Alternative energy opportunities for rural industries

Short report 5 Wind energy

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Short report 5: Wind energy

This AgriFutures Australia short report introduces and describes in more detail wind energy. The report is designed to give rural producers and farmers a practical understanding of how this technology works, the benefits it can generate and how it can reduce carbon emissions.

What is wind energy?

Humans have used wind energy to power machines for thousands of years. Its earliest uses were as a power source for sail boats and to power windmills for grinding grain into flour or pumping water.

Wind arises from atmospheric changes in temperature and pressure that make the air move around the surface of the earth. These atmospheric changes are triggered by the sun; in a way, wind energy is another form of solar power.

Converting wind energy into wind power

Wind energy is usually converted into wind power, as electricity or mechanical power, using wind turbines. These turbines have blades called rotors connected to a shaft that the wind rotates (or spins). They are elevated above the ground on a tower (or structure), where wind speeds are higher and/or to provide (safe) clearance from the ground and people for rotors to operate.

There are two main types of wind turbines:

- **Horizontal-axis turbines**, which, like aeroplane propellers, rotate the shaft parallel to the ground and swivel to face the wind direction (Figure 1a).
- **Vertical-axis turbines**, which rotate the shaft vertically and don’t need to swivel, no matter the wind direction (Figure 1b).

The rotating shaft of the turbine can generate:

- Electricity via a generator usually integrated into the turbine body or ‘nacelle’ (Figure 2).
- Mechanical power by connecting it to a machine (e.g., for flour mill grinding) or pumping mechanism (e.g., windmill pumping water) (Figure 3).

Wind arises from atmospheric changes in temperature and pressure that make the air move around the surface of the earth. These atmospheric changes are triggered by the sun; in a way, wind energy is another form of solar power.
Figure 2: A horizontal-axis turbine with electricity generator integrated into its body or ‘nacelle’. The illustration shows other components required for the wind turbine to work effectively, including gear box between the turbine and generator; wind vane and anemometer to control and orient (swivel) the turbine as wind speed and direction change; and brake to stop the rotor spinning when the wind speed is too high for it to operate safely.

Gearbox: Converts shaft rotation into vertical motion to drive the pump rod up and down

Blades: Causes the rotor to spin

Gearbox: Connects the rotor shaft to a higher-speed generator shaft, e.g., 1,000-1,800 rpm

Generator: Produces AC or DC electricity

Controller: Starts and stops the turbine

Wind vane and anemometer: Measures wind speed and direction for turbine control

Brake: Stops the rotor in emergencies or when the wind speed is too high

Yaw drive and motor: Rotates and orients the rotor to face the wind

Rotor shaft: Rotates at low speed, e.g., 30-60 rpm

Figure 3: Illustration of how a horizontal-axis turbine can convert wind energy into mechanical energy for water pumping from a farm bore. It shows how the rotor shaft drives a pump rod (via the gearbox) to operate a pump cylinder up and down in a bore casing to lift water to ground level and into a tank. Source: Modified from Prasad, S. S. et al. (2012). Optimized Design of Rotor Blade for a Wind Pump. International Journal of Renewable Energy Research, 2(4). Available at: www.ijrer.ijrer.org/index.php/ijrer/article/download/364/pdf.
Wind power in Australia

Wind power in Australia has become increasingly common. It is Australia’s leading source of clean energy, supplying 35.9% of the nation’s renewable electricity in 2020 and meeting nearly 10% of Australia’s electricity demand (Figure 4).1

Most wind power generation occurs at utility scale (supplying the electricity grid) from large wind farms with many MW of generating capacity. In 2020, there was nearly 7,400 MW of utility-scale wind generation.1 Most sites are greater than 50 MW with multiple large wind turbines (each at least 1 MW). Some rural producers or farmers make money by selling or leasing land to companies that operate the wind farms (Figure 5).

Smaller wind turbines, in the range 1–100 kW, have been installed across regional areas by businesses and/or farmers for on-site power generation (Figure 6). Installations of these have decreased in recent years as solar PV (at <100 kW) has become more affordable. These smaller wind turbines are most often integrated with solar PV for off-grid supply to diversify renewable power generation (i.e., generate power when the sun is not shining).


Figure 5: The Collgar Wind Farm, near Merredin in Western Australia, is an example of utility-scale wind generation. The wind farm has 111 × 2 MW wind turbines, or 222 MW total maximum capacity, and generates up to 670,000 MWh of electricity per year. Photo: Collgar Wind Farm, www.collgarwindfarm.com.au.

Figure 6: This small-scale installation at Kingston in South Australia includes a 5 kW wind turbine on a 12 m tower. Wind power generation is integrated with a 7.5 kW solar PV system and a 26.4 kWh battery for off-grid power supply. Photo: Australian Wind and Solar, www.australianwindandsolar.com/kingston-south-east-sa.

Is wind power a reliable energy source?

Wind, and the energy it provides, can be highly variable and influenced by location, weather conditions and landscape (or topography). Wind can change in speed and/or direction from hour to hour and from day to day, and between seasons. Figure 7 illustrates several examples of wind variability, and how it can be depicted.

- A wind rose shows the frequency of wind direction and speed at a site.
- Daily average wind speed is the average daily wind speed each day at a site.
- Hourly wind speed is the wind speed and direction observed each hour during a day.

Like solar PV, wind will not generate dispatchable power (i.e., when you need it); it must be coupled with other energy sources, such as grid power, solar PV, battery storage or a diesel genset, to provide a reliable continuous supply.

Figure 7: Publicly available data illustrating the variability of wind. (left) Wind rose for the weather station at Wagga Wagga, New South Wales, which summarises direction and strength of wind (at 10 m) at 9am each day. Source: Bureau of Meteorology, www.bom.gov.au. (top-right) Variation in the daily average wind speed (at 10 m) over a year at Port Pirie, South Australia. Source: Weather Underground, www.wunderground.com. (bottom-right) Hourly wind speed (at 10 m) for a seven-day period at Port Pirie, South Australia. Source: Weather Underground, www.wunderground.com.

How is wind power integrated with other alternative energy technologies?

Commercial wind power systems can be connected to grid or off-grid systems and integrated with other alternative energy technologies like solar PV and battery storage. Figure 8 depicts how this can occur.

Wind turbine generators typically produce alternating current (AC) electricity. This AC electricity is usually first converted back into direct current (DC) so it can be combined with DC power from a solar PV system and/or a battery, after which it is converted back to AC and synchronised with the grid (or off-grid) AC supply. This AC-DC conversion process is performed by a device often called the ‘wind turbine charge controller’, which also manages operation of the wind turbine (i.e., speed, direction, blade pitch, power output).

Electricity from a wind turbine that has been converted to DC can be directly used to power devices and machinery that have a DC power output (e.g., vehicle battery charger), which is more efficient than converting it to AC and back to DC again.

Figure 8: How wind power can be integrated with a solar PV system and battery storage to generate power for use on farm or to supply the grid. Wind power usually generates AC power, so it may need to be converted to DC to be combined with solar PV and battery DC power output, and then converted into AC to synchronise with grid AC supply. For an off-grid system, the grid supply would be replaced with AC supply from a diesel genset.
How much wind power can a turbine generate?

Wind turbines generate more power as the wind speed increases. Most wind turbines, however, have a ‘rated output or speed’ in kW or MW (e.g., 5 kW, 10 kW or 1 MW), which is the maximum power or output a turbine can generate at a certain wind speed (e.g., 10 kW at 10 metres per second).

This behaviour is described by a power curve unique to each type of turbine (Figure 9) that shows the wind speed required for the turbine to start generating power; the wind speed at which the turbine reaches its maximum power output; and the wind speed at which the turbine can no longer operate safely.

- **Cut-in wind speed** – when wind turbine rotation can start generating electric power or mechanical work.
- **Rated wind speed or power** – when 100% of the turbine’s generation capacity is reached.
- **Cut-out wind speed** – when the turbine will stop operating or spinning (e.g., using a brake) to protect it from damage.

Example 1 details how to read the power output for a commercial 10 kW wind turbine based on wind speed using its power generation curve.

Example 1
Reading a power curve for a 10 kW rated wind turbine

The power curve below is for a 10 kW rated wind turbine supplied by Ryse Energy (www.ryse.energy/wind-turbines/). The cut-in speed is 2 m/s, rated power occurs at 9 m/s, and cut-out speed is 30 m/s. The power output at 4 m/s is about 1.2 kW. At 8 m/s, the power output is nearly 9 kW, which is 7.5 times more generation from a doubling of wind speed. The rated power of 10 kW occurs at a wind speed of about 9 m/s, after which it stays at this level until the cut-out speed is reached.

Figure 9: Example power generation curve for a wind turbine. Percentage of rated power generation/output increases from 0% at the cut-in wind speed up to 100% at the rated power (maximum generation capacity). Above the rated speed, the turbine can still operate but will not generate additional power, and power output may even decrease as the turbine is not operating efficiently.
What are wind energy opportunities like in my location?

Many regions across Australia have excellent wind resources that provide wind power opportunities for rural producers or farmers (Figure 10).

Locations with the strongest wind, and thus the greatest potential for wind energy generation, are close to the coast, on rising escarpments facing prevailing winds, and/or on elevated areas. For example, the Atherton Tablelands region in Queensland has an average annual wind speed (at 100 m) of 8-10 m/s, whereas Grafton in NSW has an average annual wind speed (at 100 m) of 4-6 m/s.

Wind speed changes with elevation above the ground (Figure 11). Below the height of 20 m, the friction between wind and earth slows the wind speed significantly. For example, a 1 kW turbine operating at 10 m may only face wind speeds at 60-70% of those experienced at 100 m by a 2 MW turbine.

Additionally, the wind speed below a height of 20 m is also often very turbulent, exacerbated by buildings and other structures. This can negatively affect wind turbine operation and performance (Figure 12). Where these situations occur, the height of a turbine may be raised even further.

More detailed (including hourly and directional) wind data for specific locations are available from the Bureau of Meteorology2 and other websites.3 However, data from other websites is often recorded at 10 m, not 100 m, and turbine operators relying on such data may need to adjust the turbine depending on its size and height it operates at. Consideration must additionally be given to the effects of local topography on wind speeds. The best and most reliable data is measurement of wind at a specific site (whereas Figure 11 is wind speed data based on global weather simulation models).

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Figure 10: Mean or average annual wind speed (m/s) at 100 m elevation (above ground) across Victoria. This map is based on global weather simulation models and should only be considered a guide to wind speed likely at different locations. These predictions should be verified against actual wind measurements at (or near to) a proposed wind turbine site. Source: https://globalwindatlas.info.
How does wind translate into wind power?

A quick estimate of the potential annual wind power generation at a site can be made using its average annual wind speed (at 100 m) and a simplified design chart (Figure 13).

1. Select turbine size, e.g., 10 kW, 1 MW
2. Look up average annual wind speed at 100 m using the Global Wind Atlas (Figure 10) or another source (if not recorded at 100 m, adjust the height to 100 m using the relative wind speed values in Figure 11).
3. Estimate the annual power generation using the turbine size curve in the design chart (Figure 13).

Below is an example of estimating annual wind power generation for a 100 kW wind turbine on King Island in the Bass Strait.

More accurate calculations for wind power (by hour) can be performed by a specialist or equipment supplier and require detailed (i.e., hourly) wind data over multiple years for a site; knowledge of local topography and its effects on wind speed; and the power curve and operating height for a wind turbine.

Figure 14 gives example results of hourly wind power modelling for a 1 MW wind turbine at a location with average annual wind speed of 8 m/s.

Example 2

Estimating annual wind power generation for a 100 kW rated wind turbine

The 100 kW wind turbine would be located on the west coast of King Island, where prevailing wind speeds are greatest. The turbine would be 30 m above ground. The annual average wind speed at 100 m at this location is at least 9 m/s.

Reading the design chart (Figure 13) for wind speed of 9 m/s, using the 100 kW curve, the annual power generated would be an estimated 220,000 kWh/year, or an average of 25 kW (i.e., average of 25% of the rated power over 8,760 hours in a year). This wind power generation could be 70-80% more than that achieved by solar PV (estimated at 120,000 kWh/year for this location).

Note: Bureau of Meteorology (BOM) weather data recorded at 10 m only gives an average wind speed for similar locations on King Island of 5.5-6.5 m/s, or 60-70% of the 100 m value.
Can a wind farm generate more power than a solar PV system?

Yes, but not always and only when the wind speed is high – and this depends on where you are in Australia and the size and height of the turbine (turbine size and height affect the ability to access higher wind speed and generate more power).

Figure 13 included a simplified comparator line (orange) predicting what a same sized (or rated) solar PV system might generate compared with wind power. To the right of this comparator line, a wind farm can generate more power than a solar PV system. To the left, the wind farm would produce less power.

This comparator line would shift (left or right) depending on a site’s location and the solar PV power generation potential. For instance, solar PV at a site in Tasmania would produce less power than a site in Queensland. A wind farm in Tasmania would therefore have a greater advantage over a solar PV system at lower wind speeds.

Example 2 included a comparison between wind power generation for a 100 kW wind turbine versus a 100 kW solar PV system on King Island.

Does wind power generate renewable energy certificates?

Like solar PV, wind power can create renewable energy certificates (RECs) under the Australian Government’s Renewable Energy Target (RET) scheme. These RECs are equal to 1 MWh of renewable electricity generated. They are divided into two types depending on the system size:

- **Small Technology Certificates (STCs),** where the system size is <100 kW. The value of STCs created up to 2030 can be rolled up and sold upfront as a cost offset or a subsidy.
- **Large Generator Certificates (LGCs),** for larger systems. These RECs can be redeemed and sold on an annual basis to generate income.

Market prices for these certificates can change but have been in the range $34–55/MWh during 2021-22 (Figure 15).

Example 3 gives an estimate of the RECs generated from the proposed 100 kW wind turbine on King Island in the Bass Strait (presented in Example 2).

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Does wind power reduce my carbon emissions?

In the same way as solar PV, wind power can reduce carbon emissions by avoiding the use of electricity generated from fossil fuel sources (e.g., coal-fired power station, gas turbines) or on-site power generation (e.g., diesel genset).

The mix of fossil fuels used for the grid supply depends on where the retailer or customer buys the electricity from (i.e., coal-fired power station, gas turbine, wind, solar, diesel genset). The emission of grid electricity or on-site power generation can be estimated using Australian Government reference emission factors.

Example 3 includes an estimate of the carbon emission reductions for the proposed 100 kW wind turbine on King Island in the Bass Strait (presented in Example 2).

What about carbon credits?

Wind power cannot create Australian Carbon Credits Units (ACCUs) if generating electricity and claiming RECs under the RET scheme. But if used for another (mechanical) purpose (e.g., directly pumping water), it may be able to create ACCUs if wind power is replacing another non-renewable energy source (e.g., diesel/petrol).

Example 3

Renewable energy certificates generated and carbon emissions saved from a 100 kW rated wind turbine

The 100 kW wind turbine on the west coast of King Island was estimated as generating about 220,000 kWh/year.

Renewable energy certificates (RECs)

220,000 kWh/year = 220 MWh/year or 220 RECs

As the system is 100 kW or greater, these RECs would be Large Generator Certificates (LGCs) and must be redeemed and sold annually.

Carbon emission savings (t CO₂-e/year)

King Island is not connected to the mainland supply and generates non-renewable electricity from diesel gensets. The emission factor (EF) for diesel fuel use is 70.1 kg CO₂-e/GJ. Diesel fuel required to generate one MWh of electricity is typically 290 L or 10.3 GJ.

The carbon emission saved per MWh is:

70.1 kg CO₂-e/GJ × 10.3 GJ
= 722 kg CO₂-e/MWh
= 0.72 t CO₂-e/MWh

Total carbon emissions saved:

~220 MWh/year × 0.72 t/MWh
= 158 t CO₂-e/year

Is wind power more expensive than solar?

Wind power is more expensive than solar PV on a rated power ($ per watt) basis (Figure 16).

At a small scale (<100 kW), it can cost 3–4 times the lowest cost6 of solar PV (e.g., for a 99.9 kW rated system, $2.20–2.60/W for wind power vs $1.10–1.30/W for solar PV).

At larger utility scales (>10 MW), the cost gap narrows to just over double (e.g., for a 100 MW rated system, $2.20–2.60/W for wind power vs $1.10–1.30/W for solar PV).

To compete with solar PV, wind power must generate more power and/or add value by diversifying renewable power generation:

- **More power** – wind power must usually generate 2–3 times more power than solar PV, and even more for smaller-sized turbines, by locating wind turbines at high wind speed sites.

- **Diversifying renewable power generation** – wind power must produce power at times when solar PV or other generation sources cannot (e.g., at night) and/or when it is more expensive to do so (e.g., instead of using a diesel genset when grid prices are high).

The higher cost explains why wind power has fallen out of favour as a small-scale (<100 kW) power generation option. However, in some situations, off-grid wind power systems can generate the same amount of electricity as a diesel genset but at less cost. However, wind power remains competitive at larger (>1 MW) and utility scales because it can supply power when solar PV is not available at lower cost than other sources. ARENA predicts that new utility-scale wind farms built since 2020 can generate electricity for grid supply at a cost of about $50–65/MWh.7

I still want to install wind power – how much will it cost?

Wind power system costs can vary widely depending on size, quality of components and location. Figure 17 provides a guide to the cost based on the rated power installed.

Wind power systems usually comprise one or two wind turbine(s) at <1 MW, with multiple (1-3 MW) turbines used for larger wind farms.

A substantial part of the installation cost (Figure 18) is for the turbine tower, transporting the turbine to the site, and specialised equipment and labour needed to erect the tower and mount the turbine (at heights up to 100 m). Like a solar PV system, costs can increase (e.g., by 50–100%) where the location is remote and/or there are extra costs to connect and integrate a wind power system with the grid or an off-grid system. These potential extra costs can only be confirmed by speaking to a supplier.

Example 4 provides a cost estimate for the proposed 100 kW wind turbine on King Island in the Bass Strait (presented in Box 2).

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6 Lowest cost would be for the simplest installation near an urban or major town centre.


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Figure 16: Relative installation cost (2022, ±10–20%) in $/W for wind power versus solar PV for an installation next to an urban or town area. Cost would be higher in remote areas or where extra infrastructure (e.g., for grid connection) or site preparation is required. An installation cost subsidy for systems <100 kW is potentially available as a result of generating Small Technology Certificates under the Renewable Energy Target (RET) scheme.

Figure 17: Potential cost range ($) for a wind power system based on size (in kW). Dashed lines reflect the cost range.
Will a wind power system save me money?

Installed on your farm or land, wind power can save money by replacing electricity paid for from the grid or generated on-farm using a diesel genset.

- **Grid-supplied electricity** – replacing electricity you buy will be a behind-the-meter (BTM) saving. This BTM saving can be identified from electricity bills to see what energy use, network and other charges wind power can avoid.

Example 5 includes an estimate of the cost savings and potential investment return for proposed 100 kW wind turbine on King Island in the Bass Strait (presented in Box 2).

- **On-site electricity generation** – the money saved from replacing on-site electricity generation will be the variable cost of fuel and other maintenance/operating costs.

Example 5

**Estimated cost savings and investment return from a 100 kW rated wind turbine**

The 100 kW wind turbine on the west coast of King Island was estimated to cost $620,000.

The cost of fuel on the island is more expensive than the mainland, at up to $2.50/L. A diesel genset might use 290 L/MWh, so to generate 220 MWh of electricity per year, up to 63,800 L might be required, which would cost $159,500 per year.

The information below summarises potential savings and time to payback for the wind power system based on energy cost savings alone. It assumes all the wind power generated is used in place of diesel-generated electricity (which may not always be the case). It allows some additional costs for maintaining the wind turbine ($25,000/year) and suggests an investment payback of 4.4 years for the wind turbine.

<table>
<thead>
<tr>
<th>Wind power generation</th>
<th>220,000 kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net annual savings/revenue (A)</td>
<td>$142,200</td>
</tr>
<tr>
<td>Diesel savings (avoided)</td>
<td>$159,500</td>
</tr>
<tr>
<td>Extra wind turbine maintenance/repair costs</td>
<td>($25,000)</td>
</tr>
<tr>
<td>LGCs at $35/MWh</td>
<td>$7,700</td>
</tr>
<tr>
<td>Investment (B)</td>
<td>$620,000</td>
</tr>
<tr>
<td>Investment payback (B/A)</td>
<td>4.4 years</td>
</tr>
</tbody>
</table>

Figure 18: Potential cost breakdown for a 5 kW wind turbine. Cost breakdown includes the STC rebate or subsidy for RECs generated by a <100 kW system over the deeming period, which would be taken off the installation cost by the supplier (and reduces the net cost to ~$28,500). Information based on industry feedback.

**Example 4**

**Estimated cost for a 100 kW rated wind turbine**

The proposed wind turbine on the west coast of King Island has a rated power of 100 kW. Per Figure 17, a 100 kW wind turbine would cost in the order of $440,000. However, it would need to be built on King Island, requiring all equipment to be transported by ship and remote labour working conditions. According to the supplier, this situation could add up to 40% of the system cost, making the installed cost potentially $620,000.

The 100 kW wind turbine on the west coast of King Island was estimated to cost $620,000.
Can I lease my land for a wind farm instead?

Leasing land for a wind farm if you have a suitable location can be an opportunity for rural producers or farmers to earn income (Figure 19). Suitable locations typically have average wind speed of 8–9 m/s; reliable and consistent wind or airflow all year round; low impacts on the environment, visual amenity and neighbours; and planning development approval permission.

A wind farm lease allows the developer to construct wind turbines and other structures (e.g., access roads, power cables, substation) on the subject land. In return, the property owner receives land rental payments over the lease period (which may be up to 35 years).

A typical wind farm project can require 15–20 hectares per megawatt installed (or ~4–5 MW per square kilometre), even though only about 3% of this area is used. This area is needed to space turbines apart (usually by seven rotor diameters) to avoid obstructions in airflow that can reduce turbine performance.

Figure 19: Yandin Wind Farm in Western Australia has 214.2 MW (51 x 4.2 MW) of wind turbines and was built by Alinta Energy on leased land, enabling the landowners to continue their normal farming activities. Despite their size, the turbines only occupy about 0.03% of the project site, meaning existing land uses can co-exist. Photo: Energy, www.energymagazine.com.au/was-biggest-wind-farm-open-for-business.

Do wind turbines impact the environment?

As with other energy supply options, wind power systems can have environmental and amenity impacts. These can include, but are not limited to:

- Land clearing for the tower and other infrastructure (roads, structures, power lines), which can reduce habitat quality or degrade habitats for wildlife, fish and plants.
- Spinning rotors, which pose a threat to flying wildlife like birds and bats.
- Visual amenity, as large wind turbines can diminish views and the visual beauty of landscapes.
- Noise, which can cause health annoyance or effects for some individuals (although not all such effects have been confirmed).

A wind farm or turbine will nearly always require planning or development approval. For larger turbines or wind farms, these approvals will require assessment of the potential environmental impacts. Planning permits may impose limits or controls on where and how they can be installed and/or operated.

Local government planning and state government environmental agencies should be consulted when planning a wind turbine or wind farm. Across Australia, there are different policies and guidelines that can apply, especially for noise limits. The Clean Energy Council of Australia (www.cleanenergycouncil.org.au) provides further information, including best practice guidelines for developing wind energy projects.

End-of-life disposal options

Wind turbines have a life expectancy of 20–30 years, although some can last longer. In Australia, there are more than 100 wind farms, and very few of these are more than 15 years old, so there has been no demand for end-of-life (EOL) disposal. Luckily, when this time comes, many components of a wind turbine are recyclable or can be disposed of without using landfills.

The tower and nacelle, which contains the gearbox, rotor shaft, generator and other mechanical components, contain large amounts of steel, copper and aluminium, and there are well-established recycling processes and demand in Australia for these materials. Blades, which are mostly made from composite materials (plastic, fibreglass, carbon fibre), are more difficult to recycle but can be processed and disposed of using a waste-to-energy system.

The biggest challenges associated with EOL disposal of wind power system components are the logistical hurdles and costs involved in dismantling and removing decommissioned wind turbines from often remote locations, and removing paint from towers, which can require sandblasting and be labour intensive.

There is much research and development being undertaken to make wind power systems more sustainable – from prolonging their design life to improving the recyclability of materials used in their manufacture.

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Challenges that may occur when installing wind power systems

There can be reasons why a wind power system can't be installed at a site and additional cost implications.

Some of these are summarised in Table 1 and they should be raised with a supplier when considering a wind power system and the cost savings and/or investment payback you may achieve. Many of these are the same as for installing solar PV. Remember, an equipment supplier will often paint the most optimistic picture, so it is important to understand what might go wrong or other costs you may end up paying.

### Table 1. Challenges that can hinder using a wind power system at a site.

<table>
<thead>
<tr>
<th>Challenge/issue</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low wind speed</td>
<td>Mean average annual wind speeds need to be ≥6 m/s at the turbine operating height for wind power to be viable when compared with a solar PV system. It is often recommended that wind speed on a site be measured for at least 12 months prior to installation.</td>
</tr>
<tr>
<td>Extreme wind gusts</td>
<td>There are maximum wind speeds that wind turbines cannot handle (even when they are not operating), and these should be checked with a supplier.</td>
</tr>
<tr>
<td>Inadequate area or setback distances from neighbours</td>
<td>Enough space is needed to ensure unobstructed airflow, especially where land is well-developed or not cleared (i.e., buildings, trees, other structures) and/or more than one turbine will be installed. There should be a large enough setback (at least several hundred metres and even more for larger wind turbines) to prevent potential noise nuisances for neighbours.</td>
</tr>
<tr>
<td>Planning rules</td>
<td>Planning rules may restrict wind power systems or require onerous development requirements and/or environmental assessment that add to the cost.</td>
</tr>
<tr>
<td>Environmental concerns</td>
<td>The presence of rare birds or concerns about impacts on wildlife or visual amenity may impede or prevent a wind power system from being installed at a site.</td>
</tr>
<tr>
<td>Inadequate electrical system/wiring</td>
<td>There may be a need to upgrade the electrical wiring and switchboard at extra cost.</td>
</tr>
<tr>
<td>Network approval requirement and connection conditions</td>
<td>The network connection may restrict the size of the system. Approval requirements may delay installation. The network operator may restrict operation and/or inverter power factor settings. Network safeguards and monitoring requirements for larger systems may increase the installation cost and ongoing costs.</td>
</tr>
<tr>
<td>Variable on-site demand, too much export</td>
<td>Poor use of wind power by on-site demand means power exported to the grid will have a lower value, reducing the cost savings a system can deliver.</td>
</tr>
<tr>
<td>Low cost and poor-quality turbine, charge controller and/or inverter</td>
<td>A poor-quality turbine, charge controller and/or inverter can require frequent replacement if not covered by warranty, resulting in lower power generation and more rapid decline in output.</td>
</tr>
<tr>
<td>Electricity and/or REC prices fail</td>
<td>Cost savings will be reduced if electricity or REC prices fall.</td>
</tr>
<tr>
<td>Restricted/limited warranty</td>
<td>A restricted or limited warranty will not adequately cover the expected life of the turbine, charge controller and/or inverter, resulting in replacement costs when components fail.</td>
</tr>
<tr>
<td>Maintenance and support</td>
<td>Poor maintenance of the system can lead to system failure or performance decline, and support can be expensive to access if components fail and there is no local maintenance service available. Maintenance also requires expensive equipment to access turbines at elevated heights.</td>
</tr>
<tr>
<td>Ineffective operation with diesel gensets for off-grid applications</td>
<td>Diesel gensets struggle when operating at &lt;30% of their load, which can be problematic as they need to be able to provide a reliable supply for wind turbines to operate with.</td>
</tr>
</tbody>
</table>

Where can wind power systems work best?

The success of a wind power system depends on the reason for the system being installed, where it will be located, its size, what the operator expects it to achieve, and their investment criteria. The following are some general guidelines to ensure the success of a system, but every situation is unique and should be considered on an individual basis.

- **Consistent and high wind speeds throughout the year** – average annual wind speed (at wind turbine operating height) should be at least 7 m/s for small-scale wind turbines (<100 kW) and at least 6 m/s for large-scale wind turbines (>500 kW).
- **Non-developed and (partially) cleared land** that minimises obstructions to airflow.
- **Supplementary to existing power supply** – if a battery is not available, wind power works best when paired with an existing power supply because it is not dispatchable and can’t be relied upon.
- **High power cost** – if you are paying a high tariff or using a diesel genset, wind power can generate greater savings and be more affordable.
- **Low solar potential** – wind power may have an advantage over solar PV at southern latitudes or in areas with lots of cloudy weather where solar PV generation is lower and/or less reliable.
- **Power diversification** – wind power can be effective where it diversifies renewable generation and improves supply reliability, or reduces energy costs and emissions.
- **Systems ≥500 kW** – even though they do not attract the STC subsidy/rebate, these systems generate much more power as their turbines operate at greater heights where wind speeds are higher.
- **Carbon emission reduction potential** – like solar PV, wind power can lower carbon emissions, although this may depend on whether you are using on-site diesel generation or grid power, and which state you are in.
- **Investment payback of 6-12 years** – the payback will usually be longer than for a solar PV system, depending on the electricity tariff of cost, although it can be shorter, e.g., four years for an off-grid system that relies on expensive electricity from a diesel genset.
Emerging wind power technologies

New technologies are being developed to improve the performance of wind power systems (Figure 20).

Some of these technologies rely on very different approaches to convert wind energy into electricity, or change the design of the turbines to make them safer or improve their efficiency. Some examples are:

- ‘Resonant’ oscillations created by the wind in materials to generate electricity.11
- Having the wind move charged ions through an electric field to generate electricity.12
- Directing wind into an enclosed vessel where rotating blades are contained and can safely operate.13
- Enclosing the blades on a horizontal-axis turbine to nearly double their performance.14


13 See www.halcium.com.
How big should a wind power system be?

It depends on the situation. If connected to the grid and behind the meter (BTM), a system is most often sized at or just below the peak or highest electricity demand in kW, as observed on the electricity meter or by monitoring. This sizing will generally result in a close to zero-export system, where wind power generated is mostly used to displace on-site demand throughout the year. The system is usually not sized any larger unless there is a battery to store surplus generation or there is a good feed-in tariff for exporting it to the grid.

For a larger utility-scale system, the size will depend on land available and the commercial business case or investment return. With an off-grid system, a larger-than-peak-demand wind turbine may be installed to maximise demand displacement, even if it means limiting (or tapering) wind turbine generation (i.e., not fully using the wind turbine electricity generation potential).

How much land do I need?

Wind turbines need larger areas than solar PV systems to provide spacing between multiple turbines and be set back (up to several hundred metres) from neighbours. A good heuristic is 15-20 hectares per megawatt of rated power input plus setback, e.g., a 100 kW turbine would require 1.5-2 hectares, or at least 125 m × 125 m, plus additional space if needed to be set back at least 300 m from nearest receiver.

What wind speeds do I need?

Average annual wind speeds (at wind turbine operating height) should be at least 7 m/s for small-scale wind turbines (<100 kW) and 8 m/s for large-scale wind turbines (>500 kW). These wind speeds should be relatively consistent all year round. It may be prudent to first measure wind speed for at least 12 months if wind data is not available, to confirm that wind turbines would work well on a property.

How can I find out how much energy I can generate from wind power?

Speak to a supplier or use the design chart (Figure 13) and wind speed map (Figure 10) in this report to make an estimate of annual electricity generation potential. More detailed (hourly) modelling requires specialists or should be provided by suppliers.

Can I mount a wind turbine on my roof?

Yes, but it may require specialised support and/or reinforcing to take the forces that will be on the wind turbine. You should speak to the supplier and may need to obtain advice from a structural engineer.

Can I check if a wind power system provider is properly trained/accredited to install my system?

The Clean Energy Council-approved installers list includes some accredited for wind power. If possible, use one of these. Otherwise, carefully check the qualifications and experience of the supplier, including checking with the owners of wind power systems they previously installed, and review guarantees, warranties and any ongoing maintenance support that is offered.

Where can I go for information on wind power that is not from a salesperson?

The Clean Energy Council website (www.cleanenergycouncil.org.au) provides information about wind power, including guidelines for wind energy projects and wind farms. Other useful information resources are published by government agencies and industry, and a selection of these are listed below.


How else can wind power benefit our farm?

Besides reduced electricity costs and carbon emissions, other benefits include the opportunity to market to sustainability-minded customers, the use of non-productive land, and for additional revenue through co-use of suitable farmland.

Can wind power cause environmental problems or impact wildlife and/or neighbours?

Wind turbines can potentially be dangerous to birds. Land clearing for wind turbines and other associated infrastructure can affect sensitive habitats. Wind turbines can affect visual amenity due to their heights of up to 100 m. Noise nuisances can be a potential issue for neighbours if setbacks or buffer distances are not sufficient.

Are wind turbines easily damaged?

Not under most conditions. However, turbines do have cut-off wind speeds above which they should not operate and need to be regularly maintained to ensure braking mechanisms work reliably. Very large hail and high wind speeds or cyclonic conditions can cause damage, and most turbines also have a maximum wind speed for installation. Check with suppliers on the quality of wind turbines as this can affect their resilience and potential for any weather damage.

Can crops be grown or can animals graze near or between wind turbines?

Yes, so long as clearances below spinning rotors are sufficient so there is no risk to farm machinery that requires access and animals won’t be adversely affected by wind turbine noise.

Is wind power noisy?

Yes, and setbacks of several hundred metres at least are recommended to ensure that noise does not impact your home or annoy neighbours. Larger setbacks (e.g., up to 1 km) may be necessary to ensure that people or farming activities sensitive to noise are not affected.

What can I do if my system is not working or needs maintenance and my farm is in a rural area?

Contact the system supplier. If they are a Clean Energy Council-approved wind power installer, they must provide a warranty and this should be factored into the purchase price, and response and repair times should be requested and agreed, along with any added costs. If outside the warranty period, a suitable maintenance agreement can be put in place that specifies potential repair costs or charges. The capability and cost of a supplier to maintain and repair the wind power system should be considered at the time of purchase.

What regular maintenance is needed for a wind power system?

A wind power system should be regularly inspected (e.g., at least yearly and generally twice a year) to keep it in consistent working order. During the inspection, the wind turbine is shut down and all important mechanical and electrical assemblies are checked (and cleaned as necessary), minor repairs are performed, and consumables such as greases, oils and filters are changed. In remote and regional areas, some suppliers install monitoring equipment that indicates whether there are fault or maintenance issues, which even though may cost extra may save money in the long run.

What can affect installation costs?

Refer to the ‘Challenges that may occur when installing wind power systems’ section.

Can I install the system myself?

Yes, a wind power system can be included on the homeowner’s property insurance policy, but this should be confirmed with the insurer and there may be an additional premium. This discussion should occur before buying a system as the insurer may have specific requirements on the type and quality of installation and installer. In some cases, suppliers may be able to offer standalone policies to cover the wind power system at added cost, which may include other warranty, repair, and maintenance benefits.
Do I have to also install a battery?

No. A battery is optional but can help maximise the use of power generated by a wind turbine. However, batteries can be expensive to install and may not have the same financial payback.

What can I do if my system is incorrectly installed or the supplier won’t honour the warranty?

National consumer laws (see www.consumer.gov.au) guarantee rights when goods and services are bought, including rights to repairs, replacement and a refund. You can lodge a complaint with the Office of Fair Trading (sometimes called Consumer Affairs) in your state or territory. But these rights may not apply if the system cost is >$100,000 and bought for businesses purposes. If a Clean Energy Council-approved installer is used, a complaint can be lodged with this organisation, but it does not necessarily have the power to compel action by the supplier. It may be necessary to seek legal advice on what other action can be taken. Your best protection is to ensure that you carefully review and check the purchase agreement and/or warranty for the wind power system before buying to ensure it provides you with proper assurances that you can cite in any legal action.
Successful examples and case studies in rural industries

Several different examples of where wind power systems have been installed or are proposed for rural producers, farmers and/or communities are presented below.

Wind-solar-battery storage off-grid system for a dairy farm

In 2016, the operators of a dairy farm in Gippsland, Victoria installed 3 kW of wind power (as 3 × 1 kW vertical-axis wind turbines), along with 60 kW of solar PV and 180 kWh of lead-acid battery storage to reduce their electricity costs (Figure 21).15

The dairy farm used 80,000-100,000 kWh/year to operate vacuum pumps, compressors and milk vat refrigeration systems for milking, as well as pumps for pasture irrigation in summer.

The total system cost was about $200,000, which was likely broken up as follows.

- 3 × 1 kW wind power – $15,000-20,000 (or $5-7/W)
- Solar PV – $60,000-70,000 ($1-1.10/W)
- Battery storage – $110,000-120,000 ($600-700/kWh)
- Other costs – $15,000-20,000

This off-grid system was installed in place of developing a new grid connection to replace the existing system, which was under-sized and had become damaged due to overheating. The battery storage was sized to provide enough reserve energy for 2-3 days of bad weather. While solar PV would generate most of the power needed, wind power was installed to diversify the power generation and top up batteries overnight and/or during bad weather when solar PV output was low, which was important as one-third of the farm’s electricity was required before sunrise.

The electricity cost savings of the new off-grid system were about $30,000/year, with a payback of six years when future energy price rises were considered. The installation was financed via a small business loan, with the savings in electricity costs used to make the loan repayments.

Regional wind farm community cooperative

Located at Leonards Hill, Victoria, 100 km north-west of Melbourne, Hepburn Wind was Australia’s first community-owned wind farm (Figure 22).16 Built in 2011, the 4.1 MW wind farm (comprising 2 × 2.05 MW turbines) generates enough clean energy for more than 2,000 homes in the region.

At the time, the wind farm cost nearly $15 million ($3.65/W), of which $10 million was raised from small investments made by more than 2,000 local and non-local retail investors. The balance came from state government grants and bank loans.

Project conception to completion took more than two years and involved planning, raising funding, securing development approval, organising a construction contract, and building and commissioning the wind turbines. Since commissioning, the wind farm has generated an average of about 11,000 MWh of electricity each year (at an average capacity factor of 30%), distributed via the grid. This wind power significantly reduced the region’s dependence on electricity from the coal-fired power stations in the nearby Latrobe Valley and has resulted in carbon abatement of about 12,200 tonnes of CO2-eq each year.

Small-scale wind turbine to diversify renewable electricity generation for off-grid telecommunications towers

Diffuse Energy (www.diffuse-energy.com) is a Newcastle-based start-up launched in 2018 from the University of Newcastle. The company has developed an innovative design for horizontal-axis turbines that uses a shroud or diffuser that improves power generation performance. Its first product, the Hyland 920, is a small turbine with rated power output of 200 W that is designed for remote telecommunications applications. It can be installed on off-grid telecommunications towers in regional areas (Figure 23) to replace existing diesel gensets being used with small solar PV and battery systems for power supply (i.e., it diversifies renewable electricity generation).

The turbine costs about $7,000 to install on a telecommunications tower. The turbine generates about 750 kWh of electricity per year at most sites where wind speeds are about 7 m/s. The cost of diesel-generated power at these remote sites can be as much as $1.50–4.00/kWh once the cost of diesel supply and diesel genset maintenance is considered. The turbines can therefore save up to $2,000/year, with a payback of about four years for this application.

Development and application of the new Diffuse Energy wind turbine technology is being funded by the Australian Renewable Energy Agency (ARENA). Clients that have already bought and installed the wind turbines include NBN Co, Optus, and the Newcastle and Port Stephens councils in northern NSW.
