ENERGY info

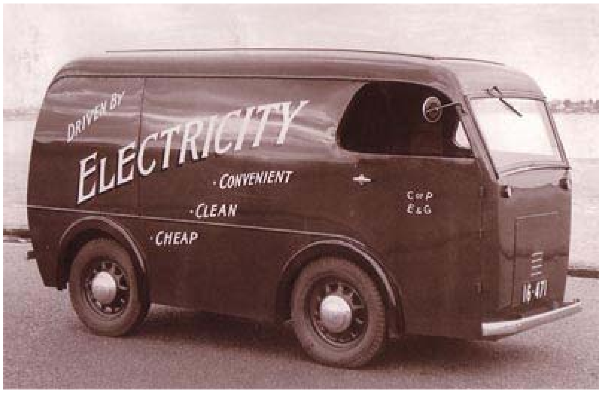
ELECTRICITY

Electricity affects our lives as no other thing does or can and it is one of the most important forms of energy on earth. Although electricity is as old as the earth itself, it is only in the past 100 years or so that we have learnt to make good use of it. It can be argued that nothing has changed our lifestyles as much as the progressive use of electricity.

Above - A school room before the advent of electricity and the wonders of the modern world. How would you cope if there was suddenly no electricity?

It can make things move, light up or get hot; it can also cool things and produce a complete range of sounds. Without electricity, modern civilisation would virtually come to a stop. Most factories would no longer be able to mass-produce essential goods, electrical appliances in the home would be useless, there would be no more electric lighting and heating, and communication systems would disintegrate.

It was in 1879 that Thomas Alva Edison improved on the 50-year-old light bulb and produced a reliable, long-lasting source of electric light. Edison's eventual achievement was the incandescent electric light and an associated electric lighting system.
It did not take people long to see the advantages of electricity and they began to use it rapidly to do work for them. Electricity runs innumerable labour-saving appliances in the home. Now, the amount of electrical energy used in homes every week is equivalent to the energy produced by more than 30 human servants working a 40-hour week!

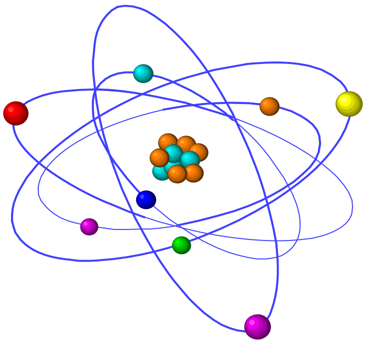


Above - Electrically operated vans were used to deliver meters and promote the benefits of electricity in 1930. Source: "The History of Electricity in Western Australia" published by Western Power Corporation.

In 1930 there were about 19 electrical appliances available in the major department stores. There are now hundreds of appliances on offer, with new technology being developed continually. With these electric servants, the average person at home can do 10 times as much work as his or her grandparents in about half the time!

Electricity generation accounts for about 30 per cent of the nation's total energy consumption. Around Australia, the grid connected generation capacity comprised 47,400MW in 2006/2007, according to the Energy Supply Association of Australia (ESAA). It is expected the electricity load in 2030 will be some 65 per cent higher than its current level and installed generation capacity will need to grow from 45,000MW to around 75,000MW.

What is Electricity?

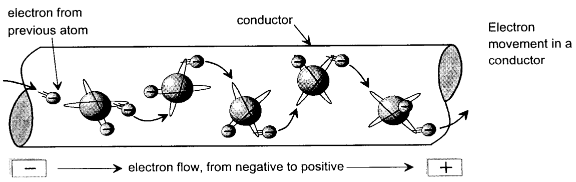


Above - An atom with electrons in orbit around the nucleus.

Everything on earth is made up of matter and matter is made up of atoms. (See figure above). Within these atoms are smaller, electrically charged, moving particles called “electrons”. The movement of these electrons creates electricity. In other words, electricity exists all around us in the world we live in and within our own bodies.

Even the air we breathe is made up of atoms. Atoms are so tiny that it takes many millions of them to form a single speck of dust. It takes millions of billions of moving electrons to light up a torch for one second. Simply, electricity can be described as a flow of electrons - a powerful, invisible force. Like water, this flow can be channelled from place to place where it is needed.

Some substances - especially certain metals - have atoms, which allow the free flow of their electrons. The amount of electrons flowing from atom to atom is what we know as an electric current. Metals have these free-flowing electrons and are therefore said to be good conductors of electricity. Copper and aluminium are particularly good conductors; that is why these two metals are the ones most commonly used in electrical wiring.



How is Electricity Produced?

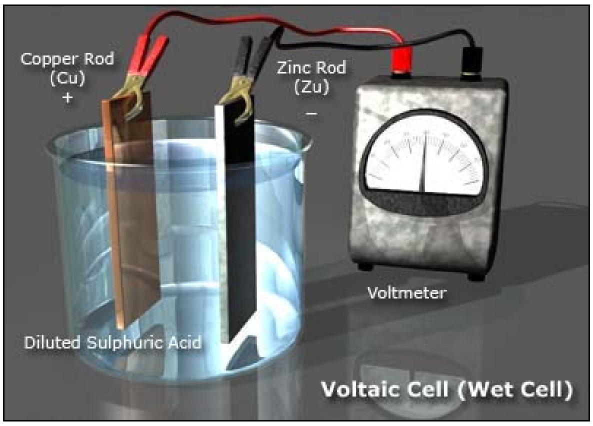
An electric current can be produced by either chemical or magnetic action. Electricity can be produced by the reaction of chemicals and metals in containers called cells (commonly known as batteries).

Using an entirely different process, electricity can be produced magnetically using the primary energy source of coal and also from the natural energy forces of the sun, wind, tides and fast-flowing water (hydro-electricity) to provide the motion needed.

Electricity Generation - Chemical Process:

An esteemed Italian physicist, Count Alessandro Giuseppe Antonio Anastasio Volta, developed the first chemical battery to produce an electric current. In 1800 he showed that an electric current could be made to flow by connecting a wire conductor between two strips of metal standing in a container of fluid.

Volta used a strip of copper and a strip of zinc in a solution of sulphuric acid and so produced the first electric battery, or voltaic cell (See figure below).



Above - An illustration demonstrating that by placing a copper and zinc rod in a solution of dilute sulphuric acid generates a small charge of electricity. This is known as a wet cell battery.

Previously electricity had only been thought of in terms of intermittent sparks and surges such as that in static electricity (caused by friction and lightning). Volta's invention provided a continuous electricity source for early telephone and telegraph systems. He showed for the first time that an unbroken flow of electricity could be maintained.

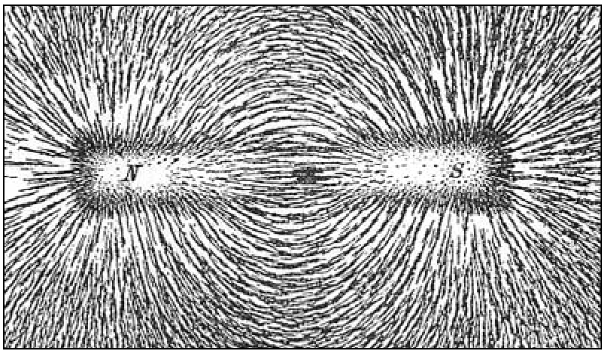
In the voltaic cell, the copper strip or rod is called a “positive electrode” and the zinc rod a “negative electrode”. The acid fluid is called an “electrolyte”. This enables the chemical reaction to take place. Modern “dry cell” batteries have a chemical paste instead of a liquid electrolyte. (Torch batteries and transistor radio batteries are examples of “dry cells”.)

When the battery is connected to an electrical circuit, there is a flow of electrons (an electric current). Electrons flow from the negative rod of the battery (electrode) to the positive one through the connecting wire conductor. The circuit must be complete (unbroken) for a current to flow.

Electron flow through a conductor is similar in many ways to the flow of water through a pipe. In both cases a difference in pressure between the ends of the circuit is used to cause the flow, and in both cases the greater the pressure difference or the larger the conductor or pipe, the greater the flow.

The force of pressure of electricity today is measured in volts – named after Count Alessandro Volta. For example a typical modern torch would use two or more dry cells rated at 1.5 volts each. (While cells are commonly called batteries, strictly speaking a battery consists of two or more cells linked together).

Electricity Generation - Magnetic process



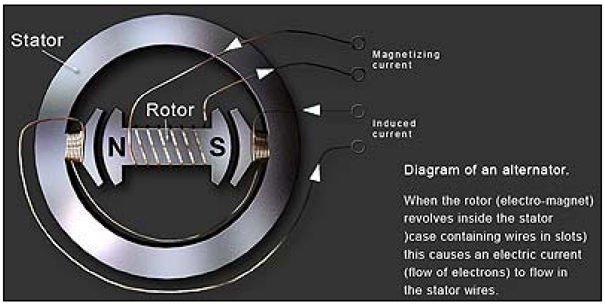
Above - Magnetic field on a bar magnet - iron filings are used so that we can see the invisible field.

Fortunately we do not have to rely on batteries for our major electricity needs. If we did we would need special rooms in our homes just to house the huge and expensive batteries necessary to provide all the electricity we need. Also batteries deteriorate as the chemicals weaken with use.

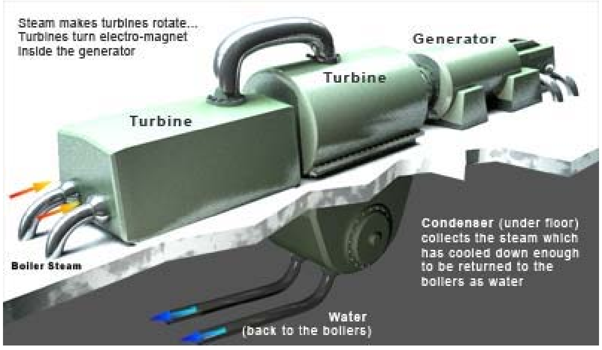
We owe our modern electricity supplies and modern electrical machinery (motors and generators) to a brilliant English inventor of the early 1800s, Michael Faraday. Ignoring the developments in chemistry which Count Volta had been making a few years earlier, Faraday concentrated on the science of matter and energy. He believed electricity could be produced more efficiently by an entirely different method.

In 1831 Faraday, experimenting with magnets, proved that by spinning a copper disc between the poles of a horseshoe magnet, electrons could be greatly activated within the magnetic field. In other words, the combination of the copper metal conductor, plus magnetism, plus mechanical movement, generated electricity. The device used for generating electricity was called the dynamo. This dynamo and the principle involved is the basis for the electricity generators used in our modern power stations.

Today's giant generators of electricity (alternators) are little more than sophisticated versions of the crude dynamo which Faraday used to generate a feeble electrical current. However, Faraday's copper disc has been replaced by wire coils and powerful electro magnets have taken over from the simple horse-shoe magnet.



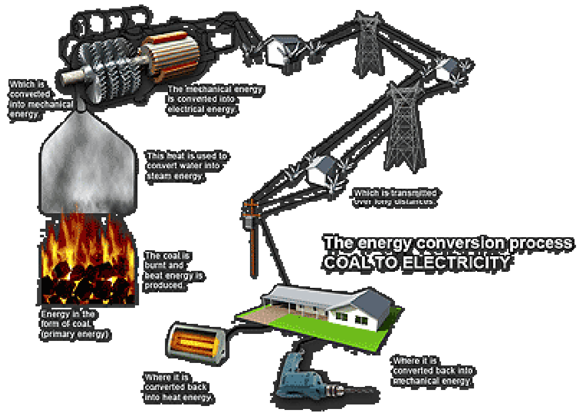
In a typical modern generator, the electro-magnet (rotor) is forced to spin inside banks of coiled wire conductors encased in a cylindrical iron shell (stator) – please refer to the above diagram. The rotor is spun by steam turbines. These steam turbines have turning blades and power generators, which produce electricity. (See figures above and below).



Above - A diagram demonstrating how steam energy is converted into mechanical energy causing the fans in the turbine to spin, thus turning the generator to produce electricity.

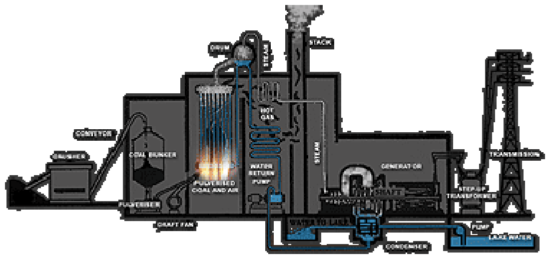
Broadly there are two types of electric current. One is called direct current or DC (a continuous flow of electricity) and the other is called an alternating current or AC. Batteries and dynamos produce DC, alternators at modern power stations produce AC. With AC, current flow reverses its direction in an alternating action. This has several technical advantages including the ease of increasing (stepping up) or decreasing (stepping down) voltages and current through transformers. There are no DC transformers.

Power Stations



A power station is a factory that produces electricity, which is simply one form of energy.

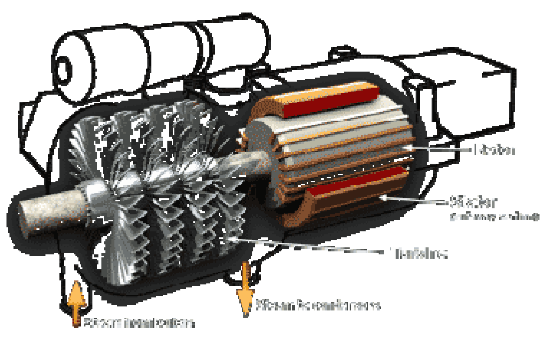
While energy cannot be created or destroyed, it can be changed from one form to another. Many power stations burn coal or gas to produce electricity.



INSIDE A COAL-FIRED POWER STATION.

Coal stores chemical energy that originates mostly from the sun. Generally, the coal is mined at open-cut or underground coal mines and then transported by conveyor lines to the power station. For best combustion, the coal is ground to the consistency of talcum powder in pulverising mills and then a stream of pre-heated air blows this powder-like substance into the boiler. The pulverised coal is burned in the boiler furnace chamber and this process will produce great heat. The boiler contains tubes lined with water and, due to the high temperature, the water is converted into high-pressure steam.

Inside the generator.

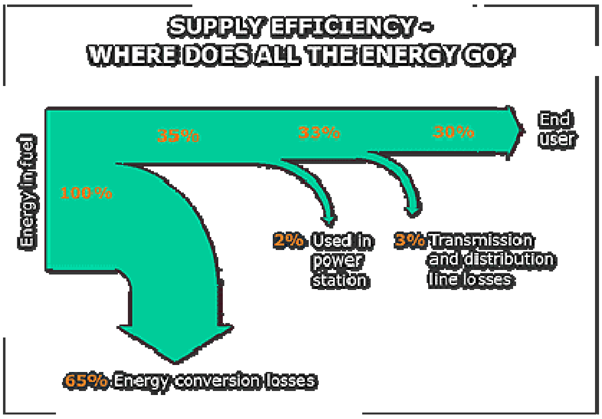


The energy force produced by the steam is so strong that it can drive a turbine in the power station. The turbine then spins a generator. The generator consists of a massive electro-magnet (called a rotor), which is encased in stationery copper wires (called a stator).

When the electro-magnet or rotor is turned, electrical energy is produced. Electricity flows through the copper wires or stator and is then drawn off through the wires. Electricity can be converted into heat, light, or sound, or energy to drive other machines that produce goods for consumers.

During this process at the power station, one kind of energy (the chemical energy inside the coal) is changing into a different kind of energy (electrical energy). There are scientific laws that govern these changes. They are called “The Laws of Thermodynamics” (“Therm” is from the Greek root meaning heat. “Dynamics” is from the Greek root *dunamis,* which means power). Thermodynamics is the science of converting heat to work.

Electricity generated at power stations is sent along high voltage transmission lines into the community. Energy losses always occur as one form of energy (such as the chemical energy in coal or natural gas) is converted into electrical energy. In fact, energy losses occur during each stage of the electricity production process. As a result, only about 30 to 42 per cent of the original energy is converted into electricity.

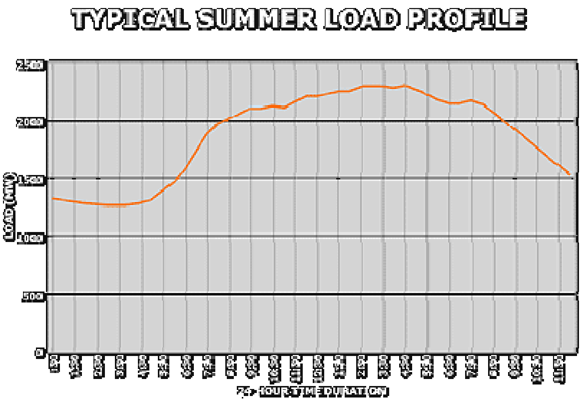


When electrical energy is sent through power lines, as much as 20 per cent of this energy is lost in the form of heat. This energy loss occurs when the electric current encounters resistance in the copper wire. As the electric current passes through the power lines, some of the electrons collide with other electrons, dissipating their energy in the form of heat.

Scientific research into “superconductivity” could lead to huge savings in energy, as well as highly efficient electric generators and motors; trains that speed across the countryside at hundreds of kilometres per hour on a cushion of magnetism; practical electric cars; more powerful computers of a more compact size; safer reactors operating on nuclear fusion (rather than nuclear fission); and a host of other rewards still undreamed of. Scientists are already working on the idea of using superconductors for electric power production. If power station generators had super-conducting electromagnets, output could be doubled. This would mean big savings to Western Australian electricity businesses and consequently to their customers. In theory, all of a large city's electrical energy needs could be supplied through a handful of underground cables.

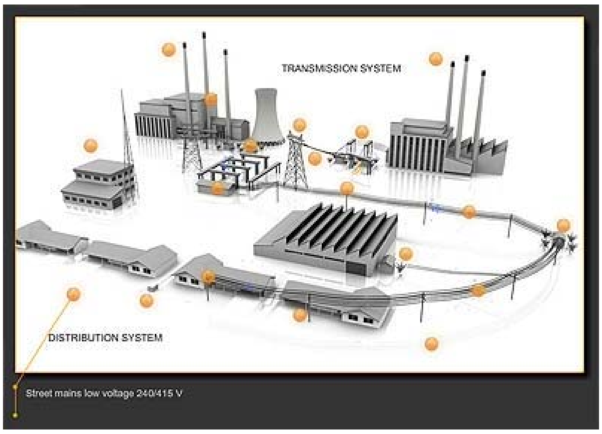
Electricity Generation - Peak Loads

People have become used to having electricity available anytime any day or night at the flick of a switch. This would have to be the last word in convenience – almost as soon as you think of the need, electricity is there. To bring this convenience to customers, Western Australia’s electricity generation company, Verve Energy, must operate its power stations continuously. As it is difficult to predict the amount of electricity that will be needed, Verve Energy keeps its generating plant running constantly, even though it isn’t always being used.



There are “peaks” when electricity demand is increasing as more customers use power in their homes. The peak times occur between 6am and 10am and then from 4pm to 10pm. Verve Energy also ensures that some plant is kept on stand-by (known as “spinning reserve”) purely in case of a sudden unexpected demand, e.g. a sudden cold spell or hot spell or in case other plant breaks down. In addition, “spare” plant is also needed to meet the sudden expected demand.

Transmission and Distribution of Electricity



Electricity provides an economical and convenient way to move energy from a source (coal, oil, natural gas, water, wind) to the place where it is needed - your place, the school, shops, and factories. The electric current can be converted into mechanical energy (to help drive your electric drill) or heat energy (to power your electric room heater).

It is this ease of transmission and distribution of electrical energy which has helped to make it so popular and widespread. Transmission is the word used for sending (transmitting) large amounts of electricity over long distances. When it reaches its destination, electricity is then distributed to customers. In Western Australia, electricity is transmitted along wires at voltages of up to 330,000 volts (the equivalent of 330 kilovolts or 330 kV).

Why do electrical supply utilities transmit electrical energy at such high voltages? The answer is that some power is lost when electricity is transmitted over distances. The most economical and practical way to minimise this loss of power is to increase the voltage in the power lines. This is done by using “step-up transformers”. Power stations use step-up transformers to increase the voltage, which allows for electricity to be transmitted long distances.

Electricity reaches a customer’s home via the main street power lines, which are connected to service wires, and the meter box. At this stage, the voltage of electricity is either 240 volts or 415 volts. It is brought down from 330,000 volts to 240 volts in several stages. During this process, “step-down transformers” are used to reduce the voltage at various stages along the route as electricity from the power station progresses towards its final destination.

For example, in Western Australia the largest power station is Muja Power Station, which is located some 22km east of Collie. There, electricity is generated at voltages between 11,000 volts and 16,000 volts (11kV-16kV). The electricity voltage is then stepped up to 330,000 volts (330kV) for its long-distance transmission to Perth along overhead wires supported on steel towers.

Above - Muja Power Station - Collie Western Australia. Source: Verve Energy.

Insulators are used at the points where the live electric wires connect with the steel towers or poles. Insulators prevent the electric current from flowing down through the steel metal to the ground. Insulators are the opposite of conductors. They are materials which do not allow electricity to flow easily through them and they are classed as very poor conductors. Good insulators include materials such as rubber, plastic, glass and porcelain.

Large step-down transformers are located in terminal stations and zone substations. These transformers vary in size according to the electrical load. They reduce the electricity voltages, which is necessary for shorter distance transmission (known as sub transmission) throughout the South West Interconnected System. This large region includes the metropolitan area and country regions from Kalbarri in the north to Albany in the south and Kalgoorlie in the east.

At the terminal stations, the transformers reduce the voltage levels for sub-transmission to 132,000 volts (132kV) and 66,000 volts (66kV). Electricity then flows to the smaller sub-stations. The electricity levels are further reduced to voltages of 33kV, 22kV, 11kV or 6kV. Electricity is then distributed via overhead or underground power lines to customers' homes and businesses.

Useful References

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