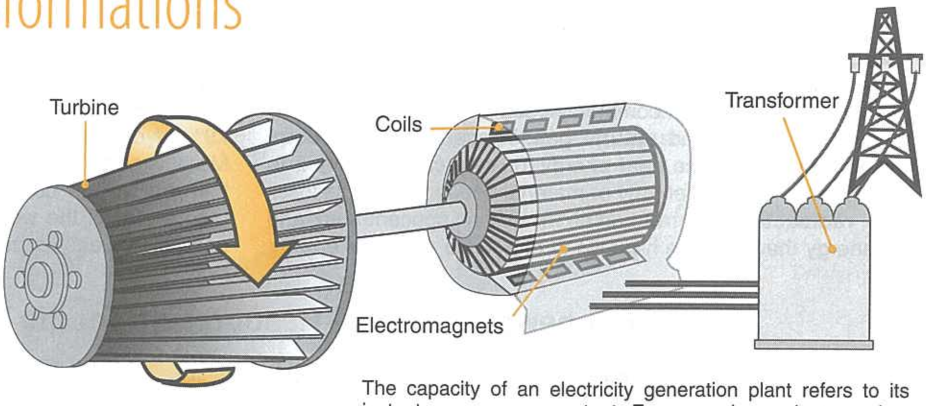
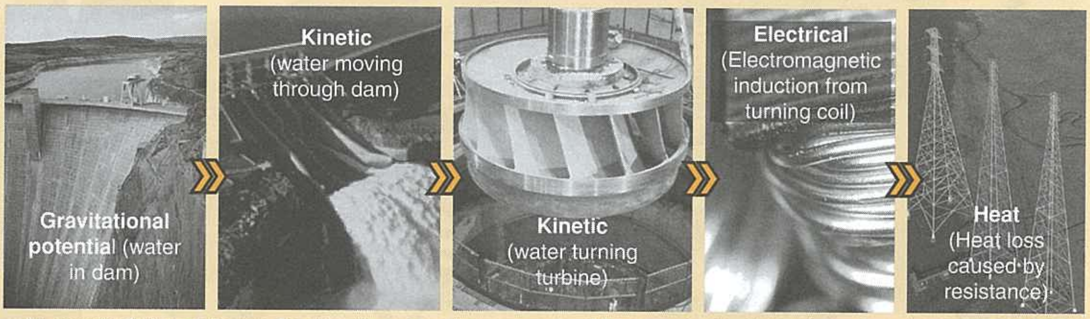
Using Energy Transformations

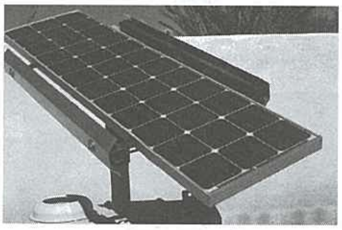
Most commercial electricity is generated by transforming **kinetic energy** into **electrical energy.** This is usually achieved by using kinetic energy to turn a turbine attached to a magnet or electromagnet housed inside a large set of wire coils (or vice versa) (the generator). Moving the magnet through the coils produces electricity by a process called **electromagnetic induction**. The difference between most forms of electricity generation is the method employed to turn the turbine. Energy comes in many forms, from **potential** (stored) energy to kinetic (movement) energy. Energy can be **transformed** easily between these forms. A rock at the top of a hill has gravitational potential energy. Giving it a push so that it rolls down the hill converts the gravitational potential energy into kinetic energy, along with some sound and heat. Energy is lost from a system (normally as heat due to friction) whenever energy is transformed from one form into another. Removing causes of energy loss improves the efficiency of the device being used. Generally, the fewer steps involved in energy transformation, the less energy will be lost from the system.



The capacity of an electricity generation plant refers to its instantaneous power output. For example, a plant rated at 1000 MW has the ability to produce 1000 megawatts (1000 megajoules per second) of electricity at any one point in time.



An energy chain can be used to describe where the energy used to generate electricity comes from (and goes to). The number of steps in the chain depends on the form of energy being used and the type of energy generation.



Photovoltaic cells (or solar cells) are increasingly being used in the production of electricity on a small scale. The solar cell is able to produce electricity directly from the Sun's energy without the need for a turbine.

1. Describe the process by which electricity is commercially generated: ______

2. Explain why no form of electricity generation can ever be 100% efficient: ______

3. For each of the following create an energy chain to show the energy transformations in the generation of electricity:

   (a) Geothermal power generation: ______

   (b) Coal fired power station: ______

   (c) Nuclear power station: ______

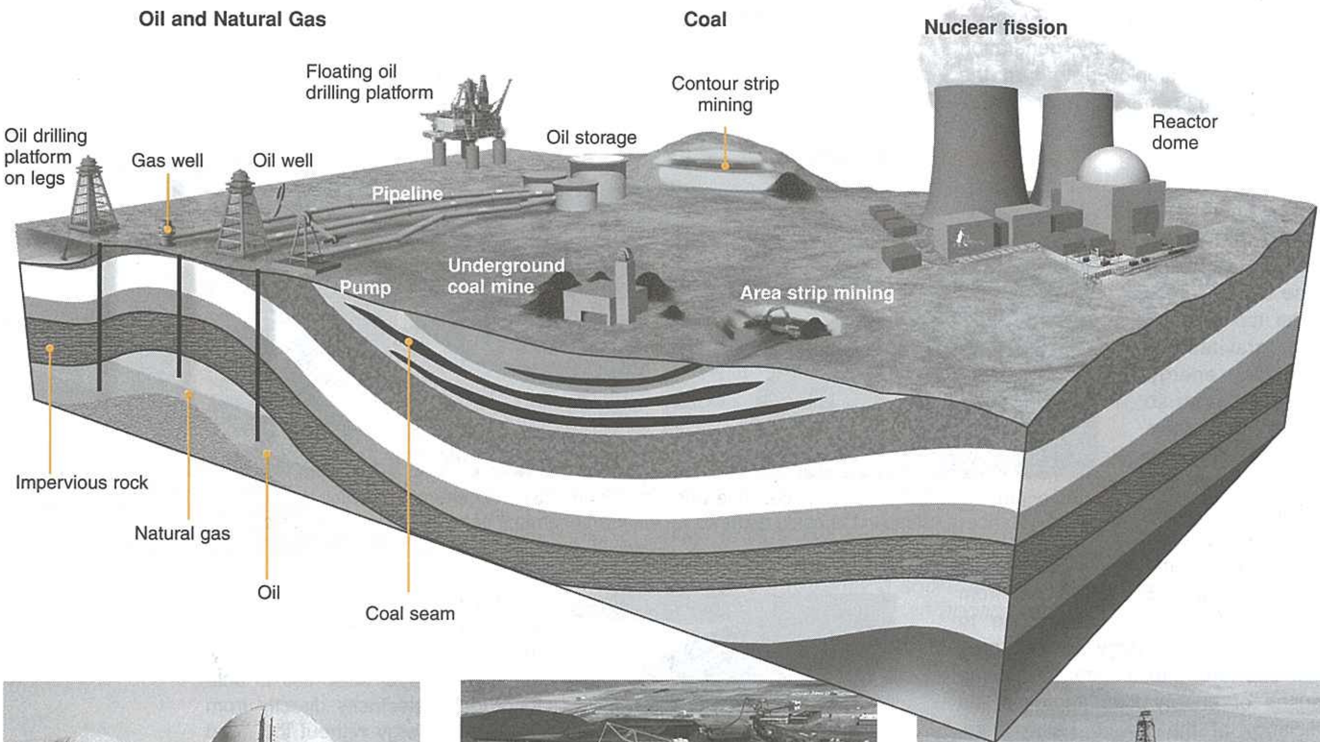
Energy

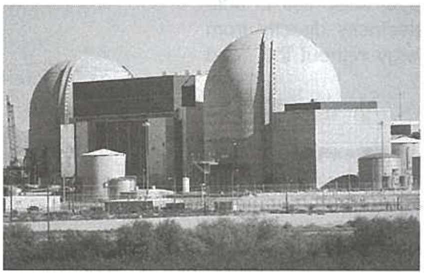
Non-Renewable Resources

The Earth contains enormous mineral resources, which are able to be obtained and used with relative ease to produce usable energy. The most commonly used of these are the **fossil fuels**, i.e. **coal**, **oil** and **natural gas.** These are can be burnt immediately to produce heat energy, or they can be refined to provide for a variety of energy or material needs. As well as fossil fuels, **radioactive** minerals can be mined and concentrated, and the energy they produce harnessed to provide electrical energy.

Around 85% of the world's energy needs comes from burning fossil fuels, with around 5% coming from **nuclear energy.** The distribution of mineral use globally is not uniform. For example, 79% of nuclear power stations are found in just ten countries. Moreover, the world's twenty wealthiest countries use more than half the world's commercial energy supply yet constitute less than a fifth of the world's population. In contrast, many poorer nations lack easy access to energy resources.

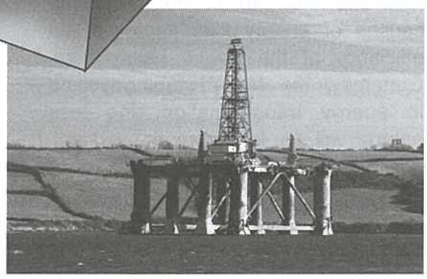
Non-Renewable Energy Resources from the Earth's Crust





A nuclear power plant uses uranium-235 or plutonium-239 as fuel in a controlled nuclear fission reaction to release energy for propulsion, heat, and electricity generation. Nuclear power does not release CO_2, but safe storage and disposal of nuclear waste remains a challenge.

Coal can be easily extracted from seams found near the surface. This causes a large amount of disruption to the landscape. Coal from deeper seams can be extracted by underground mining, which causes little surface disruption provided there is no land subsidence.



Oil and natural gas can be extracted by drilling into a reservoir and pumping the contents to the surface. Many large reservoirs are found offshore, along the continental shelves. Special drilling platforms can be towed out by boats and anchored the reservoir.

1. Explain why coal, oil, natural gas and nuclear fuels such as uranium are non-renewable: ______________________

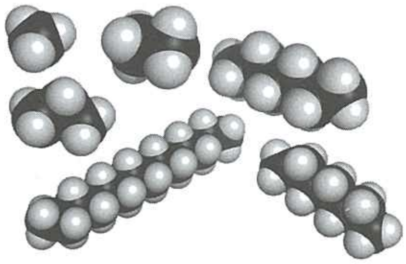
2. Describe some of the issues associated with extracting energy resources from the Earth's crust: ______________________

Oil

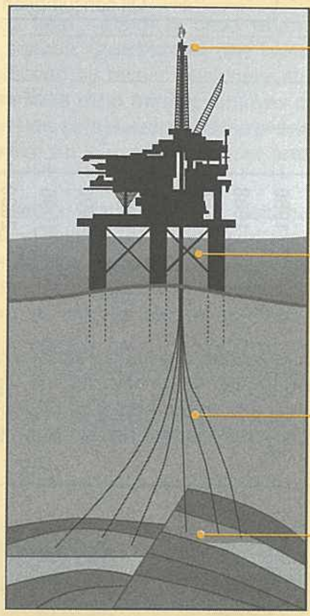
Oil is formed from the remains of algae and zooplankton which settled to the bottom of shallow seas and lakes about the same time as the coal forming swamps. These remains were buried and compressed under layers of nonporous sediment. The process, although continuous, occur so slowly that oil (and coal) is essentially non-renewable. Crude oil can be refined and used for an extensive array of applications including fuel, road tar, plastics, and cosmetics.

Oil and Natural Gas

Oil and natural gas are both composed of a mixture of hydrocarbons and are generally found in the same underground reservoirs. **Natural gas** is generally defined as a mixture of hydrocarbons with four or fewer carbon atoms in the chain (as these are gaseous at standard temperatures and pressures). **Oil** is defined as the mixture of hydrocarbons with five or more carbon atoms in the chain.

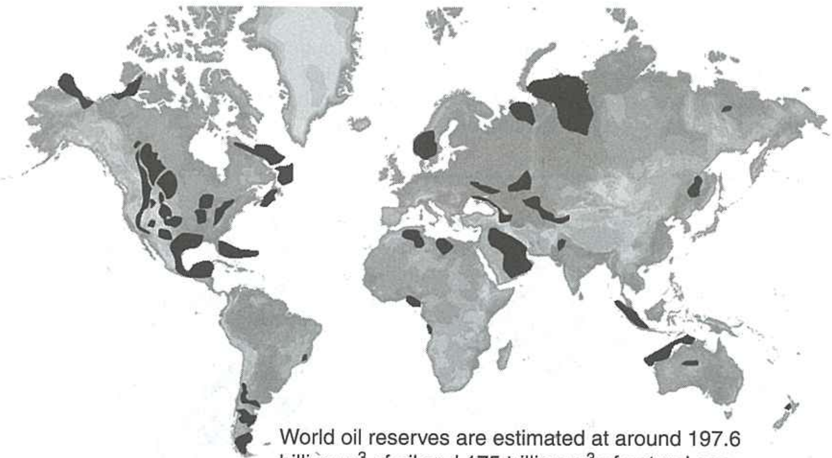


Oil and Natural Gas Extraction



Oil and natural gas reservoirs are found using a number of techniques including echolocation, gravitational and magnetic fluctuations, and geological surveys. A well is drilled once a reservoir has been located. Steerable drill heads allow multiple wells to be drilled without having to move the platform.

Major World Oil Reserves



World oil reserves are estimated at around 197.6 billion m^3 of oil and 175 trillion m^3 of natural gas.

Natural gas is often found in the same reservoirs as oil. Drilling rigs require specialized facilities to store the gas. Because of this, much natural gas is either vented, or reinjected to maintain pressure in the reservoir.

Transport of natural gas requires specialized equipment. Liquid natural gas (LNG) tankers are able to cool the gas to -162°C and transport it as a liquid (saving space). Gas can also be piped to shore if facilities are nearby.

Oil may be found in materials that make extraction through conventional drilling impossible. These **non conventional oils** (e.g. oil shale) are often mined in the same way as coal and the oil washed from them.

Crude and **heavy oils** require refining before use. Crude oil is separated into different sized fractions by a **distillation tower**. Heavy oils may be heated under pressure to break them into smaller more usable molecules.

1. Describe the difference in the composition of natural gas and oil: ______________________________

____

____

2. Describe how oil-bearing rocks are found and exploited: ______________________________

____

____

3. Explain why natural gas is often reinjected into the main oil reservoir: ______________________________

____

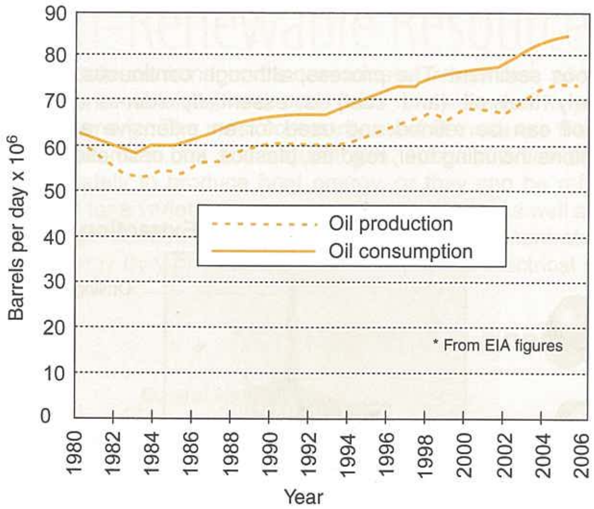
____

____

Periodicals:
The Canadian oil boom: Scraping bottom

Related activities: *Non-Renewable Resources*
Weblinks: *Coal and Oil Formation*

World Oil Production and Consumption

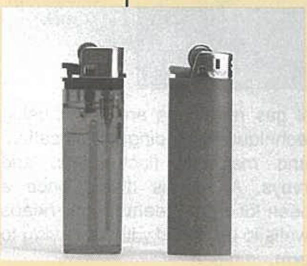


Oil	
Advantages	**Disadvantages**
Large supply	Many reserves are offshore and difficult to extract
High net energy gain	High CO_2 production
Can be refined to produce many different fuel types	Potential for large environmental damage if spilled
Easy to transport	Rate of use will use up reserves in near future

*Note: The difference between consumption and production figures are due to changes in stock and the consumption of additives which increase the volume of the resulting fuel.

Oil Refining

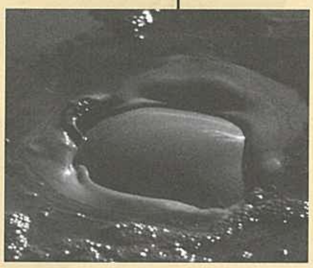
Oil is refined in a fractionating or distillation tower by **fractional distillation**. The tower is around 400°C at the bottom, but cools towards the top to less than 100°C. Crude oil is pumped into the bottom of the distillation tower and evaporates. The oil vapor cools and condenses as it travels up the tower. Long chain hydrocarbons condense near the bottom of the tower while short chain hydrocarbons condense near the top.



Short chain hydrocarbons find use in portable lighters. Butane is commonly used in cigarette lighters and camp stoves. Propane is commonly used for larger barbecue grills.

Petrol and diesel are formed from hydrocarbons with between 6 and 12 C atoms. They provide a high energy, easily combustible fuel that, being a liquid, is easily stored and transported.

Mid length hydrocarbon chains (about 15 C atoms) are used as jet fuel. They are less volatile and less flammable than shorter chain hydrocarbon fuels while providing high energy per unit volume.



Long chain hydrocarbons may be heated to split them into shorter chains (to boost the fractions of petrol and diesel produced), or used in lubricating oil, heavy fuel oil, waxes, and tar.

4. Examine the graph of oil consumption and production:

   (a) Describe the trend of the line graphs: ______________________

   (b) Describe the trend in the data from the year 2000 to 2006: ______________________

5. Describe some of the advantages and disadvantages of using oil: ______________________

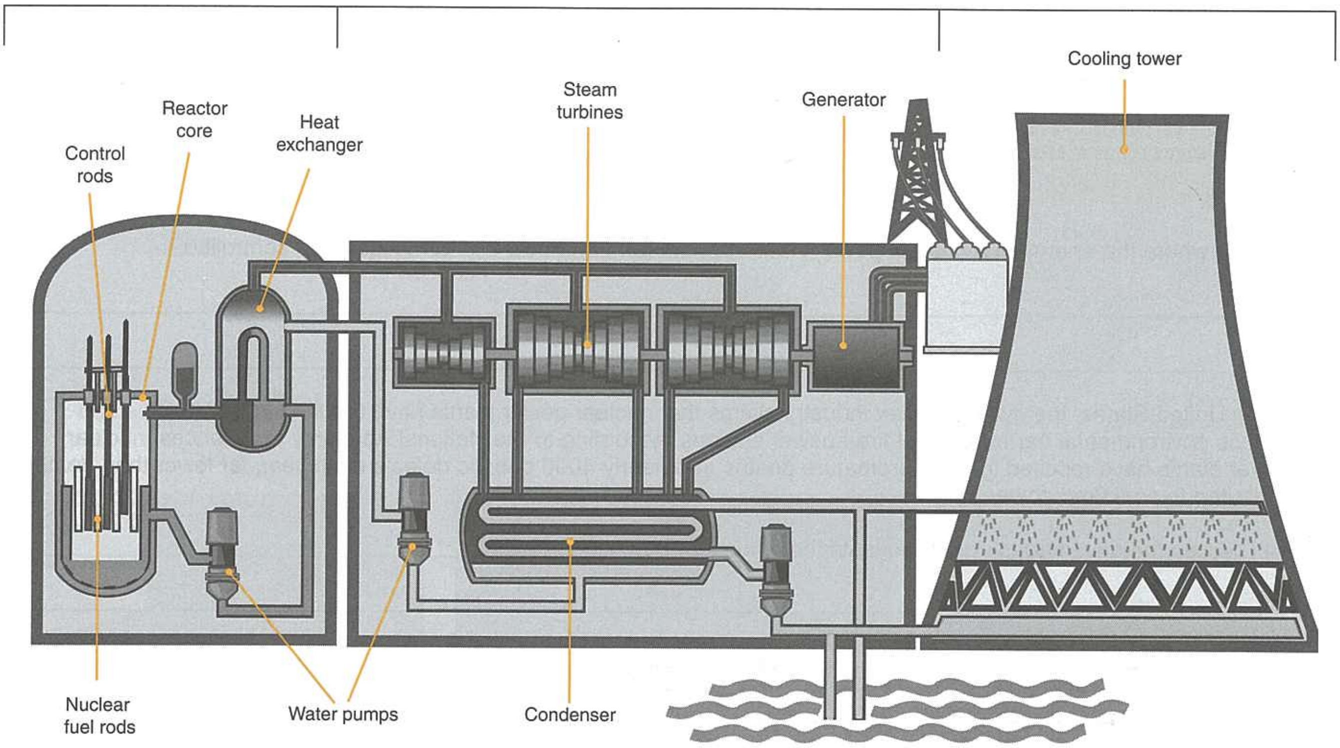
6. Explain how crude oil is refined: ______________________

Periodicals:
Scraping the bottom of the barrel

Nuclear Power

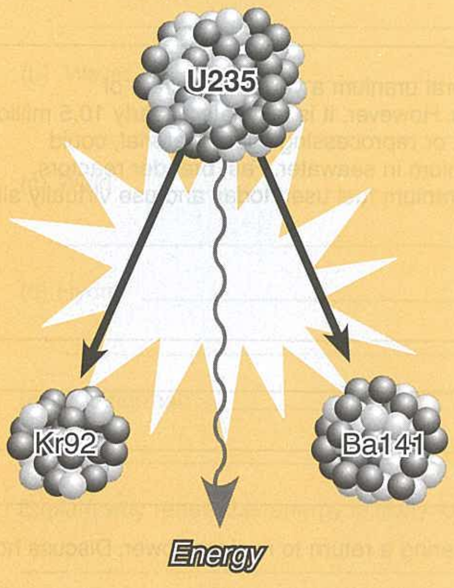
Nuclear power accounts for about 5% of the world's production of usable energy but 14% of world electricity because virtually all of it is used for electricity production. Nuclear **fission** reactors are currently the only reactor type used to produce commercial electricity, although there are a number of reactor designs. Nuclear power reactors first began to be developed for industry in the 1950s and there are now more than 400 reactors throughout the world, with most located in the USA and western Europe. The popularity of nuclear power stations declined during the 1970s and 80s due to high costs and two high profile accidents. Currently, with better technology available and growing concerns over climate change and energy shortages, nuclear power is being reexamined as a cost effective option for electricity production.

Nuclear Power Station



A nuclear power station consists of a reactor building, powerhouse, and cooling tower(s). The reactor building houses the reactor core, which consists of a series of nuclear fuel rods set between removable control rods. Heat produced in the reactor is passed through a heat exchanger to heat water to steam which drives the turbines and generator. Steam then passes into a condenser which is cooled by water pumped from the cooling tower.

Nuclear Fission



The energy in a nuclear reactor comes from the splitting of a **plutonium** or **uranium** atom. Part of the mass of the atom is converted into energy. The energy released is used to heat a heat sink (water or a metal or molten salt) surrounding the reactor.

Nuclear Power Generation	
Advantages	**Disadvantages**
Large potential fuel supply	High start up costs
Little fuel is needed so supplies last a long time	Disposal of waste presents major technical and environmental problems
Low air pollution (low CO_2 emissions)	Risk of catastrophic environmental disaster if accident occurs
Little land required	Technology can be adapted to develop nuclear weapons
Large amount of energy generated	Potential terrorist target

Photo: USDE

The energy produced by nuclear reactions is enormous. **Uranium** subjected to fission produces around three million times as much energy as an equal mass of coal. However only a small percentage of this energy is used in nuclear power plants.


Kurchatov Inst.

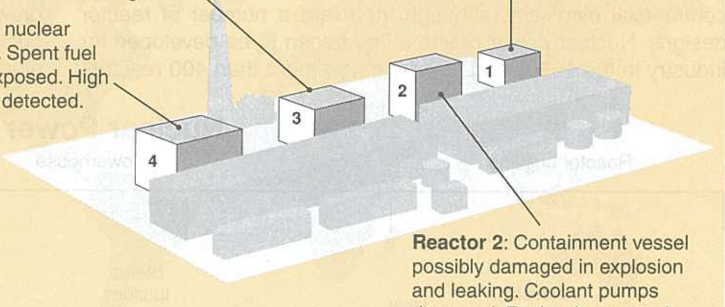
The potential disasters that nuclear power stations present were shown in 1986 when the number 4 reactor at **Chernobyl** exploded, spreading radioactive material over a wide area and causing the evacuation of the city of Pripyat.

Periodicals: *Can nuclear power compete?*

Related activities: *Non-Renewable Resources, Chernobyl Accident*
Weblinks: *How it Works*

Fukushima Nuclear Crisis

On March 11, 2011 the Fukushima Nuclear Power Station, 220 km north of Tokyo, suffered multiple reactor failures after a 9.0 magnitude earthquake and 10 m high tsunami. Coolant pumps failed with a possible partial meltdown of at least three reactors. Heat generated by the fuel rod meltdown caused reactor water to boil to steam, exposing the fuel rods to air and causing production of hydrogen gas. Venting the gas from each of the three separate reactor containment vessels led to explosions that destroyed the outer reactor buildings. The containment vessels of reactors 2 and 3 may have been damaged during the explosions, leading to radiation spikes. In last resort efforts to cool the fuel rods engineers pumped seawater into the coolant system (info as at March 17, 2011).



Schematic of Fukushima Daiichi Nuclear Plant

1. Explain where the energy in a nuclear power station comes from and how it is harnessed and controlled:

2. In the United States, the nuclear power industry claims that nuclear power plants have resulted in no fatalities and far less environmental harm that coal fired power stations. According to the National Academy of Sciences, nuclear power plants have resulted in 6000 premature deaths and nearly 4000 genetic defects each year, far lower than deaths attributed to coal fired power stations.

   (a) Discuss the advantages and disadvantages of nuclear power generation:

   (b) Explain why many people dislike the idea of nuclear power plants despite all of a nuclear power plants inbuilt safety features:

3. Present day nuclear reactors require a total of around 70 000 tonnes of natural uranium a year. At this rate of consumption, the known global supplies of uranium will last around 70 years. However, it is estimated nearly 10.5 million tonnes of uranium deposits are still undiscovered. Better refining of uranium, or reprocessing spent material, could reduce requirements by 50%.There is an estimated 4.5 billion tonnes of uranium in seawater. Fast breeder reactors, which are currently uneconomic and difficult to control, use only 1% of the uranium fuel used today and use virtually all their wastes as fuel.

   Calculate the length of time the uranium fuel supply will last based on:

   (a) Undiscovered uranium:

   (b) Undiscovered uranium plus better refining and reprocessing:

   (c) Extracting uranium from seawater:

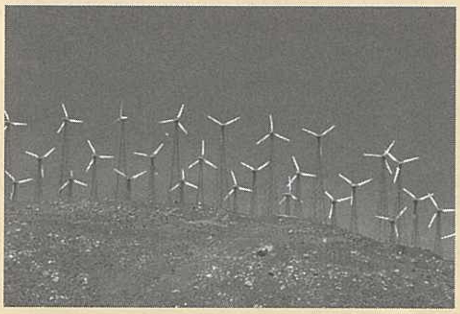
   (d) Using known reserves with fast breeder reactors:

4. After many years of its unpopularity, many electrical companies were considering a return to nuclear power. Discuss how the crisis at Fukushima may affect these considerations.

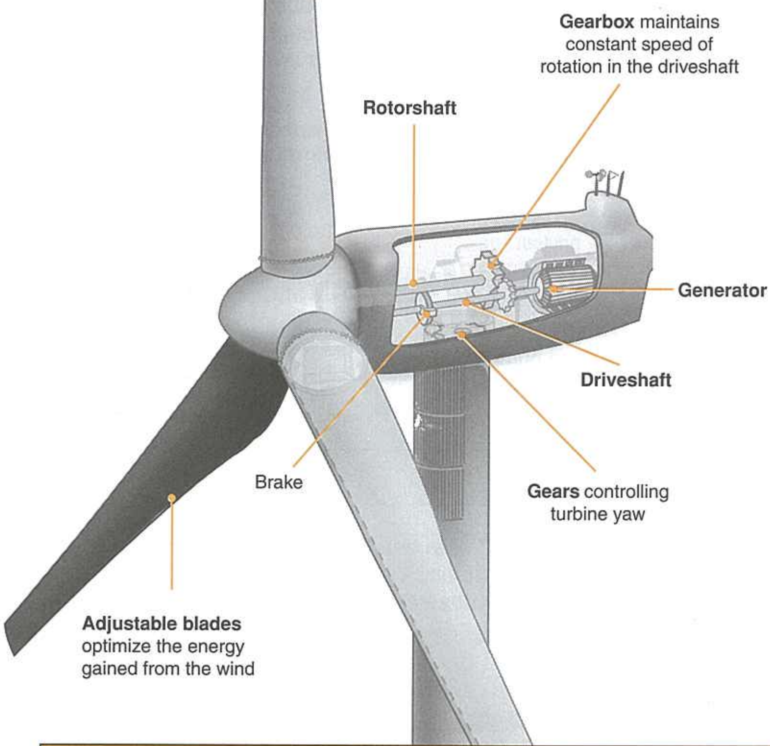
Wind Power

Wind power has be used for many years to provide mechanical energy for running water pumps or machinery. Today it is mainly used to produce electricity. Wind power is becoming increasingly reliable and cost effective as the technology develops and turbines are able to operate in a range of conditions and wind speeds. Globally, wind power is steadily increasing in generation capacity, but wind is a variable energy provider. Fluctuations in power availability begin to become discernible when it makes up more than 20% of a nation's power output, meaning output can not be matched to changes in demand.

Wind farms often cover large areas of land but turbines can be designed to operate at sea and, on a smaller scale, along highway edges. Turbines range in size from just a meter across, to the world's current largest at 198 m tall and 126 m in diameter, with a generation capacity of 7 MW. Larger 10 MW turbines are already being planned.



At the end of 2009, the power output from wind turbines was around 1.5% of the global production of usable energy. Many European countries now use wind power to generate a substantial proportion of national power requirements. Denmark, for example, produces around 20% of its required power by wind. Currently, the European Union and the United States are the biggest producers of wind energy.



Wind Power	
Advantages	Disadvantages
No emissions	Production of visual and noise pollution
Little ground disturbance during or after construction	Requires steady winds
Compact and transportable to most locations	Can interfere with the flight paths of flying animals
Can be located in many areas (even at sea)	Much of actual cost to user is repaying start up costs.
	Back up systems required in low winds

1. Explain why wind power works best when it makes up only a minor portion of national electricity requirements:

2. Discuss the advantages and disadvantages of wind power:

3. A typical wind turbine produces around 2.3 MW. The average house uses 30 kWh per day. Calculate the following:

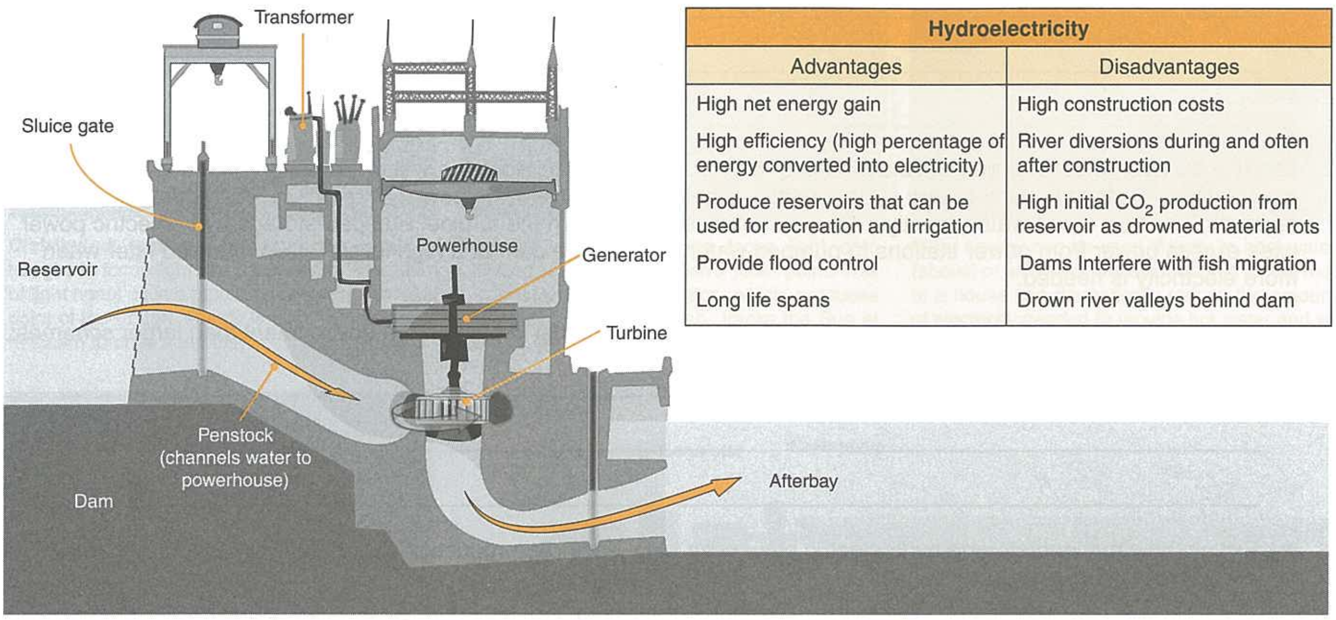
   (a) The minimum number of wind turbines required to power a town of 20 000 households:

   (b) The total cost of the wind turbines in 3a above at a rate of $1000 per kilowatt installed:

   (c) The number of wind turbines required to replace a 120 MW coal fired power station:

Hydroelectricity

Hydroelectricity accounts for around 20% of global electricity production. Electricity is produced by utilizing the **kinetic energy** of water stored in reservoirs behind **dams**. Water is directed along pipes into the powerhouse where it drives turbines connected to a generator. The larger the volume of water and the further it has to fall, the greater the amount of energy it contains. Large dams can therefore produce large amounts of electricity. The generation of electricity itself produces no CO_2 emissions or other air pollution, but the construction of the dam requires massive amounts of energy and labor and often requires river diversions. Construction of large hydroelectric dams is highly controversial because creating a reservoir behind the dam often requires the submergence of towns and land. Dams constructed inefficiently can also fill up with silt and gradually reduce in generation capacity.

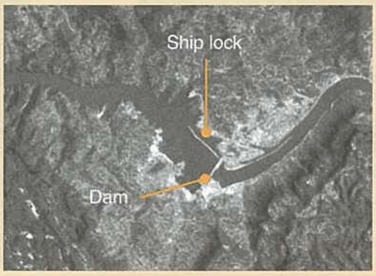


Hydroelectricity	
Advantages	**Disadvantages**
High net energy gain	High construction costs
High efficiency (high percentage of energy converted into electricity)	River diversions during and often after construction
Produce reservoirs that can be used for recreation and irrigation	High initial CO_2 production from reservoir as drowned material rots
Provide flood control	Dams Interfere with fish migration
Long life spans	Drown river valleys behind dam

The Yangtze River

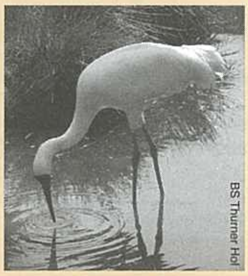
All images NASA except where indicated

1987



2006

Silt from Yangtze River

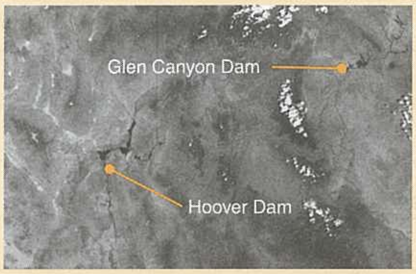


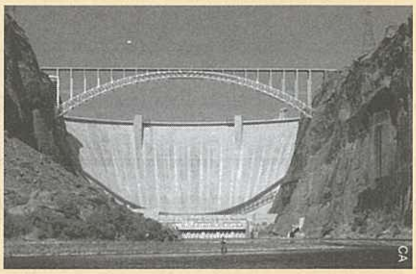
Siberian Crane

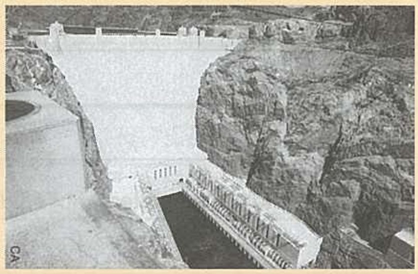
The **Three Gorges Dam** (above) on the Yangtze river, China, is 2.3 km wide and 101 m high, with a reservoir 660 km long. It has a generation capacity of 22 500 MW. The construction of the Three Gorges Dam in China caused the river water level to rise by 100 m, and required 1.2 million people to be relocated.

Dams reduce flood damage by regulating water flow downstream. However, they also prevent deposition of fertile silts. Flooding land behind the dam to create a reservoir seriously disrupts the feeding areas of wading birds.

Colorado River







A number of dams are found along the Colorado River, which runs from Colorado through to Mexico. The two largest hydroelectric dams on the river are the Glen Canyon Dam and the Hoover Dam. Together these dams have a generation capacity of over 3000 MW and provide irrigation and recreation for thousands of people. Both dams control water flow through the Colorado River and were controversial even before their construction.

The construction of **Glen Canyon Dam** effectively ended the annual flooding of the Colorado River. This has allowed invasive plants to establish and has caused the loss of many camping beaches as new silt is trapped behind the dam. The reduced flow rate of the river has severely affected native fish stocks. Controlled floods held in 1996 and 2004 have had beneficial effects on the downstream ecosystems.

Hoover Dam, which impounds Lake Mead, has a generation capacity of over 2000 MW. Water from Lake Mead serves more than 8 million people in Arizona, Nevada, and California. The dam has had a major effect on the Colorado delta, which has reduced in size from around 800 000 hectares to barely 73 000 hectares. Native fish populations have also been reduced.

1. (a) Explain how hydroelectric dams are used to generate electricity:

(b) Describe the relationship between water volume, height of the dam and electricity production:

2. Large scale hydroelectric power uses a high dam built across a river to block the water flow and create a reservoir. Water moving through pipes is used to turn large turbines. Small scale hydroelectric power uses only a small dam and no reservoir. The flow of the water directly from the stream is used to turn the turbine. Pumped-storage hydroelectric power uses excess power from power stations to pumped water to a storage dam at a high level. This is released later when more electricity is needed.

(a) Explain why small scale hydroelectric power has less environmental impact on the environment than larger schemes:

(b) Explain how pumped-storage hydroelectric power can help electricity production during periods of high demand:

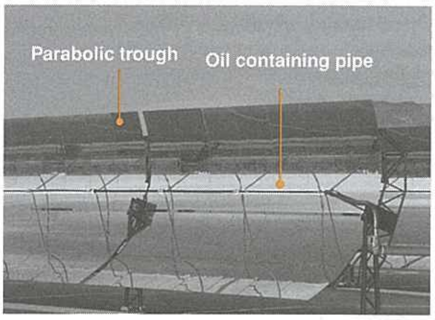
(c) Explain why pumped-storage hydroelectric power is an efficient use of electricity resources:

3. Using specific examples, describe some advantages and disadvantages of large scale hydroelectric dams:

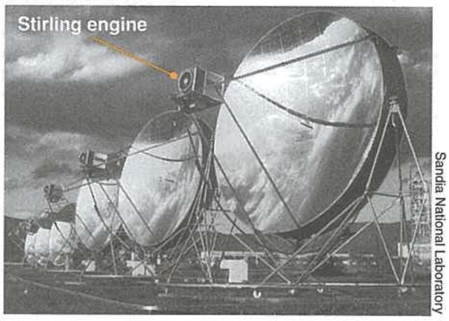
4. Discuss the following statement: "*Hydroelectric power produces clean, environmentally friendly electricity*":

Solar Power

The energy reaching the Earth from the Sun is in the order of trillions upon trillions of joules per day, far more than all of humanity uses in an entire year. This energy can be harnessed in many ways to create electricity. Currently, most large scale methods of generating electricity from sunlight involve **concentrating sunlight** to heat a fluid, which will turn water to steam to drive a turbine. Solar power stations based on concentrating sunlight include the **central receiver system** (also known as a **power tower**), **distributed receiver system,** and **parabolic dishes.** Other designs include solar ponds and photovoltaic cells.

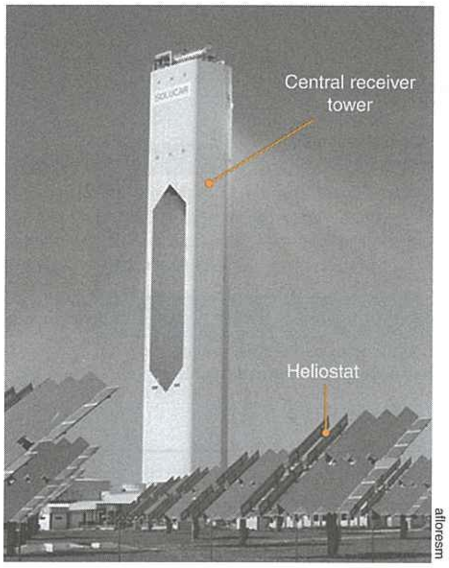


Distributed receiver systems use parabolic troughs to focus light into a thin beam. The beam of light heats oil in a pipe running along the focal point of the trough. The oil is used to heat water to steam to drive a turbine.



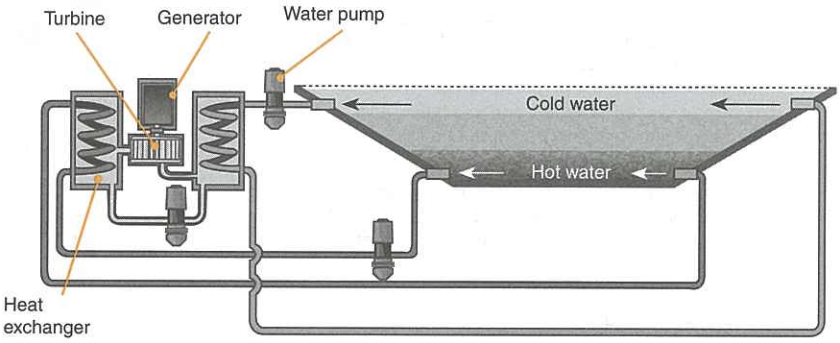
Parabolic reflector dishes focus light onto a Stirling engine at the dish's focal point. This is connected to a generator, which produces electricity directly. Each dish tracks the Sun at the most efficient angle.

Solar energy can be used directly to heat water (above) or air. Water heaters mounted on the roof of a house can dramatically reduce the amount of electricity needed to provide hot water and so lower household electricity bills.



A **central receiver system** uses mirrors, called heliostats, to focus the Sun's rays onto a central tower. The focused light is used to heat water or molten salts, which are pumped up into the central tower. These heat water to steam to drive a turbine and create electricity. Power stations that use molten salts as the heating fluid operate at between 500°C and 800°C and are able to store heat for operation overnight.

Solar Pond



Solar ponds produce a thermal gradient between the top and bottom of the pool. Hot water is pumped into a heat exchanger, causing enclosed water or gas to heat up and flow past a turbine to a second heat exchanger where it is cooled down again.

Solar Power	
Advantages	Disadvantages
Low or no CO_2 emissions	Ground shaded by large solar panels
Relatively high net energy gain	Back up systems required
Small photovoltaic cells are portable and can power many applications	Large land area needed for commercial scale production
Unlimited energy source during fine weather	High sunshine hours required
	High start up costs

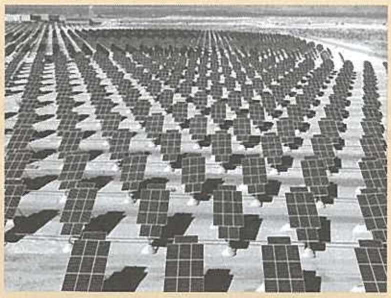
1. (a) Describe some advantages of using solar energy to produce electricity: ______

(b) Describe some disadvantages of using solar energy to produce electricity: ______

2. Explain why solar energy could provide almost limitless energy for humans to use: ______

Energy

Solar cells



Photovoltaic cells (solar cells) produce electricity directly from light. Advances in this technology have made these smaller and more efficient. There are no emissions or fuel costs once they are installed. Large power stations of 60 MW have been built.

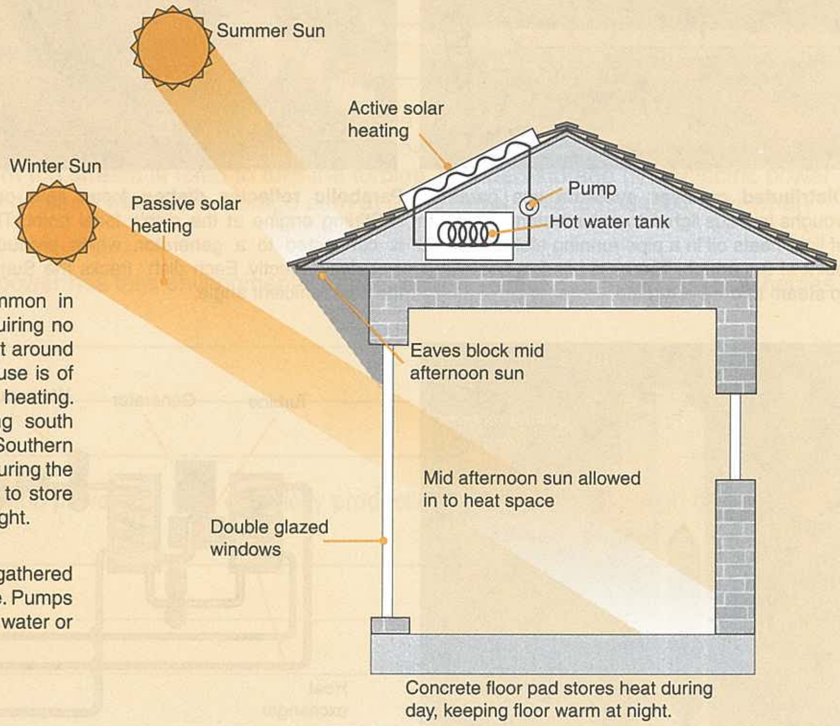
Electricity is produced when a photon of light hits a semiconducting material (such as silicon) and knocks an electron loose. The electron is captured and forced to travel in one direction around a circuit, and so produces direct current electricity.

The efficiency of a photovoltaic cell depends partially on the material from which it is made, as this affects its ability to absorb photons, capture electrons, and pass electrons through an electrical circuit. Currently the most efficient solar cells are around 40% efficient.

Solar Heating

Passive solar heating is becoming more common in houses. It can efficiently heat a home while requiring no electrical input and no equipment for moving heat around the house. The design and placement of the house is of great importance when using solar energy for heating. Houses placed with their main windows facing south in Northern Hemisphere and north in the Southern Hemisphere gain large amounts of solar energy during the day. Double glazed windows and insulation help to store this energy to keep the house warm during the night.

Active solar heating uses pumps to circulate heat gathered from a rooftop collector to various parts of a house. Pumps may circulate water through a tank to provide hot water or through a heat exchanger to feed radiators.



3. Explain how solar energy can be used to provide electricity even at night: ______________________

4. Explain the difference between passive and active solar heating: ______________________

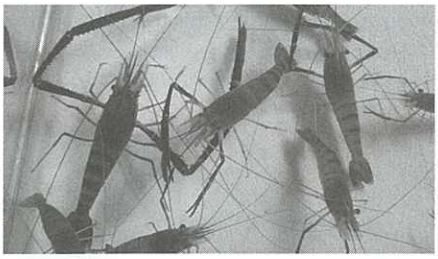
5. Discuss how a house could meet all its energy demands from solar energy: ______________________

Geothermal Power

Geothermal power stations operate where **volcanic activity** heats groundwater to steam. Bores drilled into the ground release this steam and transfer it via insulated pipes to a separator where the dry steam is separated and directed to turbines. Wet steam and waste dry steam are then condensed to water and reinjected into the **geothermal reservoir** to maintain the pressure and ground water supply. Geothermal power stations often operate at near full capacity, providing a **base load**, which other power sources can top up. Geothermal fields must be carefully managed to prevent the depletion of the reservoir and subsidence of nearby land.

Geothermal energy is produced by the fission of radioactive material deep in the Earth. This causes an enormous amount of heat that heats groundwater when close to the surface, producing a geothermal reservoir.

Geothermal power stations often provide base load supplies. This is the minimum continuous electrical supply for an area and is supplied by power stations that can operate constantly at near full capacity.



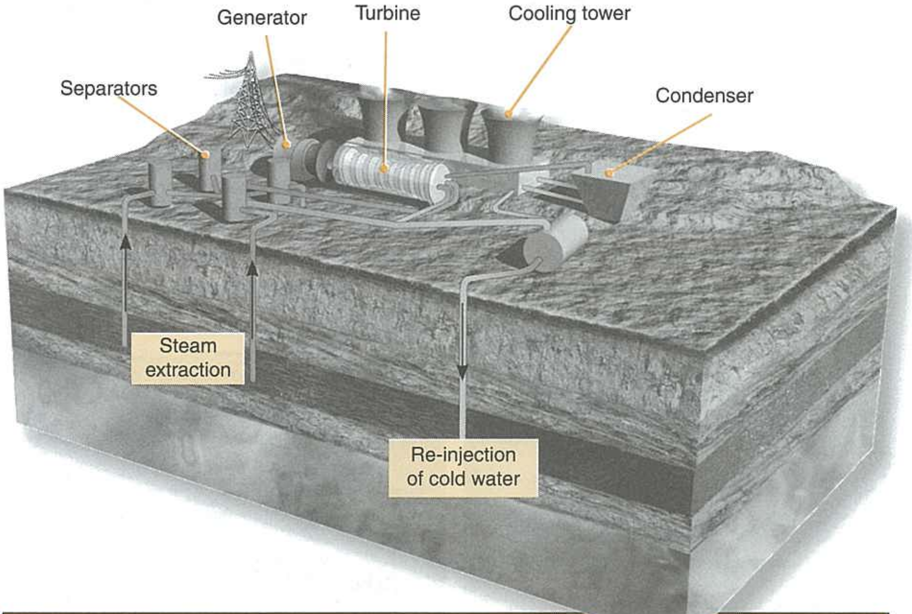
KPryor

Geothermal power is only around 20% efficient. However, waste hot water from the power plant can be used to heat other industrial operations, such as heating ponds for producing tropical shrimp in temperate environments.

KPryor

Steam fields are often large and steam must be sent along specially designed pipes that can expand and contract up to several meters in various weather conditions.

Geothermal heat pumps are now installed in many houses. These use a small pump to circulate fluid inside pipes from the roof and floor space of a house into the ground. In summer, this transfers heat from the house to the ground, cooling the house. In winter, it transfers heat from the ground into the house. Geothermal heat pumps do not have to be used in geothermal areas, they simply use the relatively constant temperature of the ground.



Geothermal Power	
Advantages	**Disadvantages**
Moderate to high net production of usable energy	Few suitable sites
Moderate CO_2 emissions	Easily depleted if not carefully managed
Low cost (in suitable areas)	Noise and odour pollution
Low environmental impact if managed correctly	Land subsidence possible

Energy

1. Explain why geothermal electricity is currently only viable in a few places on Earth: ______

2. Explain why geothermal reservoirs used for electricity production must be carefully managed: ______

3. Explain why geothermal power plants can be used as baseload supplies: ______

Biofuels

Fuels made from biological processes have been used for many years. In many regions dried animal dung is used to fuel fires. More recently there has been a move to produce more commercial quantities of renewable biofuels for use in transport and industry. **Biofuels** include ethanol, **gasohol** (a blend of petrol and ethanol), methanol, and diesel made from a blend of plant oils and traditional diesel oil. **Biogas** (methane) is an important renewable gas fuel made by fermenting wastes in a digester.

Gasohol

Gasohol is a blend of finished motor gasoline containing alcohol (generally ethanol but sometimes methanol). In Brazil, gasohol consists of 24% ethanol mixed with petrol.

Advantages

- Cleaner fuel than petrol
- Renewable resource
- Creates many jobs in rural areas

Disadvantages

- Ethanol burns hotter than petrol so petrol engines tend to overheat and they need to be modified
- Fuel tank and pipes need coating to prevent corrosion by ethanol
- Fuel consumption 20% greater compared with petrol

Sources of biomass for ethanol production

- Sugar cane (ethanol is produced in this way in Brazil).
- Corn starch (in the USA).
- Grass, certain waste materials (paper, cardboard), and from wood. Fast-growing hardwood trees can be treated to release cellulose. Once released, it may be converted to simple glucose by hydrolytic enzymes and then fermented to produce ethanol.

Biogas

Methane gas is produced by anaerobic fermentation of organic wastes such as sewage sludge at sewage waste treatment stations, animal dung, agricultural wastes, or by the rotting contents of landfill sites.

Stages in methane production

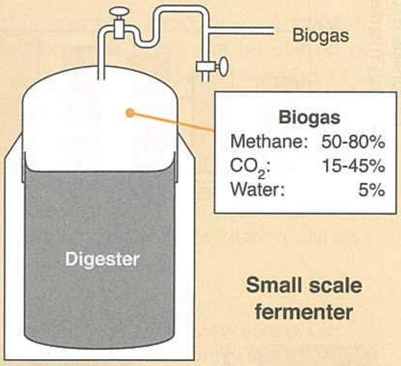
Saprophytic bacteria (facultative anaerobes) break down fats, proteins, and polysaccharides.

↓

Acid-forming bacteria break down these monomers to short-chain organic acids.

↓

Methanogen bacteria (strict anaerobes) produce methane gas.



Sources: *Biological Sciences Review*, Sep 2000, pp.27-29; *Biologist*, Feb 1998, pp. 17-21; Microorganism & Biotechnology, 1997, Chenn, P. (John Murray Publishers).

Comparisons of Renewable and Non-Renewable Energy

	Capital cost per kW	Electricity cost per kW	Advantage	Disadvantage
Biomass	Low	Medium	Readily available resources	Often inefficient
Geothermal	High	Low	No-low emissions	Few accessible sites
Hydroelectric	Medium	Low	Medium to high net energy gain	River flow restrictions and damming
Solar	High	High	No emissions Can be made portable	Large amount of sunlight needed
Wave/Tidal	High	High	No emissions	Few dependable sires
Wind	Medium	Medium	No emissions	Not fully dependable
Coal	Low	Low	High net energy gain	High greenhouse emissions
Natural gas	Low	High	High net energy gain	High greenhouse emissions
Nuclear	High	Low	No emissions	Radioactive waste

1. Explain the nature of the following renewable fuels:

   (a) Biogas: ______________________________

   ____

   (b) Gasohol: ______________________________

   ____

2. Describe two disadvantages of using pure ethanol as a motor fuel: ______________________________

   ____

   ____

3. Use the table above to explain why non-renewable energy sources has until recently been favored over renewable energy sources:

   ____

   ____

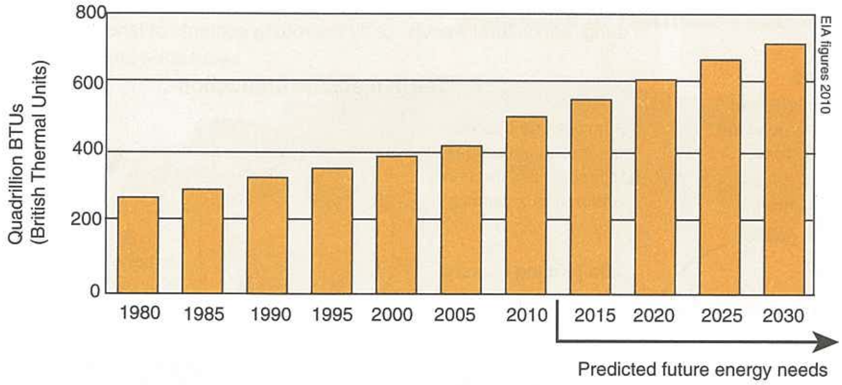
   ____

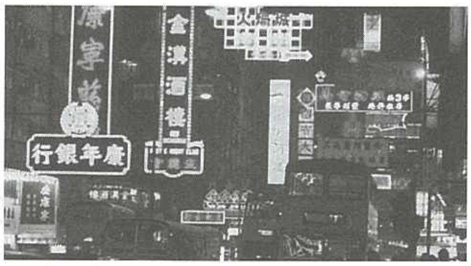
Energy

Current and Future Energy

The Earth's current total energy consumption is around 4.72 x 10^{17} (472 quadrillion) BTUs per year (about 500 trillion joules). The demand for energy is expected to increase by at least 50% by 2050, partly because of the increase in technology and its requirements for energy and partly because of the expected increase in the human population to around 9-10 billion. The majority of this increase in demand is expected to occur in developing countries. Fossil fuels will not be able to keep up with energy demands beyond 2030, so there is a growing emphasis on the development of new energy sources.

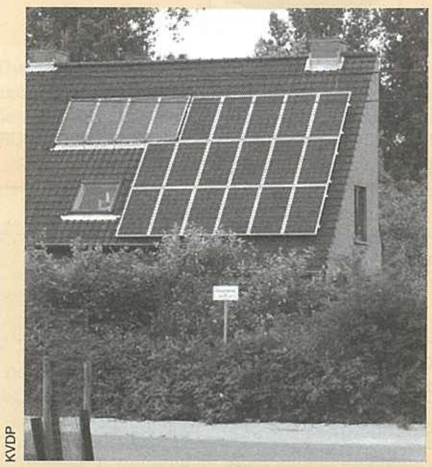
World Energy Demands



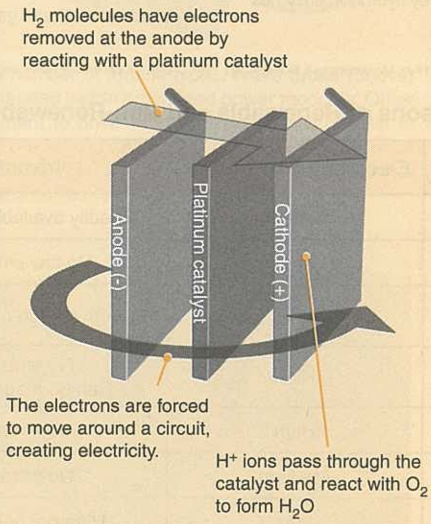


The increase in demand for energy is driven by an increase in demand for technology and an increase in population. However, large future increases in energy demand may be offset by advances in energy efficiency.

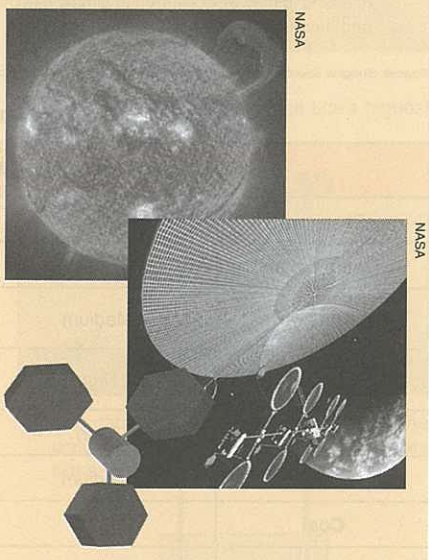
Future Energy Solutions



Energy use in the near future will come from a mix of renewable and non-renewable sources. Renewable energy use will become more common as technology improves and costs decrease. There may be a move away from large scale energy providers, with households using solar (above) and possibly wind energy to provide electricity to power lights and heat water.



Hydrogen fuel cells are expected to appear on the market soon to power vehicles, although the lack of hydrogen fuelling stations is a major obstacle to use. Hydrogen sources are also a problem, with oil required to supply hydrogen from hydrocarbons, or energy needed to split water to hydrogen and oxygen.



Distant future energy solutions may include **nuclear fusion** (joining H atoms to form He) power stations, giant solar energy collectors in space, and even nanomotors, which extract energy from the slightest movements.

1. Describe the trend in global energy demand: ______________________________

____

2. Explain where this demand in energy comes from: ______________________________

____

____

3. For any one of the future energy solutions, list some possible problems that will need to be overcome before it becomes a common form of energy generation:

____

____

____

____

KEY TERMS: Mix and Match

INSTRUCTIONS: Test your vocabulary by matching each term to its definition, as identified by its preceding letter code.

Term		Definition
BIOFUEL	A	Fossil fuel consisting of methane, ethane, propane and butane that is used as a high energy fuel.
CAFE REGULATIONS	B	A type of battery that utilizes the energy produced from the redox reaction between hydrogen and oxygen.
COAL	C	The use of sunlight to produce usable energy, often in the form of heat.
ENERGY CONSERVATION	D	The production of electricity using materials that can be replaced or regenerated within a short time span.
FOSSIL FUEL	E	The time during the 19th and 20th centuries in which scientific breakthroughs led to the mechanization of industry, resulting in a rise in technology and living standards.
GEOTHERMAL POWER	F	Black sedimentary rock, consisting primarily of carbon. Formed from the buried and compressed remains of ancient swamps and is now used as a high energy fuel.
HYDROELECTRIC POWER	G	Fuel produced millions of years ago by the burying and compression of organic matter.
HYDROGEN FUEL CELL	H	Energy produced by using the motion of waves to drive turbines.
INDUSTRIAL REVOLUTION	I	Energy produced from using radioactive material to heat water to steam to drive a turbine connected to a generator.
NATURAL GAS	J	A branch of physics that deals with the principles and relationships concerning the conversion and conservation of energy.
NON-RENEWABLE ENERGY	K	Fuel that is formed from renewable organic compounds, often in the form of waste material such as animal dung or wood pulp.
NUCLEAR FISSION	L	The splitting of a heavy atom causing the generation of large amounts of energy and lighter atoms.
NUCLEAR FUSION	M	Device that uses the force of the wind to turn rotors connected to a generator to produce electrical energy.
NUCLEAR POWER	N	Energy produced by using the force of wind to drive turbines.
OIL	O	Electrical cell that is able to convert sunlight directly into electrical energy.
PHOTOVOLTAIC CELL	P	Liquid made from hydrocarbons that was formed from the buried remains of marine or lake living planktonic organisms.
RENEWABLE ENERGY	Q	The Corporate Average Fuel Economy. A regulation designed to improve the fuel economy of cars sold in the USA.
SOLAR ENERGY	R	Energy produced by using water passing through a dam to turn turbines connected to generators.
THERMODYNAMICS	S	The use of energy in such a way that it expends the minimum amount necessary to achieve a purpose.
WATT	T	Energy derived from heat produced by volcanic activity.
WAVE ENERGY	U	The joining of hydrogen atoms to form helium, generating large amounts of energy.
WIND ENERGY	V	Energy produced by using fuels that cannot be replaced unless over geologic time scales.
WIND TURBINE	W	The unit of power. Equal to one joule of energy per second.

Energy