The Base Load Fallacy

and other Fallacies disseminated by Renewable Energy Deniers

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Abstract: The Base-Load Fallacy is the incorrect notion that renewable energy cannot supply base-load (24-hour) electric power. Alternatives to base-load coal power can be provided by efficient energy use, solar hot water, bioenergy, large-scale wind power, solar thermal electricity with thermal storage, and geothermal, with gas power playing a transitional role. In particular, large-scale wind power from geographically distributed sites is partially reliable and can be made more so by installing a little additional low-cost peak-load back-up from gas turbines. Other fallacies are refuted concisely in the appendix.

Opponents of renewable energy, from the coal and nuclear industries and from NIMBY (Not In My Backyard) groups, are disseminating the Base-Load Fallacy, that is, the fallacy that renewable energy cannot provide base-load (24-hour) power to substitute for coal-fired electricity. In Australia, even Government Ministers and some journalists are propagating this conventional 'wisdom', although it is false. This fallacy is the principal weapon of renewable energy deniers. Other fallacies are discussed briefly in the appendix.

The political implications are that, if these fallacies become widely believed, renewable energy would always have to remain a niche market, rather than achieve its true potential of becoming a set of mainstream energy supply technologies with the capacity to supply all of Australia's and indeed the world's electricity.

The refutation of the fallacy has the following key logical steps:

- With or without renewable energy, there is no such thing as a perfectly reliable power station or electricity generating system. Both coal and nuclear power are only partially reliable.

- Electricity grids are already designed to handle variability in both demand and supply. To do this, they have different types of power station (base-load, intermediate-load and peak-load) and reserve power stations.

- Wind power and solar power without storage provide additional sources of variability to be integrated into a system that already has to balance a variable conventional supply against a variable demand.

- The variability of small amounts of wind and solar power in a grid is indistinguishable from variations in demand. Therefore, existing peak-load plant and reserve plant can handle small amounts of wind and solar power at negligible extra cost.

- Some renewable electricity sources (e.g. bioenergy, solar thermal electricity with thermal storage and geothermal) have similar patterns of variability to coal-fired power stations and so they can be operated as base-load. They can be integrated without any additional back-up, as can efficient energy use.

- Other renewable electricity sources (e.g. wind, solar without storage, and run-of-river hydro) have different kinds of variability from coal-fired power stations and so have to be considered separately.

- Single wind turbines cut-in and cut-out suddenly in low wind speeds and so can be described as 'intermittent'.

- But, for large amounts of wind power connected to the grid from several wind farms that are geographically dispersed in different wind regimes, total wind power generally varies smoothly and therefore cannot be described accurately as 'intermittent'. Like coal and nuclear power, wind power is a partially reliable source of power (Sinden 2007). However, its statistics are different from those of coal and nuclear power.

- As the penetration into the grid of wind energy increases substantially, so do the additional costs of reserve plant and fuel used for balancing wind power variations. However, when wind power supplies up to 20% of electricity generation, these additional costs are relatively small.

These steps are now discussed in more detail. First it is necessary to define 'base-load'.

Base-load power stations

A conventional base-load power station is one that is in theory available 24 hours a day, seven days a week, and operates most of the time at full (rated) power. In practice, base-load power stations break down from time to time and, as a result, can be out of action for weeks. Therefore, base-load power stations must have back-up.

In mainland Australia, base-load power stations are mostly coal-fired – a few are gas-fired. Coal-fired power stations are by far the most polluting of all power stations, both in terms of greenhouse gas emissions and local air pollution.

Overseas, some base-load power stations are nuclear. They produce little greenhouse pollution during normal operation, but significant amounts of pollution (including carbon dioxide emissions) from mining, enrichment, plant construction and decommissioning, reprocessing and waste management. They also increase the risks of proliferation of nuclear weapons, are potential targets for terrorism and have the capacity for rare but catastrophic accidents.

Renewable energy can provide several different clean, safe, base-load technologies to substitute for base-load coal:

- bioenergy, based for example on the direct combustion of crop and plantation forestry residues, or their gasification followed by combustion of the gas;
- geothermal power – a new type of geothermal power (called hot rock, enhanced or engineered geothermal) is being developed in Australia, the USA and Europe;
- solar thermal electricity, with overnight thermal storage in molten salt, water, graphite or a thermochemical store such as ammonia;
- hydro-electricity in regions with very large storages (eg, Sweden, Iceland, Tasmania);
- large-scale, distributed wind power, with a small amount of occasional back-up from peak-load plant.

It is obvious that the first four of these types of renewable power station are indeed base-load. Efficient energy use and solar hot water, the natural companions of renewable electricity, can also substitute directly for base-load coal. However, the inclusion of large-scale wind power in the above list may be a surprise to some people, because wind power is often described as an 'intermittent' source, one that switches on and off frequently. Before discussing the variability of wind power, we introduce the concept of 'optimal mix'.

Optimal mix of base-load and peak-load power stations

An electricity supply system cannot be built out of base-load power stations alone, because they are too inflexible in operation. They take all day to start up from cold and in general their output cannot be changed up or down quickly enough to handle the peaks and other variations in demand. Base-load stations used as reserve cannot be started up quickly from cold.

Base-load power stations, especially coal-fired and nuclear, are generally cheap to operate, but their capital costs are high. To pay back their high capital costs, base-load power stations must be operated as continuously as possible. A faster, cheaper, more flexible type of power station is needed to complement base-load and handle the peaks.

Peak-load power stations are designed to be run for short periods of time each day to supply the peaks in demand and to handle unpredictable fluctuations in demand and supply on timescales ranging from a few minutes to a few hours. They can be started rapidly from cold and their output can be changed rapidly. Some peak-load stations are gas turbines, similar to jet engines, fuelled by gas or (rarely) by oil. They have low capital costs but high operating costs (mostly fuel costs). Hydro-electricity with dams is also used to provide peak-load power. Because the amount of water available is limited to that stored in the dam, the 'fuel' of a hydro power station is generally a scarce resource and therefore a valuable fuel that is best used when its value is highest, that is, during the peaks.

A third type of power station, intermediate-load, runs during the daytime and early evening, filling the gap in supply between base- and peak-load power (see Figure 1). Its output is more readily changed than base-load, but less than peak-load. Its operating cost lies between those of base- and peak-load. Sometimes intermediate load is supplied by gas-fired power stations and sometimes by older, smaller, coal-fired stations.

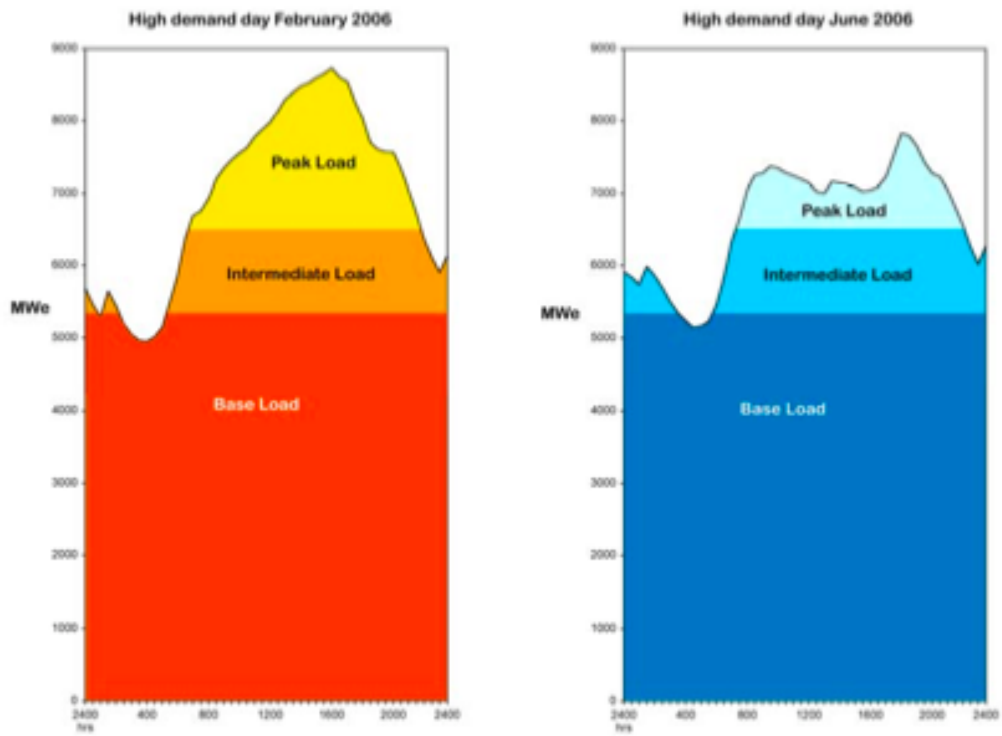
Clearly, if an electricity generating system has too much peak-load plant, it will become very expensive to operate, but if it has too much base-load plant, it will be very expensive to buy and annual loan repayments will be very high. For a particular pattern of demand there is a mix of base-load, intermediate-load and peak-load plant that gives the minimum annual cost. This is known as the *optimal mix* of generating plant.

Figure 1 sketches how an mix of base-load, intermediate-load and peak-load generation combines to meet the daily variations in demand in summer and winter in Victoria. In winter the two peaks occur at breakfast and dinner-time. In summer the single broad peak occurs in early to mid-afternoon. This particular mix may or may not be optimal.

Reliability of generating systems

Even an optimal mix of fossil-fuelled power stations is not 100% reliable, because there is always a chance that several stations might break down at the same time. To achieve 100% reliability would require an infinite amount of back-up and hence an infinite cost. In practice, a generating system has a limited amount of back-up and a specified reliability. This can be measured in terms of the average number of hours per year that supply fails to meet demand or by the frequency and duration of failures to meet demand. It is these indicators that electricity consumers see, not the reliability of individual power stations in the generating mix.

Figure 1: Load curve for Victorian electricity grid



Shown here is the typical power demand (or load) by time of day, from midnight to midnight, in summer and winter, with contributions from base-load, intermediate load and peak-load generation. Base-load is coal, intermediate load is gas, and peak-load is hydro and gas turbines. Source: Uranium Information Centre website, cited in Needham (2008).

Wind power as base-load

To replace a 1000 megawatt (MW) coal-fired power station, with annual average power output of about 850 MW, a group of wind farms with capacity (rated power) of about 2600 MW, located in windy sites, is required. The higher wind capacity allows for the variations in wind power and is taken into account in the economics of wind power.

Although this substitution involves a large number of wind turbines (for example, 1300 turbines, each rated at 2 MW), the area of land actually occupied by the wind turbines and access roads is only 5–20 square km, depending upon wind speed. Farming continues between the wind turbines. For comparison, the coal-fired power station and its open-cut coal-mine may occupy over 50 square km.

Although a single wind turbine is indeed intermittent, this is not generally true of a system of several wind farms, separated by several hundred kilometres and experiencing different wind regimes. The total output of such a system generally varies smoothly and only rarely experiences a situation where there is no wind at any site. As a result, this system can be made as reliable as a conventional base-load power station by adding a small amount of dedicated peak-load plant (say, gas turbines) that is only operated when required. The system of wind power with peak-load back-up has most of the characteristics of conventional base-load. It has high capital cost and can operate for 24 hours per day with low operating cost. The main differences are that it is much cleaner than conventional base-load and doesn't generally operate at full rated power.

Computer simulations and modelling show that the integration of wind power into an electricity grid changes the optimal mix of conventional base-load and peak-load power stations. Wind power replaces base-load power stations with the same annual average power output. However, to maintain the reliability of the generating system at the same level as before the substitution, some additional peak-load plant may be needed. This back-up does not have to have the same capacity as the group of wind farms. For widely dispersed wind farms, the back-up capacity only has to be a small fraction of the wind capacity. In the special case when all the wind power is concentrated at a single site, the required peak-load back-up is about half the wind capacity. A penetration by wind energy into the grid of at least 20% of annual electricity generation is feasible. (Martin & Diesendorf 1982; Grubb 1988a & b; ILEX 2002; Carbon Trust & DTI 2004; Dale et al. 2004; UKERC 2006; EERE 2008).

Because the back-up is peak-load plant, it does not have to be run continuously while the wind is blowing. Instead the gas turbines can be switched on and off quickly when necessary. Since the gas turbine has low capital cost and low fuel use (for 20% wind energy penetration), it may be considered to be reliability insurance with a small premium. Excess wind power can be stored by using it to produce fuels such as hydrogen, methanol or ammonia.

Of course, if a national electricity grid is connected by transmission line to another country (for example, as Denmark is connected to Norway, Sweden and Germany), it does not need to install any back-up generators for wind, because it purchases supplementary power from its neighbours when required and sells excess electricity to its neighbours.

Solar electricity

Because it is still very expensive to store electricity on a large scale, grid-connected solar electricity from photovoltaic (PV) modules is not usually stored. If and when advanced batteries become less expensive, PV electricity could become base-load. However, it may be more economically advantageous to keep it as intermediate- and peak-load. Even without storage, a large amount of solar PV can substitute for fossil fuels combusted in intermediate-load and peak-load power stations. Furthermore, by orienting the solar collectors to the north-west instead of to the usual north (in the southern hemisphere), the peak in solar generation overlaps to a large degree with the broad daily peak in Summer demand (Figure 1b). Thus, statistically speaking, even solar electricity without storage has a significant degree of reliability during the daytime.

This reliability will be boosted in the medium term when a large fraction of motor vehicles has been replaced with electric vehicles that can be charged from the grid and can also feed power back into the grid when required. The batteries in the electric vehicles will be able to act as a substantial energy store for solar PV.

Solar heat can be stored at low cost as heat in molten salt, water, graphite or thermochemical systems (eg, ammonia). Therefore, concentrated solar thermal power with thermal storage can supply base-load with the same reliability as coal. However, it is a much more flexible generating system, because it can also be operated as peak-load. Since the early 2000s, solar thermal power has been growing rapidly in Spain and the USA and several systems have thermal energy stores equivalent to 7.5 hours of full capacity. A solar thermal power station with 16 hours of storage is currently under construction in Spain.

New technological developments, coupled with expanding markets, are bringing down prices of both solar thermal and PV.

How much base-load do we really need?

Much base-load power is unnecessary. For example, between midnight and dawn, 4600 megawatts of Australia's base-load coal-fired power stations are used to heat water, which is supplied to customers at cheap off-peak rates. This is the result of the operational inflexibility of base-load power stations, which cannot be switched off overnight.

If cheap off-peak electric hot water prices and hot water systems based on electric resistance heating were both phased out, these unnecessary coal-fired power stations could be retired or an equivalent capacity of new coal-fired power stations could be deferred or cancelled. (The phase-out has already been foreshadowed officially in Australia.) Water would be heated efficiently by solar, gas and electric heat pump. The intermediate-load power that is today supplied by the unnecessary coal-fired power stations between dawn and midnight would be replaced by a combination of combined-cycle gas-fired power stations and solar power. The net reduction in greenhouse gas emissions would be significant.

Increasing the efficiency of electricity use (eg, through more efficient buildings, appliances, and equipment) and reducing unnecessary demands through energy conservation behaviour (eg, switching off lights and equipment with standing losses) can also reduce the demand for base-load electricity.

Conclusion

Combinations of efficient energy use and renewable sources of electricity can replace electricity generation systems based on fossil fuels and nuclear power, provided our governments implement effective policies (Diesendorf 2007a, b and 2010). With renewable sources, base-load electricity can be provided to the grid by bioenergy; solar thermal electricity with thermal storage in water, molten salt, graphite, and thermochemical systems; hot rock geothermal; and wind power with a little back-up from gas turbines. Natural gas and coal seam methane can also substitute for some base-load coal-fired power stations, although supplies of these gases for domestic use are limited in eastern Australia. The demand for base-load power can be reduced by efficient energy use, energy conservation and solar hot water. Intermediate-load power can be supplied increasingly by solar PV electricity without storage, as it becomes less expensive. When natural gas supplies become scarce, gas turbines used for peak-load supply can be fuelled by liquid or gaseous biofuels produced sustainably.

A study published in 2004 showed that renewable energy could supply over half of Australia's electricity by 2040, reducing CO_2 emissions from electricity generation by nearly 80 per cent (Saddler, Diesendorf & Denniss 2004; Diesendorf 2007a & b). This 2004 study only considered renewable electricity technologies that were commercially available at that time. However, with the rapid growth since 2004 in Spain and the USA of solar thermal power with thermal storage, there is no technical reason impeding renewable energy from supplying 100 per cent of grid electricity in Australia by 2040 or possibly even 2030. Recent global scenarios for 100% renewable energy include Sørensen & Meibom (2000) and Jacobson & Delucchi (2009).

The renewable electricity system could be just as reliable as the dirty, fossil-fuelled system that it replaces. Taking account of the high costs of greenhouse impacts (Stern 2006), the principal barriers to a sustainable energy future are neither technological nor economic, but rather are the immense political power of the big greenhouse gas polluting industries, especially coal, oil, electricity generation, aluminium, iron and steel, cement, motor vehicles, forestry and agriculture.

Actually, there is one possible constraint on a renewable electricity future. Growth in demand has to be levelled off, or eventually there will not be enough land for wind and bioenergy. In the long run, stabilisation of demand will entail a change in the national economic structure and the stabilisation of Australia's population.

Appendix: Refuting other fallacies spread by renewable energy deniers

While climate change deniers and their arguments and tactics have come under public scrutiny, renewable energy deniers have so far escaped. Yet the latter and their fallacious arguments are delaying effective climate action. They come mainly from the coal, oil and nuclear industries, electricity generators, other big greenhouse polluters such as the aluminium and cement industries, and the supporters of these industries. With the exception of nuclear power proponents, renewable energy deniers are generally also climate change deniers.

The tactics of renewable energy deniers are almost identical to those of climate change deniers. Unlike genuine sceptics, deniers are not open to rational argument. They repeat claims that have previously been refuted, time and time again, by renewable energy scientists and engineers, as if repetition of a false statement somehow makes it true. They look for molehills in renewable energy systems and blow them up to mountains. If they cannot refute a particular observation by rational argument, they try to cast doubt on the result by introducing irrelevant material that obfuscates the issue. They insinuate arguments rather than state them clearly and unambiguously. Then, when questioned incisively about their insinuations, they back off and shift ground. They are masters of the 10% truths: taking a few facts and then spinning them into stories that convey the opposite impression from the logical implications of those facts. Examples are given below.

Fallacy 1: Wind power has negligible reliability

Miskelly and Quirk (2010) have attempted to refute the statement in the present article that wind power is partially reliable. Their method is to select 11 wind farms in south-east Australia and only one month of their power output. Their result is that the outputs of 10 of the 11 wind farms are highly correlated. Hence their conclusion is that 'wind farms in South East Australia are not likely to supply any significant base load power that can be relied upon, and hence system operators will have to schedule generators as if there were no wind power at all.'

This conclusion follows directly from their two initial selection processes. Although the chosen wind farms span a long distance, 10 of the 11 sites lie along the southern coasts of South Australia and Victoria, or are close to the coast. They are spread out approximately perpendicular to the prevailing wind in this coastal region, which comes from the south to south-west. The particular month chosen for the study, June 2009, was characterised by the prevailing wind direction. The 11^{th} site, which is not highly correlated with the other 10, is at Cullerin in southern NSW. It is the only site chosen from NSW. The study ignores the more distant wind farms at Blayney and Hampden NSW, and fails to take into account that major wind farms are also planned for Silverton NSW and the northern tablelands of NSW. All these neglected NSW sites are likely to have very different wind regimes from the South Australian and Victorian coasts and hence low correlations with wind at these sites. In short, Miskelly and Quirk have cherry-picked their data.

Although they published their paper in an international journal (one favoured by climate change deniers), they ignored the international literature on the spatial correlations of wind speed, most notably the paper by Sinden (2007), which analysed wind data spanning 30 years from 66 sites in the UK, finding that wind power from multiple sites has a high degree of reliability in the UK. They also ignored all the international literature on the capacity credit of wind power, including mathematical and numerical studies for wind power at a single site by Martin and Diesendorf (1980) and Haslett and Diesendorf (1981), and the studies at multiple sites such as Martin and Carlin (1983) and van Wijk et al. (1992).

Thus the paper by Miskelly and Quirk (2009) has very low academic credibility, but that is of little importance to the renewable energy deniers who use it.

Fallacy 2: Renewable energy cannot provide sufficient power to run an industrial society.

This is the second most popular fallacy in the armoury of renewable energy deniers. It is easily refuted. In Australia, a square 30 km by 30 km, filled with solar collectors and installed on marginal land, could provide all of current electricity. Of course, in practice there would be a mix of different renewable electricity sources – wind, sun, biomass, etc – and part of the solar contribution would be installed on existing roofs rather than in the Outback. In the long term, Australia could export vast quantities of solar energy generated on marginal land and stored as hydrogen, methanol or ammonia.

Similarly, a tiny percentage of US land area could generated all its electricity. Although Europe doesn't have sufficient land to provide all its projected energy demand from local renewable energy (MacKay 2009), there is now a proposal, backed by major corporations, to feed solar thermal and wind power from North Africa to Europe by underwater cables (Desertec website).

Globally, there is ample renewable energy available for demands projected to 2050 (Sorensen & Meibom 2000; Jacobson & Delucchi 2009). However, like fossil fuels and uranium, renewable energy resources are not distributed equitably across the earth, and so trade will be necessary, by transmission line, pipeline and ship.

Fallacy 3: Wind power in Denmark is not the great success story it is portrayed to be, because (the renewable energy deniers claim) most Danish wind power is exported and because Danish wind power is very costly to Danish taxpayers and electricity consumers.

These and other fallacies have been published in a study published by a Danish 'think tank' called CEPOS (Center for Politiske Studier), funded by fossil fuel interests. The fallacies have been disseminated by many renewable energy deniers, including advocates of the non-existent Integral Fast Reactor.

A detailed refutation has been published by group of 14 Danish energy experts (Lund et al. 2010). These authors show that:

- Only about 1% of Danish wind power is exported and wind power meets about 20% of Danish electricity consumption. From a market perspective, it is generally electricity from power stations with the highest operating cost that is exported, rather than wind, which has the lowest operating cost.
- No taxes are recycled to support established wind turbines; however, R&D funding comes from taxes.
- The price of Danish residential electricity, excluding taxes and VAT, is actually only the 10th highest of the 27 EU countries. The high price of Danish residential electricity is actually the result of high taxes and VAT which are not used to support existing wind power.
- The price of Danish industrial electricity, excluding taxes and VAT, is actually the 7th lowest of the 27 EU countries.
- On average Danish electricity consumers pay on average an additional 0.54 €c/kWh for feed-in tariffs for CO_2-free electricity. On the other hand, with its very low operating costs, wind power reduces electricity prices in the Nord Pool market by 0.27 €c/kWh on average. Therefore, the net average price impact of wind power is the (0.54 - 0.27) €c/kWh = 0.27 €c/kWh, which is negligible, considering that wind supplies 20% of Danish electricity.

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About our organisation:

The EnergyScience Coalition <energyscience.org.au> is a co-operative production by a group of concerned scientists, engineers and policy experts that seek to promote a balanced and informed discussion on the future energy options for Australia.

With increasing concern over the looming impact of global climate change the community needs to be aware of the issues involved. EnergyScience aims to provide reliable and evidence based information to our whole community

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