# Submission to Senate Public Inquiry on the Social and economic Impact of Rural Wind Farms

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# 1. Introduction

The author of this submission was in the early 1980s a Principal Research Scientist in CSIRO Division of Mathematics and Statistics, where he led a multidisciplinary research group on the integration of wind power into electricity grids. From 1996 to 2001 he was Professor of Environmental Science and Founding Director of the Institute for Sustainable Futures at University of Technology Sydney. He is currently Associate Professor and Deputy Director of the Institute of Environmental Studies at the University of New South Wales. He has published many scholarly papers on wind power in scientific and engineering journals. His most recent books are *Greenhouse Solutions with Sustainable Energy* (2007) and *Climate Action: A campaign manual for greenhouse solutions* (2009).

This submission draws partly upon chapter 6 of the former book and other sources to refute a number of fallacies and misleading claims about wind power that are being disseminated by the coal and nuclear power industries, their supporters and NIMBY (Not-In-My-Backyard) groups. Much of the misinformation by these groups is obtained from a British anti-wind power group called Country Guardian, which has close links to the nuclear power interests. Until recently, the vice-president of Country Guardian was Sir Bernard Ingham who was (and possibly still is) either president or secretary of Supporters of Nuclear Energy (SONE), one of the principal lobby groups for nuclear power in the UK. Nuclear power and wind power and the principal competing technologies for meeting the UK's greenhouse target for the electricity generation sector.

In section 2 I address the general fallacy that wind power is environmentally damaging and then in section 3 refute 14 specific fallacies in detail. Section 4 addresses one particular fallacy, the myth of intermittency, in detail.

# 2. General fallacy on environmental impact

*Fallacy: Wind power is one of the most environmentally damaging sources of electricity.*

To the contrary, wind power has one of the lowest environmental impacts of all energy sources. Only solar photovoltaics, based on either thin films or Sliver cells could possibly compete in this regard. By almost any criterion, coal is by far the worst. The reasons why wind power has very low environmental impacts are:

- It is usually installed on agricultural land that was cleared prior to any wind farm proposal.

- It occupies less land area per kilowatt-hour (kWh) of electricity generated than any other energy conversion system (see section 3.3 below), apart from rooftop or building-integrated solar photovoltaic energy, and is compatible with grazing and almost all crops.
- It generates the energy used in its construction in three to seven months of operation, yet its operational lifetime is at least 20 years[1,2].
- Therefore greenhouse gas emissions and air pollution produced by its construction are tiny[3] and are declining with increasing size and efficiency of its wind turbines. There are no emissions or pollution produced by its operation, apart from noise over a limited range.
- In substituting for coal power in mainland Australia, wind power produces a net decrease in greenhouse gas emissions and air pollution, and therefore a net increase in biodiversity.

To assess the biodiversity impacts of coal versus wind power properly, both global and local impacts must be taken into account. Global climate change resulting from the enhanced greenhouse effect is predicted to wipe out many species of animals and plants. Indeed, there is ample scientific evidence that this is already happening. Australian ecosystems are some of the most vulnerable to climate change. In Australia the biggest single source of greenhouse gas emissions is coal-fired power stations. By substituting for coal and other fossil-fuel power stations, wind power reduces carbon dioxide emissions and therefore saves global biodiversity.

To reduce *local* biodiversity impacts of wind farms, planning guidelines for the siting of wind developments have been put into place by the Federal, State and Local Governments. Proposed wind developments must receive federal planning approval under the Environment Protection and Biodiversity Conservation Act and also under any local regulator. These measures address the avoidance of principal bird migration routes and protection of wetlands and other specific areas of environmental importance and sensitivity.

## 3. Specific fallacies

### *3.1 Fallacy: Bird kills are generally a serious problem.*

The main human-induced threats to birds are habitat destruction, pet cats, buildings, motor vehicles and powerlines. Only two wind farms out of thousands around the world have been a serious problem for birds: Altamont Pass in California and La Tarifa[4] on the southern tip of Spain. In the USA typical bird death rates are two per turbine per year, and some European studies find about one-tenth of this[5].

Australia has only limited experience with wind farms. So far studies reveal an impact level even lower than predicted on the basis of Northern Hemisphere experience and lower too than levels approved by planning authorities prior to wind farm construction. This may be because Australia's geography and bird ecology differs from that of the Northern Hemisphere: we do not experience the same concentrations of migrating birds – in particular, we lack the large numbers of night-migrating songbirds[6].

With modern wind turbines and careful siting, both bird and bat kills are rare. In comparison, on a single foggy night, about 3000 birds were killed when they collided with the chimneys of a thermal power station in Florida, USA[7].

### *3.2 Fallacy: Noise is a common problem.*

Modern wind turbines are much quieter than people have been led to believe. A normal conversation can be held at the foot of a wind turbine going at maximum speed, without raising one's voice. The main sound is a 'swoosh' as each blade passes in front of the tower. A listener's perception of the sound depends on the level of background noise and declines with the inverse square distance from the source. In other words, double the distance means one-quarter of the noise level. As wind speed increases, both the wind turbine noise and background noise (from wind passing through vegetation) increase as well, and the background tends to mask the wind turbine noise.

Noise is rarely a problem beyond a distance of 500 m and very few dwellings in Australia are within 400 m of a large wind turbine. Licence conditions for wind farms should, and mostly do, set objective, measurable noise limits. On the rare occasions where these limits are surpassed, for example, resulting from a faulty turbine or sound propagation resulting from peculiar topography, affected residents can have the problem fixed or the offending turbine shut down.

Infra-sound used to be a problem with some of the early wind turbines in Europe. However, according to recent European studies, modern wind turbines emit generally very low levels of infra-sound, virtually undetectable at a range of 500 m and much less than comes from motor vehicles on nearby roads. Although there have been several studies, there is no *scientific* evidence that infra-sound from wind turbines located at a distance greater than 500 m is a health hazard.

### *3.3 Fallacy: To substitute for one 1000 MW coal-fired power station, wind power would need vast areas of land.*

Wind farms are highly compatible with agricultural and pastoral land use. While they span approximately 25 ha per megawatt (MW) of installed capacity, only about 1–3% of that land

(0.25–0.75 ha/MW) is actually taken up by their towers, access roads and other equipment, while 97–99% of the land can continue to be used for crops or grazing. For comparison, a fossil-fuelled 1000 MW power station has an average power output of about 850 MW. To substitute for this, about 2600 MW of wind power capacity would have to be installed, spanning 65 000 ha (650 square km), but only occupying physically 650–1950 ha (6.5–19.5 square km). This is less than the area of a typical open cut coal mine required to serve the coal-fired power station (50 –100 $km^2$).

### *3.4 Fallacy: Wind farms don't work.*

If this myth were true, wind farm developers would go bankrupt, because they are paid for generating electricity, not just for erecting wind turbines.

### *3.5 Fallacy: Wind turbines are inefficient.*

Large wind turbines convert into electricity about 45% of the wind passing through the area swept out by the blades[8]. For comparison modern black coal-fired power stations convert into electricity only 35% of the energy stored in the coal. Taking into account the electricity used in operating the coal station reduces this to about 32%. Some brown coal stations are only 20-25% efficient. So wind turbines are more efficient at converting their primary energy source into electricity than coal power stations.

The disseminators of the fallacy appear to believe that wind turbines are 'inefficient' because they have lower *capacity factors* than conventional base-load power stations.

> (Capacity factor is average power output divided by rated power, often expressed as a percentage. A power station with a capacity factor of 100% would have to operate continuously at its rated power, without stopping for breakdowns or maintenance. Of course, such a power station does not exist in the real world.)

Capacity factor is not a good measure of efficiency of performance, because capacity factor depends on the operational strategy of the whole electricity generating system. For instance, conventional peak-load plants such as gas turbines have much lower capacity factors (2–10%) than wind farms (20–40%), but they are not labelled as 'inefficient'. Capacity factors are taken into account as a matter of course in evaluating the economics of wind farms. An electricity generating plant needs a mix of different types of power station with different capacity factors and different operational flexibilities.

### *3.6 Claim: Wind farms are subsidised.*

This claim is a partial truth, but misleading, because coal-fired electricity receives much greater *de facto* subsidies through the refusal of many governments to include the costs of coal's massive environmental and health damage in the price of coal-fired electricity. Coal also receives huge direct economic subsidies in several countries. Nuclear power in the UK and USA is generally more expensive than wind power and receives much bigger subsidies[9]. Wind power is the least-cost of the non-hydro renewable energy sources. To reshape the energy market to response to the greenhouse problem, carbon pricing must be introduced and renewable energy sources also should receive temporary direct subsidies, for example through an extended and expanded Renewable Energy Target and gross feed-in tariffs.

### *3.7 Fallacy: To maintain a steady state of voltage and frequency requires much additional expense.*

Modern large wind turbine generators, with variable speed drives and power electronics, can control voltage and frequency *locally* at no extra cost. Furthermore, sudden changes in wind speed, or a sudden shut-down or start up of large amounts of wind power capacity, can be ameliorated by installing wind farms separated by large distances in different wind regimes, and by using computer control to stagger start-ups and shut-downs of individual wind turbines in a wind farm.

### *3.8 Fallacy: Efficient energy use is sufficient to reduce greenhouse gas emissions.*

Efficient energy use is certainly necessary and plays a vital role in various energy scenario studies for Australia, including some by the present author[10]. In some of these studies it was found that cost-effective efficient energy use can just balance temporarily the growth in $CO_2$ emissions resulting from economic and population growth, but is not sufficient to achieve the large greenhouse gas reductions of 80% or more that are needed to protect the Earth's climate. Clean energy supply is also essential.

A variant of the above fallacy is the following:

### *3.9 Fallacy: Since the rate of growth of electricity demand is higher than the rate of growth of renewable energy supply in some States, they should stop building renewable energy and focus their efforts on efficient energy use and demand reduction.*

This recommendation assumes incorrectly that we have to choose between the implementation of efficient energy use and demand reduction on one hand and renewable energy on the other. In reality, the two courses of action are complementary, requiring different strategies, and both must be implemented simultaneously for effective reduction of $CO_2$ emissions.

As already foreshadowed, lower cost renewable energy technologies (wind and bioenergy) need an expanded Renewable Energy Target (RET) or feed-in tariffs and some form of carbon pricing (preferably a carbon tax in my view) in order to compete with dirty coal.[11] With these policies we can build up manufacturing and market share. High-cost renewable energy technologies (for example, direct solar) need increased funding for research, development and demonstration, and a temporary feed-in tariff for increasing market share.

Holding back renewable energy will not assist efficient energy use at all, because the latter does not need additional funding (although it will benefit slightly from carbon pricing). Efficient energy use already offers a huge range of cost-effective measures that are currently held back from widespread dissemination by market failures, not by price[12]. Therefore, efficient energy use needs regulations and standards by State and Federal Governments to increase the energy efficiency of buildings (existing as well as new), appliances, equipment and industrial processes. Demand reduction also needs policies to stop the construction of new dirty coal-fired power stations.

### *3.10 Fallacy: Solar electricity could replace wind power.*

Not for at least 20–30 years. Although solar electricity has huge potential in Australia, the generation cost of grid-connected solar power (40–50 c/kWh for photovoltaics; 20–40 c/kWh for concentrated solar thermal electricity) is currently several times that of wind power (7–10 c/kWh depending upon siting). Solar electricity will be able to play a greater role when time-of-day electricity rates and smart meters are introduced and its price is brought down by R & D and increased market share and improved technology.

### *3.11 Fallacy: Wind power makes insignificant contributions to electricity generation.*

Of course, if one averages over the whole world, in which many countries have no wind power, the total is small. But the rate of growth is high, 25-30% per year, and has been high for the past 25 years. If this growth rate continues, wind power will overtake nuclear power as a global source of electricity within a few decades.

In Denmark wind power has supplied 20% of electricity since 2003 and the Danish government plans to expand this to 50% by 2025. In each of Germany and Spain, wind power will soon be contributing 10% of electricity. In Europe in each of 2008 and 2009, the biggest increase in electricity generating capacity came from wind power. A recent report to the US Department of Energy showed that 20% of USA's electricity could be generated from wind power by 2030.[13] In my assessment, given appropriate federal and state government policies in Australia, wind power could contribute up to 20% of electricity by 2020 and substantially more by 2030.

### 3.12 *Fallacy: Wind farms should be located in valleys or industrial zones where they cannot be seen from the distance.*

Wind turbines must be located at sites that are exposed to the wind, since wind power increases with the cube of the wind speed[14]. Strong and consistent winds are very rarely found in valleys. In industrial zones, other buildings slow the wind, making these zones unsuitable for wind power. By its very nature wind power has a visual impact, which most people accept and a small minority dislikes. To resolve these differences, community consultation on individual wind farm proposals and State planning processes with clear guidelines are needed. Public opinion surveys have found that the vast majority of respondents support wind power[15]. Some surveys find that those who originally opposed a wind farm in their district find them acceptable several years after their installation. Many respondents say that the alleged environmental impacts, noise and bird kills, are not a problem, despite initial fears[16]. Some surveys find that people who live closer to wind farms are even more supportive towards wind power than people who live further away[17].

### 3.13 *Fallacy: Wind farms cause bushfires.*

It has never happened. Indeed, the opposite is true. Fossil fuels cause global warming and, in some regions, drought, and so increase the prevalence and severity of bushfires. In so far as wind power substitutes for fossil fuels, it reduces the risk and intensity of bushfires.

### 3.14 *Fallacy: Since wind power is an intermittent source, it cannot replace coal-fired power unless it has expensive, dedicated, long-term storage.*

Variants are: '*Wind power is not base-load*' and '*Wind farms don't reduce $CO_2$ emissions, because coal-fired power stations have to be kept running to back up the fluctuations in wind.*'

All these statements are wrong and are answered in more detail in the next section. The short answer is:

With or without wind power, there is no such thing as a perfectly reliable power station or electricity generating system. 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 adds a third source of variability that can be integrated without major technical difficulties into such an already variable system. For several dispersed wind farms, total wind power generally varies smoothly and therefore cannot be described accurately as 'intermittent'. As the penetration of wind power increases substantially, so do the additional costs of reserve plant and fuel used for balancing wind power variations. When wind power supplies up to 20% of electricity generation, these additional costs are still relatively small. This has been verified recently by detailed separate computer simulations of both the east coast and west coast electricity grids of the USA[18,19].

Of course, to replace completely a 1000 MW coal-fired power station, either by retiring an existing station or deferring a new one, sufficient wind power capacity has to be installed (2600 – 2700 MW). Opponents of wind power claim that there is insufficient wind power to replace a coal-fired power station, while opposing the construction of sufficient wind farms needed to do the job. I next consider the myth of intermittency in more depth.

## 4. The myth of intermittency

With the failure of the environmental arguments against wind power, a subtler piece of misinformation is being disseminated against this technology: to label renewable energy in general and wind power in particular as 'intermittent' and then claim that it can never replace existing base-load power stations, such as coal and nuclear, which are described as 'firm' or 'reliable' sources of power. For renewable energy to become a significant energy source, the assertion goes, it would need a new kind of inexpensive long-term storage.

Superficially, this argument sounds plausible. Everyone knows that a single wind turbine may start and stop abruptly many times in a day and therefore can be described accurately as 'intermittent'. On the other hand, everyone knows that conventional electricity supply systems are highly reliable, at least in most developed countries. Nevertheless, further thought exposes several false assumptions. The main steps in the refutation of this myth are:

- Conventional power stations are intermittent.
- Because electricity demand fluctuates continuously, electricity grids are already designed to balance intermittent conventional supply against variable demand.
- The variability of large-scale wind power is generally slow and manageable, in both theory and practice. It cannot be described accurately as 'intermittent'.
- Wind power can substitute directly for coal power.

### *4.1 Conventional power stations are intermittent*

There is no such thing as a totally reliable source of electricity. Every conventional power station breaks down unexpectedly from time to time, causing an immediate loss of all its power. That is true intermittency, a particular type of variability that switches between full power and no power. Once a conventional power station has broken down, it may be offline for weeks, much longer periods than calms in the wind (hours or days). Transmission lines also break down unexpectedly, either the result of overloading, or bushfires, or a tree falling, providing another source of intermittency in existing grids.

### *4.2 Electricity supply systems are designed to handle variability*

The demand for electricity varies on daily and seasonal basis, as well as having unpredictable changes, both slow and sudden, resulting from a wide range of factors such as the weather or an advertising break in a popular TV show.

Because it is very expensive to store electricity on a large scale, electricity grids are perpetually balancing intermittent supply against variable demand. They do this by providing a mix of base-load, intermediate load and peak-load power stations to meet changes in demand and by providing reserve base- and peak-load plant to cover breakdowns.

Base-load power stations have high capital cost and low running cost. Therefore, they are operated 24 hours a day every day, except when they break down or undergo planned maintenance. They are inflexible, in the sense that their power generation cannot be ramped down and up rapidly. In the absence of hydro-electricity, peak-load stations are gas turbines, which have low capital cost and high operating cost. Their fuel, usually natural gas, is much dearer than coal. Because peak-load stations can be turned on and off very quickly, they are valuable for ‘balancing’ sudden fluctuations in demand and for rapidly covering the unexpected failure of a base-load power station.

So, variability is nothing new to fossil fuelled electricity generating systems. As a result of the variability of demand and supply, the reliability of the whole generating system can never be 100%. To achieve this would require an infinite amount of back-up and hence an infinite cost. In practice, reliability can be measured in terms of indicators such as the average number of hours per year that supply fails to meet demand.

### *4.3 Large-scale wind power is not intermittent*

The integration of wind power into the grid adds a third type of variability. Large-scale wind power is not intermittent, because it does not start up or switch off instantaneously at irregular intervals. In practice the variations in thousands of wind turbines, spread out over several different sites and wind regions, are smoothed. As the distance between sites increases, the correlation between wind speeds measured at these sites decreases. This was confirmed by Graham Sinden from Oxford University, who analysed over 30 years of hourly wind speed data from 66 sites spread out over the UK. He found that the correlation coefficient of wind power fell from 0.6 at 200 km to 0.25 at 600 km separation (a perfect correlation would have coefficient equal to 1.0.) There were no hours in the data set where wind speed was below the cut-in wind speed of a modern wind turbine throughout the UK, and low wind speed events affecting more than 90% of the UK had an average recurrent rate of only one hour per year[20]. Nowadays wind power generation can be predicted with increasing accuracy from hour to hour and from day to day[21].

When wind power contributes only a few percent of total electricity generation, its variability is unnoticed among the fluctuations in demand. Under these conditions, it is easy to show that wind power can be treated statistically to a good approximation as a completely reliable source of power equivalent to its *average* power output[22-23], which is typically about 20–40% of its rated power capacity, depending on type of wind turbine and site installed.

How big a contribution to electricity generation can wind energy make without introducing long-term energy storage? It turns out that the limitation is primarily economic rather than technological. In several small, isolated electricity supply systems, wind energy is *already* contributing more than 40% of the electricity generated: examples are Denham, Hopetoun and Bremer Bay in Western Australia[24] and the Australian Antarctic base at Mawson, where the variations in wind power are balanced by varying the outputs of the low-load diesel generators[25]. Because diesel fuel is expensive in these remote locations, wind energy can economically contribute a large fraction of total generation. In effect, the diesel fuel provides the long-term storage.

In a large-scale state or national electricity grid, the balancing of wind power is done primarily by peak-load plant, with the 'fuel', gas or dammed water, providing the stored energy. Recent reports show that the additional costs of balancing and back-up for wind are small[26,27,28,29].

### *4.4 Wind power can substitute for coal power*

The economics of wind power must take into account its effect in changing the economic *optimal mix* of conventional base-load and peak-load plant. If there is too much peak-load plant in the grid, the annual costs of the generating system are higher than optimal, because of the high fuel costs of the peak-load plant. On the other hand, if there is too much base-load plant, the annual costs are higher than optimal, because of the high annual charges on the capital cost of base-load. Optimal mix of base-load and peak-load gives the minimum annual cost.

When a large amount of wind power is introduced into an electricity supply system, this optimal mix changes. Using mathematical and computer models which represent the three sources of variability in the electricity supply and demand system by means of probability distributions, it is found that wind power replaces base-load power stations with the same annual average power output[30,31,32,33]. For example, 2700 MW of wind turbines may have an average power output of about 850 megawatts, which is about the same as the average power output of a 1000 MW coal-fired power station. Therefore, such a power station could be retired at the end of its operating life (or never installed in the first place) and replaced with 2700 MW of wind power, which would generate the same annual average quantity of electricity.

As expected, the reliability of the generating system would decrease a little, but this is easily restored by installing a little additional peak-load plant, that is, gas turbines or hydro. For an electricity supply system in which geographically dispersed wind farms contribute 20% of electricity, this additional peak-load plant is typically a small fraction of the wind capacity and is only operated infrequently. Since its capital and fuel costs are both low, it plays the role of reliability insurance with a low premium.

As mentioned previously, the fact that the average power of a wind turbine is typically 20% to 40% of its peak power is not a serious problem – it is taken into account as a matter of course in the economics wind power.

### *4.5 Practice*

Since 2003, Denmark has generated 20% of its electricity from wind power, allowing some coal-fired power stations to be retired. There have been no major problems resulting from wind variability, although there is a temporary problem resulting from the connection of a large bloc of wind power from off-shore wind farms to a single point on a weak section of the transmission network. Denmark is connected by transmission lines to other European countries and therefore it does not need to install additional peak-load plant to balance its wind power. Instead, it purchases additional power from its neighbours when necessary. In practice, it makes little difference whether the back-up is purchased from other countries or from a local gas turbine or hydro-electric power station. (Incidentally, the claims by anti-wind campaigners that Denmark's wind power has greatly increased the price of electricity and that most Danish wind power is exported to the rest of Europe, are both false, and have been refuted by Danish energy experts[34].)

With some strengthening of the grid, Denmark plans to increase wind's share to 50% of electricity generation. As wind penetration increases, the costs of balancing the wind and of discarding wind energy during off-peak periods gradually increase too. The position of Eltra, the transmission operator of western Denmark, was stated when presenting its annual report:

> Seven or eight years ago, we said that the electricity system could not function if wind power increased above 500 MW. Now we are handling almost five times as much. And I would like to tell the Government and the Parliament that we are ready to handle even more, but it requires that we are allowed to use the right tools to manage the system.[35]

Clearly, without long-term storage – that is, in the form of hydrogen or advanced batteries or pumped hydro or compressed air – it is not possible to generate 100% of grid electricity from the wind. But, a mix of different kinds of renewable energy sources with different kinds of variability – such as wind, solar, wave and bioenergy – could provide a complete generating system. The national scenario study, *A Clean Energy Future for Australia*, shows that even with existing technologies with small improvements, renewable energy could contribute 60% of Australia's electricity by 2040. That was not an upper limit.[36]

## 5. Conclusion

The various criticisms of wind power discussed in this submission are either untrue or gross exaggerations. Compared with almost all other sources of large-scale electricity generation, wind power is efficient, environmentally sound and the least-cost of the non-hydro renewable energy sources. In Australia wind power is capable of substituting for several large coal-fired power stations and generating at least 20% of our electricity. To enable this growth in a job-creating technology to occur, effective policies are needed from both federal and state governments. These government should include large-scale wind power in their feed-in tariffs. They should also fund the upgrade and expansion of the transmission system for the National Electricity Market, to enable wind power generated in South Australia to be transmitted to the eastern states..

## Notes and references


1 For example, Danish Wind Industry Association (1997) *The Energy Balance of Wind Turbines*, www.windpower.org

2 Energy balances calculated by Vestas, the world's largest manufacturer of wind turbines, can be accessed at www.vestas.com/uk/environment/2005_rev/energybalance.asp

3 ISA (2006) *Life Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia*, <http:// www.isa.org.usyd.edu.au>; Lenzen, M. (2008) Life cycle energy and greenhouse gas emissions of nuclear energy: A review. *Energy Conversion and Management* 49:2178–99. These studies find that life-cycle emissions from wind power are 13–40 g/kWh, much less than from nuclear power with low-grade uranium.

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11 Initially the level of a carbon tax or the price of tradable emissions permits is likely to be too low to assist renewable energy sources to compete with dirty coal, although it would assist natural gas to compete with coal. Hence a MRET is needed as well and must be kept until the carbon price makes it redundant.

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14 For example, doubling the wind speed gives $2^3 = 8$ times the wind power.

15 www.ewea.org/fileadmin/ewea_documents/documents/publications/WD/WD22vi_public.pdf

16 www.bwea.com/ref/surveys-90-96.html

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24 www.verveenergy.com.au/mainContent/sustainableEnergy/futureProjects/projectsProgress.html

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[35] Quoted in European Wind Energy Association (2005) Large-scale integration of wind energy in the European power supply: analysis, issues and recommendations, Executive Summary, p. 10. www.ewea.org/index.php?id=178

[36] Saddler, Diesendorf & Denniss (2004 & 2007).