Renewable Energy Equipment

Performance Evaluation

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Southwest Windpower
Air X Wind Turbine

Air X on a 122 foot tower with an anemometer at hub height

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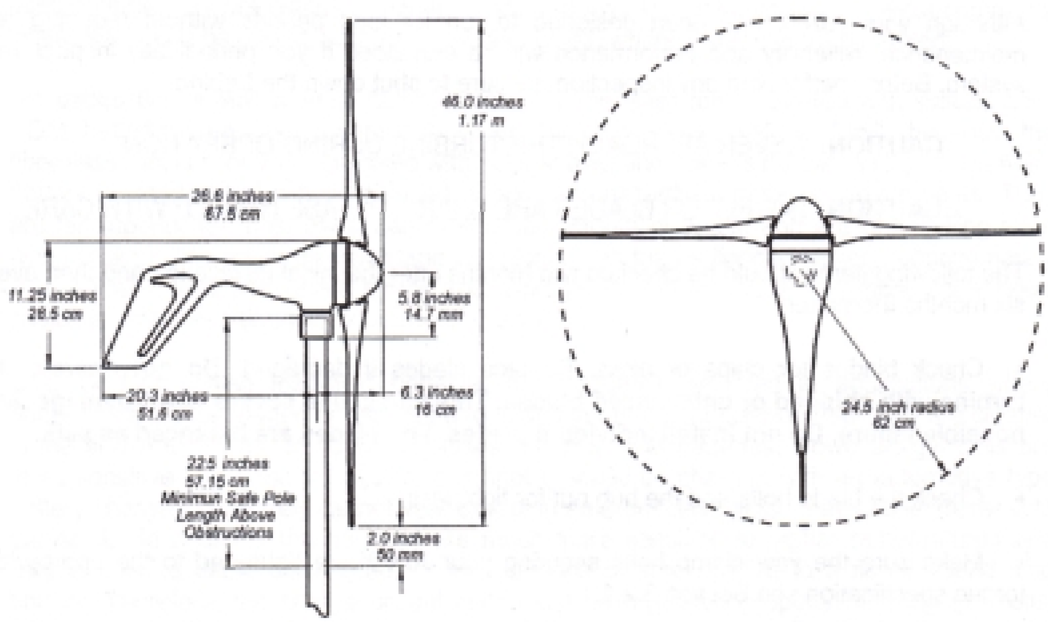
Objectives of Testing the Air X

Does the SWWP Air X perform as rated?
Can the Air X be used to accurately evaluate the Wind Resource?
How does it's performance compared to other RE generating equipment?

Southwest Windpower Air X

Manufacture's Specifications

Rotor Diameter	46 inches	Weight	13 lbs.
Rotation Axis	Horizontal	Over Speed Control	Stall
Orientation	Upwind	Start up Speed	7 mph
Rated Power	400 watts @ 28 mph	Rotor Speed	0 to 1,800 rpm
			(charging starts at 500)



Source: Southwest Windpower Air X manual

Renewable Energy Equipment Evaluation

Tests are being conducted on various types of renewable energy equipment applicable to the home size off-grid or grid-tie user. These tests focus mainly on wind turbines and photovoltaic modules. All the equipment evaluated has been purchased by *Detronics Limited* at regular prices. The only exception to date, is the *Air X* turbine which was donated by *Southwest Windpower* (*SWWP*). *Detronics Limited* is not compensated for these tests nor are the results influenced by any of our suppliers. The data is presented as collected, without bias to any product or company. Our objective is to obtain a greater working knowledge and understanding of these devices. Hopefully, everyone in the renewable energy industry will benefit from these evaluations.

Working with Specifications

In order to properly size a Renewable Energy (R.E.) home there are several values that must be determined. First: the amount of electrical energy required to maintain normal household operation. Second: the energy resource available, whether it be hours of sunlight per month for solar power or average wind speed for a wind turbine. If the data provided is accurate, the size of a solar array or wind turbine can be selected based on the performance specifications provided by the equipment manufacturer.

Users of RE equipment expect these products will meet the manufacturer’s specifications. They need to understand that these specifications may only be achieved under optimal conditions. But nevertheless, if these conditions exist, the product *should* perform as rated. Reponsible companies and retailers will inform their customers that limitations may exist in performance so adjustments can be made when sizing a system.

For example, solar modules produce their rated power at an irradiation of 1,000 watts per square meter at 25ºc. Under sunny conditions the modules will rise in temperature which reduces their output by approximately 0.4% per 1ºc. With an ambient temperature of 25ºc, the panel temperature may be 55ºc, so output will drop by approximately 12%. Inversely, the same is true: when the ambient temperature drops, output will increase by the same percentage.

A solar system installed with properly sized conductors to minimize voltage drop, a Maximum Power Point Tracking Controller to take full advantage of the modules’ cold weather performance and a proper site location should produce the rated output under optimal conditions. In fact, when these conditions exist, the customer may experience a system output that exceeds the manufacturer’s rating by a considerable margin. It is not unusual to see a sustained 900 watts output from our 750 watt test array during the winter months.

Why Accurate Performance Curves Are Important

Before investing in a large turbine installation, several authors and *SWWP* (*Southwest Windpower*) in their dealer training program recommend installing a small turbine like the *Air X* to assess a site's suitability for wind power. This has several advantages compared to installing a wind speed data logger. "Data loggers can cost several thousand dollars"[2]. A small turbine can provide some usable power whereas a data logger only provides data. Plus, it provides the user with hands on experience, valuable for tackling a larger turbine installation.

Following this method, output energy from the small turbine is monitored and the total monthly production is compared to the manufacturer's performance curve in order to determine the wind resource of the site. A turbine that produces less than claimed in its performance graph will indicate an inaccurately low wind resource. Based on these findings, a site may be deemed unsuitable for a larger wind turbine because of a perceived low wind resource. Therefore customers could believe there is no point to invest a larger turbine because they have been given incorrect information

Inaccurate power curves also effect system sizing. With the data from a wind study, a turbine will be selected based on it's performance curves to supply the customers energy needs. An exaggerated power curve will undersize the turbine leaving the customer without sufficient energy.

In either case, an inaccurate performance curve could lead to a person abandoning wind power because they think it does not perform well. This has an adverse effect on the entire industry.

[2] This statement was made in publications from several years ago, and was recently repeated in a *SWWP* training seminar in January 2005. While this was applicable years ago, today wind speed data loggers are available for less than $550.00 (Canadian dollars). These units perform all the mathematical equations and store a years data internally.

In several discussions with Mr. Andy Kruse from *Southwest Windpower* the test procedures were outlined and agreed upon prior to commencing.

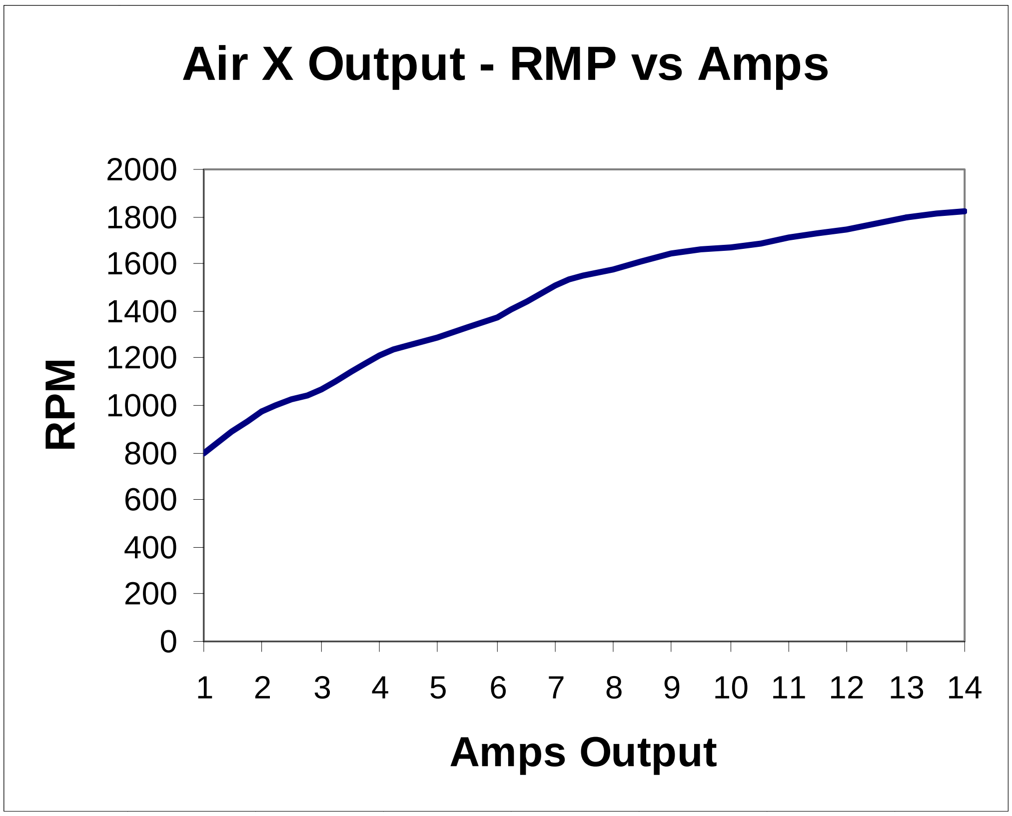
Power Output Test - RPM vs Amps

The 24 volt Air X was first tested in the lab using the following equipment:

Current	Fluke 87 DVM with shunt
Voltage	Fluke 87 DVM
RPM	Monarch non contact tachometer
Temperature	Simpson 383 digital temperature meter

Test instruments have a current certification of calibration or have been checked for accuracy to the lab standards which are traceable.

The internal regulator of the turbine was set to maximum and voltage was controlled by a C60 diversion controller connected to a 24 volt battery bank.



This test was conducted rapidly to reduce the effects of heat. The duration was only long enough for readings to stabilize prior to increasing to the next output level. Starting case temperature 68.7°f., final case temperature 93.7°f.

Sustained Power Test

Prior to testing the ambient and case temperature was 66.8 °f.

In a test stand, the turbine was run at 1,805 RPM, the current measured 15.3 amps and the voltage measured 25.7 VDC for an output of 393.2 watts. After 4 minutes, 23 seconds the unit went into stall* (regulation). The drive power was immediately stopped and not re-engaged until stall was completed. The drive power was again engaged at 1,805 rpm. Case temperature now read 87°f., current output 13.1 amps. The turbine went into stall again after 5 minutes, 41 seconds from initial start. The drive was again immediately stopped. The turbine indicated regulation was completed after 6 minute and 10 seconds but excessive drag indicated stall mode was still occurring.

After the turbine cooled to room temperature, the unit still appeared to be in stall mode. The turbine was disassembled and it was confirmed that the controller had failed. One (or more) of the FETs failed in a closed condition, causing the stator to remain shorted.

Total test time 6 minutes, 10 seconds. Final case temperature 97.2 °f.

* This occurred even with the voltage held well below the regulation point by the diversion controller and speed was held below the rated furling stall speed throughout the test.

Sustained Power Test Conclusion

This *Air X* failed during this test. Although the turbine did produce 393.2 watts for 4 minutes, 23 seconds, the unit entered “regulation” even though the battery voltage was well below the regulation point and RPM was below the furling speed. This test would have to be repeated in order to verify if this was a defective unit or if the *Air X* turbine is incapable of producing a sustained high output. Neither of the stall or regulation triggers should have come into effect during this test. Considering the rapid rise in temperature and evidence of saturation, repeating this test would likely produce the same results with other *Air X* units.

The sustained power test results were discussed with Mr. Andy Kruse of Southwest Windpower and he felt we must have received a defective unit and said it would be replaced. However, he felt the tests should not be repeated but rather suggested that we test the turbine under real-life conditions and stated that “rated watts was meaningless, it’s kilowatt produced that is important.” Details of the site prepared to field test the *Air X* are outlined on page 6.

Test Installation

Tower	Guyed Tube
Hub Height	122 feet
Conductor Size	# 2 copper
Conductor Length	342 feet
Site elevation	1,042 feet above sea level
Anemometers	3- NRG model Max 40
	1- F.E
Direction Vane	NRG model 200
Mounting Height	Hub Height
Boom length	2.3 rotor diameters
Data Loggers	Second Wind Nomad II
	2 - NRG WindWatcher
	Detronics - Data Wind

Optimal Conditions

Every effort was made to ensure the *Air X* was given a fair test environment.

- The *Air X* is installed on a 122 foot test tower, the comparison turbine is on a 100 foot tower.

- The power conductors are larger than specified to reduce the losses of voltage drop.

- The internal voltage regulator is set to maximum (34 VDC according to the *SWWP* manual) and battery voltage (24 volt system) was controlled by two separate diversion controllers. This would minimize the non production periods associated with the turbine shutting down during regulation.*

- During the test period, the average temperature was below standard temperature. When temperature and altitude are calculated, output production should exceeded the manufacturers ratings.

- The turbine was installed and in operation for four months prior to data collection. This should have allowed the seals and bearings sufficient time to be worked in.

* see *Voltage Control* on page 7 for additional information.

Over Speed Control

The *Air X* incorporates an internal speed sensor which disconnects the turbine from the batteries while simultaneously connecting the stator windings together (shorting the stator windings). This increases drag on the rotor, slowing it down and preventing over speed. During these shut down periods, the turbine produces no power. This system is used on most permanent magnet turbines (like the *H80*) but only for shutting the turbine off. Over speed is typically accomplished by furling the rotor or adjusting the pitch angle of the rotor blades. The latter two systems prevent over speed but also allow the turbine to continue producing power above the furling or governing speed.

Voltage Control

Every battery charging wind turbine requires a regulator incorporated into the system to prevent battery over-charging. The most common system is a Diversion Controller which automatically applies a load to the batteries. The turbine constantly produces maximum power and any excess is diverted to the dump load. The *Air X* uses a voltage regulator built into the turbine body. In order for the internal regulator to be able to read battery voltage, the turbine is also shut down for a period. This further increases periods of zero production.

Air X Performance Curves
Power Output

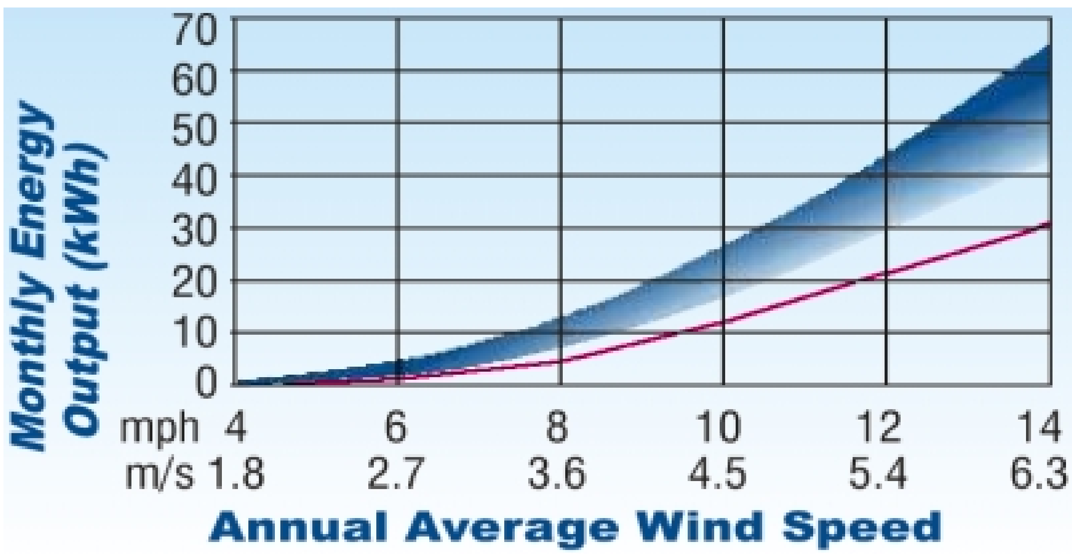
The power curve supplied by *Southwest Windpower* does not take these down periods into account. They state “instantaneous power” which is the peak power. When observed in operation the *Air X* may momentarily peak to the equivalent of 400 watts for a few seconds but then the turbine will go into stall mode. When averaged over time, the true power curve is less than half of the factory claim. When compared to other turbines of conventional design, the *Air X* is in the 180 watt class[1].

[1] Also confirmed in tests conducted by the *National Renewable Energy Labs*. (*N.R.E.L.*), & Paul Gipe.

Air X Performance Curves

Monthly Output

The monthly energy production curve of the *Air X* as published by *SWWP* shows two lines on the graph. The lower line represents a turbulent site and the upper line is for a non-turbulent site. The *Air X* on test is mounted on a 122 foot tower, 80 feet above any surrounding objects. This installation represents as close as practical, in the real world, a non-turbulent site. Even so, the mean average of the two factory power curves was used for data comparison. The predicted output was further reduced by 30% to allow for losses caused by elevation, temperature, wiring losses[2] and battery state of charge. Even with these factors taken into account, the *Air X* produces 20% less power on average than claimed[3].



Manufacturer's monthly energy output curves for turbulent (upper) and non turbulent (lower) sites [Air X manual Figure 7.2]

Detronics Estimated output

[2] The test site elevation is 1,042 feet above sea level. At standard temperature this would account for an approximate decrease in performance of 5%. However, the average temperature during the tests decreased the density altitude to approximately 500 feet *below sea level* at standard temperature. These combined conditions should have a net increase of approximately 10% in production. Under these conditions, the output should exceed the predicted monthly projections. The conductor cable on this installation is one gauge heavier than recommended in the installation manual to minimize losses.

[3] adjacent to the *Air X* tower, a comparison turbine mounted on a 22 foot shorter tower (100 foot), on average generated within 1% of it's claimed monthly production.

Cost

The cost per watt is often introduced when comparing solar to wind power. Typically, a turbine rated at X number of watts is less expensive than a similarly sized solar array. A comparison based solely on that information is not a complete equation. Unless the average energy resource, wind speed for wind power and sun hours for solar is taken into account, the production potential of neither device can be calculated.

In our area a hybrid system of both wind and solar is the most productive and economical. The cost per ***produced*** watt for solar power is extremely high here in the winter. The same is true for wind power in the summer.

The cost to install the various units under test are as follows:

Air X Turbine	$1,072.00	Ten- 75 watt Modules	$6,200.00	Comparison Turbine	$3,300.00
Tower	$3,000.00	Fixed Rack	$1,570.00	Tower	$3,000.00
		MPPT Controller	$971.00		
Total	**$4,072.00**	**Total**	**$8,741.00**	**Total**	**$6,600.00**

(wiring is equivalent for all systems, list prices shown in Canadian dollars)

From Nov 2004 to Jan 2005

- the *Air X* produced a total of 50.39 kWh
- the solar array produced a total of 123.5 kWh
- comparison turbine produced a total of 326.5 kWh

energy produced by the *Air X* test system	$80.81 per produced watt
energy produced by the solar array	$70.77 per produced watt
energy produced by other turbine	$20.21 per produced watt

The *Air X* as tested has a higher cost per produced watt than a solar array during the months of November through January. These months are typically the highest wind energy producing months of the year. If a less expensive 45 foot tower is used, the estimated cost per produced watt may be comparable to solar *only* during these high wind months.

All figures are based on data from this test site. Your results my vary.

Cost per Produced watt

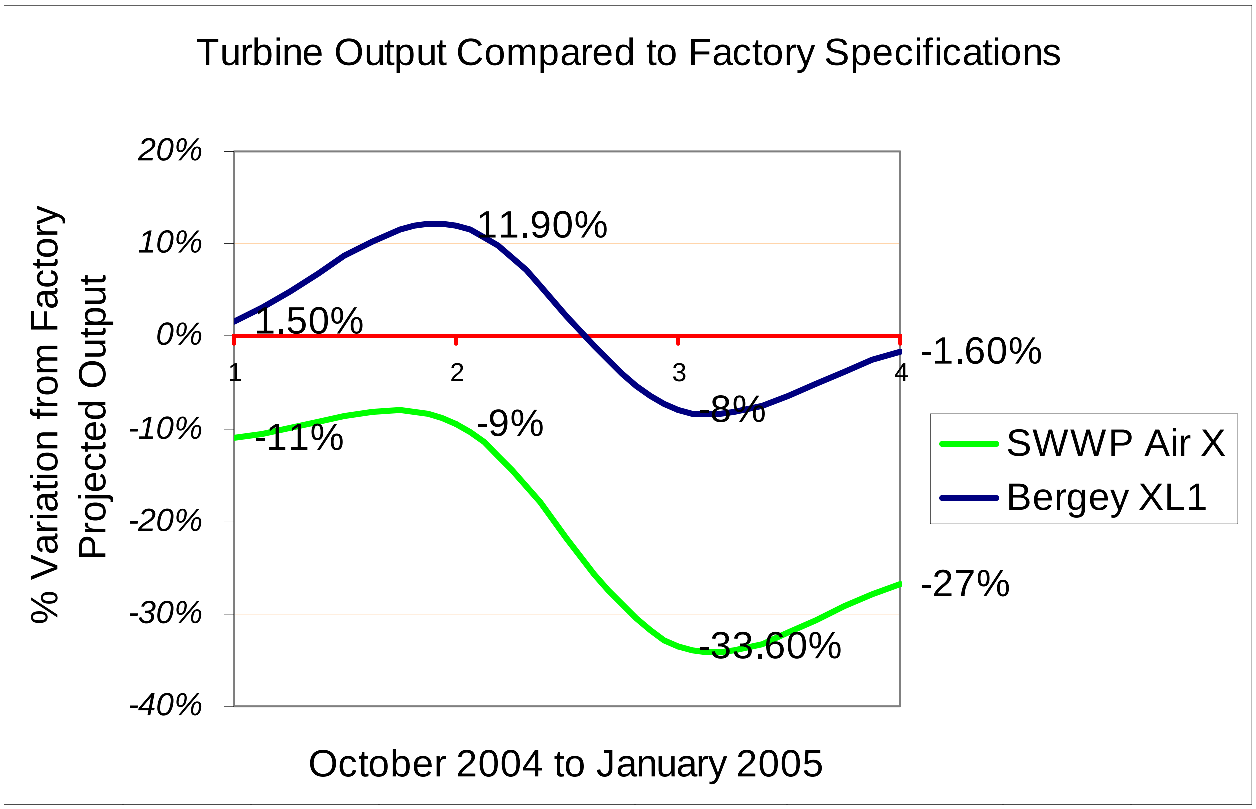
Based on the wind and solar resources available during the test period, the *Air X* is only competitive to solar during the high wind, low sun winter period. The cost per *produced* watt is 3.4 times higher for the *Air X* than for the comparison turbine on test. Our tests revealed that the *Air X* is not an economical choice compared to solar in areas with a similar wind / solar resource.

Monthly Energy Output

Monthly Energy output of the *Air X* was well below the manufacture's claims.

To account for potential system losses, an average of the manufacturer's two predicted output curves were reduced by 30% to establish an acceptable target. *The production of the Air X was an additional 20% lower, on average, than the target.* The comparison turbine, on a 22 foot shorter tower produced on average within 1% of it's predicted output during the same test period.

If the *Air X* is being considered in a RE system, the manufacturer's predicted output must be derated by a considerable margin to ensure sufficient load coverage.



Results are based on the data from tests at this site. Your results may vary.

Site Assessment

Date	Energy Produced	Predicted Wind Speed	Actual Wind Speed	Degree of Error in %
Oct 2004	13.7 kWh	8.2 to 9.5 mph	10.1 mph	-6 to 19 %
Nov 2004	14.97 kWh	8.3 to 9.6 mph	10.3 mph	-7 to -19%
Dec 2004	16.85 kWw	8.6 to 9.3 mph	11.9 mph	-22 to -28%
Jan 2005	18.54 kWh	8.9 to 10.2	11.9 mph	-12 to -25%

Results of the test *Air X* in predicting wind speed

Several data loggers were used for actual wind speed data collection during this test with an anemometer located at turbine hub height.

On average, the estimated wind speed calculated using the energy output of the *Air X* was 17.25% below actual wind speed. Since the *Air X* does not meet its performance curve, the performance curve cannot be used to calculate wind speed at a site. This test concludes that the *Air X* can not be considered an accurate tool for measuring the wind resource.

Test Objectives Summary

The test objectives are shown below:

1- Does the SWWP Air X perform as rated?
2- Can the Air X be used to accurately evaluate the Wind Resource?
3- How does it's performance compare to other RE generating equipment?

The *SWWP Air X* did not perform as rated in our tests.

The *Air X* did not accurately replicate wind speeds compared to a wind speed data logger.

Other renewable energy equipment had a much lower cost per produced watt than the *Air X*.

Air X Test Summary

Lab tests and field evaluations showed that the *Air X* is incapable of producing a sustained 400 watt output. The pulse width modulation characteristics of the output and the design (over speed and voltage control) prevent this from happening. A 180 watt rating would be more realistic.

Conclusions

The *Air X* turbines used in our tests did not approach the performance claims shown in the manufacture's literature.

It is a small, lightweight turbine which can be easily installed by an individual. For applications where minimal power is required and a suitable site exists, the *Air X* may be considered, assuming the all the limitations of the unit are taken into account. Lacking good low wind performance, this turbine is best suited for high wind locations. Due to the high rotational speed of the turbine, noise emissions can be relatively high and should be taken into consideration when locating the unit. When the unit enters regulation, additional noise and vibration resonates from the tower.

All figures are based on data from this test site. Your results my vary.