The Viability of Domestic Wind Turbines for Urban Melbourne

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Prepared for:

Executive Summary

Sustainability Victoria engaged the Alternative Technology Association to investigate the feasibility of small-scale, grid-connected wind turbines for urban Melbourne. This report outlines the findings of this research, highlighting issues which may face the emerging market for this technology, including turbine performance, planning and grid-connection.

Case studies of urban wind turbines overseas demonstrate poor economic performance and long payback periods, a problem frequently attributed to a lack of accurate wind measurement preceding installation. In cases where the wind regime is known, power curve data from manufacturers has been found to be inaccurate, and there is a lack of standardised testing done to verify these power curves.

Urban areas have, by the nature of their built-up topography, slower wind regimes than open rural areas. The number of obstacles in the path of the wind also makes it difficult to model the wind resource. Models and wind maps that do exist have a resolution far lower than the size of an average building, and turbulence can result in two adjacent locations having vastly different wind regimes.

Due to the difficulty of predicting wind resource in a given urban location, the report has found that the installation of anemometers to measure the wind in a potential location is recommended before considering any wind turbine installation. Anemometers are both affordable and available, and although collecting data for one year is ideal, compromises can be made for small domestic installations.

Planning requirements specifically targeting small-scale wind turbines in urban Melbourne are still some way off. The number of grid-connected wind turbines across the state is very small at present, and, as a result, councils are yet to produce any planning guidelines governing their installation. At this stage, turbines are treated on a case by case basis, resulting in little consistency. Turbines are likely to require more complex regulations than solar PV due to the nature of their construction; noise and aesthetics for example are certainly not an issue for solar photovoltaic systems.

Domestic wind turbines experience many of the same difficulties as solar photovoltaics when negotiating grid connection. Whilst much has been done with respect to standardisation of terms and conditions for connection with distribution businesses, electricity retailers still have very little standardisation in their procedures, and the cost of grid connection and new meters is large compared to the potential returns from domestic generation. Work is currently being done to rectify this situation for the growing solar photovoltaic market and any advances in regulations and procedures should also benefit domestic wind.

The desktop study successfully concluded that:

- the urban environment is too complex to model with any accuracy; therefore
- the use of anemometers would be advised to check the wind resource at any potential site
- urban turbines have performed poorly overseas and payback periods are likely to be long
- bird strike and electromagnetic interference are unlikely to be significant

- turbines are still expensive, with installation and grid connection costs adding around $10,000 to the cost of the turbine
- at present, relatively few turbines are available on the Australian market and nearly all of these are horizontal axis machines

Due to the inherent limitations of a desktop study, further clarification on some issues would greatly benefit from a field trial. These include:

- specific local urban wind regimes
- technical performance of turbines and accuracy of manufacturer power curves
- noise output
- planning issues, for example height and noise restrictions and the ability of councils to process applications on a case by case basis
- grid connection issues particularly the negotiation of a retailer contract for the sale of excess electricity
- community acceptance of domestic wind turbines

From calculations performed using manufacturer power curves and approximations of system costs, it seems that there would be little value in installing a wind turbine in a location with wind speed less than 5m/s.

However, in suitably windy locations, wind turbines could prove an attractive alternative to solar photovoltaic power systems, with similar output and a lower capital cost. Finding out how much wind is necessary for this will require field trialling to see how individual turbines perform compared with manufacturers' claimed power curves.

Individual locations with reasonable wind speeds can best be identified using anemometers. Although these locations can not be used to generalise a wind regime, they could be used in field trials to establish a base wind regime at which the economics of domestic turbines are attractive enough to ensure mainstream uptake of the technology.

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1. Introduction

Currently, politics and media in Australia are focusing strongly on the dangers of climate change and what needs to be done to address the issue. Public awareness is growing and the desire to act is driving an interest in renewable power generation for homes. These drivers mean that the emerging international micro wind industry is attracting increasing interest.

Micro-wind is a new category of small rooftop mounted urban wind turbines and is an expanding market overseas. For the purpose of this report, micro-wind power has been taken to represent small-scale wind turbines up to 10kW rated output.

Small-scale wind turbines allow home and business owners to contribute to their own energy usage by harnessing the clean and renewable power of the wind. However deployment of the technology is at a very early stage in Australia. Some home owners in rural areas already have domestic wind turbines which tend to be in unobstructed surroundings and are generally not grid connected, whereas urban grid-connected turbines are relatively rare.

Those that do exist are most frequently owned by educational institutions, city councils and community parks. Where solar PV is a well known and widely recognized way to generate clean electricity, domestic wind turbines have the potential to become an alternative renewable energy for the small scale generation market.

The application of this technology in a grid-connected, urban environment has many advantages, including the generation of renewable energy and the accompanying greenhouse gas abatement. Other advantages include the potential for changing domestic power usage attitudes and habits and the reduction of transmission losses with power generated close to the point of consumption. However, there are a number of unanswered questions regarding their deployment, including both technical and non-technical barriers.

Investigation of the viability of domestic wind turbines in urban Melbourne involved examining factors such as planning issues, grid connection, technical performance, and turbine availability and cost. Although these issues have previously been investigated in the context of urban solar photovoltaic, the domestic wind turbine market has been largely ignored.

2. Background

2.1. Wind Turbine Systems

A grid-connected wind turbine system consists of a variety of components, including the turbine, the control system, cabling, the inverter and the meter. Some of these components are detailed below.

2.1.1. Wind Turbines

A wind turbine's blades harness the kinetic energy in the wind and use it to generate a typically DC current using a permanent magnet generator. There are two main types of wind turbine: horizontal axis and vertical axis.

Horizontal Axis Wind Turbines (HAWT)

Figure 2.1. An example of a horizontal axis wind turbine

HAWTs are the more recognisable, common turbine design and this type dominates the large commercial wind farm industry. HAWTs typically have three lift style blades and point into the wind stream. In large wind turbines this is done using direction sensors and large hydraulic 'yaw' motors. In small turbines the yawing is typically passive, where the fin behind the turbine causes it to point in the direction of the wind stream. Turbulence is a big problem for both hydraulic and passive yawing systems, as the turbine is constantly twisting around its vertical axis increasing wear and tear.

HAWTs can also have problems with over-speeding when running in an unloaded state resulting from grid failure or battery bank disconnection. A free-spinning turbine causes extra stress on components and can result in the machine self-destructing.

Noise is also often a problem, as it is the air flow over the fast-moving blade tips that can cause the high pitched whine commonly associated with small turbines. This design issue is widely understood, and some new turbine designs have a ring around the circumference of the blade tips, which successfully silences that whine.

Modern domestic HAWTs are typically equipped with some over-speed mechanism, such as 'furling'. Furling is when a turbine bends out of the wind during very high wind speeds and thus protects itself from the full force of the gusts.

Despite these disadvantages, HAWTs are still the most efficient in a clear wind stream and almost all of the domestic turbines currently available on the domestic market are horizontal axis machines.

Vertical Axis Wind Turbines (VAWT)

Figure 2.2: Two types of vetrical axis wind turbines, a Darrieus (left) and Savonius (right)

VAWTs come in two types: Darrieus and Savonius. Darrieus turbines are lift-based and generally have a few blades (typically three) joined to the central axis at their top and bottom or in the H-darrieus configuration where they are joined at their middle.

Savonius turbines, like anemometers, are drag-based. As such, Savonius turbines can never have a ratio of tip speed to wind speed (known as tip speed ratio) greater than one, and this reduced rotational speed can result in quieter operation.

Of the two types of VAWTs, Darrieus are significantly more efficient and it is this style which are mainly being developed for domestic use. However they still have a lower aerodynamic efficiency compared to a lift-driven HAWT, because the airfoils periodically stall during each revolution.[1]

VAWTs typically have fewer moving parts and a lower tip speed ratio than HAWTs which gives them the advantage of being significantly quieter. This is certainly an important consideration when considering a turbine for an urban environment.

Not having to yaw and face into the wind, VAWTs are also less sensitive to changing wind directions and therefore to turbulence. This is also a very important advantage for the urban environment.

[1] Refocus Volume 3, Issue 2, March-April 2002, Pages 22-24 *Wind energy in urban areas; Concentrator effects for wind turbines close to buildings*

A disadvantage of the VAWT is that they do not generally self-start. That is, they require power from the grid in order to start when adequate wind is blowing. This problem can be overcome by specialised design allowing the rotor to divert the air[2].

Despite the fact that there are no domestic VAWTs currently available in Australia, many are being developed for the international domestic wind turbine market. A notable Darrieus turbine from the Netherlands is called the Turby. There are several Turbys working in urban environments, most famously on the Town Hall in the Hague but also on top of a block of flats in the university town of Tilburg in the South of the Netherlands. The turbine is discussed later in this report.

2.1.2. Inverter

The inverter turns the DC output of the wind turbine into useable grid-compliant 240V AC. It is also an important safety device, and approved inverters will shut off the grid supply in the event that the grid fails or is switched off for maintenance. As it is vital that the wind turbine is safe and that the power is conditioned to match grid power, inverters require testing and approval before they are allowed to connect to the grid.

As with all electrical equipment, inverters must comply with the Australian Standard *AS3100 – Approval and test specification - General requirements for electrical equipment*, or an IEC equivalent. In addition, inverters must comply with Australian Standard *AS4777 – Grid connection of energy systems via inverters - Installation requirements*, containing requirements for the installation and testing of the devices.

Additionally, inverters require a Certificate of Suitability, handed out by the electricity regulators in each state – in Victoria the certification body is Energy Safe Victoria. Imported inverters (though not locally manufactured ones) must have approval under the Trade Practices Act (TPA)[3]. Finally, inverters must get an approval called a C-tick[4]. C-tick testing includes conducted and radiated emissions compliance measurements.

Testing and Certification Australia (TCA), the C-tick certification body, require emission output graphs from the inverter manufacturer which are tested for compliance with Australian Standards. There is no single Standard which is used for this approval, as some inverters have high frequency transformers, some have standard frequency transformers, and some new inverters operate without a transformer. A list of approved inverters is attached in Appendix 1.

Most approved inverters on the Australian market were designed for PV panels however in principle, are suitable for any small generator. In practise, minor adjustment of a software set-point makes them more suited to wind. Hush wind turbine's engineer, Peter Chrysostomou, explained that he reduced a delay period in the software to make their inverter more suitable for the intermittent nature of wind power.

[2] Refocus Volume 4, Issue 4 , July 2003, Pages 44-46 HAWT versus VAWT; Small VAWTs find a clear niche
[3] Trade Practices Act online at: http://www.austlii.edu.au/au/legis/cth/consol_act/tpa1974149/
[4] C-tick information available online at: http://www.rfi-ind.com.au/emc/c-tickEMCtest.htm

The only inverter designed specifically for the domestic wind turbines is the WindyBoy, made by the manufacturers of the popular and already approved SunnyBoy from Germany[5]. The WindyBoy has not yet been added to the approved list, however according to the manufacturer's specification (Appendix 2), the SunnyBoy and the WindyBoy are identical and can each be used interchangeably, with the exception of a single software set-point. Approval for this device is pending.

2.1.3. Load Dump

PV cells can be turned off when necessary, with no damage. However, most wind turbines should not run unloaded. In an unloaded situation a turbine may spin too fast and eventually self-destruct. If the turbine is generating power but there is nowhere for that power to go, it must be 'dumped'.

Such a load dump is necessary in the case of grid failure, or when the power company shuts the grid down for maintenance. Also, any power generated in the delay time before the inverter connects the turbine to the grid goes to the load dump.

Additionally, the load dump is necessary in times of extreme gusts, as only a certain amount of current can be drawn out of the generator before it overheats. Sometimes this dumped energy can be harnessed for something useful, such as heating water, but more often it is simply diverted into a heating element.

In the case of the Hush prototype, located at the Hume City Council offices in Sunbury, the load dump is a simple heating element located near the controller.

2.1.4. Metering

There are two basic types of standard uni-directional electricity meter commonly used in Victoria. The older type is the electro-mechanical induction disk meter, which uses a rotating disk linked to mechanical dials. The newer type is electronic with a digital LCD display, which is being increasingly employed in new installations.

These are typically programmable and include extended functions such as time-of-use (TOU) metering, which allows different tariffs to be applied at different times. Metering arrangements for grid connection are explained further in Section 3.3 - Grid Connection.

The metering of small embedded generators is governed by the Essential Services Commission's (ESC) Electricity Customer Metering Code[6].

Section 8.4(c) of the Metering Code Mar 2007 states the following:

> 'Metering equipment for non-market generators must be able to measure positive and negative flows separately' that 'allows the customer load and the non-market generator to be connected together on the customer's side of the meter so that any exports are "net metered"'; and

[5] SMA – online at http://www.sma.de/en/

[6] http://www.esc.vic.gov.au/NR/rdonlyres/FB66DEE0-B653-4395-B287-6B3D8C251794/0/ElectricityCustomerMeteringCodeECMCRevised20070301.pdf

> 'Where avoided cost payments or tariffs for the purchase of electricity from the non-market generator are based on different rates according to the time of day, interval metering equipment must be installed.'

That is, a new bi-directional meter must be installed. The code also indicates that the cost of this installation is to be borne by the customer.

2.2. Theoretical Power in Wind

Wind turbines are driven by the kinetic energy of the wind and it is very important to understand the limitations of the available resource – especially for small domestic turbines which have short blades and a small ‘swept area’.

The formula for the kinetic energy of a body is given by:

$$E_{kin}=½.m.v^2,$$

in which *m* is the mass of the moving body and *v* is its speed.

To apply this formula to wind, it is possible to substitute the amount of air flowing per second through an area of 1 m^2 for the mass value. The result is energy per second, or power, given in watts [W].

For a the total mass passing per second through the rotor we can use the equation

$$m = \rho.v.A.$$

where the wind has velocity *v*
the air density is ρ
the wind turbine has a swept area of *A* m^2

Substitution of the second formula into the first one leads to the formula for the power the turbine is theoretically exposed to and could harness if it were 100% efficient:

$$P_{wind} = ½.\ \rho.v^3.A$$

If the density of air[7] is 1.2 kg/m^3 the available power per m^2 rotor area is given by:

$$0.6v^3 \text{ Watt}$$

This is represented graphically below.

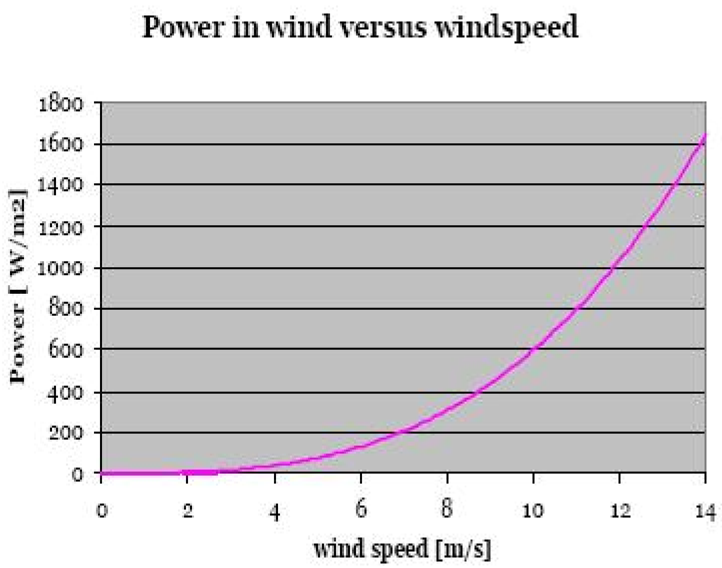


Figure 2.3: Theoretical power in wind

[7] Dry air at standard ambient temperature and pressure (25 °C and 100 kPa)

This means that at a wind speed of 4 m/s, for a theoretical 100% efficient wind turbine operating in theoretical 100% smooth wind, the total power per square metre available in the wind would be 38W

Power per square metre = 0.6 x 64 = 38 W.

Unfortunately, it is not possible to harness all of the available power as the wind escapes around the turbine and also will never slow to zero velocity. The maximum power able to be harnessed is given by Betz law.

2.2.1. Betz' Law

Betz' law was first formulated by the German Physicist Albert Betz in 1919. His book, 'Wind-Energie', was published in 1926. The law states that it is only theoretically possible to convert a maximum of 59.3% of the kinetic energy in the wind to mechanical energy using a wind turbine, and that this maximum power output occurs when the downstream wind has 1/3 the speed of the upstream wind. Proof of Betz' law is widely published on the internet and in academic papers[8].

Therefore, at 4 m/s, the theoretical maximum power that a turbine can extract from the wind is 59.3% of 38W per square metre of swept blade area, or 22.8W for a 1m^2 turbine. The swept area is related to the blade radius by the formula:

$$A = \pi r^2$$

It is very important to consider this data when evaluating the potential dimensions of an urban wind turbine.

The table below shows the theoretical maximum power extractable from with the wind passing through a given area.

			Maximum extractable per day at blade diameter (kWh)		
Wind Speed (m/s)	**Maximum extractable instantaneous power per square metre (W)**	**Maximum extractable energy per day per square metre (kWh)**	**1.15 m**	**2.1 m**	**3.7 m**
3	9.61	0.23	0.24	0.80	2.48
4	22.8	0.55	0.57	1.89	5.88
5	44.5	1.07	1.11	3.70	11.48
6	76.9	1.84	1.92	6.39	19.83

Table 2.1: Maximum extractable power in wind

A 3.7m blade diameter is quite large for a domestic turbine and is representative of the Westwind 3kW or the Skystream 1.8kW. The Swift turbine from the UK has a blade diameter of 2.1m and the Air X has a diameter of 1.15m.

[8] Betz, A. (1966) *Introduction to the Theory of Flow Machines.* (D. G. Randall, Trans.) Oxford: Pergamon Press.

2.2.2. Power Curves

A turbine's performance will be determined by the wind regime and by its power curve. A typical power curve for a wind turbine plots wind speed on the x axis against power output on the y axis. It will generally consist of a cubic curved section intersecting the x axis at cut-in speed, and flattening out or dropping at rated wind speed. The power curve below is for a Proven WT2500 Horizontal axis machine. It is rated at 2.5kW at 12m/s and has a cut in of 2.5 m/s.

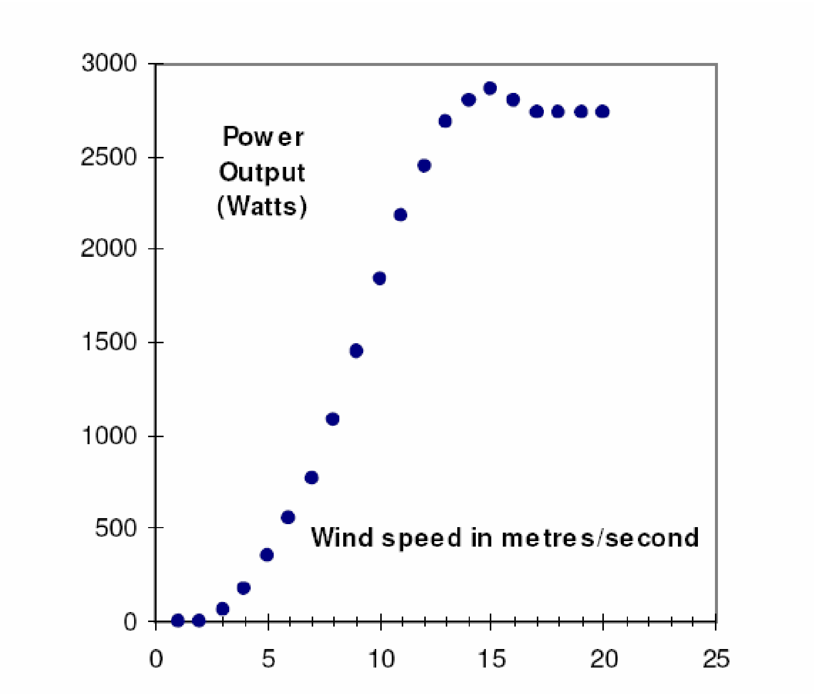


Figure2.4: A typical power curve

Turbine manufacturers will typically provide a power curve with their other specification data. Like the example above, they tend to be a low resolution curve showing approximate values and generally manufacturers do not provide anything of a higher accuracy. The data contained within a power curve is often not verified by an independent party and as such should be treated with caution. Even when wind turbines are tested, it is difficult to do so in an environment that is representative of a typical urban arrangement. For example, a wind tunnel test will give an accurate power curve for ideal conditions, such as smooth and steady wind flow. However, turbines will behave significantly differently in the real world.

Manufacturer power curves do not continue to increase in a cubic fashion like the power in the wind does. Instead they tend to reach their rated power and then either flatten or taper off again. Below rated winds speed however they do exhibit similarities to the cubic curve of the theoretical power in the wind.

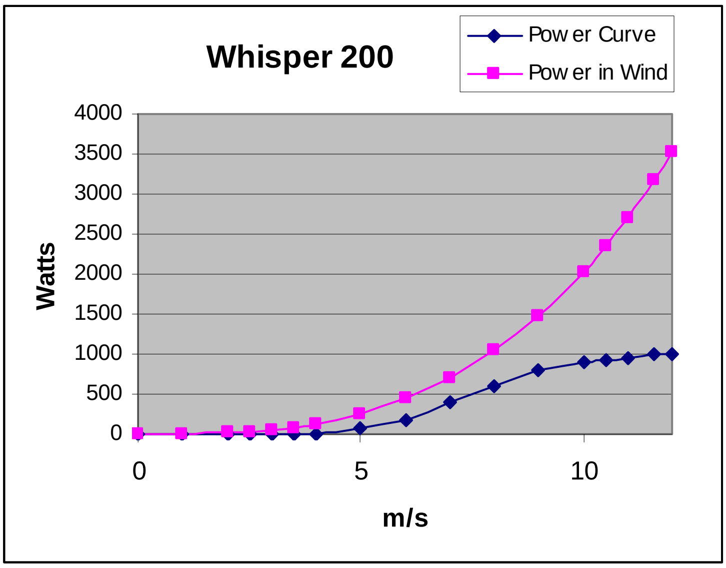


Figure 2.5: Whipser 200 Power Curve

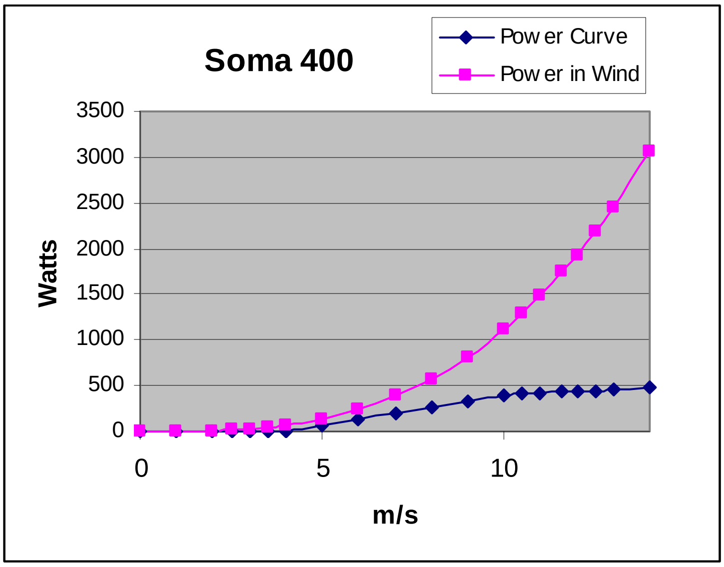


Figure2.6: Soma 400 Power Curve

At present, a significant gap exists between the potential power in the wind and power curves of existing small wind turbines. Whilst developing wind turbine technology further may increase efficiency and reduce this gap, it can never be higher than that given in the tables above, and consequently is limited by turbine size and the available wind regime in urban areas.

For urban locations, the potential for power generation will be limited by turbine size, which will in turn be limited by potential council regulations and / or planning guidelines.

2.3. Locally Available Wind Turbines

There are approximately 10 different brands and 30 different models of domestic wind turbines distributed in Australia. The output of these machines ranges from just a few Watts up to the large Westwind 20kW machine. A table detailing the specifications and prices of the machines is attached in Appendix 3.

The Southwest Wind Power, Air and Whisper machines in particular have been on the Australian market and relatively popular for many years. There are a few newer machines also available, such as the Enviro Wind from China that is available cheaply online, and in retail outlets. Product brochures including specifications are available online and the manufacturer websites are listed in Appendix 3.

2.3.1. Australian Manufacturers

There is currently only a single operating Australian manufacturer of wind turbines, Soma Power Pty Ltd.

Soma

Soma Power Pty. Ltd. in Copacabana, NSW manufactures a 400W and a 1000W machine. Both are widely available throughout Australia.

Figure 2.7: Soma Turbine

2.3.2. Ex-Manufacturers

Westwind

Westwind is a well-known manufacturer of wind turbines, and was previously based in Perth Western Australia. However the company was sold and relocated to Northern Ireland in 2006. The turbines are still available but must be ordered well in advance. They manufacture a 3kW, 5kW, 10kW and 20kW machines.

Figure 2.8: Two Westwind Turbines

Flowtrack

Flowtrack, based in Nimbin NSW, were manufacturing a 5kW two bladed machine developed with the University of Newcastle. However they are not currently manufacturing. Kali McLaughlin from Flowtrack reports that a sequence of unfortunate political/commercial events has led to a situation where the Flowtrack staff are spending all of their time on repairs and maintenance on existing turbines.

Flowtrack chose to sell small wind turbines with warranty periods which, it appears, has resulted in them spending a significant amount of time honouring warranty commitments. This may be either due to an overly-generous warranty, or perhaps an unreliable product.

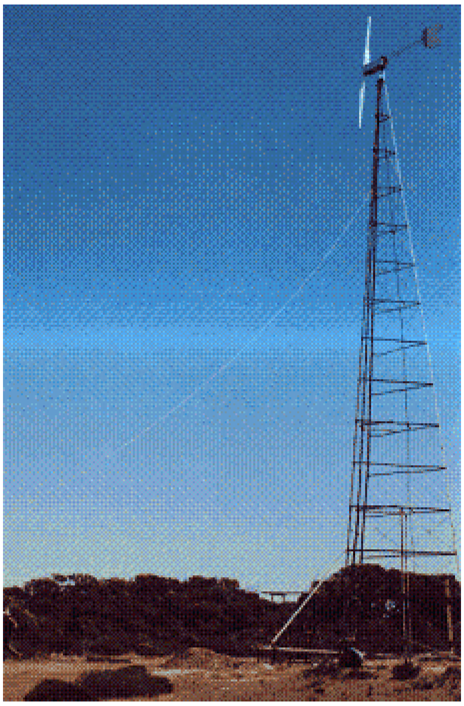


Figure 2.9: Flowtrack Turbine

2.3.3. Upcoming Manufacturers

Hush

The Hush Turbine is being developed here in Victoria. It is still in the development stages although its manufacturer hopes to have it on the market within a year. There is no power curve data available as yet. Hush has undertaken testing of two different sized prototypes – a 1KW and a 5KW version – with the 1kW machine presently being tested at the Hume City Council building in Sunbury, and the 5kW machine undergoing testing in a rural setting nearby.

Figure 2.10: Hush Turbine

Aerogenesis

A company called Aerogenesis are in the final testing stages of an upcoming 5kW machine. The owner David Wood is from the University of Newcastle and has recently been appointed the Editor for Aerodynamics and Small Turbines by the international journal 'Wind Engineering'. Commercial production of their turbine is expected in the next year or so.

Figure 2.11: Aerogenesis Turbine

Altaus Urban Turbine

A company called Altaus are in the process of developing a vertical axis turbine for the domestic market. They hope to have the turbine commercially available on the 1st of January 2008, and they already have many commercial commitments.

Figure 2.12 Altaus Urban Turbine

The performance of these machines remains to be seen but in the current climate of environmental concern, these emerging companies have the potential to lead a new Australian domestic wind turbine manufacturing market.

2.4. New and Emerging Technology

Below are some of the more interesting turbines which are either not available locally or not yet being marketed. The turbines are in various stages of market-readiness. Some are installed at test locations and some are still in development and are yet to publish power curves. Like domestic turbines all over the world, their power curves are typically not tested in the field.

Turby

The Turby is a reasonably well-known Dutch VAWT designed to be mounted on top of flat roofs. It has a 2m diameter and is 3m tall, and is rated at 2500W at 14m/s. Several Turbys have been installed in Europe although they are not yet available in Australia.

Peddle Thorpe Architects are tendering for the new Launceston Swimming pool facility and will be including a Turby on the roof of the building. They are not yet sure of costs but have allowed around $50,000 for the manufacture, transport and installation of a custom machine. They expect that if they win the project it will be arriving in approximately 1 year and installed soon after.

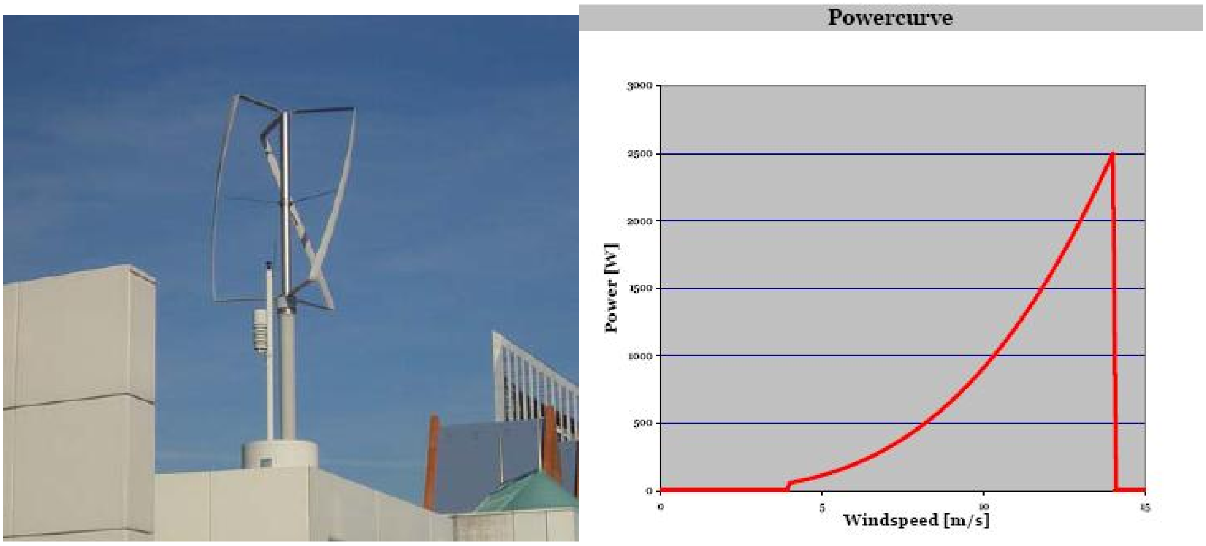


Figure 2.13: The Turby wind turbine and manufacturer's claimed power curve

The power curve for the Turby shows a cut-in speed of 4m/s and a peak output at 14m/s, followed by a shut down of the machine at higher wind speeds. At 5m/s the turbine output is around 100W.

Renewable Devices – Swift

The Swift turbine is a 5-blade, 1.5kW turbine manufactured in the UK. There is a circular rim around the blade tips which dramatically reduces noise.

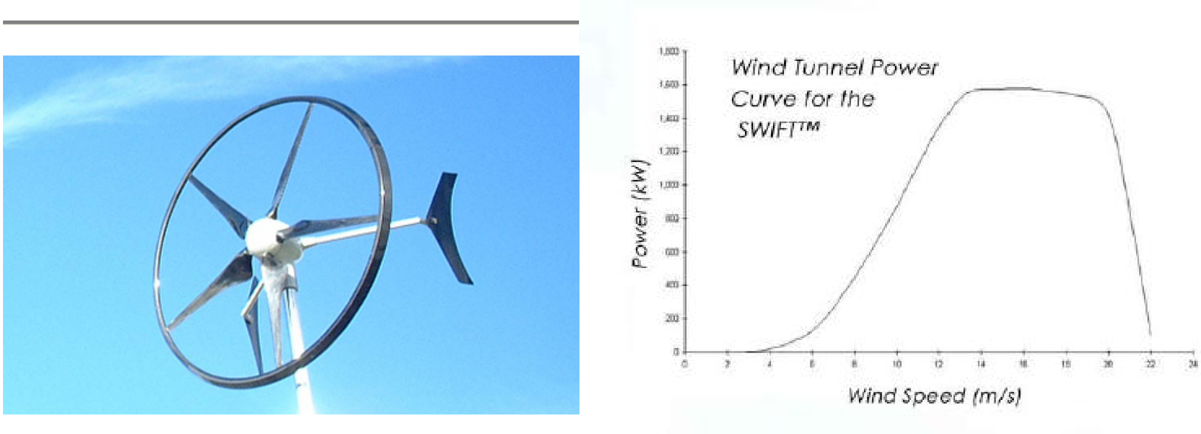


Figure 2.14: The Swift wind turbine and associated power curve

The swift has received several design awards and plenty of exposure unfortunately the product is still not market-ready. This is highlighted in the recent Warwick Wind Trials report (see section 2.5), where Swift promised several turbines to householders but later pulled out. This delay in production in the Swift's home country indicates that availability in Australia is still some time off.

Like the Turby, the Swift cuts in at around 4m/s, however it peaks at a lower 12m/s. Again, the output at 5m/s is somewhere around 100W.

NGUp WindWall

This very different Dutch turbine is similar to a VAWT but is installed horizontally. It is designed to be mounted on the edge of buildings and to capture updrafts. A 1.2m diameter, 9m long WindWall system rated at 3kW has been mounted on the roof of the head office of a light rail company in the Hague, Netherlands[9].

Figure 2.15: Windwall turbine in the Hague

[9] Dutton, A G, Halliday, J A, Blanch M J The Feasilibity of Building-Mounted/Integrated Wind Turbines (BUWTs): Achieving their potential for carbon emission reduction. May 2005

Skystream

The skystream turbine is manufactured in the US and is an all-inclusive wind generator (with controls and inverter built in) which is designed to be very quiet and to connect to the grid in residential areas. Energy Matters is a retailer in South Melbourne who have some Skystream systems on order. They were expecting delivery in May however no turbines have arrived as yet. Although it is not yet available in Australia, testing is underway for approval and if this proceeds as expected it will be available soon.

The Skystream turbine is a downwind machine with a 3.7m rotor diameter, and is probably not suited to inner urban homes. The manufacturer also recommends mounting it quite high in the air, at least 6m higher than anything within 100m of it. The power curve shows a cut in wind speed of about 3m/s and a rated 12m/s (2400W). At 5m/s it will generate around 200W.

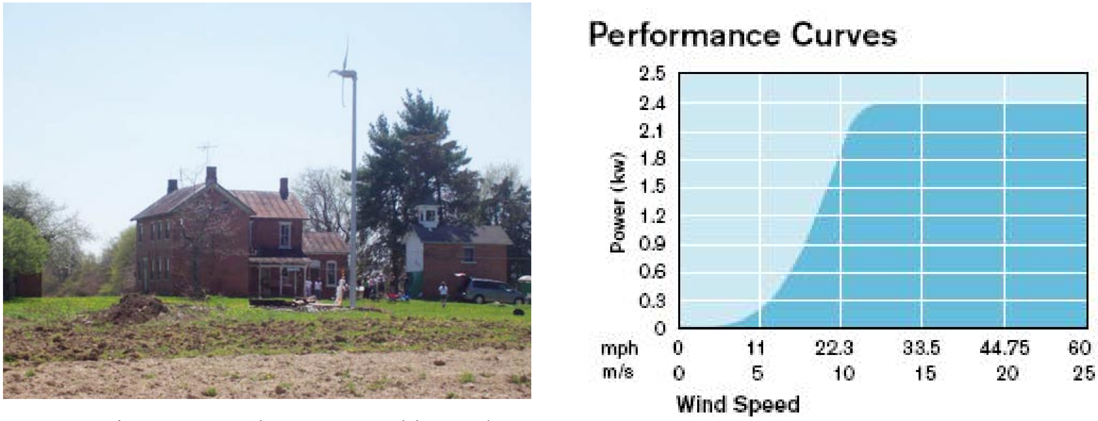


Figure 2.16: Skystream Turbine and power curve

QuietRevolution

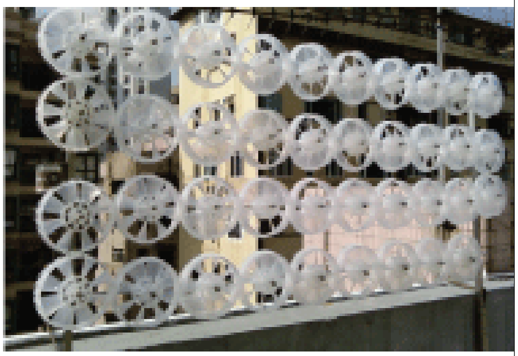
This is another VAWT, similar to the Turby but manufactured in the UK. It is not available in Australia as yet, but even if it were it would be prohibitively expensive at around £33,000 (AU$78,000). It is 5m high and 3.1m in diameter. Power curves are not published as yet although they estimate that in a 5.9m/s wind area the machine would generate around 10,000 kWhs annually.

Figure 2.17: QuietRevolution VAWT wind turbine

Motorwave

A company in Hong Kong have invented a wind system which consists of an array of small, cheap plastic rotors. These can be purchased online in kits of either 8 or 20 turbines. The idea is that the individual turbines are built up as an array. Not including postage, 8 turbines cost US$150 (AU$180) and 20 turbines cost US$250 (AU$295).

Obviously these turbines are built to be used in large arrays and the output at 5 m/s is too small to predict in the 8 and 20 turbine arrangements. It would be more useful to produce a power curve for a larger array of the turbines.



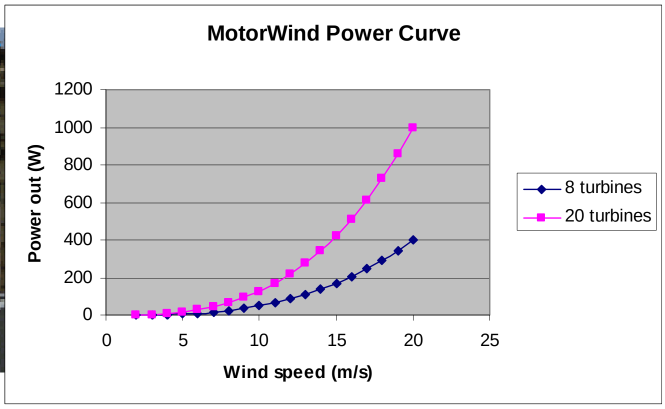


Figure 2.18: MotorWind turbine array and power curve

Turby	www.turby.nl
Swift	http://www.renewabledevices.com/swift/
WindWall	http://www.indiaenergyportal.org/files/CS130.pdf
Skystream	http://www.skystreamenergy.com/skystream/
Quiet Revolution	http://www.quietrevolution.co.uk/
Motorwind	http://www.motorwavegroup.com/new/motorwind/index.html

Table 2.2 Internet references for new and emerging turbines

2.5. International Research Reports

Domestic wind is a topic that has been studied previously by many groups in many countries, with some of the most informative and relevant studies summarised below. Typically, past studies of domestic wind turbines have shown that the technology is not economically viable. However, the studies generally point out various non-economic reasons why domestic turbines can still be beneficial. Commonly cited benefits are public education, CO_2 emission savings, and positive changes in the home energy usage patterns of the owners of the micro wind turbines.

The Warwick Wind Trial Project

The most recent domestic wind study is based in the United Kingdom and is called the Warwick Urban Wind Trial Project[10]. An interim report was published in early April of 2007. The project involves the evaluation of various domestic wind turbine case studies.

The Warwick Wind Trials interim report describes the behaviour of three turbine manufacturers who took part in the study, outlining their dealings with customers. There were several potential sites for turbines, which were surveyed for suitability by the manufacturers. Windsave and Swift (two of the manufacturers) accepted all of the sites they surveyed. Ampair had a structured process for site surveys and eliminated several sites based on photographs of the sites or access issues.

The report points out that it should be read in the context of a developing market. That is, despite some disappointing experiences with wind turbine manufacturers and suppliers, these companies are learning and developing and will not necessarily make similar mistakes in future.

The first half of the trial, which has been summarised in the interim report, concentrated on isolating and overcoming non-technical barriers. It was found that the public were ready for the systems, but that a major issue was the market readiness of the various small wind turbines. That is, several manufacturers had made delivery promises but then either been unable to meet demand or had withdrawn their machine altogether.

The preliminary report discusses experiences and findings with regard to marketing of the domestic wind technology. The writers report that “we needed to make no efforts to recruit volunteers for the trial”.

A key outcome of the interim report was that “predicted wind speed data is inaccurate for urban sites”. One case study known in the report as ‘Lillington Road’ has a national wind database prediction of an annual average wind speed of 4.9 m/s. In actual fact an anemometer at the site has measured average wind speeds of just 1.3 m/s. In practice the turbine on the roof has generated 14kWh of electricity in 694 hours of operation over February and March 2007. A second case study, called ‘Maidenhead’, generated 10.1kWh between 18 December 2006 and 3 March 2007 and had a wind speed estimate of 4.7 m/s.

[10] The Warwick Urban Wind Trial Project; Interim Report; March 2007. Online at http://www.warwickwindtrials.org.uk/8.html

Although the report is only the interim one, the writers conclude that predicted wind speeds frequently overestimate the wind resource in urban areas. This is discussed further in Section 3.1 Urban Wind, below.

The report found that manufacturers didn't need to spend money on promotion due to the good-will and eagerness for climate change solutions which exists within the community. Interestingly, this support continues despite the fact that when the Warwick Wind Trials published some preliminary production data for urban turbines, newspaper headlines read "£3000 turbine saves £1 in six weeks".

According to the report, in the UK "the industry as a whole now recognizes that performance is highly site specific" and that "the skill and integrity of the surveyors and sales people is clearly an important consideration in ensuring this technology is deployed effectively". The report suggests that further investigation should be done into drawing general conclusions about the relative suitability of various sites and buildings.

Further, noise is not an issue externally on any of the sites. It does say however that the internal noise levels at one house, despite not being a concern for the current occupant, may be worth further investigation.

Because the Ampair machines are lighter than the Windsave machine, they start to rotate at a lower wind speed. Despite the power being produced, the report believes that this "gives a favourable impression to passers by". This sort of positive perception may be important in Australian urban areas if the technology enters the suburbs.

Ampair is a major contributor to the report and despite being a micro turbine manufacturer they say in their final statement; "keep an open mind: urban micro wind may not be viable". This infers that continued research and development may still conclude that the wind resource is inadequate to create any real benefit.

The most important conclusions drawn from this report are that public support is high, technical performance is low, and the manufacturers are as yet unready for mass deployment of the technology.

Ealing Urban Wind Study[11]

This report is less applicable because it concerns a large and relatively high turbine in community parkland. However, it contains some interesting findings. It was published in July 2003 and is concerned with the viability of erecting a small wind turbine (~10kW) in a specific site in London's western borough of Ealing. It was written by the Centre for Sustainable Energy (CSE) in Bristol, and identifies and analyses the issues that may arise in planning for, installing and operating a small-scale wind turbine.

[11] The Centre for Sustainable Energy; Ealing Urban Wind Study; Final Version; 21 July 2003. Online at: http://www.cse.org.uk/pdf/pub1027.pdf

The researchers undertook a desktop wind study for the site, including data from the UK's national wind speed database NOABL[12], a nearby meteorological mast, and modelling software. The greatest difference between this study and the Ealing study is the height of their turbine. Rather than typical domestic roof heights, they are planning a 15m tower on a 20m mound of raised earth. They concluded that the theoretical wind speed for their site , at a height of 35m, would be somewhere between 4.4 m/s as modelled by the software, and 5.6 m/s as modelled by the NOABL database (discussed further in section 2.6.2 UK Case Studies)

The main conclusions from this report that are particularly relevant to domestic scale wind energy in Victoria include:

- Average wind speed in urban areas is significantly lower than normally encountered in rural areas. The report claims that research into the suitability of urban areas for wind power is comparatively rare and the low wind speeds commonly inherent in built-up areas are seen to justify this;
- On-site measurements are preferable to any sort of modelling or prediction and provide more accurate results;
- Estimates of annual energy production should be regarded with caution because power curves are rarely independently certified;
- Economic viability is sensitive to annual average wind speed;
- Turbines are unlikely to have any adverse environmental impacts.

Like many groups that install urban wind turbines, the CSE are interested in factors other than economics. They consider start up speed an important factor in turbine choice, as having the turbine spinning (despite the energy yield) is a high priority in terms of 'education' and general positive impressions of the technology.

The conclusion of the report contains the following excerpt in bold print:

> *It should be emphasized that the relatively low wind speeds predicted on-site will result in very long payback periods making the project unviable in purely economic terms…. The low annual average wind speeds will also result in the rotor of an installed turbine being stationary for a significant proportion of the time*[13].

Domestic Roof-Mounted Wind Turbines: the Current State of the Art[14]

This report was written by the mid-Wales energy agency and published in August 2005. It points out the rapid increase of public awareness of global warming and the climate of excitement surrounding micro generation. It examines two turbines, the Swift and the Windsave, which at the time of reporting were at the post-development stages. The report suggests that the Swift turbine is 18 months from the market and the Windsave is 12 months away. When calculating payback times, the report uses only the Swift because the Windsave did not yet have a power curve available.

The report is extremely optimistic, and pay back period calculations are done using an estimated wind speed of 5.5 m/s. This is based upon the NOABL database estimations

[12] NOABL (mass consistent model developed by Traci and Phillips in 1977) Online at http://www.dti.gov.uk/energy/sources/renewables/renewables-explained/wind-energy/page27326.html
[13] pp 33-34 of the report
[14] Mid Wales Energy Agency; Domestic Roof-Mounted Wind Turbines; The Current State of the Art; August 2005; Online at: http://www.bwea.com/pdf/small/mid-wales-microwind.pdf

which have repeatedly been proven inaccurate in urban environments. The calculated payback period for the Swift turbine is 8 years based on avoided energy costs.

As found in the Warwick report above, neither Swift nor Windsave are ready for mass distribution at this time.

WINEUR Techno-Economic Report[15]

This report was published in January 2005 and examines the economics of domestic urban wind turbines in France, the Netherlands, and the United Kingdom. The report points out major factors affecting the economics of the turbines, such as applied discount rate, subsidies, and wind resource, and also points out major factors affecting the economics of installation, such as planning permissions, health and safety and structural additions to buildings.

The report goes into some detail regarding estimated installation costs, presenting the high and low estimate of Euro per kW installed for around eight different machines for each country. In the UK section of the report, the writers discuss wind speeds at three different urban sites. The findings show that the actual wind speeds are far below that estimated by the NOABL database, even as high up as 30m. They report that “the owners of the urban turbines who responded to the questionnaire tended to be disappointed with the energy yield of their wind turbine.”

The UK report concludes that “the UK urban wind industry has much potential; its biggest asset is currently the overwhelming interest from both public and private sector actors and the positive attitude these actors have towards the technology”. However it notes that “the installations studied in this report showed that at the moment small scale wind can not be justified as a financial investment.”

The report as a whole concludes like many others that “overall, most of the small wind turbines studied in this report are not economic today, but it is also currently true that economic factors are often not the primary reason for individuals and organisations installing wind turbines.”

The Feasibility of Building-Mounted/Integrated Wind Turbines (BUWTs)[16]

This report was written in May 2005 by a number of UK groups. The executive summary concludes that “a more detailed evaluation of the resource (wind) is justified”. The main recommendations of the report are to carry out the following:

- detailed assessment of urban wind resource,
- detailed assessment of structural and noise implications,
- turbine design optimization,
- investigation of non-technical barriers, and
- establishment of a national test centre for BUWT technologies.

[15] WINEUR: Intelligent Energy Europe; Wind Energy Integration in the Urban Environment, Techno-Economic Report (final report); May 2006; Online at: http://www.urban-wind.org/index.php?rub=6&srub=21

[16] Energy Research Unit, CCLRC; The Feasibility of Building-Mounted/Integrated Wind Turbines (BUWTs): Achieving their potential for carbon emission reductions. May 2005. Online at: http://www.eru.rl.ac.uk/BUWT.htm

This report shows that, at the time, relatively little was known about domestic wind turbines in terms of technical performance and wind resource modelling.

Wind Energy Technologies for use in the built environment[17]

This paper, published in the journal 'Wind Engineering' in 2002, describes the state of the technology at that time. There were a few examples of concept buildings integrating many varied types of turbines. Among the more standard turbines, it is interesting to note that many are still around today in the same form. The Turby and the Proven turbines for example have remained unchanged for 5 years now.

The paper highlights the fact that turbine technologies are developing slowly and many new and exciting concepts are never developed.

Wind Energy in Buildings[18]

In this March/April 2006 article in ReFocus magazine, a consultant at the UK's Building Research Establishment (BRE) argues that despite the fact that urban environments have reduced and more turbulent wind flow, "mounting turbines at high points on buildings may provide the perfect opportunity for onsite generation from wind power".

In contrast to many other studies, this report argues that the sector's biggest challenge is public acceptance and confidence in the technology. Conversely, every other report states that the biggest challenge is the technology and economics, and that public support is wide spread and enthusiastic. The Warwick project described at the beginning of this section is more recent and reports overwhelming public support, possibly fuelled by ever-increasing concern with climate change.

[17] Blanch M.J. Wind Energy Technologies for use in the Built Environment; Wind Engineering, 1 May 2002, vol. 26, no. 3, pp. 125-143(19)

[18] Dayan, Emma. BRE UK. Wind Energy in Buildings. Refocus Volume 7, Issue 2 , March-April 2006, Pages 33-38.

2.6. Case Studies

2.6.1. Local Case Studies

In order to gather case study information for this report, a number of small wind turbine owners were contacted to take part in an online survey. The survey was designed to learn about several aspects relating to installation of small turbines, including costs, output, planning, noise and siting issues. Nine respondents described their experience with 10 turbines.

Most of the respondents to this survey live in windy rural areas and have purchased turbines that are readily available in Australia. Typically the turbines have been sited on hills or raised areas and away from houses. All have installed the turbines themselves, which reflects the technically proficient nature of the owners and almost all of the turbines covered were not grid connected.

Only five of the nine respondents measured their wind resource, and eight of the nine did not care about the payback period when installing the wind turbine. This points to the fact that economics is not an important consideration for these early-adopters of small-scale wind turbines.

Planning was not an issue for the turbine owners as only three of the nine had planning permission, a process which did not seem overly difficult. The other six did not have permission for varying reasons. Some had been told by councils that it was not required or that there were no guidelines and others had erected turbines without seeking any permission. One respondent said that the turbine was erected for experimental purposes and would be taken down if directed. To date, he had not been directed to take it down..

The survey confirms that the turbine is a small portion of the cost of the entire system and that maintenance is a minor cost. However, a contributing factor to this low maintenance cost is the mechanically savvy nature of the turbine owners, who also performed their own installation. Owners are not claiming Renewable Energy Certificates (RECs), generally because they consider it too much hassle or didn’t realise they were eligible.

Nearly all of the turbine owners had an existing PV system before deciding to add a turbine to their power system. This indicates that PV is the first choice for these householders for renewable energy generation.

Reliability is generally perceived as good, noise is generally low, and satisfaction with the turbine installation varies across the board from very satisfied to very unsatisfied. Dissatisfaction tends to be tied to poor perception of performance and noise issues.

None of the turbine owners surveyed are accurately logging the output from their machines. This could be because they don’t care, because they don’t have logging equipment, or because the power from the turbine and the PV panels go to the same logging device, making it difficult to separate.

In addition to the survey, a field visit was undertaken to the Hush prototype turbine operating under testing conditions at the Hume City Council offices. A description of this field visit is included in Appendix 4.

2.6.2. UK Case Studies

The following case studies from the UK show some performance results for a number of micro-wind turbine installations.

Lillington Road

The first was included in the recently-completed Warwick Wind Trial, as discussed in Section 2.5, above. The turbine is an Ampair model, installed on 31 January 2007.

Figure 2.19: Lillington Road case study from Warwick Wind Trials in UK

An anemometer was installed approximately 70cm above the ridgeline at the gable end ahead of the trial starting in May 2006. Average wind speeds recorded are listed in the table below.

Month	Average anemometer readings (m/s)
May-06	1.9
Jun-06	1.1
Jul-06	1.1
Aug-06	1.1
Sep-06	1.1
Oct-06	1.4
Nov-06	1.4
Dec-06	1.8
Jan-07	2.2
Feb-07	1.0
Mar-07	1.6

Table 2.3: Actual measured wind speed in UK case study.

NOABL is a mass consistent wind model developed by Traci and Phillips in 1977. A database based on this model was developed by the UK's Department of Trade and Industry and is online for public use[19]. For the Lillington Rd case study, the database estimated an annual average of 4.9m/s at a height of 10m. Clearly there is a very significant discrepancy between this estimate and the actual measured values. This is because NOABL assumes a smooth, uniform environment and does not adequately account for the turbulence and unpredictability of wind in an urban environment.

The output of the turbine between the 1st of Feb and the 20th of March 2007 was 14kWh, which means that the turbine is generating an average of 0.3kWh per day. This is a very low output, demonstrating the importance of a properly-monitored field trial in order to establish the performance of a wind turbine in practice.

Urban London

Donnachadh McCarthy is an environmental and political campaigner who now works freelance as an environmental writer, green lifestyle coach and environmental auditor for small and medium sized businesses and organizations. He put a turbine on his roof in urban London and became the first Londoner to sell wind power back to the grid.

The total installed cost of the system was about £3,000. He has been very satisfied with the noise levels; it has been in place for about a year and a half and he has experienced no neighbour complaints. There has, however, been vibration problems which have led to internal noise, leading to Donnachadh turning it off during the night on windy occasions.

The output has been about 10 kWh over the last 5 months[20], a dismal result particularly because the 5 months in question fell during the English winter and spring and should have, on average, higher wind speeds than other times of the year. Donnachadh has admitted that his turbine outputs very little electricity, although believes that this could be improved if he installed an inverter designed specifically for wind rather than for solar photovoltaic. In summary, Donnachadh believes that there are more effective ways to spend money if green house gas abatement is a priority.

[19] Wind Speed Database online at: http://www.dti.gov.uk/energy/sources/renewables/renewables-explained/wind-energy/page27326.html

[20] Personal correspondence with Donnachadh.

3. Issues for Urban Wind Power

3.1. Urban Wind

Despite the fact that wind resource is the most important factor in calculating the economic viability of a wind turbine, it is very difficult to predict in an urban area. This is because modelling such a diverse and dynamic environment is infinitely complex and actual wind speed data is only accurate very close to the monitoring station.

3.1.1. Urban Wind Mapping

A typical wind map indicates annual mean wind speeds for a given geographical region at a given height. These can be very useful for gaining a general picture of a large area. These maps are put together using computer models which take into account topographical data (the shape of the land), roughness models (the nature of the land, eg: is it smooth pasture or urban area or forest) and wind data from a number of point sources. The resulting map is most accurate closest to the wind data sources.

Wind maps are useful for deciding where to site large commercial wind farms because the turbines are at such a height so ensure that surface roughness is a less significant issue. Closer to the ground however, and in urban environments, roughness becomes more variable and conditions are much more difficult to generalise.

According to Garrad Hassan Pacific Pty Ltd, experts in wind energy, an urban wind map for Melbourne would give useful data for an elevation of 25m and higher. Below that, the terrain is too complex for accurate computer modelling. Unfortunately 25m is an impractical height for most urban dwellings as a mast that high would make it difficult to get planning permission. As such, wind maps have limited application in urban areas.

3.1.2. Roughness

The obstructions associated with urban environments create significant surface 'roughness', which is a wind industry term describing the nature of the land.

Terrain	**Roughness**
Open water, sand or snow	0
Open farmland	1
Open land with some vegetation	2
Urban areas, cities, dense vegetation	3

Table 3.1: Roughness definitions for various terrain types

Roughness is important because it causes turbulence in the flow, and as such wind speed in urban areas is typically significantly lower and more turbulent than in open rural areas. Turbulent winds can cause problems for wind turbine operation and result in irregular performance, directional instability and increased wear and tear.

It is for this reason that urban wind mapping must be approached with caution. In less built up areas with single storey suburban houses the 25m estimate may be reasonably reliable. However in more built up areas, such as Melbourne city where the buildings exceed 25m, the useful zone of the wind map would be much higher.

3.1.3. Modelling Urban Wind Turbine Performance

A study published in March 2007 in the UK journal 'Wind Energy' looks into the potential yield of small building-mounted wind turbines[21]. The writers point out that although there is a large market for domestic roof-mounted turbines, very little research has been published on the potential yield. To do this, the researchers use an advanced computational fluid dynamics model to model the wind flow around a 'typical' house, both in isolation and within an array of similar houses. They even estimated the potential yield for a hypothetical house in west London. For this case study, they used a 1.5kW Swift turbine. A complex calculation was done to take into account the 360 degree wind rose, and it was found that the turbine would generate an annual total of 520kWh.

This study concludes that, "The energy yield is shown to be very low, particularly if the turbine is mounted below rooftop height. It should be stressed that the complexity of modelling such urban environments using such a computational model has limitations and results can only be considered approximate, but nonetheless, gives an indication of expected yields within the built environment".

A lot of time and money could be spent modelling urban wind with complex software packages. However, it is universally acknowledged that such micro environments would require individual modelling. A general guideline for the best place to mount a turbine would be a useful outcome of this type of resource. However, a far cheaper way to get more accurate results than these would be on-site measurement using anemometers.

3.1.4. Existing Data

The Sustainable Energy Authority of Victoria published a Victorian wind atlas, which is available from the Sustainability Victoria website[22]. The wind map states that "the mean wind speed across metropolitan Melbourne is 6.3 metres/second, marginally below the Victorian average".

It is important to note the resolution of this data. The wind atlas models annual average wind speeds using the WindScape wind resource mapping tool which was developed by the Wind Energy Research Unit of CSIRO Land and Water. This software uses atmospheric data and regional topography to model the wind resource at 65 metres above ground level to a resolution of 3 kilometres. Resolution this large means that the micro environment is not considered. In fact, the resulting map "does not incorporate the effects of local landscape features smaller than 3 kilometres in size, like small hills and ridges" let alone buildings trees and structures.

Below is an excerpt from Sustainability Victoria's online interactive version of the wind map. In this map, the green colour represents a slower average annual wind

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[21] Pages: 271-287 *Estimating the potential yield of small building-mounted wind turbines* Malcolm A. Heath, John D. Walshe, Simon J. Watson http://www3.interscience.wiley.com/cgi-bin/abstract/114175407/ABSTRACT

[22] *The Victorian Wind Atlas*; Sustainable Energy Authority Victoria. December 2003. http://www.sustainability.vic.gov.au/www/html/2123-wind-map.asp.

speed than the yellow colour. It is clear to see that even at a height of 65m, which is in general far above the trees and urban houses, the wind slows down over Melbourne's urban area.

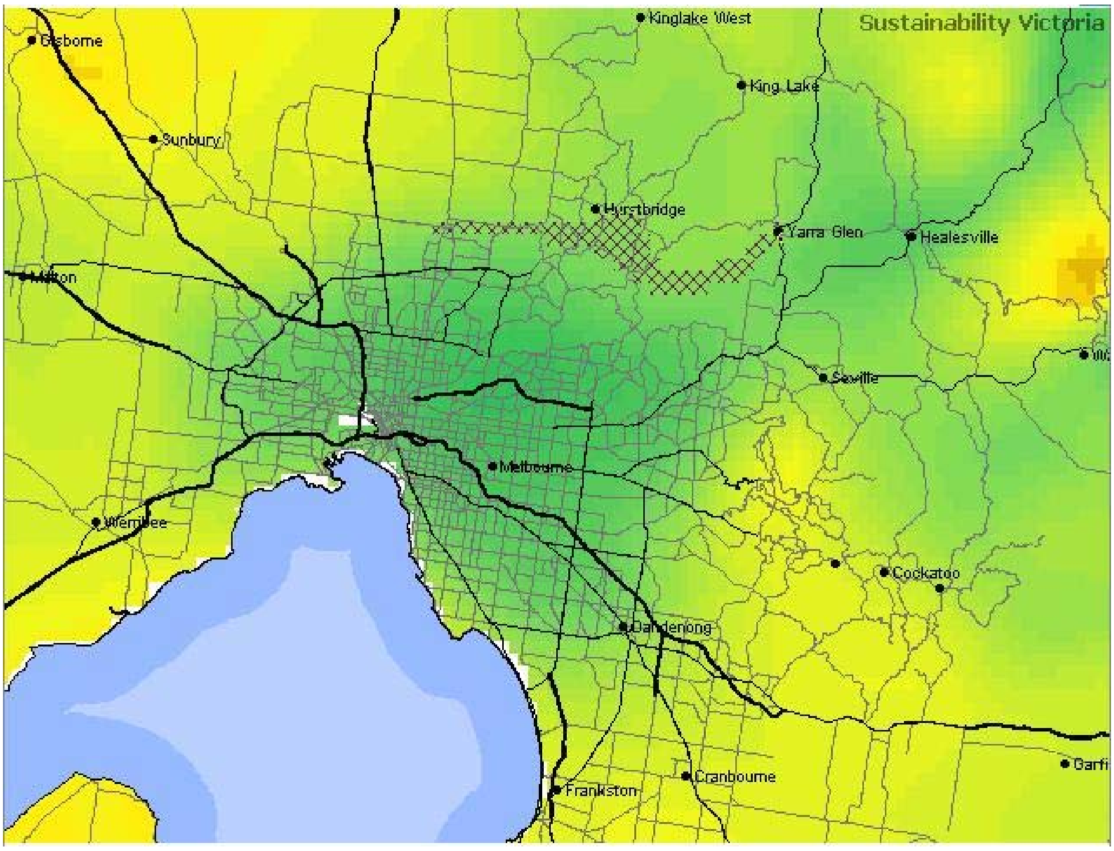

Figure 3.1: Wind Map of Melbourne

This map states the wind speed at 65m to be between 5.2 and 5.8 m/s over urban Melbourne. However, calculating expected wind turbine output based on an urban wind map and then placing the turbine on a typical roof will result in very disappointing power production. Wind speed at roof top height will not only be slower than at a 65m altitude, but it will also be significantly more turbulent.

The Bureau of Meteorology (BoM) also publishes wind speed data on their website, in the form of wind roses[23]. Wind roses illustrate the distribution of the wind in terms of direction and speed.

[23] http://www.bom.gov.au/climate/averages/wind/selection_map.shtml

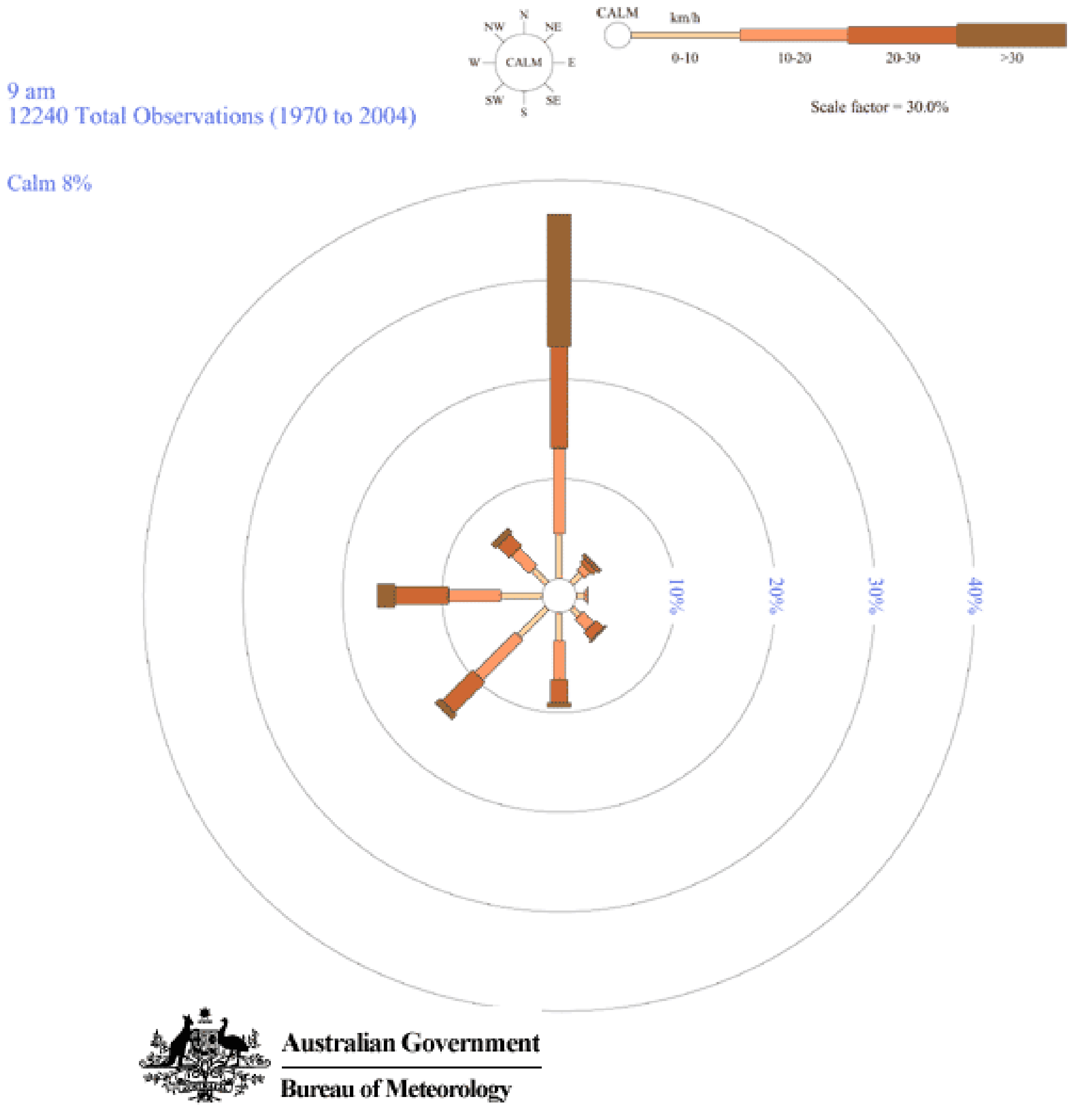

Figure 3.2: Melbourne Airport Wind Rose

The wind rose divides the wind into 8 compass directions and the circles represent the occurrence of the wind in that direction in terms of time. The directional branches are also divided to illustrate the distribution of different wind speeds.

The above wind rose, from the Melbourne airport anemometer, indicates that at this measurement location, there is calm 8% of the time, and the wind is from the north approximately 37% of the time. Of that, around 30% of the wind is at more than 30km/hr. This means that the wind is blowing at or faster than 8m/s only 11% of the time.

Possibly of more relevance to small-scale urban wind is another anemometer in Melbourne’s CBD, located on a 10m mounting on the corner of Victoria Parade and Latrobe Street. Data from this location will be subject to significant turbulence. At this location the annual mean is shown to be 2.9 m/s at 9AM and 4.0 m/s at 3PM, with a full table of the data attached in Appendix 5.

Clearly these figures demonstrate very low wind speeds at the location of the anemometer. This may be an indication of generally low city speeds, or it could be in a localised low wind area. Either way, it would indicate less than desirable conditions for a wind turbine.

As discussed previously, the urban environment experiences such variation and turbulent flow that it is possible to have to nearby locations with vastly differing wind regimes. As such, it is important to note that urban wind data should generally be considered unreliable as s guide of wind regimes, even in relatively nearby locations, and direct wind measurements are required to give an accurate wind resource guide for any given location.

3.1.5. Past Experiences

In the UK there is a national estimated wind speed data system which is available online[24]. A user can simply enter a postcode or OS grid reference and the NOABL database will provide an average annual wind speed at three different heights: 45m, 25m and 10m.

These values are generally reliable in rural areas with low roughness values. However the NOABL accuracy in urban areas has been disputed by Hugh Piggott, a well known expert in domestic wind energy who travels internationally giving workshops on building domestic wind turbines. He launched an experiment to compare NOABL predicted wind speed with actual measured wind speeds at an urban Edinburgh house, and published the results on his website[25].

For the location in question, NOABL predicts:

7.1 m/s at 45 m
6.4 m/s at 25m
5.6 m/s at 10m

Hugh's measured anemometer data gives an average annual wind speed of 1.73 m/s on the rooftop, well below the prediction of the database. The rooftop is approximately 10m high. This indicates that urban roughness and the resulting turbulence is not taken into account by the UK's wind model and further reinforces the need to directly measure wind power to determine a wind regime rather than relying on wind maps or predictions.

3.1.6. Anemometer Measurement

Taking into account the difficulty of predicting urban wind with any accuracy, the best remaining option for accurate wind resource measurement is anemometer logging. An anemometer is a reasonably cheap device for measuring wind speed, usually consisting of three small wind cups, with an attached data logger.

They are used for large commercial wind farms, in which case the data is recorded at 10min time intervals and includes information on average speed, standard deviation of the measurement during the 10min period, maximum 3 second gust and minimum

[24] http://www.dti.gov.uk/energy/sources/renewables/renewables-explained/wind-energy/page27326.html
[25] http://www.scoraigwind.com/

speed. Once 12 months of data has been gathered, it is compared to the long term data from the BoM mast in the region to see if the year in question was representative of the average. They may scale this data up or down depending on whether the year was more or less windy than the long term average[26]. This extensive approach could be adapted and simplified for domestic use.

Anemometers are available for sale online or from retail outlets and cost between $150 and $1000. A lower-end plastic anemometer kit will give reasonable data and includes a cord to connect it to a computer. The software for logging the wind speeds can usually be downloaded for free. A year of data is ideal because it takes into account all the seasons; however less data could be used as a guideline.

Ideally, the wind speed and direction should be measured at the same location as the proposed turbine, at hub height. This is especially important in the urban environment where highly localised turbulent wind flows can cause significant differences in two nearby locations.

A small number of available products are detailed in Appendix 6.

[26] Personal correspondence from Thomas Mills, Wind and Site Engineer for Vestas Americas

3.2. Planning

Because so few urban wind turbines have been installed, many councils are yet to establish planning guidelines for them. Thus it is difficult for councils to respond clearly to questions of how large/noisy/high a domestic turbine may be.

3.2.1. Local Councils

In exploring council planning requirements, emails requesting information on planning guidelines for domestic wind turbines were sent to a number of city councils and the Department of Sustainability and Environment. (Emails and responses are included in Appendix 7.)

Port Phillip City Council
Port Phillip City Council confirmed that their planning scheme does not specifically mention domestic wind turbines, only large wind farms. The council would class a domestic wind turbine as buildings and works, and that due to zoning and overlays in Port Phillip "a permit would be required in the majority of locations within the municipality". Rather than provide general information regarding which permits might be required in various areas, Port Phillip council will only provide this information once a specific location is decided upon.

Port Phillip City Council listed the following as requirements for permits: plans of the turbine in its proposed location; a current copy of title; application forms; and any relevant fees. According to the Council, it would be helpful if the applicant also provided some information on the possible noise emissions.

Banyule City Council
Banyule City Council sent an email containing detailed information on local requirements and building requirements. They confirmed Port Phillip's information that the only reference to wind turbines refers to large commercial machines[27]. There is a clause in the policy that encourages renewable energy – but once again this refers to commercial wind farms[28]. There is also a clause which lists buildings and works not requiring a planning permit which makes reference to solar panels, but not domestic wind turbines[29].

Under the local requirements section of Banyule's information, it is suggested that a planning permit would be required if no other overlays were triggered first. Apparently key assumptions are that the site:

- is not in a heritage overlay or other overlay area,
- is greater than 500 square metres
- is in a standard Residential 1 Zone
- contains a single dwelling
- does not have a previous planning permit under consideration

Banyule Council also raised an interesting point regarding satellite dishes. Apparently planning controls were introduced following the proliferation of these installations on

[27] Banyule Planning Scheme Clause 52.32
[28] Clause 15.14 in the State Policy Section of all Victorian Planning Schemes
[29] Clause 62.02 in the State Policy Section of all Victorian Planning Schemes

residential properties. That is, there were no rules to start with but when enough satellite dishes were installed the Department of Sustainability and Environment (DSE) followed with some control guidelines. There is a high likelihood that this pattern will also apply to domestic wind turbines.

Information provided also details a precedent from the Victorian Civil and Administrative Tribunal (VCAT)[30]. In this case, planning approval requirements were triggered because the wind turbine was considered “buildings and works associated with a section 2 use (dwelling in Rural zoning)”.

Another issue is that in the case of electricity being sold back to the grid, the turbine is no longer considered to be used for domestic purposes, but instead for commercial purposes.

DSE agree with Banyule Council that there are no specific references in the Victoria Planning Provisions (VPPs) for domestic wind turbines.

3.2.2. Planning Case Studies

There are two quite visible small wind turbines in urban Melbourne: one at the CERES Community Park in East Brunswick, and the other by the side of the Monash Freeway near the intersection with Warrigal Rd in Chadstone. The CERES turbine underwent a long and involved planning approval process, whereas the Chadstone turbine did not. Both case studies are outlined below.

CERES Community Park

The CERES community organisation applied for planning approval for a 15kW wind turbine at their Brunswick location. This application was lodged with Moreland City Council and proved to be a major undertaking. This was primarily because Moreland Council did not have any guidelines specifically for small wind turbines, and as a result forced CERES to comply with some of the planning guidelines intended for large commercial wind farms.

The main requirements for lodging this application were:

- A pre-installation acoustic study
- A post-installation acoustic study
- Contact with airport to ensure turbine was not in a flight path
- Soil testing

Whilst there was no requirement to also undertake flora, fauna, heritage and visual assessments, as required by large commercial wind farms, the process still took approximately 1.5 years to complete and was considerably onerous. However, CERES acknowledges that some of the work was hindered by contractor delays which were difficult to address because the work was done pro bono.

Moreland City Council confirmed that there were no guidelines in existence applying specifically to small wind turbines and that each application would be considered regarding its individual merits and location. Special notice would be given to zoning

[30] *Warren v Golden Plains SC [2001]* Available online at: http://www.austlii.edu.au/cgi-bin/disp.pl/au/cases/vic/VCAT/2001/1705.html?query=1705

and planning overlay controls. It was pointed out that generally a wind turbine would need a permit for its use, and a separate one for its buildings and structures. The draft planning report regarding the CERES turbine is attached in Appendix 8.

Monash Freeway
The prominent and recognisable turbine near the Monash Freeway and Warrigal Road intersection does not have any planning permission. David Sharpe who installed it reports that it was exempt because it was erected by an education body, Gippsland TAFE on government land that is not subject to local council planning provisions

Hume City Council Hush Trial
There were no planning requirements for the Hume City Council Hush installation because the council owns the land and were able to approve the project themselves.

Typically, councils will create guidelines for something once people begin installing it, as seen previously when television satellites began infiltrating the suburbs. Grid-connected urban wind turbines are still extremely rare in Melbourne and as such councils have no guidelines relating specifically to them. As a result, each turbine installation is being treated individually at this time.

Rather than several councils devising their own separate guidelines, increased consistency could be achieved by a top down approach from the Department for Sustainability and the Environment (DSE).

3.2.3. Standards

The international standard applying to wind turbines is called the IEC 61400 – Design Requirements for Wind Turbines. The technical committee working on most of the wind turbine standards is called the IEC TC 88 (International Electrotechnology Commission Technical Committee), located in Switzerland.

All but one of the standards they have produced is in the series 61400, part two of which is concerned with 'small' wind turbines.

However, Clause 3.48 of the standard defines a small wind turbine as one with a swept blade area of less than 200m^2, which is equal to a blade diameter of around 16m. Obviously this is significantly larger than any of the domestic wind turbines considered in this report.

The Australian group converting the IEC 61400 standards into Australian versions is called EL48 and the Standard is currently at an interim stage. It will be open for public comment for some time and eventually be finalized as an Australian Standard. A list of the IEC 61400 standards and also some other Australian standards which apply to domestic wind turbines is attached in Appendix 9.

Main issues to consider in devising standards for domestic wind turbines are vibration and ensuring the structural adequacy of buildings. According to Stephen Cook, an accredited renewable energy installer, 5 or 6 years ago most people installing PV panels would construct their own frames.

These days, due to strict standards and risks of litigation, people tend to buy approved off-the-shelf mounting frames. This sort of development is likely in the wind industry, and is necessary to avoid potential problems associated with people constructing their own inadequate poles and mounting structures in their backyards.

3.3. Grid Connection

Grid connection allows a turbine owner to generate a portion of their household supply, drawing from the grid at times when their demand outstrips their ability to generate, and feeding into the grid when production exceeds consumption. Grid connection of embedded generators is governed by the Essential Services Commission's (ESC) Electricity Guideline No. 15; Connection of Embedded Generation[31].

Although there are increasing numbers of grid-connected PV systems, the vast majority of small wind turbines in Australia are not grid connected.

- Powercor's Colin Jenkins said that to date, Powercor had received no applications to grid connect a domestic wind turbine.
- Citipower's Scott Thompson reported no grid connected domestic turbines on their network.
- Alinta's (previously Agility) Debbie Pollock reported two commercial but no domestic turbines.
- SP Ausnet's Larry Westney reported one. It is approx 150kW in size and is located at a winery.

Despite the low number of turbines currently grid-connected, the international trend towards grid-connected urban installations means that this issue needs careful consideration.

Grid connection is a complex issue because distribution businesses need to protect the integrity of the electricity supply. Any generator has the potential to cause electrical disturbances to the network, such as voltage fluctuations and harmonics.

It should be noted however that this policy of protecting the grid from harmonic/fluctuating sources is applied across the board to all power generation from multi-megawatt commercial generators to tiny domestic turbines. In reality, the level of disturbance possible from a domestic turbine is minimal. However, it is vital that the turbine is isolated in the event of grid failure, to prevent 'islanding', as discussed in section 2.1.2 Inverters.

3.3.1. General Advantages

Potential benefits and advantages of distributed domestic wind power generation include:

- improved supply reliability through generation diversity;
- greater individual and community control over energy sources;
- reduced dependence on a small number of large remotely located generators;
- generation closer to customers resulting in improved power quality and reduced power losses;
- reduced greenhouse gas emissions resulting from both reduced transmission losses and generation from renewable wind energy;
- avoided network augmentation costs;

[31] Available online at: http://www.esc.vic.gov.au/NR/exeres/ED979458-AA36-43BE-BA25-DFA5B40E416C.htm

3.3.2. Grid Connection Requirements

In order to connect a domestic wind turbine to the grid, the following things are required by electricity distributors and retailers:

- An approved inverter to condition the power so that it suits the grid
- A bidirectional electricity meter
- A signed agreement giving approval to connect from the network distributor
- An approved electrician to install the 240 V installation to the grid. A signed retailer contract for the purchase of any power fed back to the grid.

The Business Council for Sustainable Energy (BCSE) has published a list of inverters[32], approved under Australian Standards AS3100 and AS4777. This list was most recently updated on 5th March 2007 and includes manufacturers and distributors. The list of approved inverters is attached in Appendix 1.

Distributor contracts typically require that mains wiring side, connection to the grid and the inverter be checked, approved, and installed by an accredited electrician, and that anything on the customer side of the inverter is the customer's responsibility. The customer guidelines are available from the BCSE website and are attached in Appendix 10.

The retailer contract details metering and pricing tariffs. Section 23B of the Electricity Industry Act (2000) requires retailers to publish prices in the Government Gazette[33]. Prices and relevant Electricity Act excerpts are included in Appendix 11.

It should be noted that for under the Federal Government Solar PV Rebate Program the system installer must be accredited by the BCSE. However, there are currently no wind rebates, so there are no specific requirements for system installation other than complying with the requirements of the network distributor and the relevant state codes for grid connection.

3.3.3. Issues in negotiating retailer contracts

At present a significant number of impediments exist in the negotiation of retailer contracts for domestic wind power, most of which are similar to the impediments facing solar PV. On the grid side of the inverter, small embedded generators look the same and encounter the same issues, including:

- Lack of standard retailer connection agreements
- Excessive charges for required connection call-outs and meters
- Lack of standard terms and conditions which makes it difficult for owners to change retailers due to the different metering conditions which exist between companies;
- an economic regulatory framework which provides:
    - little incentive for retail or distribution businesses to actively encourage small renewable embedded generation; and
    - minimal protection for system owners.

[32] www.bcse.org.au/default.asp?id=233
[33] http://www.austlii.edu.au/au/legis/vic/consol_act/eia2000261/

- a lack of publicly-available information that can assist system owners negotiate and undertake what is often an unnecessarily technically and administratively complex process;
- unnecessarily meagre returns on investment, despite the many benefits these systems produce; and

There is a current focus on resolving these issues for grid connected PV systems. If domestic wind turbine deployment follows PV it is likely it will be able to benefit from any future reforms.

3.3.4. Issues Facing Grid Connection

The main issue facing grid connected wind turbines is a lack of available, approved inverters designed specifically for wind turbines. Currently, the only wind-specific inverter is the SMA Windyboy and this is still in the process of being approved for use in Australia.

The BCSE website provides links to the grid connection instructions and flowcharts for each distributor across Victoria[34]. Although there has been a lot of work done on standardising distributor agreements, the retailer side still has a long way to go.

The websites of each of the distributors details their costs for connection call-outs and meters. The total costs lie between \$110 and \$500, depending on the time of day of the callout and which distributor area the system is in. Full details of charges are included in Appendix 12.

3.3.5. Metering and Tariffs

There are three main metering and billing arrangements for grid-connected generators in Australia. The first, commonly known as net export metering, involves a bi-directional interval meter. Such a meter measures either export of electricity when the renewable energy system is producing more than is being consumed in the home, with this excess being fed into the grid, or import of electricity, when the homeowner's load exceeds the production of the system. The owner is then paid for the total export from the system (total export after in-home consumption) and is charged for the electricity imported.

Secondly, true net metering involves a simple induction disc meter which can either roll forwards or backwards depending on whether electricity is being imported or exported at any moment. At the end of the billing period, the meter will indicate the difference between the amount imported and exported, giving either a positive or negative value. The customer is then either charged or credited depending on this value.

Finally, gross export metering requires two separate measurements: one for electricity imported from the grid and one dedicated for measuring the total electricity generated by the wind turbine and exported to the grid. This allows different prices to be paid for the grid electricity consumed, and the total electricity generated by the grid-connected system.

[34] http://www.bcse.org.au/default.asp?id=305

Differential tariffs can be applied to either net metering or gross metered systems. Where price or buyback rate is higher than the normal retail price for the supply of electricity this can work in the favour of the resident or customer. This is yet to be offered in Australia.

3.3.6. Foreign Feed-in Tariffs

A feed-in tariff is a premium rate paid for electricity fed back into the electricity grid from a renewable electricity generation source. At present, feed-in regulations for renewable energy exist in over 40 countries, states or provinces internationally. These feed-in tariffs are typically for solar photovoltaic energy however many countries also have separate wind energy tariffs. A few examples are described below:

France
In 2005 France introduced a PV feed-in tariff of 22.608 cents, where standard grid purchase price was 16.9 cents. Market growth was disappointing so in 2006 the price was fixed by a ministerial order at 48 cents for add-on panels and 88 cents for panels included in the building architecture. These prices are about 3 times the price paid for electricity used (16.9 cents), but the tariff for new systems will decrease each year by 5 per cent. Additionally, the rebate on capital costs has risen from 40 to 50 per cent.

Germany
In August 2004 Germany had a PV tariff of 57.4 euro cents per kWh for domestic solar systems installed on buildings, and 62.4 cents for those integrated into the façade of buildings. This has a digression of 5% per year[35]. The wind tariff is significantly lower, at 8.4 cents per unit. This rate is obviously targeted at large commercial wind farms, with no additional higher rates for smaller-scale wind turbines.

Spain
As of 2004, the Spanish solar feed-in tariff was 41.4 euro cents/kWh. The wind rate is 6.9-9.4 cents per unit. As with Germany, the wind rate is obviously targeted at large-scale wind farms.

Australia
Australia does not currently have any feed-in tariffs in existence. Recognising the higher value of distributed generation and also renewable electricity, such tariffs make the installation of domestic wind turbines more economically attractive to consumers. A table demonstrating the effect of a feed-in tariff on payback periods of Australian turbines is included in the section on economic analysis.

A table showing the international tariff levels in 2006 is attached as Appendix 13[36].

[35] Ragwitz, Dr. Mario and Huber, Dr. Claus. Feed-In Systems in Germany and Spain and a comparison. Online at: http://www.erneuerbare-energien.de/files/english/renewable_energy/downloads/application/pdf/langfassung_einspeisesysteme_en.pdf

[36] Table is extracted from Evaluation of Different Feed-In Tariff Design Options – Best Practise Paper for the International Feed-In Cooperation. Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). Available online at: http://www.feed-in-cooperation.org/images/files/best_practice_paper_final.pdf

3.3.7. Recommendations for Grid Connection

In 2005 the Alternative Technology Association with assistance from Marsden Jacob Associates wrote a report detailing impediments to grid connection for solar photovoltaic systems[37]. The findings of this report are largely applicable to grid connection for domestic wind.

The report recommends that improvement initiatives include:

- Recognition of, and regulatory support for, the vulnerable negotiating position of system owners through standard contracts and agreements
- Clarification of the existing regulatory framework
- Development of 'how-to-guides'
- Separate and higher tariffs for the export of renewable electricity

Feed-in Tariffs overseas and the local Photovoltaic Rebate Program (PVRP) grant have been shown to stimulate growth in the solar photovoltaic industry. Similar supports for domestic wind would go a long way to improving their economic attractiveness to Australian householders.

Additionally to these issues, domestic wind would benefit from the development and approval of more specifically designed inverters.

[37] Thornton, Kane. Impediments to Grid Connection of Solar Photovoltaic: the consumer experience. May 2005. Alternative Technology Association.

3.4. Other Issues

3.4.1. Noise

Noise is a critical issue for small turbines especially in the urban context, as they will always be placed very close to houses. Noise is generally related to tip speed, which is why slower-moving VAWTs tend to be quieter than HAWTs.

Paul Gipe is a small wind power expert who has worked with the American, Canadian and British Wind Energy Associations, among many other organisations. In 2000, he published a paper called 'Noise from Small Wind Turbines: An Unaddressed Issue', which is available online[38]. The report points out that there was at that time a lack of data on sound power levels for small turbines. The author then performs sound tests on the Air, the Bergy and an Ampair turbine, key domestic turbines that still exist on the market and are available here in Australia. A summary of results appears in Appendix 14.

The report argues that noise data did not exist because manufacturers were not testing the turbines, and those that did were keeping the data secret. It also notes that the most notorious turbine at the time was the Air 403 model, which preceded the current Air X. This turbine was involved in a noise complaint in Wellington, New Zealand. A neighbour of the turbine owner lodged a complaint to the council who reacted by performing noise tests. It was measured at 54dBA, which exceeded the limit of 45dBA and the owner was forced to shut the turbine down permanently. Gipe claims that anecdotes such as these are numerous on the internet and in traditional media.

Gipe also says that "As with power curves, no U.S. manufacturer of wind turbines complies with either the International Energy Agency (IEA)[39] or American Wind Energy Association (AWEA)[40] noise standard".

The United States' National Renewable Energy Laboratory (NREL) published a conference paper in October 2003 entitled "Acoustic Tests of Small Wind Turbines". This paper is less focussed on anecdotes and more focussed on the gathering of actual data. The turbines tested include the AIR X, the Whisper and the Bergey XL.1 which are currently available in Australia and mentioned in this report.

The report concludes that for the Bergey XL.1, "the apparent sound power level at 8m/s cannot be reported because the turbine noise level could not be separated from the background noise". The Whisper was a little louder and the Air X was the noisiest. The report does note however, that "Control improvements in the AIR X, which stall the blades when rotor speed exceeds set limits, reduced the occurrence of this flutter-induced noise".

Recently developed turbines such as the Swift in the UK and Victoria's Hush, have modified the traditional HAWT design to include a ring around the blade tips. This ring prevents some vibration of the blade tips and is claimed to dramatically reduce

[38] www.wind-works.org/articles/noiseswt.html
[39] www.iea.org
[40] www.awea.org

noise. According to Swift technical information, “acoustic suppression aerodynamics, notably the patented diffuser, removes the noisy, turbulent vortices at the blade tip”. The Swift’s technical specifications list the acoustic emissions as less than 35dB(A) for all wind speeds.

The UK’s Department of Trade and Industry (DTI) wrote a report called ‘The Assessment and Rating of noise from wind farms’ which was drawn up by a noise working group in the Department of Trade and Industry[41]. The report states that as a general rule, noise emitted from any turbine should not exceed 5dB(a) above background noise, with a fixed limit of 43dB(A) recommended for night time. They recommend that day and night noise limits can be increased to 45dB(A) where the owner of the property benefits directly from the operation of the turbine.

Different states have different noise standards for large wind farms with, for example, Victoria adopting the New Zealand standard[42]. These large wind turbine standards are the only standards that councils have reference to. If a council had a noise-related complaint regarding a domestic wind turbine, there is no simple standard or guidelines for them to refer to.

Measuring background noise is a standardised procedure and for large wind turbines, this is generally compared to sound emissions published by the manufacturers. The difficulty in completing these measurements for small wind turbines arises because manufacturers do not provide the sound emission specifications as it is harder to justify the expense of testing the smaller, cheaper machines.

3.4.2. Roof Mounting

Mounting a wind turbine on the roof of a dwelling or other building presents a range of issues which require careful consideration. In terms of planning, a roof mounted turbine will require additional buildings and works permissions.

Vibration from the turbine could enter the dwelling through the structure creating noise inside. Anecdotal evidence has pointed to this presenting an issue. For example Donnachadh McCarthy in London and Mick Harris from Melbourne have mentioned this effect as being an issue of concern.

The structural integrity of the building will need very careful consideration due to the turbine’s load. The turbine will have a significant weight – in the order of 50 to 100 kgs for a one or two kW machine – comparable to the weight of solar panels. Unlike solar panels however, the turbine will introduce torque and bending moment forces about the mounting structure.

There are some standards already in place which deal with mounting turbines on structures and these are listed in Appendix 9. They include AS1170 - Minimum design loads on structures.

When solar PV cells were new to the market many consumers built home-made frames to mount them on roofs. However, the dangers associated with this practise

[41] Online at: http://www.dti.gov.uk/files/file20433.pdf
[42] NZS6808

prompted government action and standards were drafted. Now PV mounting structures must be approved and as a result they are generally purchased off-the-shelf. There is potential for wind turbine structures to develop in this way also, and similarly structured standards would certainly be required if the level of deployment of domestic wind reached the levels of solar PV.

3.4.3. Bird Strike Risk

Numerous studies have been undertaken all over the world with respect to large wind farms and the potential risks they pose to birds. However, there is very little known about the potential effect of domestic wind turbines. The UK's Royal Society for the Protection of Birds (RSPB) has a section on their website regarding large wind turbines. They believe that the greatest risk to birdlife is climate change and therefore they support the government's plans to source 15% of the UK's energy from renewable sources.

The RSPB wrote a letter to a turbine manufacturer's website regarding small wind turbines specifically[43]. This letter points out that the studies done on large windfarms bear little significance to domestic turbines. The RSPB say that birds are quite good at avoiding obstacles in normal flight and quotes that "it is not impossible that a bird or bat could strike the blades. However, I believe this would be likely to be a rare event."

The American Wind Energy Association website has a very brief section regarding the bird strike risk of domestic wind turbines. The opinion of the AWEA is that, although there no studies have been done on this question, the risk posed to birds is equal to that of any normal structure and is not expected to have any impact on bird populations.

The Scottish government's "Planning for Micro Renewables" document takes a very similar view to the AWEA[44]. They believe it is "unlikely that micro-wind turbines will cause a significant increase in bird strike, beyond those already arising from birds flying into existing buildings, windows and other obstacles".

Studies carried out so far indicate that risk seems limited, and support for wind turbines by bird protection organisations indicates that climate change is a far more serious concern for birds than domestic wind turbines.

3.4.4. Electromagnetic Interference

A common concern regarding wind turbines is the 'chopping up' of television signals causing a ghosting effect on screen. According to the American Wind Energy Association (AWEA) website this has occasionally happened where a wind farm is in the line of sight between a television transmission tower and the residential reception antenna[45]. This was perhaps 20-30 years ago and caused by large turbines with metal blades.

According AWEA's handbook on permitting small wind turbines, the US National Renewable Energy Laboratory (NREL) is yet to encounter a problem with

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[43] http://www.bettergeneration.co.uk/wind-turbines/small-wind-turbines-impact-on-birds.html
[44] http://www.scotland.gov.uk/Publications/2006/10/03093936/2
[45] http://www.awea.org/faq/sagrillo/ms_telint_0304.html

electromagnetic interference in 10 years of research[46]. In fact, the US Navy uses small wind turbines to power military communications systems.

According to experts at AWEA, modern domestic wind turbine blades are far too small to cause this effect. Additionally they are made from fibreglass, wood and plastic which are all materials that are transparent to electromagnetic signals. As such, it appears that there is little threat of electromagnetic interference from small wind turbines would be negligible.

3.4.5. Lightning Strike

Lightning strikes do occur and can cause significant damage to the electrical components of a domestic wind turbine. Some domestic wind turbines come with lightning protection systems although it is very difficult to completely protect a turbine from lightning strike.

Lightning protection generally involves grounding the turbine’s tower and attaching a lightning rod which is higher than the turbine and mounted on the tower at a lower point than the turbine. An alternative method is to build a secondary separate tower which is taller than the wind turbine although this could have the adverse affect of attracting lighting strikes to the area. In an unprotected system, lightning will hit the turbine casing and induced voltages and currents will cause damage to the electrical components inside. In a protected system, it is hoped that the lightning will skip over the turbine and run to ground. According to the British Wind Energy Association’s website, insuring the turbine against lightning damage may be a wise precaution[47].

Iskra is a turbine manufacturer in the UK, and their turbines have limited protection against lightning. Full protection can be installed but Iskra suggest that this is unlikely to be worth the expense, unless the turbine is to be in an area where lightning strikes are frequent.[48] The Australian Greenhouse Office recommends that lightning arrestors should be installed to protect the electrical components of the turbine.[49]

[46] www.awea.org/smallwind/documents/permitting.pdf
[47] http://www.bwea.com/small/faq.html
[48] http://www.iskrawind.com/faqs/faq12.htm
[49] http://www.greenhouse.gov.au/yourhome/technical/fs48.htm

3.5. Economic Analysis

The cost of installing a grid-connected domestic wind turbine is made up of capital costs and running costs. The capital cost has many components, including the turbine, the tower, the cabling, the inverter, the meter, the grid connection and the installation. The running costs generally involve maintenance and perhaps insurance.

3.5.1. Capital Costs

As a good guideline of fully installed costs, the Energy Matters shop[50] has some package deals for full installation and grid connection of selected wind turbines.

Soma 1000 including Latronics PV Edge inverter and 20m tower - $16400
Whisper 1kW including Latronics PV Edge inverter and 20m tower - $14600
3kW Westwind including Fronius IG30 inverter and 24m tower - $32000

A general rule of thumb is that the full installed and connected package is equal to the cost of the turbine plus $10K. More detail on costs of system components is listed in Appendix 15.

3.5.2. Maintenance

According to case studies or turbine owners surveyed for this report, maintenance is not a significant cost to domestic wind turbine owners. Survey participants report that the frequency of their turbine maintenance ranges from twice a year to never. Responses to the question of how much this maintenance costs them range from “nil cost so far” to “$1 and time to take it down”. One respondent reported that although maintenance generally costs nothing, a special 5-yearly service may cost “$50 max”.

It should be noted here however that several of the respondents were performing the maintenance themselves. This indicates that the turbine owners have mechanical skills. The possible future proliferation of the domestic turbine to urban areas would likely see a decline in the number of owners capable of performing their own maintenance, and as such, higher maintenance costs for these owners.

The engineers developing the Hush turbine claim that it will be exceptionally reliable and require maintenance every 5 years for the duration of its 20 year life. The maintenance is expected to be a 2 hour job and may or may not involve a cherry picker. Of course, these claims remain untested as the Hush is new and emerging technology.

Trevor Robotham is an experienced wind turbine installer. He reports that annual maintenance costs between $300 and $500 plus parts. The variation in costs is defined by the complexity of the job. Standard maintenance includes replacing rusted parts, bearings and leading edge blade tape, and replacing grease and oil.

[50] Matthew Lyons, Energy Matters. Online at: www.renewablestore.com.au

3.5.3. Warranties

Warranties on the turbines available in Australia are included in the table of specifications in Appendix 3. They are between 1 and 5 years and typically guarantee the performance of the parts.

3.5.4. Insurance

Several insurance companies were approached with a question regarding the nature of insurance for a domestic wind turbine and the costs associated. The NRMA Network Support Team report that a domestic turbine would be covered under ‘buildings insurance’ – which covers any permanent structures on the property, providing that planning regulations are met. A domestic wind turbine will be included in calculations of property value but will not be individually rated or charged for.

A representative from AAMI reports that the building excludes “any part of the home building or the site used for conducting a business, trade, professional services, or farming of any description”. Therefore, provided that the wind turbines are used purely for domestic purposes, they would be covered under the Home Building insurance policy.

When questioned on liability limits, AAMI replied that under AAMI Home Insurance, the turbine owner would be covered for legal cover up to $10 Million. Allianz quoted the same sum, and under their ‘Gold’ package the legal liability would be $20 Million.

This means that insurance is unlikely to be a significant cost for owners of domestic turbines. No respondent to the case study survey had paid any extra insurance for their turbine.

3.5.5. Revenue generation and payback – net metering

Electricity generated by domestic wind turbines replaces grid electricity that a homeowner would normally buy from their retailer. The value of that electricity can be used to calculate a payback period, based on the capital cost of the turbine and the annual return on investment through electricity bill savings.

The table below shows the annual value of power generated by a range of turbines at a range of wind speeds. Manufacturer power curves were used to calculate instantaneous power at the wind speeds below. A value of 14cents per kWh of electricity was used because this is the approximate value of grid electricity in Victoria, including GST. The figures in this table are indicative only.

	Annual Value of Power @ 14c/kWh ($)					
Wind Speed (m/s)	Air X	Whisper 100	Whisper 200	Whisper 500	Soma 400	Soma 1000
3	0	0	0	0	0	0
4	10	10	10	100	0	90
5	20	60	90	370	80	280
6	40	120	220	740	160	470
7	80	250	500	1220	250	660
8	110	340	740	1840	330	850
9	150	500	980	2580	410	1040
10	200	600	1100	3200	490	1230

Table 3.2: Dollar value of annual power yield at a 14c /kWh buyback rate

Although the values are indicative only, the table clearly shows that larger turbines and faster wind speeds will generate more power.

An interesting consideration is the ability of the turbine to pay for the costs of maintaining it. As mentioned above, Trevor Robotham, an experienced wind turbine installer, estimates annual maintenance costs at between $300 and $500 plus parts. According to the above table the smaller turbines would not be able to generate enough electricity to cover these costs, at current electricity price. The larger turbines such as the Soma 1000 and the Whisper 500 could pay off the maintenance costs at around the 5-6 m/s wind speed, however leaving little left over to cover the up-front capital invested.

The next table uses the annual electricity values above and some approximate capital costs to calculate indicative payback periods of the turbines in years. Capital costs are estimated using the rule of thumb of turbine cost + $10,000, and are rounded to the nearest $500.

	Payback in Years @ 14c/kWh					
Wind Speed (m/s)	Air X	Whisper 100	Whisper 200	Whisper 500	Soma 400	Soma 1000
4	900	1200	1200	220	na	180
5	450	240	180	60	180	60
6	260	120	70	30	90	40
7	150	60	30	20	60	25
8	100	40	20	12	50	20
9	75	30	15	10	40	15
10	50	25	14	7	30	10

Table 3.3: Payback in Years for various wind turbines at 14c/kWh

This table shows that payback periods depend greatly on the turbine. As a general rule, larger turbines have shorter payback periods. A discount was not applied to these calculations because a 6% discount results in many of the turbines having infinite payback periods.

The next table below shows the cost per unit of electricity per day of the Whisper 200 turbine. This turbine was chosen at random and tables generated for two other turbines are included in Appendix 16. The point of the table is to compare the cost of installing a domestic wind turbine to the cost of installing solar photovoltaic, in terms of electricity generated.

Solar cells cost around $16,500 for a 1kW system, fully installed, and around $26,500 for a 2kW system. Additionally, it is known that in Melbourne, a 1kW system generates approximately 3.15 kWh/day. This information can be used to calculate a cost of between $4200 and $5200 per kWh per day, for solar PV cells.

Wind Speed (m/s)	Power (W)	kWh/day	Cost/kWh/day ($)
4	10	0.2	60500
5	70	1.7	8600
6	180	4.3	3400
7	400	9.6	1500
8	600	14.4	1000

Table 3.4: Cost per kWh per day for the Whisper 200

This table shows that the Whisper 200 turbine becomes economically competitive with Melbourne-based solar PV at a wind speed somewhere between 5 and 6 m/s. Three different turbines were analysed in this way and in all cases it was found that wind turbines become cost comparative to PV at wind speeds between 5 and 6 m/s.

In general the economic performance of domestic wind turbines is poor and payback periods are long. The tables above show the importance of choosing a site with good wind speeds. However, it should be noted that all of the above tables are based on estimated values from manufacturer power curves, most of which are untested. Further tables are included in Appendix 16.

3.5.6. Rebates

The only rebate that grid-connected turbine owners can benefit from is through the generation of Renewable Energy Certificates. Whilst solar photovoltaic systems in Australia can benefit from a rebate under the Photovoltaic Rebate Program (PVRP), no such program exists for domestic wind turbines at present.

For off-grid wind systems, some areas of Australia benefit from the Remote Renewable Power Generation Program (RRPGP). To qualify for an RRPGP rebate, potentially eligible installations are those for which renewable energy generation replaces all or some of the fossil fuel used for 'off-grid' or 'fringe-of-grid' electricity generation[51].

Renewable Energy Certificates - RECs

A Renewable Energy Certificate (REC) is equal to 1MWh of electricity generated from renewable sources. Under the Mandatory Renewable Energy Target (MRET), owners of domestic renewable energy systems that qualify under the Renewable Energy (Electricity) Act 2000 can benefit financially from RECs. The Renewable Energy (Electricity) Regulations 2001 define a wind turbine as a ‘small generation

[51] More information is online at: http://www.greenhouse.gov.au/renewable/rrpgp/about.html

unit' if it has a power rating of no more than 10 kW and generates no more than 25 MWh of electricity each year.

The Office of the Renewable Energy Regulator provides details on how a small wind turbine owner can go about creating and selling their RECs[52]. This can even be done upfront using the ORER calculator to estimate the number of RECs that will be generated over the anticipated life of the system. This calculator is included in Appendix 17. According to the calculation, in a default wind; a 1kW rated turbine is worth 1.9 RECs/year.

RECs may be claimed annually, or on installation for the first 5 years. At the start of each subsequent 5 year period, the Regulator must be satisfied that the small generation unit is still installed and is likely to remain functional for the next five years. The ORER may request evidence to support this claim[53].

The value of RECs varies depending on demand - in the last 12 months they have been worth between $12 and $30. There has been a recent increase based on speculation of an increasing Mandatory Renewable Energy Target. At these prices, the REC scheme would add little discount to the long payback periods of domestic wind turbines.

[52] http://www.orer.gov.au/

[53] Online at: http://www.orer.gov.au/sgu/index.html

4. Conclusion

4.1. Urban Wind

The uneven nature of urban areas acts as a brake to wind and creates turbulent flow. Overseas, field trials have shown that wind models that have acceptable accuracy in flat rural areas tend to overestimate wind speeds in urban areas. This is due to the complex terrain creating unpredictable wind patterns at a micro level and making the wind virtually impossible to model.

The Victorian Wind Atlas shows that the wind speed 65m above Melbourne is approximately 5 to 6 m/s, and it will be less than this at lower altitudes. Whilst Bureau of Meteorology wind data indicates wind speeds of between 3 m/s and 4 m/s at a location in central Melbourne, urban wind is so complex that a measured wind speed at one point may have very little correlation with the wind speed at another point nearby.

The most reliable and accurate way to estimate wind speed at any urban location is to install an anemometer and gather site-specific data.

4.2. Planning

Planning barriers are currently quite difficult to define. Because installation of domestic wind turbines has not yet reached a critical mass, city councils are yet to put together any guidelines for them. There are various clauses in current planning guidelines, most of which refer specifically to large wind turbines.

Guidelines will follow the proliferation of domestic turbines in urban areas; much like television satellite guidelines followed their mass installation. It is understood from councils that turbines will be treated on a case-by-case basis until such time as guidelines do exist.

4.3. Grid Connection

The grid connection issues faced by domestic wind are very similar to those faced by solar photovoltaic installations. Like PV, the domestic wind industry would benefit from the standardisation of agreements across retailers, and also clear consumer guides for the process.

At this early developmental stage of the market, there are very few grid connected urban wind turbines and as such the process remains largely untested.

4.4. Other Issues

Issues such as bird strike, electromagnetic interference and lightning have been previously investigated although not frequently and not by manufacturers. Research shows that domestic wind turbines are unlikely to cause any problems for birds or for electromagnetic signals. Lightning strike could be a problem in high lightning areas although there are measures than can mitigate this risk. Noise could be an issue specifically in urban areas however manufacturers are working to improve design to overcome this.

Research in these areas has mainly focused on large commercial wind turbines and is not applicable to the small versions. A lack of specific research is mainly contributable to the early stage of the developing market.

Roof mounting turbines requires careful consideration of the structural integrity of buildings. Wind turbines have significant weight and can also subject a structure to torque and bending moment forces. Additional planning permits will be required, and if roof mounted turbines become as common place as solar photovoltaic panels, specific standards will likely be drafted and the approved mounting devices will be manufactured and sold off the shelf.

4.5. Economic Analysis

The economic analysis shows that the payback period of a domestic wind turbine is extremely dependent on the wind speed. Generally, the economics of domestic wind turbines show that the technology is not commercially viable; the capital installation costs are high and the annual return on energy produced is meager. Although they are economically better than solar PV at certain wind speeds, this assumption is based on untested manufacturer performance claims.

Feed-in tariffs, reduced grid connection costs and rebates would improve the situation dramatically. Some level of government support would be required for the wide spread adoption of the technology.

4.6. Existing Markets

The domestic wind energy industry is developing overseas due to increased concern about climate change and consumer willingness to take action. However there remains doubt as to the suitability of the technology in an urban environment. Field trials show poor results, and yet a study in the UK found, despite this, high levels of public support for the technology continues. It remains to be seen how long this pubic support is maintained in the face of poor performance.

Major issues in the UK at this time include the market-readiness of the turbines, manufacturers keeping up with demand, and the verification of the manufacturers' power output claims. These issues will need to be overcome before large-scale roll-out of the technology in Australia

4.7. Further Work

This report provides a basis for evaluating the applicability of small-scale wind in urban Victoria. However, significant further work will need to be undertaken to fully evaluate the viability of urban wind turbines for electricity generation. This may involve field trialling of turbines, the installation of anemometers to more accurately measure urban wind regimes, and/or additional economic modelling and scoping of potential rebates and economic incentives.

One of the major advantages of a field trial would be to assess the actual energy output of wind turbines and their level of noise emissions. It would also be valuable to research the level of community acceptance of the small urban wind turbines, particularly from the perspective of neighbours.

The investigation of planning issues should also be further pursued to cover the relevant planning overlays in which turbines can not be installed, height restrictions, noise restrictions and the ability of the council to handle planning applications on a case by case basis.

While a field trial would add value to areas of uncertainty, such as technical performance, community acceptance and planning issues, increased uptake is unlikely to follow regardless of the result, unless accompanying inhibiting economic factors are addressed.

This report clearly shows that localised wind regimes need to be individually assessed, as modelled and computer generated assessments are of little value. Case studies show that the technology has been an enthusiast's endeavour rather than a serious attempt to generate electricity in a cost effective manner. As a result, those hoping to erect a turbine need to assess their wind regime and also be very clear as to their reasons.

Calculations were performed using manufacturer power curves and approximations of system costs, and typically show that there would be little value in installing a wind turbine in a location with wind speed less than 5m/s.

In locations with annual average wind speeds of 5m/s or more, wind turbines may prove an attractive alternative to solar photovoltaic power systems, with similar output and a lower capital cost. Field trials in suitable locations could assist in identifying actual performance curves.

Anemometers could be used to identify locations with reasonable wind regimes. Although this would not assist in generalising wind patterns, the particular locations identified could be used in field trials to establish a base wind regime at which the economics of domestic turbines are attractive enough to ensure mainstream uptake of the technology.