towers. Wind farms can now be seen on the tops of many hills to maximise the benefit of windy positions.

The most prominent and essential form of energy in our lives is the sun and methods of harnessing solar energy have now been developed, the most common of which is the solar powered calculator. Solar cells, more correctly called *photovoltaic* cells work by converting photons of light from the sun in to an electric current and they are made from semiconductors. When a photon of light impacts upon the surface of the semiconductor some of its energy is absorbed, knocking electrons out of their orbit and allowing them to flow. If there is an electric field present the electrons are encouraged to flow in a particular direction thereby generating an electric current. In addition to the simple calculator these cells are used to power satellites. It is hoped that solar energy may also one day power vehicles and our homes.

One other form of energy which may play a central role in the future is the hydrogen fuel cell. The fuel cell consists of two porous platinum electrodes separated by a polymer membrane. Hydrogen coming in to contact with the anode gives up its electron, leaving an hydrogen ion, and oxygen from the air is absorbed by the cathode. The free electrons from the anode flow through an external circuit to produce oxygen ions at the cathode. The hydrogen and oxygen ions can then diffuse through the membrane to combine and form water. The main draw back of this system at present is the production and storage of sufficient amounts of hydrogen. A large amount of international research is currently underway to develop materials for hydrogen storage and at present there are two camps: compressed hydrogen gas storage and storage in the form of a metal hydride. Glass microspheres are tiny glass bubbles which will store hydrogen when they are heated to 200-400°C. The hydrogen is trapped at room temperature and release by reheating. Carbon nano-tubes are created by rolling sheets of hexagonally-arranged carbon atoms. The tubes are only one atom thick and the core is just big enough to store hydrogen molecules. The hydrogen is stored by first heating the tubes to 900°C in a vacuum and then filling the system with hydrogen at a pressure of 120 atmospheres. The hydrogen is gradually released as the pressure is released. Research has shown that around 30 litres of hydrogen can be stored in 1 gram of carbon. Palladium soaks up hydrogen like a sponge, forming the palladium hydride, and can store up to 900 times its own volume. At present all of these methods are expensive and not practical on a day-to-day basis. Maybe one day in the future the hydrogen economy will become a reality.

Further information

http://encarta.msn.co.uk
www.howstuffworks.com
www.nano.unr.edu/KeyTOpics/fuel_calls.asp

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www.materials-careers.org.uk

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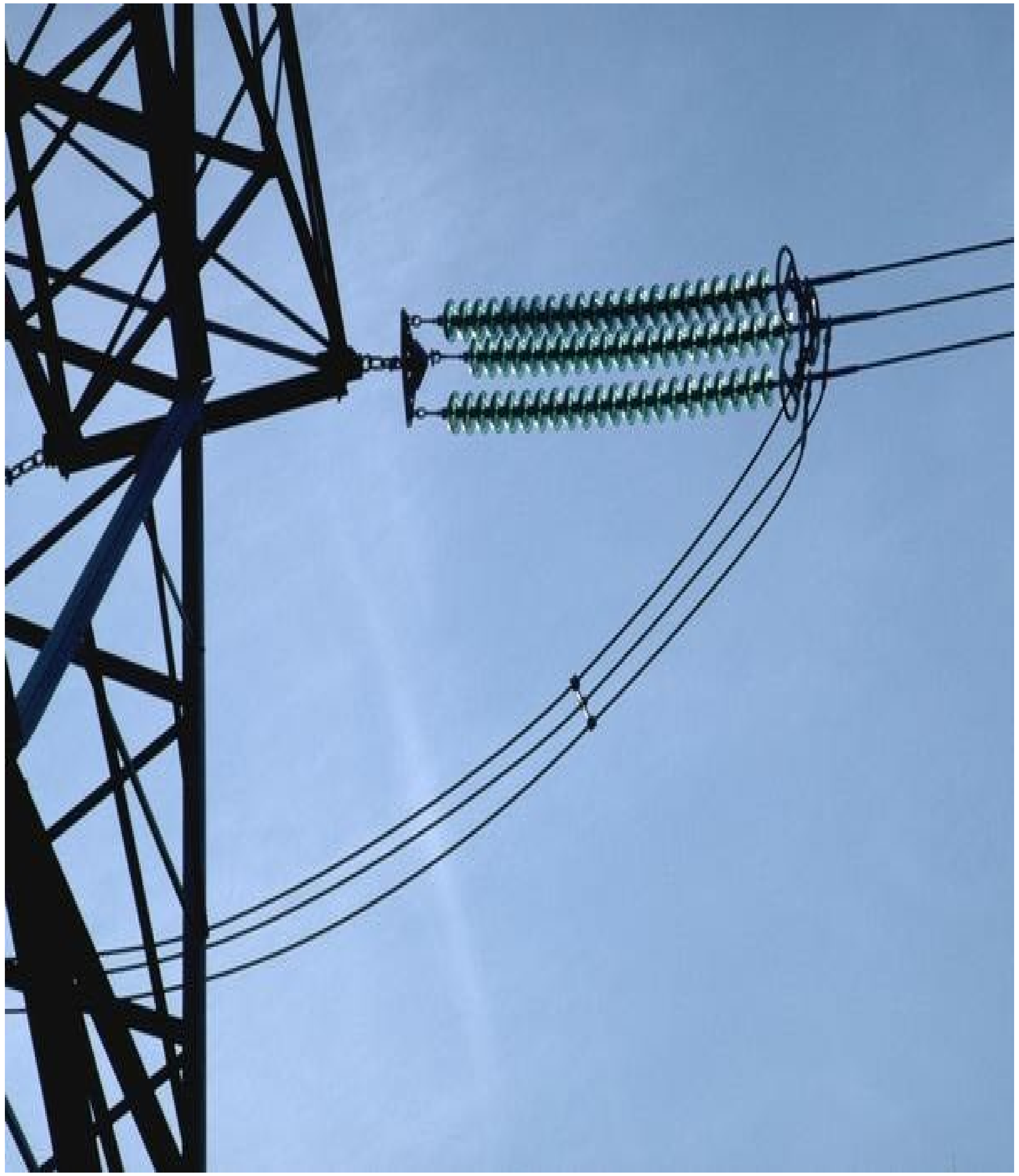


Materials in Power

- **Materials for generating power**
- **Materials for distributing power**
- **Materials for the future of power**

Materials in Power

Electricity has been around since the creation of the Earth. On occasion we witness its raw power in the form of lightening, but it was not until Otto von Guericke built the first machine to create an electric charge in 1672 that we could produce electricity ourselves. However, at this stage no means were available to store the electricity. The first battery was developed by Alessandra Volta in 1800 and in recognition of is discovery the unit of potential difference was named after him (i.e. the *volt*).

Electricity has now become a resource which we could not live without and as with other areas of technology materials have played a central role in both its generation and distribution.

Materials for the generation of power

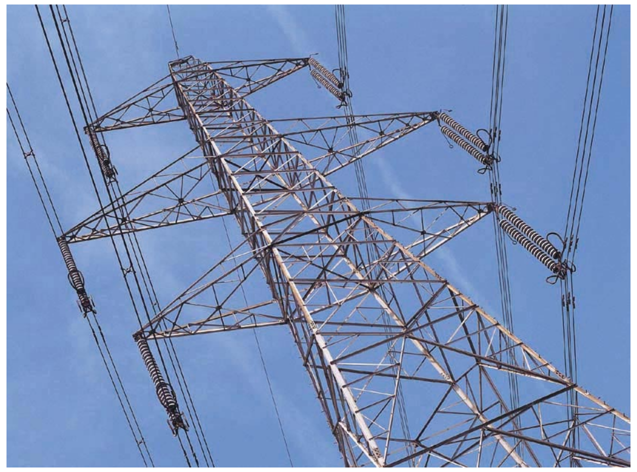
Electricity is usually produced by converting heat energy in to mechanical energy using a heat engine such as a turbine. This turbine may be driven from gas or by steam, but in each case some form of fuel is required. Gas-fired power stations require a plentiful source of natural gas which leads to materials issues in itself. Offshore gas rigs need to be made from materials which can withstand the battering from the ocean and the salty environment and this requires the use of tough strong alloy steels. The pipes which carry and distribute the gas must also be made from special steels which are resistant to the ingress of hydrogen from the gas, which can lead to cracking. Once at the power station the natural gas (or gas made by burning powdered coal) can be used to drive a gas turbine. Gas turbines have an efficiency of in the region of 40% so a great deal of heat remains in the gas flow and this can be used to heat water to drive an additional steam turbine. This type of operation is known as a Combined Cycle power plant and has a combined efficiency of around 55%. Steam turbines are also very common in power plants. Gas or coal is burnt in an enormous boiler lined with water pipes many kilometres long. This allows as much heat as possible to be transferred to the water causing it to boil and produce high pressure steam. The steam then passes through the turbine and the low pressure, low temperature steam is condensed back into water in giant cooling towers prior to being fed back through the boiler. The material used in the turbine is generally a high strength, high toughness special steel containing a high alloy content. It must also be able to withstand prolonged exposure to the steam.

In the case of nuclear power plants the heat needed to generate steam originates from the nuclear fission of a material such as uranium. When a uranium-235 atom is bombarded with a neutron it splits forming new atoms and neutrons and emitting gamma radiation and heat. The resulting neutrons can then go on to bombard other uranium atoms. If left unchecked the rate of this reaction can become critical and lead to a nuclear explosion. Neutron absorbing materials act as control rods to control the rate of the nuclear reaction to produce the level of heat required. The materials used in a nuclear reactor must be able to withstand exposure to radiation and much of the pipe work is made from stainless steels. The reactor must be surrounded by a biological shield to prevent the escape of radiation should an accident occur and this is composed of concrete several metres thick. Around 17% of the world's electricity is now produced in nuclear power stations and this method does offer a significant advantage over conventional fuels in that no carbon dioxide is produced. However the safe disposal of radioactive nuclear waste is an issue. High level waste is mixed with glass and vitrified to produce a solid material which is encased in steel cans prior to being buried. This waste will remain hazardous for thousands of years and there is a great deal of controversy over where the waste should be stored.

Electricity is generated by coupling the shaft of the turbine to the rotor of a generator that rotates at around 3000rpm. The rotor, which is made from solid steel, is converted in to a strong electromagnet by the presence of windings which carry a direct current. The rotating magnetic field induced an alternating voltage in the stator section of the generator and the efficiency of this system is around 100%.

Materials for distributing power

Once the electricity has been produced it must be transported into our lives for us to use and this is done using the National Grid. Transformers are used to alter the voltage and current at which the electricity is moved in order to minimise losses due to resistance heating. The best conductors of electricity are metals. The bonding between the atoms of a metal is such that there is a shared sea of electrons which are free to carry the current. The best of the metals is gold, however, its mechanical properties are relatively poor and it is of course very expensive. The same problems also prevent the use of silver. Copper is the third best electrical conductor and copper wires are used extensively in domestic wiring. However if electricity is to be transported over large distances cables made from aluminium and steel are used. The aluminium cables used to transport the electricity are strengthened by a core of steel in order that they have the necessary strength required to be hung over the large distances between pylons.



Electrical insulators are also very important in power distribution. On a metal pylon there must be some way of isolating the cable carrying a high voltage supply from the metal tower supporting it. Ceramics such as silica and alumina are used as they also offer inertness to the atmosphere. In domestic wiring polymers are used to insulate copper wires. Polymers offer the advantage of being able to be formed over the wire and being flexible. They are also easily coloured to allow identification of different wires. The nature of the bonding in polymers (covalent) and ceramics (ionic) ensures that all of the electrons are tied up and are not freely available to move

Materials for the future of power

As our resources of oil, gas and coal are dwindling and legislation on the emission of greenhouse gases (carbon dioxide being the main concern) is becoming more stringent there is a need to seek alternative means for producing electricity from sustainable resources. Electricity is now being generated using modern equivalents of the oldest types of turbines: the water wheel and the windmill. Hydroelectricity is generated by using the power of falling water to drive a turbine. This method has the advantage that in times when there is little demand for electricity the turbine can be used as a pump to move the water from a lower reservoir back up hill to the upper reservoir where is can be used again.

Modern day windmills use the action of the wind to rotate the turbine and produce electricity. The sails which can be rotated to remove the maximum energy from the wind are built on the top of tall concrete