School of Engineering and Built Environment

Energy Resources, Generation and Utilisation

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Section 4: Negative effects of energy use

We have seen that consuming fossil fuels probably influences (or will influence) world climate. This is not the only way the Earth is being affected by burning fossil fuels; we will consider here other ways the atmospheric chemistry is being altered. Alternative energy sources have their own specific environmental problems which will also be described.

Atmospheric pollutants

CFCs, chlorofluorocarbons, are simple chemical compounds composed of carbon, fluorine, and chlorine. T hey were formerly used for refrigeration and as solvents, but are now banned by the **Montreal Protocol** (1987-1999) agreed internationally after the effect of CFCs on the ozone layer became universally accepted in the 1980s. The ozone layer protects the surface of the Earth from harmful high energy radiation such as UV, and this layer is depleted because CFCs dissociate in the upper atmosphere releasing chlorine which can react with and breakdown ozone molecules (O_3).

Since the ban, the ozone layer is recovering, and this is a good example of how a major man-made (**anthropogenic**) threat to the environment and the planet can be averted through appropriate and consistent world-wide action. This could be a model for an effective response to the current threat of global warming arising from the combustion of fossil fuels. Fossil fuels cause other environmental problems as well. It is difficult to achieve complete combustion and soot is often released into the atmosphere. Soot is what gives smoke its colour and is mostly made up of tiny particles of carbon. The particles form in the yellow part of a flame and are carried into the atmosphere, but they will always return to the ground to cause breathing and other health problems, as well as forming unsightly deposits blackening buildings facades.

For the time soot particles remain in the air, they may affect the albedo of the Earth and may actually contribute to a cooling effect referred to as global dimming. This may counteract global warming.

Another form of air pollution associated with the burning of fossil fuels is the release of gases such as carbon monoxide, sulphur dioxide, nitric oxide, nitrous oxide, and nitrogen dioxide. The sulphur and nitrogen oxides react with water in the atmosphere to form sulphuric and nitric acids which fall back on the ground. **Acid rain** can harm plants, aquatic ecosystems, buildings, and people.

Of the fossil fuels, coal releases the greatest proportion of sulphur dioxide. But in recent years, coal-fired power stations have been routinely fitted with scrubbing systems to remove sulphur oxides from the stack gases. In addition there is a trend away from the use of coal for domestic heating, and car exhausts now use a **catalytic converter** to remove polluting gases. Supported by international agreements, these measures have lessened the problem considerably.

Task 4.1

Would the release of more smoke to increase global dimming be a sensible way to counter the growing greenhouse effect?

Environmental pollution

Significant environmental damage accompanies the extraction and transportation of fossil fuels. Oil is moved around the world by sea in tankers, and some supertankers are capable of conveying 2 billion barrels of oil, equal to the daily consumption of the UK. Ships of this size are vulnerable to damage and accidents release oil into the marine environment. The effect of oil spills is often disastrous to wildlife. Seabirds get covered in heavy oil and drown, water is polluted, light is blocked from the sea, and gas exchange is prevented.
Probably the worst disaster (but not the most oil) was when the Exxon Valdez tanker struck a reef off Alaska in 1989 releasing 11 million gallons of oil into the sea. Half a million seabirds are believed to have died as a result. The clean-up operation cost Exxon Mobil over $2 billion.

Oil spills are cleaned by a variety of methods: booms round up the floating oil; skimming the oil off the surface; absorbing the oil; burning the oil; using solvents and detergents; dredging heavy oil off the sea floor; the use of digestive micro-organisms.

A direct result of the Exxon Valdez disaster is that all tankers must be double-hulled in US waters by 2015 and in European waters by 2010. A double hull makes an oil leak less likely when the outer skin is breached.

There have also been serious accidents in UK waters. The worst were the Torrey Canyon in 1967 and the Sea Empress in 1996 (though there have also been significant leaks from North Sea oil rigs and wells).

In Scotland, the Braer ran aground off Shetland in 1993 and spilt 84,000 tonnes of oil, but remarkably there was little environmental effect because the stormy conditions quickly dispersed the light oil. However there is still concern that the west coast of Scotland is vulnerable to an accident associated with tanker traffic through the Minch.

Coal mining is a dangerous occupation with a human price associated with extraction. Inhalation of coal dust causes emphysema and chronic bronchitis and thousands still die each year from these legacy diseases in the UK - though few active pits remain. The national UK mining database lists 90,000 names of persons who died or were injured in mining accidents between 1815 and 1914.

The waste from mining, coal spoil, and oil shale mining is often left on the surface as huge heaps which are acidic and contaminated with heavy metals. In Scotland, these mounds are called bings**.** They are generally hostile to plant life, but recent research has shown that they can be reclaimed through soil modification after which plant cover can become established. Opencast mining is employed when coal deposits are near to or on the surface. The top soil is removed and the coal is mechanically excavated. This can result in significant ecological damage, though not necessarily more so than other types of quarrying.

Task 4.2

Using the information from Wikipedia on oil spills produce a graph showing the total volume of oil spilt in 5 year slots in the 40 years up to now. What is the trend?

Safe energy sources?

Although a count of immediate fatalities is a reasonable way of measuring the safety of most energy sources, this criterion is not necessarily applicable to nuclear energy. The nature of radiation is that it usually does not kill instantly (or obviously) but will induce DNA mutations that can sometimes result in the subject developing cancer. The effect is cumulative in the sense that prolonged exposure or higher energy radiation increases the risk.

The Chernobyl nuclear disaster in 1986 occurred when the core overheated and a resulting (non-nuclear) explosion sent radioactive material into the air. It subsequently came back to the ground as **fallout** or contamination. In the actual event 30 people died, but many millions of people throughout Europe have been exposed to radioactive dust and gas. It is difficult to gauge the overall consequences of the explosion because there is no clear way of distinguishing cancers caused by this event from those with other causes. The UN estimate that 4,000-9,000 people throughout Europe have died or will die of cancer as a result, though a statistical analysis does not back these figures up and only 28 people are definitely known to have died since as a result of the accident.

In spite of the apparent low number of fatalities, the lives of hundreds of thousands of people were affected through displacement from the contaminated surroundings, and the worry of the consequences of radiation exposure. Nuclear power therefore poses a greater threat to the population and the environment than might be apparent from bare statistics.

Hydroelectricity is a renewable source of energy that supplies 20% of the world's electricity. The power is obtained by damming fast-moving rivers to build up a **head** of water. As the water is contained, it floods the area behind the dam. This means a lot of land may be lost and many people displaced during project construction. Downstream, a dam will severely disrupt a river ecosystem. Dams can also fail catastrophically with flooding and loss of life.

Large wind turbines would seem to be an effective way of generating clean energy, but they too are not without environmental problems. Construction and siting can release huge quantities of carbon dioxide into the air, particularly on peat subsoil which is also vulnerable to movement and subsidence. Turbines can be noisy and, for some people, are visually unappealing, and can adversely affect tourism. Offshore wind farms in shallow waters can affect fishing.

Many of the large areas free from development and habitation in the UK are in that state because of conservation measures to protect wildlife, but they are obvious targets for large wind farm developments because of the need for a lot of space away from populated areas. This results in conflict between planners and conservationists on the basis of damage to important habitats and the death of birds and other wildlife.

Task 4.3

Consider the effect of wind turbines on wildlife and the economics of host communities and examine the competing interests. Should these developments override conservation issues?

Accepting compromise

We have seen there appears to be no way of generating power in the quantity needed in the world today without some impact on people and the environment. This should come as no surprise - we are consuming fossil fuel at a rate thought to be over 100 times as fast as it was originally produced. The level of demand is astonishing: As an indication, if we were to obtain all our energy from the gravitational attraction between the Earth and Moon, the Moon would come crashing down onto the Earth within 50 million years.

The idea of a future where we somehow harvest sufficient energy without affecting the planet is probably fantasy, unless a dramatic scientific breakthrough comes along. Until then we have to recognise that there will have to be some trade-offs. Energy production comes at a cost and the people benefiting and those adversely affected are not necessarily going to be the same people. And one can guarantee the environment will suffer as usual.

The sensible approach is to try to reduce consumption and to look at the detail of each method of producing, distributing, and using energy - and consider where existing efficiencies can be bettered. Alternative/renewable technologies should be adopted where this is justified and not merely on a matter of principle. By adopting this approach, the release of carbon dioxide may be reduced to a level that is 'safe' for the planet without the population succumbing to economic chaos.

One of the main problems in evaluating technologies and their environmental and economic effects is that everything is so deeply interlinked and knock-on effects must be accounted for. This is clearly illustrated in the decision to encourage motorists to switch from diesel to biodiesel, and the concept of **carbon trading**. These ideas were advocated for the best of motives, but may instead result in overall damage to the environment. The CO_2 emission targets agreed by Europe can be partly achieved by using biodiesel for road fuel. However there is not enough agricultural land available in Europe to grow crops from which the basic oil is extracted. Consequently, it must be imported from overseas. Because of this demand, huge tropical peat bogs in Sumatra have been drained and trees felled to produce palm oil for European consumption. A simple analysis shows that draining the bogs releases 30 times more CO_2 than is ever saved by replacing fossil fuel with biofuel.

Writing in New Scientist, Fred Pearce comments:

'The fact that European countries can meet their Kyoto protocol obligations by sponsoring activities that have helped turn Indonesia, of which the giant island of Sumatra is a part, into the world's third largest emitter of greenhouse gases is a savage indictment of the perverse incentives created by the protocol.'

There are no quick, simple solutions. An effective response to the threat of global warming requires consistent and probably rapid worldwide action.

Task 4.4

Do you think it is reasonable that alternative energy generation (ie non-fossil fuel) should be located in relatively remote regions of Sub-Saharan Africa for the benefit of the population centres? Give a clear logical reason for your answer.

Notes

Oil shale and oil sand

Shale is a brittle sedimentary rock formed from the compaction of silt. When subject to elevated pressure and temperature it is transformed into a metamorphic rock called **slate**. A particular type of shale called oil shale contains a large fraction of solid hydrocarbon matter (**kerogen**). This has not undergone the natural process of **pyrolysis** that produces the underground oil and gas, but the process can be artificially replicated by heating the rock to 500 ^{o}C in the absence of oxygen to produce synthetic oil and gas.

This is an important source of oil. The US has 60% of the world oil shale reserves, equivalent to 450 Gtoe following extraction, 150 times the US conventional oil reserves. Oil shale is not normally included in a statement of proven oil reserves. The world conventional oil reserve is currently about 200 Gtoe. Oil shale can be on the surface or deep underground. The problem is that the energy processing cost is high and recovery is thought to be completely economical only when the cost of crude oil is somewhere between $50 and $100 per barrel. The additional energy required to process the shale means the use of this type of synthetic oil releases overall a greater quantity of carbon dioxide (perhaps 3 times as much). The sulphur content is also much higher.

Oil shale is not the same as oil sand. Oil sand is a mixture of heavy oil or bitumen with sand and other materials. It is also difficult to extract because the hydrocarbon viscosity must be reduced to allow the material to flow. Oil sand is the residue of oil fields that made their way to the surface and have since been mostly consumed by bacteria. The total world reserve is thought to be 650 Gtoe, mostly located in Canada and Venezuela, and this is not normally included as a measure of the proven oil reserves. Adding all these together, the total reserve of all types of oil is 1,300 Gtoe. Synthesizing oil from coal and biofuels can double this. There is technically enough oil to last more than 100 years.

Types of radiation

Radiation can be **alpha** rays (a helium ion), **beta** radiation (fast electrons like in a TV tube), **gamma** photons (high energy electromagnetic waves), or **neutrons**. Any material that emits any of these types of radiation is considered radioactive. Gamma radiation generally has more penetrating power and can therefore be considered most dangerous.
There is always some radiation about us (**background radiation**). Some is emitted by naturally radioactive elements present in small quantities in rock and some comes from space. Some rocks emit radioactive radon gas which can accumulate in buildings and increase the background level considerably.

A **Geigertube** can be used to count individual particles or photons to measure the radiation level. The unit of radiation is the **becquerel** (**Bq**) and is a count of the number of decays per second. The acceptable radon limit of 200 Bq m^{-3} is less than 200 decays in one cubic metre of gas each second. The **rem** is the accumulated radiation dose and is calibrated for damage to human tissue. It is equal to 0.01 **sievert** (Sv), the standard unit.

Though cumulative, the effect is not strictly linear - a high dose for a short period is worse than a smaller dose over a longer period. Acute symptoms occur when the radiation massively disrupts cell activity preventing cell division and interfering with metabolism. Low dosage exposure will have the same effect, but fewer cells are damaged and the body is

able to recover and replace these. However there will be residual DNA damage that can result in cancer, perhaps years later.

Summary

Along with the problem of diminishing supply, we have seen that the consumption of fossil fuels may also be critically affecting the global climate, though the models do not predict accurately what the eventual consequences might be. The sensible response is to use less fossil fuel, or to trap the carbon dioxide and prevent its release into the atmosphere. Less fossil fuel will be burnt if we use less energy and/or adopt alternative/renewable/sustainable methods of energy generation. However, even non-fossil energy sources can have a significant environmental impact.