Chapter 7 – World Energy

<u>Energy from the sun</u>. Wind, waves, heat, rainfall.

- *Wind.* Wind turbines. Why size matters. Kites.

The energy from the sun and the rotation of the Earth creates wind. This energy is called renewable because it has continued over the history of the Earth.

Wind energy can be harnessed by wind turbines, shown in the diagram.

For a wind turbine, as the blade size doubles the area swept out goes up four times, and the energy goes up four times as well. As the wind speed doubles the energy goes up eight times. That is why for wind turbines size matters, and why farms of large offshore wind turbines are important, because wind speed is usually greater offshore than inland.

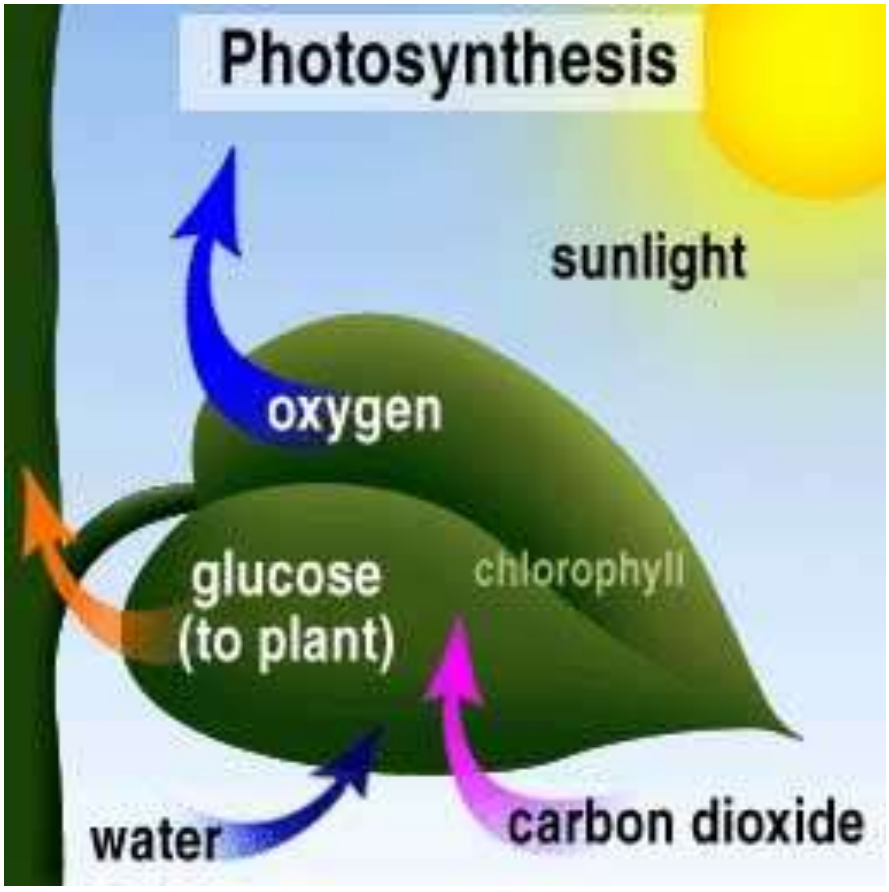
Like the wing of a propeller plane without a cockpit, a Makani Airborne Wind Turbine stirs the air in a California field where it is being tested to capture high-altitude wind power.

Wind velocity is very much higher in the stratosphere, so if a set of kites were launched into high altitude a lot of energy could be obtained.

- *Waves.* Britain has much energy reaching its shores in waves, particularly in Scotland. Shown on the right are a collection of a type of wave power machine called the Pelamis.

- *Heat from the sun*. Food and agriculture. Photosynthesis. Solar thermal panels. Photovoltaics.

  Sunlight is absorbed by plants in the green substance chlorophyll in a process known as photosynthesis. This, directly or indirectly, is the source of our food.



A way of collecting solar energy, for example on a roof, is to use a solar thermal panel. Sunlight heats a liquid in the panel and can be used to heat water for the house throughout the year.

Photovoltaics capture the energy from sunlight and convert it to direct current electricity. At the moment, the technology and efficiency is rapidly advancing.

Evaporation from the oceans causes clouds which fall as rainfall.

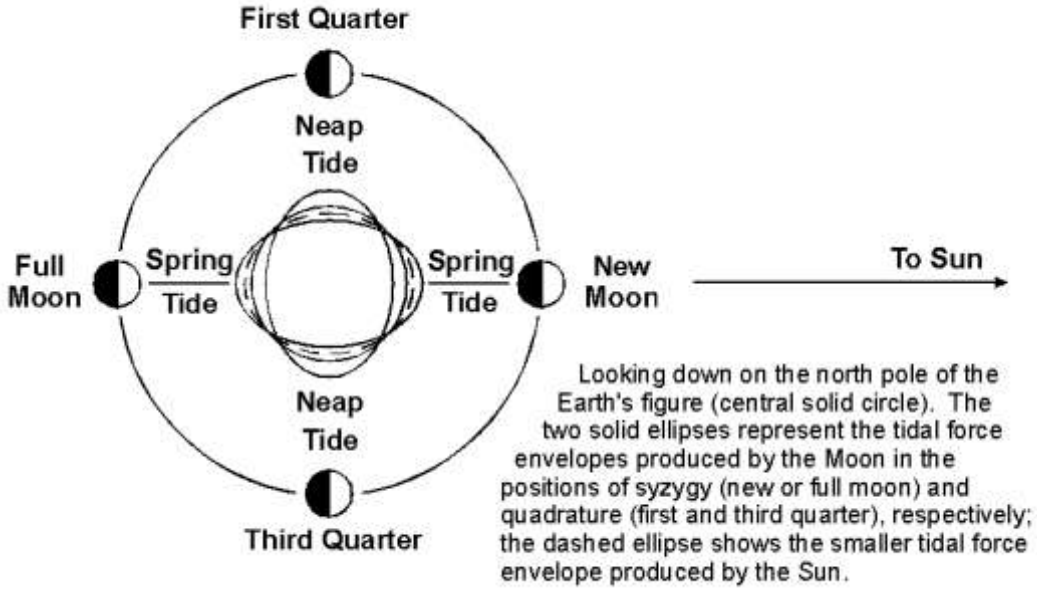
A typical thunderstorm liberates as much energy as a 20 kiloton nuclear warhead – 10 gigawatt-hours. The energy circulating from evaporation from trees in the Amazon is as much as 950 terawatts.

By cutting down tropical rainforests we are changing this energy circulation and changing the climate.

We can collect the energy from rainfall in rivers and dams. The dam in Dinorwig in Wales serves the use for variable storage and release of 1.6 gigawatts of power in Britain.

Energy from the moon. Tides.

- *Gravitational pull of the moon on the Earth, and tides.*

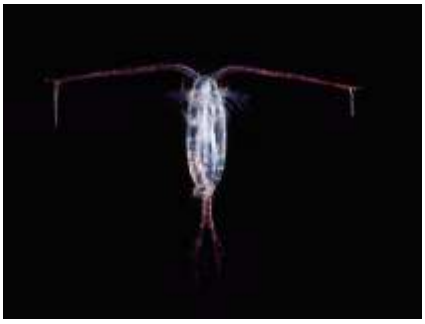


Shown in the diagram, much exaggerated, is the envelope of the oceans under the gravitational pull of the moon. As the moon circles the Earth, this causes the tides.

- *Tidal barrages*.
  The Bristol Channel acts as a funnel for tidal energy, potentially one of the most significant sites in the world. If implemented, the Severn barrage could generate over 8 GW of electricity, and even store and release much more energy than Dinorwig.

<u>Energy from the Earth</u>. Oil, gas, coal, geothermal, uranium, thorium, thermonuclear.

- *Oil, gas, coal and the Permian extinction*.



Oil is derived from ancient biomass – prehistoric zooplankton and algae. Coal comes from the compacted remains of ancient forests.

250 megayears ago the Earth had many creatures. Some of them looked rather strange compared with modern lifeforms.

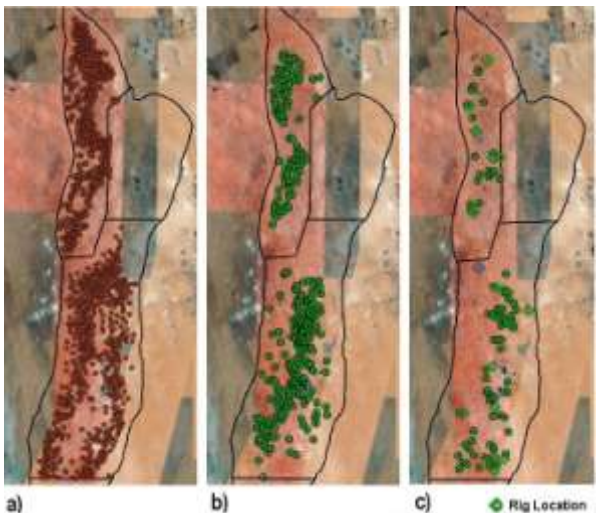
As the 'tectonic plates' – the movable crust of the Earth – moved to create the ancient continent of Pangaea, covering greater than modern-day Europe and Asia, a series of volcanic eruptions took place in the Siberian Traps covering 200,000 square kilometers with lava. These spewed volcanic greenhouse gases into the atmosphere (at a lesser rate than we are emitting CO_2 at the moment). This, and other events over a long period of time raised the temperature of the Earth, deoxygenated the atmosphere, and led to a mass dying of species. In this Permian extinction even algae in the oceans died, and fell to what became later deposits of oil and gas.

- *Depletion of fossil fuels*. The industrial revolution. Energy consumption in Africa. Why China wants energy consumption like the West.



Oil depletion is like drinking a pint of beer. When the glass is full, there is plenty of beer there. When it is half drunk, there is only half the amount of beer there, and when the pint has been consumed, there is no beer left. The difference with oil is we cannot get a replacement glass.

Below are Saudi oil wells in 'Ain Dar and Uthmaniyah: a) before ca. 2000, b) between 2000 and 2003, and c) developed after 2003 including sites prepared for drilling and those undergoing active drilling in summer 2006. Source: Satellite O'er the Desert.



Oil production peaked or plateaued in 2008. Peak gas has happened five years after that, and the decline is expected to be steeper. Peak coal is more long term, but will follow the same pattern. The effect of coal on climate is more devastating than oil and gas.

Britain led the world in creating, in the Industrial Revolution, a high-energy economy based on coal. This liberated human energies to replace them with machines and led to an Empire with economic and military dominance over other civilisations.

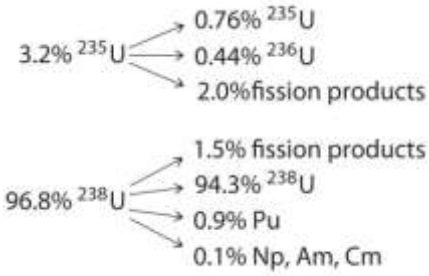
In Africa today, the per capita consumption of energy is one tenth of what we have in Britain today.

Many countries want the standard of living we enjoy in the West, and China and India are cases in point. This means more energy usage, competition for energy resources with other counties, and internally in China the use of wind energy and coal on a massive scale.

- *Geothermal*. Iceland. Britain.
  Because of radioactivity in the Earth's core and slow internal circulation the Earth is self-heating. This heat can be trapped from underground sources and used as energy. This is known as geothermal energy.

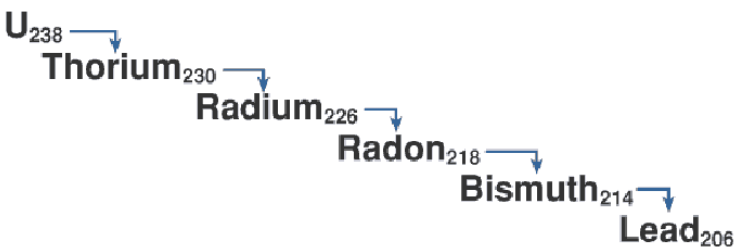
An example of the use of geothermal energy in Britain is a district heating scheme in Southampton. Iceland, being volcanic, has very much greater sources of geothermal energy, and so it would be sensible to site industrial processes there which consume a large amount of heat energy. Electricity derived from Icelandic geothermal sources will be exported to Britain, and could be exported to Ireland.

- *Uranium and plutonium. Weapons. Thorium. Reserves. Reactors and waste*.
  Some atoms are so big in their nucleus that they spontaneously decay. Another reason big atoms can decay is when they are bombarded with neutrons. Uranium is an example of such a heavy atom. When a type of uranium decays it gives off neutrons that can cause a chain-reaction of further decays. This is known as nuclear fission. In fact, there can be a series of decays to lower elements, finally leading to the stable element lead.



One of the intermediate stages in this decay chain can be the production of the radioactive element plutonium, which is also highly toxic. Uranium and plutonium can be used to create nuclear weapons.

Thorium: Another element that is radioactive is thorium, but its decay chain is very much less toxic.



Reserves: There is twice the amount of thorium in the world as uranium, which like oil is finite.

Reactors and waste: Uranium reactors which produce energy leave plutonium as waste. These and other products cannot be thrown away. The plutonium can also be used as fuel for reactors using liquid sodium as coolant. They are stored in a type of glass and kept cool. This permanent storage is very expensive. Reactors that use thorium have been built, but the decay products cannot be used for nuclear weapons.

Uranium and thorium take much energy to mine and process, so the energy cannot be said to be entirely renewable. The permanent storage of radioactive materials should be considered in the economics of nuclear power. If the ancient Egyptians had used nuclear power to build the pyramids, they would still have to store the nuclear waste today.

- *Thermonuclear energy*.
  A large project to create the processes that provide energy in the sun is the ITER project in Europe. If the world runs out of energy, it is unlikely a solution like ITER will be available in time, or even, because of the high technology costs, that the energy produced will be commercial.