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Wind Farms
The facts and the fallacies

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Summary

In recent times, concerns have been raised about the growing number of wind farms and their impacts on communities and the environment. Many of these concerns have been fuelled by well-organised anti-wind groups modelled on similar establishments in the US and UK. By spreading disinformation about wind energy, these groups have successfully persuaded many people, including several prominent politicians, that wind energy does not have a legitimate role to play in addressing the challenges posed by climate change.

The purpose of this paper is to assess the merits of the main arguments used to justify opposition to wind farms, namely: the competitiveness and cost of wind energy; its efficiency and reliability; its ability to reduce greenhouse emissions; fire risk and noise pollution; impacts on biodiversity, landscape and heritage values; and effects on property prices. The evidence indicates that almost all of the claims made by anti-wind groups lack substance.

The competitiveness of wind energy

Wind energy is competitive with all other sources of renewable energy. The evidence indicates that if electricity generators were required to internalise the costs of pollution, it would also be competitive with coal- and gas-fired power stations. Economies of scale and technological improvements are likely to continue to improve the efficiency of wind energy, with projections suggesting that wind energy could be competitive with gas- and coal-fired power generation by 2020.

Does wind energy increase the cost of electricity?

The displacement of conventional fossil fuel-based generation for wind energy does increase the cost of electricity. However, at current levels of wind penetration, the additional cost to most consumers is negligible. If wind penetration increased substantially, the additional cost to consumers would be more significant, but still only small to moderate depending on the size of the increase in wind energy. The evidence suggests that increasing the proportion of electricity that is obtained from renewable sources from 11 per cent to around 15.5 per cent in 2010 is likely to result in a 1.5 – 2.5 per cent increase in the average household electricity bill, or an additional $15 – $25 a year. If this occurred, a large proportion of the increase in renewable energy is likely to be sourced from wind.

The efficiency of wind energy

Wind farms, like all other types of electricity generators, do not operate at 100 per cent capacity 100 per cent of the time. They usually generate between 20 and 40 per cent of their maximum capacity. However, the fact that wind farms operate at less than their maximum capacity is largely immaterial; the critical issue is whether they can supply electricity at a price that is competitive in the electricity market. The fact they do and that financiers continue to invest in wind energy is testament to their efficiency.

Is the variability of wind energy a problem?

There is a considerable amount of variability in the supply of, and demand for, electricity in most electricity systems. The demand for electricity is constantly fluctuating in response to the needs of consumers. Similarly, generators can fail and other unexpected events can occur that cause fluctuations in electricity supply. These fluctuations present a challenge for system operators as supply and demand must be kept in balance in order to ensure the security and reliability of the system. To address this issue, system operators use a number of different measures, including supply forecasting, demand monitoring and what are known as ancillary services.

The current level of wind penetration (around 0.5 per cent of total electricity supply) is too small to cause any significant variability-related problems in the National Electricity Market (NEM). Any variability in the output from wind farms is handled in the same way as other fluctuations in supply and demand. If wind penetration increased substantially, issues could arise. However, research has shown that the NEM could readily accept a 1,100 per cent increase in the amount of wind energy if it is not accompanied by a substantial increase in other forms of intermittent generation. Most analysts agree that up to 20 per cent wind capacity penetration is possible without posing any serious technical or practical problems.

Wind energy and greenhouse gas emissions

For every megawatt hour (MWh) of wind energy, one less MWh of output is needed from another source. As around 90 per cent of Australia’s electricity comes from fossil fuel-based generation, this means that the energy production that is displaced by wind farms is likely to be from coal- or gas-fired power stations. By displacing coal- and gas-fired generation, wind farms reduce greenhouse emissions. The evidence indicates that a modern 50 megawatt (MW) wind farm operating at 30 per cent capacity will reduce emissions by approximately 120,231 tonnes of CO_2-e each year, which is equivalent to the annual emissions from 27,767 cars.

The fire risk from wind turbines

The risk of fire from wind farms is minuscule. In almost 20 years of wind farm operation in Australia, there appear to have been only two fires, neither of which resulted in a wildfire. Provided wind farms are constructed and managed in an appropriate manner, fires caused by wind turbines are likely to be very rare and pose little risk to surrounding property.

Noise pollution from wind turbines

The noise pollution from wind turbines is negligible. In fact it is possible to stand underneath a wind turbine and have a normal conversation without raised voices. A modern 10 turbine wind farm would create a sound pressure level of 35 – 45 dBA at 350m, the equivalent of a quiet bedroom or the background noise in a rural area at night.

The impact of wind farms on biodiversity

The available evidence indicates that provided wind farms are located in appropriate areas the risks to biodiversity are likely to be small. Overseas research indicates that the mortality rate for birds and bats from wind turbine collisions is low – typically less than five birds and five bats per turbine per year. If this rate is used as a rough guide, it would suggest that less than 2,550 birds and 2,550 bats currently die each year in Australia as a result of collisions with wind turbines. By comparison, an estimated 8.5 million birds died each year in Queensland alone in the late 1990s as a result of land clearing. While care should be taken in the siting and operation of wind farms, the risks to biodiversity should not be exaggerated and must be weighed against the potential for wind farms to contribute to reducing the severity of the impacts of climate change.

The impact of wind farms on landscape and heritage values

When poorly sited, wind farms can have an adverse impact on landscape and heritage values. However, if appropriate planning procedures are followed, the risks to landscape and heritage values should be minimal. Also, any concerns about aesthetics should be considered in the context of climate change and broader community attitudes toward renewable energy.

Wind farms and property prices

The available evidence indicates that wind farms are unlikely to have a significant impact on property prices. At worst, wind farms can lead to a small short-term decline in property prices, but these impacts dissipate quickly.

1. Introduction

Since the federal Mandatory Renewable Energy Target (MRET) scheme commenced in January 2001, wind energy has been one of the fastest growing energy sectors in Australia. Installed wind capacity increased from 104 megawatts (MW) in 2002 to 708 MW at the close of 2005.[1] There are now approximately 505 wind turbines in Australia in 41 separate wind farms generating around 2,262 gigawatt hours (GWh) of electricity each year, which is enough to power around 314,000 homes (Auswind 2006b).

Despite the rapid rate of growth, wind energy currently constitutes only a small part of the electricity market. In 2003/04, it accounted for around 0.5 per cent of total electricity supply and although the amount of wind energy is expected to increase over the next two decades, so too is the demand for electricity (Akmal and Riwoe 2005). The Australian Bureau of Agricultural and Resource Economics (ABARE) has projected that wind energy output will increase by around 700 per cent between 2003/04 and 2029/30, rising from 1.1 terawatt hours (TWh) to 7.9 TWh (Akmal and Riwoe 2005). Over the same period, total electricity supply is expected to increase by approximately 73 per cent, meaning that the proportion of wind energy is only likely to rise from 0.5 to 1.9 per cent.

Australia is not alone in experiencing significant growth in wind power. Global installed wind capacity has grown by over 20 per cent per annum since the mid 1990s.[2] Most of this growth has been concentrated in a small collection of developed nations. Germany has the highest amount of installed wind capacity at 18,428 MW and it now gets around three to five per cent of its electricity from wind. Behind Germany is Spain (10,027 MW), followed by the United States (US) (9,149 MW), India (4,430 MW) and Denmark (3,122 MW), which gets around 20 per cent of its electricity from wind (Outhred 2003a; AWEA 2005a; GWEC 2006).

Consistent with what has occurred in the United Kingdom (UK), Europe and the US, the growth in wind power in Australia has caused disquiet within certain quarters. Predictably, the fossil fuel sector has been active in criticising the government support provided to the wind industry and the renewable energy sector more broadly, notwithstanding the fact that it is also subsidised. In addition, a proportion of the community appears to be anxious about the environmental and social impacts of wind farms and a number of non-government organisations have formed to oppose the wind industry. Amongst the anti-wind groups, the most widely known are the Coastal Guardians and Landscape Guardians, which are modeled on an organisation in the UK called Country Guardians. Other community-based anti-wind groups have also sprung up in the face of specific wind farm proposals, including at Bungendore in New South Wales and Bald Hills and Tooborac in Victoria.

Although the renewable energy sector has been given a degree of support through government programs like MRET, there appears to be growing opposition to the wind

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[1] See Tambling *et al.* (2003) and Barker and Outhred (2006). See also Auswind (2005) and Auswind (2006a).

[2] In 1995, global installed wind capacity was around 5,000 MW. At the end of 2005, it stood at 59,084 MW (AWEA 2005a; GWEC 2006).

industry within the Federal Government. In April 2006, the Federal Environment Minister, Ian Campbell, took the unprecedented step of blocking a wind farm proposal under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act). It was only the fourth time a development proposal had been refused approval under the EPBC Act. It was also the only one of sixty wind farm referrals to be refused under the Act since it commenced.[3] The Minister claimed his decision to block the development at Bald Hills in Victoria was made on the basis of the threat to the endangered orange-bellied parrot, but it appears that the real reasons were the degree of local opposition and the desire to manipulate the situation for political gain.

Following the Bald Hills decision, the Federal Agriculture Minister, Peter McGauran, said in June that the claims about the energy and environmental benefits of wind energy were ‘fraudulent’ and that wind farms ‘are not producing any electricity of any measurable amount’. He also argued that because of the ‘deleterious effect’ of wind farms on neighbours and ‘rural communities’, they should not be allowed to proceed unless they have strong community support (McGauran cited in ABC 2006).

The Agricultural Minister’s comments about wind farms reflect some of the anxieties expressed by anti-wind groups. The main arguments put forward by opponents of wind farms are that wind energy is expensive, it is inefficient and unreliable because it is dependent on a variable source of energy, it does not significantly reduce greenhouse gas emissions, wind turbines are a fire risk and a source of noise pollution, and wind farms have deleterious impacts on biodiversity, landscape values, heritage and property prices. The purpose of this paper is to evaluate the merits of these arguments to promote a more informed debate about wind energy.

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[3] Between July 2000 and July 2006, approximately 60 wind farm referrals were made under the assessment and approval provisions of the EPBC Act. Forty-four of these were declared to be exempt from the approval requirements, nine were declared to be exempt if they were carried out in a particular manner and seven were declared to require approval. Of the seven, three were approved with conditions, one was rejected (an 80 turbine proposal at Bald Hills in Victoria) and, at 16 July 2006, three were still awaiting a final decision. This data was obtained from the Department of the Environment and Heritage’s public notices website (http://www.deh.gov.au/epbc/publicnotices/index.html) on 20 July 2006.

2. Is wind energy expensive?

The two main questions associated with the cost of wind energy are:

- is it competitive with other sources of electricity?; and
- has the increase in wind energy significantly increased the cost of electricity?

2.1 Competitiveness of wind energy

Estimating the cost of electricity from wind is complex because it depends on a range of variables that are difficult to predict, including access to appropriate sites (i.e. where average wind speeds are equal to or greater than eight metres per second), turbine design and system costs (i.e. the additional costs associated with adding wind energy to the electricity grid). Making comparisons between wind and other sources of energy can also be difficult because of the cost profiles associated with wind developments. The vast majority of the costs associated with wind developments are upfront capital costs. The operating costs are relatively low, with each additional unit of wind power costing very little to produce. By comparison, conventional gas and coal developments have large capital costs, as well as significant operating costs. The difference in cost profiles creates difficulties when trying to compare the cost of alternative energy sources.

Despite these complexities, most of the data indicate that wind energy is one of the most cost efficient sources of renewable energy and that when the costs associated with pollution are factored in it is competitive with coal- and gas-fired power stations. According to Associate Professor Hugh Outhred from the Centre for Energy and Environmental Markets at the University of New South Wales:

> [w]ind farms are one of the most cost effective of the ‘new’ renewable energy technologies and, when installed in appropriate locations, can produce electrical energy at a cost that is comparable with fossil-fuel power stations if externalities are taken into account (Outhred 2003b, p. 4).

A report prepared for the Ministerial Council on Energy concluded that electricity from wind costs between $60 and $80 per megawatt hour (MWh), compared to $31 to $40/MWh for coal and $37 to $44/MWh for natural gas – see Table 1.[4]

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[4] The estimates in RDGWG (2006) are roughly consistent with those found in a number of other reports (see, for example, SDC (2005) and Saddler *et al.* (2004)).

Table 1 Estimated cost of electricity generation from fossil fuel and renewable sources

Energy source	Estimated cost ($/MWh)
Wind	60 – 80
Fossil fuel	
Coal	31 – 40
Natural gas combined cycle	37 – 44
Renewables	
Solar	400 – 800
Tidal	80 – 150
Geothermal	40 – 130
Biomass	50 – 75
Bagasse	30 – 100
Small hydroelectric	40 – 70
Large hydroelectric	10 – 81

Source: RDGWG (2006).

As Table 1 illustrates, although wind cannot currently compete with fossil fuels without adjustments being made for the costs of pollution, it is generally competitive with all of the renewable sources of energy. Some even argue that in certain circumstances wind can be competitive with fossil fuel-based electricity generation. For example, the former Chairman of the UK's Royal Commission on Environmental Pollution, Sir Tom Blundell, has stated that:

> [a]t current levels of gas prices, and certainly if credit is given for its carbon-free status in line with current Government estimates of the social cost of carbon, [wind] is already cost-competitive with gas-fired electricity on the best onshore wind sites, and seems likely to be the cheapest of all forms of power generation by 2020 on such sites, even without a carbon credit (Blundell in SDC 2005, p. i).

The conclusion that wind energy is currently competitive with other energy sources is supported by the fact that it has been one of the most successful renewable energy sources under the MRET scheme, generating approximately 18 per cent of renewable energy certificates (RECs) between 2001 and 2005.[5] Only hydroelectricity (approximately 35 per cent) and deemed solar water heaters (22 per cent) have been more successful in the REC market.[6] Wind energy would not have captured such a large

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[5] See ORER (2002; 2003; 2004; 2005; 2006) and Kent and Mercer (2006). In 2005, wind energy generated the most RECs of all eligible renewable energy sources (ORER 2006).

[6] It is arguable that the success of both hydroelectricity and solar water heaters over wind has been partly due to Federal Government policies and the design of the MRET scheme. The baselines for hydroelectricity under the MRET scheme were arguably set too low, which enabled operators of existing hydro schemes to capture a significant proportion of the REC market by increasing output rather than

proportion of the REC market if it was not competitive with other forms of renewable energy.

In addition, the cost of wind energy has fallen by approximately 75 per cent over the past 30 years and is expected to continue to decline (RCEP 2000; Mallon and Reardon 2004; AWEA 2005b). Mallon and Reardon (2004) have projected that cost of wind energy in Australia could converge with gas-fired generation at some time between 2008 and 2015, and with coal-fired generation from 2016 onwards. Beyond 2020, they anticipate that wind projects will be ‘self sustaining’, meaning they will no longer need government support to be economically viable. These projections are contingent on continued growth in the wind energy sector, which would enable greater economies of scale and facilitate industry learning.

The declining cost of wind energy is a result of several factors, including technological improvements, greater acceptance of wind energy in capital markets, and economies of scale in construction and wind farm development. One of the greatest technological advances over the past three decades has been the expansion in the size of wind turbines. In the 1980s, the length of the rotor blades on wind turbines was typically between five and 10 metres. Today, it is generally between 30 and 45 metres, which increases the electricity output from each turbine because of the increase in the swept area of the blades. Similarly, the height of wind towers has increased dramatically over the past 20 years. As wind speeds tend to be higher at higher altitudes, this has also increased the electrical output from wind turbines.[7]

One issue that is often raised in the context of the competitiveness of wind energy is the costs associated with connecting wind farms to the electricity grid (i.e. the system costs). In certain cases, the network may be unable to handle the output from a proposed wind farm, resulting in the need to make adjustments to accommodate the development. Networks may also need to be extended to connect wind farms to the grid. These systems costs can have a significant influence on the economic viability of individual wind farms.

There are four relevant points about system costs in the context of debates about the pros and cons of wind energy. Firstly, the system costs faced by wind farm developers should not be of great concern to the general community in a competitive energy market. Wind developers will generally be responsible for covering the system costs associated with the construction and operation of wind farms. If these and the other costs faced by wind developers are excessive, wind energy will not be competitive in the market and wind farms will not be built or, if they are, the developers and their financiers will lose money. Secondly, wind farms are not the only types of generators that face system costs. New gas- and coal-fired power plants, as well as other renewable generators, can also face considerable system costs that can significantly increase the cost of the electricity they produce. Thirdly, the system costs faced by wind developers can be significantly reduced if they are spread across a number of wind developments. As a result, appropriate coordination of wind farm proposals can enable developers to

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through major capital investments and technological innovation (Kent and Mercer 2006). Similarly, the Government has provided an additional subsidy to support the uptake of solar water heaters, which has aided their success in the REC market (see Pollard (2003)).

[7] See AWEA (2005) and Outhred (2003c).

capture economies of scale and reduce the cost of wind energy (Outhred 2003b). Finally, although system costs can create difficulties for certain wind farm proposals, there are cases where wind farms can actually reduce the need for network upgrades and decrease the transmission losses in the system. As Outhred (2003b, p. 19) describes:

> … small wind farms connected to existing distribution networks may, if their output is strongly correlated with local demand, offer opportunities to defer network augmentation costs and reduce network losses.

Yet, irrespective of the nature of the system costs faced by individual wind farms, the evidence indicates that wind energy is competitive with other forms of renewable energy and that, provided the wind industry continues to grow, it will become increasingly competitive with coal- and gas-based electricity generation. The financial viability of individual wind farms will vary, but overall there is no doubt that they offer a competitive alternative to fossil fuel-based sources of energy, particularly if generators are required to internalise the costs associated with pollution.

2.2 Does wind energy significantly increase the cost of electricity?

Because wind turbines are dependent on a variable energy source, the amount of energy they generate fluctuates and, unlike many other types of generators, they cannot rapidly increase their output in response to human demands. This means that wind farms are generally ill-suited to participate in the normal National Electricity Market (NEM) dispatch procedures, where generators respond to instructions from the National Electricity Market Management Company Ltd (NEMMCO) to increase and decrease supply.[8] Consequently, like other intermittent power sources, '[w]ind power … should be thought of as a reduction in load rather than in terms of supplying base-load, intermediate-load or peak-load generation' (Sustainable Energy Australia 2004, p. 39). That is, because wind farms are dependent on weather patterns, their primary role should be seen as reducing the amount of electricity that is needed from other sources rather than being a means of meeting short-term fluctuations in demand.

The fact that wind energy displaces production from other sources has led some to argue that wind farms impose significant costs on consumers by replacing a low-cost energy source with a higher-cost one. Whether this is correct depends on the circumstances in which the wind energy is supplied.

Most electricity generated by wind farms is sold under contract to specific electricity retailers in order to meet the requirements of the MRET scheme or to satisfy demand for 'Green Power'. To the extent that the cost of electricity under these contracts exceeds the going price of electricity in the NEM, wind power will increase the amount that consumers pay for electricity. However, in the case of Green Power, the consumers have voluntarily elected to pay the additional amount.

With respect to the amount supplied to meet MRET obligations, the additional cost to consumers is very small because only a small amount of electricity is required to be obtained from renewable sources. The MRET target is currently an additional 9,500

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[8] See below at pp. 8 – 10 for further details on the operation of the NEM.

GWh of renewable electricity per annum by 2010. When first established, this was supposed to increase the proportion of renewable energy in the national market from 10.5 per cent in 1997 to 12.5 per cent in 2010 (i.e. a two per cent increase). However, the projections on which this estimate was based underestimated the rising demand for electricity. As a result, the additional 9,500 GWh is now only expected to increase the proportion of renewable energy by around 0.6 per cent, to just over 11 per cent in 2010. If nothing changes, by 2020, the proportion of energy supplied by renewables is expected to decline by around 1.7 per cent.[9]

Analysis undertaken for the Australian Greenhouse Office found that the average additional cost of electricity to end users as a result of MRET would initially be around $0.97 per MWh, which should rise to $1.44/MWh between 2008 and 2012, before falling back to $1.23/MWh between 2013 to 2020 (Tambling *et al.* 2003).[10] This is likely to represent around a one to two per cent increase in the average household electricity bill in 2010 (Auswind 2004). Further, the evidence indicates that the additional cost to consumers associated with increasing the MRET target to around 20,000 GWh by 2010 (roughly a five per cent increase in the proportion of electricity derived from renewables on 1997 levels) would not be excessive. Most estimates of the resulting increase in the wholesale price of electricity in 2010 range from around $2.40 – $3.50/MWh (Tambling *et al.* 2003; Reardon and Mallon 2004; Auswind 2004).[11] For residential consumers, this is likely to translate into roughly a 1.5 – 2.5 per cent increase in the average electricity bill, or an additional $15 – $25 a year.[12] The data indicate that a substantial proportion of any increase in the renewable energy market that is triggered by raising the MRET in the short to medium term is likely to be taken up by wind energy (Tambling *et al.* 2003).

In summary, the displacement of conventional fossil fuel-based generation by wind energy does increase the cost of electricity. However, at current levels of wind penetration, the additional cost to most consumers is negligible. If wind penetration increased substantially, the additional costs to consumers would be more significant, but still only small to moderate depending on the size of the increase in wind energy. Further, these costs are likely to be similar to those associated with other forms of renewable energy.

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[9] See Reardon and Mallon (2004).

[10] A report prepared for Origin Energy made similar findings, with the estimates of the additional costs to end users ranging between $0.90/MWh and $2.10/MWh in 2010 (Tambling *et al.* 2003).

[11] This projected increase is based on the wholesale price that would be expected if MRET remains unchanged at its current rate of an additional 9,500 GWh on 1997 levels.

[12] Calculated using figures from Tambling *et al.* (2003), Reardon and Mallon (2004) and Auswind (2004). Compared to the situation where there was no MRET, a five per cent MRET target is likely to result in a 2.5 – 3.5 per cent increase in the average household electricity bill (around $25 – 35 per year).

3. Is wind energy inefficient and unreliable?

Because wind turbines are dependent on a fluctuating energy source, there is greater variability in the amount of electricity they produce than that which is associated with most fossil fuel generators. They need a reasonable amount of wind to start generating (around 3 – 4m/s), will shut down in high winds (25 – 26 m/s) and their output will fluctuate while they are operating due to changes in wind speed (Outhred 2003a; SDC 2005; MacGill and Outhred 2005). This has led opponents of wind farms to make two claims about wind farms:

- they are inefficient because they do not generate electricity at or near their maximum capacity all the time; and
- they are unreliable, which can cause problems for the management of the electricity system.

3.1 Are wind farms inefficient?

The blunt response to the argument that wind farms are inefficient is that it does not matter. If wind farms can supply electricity at a price that is competitive then it is irrelevant how often they operate at maximum capacity. The fact that wind turbines do not operate at their maximum capacity all the time is a problem for wind developers, not consumers or the community.

In addition, no form of electricity generator operates at maximum capacity all of the time. The phrase 'capacity factor' is used to describe the ratio of a generator's actual electricity output to its theoretical output if it was running at maximum capacity over the relevant timeframe (usually a year). Wind farms usually have a capacity factor of somewhere between 20 – 40 per cent, depending on the technology used and their location (Sustainable Energy Australia 2004; SDC 2005). By contrast, large base-load fossil fuel power stations can have capacity factors in excess of 85 per cent. Yet, where fossil fuel power stations are unreliable, or they are only used to supply electricity in certain periods, their capacity factor will be much lower. For example, in the late 1980s and early 1990s, the capacity factors of the Yallourn W (Victoria) and Hazelwood (NSW) coal-fired power stations were less than 70 per cent (Sustainable Energy Australia 2004).

The relatively low capacity factors of wind farms is problematic for wind developers and their creditors as it means they cannot earn as much money from the wind turbines as is theoretically possible. For everybody else, the low capacity factor is not a significant issue – just as the low capacity factor of underutilised fossil fuel generators (for example, peak load generators) is not an issue.

3.2 Is reliability a problem?

The term reliability is generally used in energy policy circles as 'a measure of how long a period of time occurs between failures of the machine or how long those failures last' (Sustainable Energy Australia 2004, p. 58). Wind turbines are extremely reliable. They generally have reliability ratings of 99 per cent or more (Sustainable Energy Australia 2004). However, when opponents of wind energy talk of reliability they are generally referring to the variable nature of the electricity supplied by wind farms.

The key issue in this context is whether the variability associated with wind farms can cause problems for the management of the electricity system. To answer this question, it is necessary to look at three issues:

- is there already variability in the supply of, and demand for, electricity and, if so, how is this managed?;[13]
- is wind-related variability currently a problem in the NEM?; and
- if the proportion of electricity that is supplied by wind increases, will wind-related variability become a significant problem?

Existing variability

All electricity systems including the NEM have to deal with considerable variability in both the demand for, and supply of, electricity. Each day, demand surges in the early morning as people awake and turn on home appliances and then again in the evening when people return from work. There are also significant day-to-day fluctuations in demand depending on the temperature and business requirements. These short-term variations in demand must be matched by changes in supply in order to keep the electrical system in balance. Unexpected supply-side events can also occur like the loss of generators and interconnectors that put pressure on the system. To ensure reliable access to electricity, the system must be able to respond to these fluctuations.

NEMMCO employs a range of measures to ensure that fluctuations in demand and supply can be accommodated in the NEM.[14] These can be divided into three main categories: the market-based dispatch process; monitoring and forecasting; and ancillary services.

At the core of the NEM is the centrally-controlled dispatch process that governs most of the wholesale trading in electricity between generators and retailers. Under this process, generators submit offers to NEMMCO to supply electricity at a particular price for every five minute interval in the day (or dispatch period). The bids are then stacked in ascending price order for each dispatch period. After the bids have been stacked, NEMMCO schedules the relevant generators into production (a process called dispatching) to ensure that the demand for electricity is satisfied at the least cost. The price of electricity for the dispatch period (dispatch price) is the highest price paid to a generator for electricity during the period. For every half hour interval (trading interval), a spot price is calculated as the average of the six dispatch prices. The spot price is then used as the price paid to all generators for the electricity they supplied during the trading interval.

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[13] The NEM provides electricity to most people in east and south-eastern Australia. According to NEMMCO, it is ‘the world’s longest interconnected power system’ (NEMMCO 2005a, p. 4).

[14] The following discussion of features of the NEM is drawn from NEMMCO (2001; 2005a; 2005b).

In order to keep the system stable, it is essential that the supply of electricity balances demand. The market-based dispatch process contributes to this by enabling NEMMCO to control the output from generators. It also sends price signals to consumers, which should help to smooth out fluctuations in demand. However, in practice, the fluctuations in price have only a small impact on consumption patterns as the demand for electricity is relatively unresponsive to price changes (i.e. demand is price inelastic) (Sayers and Shields 2001).

The dispatch process is complemented by demand monitoring and supply forecasting. NEMMCO evaluates the regular trends in demand (for example, daily, seasonal etc.) to enable it to anticipate the required levels of supply. Generators are then required to submit details of their available capacity and intended production levels for each trading interval, which NEMMCO uses to develop supply forecasts (known as projected assessments of system capacity). These forecasts are developed two years ahead (and are updated weekly) and seven days ahead (updated every two hours). In addition, two days before each trading day, generators submit their bids for the 48 trading intervals in the day. The bids are used to develop a pre-dispatch schedule which is published every day ‘that covers supply and projected demand for all periods from the next trading interval to the final trading interval of the next trading day’ (NEMMCO 2005b, p. 11). Generators can vary the quantity of electricity they are willing to supply up until the time of dispatch, but they cannot change their price.

The dispatch, monitoring and forecasting processes enable NEMMCO to respond to a considerable amount of variability in both demand and supply. However, these processes are insufficient to guarantee the complete reliability and security of the system. Consequently, NEMMCO employs what are called ancillary services to ensure the system remains operational and stable. These ancillary services can be divided into three categories: Frequency Control Ancillary Services (FCAS), Network Control Ancillary Services (NCAS), and System Restart Ancillary Services (SRAS) (NEMMCO 2001).

Frequency is essentially a measure of the balance between the supply and demand of electricity. In the NEM, frequency is required to be maintained between 49.9 Hertz and 50.1 Hertz. If demand exceeds supply, frequency will decrease; if supply exceeds demand, frequency will increase. The FCAS, also known as ‘spinning reserve’ or ‘load-following reserve’, are intended to ensure frequency is kept within the prescribed parameters. They are often divided into two groups: regulation frequency control services and contingency frequency control services. Regulation frequency control services are designed to address minor changes in frequency that occur over short-time frames due to imbalances in supply and demand. These services are provided by specific generators that employ a technology called automatic generation control, which enables NEMMCO to constantly monitor frequency and send electronic signals to generators to increase and decrease electricity output. Due to the dynamic nature of the NEM, regulation frequency control services are continually in use.

Contingency frequency control services respond to changes in frequency that are caused by a contingency event – for example, the loss of a generator or transmission element. Under the rules that govern the management of the NEM, NEMMCO is required to ensure that frequency deviations remain within the prescribed parameters following a contingency event and that frequency returns to the normal operating band within five minutes (NEMMCO 2001). The contingency frequency control services are provided by a range of measures including load shedding (where certain users are disconnected from the grid), generator governor response (where generator controllers increase or decrease electricity output), rapid generation (where low frequency triggers generators to start up) and rapid unit unloading (where high frequency triggers a reduction in generator output). Unlike regulation frequency control services, contingency frequency control services are only used occasionally in response to unscheduled events.

To ensure the provision of FCAS, NEMMCO operates separate FCAS markets and acquires the required services from registered market participants. These markets operate in a similar manner to the general electricity market in that bids are submitted and NEMMCO dispatches instructions to the least cost providers. Under the rules that govern the NEM, NEMMCO is required to ensure that there is a specific amount of FCAS available for each dispatch interval. The cost of providing these services is then recovered from market participants in accordance with prescribed recovery rules. In addition, NEMMCO has the power to issue directions to generators to force them to increase and decrease their output against their bids if it is deemed necessary to ensure the security of the system.

NCAS perform two main functions: they control voltage at different points on the network; and ensure power flow on network elements or inter-connectors is kept within prescribed limits. Voltage control services 'involves generators either absorbing or generating reactive power from or onto the electricity grid' (NEMMCO 2005b, p. 17).[15] Network loading services control the flow of electricity on network elements by either altering generation levels (for example, via the use of automatic generation control) or electricity demand (for example, via load shedding) at specific points on the network.

As the name suggests, SRAS are intended to ensure the system can be restarted from a partial or complete stoppage. They are provided by general restart sources (generators that can start up without an external power source) and a technology known as 'trip to house load', which enables a generator to detect a system failure and 'fold back onto its own internal load' until NEMMCO restarts the system (NEMMCO 2001, p. 7).

In summary, there is already a considerable amount of variability in the supply of, and demand for, electricity on the NEM. To address the problems caused by fluctuations in supply and demand in the market, NEMMCO has an array of tools ranging from the relatively passive to the highly interventionist. The existing measures have proven to be very effective in guaranteeing the security and reliability of the NEM.

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[15] Reactive power can be defined as 'the background energy movement in an Alternating Current (AC) system arising from the production of electronic and magnetic fields. These fields store energy which changes through each AC cycle. Devices which store energy by virtue of a magnetic field produced by a flow of current are said to absorb reactive power; those which store energy by virtue of electric fields are said to generate reactive power' (NGC 2001, p. 1). Reactive power flows influence voltage. Hence, in order to control voltage, it is necessary to maintain reactive power balances at appropriate points in the network.

Current wind-related variability

Significant problems caused by the intermittent nature of wind energy only arise when wind constitutes a large proportion of the relevant energy system (EWEA 2005; SDC 2005; Gül and Stenzel 2005). As the UK's Sustainable Development Commission has stated:

> [i]t is generally considered that up to 20% wind capacity penetration is possible on a large electricity network without posing any serious technical or practical problems. Indeed, there is no absolute technical limit to UK wind capacity – instead the issue is an economic one, with higher penetrations leading to increased unit costs (SDC 2005, p. 26).[16]

At present, wind farms only produce around 0.5 per cent of Australia's electricity. This level of wind energy is too small to cause any significant system-wide problems in the NEM (WEPWG 2005; Outhred 2003a). The ancillary services and other measures that are in place are able to deal with the variability associated with wind output and there is no evidence that there has been a significant increase in the demand for ancillary services over the past years in response to the growth in wind energy (Sustainable Energy Australia 2004). This is hardly surprising as the existing ancillary services must be able to handle large contingency events, as well as minor short-term fluctuations in supply. The fluctuations in supply from the small number of existing wind farms are insignificant compared to the other sources of variability.

The fact that the variability associated with wind has not caused any significant problems in Australia is consistent with the evidence from other countries. Twenty per cent of energy in Denmark, and over four per cent in Spain, comes from wind energy, and neither country has experienced significant problems associated with intermittent supply.[17] There are also a number of small electricity systems in Australia that are reliant on wind energy for a large proportion of their needs. These include on King Island in Tasmania (where wind supplies over 20 per cent of the island's electricity), Denham in Western Australia (where wind can supply up to 70 per cent of annual energy) and Mawson in the Australian Antarctic Territory (where they plan to have 100 per cent of energy supplied by wind for 75 per cent of the year) (Outhred 2003a).

Contrary to what certain anti-wind groups have suggested, the fact that wind is a variable source of energy does not mean that it currently has to be backed up by additional 'spinning reserves' from other more reliable sources of electricity to cover periods when there is little or no wind. The variability associated with wind energy is managed by the measures that are in already in place to address fluctuations in the supply of, and demand for, electricity.

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[16] See also EWEA (2005).

[17] The Danish electricity system is linked to a larger European system, which reduces the magnitude of the system-wide problems. The Danish experience does, however, indicate that regional and local-level problems are manageable. For example, in west-Denmark, around 25 per cent of electricity is derived from wind and the system has not confronted any significant problems (EWEA 2005).

Could intermittency become a problem?

Greater wind penetration in the NEM could give rise to a number of challenges. However, as Outhred (2003a) and others have noted, there is currently considerable scope for greater penetration of wind energy in the NEM.[18] In fact, it has been estimated that the NEM could readily accept 8,500 MW of wind energy 'in the absence of significant amounts of other forms of intermittent generation' (Outhred 2003a, p. 14), which constitutes roughly an additional 7,800 MW on existing levels (Barker and Outhred 2006).

One issue that will arise with greater wind penetration is an increase in the demand for, and the costs of, ancillary services to address wind-related variability (SDC 2005; Gül and Stenzel 2005). However, the additional costs of ancillary services are unlikely to be substantial (Gül and Stenzel 2005; SDC 2005). Overseas research indicates that the cost associated with the need for additional ancillary services is likely to be around 1.20 – 1.50 USD per MWh if wind reaches two per cent of the relevant electricity market, 1.70 – 3.00 USD/MWh at five per cent and 3.00 – 5 USD/MWh at 10 per cent (SDC 2005).[19] These estimates may not be directly transferable to Australia, but they indicate that the additional ancillary service costs are unlikely to be prohibitive.[20]

A number of measures can also be used to reduce the costs and technical challenges posed by greater wind penetration (Outhred 2003a; Gül and Stenzel 2005; EWEA 2005). Most simply, the strategic placement of wind turbines can reduce the variability in the output from individual wind farms. This is because the turbines can be located in positions that have different wind profiles, meaning that the overall variability from the entire farm is reduced. Similarly, by placing wind farms across a wide area, it is possible to significantly reduce the impact of wind-related variability on the electricity system as a whole. Again, this is because different wind farms will face different wind profiles. Given the size of the NEM, there is considerable scope for siting to be used as a means of reducing the problems associated with intermittency (Outhred 2003a; Davy and Coppin 2003).

Other strategies to minimise the costs associated with intermittent supply include controlling groups of wind farms to limit fluctuations and the use of wind forecasting to enable system controllers to anticipate changes in wind output. Technological devices can also be used to limit variability in output from wind farms, including turbine and generator designs, as well as voltage control devices.

While wind-related variability is unlikely to cause any significant system-wide problems while wind penetration remains below 20 per cent, there is the potential for wind farms to cause problems in certain local distribution and regional sub-transmission networks. This is due to weaknesses in these networks that reduce their capacity to handle fluctuations in electricity supply. However, according to Outhred (2003a, p. 5) these potential constraints 'should be manageable with good network design and operation.'

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[18] See Outhred (2003a; 2003b); MacGill and Outhred (2005); and ESIPC (2005).

[19] See also EWEA (2005).

[20] The costs associated with the additional ancillary services may be lower in Australia due to the size of the NEM and relative abundance of suitable locations for wind farms.

Specific concerns have been raised about the impacts of wind-related variability in South Australia, where the proportion of electricity supplied by wind already exceeds five per cent (ESIPC 2005). However, again, the evidence suggests that the problems associated with variability are manageable. The Electricity Supply Industry Planning Council of South Australia has indicated that increasing the installed wind capacity in South Australia from its current levels of around 390 MW to 500 MW would have only a modest impact on the South Australian electricity system in terms of security and price and that penetration beyond 500 MW is readily achievable with appropriate technical and forecasting standards. The Council has stated that, provided the suggested measures are adopted, ‘market forces should determine an appropriate level of wind generation in South Australia’ (ESIPC 2005, p. viii).

In summary, there is considerable scope for wind power to be increased in Australia before intermittency causes any significant problems. At one point, the marginal costs associated with increasing wind energy will exceed the related benefits because of the difficulties associated with managing wind-related variability, but this point is still a long way off.

4. Does wind energy reduce greenhouse gas emissions?

To evaluate the argument that wind farms are not effective in reducing greenhouse emissions, it is necessary to look at three main issues:

- how does wind energy displace fossil fuel power generation?;
- to what extent do wind farms reduce greenhouse emissions?; and
- does wind-related variability substantially reduce the emissions benefits of wind energy?

4.1 Displacing fossil fuel power generation

Most electricity generated by wind farms is sold under contract to specific electricity retailers in what are often called ‘off-market trades’. This means that one or more electricity retailers enter into an agreement with a wind farm operator for the supply of a given amount of electricity at a specific price. In the NEM, these off-market trades do not result in the wind farm operator supplying electricity directly to the retailer. Rather the wind farm operator simply generates the required amount of electricity, which is entered into the NEM. As the NEM operates like a pool, the amount of electricity the retailer draws from the NEM effectively cancels out the amount supplied by the wind farm operator.

To complete the off-market trades on the NEM, wind farm operators bid their output at zero dollars for the relevant dispatch periods. As NEMMCO stacks bids in ascending order, this means that the wind farm bids are generally assured of being dispatched. The net effect is to reduce the amount of electricity required to be dispatched from other sources. That is, it displaces generation from the top of NEMMCO’s dispatch stack (i.e. the generators who submitted the most expensive bids). When this occurs, the generators that are displaced will reduce their output, meaning one MWh of wind output leads to one MWh less output from another source. If the displaced generators rely on fossil fuels, this will reduce the emissions from the stationary energy sector.

In order to calculate the extent to which wind generation reduces greenhouse gas emissions, it is necessary to determine what types of generators are displaced by wind energy. Around 90 per cent of Australia’s electricity supply comes from fossil fuel generators. Further, of the 10 per cent that is sourced from renewables, more than 85 per cent comes from hydroelectricity (Akmal and Riwoe 2005). Wind energy will rarely, if ever, displace hydroelectric generation because hydro generators are usually ‘price-takers’, meaning they bid their output at zero dollars and take whatever spot price is determined by the market. As with wind energy, this means that hydro will usually be dispatched first in the NEM’s dispatch process. In addition, hydro generators can often delay production by storing energy in dams if there is any chance they could be displaced by other generators. As a result, it is likely that the vast majority of the generation that is displaced by wind energy would have been derived from fossil fuels.

4.2 Reductions in greenhouse emissions from wind

An example of a wind farm with a 50 MW capacity in New South Wales can be used to demonstrate the extent to which wind energy reduces greenhouse gas emissions.[21] If we assume the wind farm has a capacity factor of 30 per cent, the total annual electricity output can be calculated as follows.

Wind farm output = 50 MW x 8,760 hours in a year x 0.3 = 131,400 MWh

Having determined the likely total annual electricity output, the next step is to calculate the amount of carbon dioxide equivalents (CO_2-e) that would be emitted if the same amount of electricity was obtained from other sources. To do this, we can use an emission coefficient (or emission factor) that estimates the average amount of greenhouse emissions from each unit of electricity produced in the relevant system (i.e. it takes into account generation from both fossil fuels and renewables). The New South Wales Greenhouse Gas Abatement Scheme currently has an emission coefficient of 0.929 tonnes of CO_2-e per MWh of electricity (NSW Government 2006).[22] Using this coefficient, the annual reduction in emissions as a result of the 50 MW wind farm would be:

Emission reduction = 131,400 MWh x 0.929 = 122,071 tonnes of CO_2-e per year

An additional factor that should be taken into account is the emissions that arise from the manufacture, construction and management of the wind farm. Given the size of wind turbines and the technologies used in their construction and operation, these emissions are small compared to those associated with the construction and operation of other types of generators, particularly large fossil fuel and nuclear generators. Nevertheless, they should be taken into account when calculating the greenhouse benefits of wind energy.

The available evidence indicates that a modern 50 MW wind farm is likely to be responsible for around 14 kg of CO_2-e per MWh of electricity produced (IEA 2000; URS 2004).[23] This means that annual emissions associated with the wind farm are likely to be:

Annual emissions = 131,400 MWh x 0.014 tonnes of CO_2-e per MWh = 1,840 tonnes of CO_2-e

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[21] This example is based on the proposed Woodlawn Wind Farm in New South Wales (see URS (2004)). For a similar analysis, see MMA (2006).

[22] See also AGO (2005) that suggests the use of an emission factor for the consumption of purchased electricity in New South Wales and the Australian Capital Territory of 0.985 tonnes of CO_2-e per MWh of electricity. These estimates are based on a full fuel cycle analysis, meaning they take into account the emissions from electricity generation, as well as those attributable to such things as the extraction and production of the fuels used in the relevant generators.

[23] The emissions associated with the manufacture and construction of wind farms are fixed, meaning they are not affected by the level of output. Hence, when the emissions are converted to a per MWh figure, they will depend on the quality of the wind farm site. Good quality sites that generate high levels of electricity will have relatively low per MWh emissions, while poor quality sites that generate low levels of electricity will have high per MWh emissions. The figure used here is an average drawn from the available research.

In other words, the emissions related to the manufacture, construction and operation of the wind farm are likely to be equal to less than two per cent of the emission reductions that arise as a result of the displacement of fossil fuel-based electricity generation.

Consequently, the total annual reduction in emissions as a result of the installation and operation of the 50 MW wind farm would be:

Total emission reduction = 122,071 - 1,840 = 120,231 tonnes of CO_2-e per year

This is roughly equivalent to the annual emissions from 27,767 cars.[24]

4.3 The impact of wind-related variability on greenhouse emissions

Anti-wind groups often argue that because the output from wind farms is variable, there is a need for greater reserves (i.e. ancillary services). According to this argument, the need for greater reserves means that the greenhouse benefits of wind energy are negligible or that they will be substantially reduced.

As discussed in Section 3 above, the fact that wind is a variable source of energy does not mean that the amount of electricity that is supplied by wind farms needs to be backed up by additional spinning reserves to cover periods of little or no wind. The existing measures that address fluctuations in supply and demand are able to cope with the variability associated with the current levels of wind energy. If there is a substantial increase in the amount of wind energy in the NEM, there is likely to be an increase in the ancillary services that are necessary to ensure the security and reliability of the system. However, the increase in emissions associated with the rise in the demand for ancillary services is likely to be small (SDC 2005; EWEA 2005). According to the Sustainable Development Commission (UK):

> [w]hen wind produces 20% of total output, it is estimated that the emissions savings from wind will be reduced by a little over 1%, meaning that 99% of the emissions from the displaced fuel will be saved (SDC 2005, p. 26).

Consequently, increased penetration of wind energy will provide substantial greenhouse benefits, which will only be slightly reduced as the proportion of wind energy increases.

An issue that can cause confusion in this context is the relationship between the so-called ‘capacity value’ of wind farms and greenhouse emissions. Capacity value is a measure of a generator’s ability to ‘contribute firm capacity’ to the electricity system (SDC 2005, p. 23). Most modern base-load gas and coal generators have a capacity value of around 85 to 90 per cent, meaning they can be relied upon to provide 85 to 90 per cent of their rated capacity. In contrast, when wind energy only contributes a small proportion of total electricity, the capacity value of a wind farm is likely to be similar to its capacity factor (typically 20 – 40 per cent) (SDC 2005; Sustainable Energy Australia 2004). At higher penetrations, the capacity value of wind farms declines slightly. As the Sustainable Development Commission (UK) explains:

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[24] This was calculated using data from Greenfleet (2006), which assumes that the average car that uses unleaded petrol emits approximately 4.33 tonnes of CO_2-e per year.

> [t]his is because with low penetrations wind output is hardly noticed on the system, but when this increases, the variability of wind becomes more noticeable and its ability to provide firm capacity is reduced (SDC 2005, p. 23).

Evidence from the UK suggests that with wind penetrations of five per cent, the capacity value of wind farms should remain roughly the same as their capacity factors. However, if wind penetration reached 20 per cent, the capacity value of wind generators would fall to around 20 per cent (SDC 2005). This means that at the current levels of penetration in Australia, a new wind farm with installed capacity of 50 MW is likely to reduce the need for around 15 MW of *capacity* from other sources (for example, coal-fired generation capacity). At ten per cent wind penetration, a 50 MW wind farm would displace approximately 12.5 MW of conventional capacity and at 20 per cent penetration, the same wind farm would displace around 10 MW of conventional capacity.

The declining rate at which wind farms displace conventional capacity does not significantly affect the ability of wind energy to reduce greenhouse emissions – although conventional *capacity* will not be displaced at the same rate, the rate at which *output* is displaced will remain roughly the same. The small decrease in the ability of wind to reduce greenhouse emissions at high penetration levels is mainly due to the need for additional ancillary services rather than anything to do with its capacity value.

5. Fire risk and noise pollution

5.1 Fire risk

Anti-wind farm groups have argued that wind farms pose a fire risk. This is because of the risk of lightening strikes, sparks emanating from turbine equipment and the potential for fires being started during construction and management works.

The Australia Institute undertook a phone survey of 40 of Australia's 41 wind farm operators between 4 May and 8 May 2006 to determine the frequency of fires.[25] Only two of the 40 operators reported a fire at any time during the life of the wind farm. The first occurred at Ten Mile Lagoon in Western Australia in the mid-1990s and the second at Lake Bonney in South Australia in 2006. Neither fire spread beyond the relevant turbine. Further, the fire in Western Australia occurred with technology that is now redundant.[26] Consequently, in almost 20 years of wind farm operation in Australia, there appear to have been two fires, neither of which resulted in a wildfire and the only property damage caused by the fires was to relevant wind turbines.

The low incidence of fire is likely to be attributable to a number of factors. Firstly, wind turbines are a relatively passive technology that use few flammable materials. Secondly, although turbines do attract lightening, their design minimises the associated fire risks. Turbine lightening protection systems are now used that extend from the blade to the bottom of the tower and dissipate lightening into the ground.[27] Thirdly, wind turbines are generally placed in open areas, limiting the chance of fires spreading when they do occur. Finally, due to the financial cost associated with wind farm developments, operators generally manage the sites in a manner that minimises the risk to the turbines and surrounding property.

The risk of fire associated with wind farm developments is minuscule. Provided wind farms are constructed and managed in an appropriate manner, fires caused by wind turbines are likely to be very rare and pose little risk to surrounding property.

5.2 Noise pollution

The main source of noise from wind turbines is the rotor blades. As wind passes over the blades it creates fluctuations in air pressure that are detected by the human ear. A small amount of noise can also be emitted from the moving parts in the turbines.

In the past, some wind turbines could be noisy. However, modern turbines create very little noise. At around 40m, the noise created by a single turbine is the equivalent of conversational speech, which is around 50 – 60 decibels (adjusted using an A filter or

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[25] Details of the 40 wind farm operators were obtained from the Australian Wind Energy Association website (http://www.auswea.com.au/).

[26] Personal communication, Western Power, May 5, 2006.

[27] Personal communication, Stanwell Corporation, May 5 2006.

the A scale) (dBA) (SDC 2005).[28] According to the Sustainable Development Commission (UK):

> [i]t is perfectly possible to stand underneath a turbine and have a normal conversation without raised voices (SDC 2005, pp. 75 and 78).

A wind farm comprised of ten turbines would create a sound pressure level of 35 – 45 dBA at 350m if the wind was blowing from the turbines to the observer. This is roughly the equivalent of a quiet bedroom or the background noise in a rural area at night – see Table 2.

Table 2 Noise levels compared to ten turbine wind farm

Activity	Sound pressure level (dBA)
Wind farm (10 turbines) at 350m	35 – 45
Jet aircraft at 250m	105
Noise in busy office	60
Car travelling at 64 kph at 100m	55
Quiet bedroom	35
Background noise in rural area at night	20 – 40

Source: SDC (2005).

The fact that wind turbines are not a significant cause of noise pollution is supported by studies of residents living in close proximity to wind farms. A European study of residents in Denmark, the Netherlands and Germany found that over 90 per cent of residents were ‘not annoyed by noise from wind turbines’ (Pedersen and Halmstad 2003, p. 11). Similarly, a study in Scotland found that most residents did not have noise issues from wind turbines (Warren *et. al.* 2005).

In summary, although noise issues are often raised as a major ground for objecting to wind developments, the evidence shows that the noise created by wind farms is negligible. Provided appropriate buffers are created around wind farms, noise pollution should not be a significant issue.

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[28] The adjustment to decibels using an A filter is intended to provide a measure that is similar to the human ear. This is because human ears are sensitive to certain frequencies.

6. Are wind farms a threat to biodiversity?

Wind farms can adversely affect biodiversity in three main ways:

- clearing vegetation to allow for their construction and operation;
- bird and bat collisions with turbines; and
- behavioural disturbance to animals caused by their operation (Langston and Pullan 2004; SDC 2005).

6.1 Vegetation clearance

The risks associated with vegetation clearance vary and will depend on the specifics of each development. In most cases in Australia, wind turbines are located in cleared agricultural areas, meaning the risks associated with habitat loss are minimal. However, in some instances, developers seek to place turbines in vegetated areas to reduce costs or maximise available wind resources. In these cases, there is the potential for adverse biodiversity effects, particularly if the area supports threatened species or ecological communities.

6.2 Bird and bat collisions

Birds and bats can potentially collide with either the moving rotor blades or the ‘essentially stationary elements’ of wind turbines (i.e. tower and nacelle) (Smales 2006, p. 7).[29] Bird and bat collisions with stationary objects are relatively rare. Consequently, the risk posed by towers and nacelles is generally considered to be ‘negligible’ (Smales 2006, p. 7).

The main problem relates to the risk of birds and bats colliding with moving rotor blades. The tips of the blades generally rotate at speeds between 200 and 300 km/h, meaning that there is a high risk of mortality if animals do come in contact with them while they are moving (Smales 2006). However, most modern wind turbines used in Australia consist of three rotor blades that are between 30 and 45 metres in length attached to towers that are generally between 65 and 100 metres tall. As a result, there is a considerable amount of space between the rotors, which reduces the risk of collisions.

Notwithstanding the extent of the space between the rotor blades, bird and bat strikes do still occur. Most of the available evidence, which is relatively limited, suggests that the mortality rate for birds and bats from wind turbine collisions is low – typically less than five birds and five bats per turbine per year (Erickson *et al.* 2001; Langston and Pullan 2004; USGAO 2005). However, the likelihood of collision mortality is highly dependent on the siting of wind farms and the characteristics of the relevant bird and bat species. For example, species that fly at the rotor height, particularly those that tend to hover or circle, are at greater risk than those that tend to fly below or above rotor height (Smales 2006). Similarly, the proximity of wind farms to feeding, foraging and breeding

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[29] The nacelle is the enclosure on top of the tower. Nacelles rotate, but the space they occupy remains relatively unchanged when they do.

habitats, and whether they are located in migration paths, will have a significant effect on the collision mortality risk (Langston and Pullan 2004).[30] Above average collision mortality rates have been found at a number of poorly sited wind farms, for example at several large wind farms (200 plus turbines) in Spain and in West Virginia and northern California in the US (Langston and Pullan 2004; SDC 2005; USGAO 2005). Generally though, where wind farms have been located in appropriate places the number of bird and bat deaths from collisions appears to have been small. As the UK Department of Trade and Industry has stated:

> [e]vidence to date suggests that there is minimal risk to birds from the operation of properly sited wind turbines (DTI 2005, p. 3).

Relatively little research has been done on the risk of bird and bat collisions with wind turbines in Australia. This makes it difficult to estimate the likely number of collision-related deaths at domestic wind farms. However, if the international research (which relies heavily on data from Europe and the US) is used as a rough guide, it would suggest that less than 2,550 birds and 2,550 bats currently die each year in Australia as a result of collisions with wind turbines.[31]

Some of the birds killed by wind turbines will be exotics (i.e. non-native species) and these losses may actually constitute a net benefit to the environment. Yet, native species are also likely to be affected. This will be of greatest concern where the deaths involve threatened species, as has been recorded at wind farms in northern Tasmania, where a number of threatened Tasmanian wedge-tailed eagles have died after colliding with turbines.

Although the number of deaths is likely to be relatively small, bird and bat mortality from collisions with wind turbines is an issue that should be considered with all wind farm proposals. However, these risks should be put in perspective as there are numerous other issues that pose a far greater threat to birds and bats than wind farms, including climate change, habitat loss and invasive species. For example, in the late 1990s an estimated 8.5 million birds died each year in Queensland alone as a result of land clearing (Cogger *et al.* 2003). Similarly, in relation to the Tasmanian wedge-tailed eagle, it has been estimated that 173 eagles are killed each year as a result of human activities, of which only one is likely to be due to wind farms (Bevilacqua 2006). The major causes of human-related mortality are vehicle collisions (50 deaths), poisoning (40), electrocution (32), collisions with wires and fences (30) and shootings (20). Modelling conducted by Biosis Research indicates that the cumulative impact of the eight existing and proposed wind farms in the range of the Tasmanian wedge-tailed eagle is likely to be a 0.001 per cent increase in the mortality rate, which is 'not significantly different from that indicated for the population in the absence of those wind farms' (Smales and Muir 2005, p. 39).

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[30] For this reason, important wetlands should be avoided, as well as national parks and other nature reserves that provide habitat for bird and bat species. Care should also be taken to ensure that wind farms are not located in the migration paths of bird species that are susceptible to colliding with turbines.

[31] Bird and bat collision risk is highly site dependent. These figures have been included simply to give some sense of the magnitude of the associated mortality.

The biodiversity risks associated with wind turbine collisions are usually insignificant compared to the threats associated with other activities and processes. In fact, the evidence indicates that wind turbine collision deaths are likely to constitute only a small proportion of the total number of bird and bat deaths caused by collision incidents, let alone total mortality from all sources. This is illustrated by US study that found that wind turbine collision deaths ‘probably represent from 0.01% to 0.02% (i.e., 1 out of every 5,000 to 10,000 avian fatalities) of the annual avian collision fatalities in the United States’ (Erickson *et al.* 2001, p. 2). The researchers concluded that the greatest causes of collision mortality amongst birds in the US were buildings, windows, vehicles and powerlines. Consequently, the collision risks associated with wind turbines should not be exaggerated.

6.3 Behavioural disturbance

There is some evidence that the behaviour of certain bird species can be affected by the construction and operation of wind farms. In most cases, this has involved a small number of species avoiding the area around wind turbines and, as a consequence, being displaced from important habitats (Langston and Pullan 2004; SDC 2005). These displacement effects appear to extend to a maximum distance of around 500 – 600m from the turbines, although the exact distances have tended to vary between species (Langston and Pullan 2004). Another behavioural issue concerns the risk that if wind farms are clustered together in large numbers and bird species are forced to undertake large diversions to avoid them, it could increase mortality rates due to the impacts on the energy balance of the animals.

As with the risk of collisions, the nature and significance of the behaviour-related risks associated with wind farms will vary considerably depending on the location and the species involved. Provided wind farms are sited and managed appropriately, the behaviour-related risks will generally be negligible.

6.4 Summary

The available evidence indicates that provided wind farms are located in appropriate areas the risks to biodiversity are likely to be small. When wind farms are properly sited, a small number of animals and plants are still likely to be adversely affected, but these impacts must be put into perspective and weighed against the threat posed by climate change. The *Royal Society for the Protection of Birds* has described climate change as ‘the most serious threat to wildlife’ (RSPB 2006), a view that is shared by many other environment groups and environmental scientists. Consequently, while care should be taken in the siting and operation of wind farms, the risks to biodiversity should not be exaggerated and must be weighed against the potential for wind farms to contribute to reducing the severity of the impacts of climate change.

7. Wind farms and landscape and heritage values

Wind turbines by their nature are tall structures that are often located in exposed and elevated positions to harness wind power. These areas can have important cultural and heritage values that can be affected by wind farm developments. Further, the construction of wind farms can also disrupt objects and places of heritage significance.

Relevant cultural and heritage values associated with wind farm developments include aesthetics, sense of place, the landscape context of heritage places, Indigenous heritage (for example, sight lines, sacred views and ceremonial areas), natural heritage (for example, fossils and geology),[32] and recreational and wilderness values (Planisphere 2005). Where the relevant values are linked to specific sites or objects, the evaluation of the impact of a proposed wind farm on heritage and cultural values can be relatively easy. However, difficulties can arise where the values relate to landscape issues. This will not always be the case as there may be clearly recognised and accepted values associated with certain landscapes. Yet, where there is ambiguity about the significance of certain areas, disputes can arise about how to measure the likely cultural and heritage impact of wind farms. To assist in this process, the Australian Council of National Trust and the Australian Wind Energy Association are currently working on methodologies for assessing landscape values for the siting of wind farms and other energy infrastructure.

Even with an accepted methodology of measuring landscape issues, the aesthetic impacts of wind turbines are likely to continue to cause problems because of the inherently subjective nature of aesthetic values.[33] Some people loathe the look of wind farms, while others think they enhance the landscape or have no affect on it. In many cases in Australia, it appears that aesthetics has been one of the major drives behind anti-wind campaigns.

Numerous overseas studies that have looked at the attitudes of residents who live in close proximity to wind farms have found that the majority of them are either supportive or neutral toward wind developments, and that most believe they have a negligible impact on the landscape.[34] For example, in a Scottish survey of residents living within 20km of a wind farm, approximately 94 per cent of respondents said they thought the turbines either had a positive impact on the area (20 per cent), neutral impact (51 per cent) or had no opinion either way (23 per cent) (Braunholtz 2003). Interestingly, people who lived closer to the wind farm (0 – 10km) tended to hold more positive views on the impact of the development than those who lived further away (10 – 20km). This finding is consistent with other research on public attitudes to wind farms.[35] Another Scottish survey found that 74 per cent of respondents said there was nothing they disliked about having a wind farm in their local area, while only ten per cent said they were unsightly or spoilt the view (Dudleston 2000).

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[32] Biodiversity forms part of natural heritage. However, biodiversity issues are discussed in Section 7.

[33] Although aesthetic values are influenced by cultural and social factors.

[34] See, for example, Dudleston (2000), Pasqualetti (2001), Braunholtz (2003) and Warren *et al.* (2005). For a summary of survey data on wind farms, see EWEA (2003).

[35] See, for example, Dudleston (2000), EWEA (2003), Warren *et al.* (2005) and SDC (2005).

In Spain, several surveys have found that the majority of respondents thought wind farms had no effect, or a beneficial effect, on the landscape. Although significant minorities (typically around 30 per cent) in a number of the surveys thought the relevant wind farms damaged the landscape, the large majority of respondents were supportive of the wind developments, indicating that many people with concerns about the impacts on landscape values thought the positives of wind energy outweighed its negatives (EWEA 2003). Surveys have also shown that attitudes towards wind farms tend to improve with time and that the proportion of people with concerns about landscape impacts falls after they start operating (Dudleston 2000; EWEA 2003; Braunholtz 2003; Warren *et al.* 2005).

Data on attitudes toward wind energy and the impact of wind farms on landscape values in Australia is limited. Research undertaken for the Australian Wind Energy Association found strong support for wind energy in the community – 95 per cent of respondents supported the use of wind farms to meet the growing demand for electricity. The overwhelming majority of respondents (91 per cent) also thought it was ‘more important to build wind farms for electricity than avoid building them in rural Australia’ (Australian Research Group 2003). Yet, these and other similar results from overseas are difficult to transpose to new developments in Australia because of the differences in wind farms and community attitudes toward landscape issues. Consequently, the aesthetic and other landscape issues associated with wind farms should be approached on a case-by-case basis having regard to the views of residents and the broader community. However, the facts that those who live closest to wind farms tend not to oppose them, that landscape and other concerns seem to subside with time, and that there is strong community support for wind energy are matters that should be considered by decision makers.

In addition, although the aesthetic, cultural and heritage impacts of wind farms are important, it must be emphasised that the majority of wind turbines in Australia have been located in areas of degraded farmland that are devoid of most native vegetation (Diesendorf 2005). These areas have limited natural heritage values and many of the remaining cultural values are often associated with aesthetics and the attitudes of local communities toward artificial structures in the landscape. The attitudes of local residents need to be considered, but they should not automatically be given precedence over the views of the broader community and they must be weighed against the need to address the pressing threat of climate change.

8. Do wind farms adversely affect property prices?

Many anti-wind groups claim that wind farms can drag down property prices in the vicinity of wind developments.[36] There is very little data on the impact of wind farms on property prices in Australia. However, some insights into the likely affects can be obtained from overseas studies.

Two main types of studies have been carried out on the impacts of wind farms on property prices: surveys of interested parties (i.e. residents, realtors and surveyors); and transaction-based studies that analyse the actual prices of properties near wind farms.[37]

The picture that has emerged from the survey-based studies is not entirely clear. A number of the studies suggest that when wind farm developments are first announced, property prices may decline, probably in response to community concerns about issues like noise and landscape impacts.[38] In contrast, several other survey-based studies indicate that wind farms have no impact on property prices.[39] However, even amongst the survey-based studies that have found that wind farms may negatively affect property prices, the results indicate that the prices are likely to recover after the wind farms start operating as communities learn more about the actual impacts of wind developments.[40]

For example, a study by the Royal Institution of Chartered Surveyors in the UK found that 60 per cent of surveyors who were involved in residential property transactions where wind turbines were visible from the property thought that they decreased the value of the property (Khatri 2004). However, 40 per cent believed that wind farms had no impact on property prices and the study found evidence that the 'discount in property values … reduces over time as buyers become aware of the specific characteristics of a development' (Khatri 2004, p. 9). In addition, the results in relation to agricultural land were almost reversed, with 63 per cent of surveyors indicating that they thought the turbines had no impact, 28 per cent thought they had a negative impact and nine per cent thought they had a positive impact.

The findings from the Royal Institution of Chartered Surveyors survey are roughly consistent with those from a Scottish study that asked residents near turbines about anticipated and actual problems associated with wind farms (Dudleston 2000). Six per cent of respondents said that they believed property prices would be a problem, but only one per cent said that wind farms had actually caused prices to fall.[41]

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[36] The value of properties that are close to house wind equipment may rise as a result of the rents paid by wind farm operators. These beneficial effects are ignored here because they are rarely raised as grounds for objecting to wind farm developments.

[37] See Hoen (2006).

[38] See Haughton *et al.* (2004) and Khatri (2004), as well as Dudleston (2000) and Braunholtz (2003).

[39] See, for example, RBA (1997; 1998).

[40] See Haughton *et al.* (2004), Khatri (2004), Dudleston (2000), Braunholtz (2003) and Warren *et al.* (2005).

[41] See also RBA (1997) that found that 78 per cent of respondents living within two miles of a wind farm in the UK believed the development had no effect on property prices, while four per cent said they thought prices had increased and four per cent said they had decreased (the remainder said they did not know). RBA (1998) found similar results.

Survey-based studies of wind farm impacts suffer from a number of weaknesses that reduce their value as a means of evaluating whether property prices are likely to fall in Australia. For example, many respondents may lack information about wind farms and property markets, making their responses speculative.[42] Even so, they do suggest that any negative impacts on property prices are likely to be small and short-lived.

The evidence from transaction-based studies is that wind farms do not have a negative impact on property prices.[43] To date, only a small number of transaction-based studies have been carried out and the methods employed in some of these have been criticised.[44] Yet, the findings from these studies, particularly the analysis carried out by Hoen (2006), indicate that property prices are unlikely to be significantly affected by wind farms.

In summary, the available evidence indicates that wind farm developments are unlikely to have a significant negative impact on property prices. Initial concerns about visual and noise impacts could temporarily reduce prices, but these affects are likely to be small and dissipate quickly. If appropriate planning controls are in place, the risks of adverse impacts on property prices will be significantly reduced.

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[42] Some of the survey-based studies have been criticised for sampling errors and selection bias (see Hoen (2006)).
[43] See Sterzinger *et al.* (2003), Poletti and Associates (2005) and Hoen (2006).
[44] See Hoen (2006).

9. Conclusions

Wind farm proposals have been the subject of considerable controversy in Australia in recent times. Mirroring developments in the UK and US, vocal anti-wind groups have formed to provide structured resistance to the growth in the wind industry. These groups have been successful in attracting media and political attention for their cause and, on occasion, have prevented wind farm proposals from proceeding.

The main grounds that have been used to justify the opposition to wind farms have been the cost of wind energy, its efficiency and reliability, its ability to reduce greenhouse emissions, fire risk, noise pollution, and impacts on biodiversity, landscape values, heritage and property prices. Of these, the only concerns that have merit are the impacts of wind developments on biodiversity and landscape and heritage values.

Wind energy is an economically viable form of renewable energy that effectively displaces fossil fuel electricity generation. In doing so, it reduces Australia’s greenhouse gas emissions. It is currently responsible for around 0.5 per cent of electricity generation in Australia. At these levels, the variable nature of wind energy does not cause any significant problems for the electricity system. Research has shown that the NEM could readily accept a 1,100 per cent increase in the amount of wind energy if it is not accompanied by a substantial increase in other forms of intermittent generation. Further, the evidence indicates that in the longer term around 20 per cent of electricity in the NEM and other large electricity systems in Australia could be supplied by wind energy without posing any substantial technical or practical problems.

In the past, noise pollution was an issue for some people living in close proximity to wind farms. However, technological improvements have significantly reduced the noise emitted from wind turbines. A ten-turbine wind farm is now about as noisy as a quiet bedroom or a rural area at night, making noise issues immaterial in most cases. Similarly, the risk of fire associated with wind turbines is negligible. In 20 years, it appears that only two fires have occurred at wind farms in Australia and both were contained to the turbines that caught alight. The evidence also indicates that property prices are unlikely to be adversely affected by wind farm developments and, if they are, prices are likely to recover quickly after the wind farm starts operating.

The impacts on biodiversity will vary depending on the siting of the wind farm and the characteristics of the species that frequent the area. Where turbines are sited appropriately having regard to sensitive environments and the needs of relevant bird and bat populations, the adverse impacts on biodiversity from wind farms are likely to be small. Bird and bat collisions may still occur, but the number of fatalities is likely to be relatively low (usually less than five birds and five bats per turbine per year), particularly when compared to other threats to the relevant species.

Landscape and heritage issues can also be a significant issue for certain wind farms. However, when appropriate planning procedures are followed, the heritage and landscape risks should be minimal. Some people may still object to wind farms, perhaps on the grounds of aesthetics, but their concerns should be weighed against the need to address the threats posed by climate change and the opinions of the broader community.

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