

- Evaluation of different methods of generating electricity, when given data, such as start-up times, costs (including building and decommissioning of power stations) and reliability.
  - Evaluation of matching supply with demand, either by increasing supply or decreasing demand. Awareness of the facts that :
    - *Of the fossil fuel power stations, gas-fired have the shortest start-up time.*
    - *Pumped storage systems can not only rapidly meet peak demand, but also store energy for later use.*
  - Comparison of the advantages and disadvantages of overhead power lines and underground cables.
  - In some power stations an energy source is used to heat water, producing steam to drive a generator that is coupled to an electrical generator. Energy sources include :
    - *The fossil fuels (coal, oil and gas) which are burned to heat water or air.*
    - *Uranium and plutonium, when energy from nuclear fission is used to heat water.*
    - *Biofuels that can be burned to heat water.*
  - Wind, waves, tides and falling water used to drive turbines directly.
  - Electricity produced directly from solar radiation. Advantages and disadvantages of the use of solar cells to generate electricity.
  - Geothermal energy.
  - Small-scale production of electricity may be useful in some areas and for some uses (e.g. solar cells for roadside signs or hydroelectricity in remote areas).
  - Using different energy resources has different effects on the environment, including :
    - *The release of substances into the atmosphere.*
    - *The production of waste materials.*
    - *Noise and visual pollution.*
    - *The destruction of wildlife habitats.*
- Carbon capture and storage is a rapidly evolving technology. To prevent carbon dioxide building up in the atmosphere we can catch and store it. Some of the best natural containers are old Oil and gas fields, such as those under the North Sea.

## ENERGY SOURCES

**RENEWABLE** energy sources are those sources of energy which can be continually replaced (i.e. those that will never run out).

**SOLAR** energy  
**WIND** energy  
**WAVE** energy  
**TIDAL** energy  
**HYDROELECTRIC** energy  
**GEOTHERMAL** energy  
**BIOMASS** energy

- These energy sources **do not damage the environment**, but they **do not provide much energy** and many of them are **unreliable** because they are **weather-dependent**.
- Many renewable energy sources are powered by the **SUN** or the **MOON**.  
**TIDAL** motion, for example, is caused by the **gravitational pull** of the **MOON** on the Earth's oceans.  
 The **SUN** causes :
  - **Evaporation**, which results in rain and **flowing water**, as well as...
  - **Convection currents** which result in **wind** and the creation of ocean **waves**.

**NON-RENEWABLE** energy sources are those sources of energy which cannot be replaced within a lifetime and will eventually run out.

**COAL**  
**OIL**  
**NATURAL GAS**  
**NUCLEAR FUELS**

- These energy sources **cause environmental damage**, but they provide **most of our energy**.
- **FUELS**, such as **coal, oil and natural gas**, are substances which will release useful amounts of energy when they are burned.

These three fuels are called **FOSSIL FUELS** because they are the fossilised remains of trees, plants and animals which grew, died and decayed. Layer upon layer of this decaying matter was compressed and over many millions of years became the coal, oil and gas which have used as our main sources of energy for so long.

Since the trees, plants and animals would not have grown without sunlight, it can be said that the real source of fossil fuel energy is the **SUN**.

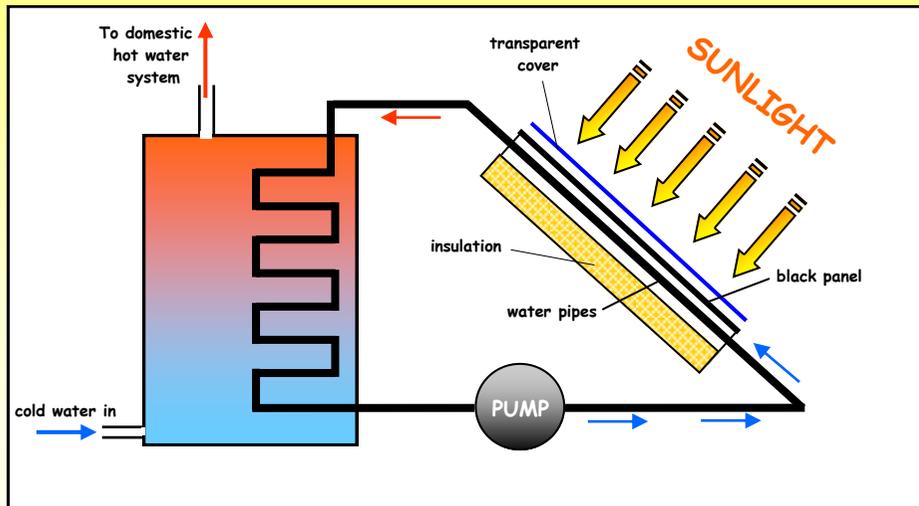
- Unlike the fossil fuels, Nuclear fuels such as uranium and plutonium are **not burned**. The energy is extracted from them by the process of **nuclear fission**.

RENEWABLE ENERGY SOURCES

1. SOLAR ENERGY

The Sun is a gigantic **NUCLEAR FUSION REACTOR** which is continually radiating vast amounts of ..... and ..... energy. Apart from the fact that this energy is essential for plant growth, there are other ways in which it can be used to produce useful energy on Earth.

SOLAR HEATING PANELS

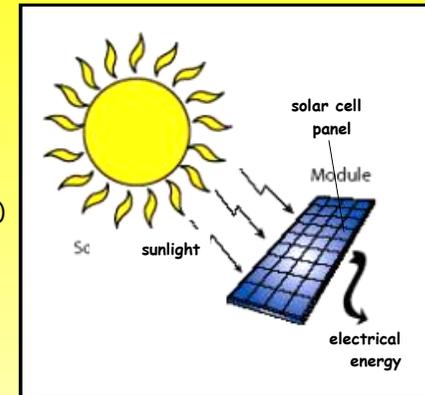


These are used to heat water for domestic use. The solar infrared radiation is absorbed by a black panel and a liquid through black pipes behind the panel carries the heat away and heats up water in a tank. Solar heating panels are fixed to the roof and obviously work best in sunny climates.

SOLAR CELL PANELS

**SOLAR CELLS** transform .....energy into ..... energy.

They are useful in situations where only **small amounts of electricity are needed** (e.g. in calculators, watches etc.) or in **remote locations** (e.g. Nomads living in the Gobi Desert can watch T.V. powered by a solar cell panel).



Solar cells cost nothing to run, but they are expensive.

Solar cells are connected together to form **SOLAR CELL PANELS**.

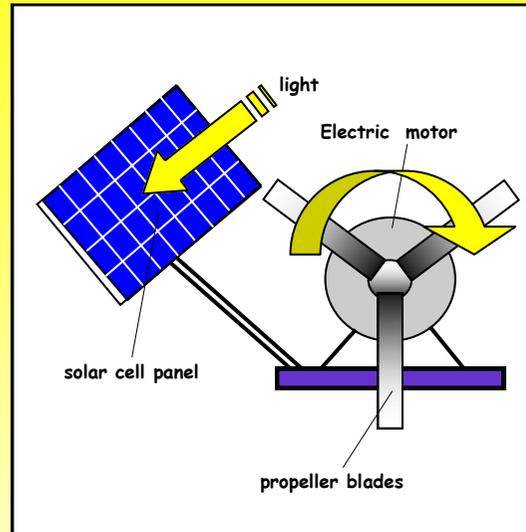


## SOLAR CELL DEMONSTRATION

When light is directed at the solar cell panel the electric current produced drives the electric motor causing the propeller blades to spin.

The closer the light is brought, the faster the blades spin.

As soon as the light is switched off the blades stop spinning.



## SOLAR POWER STATIONS

These use arrays of concave mirrors to focus the Sun's rays onto a boiler.

The steam produced is then used to drive turbines which turn generators to produce electricity.



## 2. WIND ENERGY

The energy in wind is used to turn wind turbines (aerogenerators) which transfer the..... energy from the moving air to ..... energy.

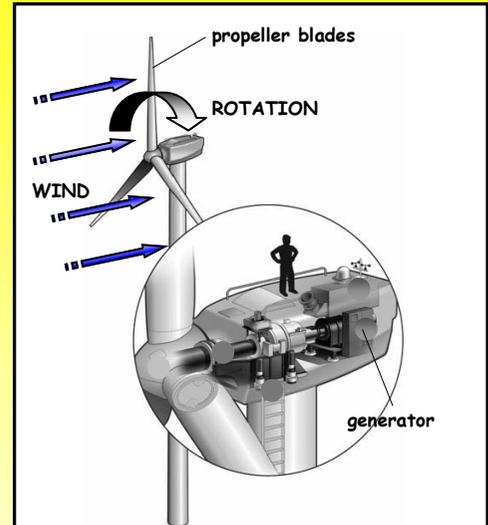
**Aerogenerators** are sited in **exposed windy places**, such as hills or offshore.

## ADVANTAGES

- No pollutant gases produced.
- No fuel and little maintenance required.
- Can be built offshore.
- 

## DISADVANTAGES

- Noise and visual pollution.
- Dependent on wind strength, which is unpredictable, so not flexible in meeting demand.
- High initial capital costs.
- Environmentally unfriendly in that birds sometimes fly into the rotating blades.



### 3. WAVE ENERGY

In one of the many designs for converting the ..... energy of sea waves into ..... energy, the up and down motion of the waves is converted into rotary motion which drives a generator.



#### ADVANTAGES

- No pollutant gases are Produced.
- No fuel required.

#### DISADVANTAGES

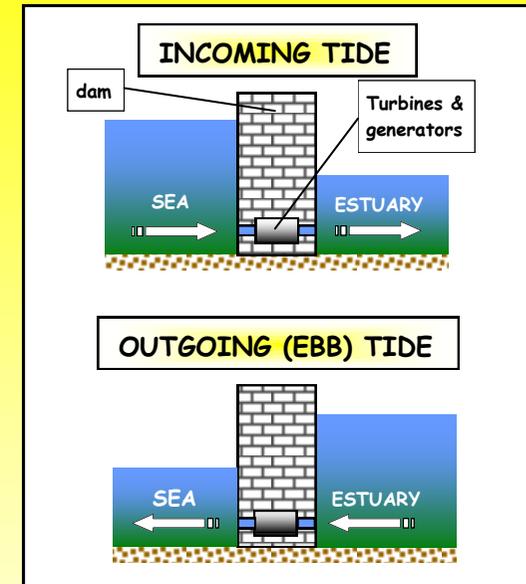
- Create visual pollution and are a hazard to shipping.
- The amount of electricity generated is small and dependent on unpredictable Weather conditions.
- Maintenance and repair is difficult, especially in rough weather.
- High initial capital costs.

### 4. TIDAL ENERGY

The gravitational pull of the **Sun** and the **Moon** cause huge movements in the Earth's oceans and seas, which we refer to as **TIDES**.

A river estuary can be dammed and the flow of water produced by the tides can be used to turn turbines which drive generators to produce electricity. This can be done with both the **incoming** and the **outgoing** tides.

The ..... energy of the flowing water is transformed into ..... energy.



#### ADVANTAGES

- No pollutant gases are produced and no fuel is required.
- Dammed water can be released when electricity demand is high.

#### DISADVANTAGES

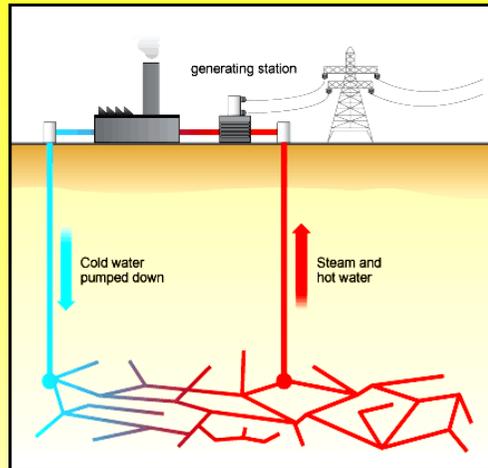
- Create visual pollution and can adversely affect fishing.
- Destruction of the habitat of mud-living organisms and the wading birds that feed on them.
- High initial capital costs.

### 5. GEOTHERMAL ENERGY

The rocks deep inside the Earth are very hot ( The heat comes from the semi-molten mantle and from the decay of radioactive elements) and can be used to produce steam.

Cold water is pumped down to an area of hot rocks ( $T \approx 220^\circ\text{C}$ ) and the heated water is pumped back up to the geothermal power station. Here it is used to produce steam which drives turbines which turn generators to produce electricity.

The very hot water which is pumped to the surface is sometimes also used to provide heating for homes in the area.



#### ADVANTAGES

- No pollutant gases are produced.
- No fuel is required.
- 

#### DISADVANTAGES

- Only possible in locations where there are hot rock reservoirs within reach.
- High initial capital costs.

### 6. BIOMASS ENERGY

The diagram opposite shows the main types of **BIOMASS** materials.

**Wood** can be burned to produce energy. It is **not a fossil fuel** and it is classed as a **renewable** energy source because trees can be replanted after a section of forest has been cut down.

#### DISADVANTAGES

- It takes many years for wood Supplies to be replenished.
- Wood is difficult to handle and transport.
- Deforestation is causing serious ecological problems in some parts of the world.

**BIODIGESTERS** are used to convert plant materials and animal dung into **METHANE GAS** which can be used for cooking, heating, lighting And even as vehicle fuel. Biodigesters are widely used in Africa, India and China.

#### TYPES OF BIOMASS



Wood



Crops



Garbage

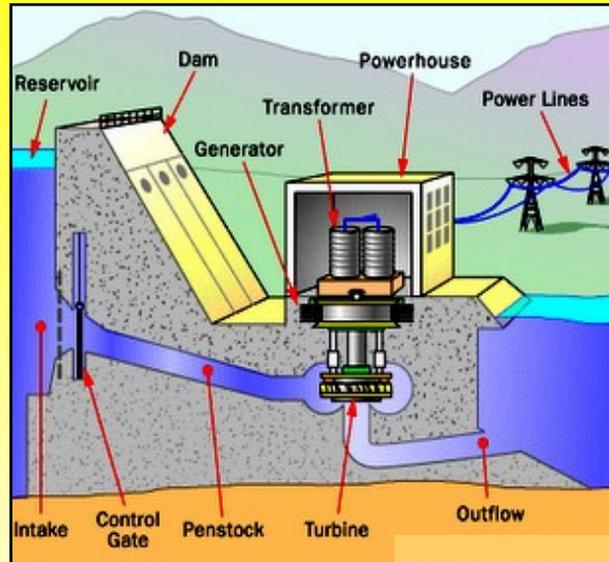


Landfill Gas



Alcohol Fuels

## 7. HYDROELECTRIC ENERGY



Gravitational potential energy of water in a high reservoir

Kinetic energy of flowing water

Rotational kinetic energy of turbines

Electrical energy from generators

An upland river valley is dammed and water is trapped in a huge reservoir.

When this is allowed to flow out of the dam, the ..... energy of the moving water is transformed into ..... energy as turbines turn generators to produce electricity.

In a **PUMPED HYDROELECTRIC POWER STATION** water from a lower reservoir is pumped back up to a higher reservoir using surplus electricity from other power stations at times when electricity demand is low.

Europe's largest of this type is at **Dinorwig** in North Wales.

**ADVANTAGES**

- Renewable energy source.
- No pollutant gases are released into the atmosphere.
- No visual pollution (Conventional power stations are a blot on the landscape).
- Very reliable and can be rapidly started up to meet sudden increases in demand for electricity.

**DISADVANTAGES**

- High initial capital costs.
- A large land area has to be inundated causing damage to plants and animals.
- Can only be sited in mountainous regions with high rainfall.

NON-RENEWABLE ENERGY SOURCES

1. FOSSIL FUELS

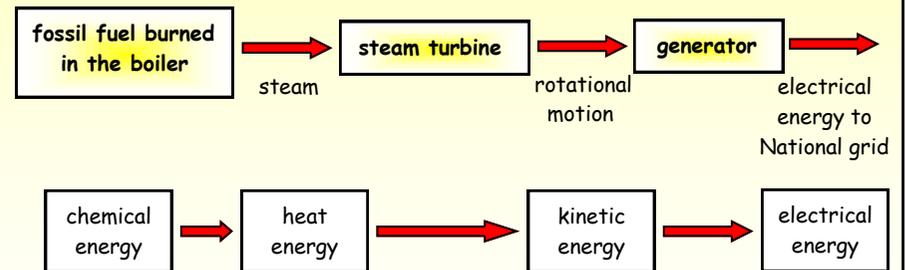
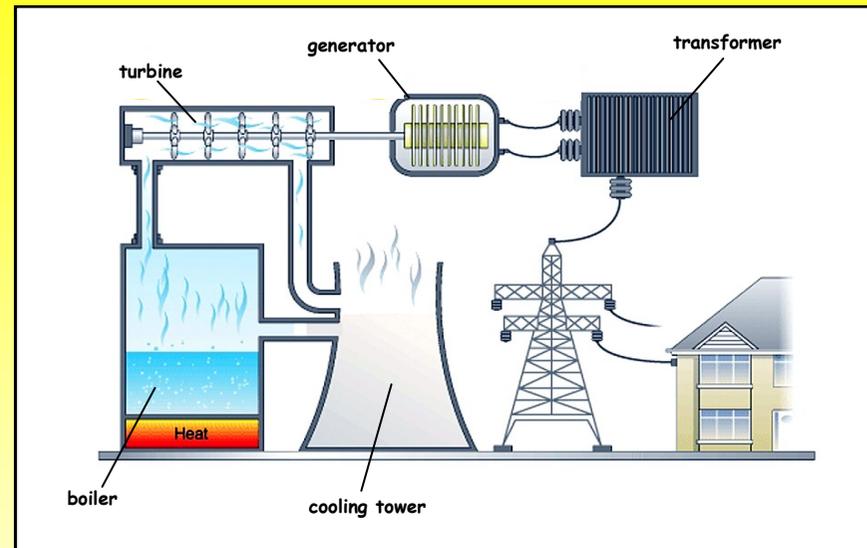
- **COAL** Formed over many millions of years as a result of continual plant decay, burial and compression.
- **OIL :** Also formed over many millions of years when tiny marine organisms died, became buried under sediments and gradually turned into oil.
- **NATURAL GAS :** Also originates from plants and marine organisms. It is mainly **methane** gas which is found with coal and oil.

Fossil fuels are still being slowly formed, but they are being used up much more rapidly. In fact the majority of the material which took about **100 million years** to be formed has been used up in the last **100 years!** It is predicted that **all known coal reserves will run out by 2250, gas by 2070 and oil by 2050.**

2. NUCLEAR FUELS

- Energy is extracted from **URANIUM** and **PLUTONIUM** in **REACTORS** using the process of **NUCLEAR FISSION**.  
  
The energy appears as heat which is used to produce steam to drive turbines which turn generators to produce electricity.

ELECTRICAL POWER STATIONS



In a **CONVENTIONAL power station** the ..... energy in a **fossil fuel** (coal, oil or gas) is transformed into .....energy by burning. The **steam** produced in the boiler is used to drive a **turbine** which turns a **generator** to produce electricity.

- Burning **fossil fuels (coal, oil and gas)** releases pollutant gases into the atmosphere. The gases released are :

- CARBON DIOXIDE (CO<sub>2</sub>)**

This increases the **greenhouse effect** causing ever-increasing global warming and climate change.

**Carbon capture and storage** is a rapidly evolving technology.

To prevent carbon dioxide building up in the atmosphere we can catch and store it. Some of the best natural containers are old oil and gas fields, such as those under the North Sea.

- SULPHUR DIOXIDE (SO<sub>2</sub>)**

This gas helps to produce **acid rain** which causes damage to crops and buildings.

The sulphur can be removed from the fuel prior to burning or the SO<sub>2</sub> gas can be removed from the waste gases before they enter the atmosphere, but this means more expensive electricity.

- In a **NUCLEAR power station** the heat energy required to make steam is produced as a result of the **fission** of nuclear fuels such as **uranium** and **plutonium**.

The rest of the process for the generation of electricity is exactly the same as that in a conventional power station. The nuclear part of the plant (i.e. the reactor etc.) is kept completely separate from the conventional part (i.e. the turbines, generators etc.)

- Nuclear fuels **do not release CO<sub>2</sub> or SO<sub>2</sub>** and when nuclear power stations are running normally, very little radiation or radioactive material escapes into the surroundings.

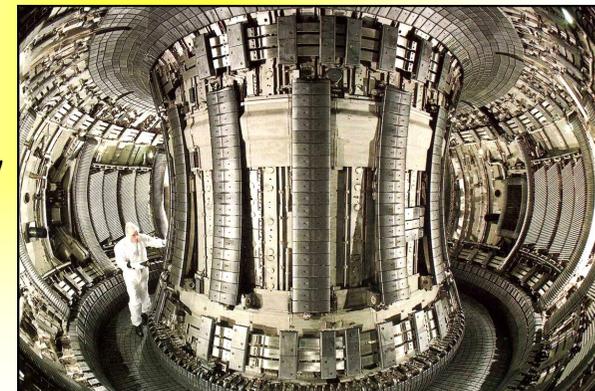
However, if there was an accident (**CHERNOBYL** was a vivid example of this), large amounts of highly dangerous radioactive material could be released over a wide area.

There is also the as yet unresolved problem of the **disposal of radioactive waste** from nuclear power stations. The high level waste in particular, remains dangerously radioactive for thousands of years and presents a very difficult storage problem.

Another factor to be taken into account is the **very high decommissioning cost** (i.e. the cost of dismantling, demolition and safe disposal all parts linked to the nuclear process) once a nuclear power station reaches the end of its life.

In the **United Kingdom**, it has quite recently been decided that it is in our best interests to build more **nuclear** power stations, whilst at the same time continue to develop and enlarge the production of electrical energy from **renewable** energy sources.

Power production from **nuclear fusion** is the vision for the future and research into this is massive and on-going. Nuclear fusion reactors would provide us with a safe, almost limitless supply of energy for the foreseeable future.



*The photo shows the inside of the prototype **JET NUCLEAR FUSION REACTOR**.*

**• PRACTICE QUESTIONS**

**1**      Use words from the list to complete the sentences below :

**Radioactivity      radiation      geothermal energy      solar energy**

(a) ..... Inside the Earth releases ....., energy.  
 (b) ..... from the Sun generates electricity in a solar cell.  
 (c) The best energy resource to use in a calculator is .....

**2**      Which of the statements below about solar cells is correct?

**A.** In a solar cell, water is heated which produces steam and drives a turbine.  
**B.** Solar cells can produce electricity directly from the Sun's radiation.  
**C.** Solar cells can produce electricity even in total darkness.  
**D.** Solar cells transform geothermal energy into electrical energy.

**3**      Renewable energy sources can be used to generate electricity. However these sources are not always available. Match words **A to D** from the list below with the numbers **1 to 4** in the table.

**A.** Hydroelectric scheme      **B.** Solar cells      **C.** Tidal barrage      **D.** Wind farm

<b>Renewable energy source</b>	<b>Source is available to generate electricity.....</b>
<b>1</b>	Only during the daylight
<b>2</b>	Only when the weather is suitable
<b>3</b>	Only during certain periods of the day and night
<b>4</b>	Usually whenever it is needed

**4**      A **pumped hydroelectric power station** uses two lakes. As water flows from the top to the bottom lake, it turns a turbine coupled to a generator that produces electricity. What is the energy transformation that takes place as the water flows?

**A.** Electrical energy to kinetic energy.  
**B.** Gravitational potential energy to kinetic energy.  
**C.** Kinetic energy to gravitational potential energy.  
**D.** Kinetic energy to heat energy.

**5**      In a **nuclear** power station the process that produces heat is called :

**A.** Fission      **B.** Fusion      **C.** Radiation      **D.** Uranium

**6**      **Geothermal energy** comes from :

**A.** Radioactive processes in nuclear power stations.  
**B.** Radioactive processes within the Earth.  
**C.** The decay of organic material.  
**D.** The movement of the tides.

**7**      Wind energy, waves, tides, falling water and solar energy can all be used as energy sources to generate electricity.

(a) What do all these sources have in common?

**A.** They are available at any time of the day or night.  
**B.** They are renewable energy sources.  
**C.** They do not affect wildlife.  
**D.** They do not cause any sort of pollution.

(b) Which of these energy sources is most appropriate to generate electricity to run a well in a remote African village?

**A.** Falling water      **B.** Solar energy      **C.** Tides      **D.** Waves

(c) Which of these energy sources is most likely to produce noise pollution when used to generate electricity?

**A.** Solar energy      **B.** Tides      **C.** Waves      **D.** Wind energy

(d) Which of these energy sources is least likely to be associated with damaging wildlife or the habitat of wildlife when used to generate electricity?

**A.** Falling water      **B.** Tides      **C.** Waves      **D.** Wind energy

- 8 If we use renewable energy sources, we will not need to burn so much fossil fuel. However, capturing renewable energy sources can also cause problems.

Match words **A to D** with the statements **1 to 4** in the table.

- A. Dams (hydroelectricity)      B. Solar cells  
C. Tidal barrages                  D. Wind Farms

What is used to capture energy	PROBLEM CAUSED
1	Can often be seen from a long way away and look unsightly to some people
2	Destroys muddy areas in river estuaries where wading birds feed
3	Land that could be used for farming in forests is flooded
4	Very high cost for each kilowatt-hour of electricity which is generated during lifetime

- 9 The main parts of a nuclear power station are :
- The **reactor** containing the nuclear fuel.
  - A **boiler** in which water is heated.
  - A **turbine**.
  - A **generator**.

Match words **A to D** with the spaces **1 to 4** in the sentences.

- A. Electricity      B. Movement (kinetic)      C. Steam      D. Uranium

- The energy source for this power station is ..... **1** .....
- The turbine is driven by ..... **2** .....
- The turbine transfers ..... **3** ..... Energy to the generator.
- The generator transfers energy to homes and factories as ..... **4** .....

- 10 Electricity can be generated in various ways. The main power stations use fossil fuels (coal, oil and gas) or nuclear fuels. No nuclear power stations have been built in the UK for some years.

Which of the following is a valid argument against nuclear power stations?

- A. For maximum efficiency, they have to be in nearly constant use.  
B. They have high decommissioning costs.  
C. They have high fuel costs.  
D. They produce gases that pollute the atmosphere.

- 11 Some people argue that we should make more use of **wind power** instead of **nuclear** or **fossil fuel** power stations. Which of the following statements supports this view?

- A. Fossil fuel and nuclear power stations are needed when the wind drops.  
B. Large wind farms can be unsightly and noisy.  
C. Wind farms have zero fuel costs to offset high capital cost.  
D. Wind farms use large areas of land.

- 12 Using **1 tonne** of uranium in a nuclear power station produces **1 600 000 000 kWh** of energy. How much uranium would be needed to fuel a **2400 MW** nuclear power station for **24 hours**? (**1 MW = 1000 kW**).

- A. 0.00035 tonnes      B. 0.000625 tonnes      C. 0.36 tonnes      D. 2.78 tonnes

- 13 The energy resource used to generate electricity depends on the location. Match the words **A to D** with the spaces **1 to 4** in the sentences.

- A. Nuclear fuel      B. Solar energy      C. Tides      D. Wind

- The best energy resource to use in a submarine which has to spend months under water is ..... **1** .....
- The best energy resource to use in a calculator is ..... **2** .....
- Generators sited on hills in the UK are most likely to use ..... **3** .....
- A power station that includes a barrage across an estuary uses ..... **4** .....