Energy Basics Fact Sheet

Measuring Energy and Power



The basic unit of **energy** is a **joule**. This is the energy contained in a teaspoon of sugar, a lump of coal, a piece of uranium etc.

A joule is the work done (energy gained/lost) when a force of 1 newton moves something 1 m. The weight of a 1 kg (force of gravity on it) is 9.8 newtons)

One joule is the energy required to lift 1 kg 10cm.

It takes 4.2 joules to heat 1 gram (ml) of water 1 degree. This is a calorie, another unit of energy measurement.


The rate at which the energy is used (**Power**) is a **watt**, so 1 joule per second = 1 Watt

Joules and watts are very small units, so when we are measuring electricity at the scale it is used by consumers; we tend to measure in **Kilowatt.**

1 Kilowatt (kW) = 1000 Watts

When we want to express **the amount of energy used over period of time**, we express it as **Watt hours (Wh)**, or more commonly when talking about how much energy a household uses **Kilowatt hours (Wh)**

Example: Fifty 20 Watt light bulbs burning for one hour, produce 1 kWh

When talking about power stations we tend to use **Megawatt hours (MWh) or Gigawatt hours**

1 Megawatt (MW) = 1000 Kilowatts
1 Gigawatt (GW) = 1000 Megawatts

Nameplate Capacity

Hazelwood power station, when it is running at its full capacity, produces electricity at a rate of **1600 MW**.

Therefore, the amount of electricity it produces in an hour is expressed as **1600 Megawatt hours (MWh).** This is known as the plant's nameplate capacity. However some of this energy is needed to run equipment in the coal plant itself. When we subtract this amount, we get the **net capacity**. At Hazelwood, the net capacity is 1540 MW

So, if Hazelwood was operating flat out all year, the electricity it would produce over a year is:

1540 MW ("**net capacity**") x 24 (hours in a day) x 365 (days in a year) = 13,490,400MWh (or 13,500 GWh)

Capacity Factor

But Hazelwood doesn't run flat out all the time. Sometimes the full 1540MW isn't required by the grid, maintenance needs to be done, and sometimes there are breakdowns etc. On average it operates at about 75% of its full capacity. This means it has a **capacity factor** of 75%

Actual Power

To calculate the actual amount of power Hazelwood produces each year

1540 MW (**net capacity**) x .75 (**capacity factor**) x 24 (hours in the day) x 365 (Days in the year) = 10,117,800 Megawatt-hours (MWh) or 10,120 Gigawatt-hours (GWh).

Primary (potential) and Delivered (useful) energy

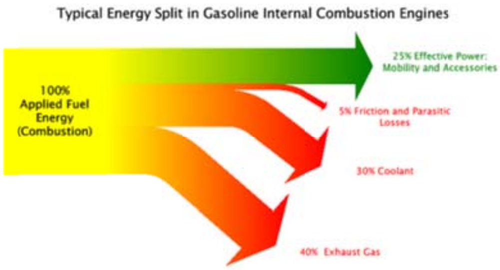
Although a barrel of oil, a lump of coal, a teaspoon of sugar are all said to have a certain potential energy, only certain amount of that potential energy can be converted to useful energy. The reason is that methods of converting that energy are imperfect, and much of the energy is lost in the process, usually in the form of heat.

Gas. There are two main types of gas plants.

Open cycle or peaking plants have around 30% efficiency. These plants can be ramped up quickly to meet increases in electricity demand, and are used less often than baseload plants.

Combined cycle plants are more efficient, around 50-60%. This is because they recycle their exhaust heat to create steam and run a second turbine (rankine cycle) to produce additional electricity. They are less flexible that peaking plants, and are run more as baseload plants.

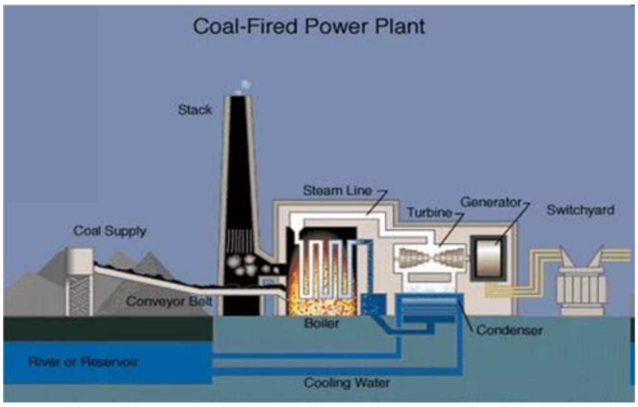
Coal: a coal power plant converts on average around 30%- 40% of the potential energy to useful energy, the rest is lost mostly as heat in the conversion process



Oil: The engine of a car is the power plant for oil ie the device that converts the oil into useful energy. As can be seen from this diagram, only about 25% is converted into useful power for mobility.

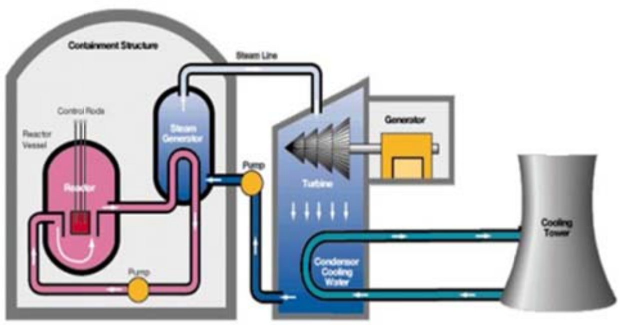
Solar thermal: Solar thermal plants, depending on the type, can convert between around 14% (parabolic trough plants) to 20% (dish systems) of the potential solar energy that hits them.

How power plants work



Coal plants

Coal plants use black coal or brown coal to boil water to create steam at a temperature of around 550-650 degrees C. This steam powers a **Rankine Cycle** turbine, which in turn powers a generator and produces electricity



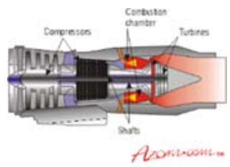
Nuclear Plants

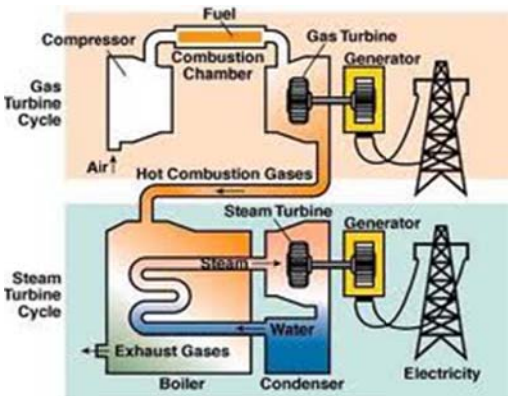
Nuclear plants, like coal plants, are thermal power plants. They operate in much the same way, but- they use a nuclear reaction instead of burning coal to boil the water- to create the steam to run the turbine and generate electricity.

Gas Plants

When we think of gas power plants, we need to remember that they do not operate discretely, but are connected to a much larger gas network. Gas is extracted from oil and gas rigs, and transported along gas pipelines to processing plants. It then goes through further pipelines until it reaches the power plant.

At the power plant is injected into a gas (brayton cycle) turbine. The gas expands when it is combusted, and the exhaust is forced through the turbine blades which turn a shaft, to drive the generator, and produce electricity

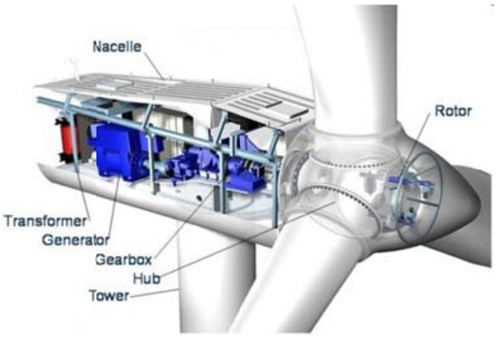




As mentioned above, there are 2 types of gas plants:

Open cycle and combined cycle. The combined cycle plants (illustrated in this diagram) are more efficient as they recycle the waste heat to run a second (steam) generator to produce additional electricity.

The initial brayton cycle is shown in the top half of the diagram, and the steam or rankine cycle is shown in the bottom half.



Wind Turbines

Wind turbines have a generator (like a coal or gas plant). To drive the generator, the winds energy is harnessed by large blades which turn a shaft to rotate the generator. In this way they are generating electricity directly (rather than creating steam to drive a turbine) and that electricity passes through a transformer and is sent directly out to the grid.

Solar thermal power plants

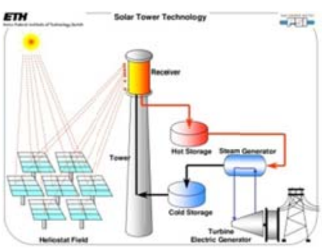
These are thermal power plants like coal and nuclear, in that they create heat which is used to make steam to power a turbine and generate electricity (rather than electricity directly like a wind turbine or solar panel). They are in fact very similar to a coal plant, except that instead of burning coal to create the steam, they use mirrors to concentrate the suns energy onto a receiver which heats up a fluid to create the steam.

Parabolic trough

Power tower

The big advantage of solar thermal power is that the heat they produce can be stored in large highly insulated tanks of molten salt. This heat can be dispatched at any time of the day or night to create steam to drive a turbine and generate electricity.

This makes is solar power that is available 24 hours a day, and is effectively baseload dispatchable renewable energy.



Power tower system with storage

Andasol 1 plant Spain

Storage tanks at Andasol 1

Energy consumption in Australia

Households
Each year, the total amount of energy use in Australia divided by the number of households equates to:
44.1 barrels of oil
9.33 tonnes of coal
375 8.5 kg LPG bottles

Victoria
85.48 million Barrels of oil per year
19.22 million Tonnes of coal
769 million 8.5 kg LPG bottles

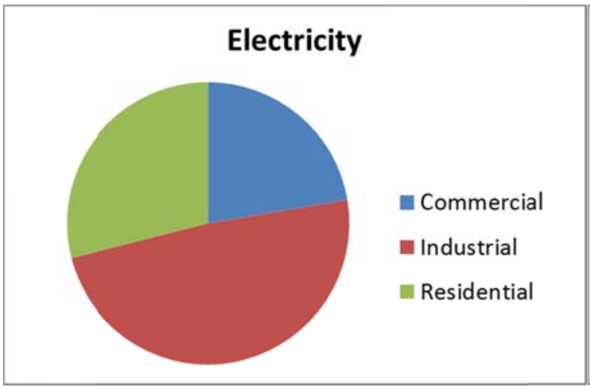
Australia
350 million barrels of oil (2124 PJ)
78.7 million tonnes of coal (2124 PJ)
3.16 billion 8.5 kg LPG bottles (1240 PJ)

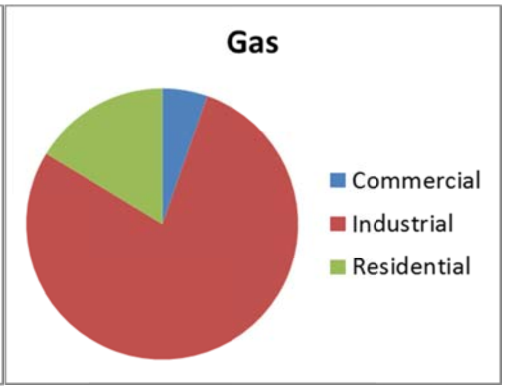
How we use the energy

Much of the electricity and gas we use in Australia are used for heating commercial and industrial buildings- anything from the local supermarket, shop or restaurant, to a huge furniture warehouse or factory.

There is also a lot of gas and electricity used for industrial processes- ranging from making steel, to running machinery in factories, to chemical reactions and mineral processing that require heat.

Almost all the oil we use is for transport- including passenger and freight, with a small amount for industrial processes.





Energy Efficiency

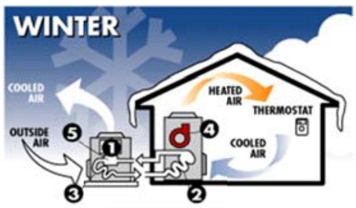
Any consideration of energy needs to address the way we use energy- energy demand. There are a vast array of measures we can take to reduce energy use, many of which are cost negative over a very short period- we actually make money by doing them!
Energy efficiency measures range from insulating our buildings, double glazing our windows, more efficient appliances, shifting passenger kilometres to public transport, taking measures to use less energy to achieve the same output in the industrial and manufacturing sectors.

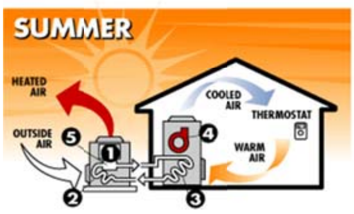
Here we will look at just a couple important measures.

Heat pumps: less energy providing more heat

A large proportion of the energy we use is to provide heating to our homes, and commercial buildings. Switching our heaters to efficient electrical heat pumps is an important part of reducing this.

When we use a gas heater to heat our home, we burn one unit of gas to provide a bit less than one unit of heat (some of the heat is lost as exhaust through the flu)





When we use a heat pump, one unit of energy can be used to provide several units of heat. The heat pump uses one unit of energy to drive a pump which circulates refrigerant gas. This draws ambient heat from the air outside, and pumps it inside.

Heat pumps have a rating of their preformance called a “coefficient of performance” (COP). The most efficient units have a COP of up to 5, which means that one unit of electricity consumed by the compressor is able to draw in up to 5 units of ambient heat from outside. Thus heat pumps have huge potential to reduce the amount of energy we use for heating.

Costs of Electricity from different sources

Current costs

Technology	Cents / kWh
Coal	4
Gas	5-8
Wind	11
Solar thermal	21
PV	40

Currently fossil fuel electricity generation is significantly cheaper per unit of electricity that renewables.

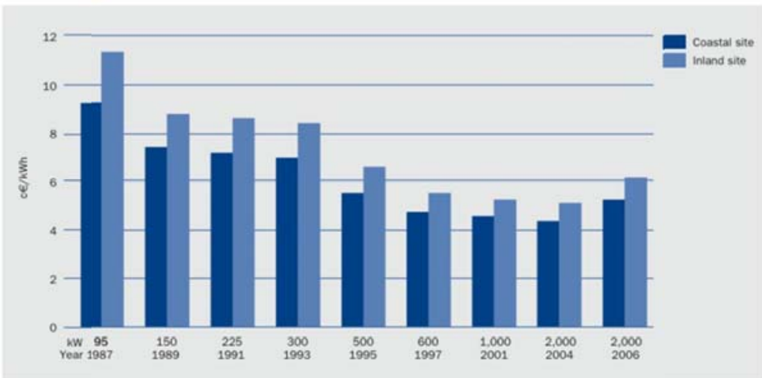
However, the unit cost of electricity decreases as the total amount of that technology (**cumulative capacity**) increases around the world.

This is because of economies of scale and finding better ways to do things through experience.

There are already huge amounts of coal, gas and nuclear power around the world, so these technologies have already hit the bottom of their cost reduction trajectories. The cost of electricity from these sources will now rise over time, as they all require fuel, and due to increasing scarcity, these fuel costs will continue to rise.

Wind and solar power however have a small cumulative capacity globally relative to coal gas and nuclear, and will continue to come down in price as they ride **the cost reduction trajectory**

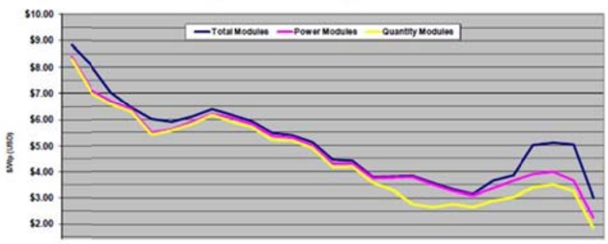
FIGURE 0.3: Total wind energy costs per unit of electricity produced, by turbine size (c€/kWh, constant €[2006] prices), and assuming a 7.5% discount rate.



Source: Risø DTU

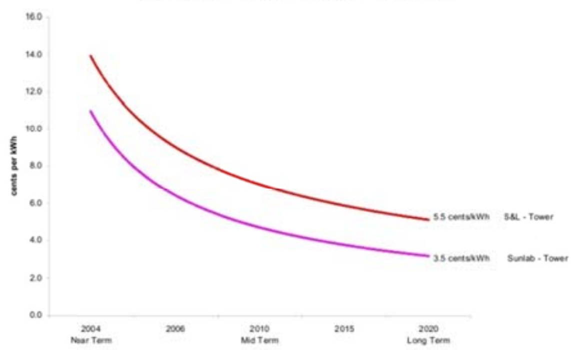
Wind has been growing at an impressive 30% pa globally for the last decade. It has already reduced its cost by about half over the last 15 years, and the entry into the market of Chinese turbine manufactures will ensure continued cost reductions.

Total module prices are averaging $3.00/Wp. Power Modules (small buyers) are averaging $2.25/Wp and quantity modules $1.85/Wp. High price is $3.55 and low price is $1.50/Wp.



Solar PV has made substantial reductions in cost over the last 2 decades, reducing its cost to a fraction of what it was just ten years ago. Much of this can be attributed to Germany making a strategic investment in this technology to increase cumulative capacity and reduce its cost, making Germany a world leader in the solar PV industry.

Figure ES-1 — Levelized Energy Cost Summary

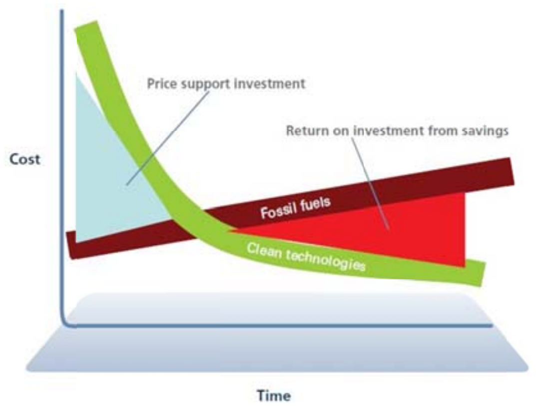


Solar thermal currently has only a small fraction of the cumulative capacity of wind. It stands at the very top of its cost reduction trajectory. Dramatic reductions

	S&L High-Cost Bound	Cumulative Deployment 2002–2020	SunLab Low-Cost Bound	Cumulative Deployment 2002–2020
Towers	5.5 cents/kWh	2.6 GWe	3.5 cents/kWh	8.7 GWe

in the cost of solar thermal electricity are expected as cumulative capacity increases. Already tens of billions of dollars of plant are being rolled out globally with much more planned.

The US Department of Energy's Sandia laboratories did detailed projections of the cost reductions that can be expected, and indicated that with the specific power tower technology specified in the ZCA2020 plan- Sandia Laboratories solar 220 power towers- with a global deployment about equivalent to around 1.5 times Hazelwood power station, the cost of electricity from these plants would be around the same as wind, and with around 5.5 Hazelwoods worth, the cost would be competitive with new coal fired power plants!



This graph illustrates the continued cost reductions of renewable energy intersecting with the continued rising fuel prices.

The blue area indicates the need for a strategic investment to bring the cost of renewables down the cost reduction trajectory. This involves **temporary** price support mechanisms. A feed in tariff is one possibility.