses two reservoirs, one being considerably higher than the other. The advantage of this design is that during periods of low demand for electricity, such as nights and weekends, energy is stored by reversing the turbines and pumping water from the lower to the upper reservoir. The stored water can later be released to turn the turbines and generate electricity as it flows back into the lower reservoir. Now that the two types of facilities have been discussed, there are also two way of obtaining the water: dam and run-of-the-river. A dam raises the water level of a stream or river to an elevation needed to create the necessary water pressure. In a run-of-the river scenario, the water is diverted from its natural path, enters the turbine, and is later returned to the river. Hydroelectric power offers several significant advantages compared to fossil based power, and even other types of alternative energy. Probably the most important asset of hydroelectric power is its reliability. Furthermore, it creates no pollution, and once the dam is built, even though that process is very expensive, the produced energy is virtually free. A dam has the ability to continuously produce electricity and can adjust to peaks in demand by storing water above the dam and by being able to increase production to full capacity very quickly. Other than the high construction and planning costs, the major drawbacks of large dams are mostly environmental. The dam does not produce harmful emissions as in the case of fossil fuel burning. It does however alter the landscape dramatically, producing several severe, even unbearable changes to the habitat of fish and other plants and animals. Building a large dam will of course flood a large area of land upstream of the dam, causing problems for the animals that used to live there. It furthermore affects the water quantity and quality downstream of the dam which in turn affects plants and animals. Blocking the river also disallows certain migration pattern of fish. Finding sites that are suitable for dams is also a challenge. This is one of the reasons why the hydroelectric power production in the U.S. cannot increase by much in the future: most of the suitable locations have already been utilized. According to the Energy Information Administration, the total amount of electricity produced in the U.S. through hydroelectric means has increased by 6.3% from 2004 to 2005. Even though U.S. construction of dams has peaked and is decreasing, advances in turbine technology maintain a slight growth margin of electricity production. Precipitation however also influences the ability of dams to produce electricity. In this sense, 2005 could have been a year of increased precipitation if compared to 2004. Overall, hydroelectric power seems to be a very good source of alternative energy: one that should be maintained at the maximum level possible. It has the main advantage over all the other forms of alternative energy production in that it is reliable, whereas the other forms of alternative energy are not. The main disadvantage is that hydroelectric energy production in the U.S. is currently being used to its maximum potential, which means that large sums of investment will produce only small increases productivity. Other alternative energy sources are not yet as developed and hence will produce greater advances in productivity with the same or even a smaller input of money. Hydroelectric spending should be maintained at current levels, and more money should be invested in the other sources of alternative energy.

Geothermal

Geothermal energy is one of the only renewable energy sources not dependent on the Sun. Instead, it relies on heat produced under the surface of the Earth. Geothermal energy already has several applications and could potentially provide a significant source of renewable power for the United States. However, it is limited by a multitude of factors revolving around the issues of sustainability and economics. There are two main applications of geothermal energy, which include producing electricity at specialized power plants, and direct-heating, which puts to direct use the temperature of water piped under the earth's surface. Geothermal power plants take on several types of forms, depending on the type of geothermal area from which they extract energy. In any case, the plants depend on steam to power turbines and generate electricity, though the methods of producing steam varies depending on the type of geothermal reservoir.12 Direct-heating, on the other hand, provides immediate, usable energy. This type of energy can heat individual buildings or entire areas, as in the city of Klamath Falls, Oregon. It can also cool buildings by pumping water underground where the temperature remains relatively stable near 60 degrees Fahrenheit, and then into buildings, where the water absorbs heat, thus helping to air condition the building. The United States also uses direct heating in fish farms, spas, and greenhouses. Geothermal energy could potentially become a major source of renewable power for the United States. This is because geothermal energy reduces the United States dependence on foreign oil, it's extremely reliable due to the constant source of heat emanating from the earth, and it has almost no negative environmental impact.15 In 2004, the US produced approximately 2300 MW of electricity, and the Department of Energy estimates that the figure could reach 15000 MW per year within a decade.16 In the grander scheme, however, geothermal energy accounted for only about 0.34% of total U.S. energy consumption, and 5.56% of renewable energy consumption.17 But more energy could be extracted using developing technology, which doesn't rely on existing hot water and steam reservoirs. The process involves drilling deep into the surface of the Earth where temperatures are hot, and then injecting water into cracks of rock, which is heated and then pumped back to the surface.18 If this "hot dry rock" (HDR) technology proves effective, then more geothermal plants could operate in more locations, since much of the Earth's surface is underlain by hot, dry rock. Some problems that geothermal energy faces are depletion of both water and heat in geothermal areas. The first problem has been partially addressed by re-injecting water into reservoirs, thus sustaining the plant's ability to operate. However, it has been shown that water re-injection can cause small earthquakes, which raises the question of whether the plants should be liable for the damages caused.19 In Alameda, California, water reinjection at a geothermal power plant triggered earthquakes of magnitudes up to 3.9 and 3.5 on the Richter scale, which were felt 90 miles away in the community of Middletown.



As of now, there is no government regulation concerning the repayment of damages caused by these earthquakes, though community groups such as the one in Middletown have pressured the plant to compensate homeowners for damages such as cracked chimneys, which can cost about $10,000 to fix.20 Heat depletion of geothermal areas is more problematic than water depletion in the long run, since it cannot be avoided. It is caused by a natural cooling-off of the earth's crust, and in these cases, plants would become less and less efficient over several decades until they were rendered useless. Other issues facing geothermal power in the United States are building costs and economic competitiveness with other energy sources. Geothermal plants can be expensive, depending on factors such as how deep the wells must be drilled and the temperature of the water or steam. These initial costs of an economically competitive plant can be as high as $2800 per kW installed capacity, which accounts for about two thirds of total costs for the plant. The plants are economically competitive in the long run however, because their fuel is free, whereas natural gas or coal plants spend up to two thirds of their total operating costs on fuel. Another problem that adds cost to geothermal plants is the problem of connecting to energy grids. This is a critical issue because geothermal plants are built where geothermal resources permit- such as geysers and areas with less-heated water. Over time, however, the plants pay for themselves and all the necessary costs because of low operating costs; namely, the fact that the plants energy is free and always available. The National Commission on Energy Policy believes geothermal energy can cost from 4-6 cents per kWh, which depends on the construction of new geothermal plants, but compares favorably with other renewable energies such as solar power, which costs 20-25 cents per kWh.22 It's also competitive with coal and natural gas, which costs about 4-5 cents per kWh.23 The projected low cost therefore depends on the availability and exploitation of existing geothermal resource Because of its reliability, accessibility, low impact on the environment, and potential low cost, geothermal energy is a very attractive source of renewable energy for the United States. Expanding use of geothermal energy depends largely upon the success of the hot dry rock technology and the simultaneous prevention of earthquakes caused by water injection at those plants and water re-injection at other plants. If the HDR technology proves to be viable and safe, geothermal plants can be built in closer proximity to electricity grids, without worrying about geothermal resources like geysers. This would make the plants more cost effective and enable geothermal energy to compete with other energy types.

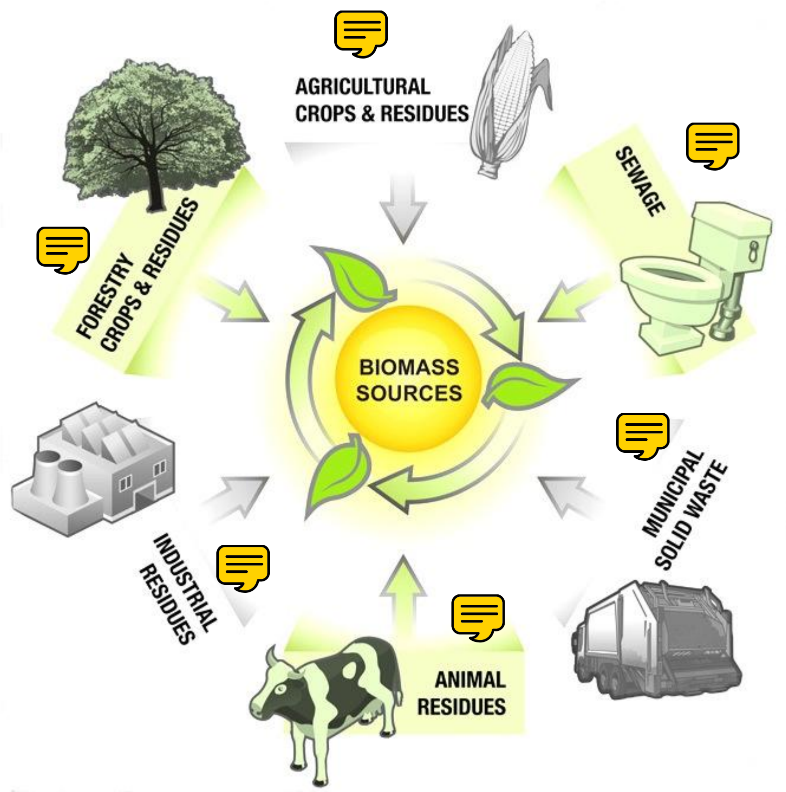
Biomass

As a pending global energy crisis appears more and more imminent, it is important to consider many different options for new energy sources. Renewable energy sources are ideal because they are more efficient, environmentally friendly and, ultimately, better for consumers. Biomass can be converted into fuels through a number of different processes, including solid fuel combustion, digestion, pyrolysis, and fermentation and catalyzed reactions. Electricity is generated in many places through solid fuel combustion. The majority of America's electricity is fueled by coal combustion. However, many states, especially California, are encouraging companies to use biomass fuels to generate electricity. These products are usually wood matter, vegetation, waste from lumber yards, and the like.25 Power plants burn such fuels to heat a boiler, and the resulting steam powers turbines & generators.26 This process still releases a lot of carbon dioxide and other polluting gases into the environment, but helps eliminate waste efficiently.

Digestion is another process that makes use of existing waste. The term is a misnomer. Digestion is the naturally occurring process of bacteria feeding on decaying matter and making it decompose. It is that which releases gases like methane, hydrogen, carbon monoxide, etc.27 In many landfills, owners are experimenting with set-ups to best collect the gases produced by such bacteria. The standard system includes pipelines running through the waste to collect the gases. Animal feed lots and other facilities are also exploring tapping such resources. A zoo in upstate New York is using their elephant manure to do the same thing. Benefits of this process include the relative lack of impurities in the gases produced and the fact that the synthesis gases (carbon monoxide and hydrogen) can be converted to any kind of hydrocarbon fuel.

A third process, pyrolysis, creates a product much like charcoal, with double the energy density of the original biomass, making the fuel highly transportable and more efficient. Anhydrous pyrolysis heats the biomass at intense temperatures in the absence of oxygen or water. Scientists assume that this is the process that originally produced fossil fuels (under different conditions). Most industrial processes of pyrolysis convert the biomass under pressure and at temperatures above 800° F (430° C). A liquid fuel can also be produced using this process.

The most widely used alternative fuel, ethanol, is created through fermentation of organic materials. Ethanol has a current capacity of 1.8 billion gallons per year, based on starch crops



such as corn. Again, the fuel conversion process takes advantage of a natural process. Microorganisms, especially bacteria and yeasts, ferment starchy, sugary biomass products (like corn), yielding products like ethanol, which can be used as fuels in a variety of applications. Biodiesel is an increasingly popular fuel, especially in the transportation sector. This mono-alkyl ester is formed by combining fuel-grade oil, processed from sources like vegetable oil, animal fats, algae and even used cooking grease, with an alcohol (like methanol or ethanol), using a catalyst. It shows great promise as both a neat fuel (used alone) and as an additive to petroleum diesel.

Using biomass could be the answer to the energy questions made more imminent by the recent crises that have further threatened our oil supply. The current technologies take advantage of many natural, long-utilized processes in order to create "new" kinds of fuel. Upon further observation, one realizes that these fuels are very basic, using the most readily available energy sources with very simple, standardized processes that greatly reduce pollution and offer hope for the future.

Ethanol

Fuel-quality ethanol is beneficial for car-owners, the economy and the environment. This growing technology is looking to be an immediate part of the solution to the forthcoming energy crisis. Ethanol, also known as ethyl alcohol or grain alcohol, is a colorless, clear liquid.The chemical formula is CH3CH2OH. Fuel-quality ethanol goes through more processes than do alcoholic beverages, in order to make it unfit for human consumption and to increase the purity so as to avoid separation when mixed with gasoline. The most common method for making ethanol used in the United States is the dry-mill method. At the beginning of 2005, the 81 ethanol plants in 20 states can produce up to 4.4 billion gallons each year, and the 16 plants under construction are expected to add 750 million gallons of capacity. The dry mill process has advanced to the point at which any cellulosic (plant fiber) biomass can be used to make fuel ethanol (and is now being referred to as the Advanced Bioethanol Technology). The variety of feedstock that can be used today includes corn, barley, wheat, cornstalks, rice straw, sugar cane bagasse, pulpwood, switch grass and even municipal solid waste, offering tremendous opportunities for new jobs and economic growth.

Ethanol is not used by itself to fuel cars. Instead, it's mixed with gasoline. The two most common blends are E10 and E85. The number refers to the percentage of ethanol in the blend. E10 is a blend of ten percent ethanol and ninety percent gasoline. E85, the most mainstream alternative fuel, is eighty-five percent ethanol and fifteen percent gasoline. Using ethanol increases the octane rating and decreases the amount of damaging emissions associated with fuel consumption. It is for this second reason that ethanol use is so strongly recommended and endorsed by state and federal governments. The Clean Air Acts Amendments of 1990 require using reformulated gasoline (RFG) to reduce emissions in major metropolitan areas. RFG blends gasoline with oxygenates, of which ethanol is increasingly popular. Methyl tertiary-butyl ether (MTBE) used to be the most popular, but there are increasing environmental health concerns, regarding seepage, surrounding its use. Oxygenates (compounds with structures similar to that of gasoline, but with the addition of oxygen) dilute the noxious, dangerous gases emitted by gasoline consumption, including nitrogenous oxides, volatile organic compounds and other toxic like carbon monoxide. It is for this reason that the Clean Air Acts Amendments require inclusion of oxygenates like ethanol in the fuel supplies of metropolitan areas, and that the government offers many incentives. These include the Clean Fuel Tax Deduction, taken off the vehicle property tax on new qualified clean fuel vehicles or the conversion of vehicles to run on alternative fuels; the ethanol and biodiesel tax credit, under the American Jobs Creation Act of 2004 (Public Law 108-357); the credit for installation of alternative fueling stations, under the Energy Bill of 2005; the new Flexible Fuel Vehicle labeling requirement, and many more. Approximately one-third of the states offer incentives as well.

Increase in use of ethanol as fuel will benefit farmers economically. The majority of ethanol used today comes from corn, and it is the farmer-owned ethanol plants that are driving the industry's growth. Half of the operating plants are owned by farmers and local investors. The United States Department of Agriculture estimates that the Renewable Fuels Standard would increase the demand for corn for ethanol to 2 billion bushels each year by 2012, almost double the current demand, which would raise net farm income to $4 billion.

There are drawbacks to using ethanol. The presence of oxygen and smaller molecules means it produces less energy than raw gas, reducing fuel economy by 2 to 3 percent. The octane boost from ethanol is smaller than that of MTBE, and ethanol raises gasoline's volatility, increasing evaporative emissions, all of which are of concern. However, these shortcomings pale in comparison to the health concerns and need to reduce the use of gasoline consumption. There is a reason ethanol blend is required in fuel by Minnesota state law. The environmental and economic benefits make it a desirable alternative. As technology improves, more of the drawbacks will be decreased, and ethanol and other alternative fuels will become mainstream and standard-issue, leading the United States away from our gasoline addiction.

Ocean Energy

Nearly seventy percent of the Earth's surface is covered by oceans, which have the potential to supply humans with an enormous amount of renewable energy. Humans have exploited the vast energy potential of Earth's oceans by taking advantage of wave movement, tides, ocean currents, and ocean thermal energy. The United States, however, has given little or no attention to ocean energy up until this point. This is because of major problems with siting power plants and various economic obstacles. Recent legislation has brightened the future outlook of ocean energy in the United States, but the fledgling technology will take years to realize its potential and account for any significant portion of the United States' consumption of renewable energy Though the United States does not currently have many power-generating facilities to take advantage of ocean energy, some private and public associations have begun eyeing existing European technologies in hopes of bringing them to American soil or rather, waters. Europe is the world's leader in exploiting ocean energy, due in large part to its location and natural geography. For example, winds blown across the Atlantic from west to east naturally increase the size of waves on Europe's western coast of the west coast of Britain. Larger waves have greater energy, and therefore more power producing ability. Europe has also led the way in technologies that exploit underwater currents and tides. The United States hopes to learn from these technologies, plus the non-European ocean thermal energy conversion (OTEC) technology, which is feasible only in equatorial waters like those around Hawaii. The city of San Francisco has recently collaborated with a Scottish group called Scotland's Ocean Power on a demonstration project for capturing wave energy, which is one of the four major types of ocean energy.49 This technology works on the principle of rolling waves flowing through joints in a large cylindrical pipe, which pushes high pressure oil through hydraulic motors to generate electricity- which is in turn fed to an onshore grid through an underwater cable. Plans are underway to create a "wave farm" off the coast of Britain using these wave energy converters. One square kilometer of ocean interspersed with the devices would produce about 30 MW of electricity, which could power 20,000 homes. About twenty square kilometers could power the city of Edinburgh.50 The U.S. has similar ambitions in areas of the Pacific Northwest, like Orego , Washington, and southern regions of Alaska. In terms of price, the technology in Europe provides electricity at the equivalent of about 9 cents per kW, which is about twice the price of wind power in Europe.51 Obviously then, the technology has a way to go before it becomes competitive in Europe, and especially the United States, which is further behind. There are numerous other variations of wave-energy systems besides the one mentioned, falling into the categories of onshore, near-shore, or offshore systems; but in any case, the systems manipulate wave motions to power hydraulic pumps or spin turbines, thus generating electricity which is fed via cable to the nearest electricity grid. Americans see another example of ocean energy technology in France, which is home to the world's largest (240 MW) tidal power plant.52 Tidal-power plants such as the one in La Rance, France, operate by damming an estuary and generating electricity from water flowing through turbines. There are a number of variations in terms of exactly how electricity is produced, but one popular method is called ebb generation. At high tide, water flows in through openings in the barrage, or dam, spinning turbines to generate electricity. The water is retained behind the barrage until low tide, when it flows out again, once again spinning the turbines and generating electricity. The predictability of tides makes tidal power a reliable energy source, though it can only produce electricity at certain times of day: during high and low tides. Unfortunately, there are only a handful of places in the world where tidal power generation is efficient, and the United States is not home to many. These places observe a difference of about 5-10 meters between high and low tide, which is ideal and also costs for building these types of projects run high, deterring investors who want quicker returns on their money. Tidal power plants typically have negative impacts on estuarine ecosystems as well, adding a further obstacle to their implementation.