Energy Needs and Global Warming

Fossil fuel reserves are in general becoming less accessible and more costly to exploit. Demand for *energy* is constantly growing. Consequently there are valid concerns about the availability and sustainability of energy supplies for future generations. In the past 150 years global temperatures have risen about 0.6 °C and the trend at present seems to be upward. This has serious economic and *demographic* implications.

The growing global energy demand

The population of the world is growing and will increase from 6 billion to 9 billion by 2050. Population growth means greater economic activity, which creates higher demand for energy. Higher energy consumption based on fossil fuels implies higher CO_2 emissions. Countries such as China and India are entering energy intensive phases of their development; this puts greater pressure on global energy resources. As people's living standards increase so does their energy usage. Today, China has an estimated 40 million cars – three for every 100 people – and by 2020 this will increase to about 150 million.

The worlds' conventional oil fields are in decline; so called 'easy oil' (conventional oil with easy extraction) is becoming increasingly difficult to find. New technologies are needed to extract unconventional energy sources such as oil sands, deep ocean oil and artic oil.

Fig. 1 Oil sand mining

Oil sands are a mixture of clay, sand, water and *bitumen*. Bitumen is a thick tar-like form of petroleum. Oil sand mining does not require conventional drilling techniques; the sand is removed using mechanical shovels and trucks. It is then mixed with warm water. The oil separates from the water and, because it has a lower *density,* it rises to the surface. New treatment methods have been developed that reduce the costs and improve the energy efficiency of oil sand extraction. This reduces *greenhouse gas* emissions by 40,000 tonnes a year. A major difficulty in extracting this unconventional energy source has been overcome.

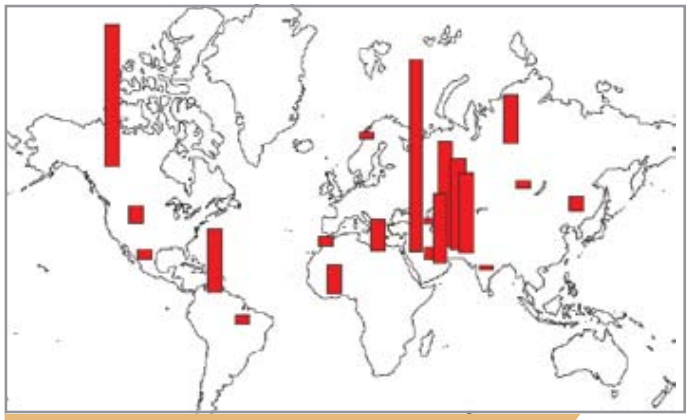

Fig. 2 Top 20 oil resrves (2006) – 95% of the known total

Exploration

Oil is most often found trapped below an impervious rock layer. *Seismic surveys* are used to map the layers in the earth's surface and locate likely sites of oil deposits. Sophisticated computer programmes have been developed to analyse the large amounts of seismic data.

Recent technology has made use of electromagnetic waves to locate oil deposits. The signal sent out changes depending on the strength of a material opposing the flow of electric current.

Electromagnetic surveying

A recent development in seabed surveying employs ultra low frequency *electromagnetic waves* (0.025 *Hz*). As the transmitting antenna is towed along about 40 m above the seabed the electromagnetic signals are reflected from the seabed and from layers over a thousand metres below. The reflected signals are detected by an array of stationary receivers on the seabed. Complex software is used to construct a profile of the seabed layers. A particular benefit of this technique is that it can distinguish between layers having different electrical resistivities such as seawater, sedimentary rock, crystalline rock or petroleum.

Seismic surveys can be used to map subsea strata and reveal spaces in which oil might be trapped; however they cannot reliably distinguish between oil and water. This usually necessitates exploratory drilling – an expensive and frequently futile process.

Oil and water have different electrical properties and it is possible to distinguish between them using electromagnetic surveying techniques.

What is global warming?

Global warming is the increase – and projected continued increase – in the average temperature of the Earth's near surface air and oceans in recent decades. Global average air temperature near the Earth's surface rose 0.74 ± 0.18 °C during the past century. This predicted warming is based on the greenhouse effect. The *greenhouse effect* is caused by gases that can reflect or trap heat; they include water vapour, carbon dioxide (CO_2), methane (CH_4), *nitrous oxide* (N_2O), *CFC* gases and ozone. Collectively they are known as greenhouse gases. Carbon dioxide, which is released from the combustion of almost all fuels, makes up 60% of the present heat trapping gases, and is expected to constitute an even larger part in the future. The greenhouse gases trap some of the heat emitted from the

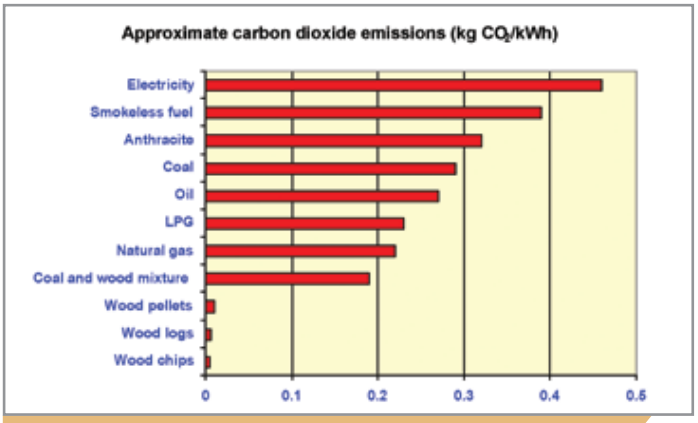

Fig. 3 Carbon dioxide emissions of various energy sources

earth; this effect is not all bad because without these gases the temperature of the earth would be on average 33 °C colder and unable to sustain present life forms. However, exploitation of fossil fuels has increased the quantity of greenhouse gases in the atmosphere; this traps more heat and leads to an increase in temperature.

Fig. 4 Planet Earth

Carbon dioxide capture

Carbon capture and storage is one of the most promising technologies for reducing CO_2 emissions. It is proposed to compress carbon dioxide from sources such as power plants, and store it underground or pump it into depleted oil or gas reservoirs. It might also be used to displace natural gas from coal *strata* that are too difficult to mine. Potentially carbon capture and storage could reduce CO_2 emission by up to 90%; however it requires the expenditure of more energy and is still at the experimental stage.

What are the alternatives to fossil fuels?

Fig. 5 Wind energy

Wind energy is one of the cleanest sources of energy available. Worldwide there has been significant investment in wind farms, generating emission free electricity.

Solar power involves a single transformation of sunlight using various technologies to produce usable forms of energy. Advanced thin film technology employs copper indium diselenide (CIS), which could provide a cost-breakthrough for solar power. The CIS metal solutions are sprayed onto a glass sheet in layers; this process means there is no need for complex wiring and assembly. This technology has excellent performance in low light conditions.

Biofuels can be broadly defined as liquid, solid or gas fuel derived from biological material. At present the two main types of biofuel are *ethanol*, produced by fermenting plant-derived sugars, and FAME (*fatty acid methyl esters*) produced by conversion of vegetable oil into a diesel-type fuel. Concern about the use of food products as raw materials for fuel has stimulated development of technologies that use non-food biomass such as straw and wood to produce biofuel.

Hydrogen power has been referred to as 'the fuel of the future'. Pure hydrogen does not occur naturally. It can be produced by electrolysis of water or by thermal decomposition of methane, petroleum, wood or other biomass. *Electrolysis* is the least efficient method requiring an energy input equivalent to 65% or more of the eventual energy output. *Thermal decomposition* also requires an energy input – typically about 25% of the eventual output.

The future of energy

In meeting future energy needs three significant problems must be addressed:

1) the accelerating demand for energy
2) the depletion of easy energy resources
3) rising CO_2 emissions as a consequence of increase fossil fuel usage.

These problems can be tackled be researching new technologies to extract unconventional energy sources and developing clean efficient fuel sources. We can use our current supplies more cleanly by applying coal gasification and carbon capture and storage methods. We should also aim to increase our use of alternative energy sources from the current 1–2% to 30%. These actions will require governments to implement the necessary legislation to secure future energy needs.

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Syllabus References

The appropriate syllabus references are:

Leaving Certificate Physics
Energy (p. 9)

- Energy as the ability to do work. Different forms of energy…
- Conversions from one form of energy to another.
- Principle of conservation of energy….
- Percentage efficiency = power output × 100/power input

Leaving Certificate Chemistry
Fuels and Heats of Reaction (p. 49)
Sources of Hydrocarbons

Leaving Certificate Geography (p. 26)
Environmental impact: Economic activities have an environmental impact. Students should study:

- the use of **renewable and non-renewable** resources in the economy
- the **impact of the burning of fossil fuels** and the use of **alternative energy sources**
- environmental pollution at a local/national and global scale
- **Sustainable economic development** so as to control its environmental impact. (students should examine past experiences, future prospects and the necessity for environmental impact studies)
- **Conflicts that may develop between local and global economic interests** and environmental interests. Students should be familiar with the issues relating to at least two examples.

Learning Outcomes

On completing this lesson the student should be able to:

- Appreciate the growing demand for energy.
- Explain the reasons behind this accelerating demand
- Recall what 'easy oil' means.
- List different forms of unconventional energy sources
- Understand the terms Global Warming and Greenhouse effect.
- Describe the process of CO_2 capture
- List alternative energy resources and how they are produced.

General Learning Points

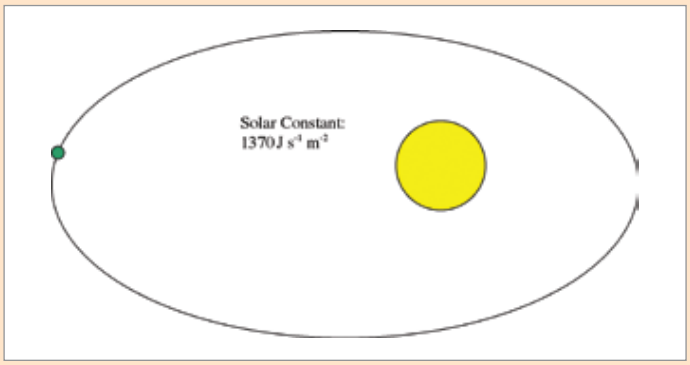
- The population of the world is growing which adds pressure to the current energy resources.
- Countries such as India and China are entering energy intensive phases of their development which will require extra energy.
- As countries accumulate wealth their energy needs subsequently increase.
- Easy oil is becoming increasingly difficult to locate and extract, this heightens the demand on unconventional fuel sources.
- Seismic and electromagnetic survey techniques are used to locate oil deposits below the earth's surface.
- Global warming is the increase in the surface temperature of the earth which is thought to be caused by the 'Greenhouse effect'.
- Gases such as carbon dioxide, nitrous oxide, methane, CFCs and ozone are all thought to contribute to global warming.
- Carbon dioxide emissions can be reduced using techniques such as carbon capture and storage.
- Wind power, solar power, biofuels and hydrogen power are all alternative sources of *renewable energy*.

Student Activities

Calculate the amount of energy given out by the sun in all directions.

Calculate the mass of the sun that disappears each second, in kilogram's and tonnes.

Equations:
Mass energy equation: $e = m.c^2$
Area of a sphere: $4.\pi.r^2$
Speed of light (c) 3×10^8 m/s
Radius of earth orbit: 150×10^9 m



True/False Questions

a) Fossil fuels are a fuel source of hydrocarbons found within the top layer of the earths crust **T F**

b) Higher energy consumption based on fossil fuels implies higher CO_2 emissions. **T F**

c) Ozone is the gas which causes about 27-30% of the greenhouse effect. **T F**

d) Fractional distillation is a method of separating out the different mixtures from crude oil according to their melting points **T F**

e) Carbon dioxide emissions can be reduced using techniques such as carbon capture and storage **T F**

f) Seismic and electromagnetic waves are techniques used to locate oil deposits below the earth's surface **T F**

g) Methane is a more effective greenhouse gas than carbon dioxide **T F**

h) Climate change could cause a major increase in insect-borne diseases like malaria throughout Europe, Asia and North America. **T F**

Check your answers to these questions on www.sta.ie

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Examination Questions

Leaving Cert Chemistry, 2002 higher level

The following hydrocarbons can all be used as fuels.

Methane (CH_4) butane (C_4H_{10}) 2, 2, 4-trimethylpentane (C_8H_{18})

(a) Butane is a major component of LPG. What do the letters LPG stand for?
Draw two structural isomers of butane.

(b) Methane is a major component of natural gas.
Why are *mercaptans* often added to natural gas?
What environmental change or effect is associated with the release of methane to the atmosphere?
Apart from leaking gas pipes, name a major source from which methane is released to the atmosphere

(c) What structural feature of 2, 2, 4-trimethylpentane results in it having a high octane rating?
Give one other structural feature which increases the octane number of a hydrocarbon.

(d) Define heat of combustion of a compound.

(e) The combustion of butane is described by the following balanced equation.

$$2C_4H_{10(g)} + 13O_{2(g)} \rightarrow 8CO_{2(g)} + 10H_2O_{(l)}$$

Calculate the heat of combustion of butane given that the heats of formation of butane, carbon dioxide and water are –125, –394 and –286 kJ mol^{-1}, respectively.

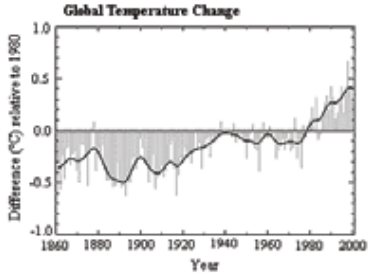
Leaving Cert Geography, 2005 Higher Level

(c) Climate Change

Examine the graph above, which illustrates how global temperatures have changed over 140 years between 1860 and 2000 (*Source:IPCC (2001).*

(i) Suggest reasons for the trend shown. Briefly outline the potential effects of global warming on human societies.

(ii) Analyze **two** ways in which attempts are being or could be made to reduce or limit the effects of global warming.



For further examples of past questions check www.sta.ie

Did You Know?

- A man called Henry Tripp located an oily deposit in south western Ontario. He had it analysed and found it could be used for waterproofing material and as a paint. He bought a large amount of land in the area and set up the first petroleum business on December 18, 1854.
- Crude oil (fossil fuel) is one of the most useful and valuable materials on earth; it is pumped from under the ground or the sea and is of little use in its natural form. It must be separated into a number of useful parts by a process called fractional distillation. This process involves heating the crude oil and separating the different substances on the basis of their boiling points. Each of these mixtures is called a fraction; this is where the name fractional distillation comes from.
- In the refining of petroleum (crude oil) the three main processes are: fractional distillation,cracking and polymerisation.
- Arctic ice is rapidly disappearing and the region may have its first completely ice-free summer by 2040.
- If global warming persists over many centuries, it could cause the complete melting of the Greenland Ice sheet which would increase global sea levels by about 7 m.

Biographical Notes

Joseph Fourier (1768 – 1830)

Jean Baptiste Joseph Fourier is generally credited with discovering the greenhouse effect. In 1824 he described how the atmosphere serves to warm the planet. This helped to establish the planetary energy balance, which is that planets obtain energy from different sources that cause temperature increase. Planets will also lose energy by infrared radiation with the rate increasing with temperature. Fourier recognised that the Earth gets energy form solar radiation and that geothermal heat contributes little to energy balance. Fourier mistakenly believed that there was a significant contribution of radiation from interplanetary space.

Svante Arrhenius (1859 – 1927)

Svante August Arrhenius, a Swedish scientist, was one of the founders of the science physical chemistry. He is best known for the Arrhenius equation. Arrhenius was greatly influenced by the work of Joseph Fourier. He used the infrared observations of the moon at the Allegheny observatory in Pittsburg to calculate the absorption of energy by CO_2 and water vapour. He suggested the human emission of CO_2 would be strong enough to prevent the world from entering a new ice age. He was the first person to predict that the emissions of CO_2 from the burning of fossil fuels and other processes would cause global warming. Arrhenius did however believe that a warmer world would be beneficial and would be needed to feed the rapidly increasing population. He expected that a doubling of CO_2 would take about 3000 years whereas present estimates would be closed to a century.

Revise the Terms

Can you recall the meaning of the following terms? Reviewing the terminology is a powerful aid for recall and retention.

biofuels, bitumen, CFC, CO_2 capture, cracking, demographic, density, electromagnetic waves, electrolysis, energy, fatty acid, fossil fuel, fractional distillation, global warming, greenhouse effect, Hz, greenhouse gas, hydrogen power, mercaptans, methyl esters, nitrous oxide, oil sands, petroleum, polymerisation, renewable energy, seismic surveys, solar power, stratum, thermal decomposition.

Check the Glossary of Terms for this lesson at www.sta.ie