NEBOSH Certificate in Envrionmental Management

Unit EC1

MANAGEMENT AND CONTROL OF ENVIRONMENTAL HAZARDS

ELEMENT 7: SOURCES OF USE OF ENERGY AND ENERGY EFFICIENCY

SAMPLE MATERIAL

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Benefits and Limitations of Fossil Fuels

Key Information

- Fossil fuels are formed from the organic remains of marine micro-organisms (oil and gas) and land-based vegetation (coal).
- Advantages of fossil-fuel use include:
  - Easy combustion and transportation.
  - Fuels are relatively inexpensive.
  - Generation of electricity is efficient and inexpensive.
  - Power stations can be built anywhere.
- Disadvantages of fossil-fuel use include:
  - Environmental effects including acid rain, climate change and damage from extraction.
  - Fuels are non-renewable.
  - Prices are variable depending on markets.
  - Emissions contribute to poor air quality.

Examples of Fossil Fuels

Coal, oil and gas are called fossil fuels for the simple reason that they are formed from the organic remains of:

- Marine micro-organisms in the case of oil and gas.
- Land-based vegetation in the case of coal.

The processes that gave rise to the current stores of oil, gas and coal began in the Carboniferous period of the Paleozoic Era some 360 to 286 million years ago.

Formation of Oil and Gas

The formation of oil and gas begins with the accumulation of large amounts of organic material falling to the ocean floor. This material is made up of the remains of dead organisms that live in the water, such as plankton. Although this process takes place in seas and oceans throughout the world, only certain areas had the right conditions under which oil and gas could be formed.

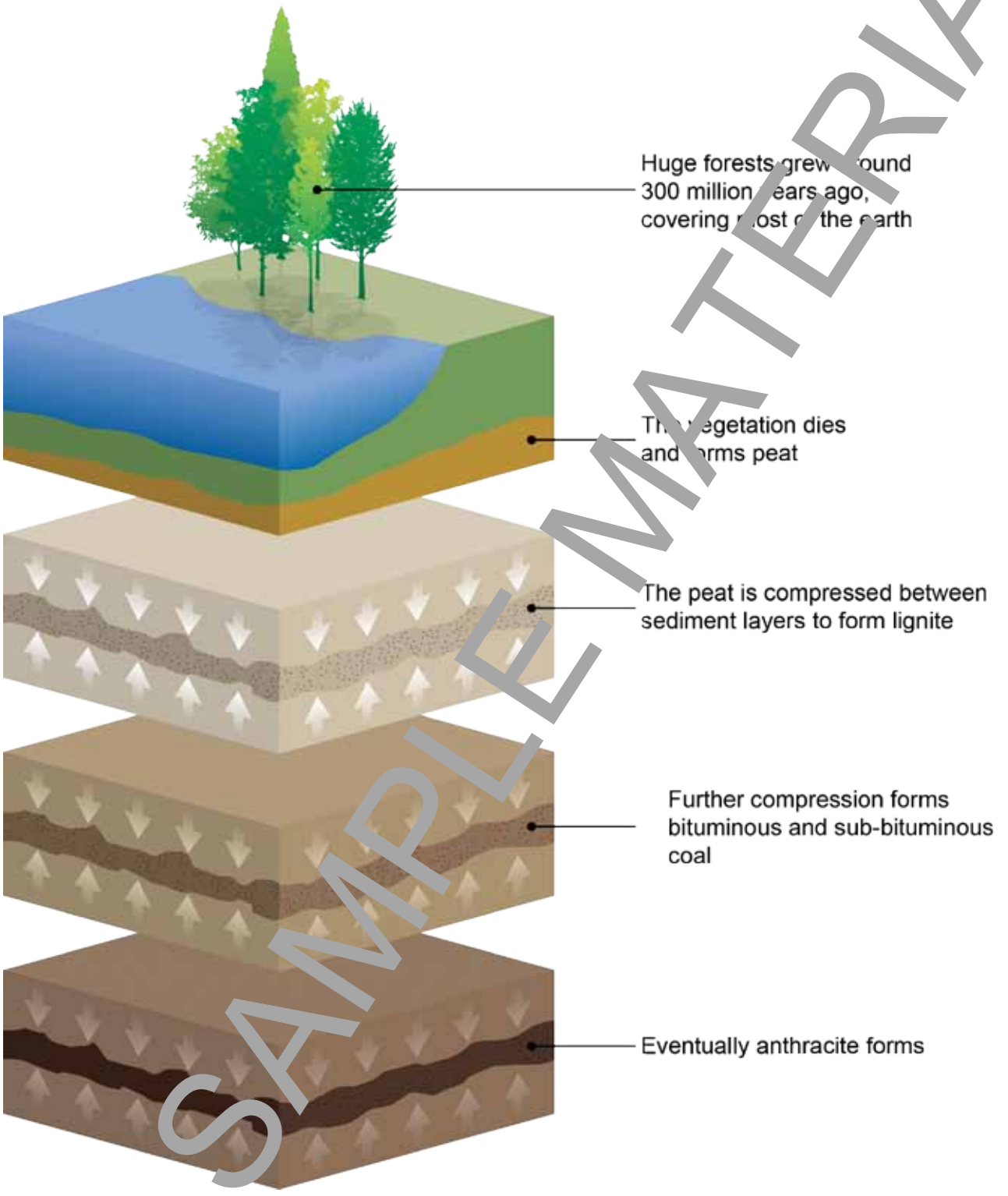
The sea floor must be stagnant and deprived of oxygen, with few or no bottom-dwelling species that will consume the dead organisms. The lack of oxygen ensures that organisms are not quickly broken down, thereby allowing an accumulation to build up that would otherwise be consumed. These conditions, combined with a high rate of sediment deposition, ensure the organisms are quickly covered.

As the sedimentation process continues the organisms are subjected to high pressure and temperatures and it is this process that leads to the formation of oil and gas. Over time the oil and gas migrate into porous rocks such as sandstone and so accumulate in distinct areas. If the oil and gas are not to simply flow out of the porous rocks it is essential that they are retained by a cap of impervious material such as clay.

Formation of Coal

Coal is formed through a very similar land-based process. Vegetation in low-lying, swampy conditions is the most likely to form deposits of coal. As with the production of oil and gas, a stagnant environment excludes oxygen and so reduces the breakdown of dead vegetation, allowing it to accumulate and to form peat. As this process continues successive layers of peat are buried and eventually covered by sediments. This process of continual burial with the addition of heat over long periods of time breaks down and alters the hydrocarbons in the peat. The peat then goes through a number of stages, becoming richer in carbon at each stage, as other elements are dispersed from the original material. These stages are:

- Peat.
- Lignite.
- Sub-bituminous coal.
- Bituminous coal.
- Anthracite coal.
- Graphite (pure carbon).



Fossil-Fuel Formation on Land

Where Supplies Come From

As you can see, very specific geological conditions are required for the formation of oil, gas and coal, so it is not surprising that deposits of fossil fuels are found in specific areas around the world. However, it is not just a question of where the deposits are that influences where the supplies come from. Other aspects are also significant, such as:

- Ease of access to the oil, gas or coal.
- How it can be transported from source to processing factory and finally to the consumer.

Clearly oil and gas have an advantage over coal in that they can be transported by pipeline.

The table below shows the level of oil consumption and production of the top 20 nations by production.

Comparative Global Production and Consumption of Oil[1]

Country	Production (%)	Consumption (%)
Oman	1.3	0.1
Libya	1.9	0.3
Indonesia	1.9	1.4
Algeria	2	0.3
Brazil	2.1	2.9
Iraq	2.9	0.6
Nigeria	3	0.4
Kuwait	3	0.4
UK	3.4	2.3
United Arab Emirates	3.4	2.3
Canada	3.6	2.2
Venezuela	4.1	0.7
European Union	4.3	19.1
China	4.4	6
Norway	5.5	0.2
Mexico	4.8	2
Iran	5	1.7
Russia	9.7	[illegible]
United States	10.7	25.9
Saudi Arabia	11.6	[illegible]

[1]From *A Brief Guide to the End of Oil* by [illegible] Middleton

Benefits and Limitations of Their Use as an Energy Source

Benefits

Since fossil fuels were first discovered, they have provided an ever increasingly important supply of energy. Our modern lifestyle would be impossible to maintain without the benefits that fossil fuels have provided. Coal was probably the first fossil fuel to be used regularly as a replacement for wood in cooking fires. In many areas of the world, low-grade coal could be found near to the surface and was therefore easy to access. The high-grade coals only became generally accessible with the invention of the steam-driven pump that could de-water deep mines where the better coal was to be found. Coal is still a major provider of energy for both domestic and industrial use. It is used in power stations to generate electricity and in manufacturing processes such as cement manufacture.

Oil has a wide range of uses, such as energy production, and is a raw material for many everyday goods such as plastics. Oil enables:

- Goods to be moved around the globe economically, so providing an ever-increasing range of consumer products for us to purchase.
- Access to cheap fuel, allowing many people to own and drive a car and have good quality food all year round in their local supermarket.

Compared to an alternative power source, such as nuclear, oil and coal are relatively safe and simple technologies. It is easy to build a coal- or oil-fired power station and relatively easy and cheap to transport the required fuel from point of production to point of use.

Limitations

Although it is clear that there are many advantages to using fossil fuels, they are not without their limitations.

- The burning of fossil fuels is now believed to be a major contributor to climate change through the emission of large volumes of CO_2 to the atmosphere.
- Fossil fuels are known to contribute significantly in some areas to the production of acid rain that leads to damage to flora and fauna over large areas of land.
- The extraction of the raw materials often leads to significant damage to the environment.
- Oil spills from pipelines and tankers often impact highly sensitive areas for wildlife.

Warning of Oil Spill on Beach

The table below summarises the advantages and disadvantages of the use of fossil fuels.

Advantages and Disadvantages of Fossil-Fuel Use

Advantages	Disadvantages
Straightforward combustion process.	Major contributor to climate change.
Relatively inexpensive.	Cause acid rain.
Easily transported.	Use a non-renewable source of energy so not sustainable in the long term.
Large amounts of electricity can be generated in one place, quite cheaply.	Prices are susceptible to changes in global politics so may rise significantly at short notice.
Gas-fired power stations relatively efficient.	Extracting the raw materials can be dangerous and damaging to the environment.
Power stations can be built almost anywhere.	Emissions may contribute to poor air quality locally, thereby affecting people's health.

Not all fossil fuels are equal in their impact on the environment:

- Gas burns cleaner than oil and produces about twice the energy per kg and proportionately less CO_2 when burnt.
- Different oil products also contribute differently to air pollution when burned, e.g. petrol burns comparatively cleanly against the heavy fuel burned in the shipping industry.
- Heavy oil and diesel produce a high volume of particulate matter that can have adverse effect on both plant and animal (including human) life.

Revision Question

1. List three advantages and three disadvantages of the use of fossil fuels.

(Suggested Answer is at the end of Unit EC1.)

Other Sources of Energy

Key Information

- Alternative sources of energy include: solar; wind; hydroelectric; wave; tidal power; geothermal; nuclear; combined heat and power; biodigesters; and methane recovery.
- There are both benefits and limitations to the use of alternative energy sources.
- Problems can occur with energy generation and supply in developing countries and remote regions.

Alternative sources of energy isf increasing for a number of reasons:

- There is concern over the effects of fossil-fuel use on the environment.
- Costs of fossil fuels are increasing.
- Demand for fossil fuels is starting to outstrip supply.

Here we will look at some of the main alternative sources, although there are many other potential sources and many new ones being developed.

Solar

Effectively, all energy on the planet originates with solar energy. Even fossil fuels originally gained the energy they stored through photosynthesis and respiration via energy from the sun. Humans have used direct solar energy for thousands of years to dry clothes and grow food. However, it is only recently that we have been using it to generate electricity. The sun produces far more energy than we require, so if we can develop efficient ways to capture that energy, many problems could be resolved.

There are three main ways in which we use solar power:

- **Solar cells** (photovoltaic or photoelectric) developed as a method of powering satellites. They are now a common way of generating power for both domestic and commercial properties in some parts of the world.

Photovoltaic Cells

- **Solar water heating** uses energy from the sun is used to directly heat water in glass panels, thereby reducing the amount of energy from fossil fuels required to provide hot water for use in the house.
- **Solar furnaces** are commercial installations that use a large number of mirrors to concentrate the energy of the sun into a small space and to allow the production of very high temperatures. Some of these furnaces can produce temperatures up to 33,000°C.

Wind

The use of wind as an energy supply is also not new:

- Wind was in use by the Babylonians and Chinese as long as 4,000 years ago to pump irrigation water.
- Windmills used for grinding corn were common in Europe in the Middle Ages.

Modern windmills are actually wind-powered turbines. They use the power of the wind to generate electricity. Wind-farms, as they have become known, are now a common sight.

Wind-Farm Operation

- There needs to be an average wind speed of 25km/h for them to operate efficiently.
- At very high wind speeds many wind turbines become less efficient or need to shut down to prevent damage occurring.

- Propellers of modern wind turbines are much larger than traditional windmills and are mounted much higher. This is to ensure they capture energy from the largest possible volume of air.
- The blades can have their pitch adjusted to increase the range of wind speeds in which they can operate and to maximise efficiency.
- The body of the turbine can be turned so the blades are always facing into the wind.

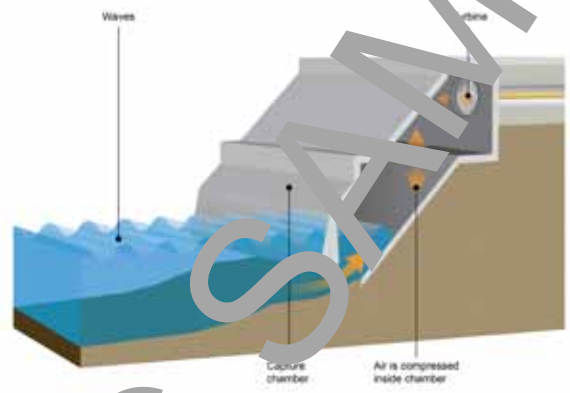
Hydroelectric

The most common type of hydroelectric energy generation uses the flow of water under gravity to turn a turbine attached to a generator. The generator converts the rotary mechanical motion into electricity. The water is usually held in a reservoir behind a dam. Hydroelectricity is extensively generated in Scotland, which has an abundance of the required natural resources.

Other methods of hydroelectricity generation use undershot waterwheels, utilising the flow of the water below a vertically-mounted wheel (like a water mill, only the mechanical energy is converted to electricity rather than being used directly).

Wave

Wave power generation is still rare as it is difficult to harness the energy of the waves. One of the most common ways of generating power from waves is through the use of an air chamber and turbine connected to a generator. The following figure shows how the waves make the water in the chamber move up and down. The movement of air drives the wind turbine and that, in turn, drives the generator.



Example of a Wave Turbine Generator

Tidal Power

Tidal power uses the energy of rising and receding tides to generate power. Although large amounts of power could be generated in this way, tidal power schemes are rare because the technological barriers are significant.

Tidal Power Operation

- The system is similar to a hydroelectric power station using the movement of water to drive a turbine.
- A dam or barrage needs to be built across a river estuary to focus the power of the tide.
- As the tide comes in water moves from the seaward side to the estuary side of the barrage.
- The turbine inside the barrage is driven by the power of the water.

Geothermal

As we go down through the Earth the temperature increases to the point where rocks become molten. In general, the temperature increases by 1°C every 36 metres in depth. The origin of the heat is continuous radioactive decay deep inside the Earth. It is possible to use this heat to generate electricity.

Geothermal Operation

- Holes are drilled down until they reach a depth where the temperature is hot enough to boil water.
- Pipes are then installed in these wells and water is pumped down the pipes.
- As the water turns to steam it drives a turbine that is connected to a generator and produces electricity.

Nuclear

Nuclear power uses uranium as the energy source and currently produces around 11% of the energy the world needs. In general, nuclear power stations are similar in the way they work to conventional coal-fired power stations in that they have an energy source that heats water into steam that then drives a turbine connected to a generator. Nuclear generation differs in that uranium is the power source and the heat is generated by a process known as nuclear fission. Although compared to coal the quantity of uranium required to generate a similar amount of power is very small, the waste produced by nuclear power is radioactive and may remain so for thousands of years, therefore producing a potential health threat to generations to come.

Jargon Buster

Nuclear Fission

This involves 'splitting the atom'. The energy used to hold the atom together is released in the form of heat.

Combined Heat and Power (CHP)

Combined Heat and Power (CHP) is the generation of usable heat and power (usually electricity) in a single process.

CHP systems can be employed over a wide range of sizes, applications, fuels and technologies. In its simplest form, CHP employs a gas turbine, engine or steam turbine to drive an alternator and the resulting electricity can be used either wholly or partially on-site, with any excess being supplied to the national grid system. The heat produced during power generation is recovered, usually in a heat recovery boiler, and can be used to raise steam for a number of industrial processes, to provide hot water for space heating or, with appropriate equipment installed, cooling.

Because CHP systems make extensive use of the heat produced during the electricity generation process, they can achieve overall efficiencies in excess of 70% at the point of use. In contrast, the efficiency of conventional coal-fired and gas-fired power stations, which discard this heat, is typically around 38% and 48% respectively. Efficiency at the point of use is lower still because of the losses that occur during transmission and distribution.

CHP is a form of decentralised energy technology. CHP systems are typically installed onsite, supplying customers with heat and power directly at the point of use and therefore helping to avoid the significant losses which occur in transmitting electricity from large centralised plant to the customer.

Biodigesters

As the name implies, biodigesters use bacteria to break down organic matter (such as pig manure). Anaerobic conditions are maintained in these digesters, the action of the bacteria producing biogas, composed mainly of methane and carbon dioxide but with some hydrogen sulphide. After purification, the methane can be used as a fuel, in the same way that conventional domestic gas is used. Depending on the sophistication of the biodigester (there are numerous commercial designs), other by-products of the process that can be extracted include recycled water (but not suitable for drinking!) and high-grade fertiliser.

Jargon Buster

Anaerobic Conditions

Low oxygen levels.

Methane Recovery

Biodigesters, discussed above, are a form of 'methane recovery' in the wider sense but this is a term most commonly associated with landfill sites. Much of the waste sent to landfill is organic and biodegradable. The action of bacteria under the anaerobic conditions in landfill sites produces 'landfill gas', which is largely methane (around 50–60%). Methane is a potent greenhouse gas and also flammable. Therefore it can:

- Contribute to global warming.
- Present a risk of explosion either at the landfill site itself or at local residential areas (as it seeps through the ground laterally and vertically).

However, if it is collected, it can be used directly for fuel and to generate electricity in 'gas-to-energy' projects (using engines/turbines). The recovered energy can either be used for running the operations at the landfill site alone or for the local community, or exported.

The landfill gas is typically collected by sinking a series of vertical wells into the landfill site. These wells are connected via pipelines and the gas is drawn off (with the aid of a vacuum system) to a collection point for purification (using a scrubber) and processing (such as compression, combustion in an engine generator and hence conversion to electricity).

Benefits and Limitations of the Use of Alternative Energy Sources

Alternative energy sources clearly have many benefits to offer, many of which they have in common. However, they also have limitations.

Topic Focus

Benefits and Limitations of Alternative Energy Sources

All alternative energy sources have the benefit of:

- Reduced or zero CO_2 production and therefore:
  - Reduced adverse impact on the environment.
  - Less contribution to climate change.
- Being 'renewable' or comparatively 'renewable' (except nuclear).

Other benefits and limitations are summarised in the table below:

Alternative Energy Source	Benefits	Limitations
Solar	• Remote areas. • Close to where energy is required. • No emissions.	• Unable to control how much and when. • No power generation at night.
Wind	• No emissions. • Remote areas. • Free form of motive power. • Small-scale operation as a local source of energy. • Plant can be prefabricated off-site.	• Unable to control how much and when. • Only generates power when there is wind. • Susceptible to damage in very strong winds (over 25m/sec). • Noise generated by turbines. • Loss of visual amenity. • Construction and maintenance costs can be significant. • Have to be large to provide sufficient energy for large- scale demand. • Remote from demand means that long supply cables required with subsequent energy transmission loss. • Objections by some to turbines.
Hydroelectric	• Dams and reservoirs provide additional recreational resources. • Long useful life of plant.	• Construction and loss of habitat (e.g. by flooding valleys). • Reservoirs can generate methane from anaerobic decomposition (tropical regions).
Wave and Tidal Power	• No emissions. • No waste products. Limited running costs.	• Unable to control how much. • Only produce power when there is wave or tidal action. • Ensuring the generator and associated equipment remain anchored in place.
Geothermal	• No emissions to air. • Remote locations. • Reliable fuel source.	• Often relatively large amounts of land required.

(Continued)

Topic Focus

Alternative Energy Source	Benefits	Limitations
Nuclear	• Quantity of uranium required compared to coal is small. • No discharge of greenhouse gases or effects on air quality.	• Non-renewable. • Unable to 'turn on and off' when power demands change. • Radioactive waste which may remain radioactive for thousands of years, requiring secure storage. • Difficult to gain planning permission. • Concern over accidental release of radioactive materials.
Combined Heat and Power (CHP)	• Efficient method for utilising both fossil and renewable fuels. • Highly efficient. • Usually generated at the point of use.	• Emissions to air. • Loss of visual amenity. • Transport of fuels to site.
Biodigesters	• Organic matter decomposes naturally - biodigesters utilise a waste product. • Relatively low cost.	• Possible odour problems. • CO_2 is still produced when methane is burned. This, although less potent, is still a greenhouse gas.
Methane Recovery	• Methane is generated by landfill sites as part of the decomposition process. • Reliable source of fuel from a landfill as it is produced for many years even after closure. • Low cost.	Uncollected methane is a greenhouse gas and presents a risk of explosion. • CO_2 is still produced when methane is burned. This, although less potent, is still a greenhouse gas.

Energy Supply in Remote Regions and Developing Countries

Developing countries face an important challenge in providing modern energy services to help alleviate extreme poverty and meet other societal development goals. However, emissions from developing countries are growing rapidly and make a significant contribution to environmental issues such as poor air quality and climate change, presenting a serious risk to the environment and human health.

In some parts of the world, cutting wood for burning also leads to significant deforestation and burning this wood in inefficient, old-fashioned stoves leads to emissions of smoke having a significant impact on local air quality. It is a key challenge to provide sustainable energy to developing countries and remote regions that is clean and yet reliable.

Revision Questions

2. List the three main ways in which we use solar power.
3. What is CHP?

(Suggested Answers are at the end of Unit EC1.)