BIOZONE

Student Workbook

ENVIRONMENTAL SCIENCE

THIRD EDITION

FREE SAMPLE

for classroom trial

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AP V a-g
IB Topic 3

Energy

Key concepts

- Energy can not be created or destroyed, it is simply transformed from one form to another.
- Non-renewable resources provide immediate low cost power in the short term.
- Renewable energy technology is rapidly becoming more efficient and more reliable.
- Increasing the efficiency of energy usage can dramatically reduce energy demands.

Key terms

biofuel
CAFE regulations
coal
energy conservation
fossil fuel
geothermal energy
hydroelectric power
hydrogen fuel cell
industrial revolution
natural gas
non-renewable energy
nuclear fission
nuclear fusion
nuclear power
oil
photovoltaic cell
renewable energy
solar energy
thermodynamics
watt
wave energy
wind energy
wind turbine

Learning Objectives

☐ 1. Use the **KEY TERMS** to compile a glossary for this topic.

Energy

pages 161, 182-184

☐ 2. Recall basic energy concepts, forms of energy, **energy transformation** and laws of **thermodynamics**. Recall that energy is lost from the system at each transformation. *Appreciate that the terminology associated with energy in the popular media is frequently a shorthand parlance for types of energy transformations associated with human application, e.g. energy production, energy consumption, energy producer etc.*

☐ 3. Describe the different methods of **electricity generation**.

☐ 4. Summarize the history of human energy use, including reference to the **industrial revolution** and our dependence on the **fossil fuels** (**coal**, **oil,** and **natural gas**).

☐ 5. Outline current and future global energy demands.

☐ 6. Examine the need for greater efficiency of energy exploitation, including considering: reducing and using waste heat, saving energy in industry and transport with reference to the **Corporate Average Fuel Economy** (CAFE) regulations, use of hybrid vehicles, and reducing energy usage in buildings.

Sources of Non-Renewable Energy

pages 163-172

☐ 7. Describe the methods of coal and oil extraction and the effects of these on the environment.

☐ 8. Discuss the advantages and disadvantages of using coal and oil as a source of energy. Include considerations of economic and environmental impacts, and efficiency with which usable forms of energy are produced.

☐ 9. Describe **nuclear power** generation. Discuss its advantages and disadvantages, including short and long term environmental effects.

☐ 10. Explain how the principles of sustainability can be applied to extending the lifetime of **non-renewable** resources.

Sources of Renewable Energy

pages 173-181

☐ 11. Discuss the production of **hydroelectric power**, its capacity to produce electricity, and its effect on the environment.

☐ 12. Describe the production of electricity from **solar energy**, **wind energy**, **wave** and **tidal energy**, **geothermal energy**, **biofuels**, and **hydrogen fuel cells**.

☐ 13. Discuss the future use, advantages, and disadvantages of solar energy, wind energy, wave energy, geothermal energy, biofuels, and hydrogen fuel cells.

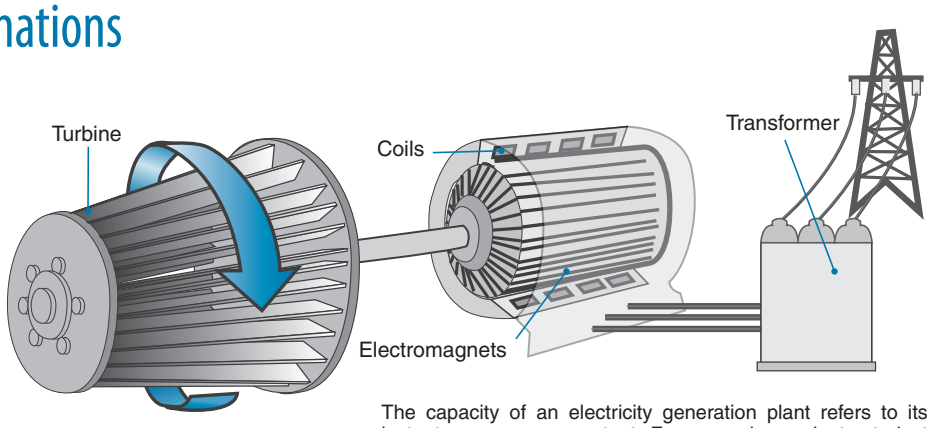
Periodicals:
Listings for this chapter are on page 247

Weblinks:
www.thebiozone.com/weblink/EnvSci-3558.html

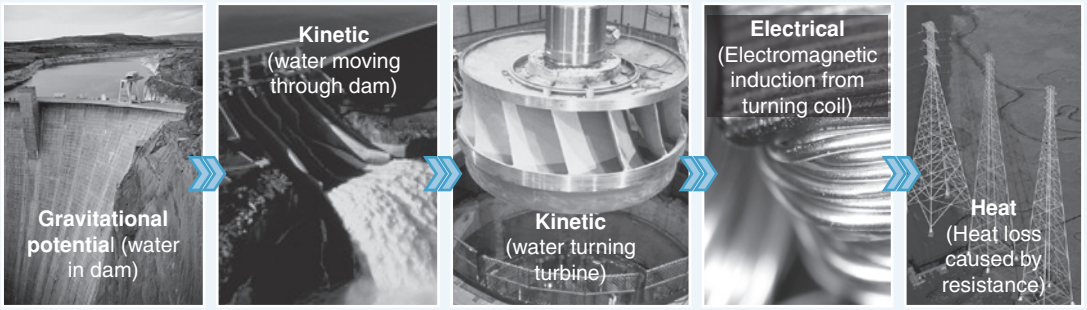
BIOZONE APP:
Student Review Series
Energy

Using Energy Transformations

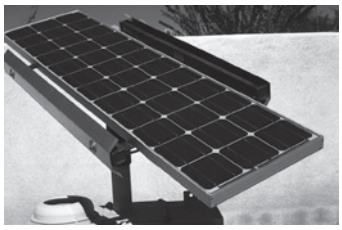
Most commercial electricity is generated by transforming **kinetic energy** into **electrical energy.** This is usually achieved by using kinetic energy to turn a turbine attached to a magnet or electromagnet housed inside a large set of wire coils (or vice versa) (the generator). Moving the magnet through 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: _____

Related activities: *Non-Renewable Resources, Renewable Energy*

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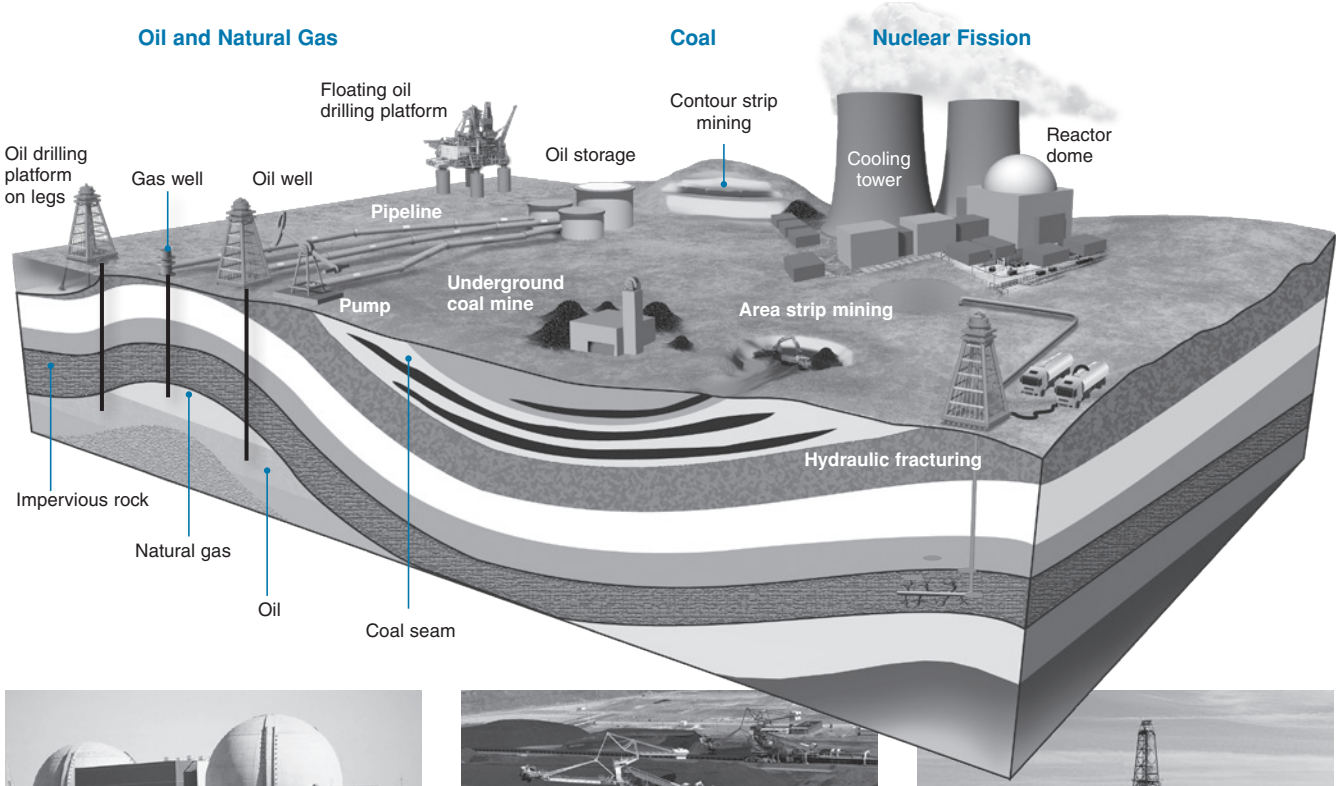
Non-Renewable Resources

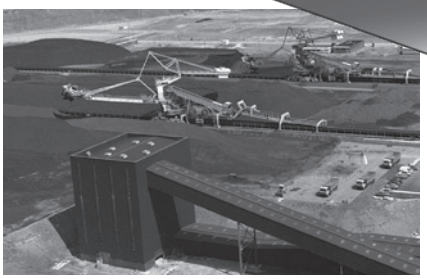
The Earth contains enormous mineral resources, which are able to be obtained and used with relative ease to produce usable energy. The most commonly used of these are the **fossil fuels**, i.e. **coal**, **oil** and **natural gas.** These can be burnt immediately to produce heat energy, or they can be 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: _____

ISBN: 978-1-927173-55-8

Periodicals: *Ice on fire*

Related activities: *Oil, Coal, Nuclear Power*

Oil

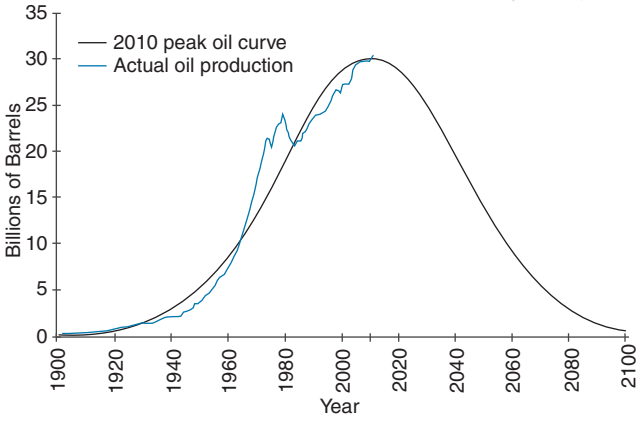
Oil is formed from the remains of algae and zooplankton which settled to the bottom of shallow seas and lakes about the same time as the coal forming swamps. These remains were buried and compressed under layers of nonporous sediment. The process, although continuous, occurs so slowly that oil (and coal) 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.

Peak Oil

It is economically and environmentally important to know when global oil production will decline. Global oil production decreased dramatically in the mid 1970s, but has since continued to increase. Peak oil is difficult to accurately predict and depends on what type of oil is included in the prediction (e.g. crude, oil shales etc) and how much new oil is being discovered (e.g. the Lula field off the coast of Brazil discovered in 2006).



Major World Oil Reserves

World oil reserves are estimated at around 250 billion m^3 of oil and 200 trillion m^3 of natural gas.

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

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

2. Describe how oil is formed and why this makes it non-renewable: _____

3. Describe some of the advantages and disadvantages of using oil as a fuel: _____

Related activities: *Oil Extraction*
Weblinks: *Coal and Oil Formation*

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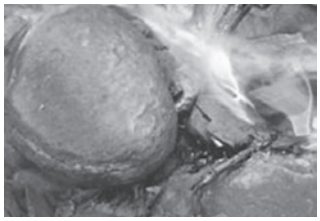
Oil Production, Transport and Refining

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.



USDE

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.

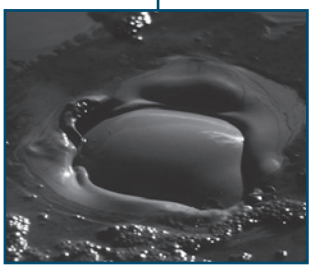
Crude and **heavy oils** require refining before use. Crude oil is separated into different sized fractions by a **distillation tower**. Heavy oils may be heated under pressure to break them into smaller more usable molecules.

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. Discuss the significance of peak oil: _____

5. Explain how crude oil is refined: _____

6. Investigate the use of refined fuels and then explain why short chain hydrocarbons, such as propane and butane, are used in gas stoves and portable lighters whereas longer chained hydrocarbons are used in vehicles:

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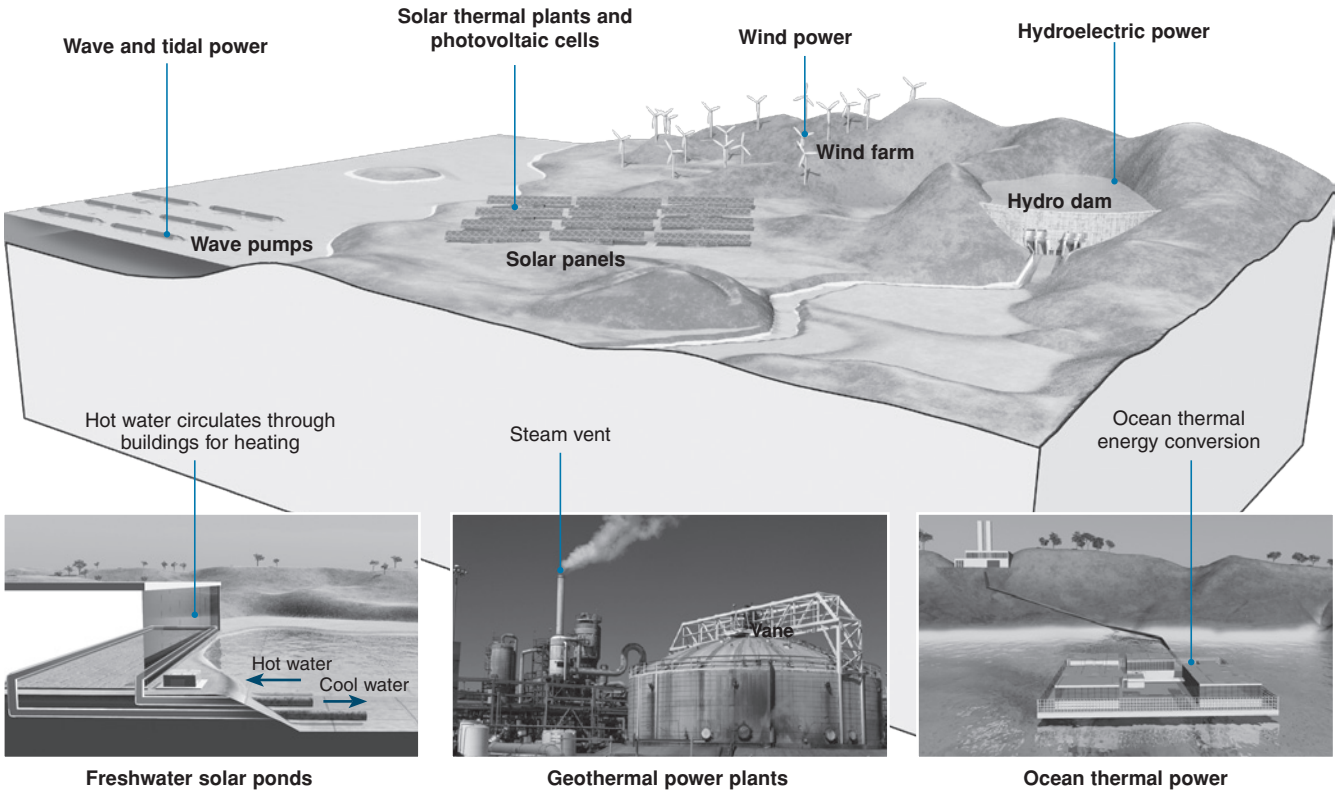
Renewable Energy

There are a number of drivers behind the demand for alternative methods for power generation. There has been a steady decrease in easily obtainable non-renewable energy resources and a steady rise in their cost and use. Coupled with these reasons, the environmental damage caused by nuclear waste and burning fossil fuels has created a strong public demand for renewable, environmentally friendly sources of energy. However, taking advantage of renewable energy resources involves making changes to infrastructure and meeting large start-up costs. Many developing nations may find this beyond their abilities, although small items such as solar cookers may become common in rural areas. Renewable energy technologies are rapidly becoming more efficient and less expensive. They are often as efficient on small scales as on large ones, and it is likely that they will soon become far more common for "off the grid" domestic energy generation, especially for lighting and heating water.



1. Describe the type of environment in which each of the following renewable energy resources would work best:

   (a) Solar: _____

   _____

   (b) Wave: _____

   _____

   (c) Wind: _____

   _____

   (d) Hydro: _____

   _____

   (e) Geothermal: _____

   _____

2. Explain why renewable energy is likely to become the predominant energy source in the future: _____

   _____

   _____

   _____

   _____

Related activities: *Current and Future Energy*
Weblinks: *Learning About Renewable Energy*

Periodicals:
A path to sustainable energy

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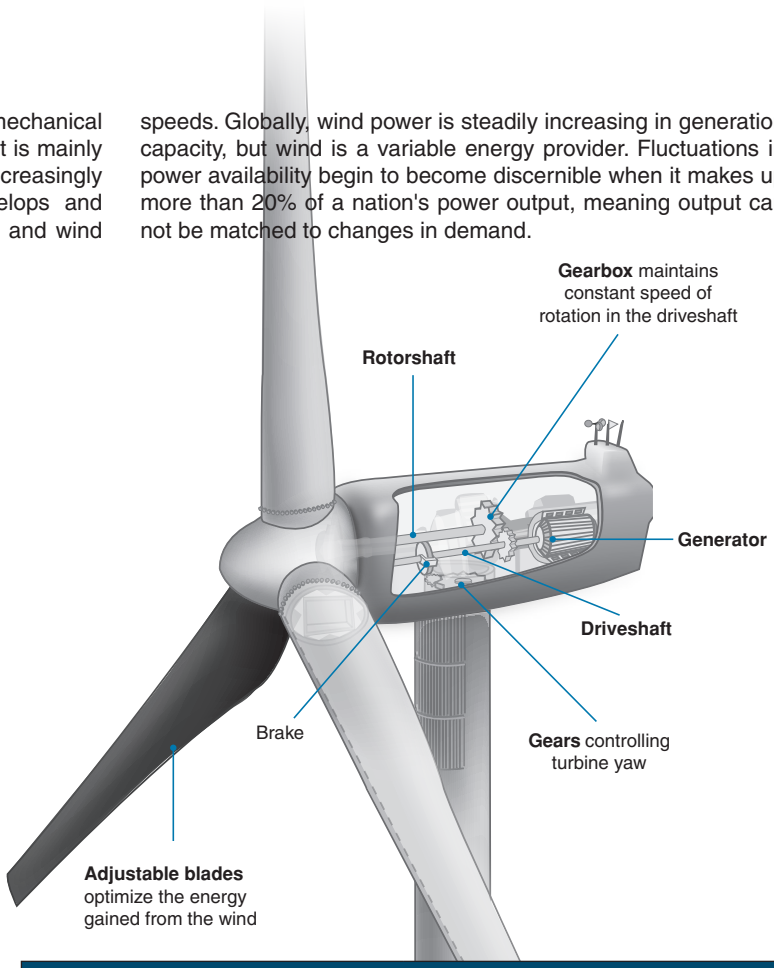
Wind Power

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 3(a) 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:

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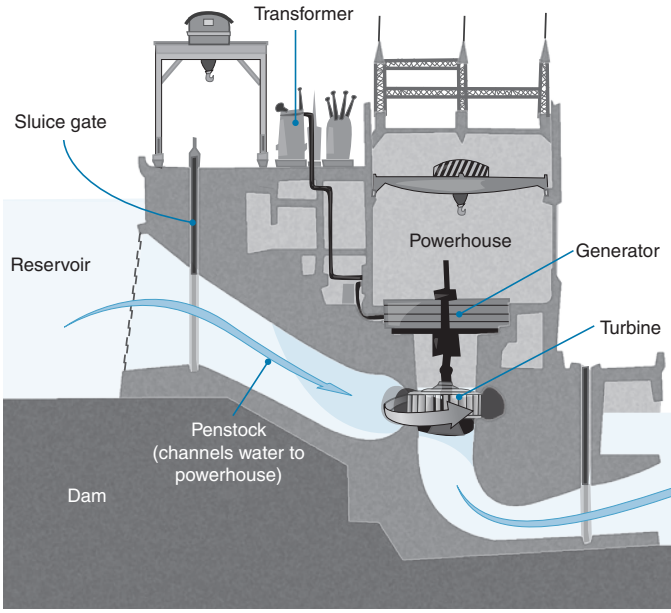
Periodicals: *Where the wind blows*

Related activities: *Renewable Energy*
Weblinks: *Wind Energy Basics*

Hydroelectricity

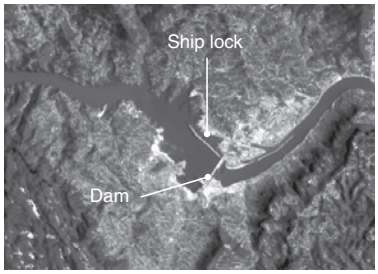
Hydroelectricity accounts for around 20% of global electricity production. Electricity is produced by utilizing the **kinetic energy** of water stored in reservoirs behind **dams**. Water is directed along pipes into the powerhouse where it drives turbines connected to a generator. The larger the volume 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.



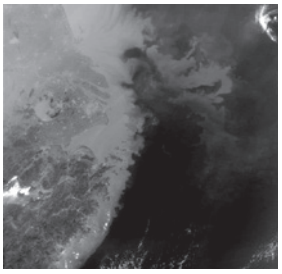
Hydroelectricity	
Advantages	**Disadvantages**
High net energy gain	High construction costs
High efficiency (high percentage of energy converted into electricity)	River diversions during and often after construction
Produce reservoirs that can be used for recreation and irrigation	High initial CO_2 production 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

1987



2006



Silt from Yangtze River

Siberian Crane

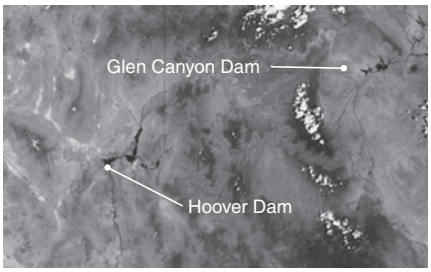
All images NASA except where indicated

BS Thurner Hof

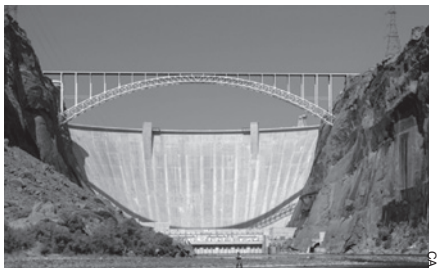
The **Three Gorges Dam** (above) on the Yangtze river, China, is 2.3 km wide and 101 m high, with a reservoir 660 km long. It has a generation capacity of 22,500 MW. The construction of the Three Gorges Dam in China caused the river water level to rise by 100 m, and required 1.2 million people to be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



CA

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.

CA

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.

***Related activities**: Renewable Energy*

***Weblinks**: How Hydroelectric Power is Made*

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