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Why Australia needs wind power

Mark Diesendorf responds to Andrea Sharam's critique of wind power in *Dissent* No. 12, Spring 2003.

Andrea Sharam's article, "What's wrong with the dash for wind?", was apparently written on behalf of the Energy Action Group (EAG), a body which addresses social equity in the context of energy. Unfortunately, in its eagerness to dismiss wind power, the article exaggerates technical and economic problems and takes up a questionable ethical position with regard to social equity. The present response to the article grapples with these issues and concludes that wind power must be an important component of a future sustainable energy system for Australia. But first, this response sets out some background information about wind power and electricity grids in general.

Wind power and electricity grids

A wind farm, when installed on agricultural land, has one of the lowest environmental impacts of all energy sources:

- It occupies less land area per kilowatt-hour (kWh) of electricity generated than any other energy conversion system, apart from rooftop solar energy, and is compatible with grazing and crops.
- It generates the energy used in its construction in just 3 months of operation, yet its operational lifetime is 20-25 years.
- Greenhouse gas emissions and air pollution produced by its construction are very tiny and declining. There are no emissions or pollution produced by its operation.
- In substituting for base-load (mostly coal power) in mainland Australia (see below), wind power produces a net decrease in greenhouse gas emissions and air pollution, and a net increase in biodiversity.
- Modern wind turbines are almost silent and rotate so slowly (in terms of revolutions per minute) that they are rarely a hazard to birds.

For the past decade wind power has been the fastest growing energy technology in the world, having an average growth rate of about 30% p.a. At the end of 2002 world installed wind power capacity reached about 32,000 megawatts (MW), of which Australia's share was a modest 104 MW. However, Australia may have the potential to install 10,000 to 20,000 MW of wind power capacity in the long term. For comparison, current total Australian electricity generating capacity is about 45,000 MW of which about 28,000 MW is coal-fired.

Electricity grids in each mainland Australian State have several large coal-fired power stations in a few central locations and long transmission lines. The coal stations have high capital cost and low fuel cost, are generally operated 24 hours a day and so are called 'base-load' power stations. Electricity grids also have 'peak-load' stations whose outputs can be varied rapidly to meet the diurnal peaks in demand. These peak-load plants are either gas turbines (like jumbo jet engines), which have low capital cost but high fuel cost, or hydro-electric plants, which have high capital cost and zero fuel cost. However, the amount of hydro-fuel (i.e. water) available each year is limited by the capacity of dams and by rainfall, so these hydro plants have to be operated mainly at peak times when their output has the highest commercial value. There are also coal-fired 'intermediate load' power stations that can vary their output substantially, but less rapidly than peak-load plants, as the demand for electricity varies through the day.

After allowing for hydro, there is an optimal mix of base-load, intermediate load and peak-load thermal power plant that gives the minimum annual cost of the system. Too much base-load increases the capital cost excessively, while too much peak-load increases the operating costs excessively. The optimal mix is changed by the presence of wind power in the grid, as discussed below and in more detail in Martin & Diesendorf (1982).

Now we can examine wind power's alleged limitations.

Claim 1. Wind power is an intermittent source and therefore cannot replace coal-fired power.

This is a hoary old chestnut that was refuted 20 years ago in a series of scientific papers by Brian Martin (then at the Australian National University) and by John Haslett, John Carlin, David Gates and me (then at CSIRO Division of Mathematics & Statistics). We did this by performing analysis of wind data and by developing computer simulations and mathematical models of electricity grids containing various amounts of wind power capacity. The computer models used hourly-averaged real data to generate probability distributions for available thermal power station capacity, electricity demand and wind speeds. In this way we addressed intermittency quantitatively.

By data analysis we confirmed that wind is partially predictable: for instance, the average wind speed in the previous hour is quite a good predictor for the average wind speed in the next hour. Nowadays, there are much more sophisticated methods of forecasting wind speeds. By modelling we showed that wind power, like coal power, is a partially reliable source of power. In technical jargon, wind power has 'capacity credit' (Martin and Diesendorf, 1980; Haslett and Diesendorf, 1981). This early work has been confirmed and extended overseas by several different authors (e.g. Michael Grubb from UK and Alkemade and Turkenburg from the Netherlands) using a number of different probabilistic methods.

For relatively small penetrations of wind power into an electricity grid, wind farms displace the amount of base-load power plant that has approximately the same annual average power output as the wind power plant. For example, in an electricity grid with total generating capacity of 10,000 MW, 2,000 MW of wind power would have an annual average power output of about 660 MW, so this amount of base-load capacity (mostly coal) could be retired or deferred. At the same time, to maintain the reliability of the grid at the pre-wind level, up to about 300 MW of peak-load gas turbines may have to be installed in grids without sufficient hydro plant. Because these gas turbines have low capital cost and rarely have to be operated, they are like reliability insurance with a low premium.

As more and more wind power is connected into the grid system, it needs more and more peak-load back-up and so costs increase. For instance, although it may be possible to operate an electricity grid with 40% of its energy generated from the wind, without highly expensive long-term storage, the average cost of such a large amount of wind power plus back-up may be about 25% higher than if only 8% of grid energy came from the wind. However, in the real world, this cost increase would be offset to some extent by the reduced cost of wind turbines in large-scale mass production.

Furthermore, in most of the Australian States (not Victoria), it is possible to vary the output of coal-fired power stations substantially over a period of an hour or so to help follow variations in demand and in wind power. In this case, these coal power stations are said to be operating as intermediate load. Since the main changes in weather patterns and associated wind conditions tend to occur every 5-8 days or so, intermediate load stations can help handle the slower variations in the output of a large amount of wind power plant.

Thus, contrary to EAG's claim, large blocks of wind power, with rapid-response back-up either from hydro or gas turbines and slow-response from intermediate load stations, can provide reliable base-load power and substitute for some coal power. This is not just theory, but is actually happening in countries that have made a major commitment to wind generation. Last year Denmark generated 18% of its electricity from wind power and still plans to increase this substantially. There are problems and costs with handling such large wind inputs, but they appear to be manageable. As wind capacity and generation have increased in Denmark, coal capacity and generation have decreased.

To be fair, before charging the additional costs of peak-load back-up and intermediate load power variations against wind power, we should also take into account the cost of backing up coal-fired stations. Although the latter break down less frequently than the wind farms suffer calms, the duration of breakdowns of coal stations is generally longer than that of wind calms. Backing up an electricity grid's coal-fired power stations requires additional base-load. In the interconnected eastern Australian grid, the National Electricity Market Management Company (NEMMCO) currently requires a total of 750 MW back-up for existing base-load plants. Whether this back-up is provided by the other coal-fired stations (the usual case) or by gas-fired stations that have to be run for quite long periods, this is expensive. An isolated electricity grid, such as Western Australia's, has to provide a much larger proportion of back-up for its fossil-fuelled base-load stations, possibly 20% or more of total grid capacity.

Claim 2. The Mandatory Renewable Energy Target (MRET) does not reduce coal-fired generation.

In making this inadvertently misleading claim, the EAG article fails to distinguish between absolute and relative reductions in coal-fired generation and omits to consider the replacement of coal-fired generating units by wind farms as discussed in my response to Claim 1.

MRET entails that electricity retailers must purchase a total of 9500 GWh of energy from renewable energy sources by 2010. Of this about three quarters is expected to come from new sources. This 9500 GWh corresponds to the electricity generation from about two of NSW's 660 MW coal-fired generating units. For the sake of argument let's assume that half of MRET is achieved by wind power in the eastern Australian interconnected transmission system. Then wind power would be responsible for a 660 MW coal-fired unit being retired without replacement at the end of its operating life along with its energy generation and greenhouse gas emissions, or the installation of a new coal unit being deferred. To compensate for the fluctuations in wind power there would be a slightly greater use of Snowy hydro (or gas turbines) and possibly a slight increase in variability of the output of intermediate-load coal power stations. The current high rate of growth of electricity demand would still entail that new coal-fired power stations would be built, but there would be one less generating unit than if wind power had not been installed. Thus the existing MRET can currently reduce coal-fired generation in relative terms.

MRET would also reduce coal-fired generation in absolute terms, if the rate of demand growth were lower and the target were larger, say 21,600 GWh in 2010 and 33,800 GWh in 2020, as recommended by the Business Council for Sustainable Energy (2003). In Denmark, where growth in demand is very low, a mix of natural gas, wind power and biomass power has already reduced the number of coal-fired power stations and coal-fired generation.

It should be added that there are some serious deficiencies in the Federal Government's present version of MRET (BCSE, 2003), for instance the rule that permits some old hydro to be counted as part of the target. However, these deficiencies could be readily removed, given the political will, and cannot be used as an argument against having a MRET.

Claim 3. To maintain a steady state of voltage and frequency requires additional expense.

In Australia, with its centralised generation and long-distance transmission lines, maintaining voltage and frequency is already an expense, even where there is no wind power plant installed. Until recently, installing a large wind farm increased voltage and frequency fluctuations and required additional equipment at additional cost. However, new types of large wind generators that are already coming on line, with variable speed drives and power electronics, can control voltage and frequency locally at no extra cost.

Claim 4. There are large energy losses in transmitting wind power to end users.

Currently about 10% of electricity sent out from centralised power stations is lost in long-distance transmission and local distribution. The transmission component of this loss is about 3% in NSW and Victoria, and is somewhat higher in the other mainland states. Distribution loss varies with locality. Although losses can be significant where wind power feeds into weak transmission systems, for large wind power generation connected by extra high voltage (EHV) transmission lines, losses are small and it is the capital cost of transmission lines that constrains locating such wind farms a long distance from the grid. In practice the capital cost means that decisions on the locations of wind farms involve some degree of trade-off between high wind speed and distance from the grid. If State governments are serious about renewable energy and decentralised development, they will fund grid extensions to tap our best wind resources.

There is precedent for this. In the 1940s and 1950s small battery-charging wind generators were widely used on farms. This domestic wind power industry was wiped out by the spread of the (then) heavily subsidised transmission and distribution lines into rural areas, carrying electricity from centralised coal-fired power stations. More recently the Victorian government funded an expensive transmission line from the power stations of the Latrobe Valley right across the state to the aluminium smelter at Portland. Perhaps State Governments could levy coal power to repay coal's debt to wind power, allowing for inflation, by funding new transmission lines to some of the more isolated high-wind regions, such as Eyre Peninsula in S.A.

Claim 5: MRET is socially regressive

The EAG article is concerned that MRET increases the price of electricity and that this falls more heavily on low-income groups. MRET currently costs residential electricity consumers only about 0.12 c/kWh or about 1% of current retail electricity prices, according to calculations by the Business Council for Sustainable Energy (2002). BCSE's recommended increase in the target to 21,600 GWh in 2010 would increase residential electricity prices by about 0.27 c/kWh or about 2.5%. These are small cost increases, which could be offset by government programs to reduce the number of kWh of electricity consumed, through increased efficiency of energy use. After all, it is the size of the energy bill that is of concern rather than the cost of a unit of electricity.

Claim 6: We need efficient use of energy instead of wind power.

Both EAG's article and my response take the view that efficient use of energy is an essential component of a sustainable energy future. Indeed, without it, demand for energy will continue to grow exponentially and will eventually become so large that it will be impossible for renewable sources of energy, such as wind and biomass, to ever become more than niche sources. There simply will not be enough wind farm sites or land for bioenergy crops.

However, the EAG article creates the incorrect impression that energy efficiency alone will be sufficient. With enough energy efficiency, the article seems to imply, the serious environmental and health problems arising from coal-fired generation (summarised below) can be ignored and so there will be no need for renewable sources of energy.

Nothing could be further from reality. Under various immigration policies, Australia's population could grow to anywhere between 21 and 30 million (5-50% growth) by 2050. If growth is near the high end of the suggested range, some energy experts would see a stabilisation of Australia's total energy use at the year 2000 level in 2050 as miraculous. Personally, I think that, even with a 40% growth in population, it might be possible to reduce cost-effectively Australia's total energy use to below the 2000 level by 2050. But, taking into account the social equity requirement that less developed countries will have to increase their energy consumption, Australia and other rich countries should plan to reduce their greenhouse gas emissions by 70-80%. This cannot be done by energy efficiency alone. By putting aside one of the least expensive and most environmentally benign renewable energy sources, wind power, it would be impossible to meet such a target.

We are not faced with a choice between efficient energy use and wind power. The real choice is between sustainable energy and coal power, where sustainable energy means renewable energy, backed up with natural gas (the least polluting of the fossil fuels), plus the efficient use of energy. The principal low-cost renewable energy sources that are presently available are wind power, energy from biomass (crops, crop residues and landfill gas) and solar hot water. All of these will have to be used much more substantially if our society is to achieve a sustainable energy future.

Before discussing Claim 7, it is necessary to consider the hazards of coal.

Environmental and health hazards of coal power

Business-as-usual in electricity generation means coal, which currently provides 84% of Australia's electricity while pumping out 170 million tonnes of carbon dioxide, the principal greenhouse gas, per year (Diesendorf, 2003). Australia is one of the largest per capita greenhouse gas emitters in the world. As such it contributes disproportionately to global climate change, which will cause hundreds of millions of additional premature deaths over the 21st century alone, especially in poor countries, from heat-waves, malaria, dengue, schistosomiasis, onchocerciasis, floods, droughts, other damage to food production and forced migration (Sørensen, 2000). Under business-as-usual energy generation, Australia would be responsible for millions of these deaths.

Surely these deaths have to be weighed against the inconveniences of small increases in the price of a kilowatt-hour of electricity in Australia, taking into account that these may not necessarily lead to increases in electricity bills? Without doing this, EAG lays itself wide open to the charge of being selective in its approach to social equity.

Not only is coal-burning Australia's biggest greenhouse gas emitter by far, but it is also the largest emitter into the atmosphere of sulfur dioxide, nitrogen oxides, fluoride, hydrochloric acid and boron. It is also a high emitter of particulate matter, sulfuric acid and mercury. It is a large user and polluter of fresh water. It is responsible for huge areas of land degradation and loss of biodiversity. Mining is the third most dangerous occupation in Australia. The debate about wind versus coal must consider the additional respiratory and other diseases suffered by Australians who live in or near coal-burning regions, and the extensive environmental damage within and beyond these regions.

Claim 7: EAG supports Least-Cost Planning

The EAG article pays lip service to Least-Cost Planning, but the author seems to be unaware of what this really means. It does ***not*** mean picking the cheapest source of electricity, but rather providing a technology mix that delivers an energy service, such as a warm home in winter, at the minimum ***total*** cost. This is generally achieved through a combination of energy demand reduction (e.g. by means of insulation and draught exclusion) and energy supply. In this context, 'total cost' comprises the economic, environmental and health costs of each technology contributing to the energy service. Recent calculations of the environmental and health costs of energy supply highlight the big difference between Least-Cost Planning and picking cheap and nasty technologies:

- Bent Sørensen's (2000) calculation of the partial greenhouse costs of coal burning takes the standard value of human life as US$ 3.3 million, assumes that it is not depreciated and then adds up expected deaths from global climate change over the 21st century. Then he finds that the cost of generating coal-fired electricity becomes about US 40 cents/kWh (A 63 c/kWh).

- A more conservative calculation from the European ExternE study (Rabl and Spadaro, 2000) values in monetary terms the years of life lost, instead of the value of a whole life. It considers a more limited set of greenhouse gas health hazards than Sørensen, but it does include impacts of a few air pollutants. Then it finds that the cost of generating coal-fired electricity becomes about A 16 c/kWh.

- An even more conservative calculation might adapt the ExternE results, by assuming arbitrarily that the cost of local air pollution in Australia is (say) one-quarter that in Europe, because of our lower population density. Then the cost of generating coal-fired electricity becomes about A 11 c/kWh.

These results may be compared with the current cost of generating electricity from coal-fired power stations in eastern Australia of about A 4 c/kWh; from Australian wind farms in 2003 of A 8-10 c/kWh; and from Australian wind farms in 2010 of A 6-8 c/kWh projected. ExternE finds that the environmental and health costs of wind power are negligible. So, on the basis of Least Cost Planning, it seems that coal could not compete with wind power even in 2003.

Employment

EAG's anti-wind article does not mention employment, a very important social equity issue. Yet wind power and other sustainable energy sources can provide more local employment than coal. Employment in coal mining peaked in the mid-1980s, has since dropped 45% and continues to drop. Employment in the existing electricity industry, which is dominated by coal, has dropped 50% since 1991.

Currently wind farms in Australia have about 40% Australian content and create 2-3 times as many local jobs per kWh generated as coal power (McGill, Watt & Passey, 2003). However, as wind power expands, Australian content is expected to rise to 80% and so the number of local jobs per kWh will rise to 4-6 times those of coal. Already job creation is under way: the world's largest wind turbine manufacturer, Vestas, is building a component manufacturing plant in Tasmania.

Conclusion

Coal burning is by far the most polluting way to produce electricity, both globally and locally. To achieve a sustainable energy future, Australia must dramatically reduce coal burning. To do this, improved efficiency of energy use is necessary but far from sufficient. In addition, large amounts of renewable energy and, for an extended transitional period, natural gas will be required.

Of all the low-cost renewable energy sources, wind power is the cleanest and currently the most readily available. Energy Action Group's technical and economic objections to wind power are exaggerated. EAG's social equity concerns about wind power and the Mandatory Renewable Energy Target are narrow and provincial, putting more weight on possible small increases in electricity prices in Australia than on millions of deaths caused in poor countries overseas by Australia's contribution to global climate change.

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