SOLAR AND WIND POWERED HYBRID AIR-CONDITIONER FOR A RAINFOREST ECO LODGE

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ABSTRACT

Eco lodges in Sri Lanka are becoming increasingly popular among foreign and domestic tourists to spend their leisure in a way which is much closer to the nature. The Eco lodges in the rainforest areas are more popular than the others but the high humidity level courses discomfort to the nature lovers. According to climate experts, the temperature of rainforest regions varies from 15 ^{o}C - 30 ^{o}C throughout the year and the relative humidity varies 70% to 95% which is on the higher side. The high humidity disrupts the ability of the human body to cool itself, which may lead to a heat stroke. Exceptionally high humidity can also trigger asthma symptoms. Another unpleasant effect of high humidity is the appearance of mold. High humidity makes it easier for molds to reproduce, and they can appear virtually anywhere, damaging whatever they grow upon. This research project has begun with the objective of converting the Lodge area into a comfort zone for the nature lovers. In addition this project will deliver a green lodge by introducing green energy to power up the system. Green energy sources like wind and solar have not been introduced to Eco Lodge sector so far and as a result, this sector contribute significant role damaging to the surrounding environment by generating CO_2 as well as noise by their power up systems. Further it will help the upcoming eco lodges as the base line study for high RH regions and the benefits of green energy.

KEYWORDS

Eco Lodge, Humidity, Green Energy, CO_2

ABBREVIATIONS

AC	-	Alternating current	**L**	-	Length
Ah	-	Ampere hour	**LED**	-	Light Emitting Diode
CEB	-	Ceylon Electricity Board	**Ltd**	-	Limited
CO_2	-	Carbon dioxide	**m/s**	-	Meters per Second
CO	-	Carbon monoxide	**MAX**	-	Maximum
COP	-	Coefficient of performance	**MIN**	-	Minimum
DC	-	Direct current	**MSL**	-	Mean Sea Level
EE	-	Energy efficiency	**Pvt**	-	Private
ESCO	-	Energy service company	**PWM**	-	Pulse-width modulation
GHG	-	Greenhouse gas (climate)	**PVC**	-	Poly Vinyl Chlorite
GMT	-	Greenwich Mean Time	**RH**	-	Relative Humidity
HRC	-	High Rupture Capacity	**SPV**	-	Solar Photo Voltaic
Kmph	-	Kilo meters per hour	**V**	-	Voltage
kW	-	Kilowatt	**W**	-	Width
kWh	-	Kilowatt Hour	**WP**	-	Peak Watts

1 INTRODUCTION

Eco lodges in Sri Lanka are very popular among foreign and local nature lovers. The eco lodges in rainforest areas are more popular than others. However, the high humidity levels of the locations are not comfortable to the nature lovers.

An Eco Lodge at Deniyaya area in Sri Lanka is under the management of Rainforest Ecologic (Pvt) Ltd. According to climate experts the temperature and relative humidity in this region varies from 15 - 30°C and 70 to 95% respectively. This location has an average wind speed of about 5.5 m/s and altitude about 800m above MSL. This land is adjacent to the Sinharaja Rain Forest which is a world heritage site.

Rainforest Ecologic (Pvt) Ltd is facing several problems in the implementation of the Eco Lodge. The problems are,

1. High Relative humidity during the year

   RH is considered as high if its level goes above 60%. The high humidity disrupts the body's ability to cool itself, which may also lead to a heat stroke. Exceptionally high humidity can also trigger asthma symptoms. Therefore, people with heart problems or asthma are advised to be extremely careful during such conditions. Another unpleasant effect of high humidity is the appearance of mold. High humidity makes it easier for molds to grow, and they can appear virtually everywhere, damaging whatever on they are growing up. Mold spores also pose a threat for allergy and asthma sufferers. Dust mites also thrive when the humidity is high. Present in almost every home, these tiny pests are yet another nuisance for people with allergies and asthma.

2. Tough environmental barriers imposed by the Central Environmental Authority of Sri Lanka due to the adjacent Siharaja Evergreen Forest ecosystem

   Sinharaja Rain Forest is a world heritage site and major eco tourism destination that describes as a Tropical Lowland Rainforest or Tropical Wet Evergreen Forest. This forest covers an extent of approximately 11187 ha. From east to west the length of the forest is about 21 km and its width from north to south is about 3.7 km. The Sinharaja forest was initially declared a Man and Biosphere Reserve (MAB) in 1978, as representative of Tropical Humid Evergreen Forest ecosystem in Sri Lanka has been recognized by UNESCO as part of its International Network of Biosphere Reserves.

3. To be a green Eco Lodge

   This Lodge is powered by an alternative energy source as a pilot project. The world's trend is more towards the renewable energy usage as the alternative. Wind and solar energy is more environmentally benign than many alternatives. [1], [2]

The project will implement by ISB Technical Services Limited, the Engineering arm of Industrial Services Bureau (ISB) Kurunegala, Sri Lanka (www.isb.lk). ISB Technical Services Limited (ISBTS) of North Western Province has been active in the field of energy and environment since 1993.Its main strength in the energy field has been the energy management and conservation and introducing new technologies to improve the energy efficiency. As the world's trend is more towards the renewable energy usage, ISBTS is actively involved in introducing renewable energy to the industry as well as for rural electrification.

2 OBJECTIVES

This project has begun with the following objectives.

1. Convert the Lodge area into a comfort zone for living
2. Introduction of green energy to power up the system
3. To be a base line study for high RH regions
4. Promoting green energy among other Eco Lodges in Sri Lanka

3 METHODOLOGY

The methodology consists of nine steps and first five steps will be completed at the first stage and the rest is more likely to complete at the second stage. The first five steps are,

1. Monitoring the variation of RH and temperature in the Lodge area

Table 1. *Measured RH and temperature of the area in the year 2009~2010*

Month	**RH (%)**	**Temperature (^{o}C)**
January '10	89.30	21.50
February '10	88.70	23.00
March '10	86.10	23.80
April '10	85.50	24.90
May '10	87.10	22.90
June '10	87.60	22.50
July '09	87.40	23.30
August '09	87.10	22.80
September '09	87.00	22.60
October '09	87.80	21.80
November '09	89.10	21.60
December '09	89.70	20.90
Average	87.70	22.63

Measurements been taken by Testo 175-H2 humidity data logger. The logger was placed at a room in the lodge and the readings taken per 6 hour basis and taken the average valve for each month. The measurement was carried out during the year 2010. Data for 2009 was taken from ISB Technical Services Ltd, Kurunegala. The recorded maximum relative humidity of the above time period is 96.80%. According to Table 1 the average humidity remains around 87.7 % and the average temperature lays around 22.63 ^{o}C

2. Designing an air-conditioning system

The main purpose of the air conditioner is to reduce the humidity up to 50% which is expected by the eco lodge management.

Table 2: *existing and the desired condition*

Existing Condition		Desired Level	
RH (%)	^{o}C	RH (%)	^{o}C
87.7 (96.8 max)	22.63	50%	As it is

Details of the lodge area needed to condition.

Table 3: *Details of Double rooms available*

	Area/ Capacity	Nos
Double Room	10’ x 10’	2
Occupancy		2 people
Family Rooms	15’ x 15’	1
Doors	3’ x 7’	2
Windows	2’ x 4’	6
No of lamps (CFL)	20 W	4
No of Lamps (incandescent)	40W	2

Total load = 36000 btu/ hr (10.56 kW)

Assumed efficiency of the system (COP) = 3.00

Total electricity consumption = 3.52 kWh

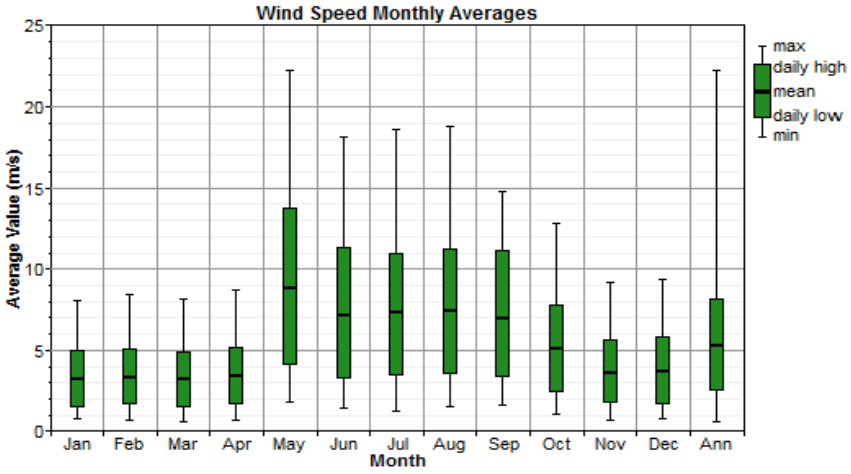
3. Collection of the past wind data measurement for the lodge area

Table 4: *Monthly wind data*

Month	Avg. wind speed (m/s)
January	3.20
February	3.35
March	3.21
April	3.45
May	8.83
June	7.16
July	7.35
August	7.45
September	6.99
October	5.07
November	3.63
December	3.70
Average	5.28

Source: Deniyaya CEB wind mast

The Ceylon electricity board (CEB) is monitoring the wind direction and wind speed in Deniyaya area from their wind mast. The data is taken from the CEB by ISB technical Services for the implementation of this project. The wind mast is continuously monitoring the wind data and updating its (



[2] , [7]

Figure 1: *Wind pattern according to HOMMER*

The data taken from CEB is been analyzed by HOMMER and obtained the figure 1. Highest wind speed (8.33 m/s) observed in May. According to figure 1 May to October is the wind season for the lodge area giving an average wind speed of 7.14 m/s. The Rest of the period of the year the average wind speed is 3.2 m/s, which is marginal to run the wind turbine.

4. Collection of the past solar data measurement for the lodge area

Table 5: *Monthly solar resource for the lodge area for year 2009*

Month	Clearness Index	Daily Radiation ($kWh/m^2/d$)
January	0.502	4.715
February	0.581	5.767
March	0.553	5.737
April	0.497	5.187
May	0.468	4.747
June	0.445	4.412
July	0.464	4.629
August	0.432	4.432
September	0.471	4.868
October	0.455	4.555
November	0.484	4.588
December	0.494	4.528

Source: Homer Version 12.19 (14 June 2005) (www.nrel/gov/homer)

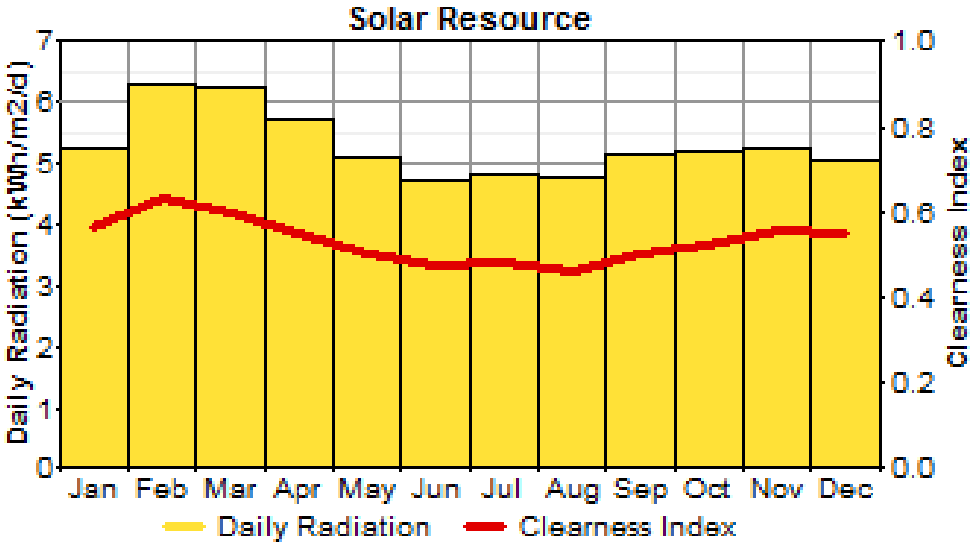


Figure 2: *Solar resource pattern according to HOMMER*

The solar resource is taken for the lodge location (latitude 6° 15' north and longitude 80° 15' West) from the HOMMER software for time zone GMT 6.00, Sri Lanka. According to Table 4 the solar radiation and the cleanness index remains same for the entire annum. February, March and April are the peak months for solar radiation and cleanness index for the lodge area.

[1], [6]

5. Designing of the wind-solar hybrid system

Table 6: *Expected power output from the hybrid system*

Month	Avg. wind speed (m/s)	Daily output from 1 X Whisper200 (kWh)	Daily output from 750W SPV (kWh)	Total (kWh)
January	3.20	1.70	3.0	4.70
February	3.35	2.00	3.0	5.00
March	3.21	1.80	3.0	4.80
April	3.45	2.10	3.0	5.10
May	8.83	12.50	3.0	15.50
June	7.16	12.30	2.1	14.40
July	7.35	12.35	2.1	14.45
August	7.45	12.40	2.1	14.50
September	6.99	10.83	2.1	12.93
October	5.07	5.50	3.0	8.50
November	3.63	2.20	3.0	5.20
December	3.70	2.23	3.0	5.23

[1], [2] , [6] , [7],[9]

Complete System Configuration

Table 7: *Aero generator Whisper 200: 1 nos. including external wind turbine controller (Housed inside master control unit)*

Model	Whisper 200
Rotor Diameter	9 feet
Weight	30 kg
Mount	2.5 inch
Start-Up Wind Speed	3.1 m/s
Voltage	48V
Peak / Rated Power	1000 watts @ 11.6 m/sec
Number of Blades	3
Material of Blades	Polypropylene & Carbon Fiber Composite
Material of Body	Cast Aluminium (Corrosion proof)
Survival Wind Speed	55 m/s
Over-speed Protection	Angle governor & dump load
Controller	External regulator
Bearings	Low Friction, totally enclosed & self lubricated
Controller output	48V DC

Wind Controller:

(a) Capacity = 1KW/48V
(b) Modular construction for easy replacement.
(c) All control cards are easy replaceable plug-in type.
(d) Operating ambient up to 52^0C
(e) Painting : Powder coated
(f) Built-in Battery reverse current flowing blocking diode
(g) Short circuit protection.
(h) Overcharge protection by load diversion to dump load.

Tower for Whisper 200 Wind Turbine

Table 8: *Tower details for the wind Turbine*

Construction Material	Mild Steel
Protection from corrosion	Hot Dip galvanized
Type	Tilt up tubular 2.5" tower, 60ft. with guy support.

SPV modules: 1 Complete Set

Table 9: *Details of the SPV modules*

Capacity	750 WP 48V nominal (750 WP x 2)
Make	MNRE approved
Peak power per module	75 Watt peak
Dimension & Weight	1 Set : 1206mmLX530mmW & 7.63 Kg
Total area required	20 sq meters
Temperature	- 40 to 90^0 C
Wind Load	Up to 200 kmph
Humidity	0 to 100 %
Voc of each module	19 volts
Type of cell	mono/poly crystalline silicon
Efficiency of cell	13% to 15 %
Lamination type	Vacuum laminated Glass to tedler

Module mounting structure: 2 set

Table 10: *Details of the module mounting structure*

Construction Material	Mild Steel (angle / flat)
Protection from corrosion	Hot Dip galvanized

Battery: 1 Set

Table 11: *Details of the battery bank*

Estimated Units generated from system	**5 to 10 units/day**
Voltage configuration	48V
D.O.D allowed tubular battery	80 % max
Battery charge Efficiency	85 %
Autonomy considered	**1.8 days**
Battery capacity required	48V 600 Ah (2X48V 300Ah)
Type	Tubular lead acid flooded electrolyte
Positive plate	Tubular
Negative plate	Pasted Flat
Voltage of each cell	2 volts nominal
Electrolyte	Dilute Sulphuric Acid

Solar charge Controller (housed inside master controller)

(a) Capacity = 2.5 kW/48V (60 amps max) (This single module used for 1kW & 2kW SPV. For 3kW to 5kW 2 modules used. For 6kW to 7.5kW 3 modules used)
(b) Modular Construction for easy replacement
(c) Built-in Amp and Volt meter
(d) All status monitoring indicating LED and control switches are available on the front
(e) All control cards are easy replaceable plug-in type.
(f) Operating ambient upto 52^0C
(g) Painting : Powder coated
(h) Built-in Battery reverse current flowing blocking diode
(i) Battery line short-circuit protected HRC Fuse with carrier
(j) PWM based overcharge protection/load diversion

Inverter: 1 Set

Table 10: Details of the inverter set

Max Load	**2.5 kVA**
Power factor	85 %
Inverter Efficiency	90 %
Inverter capacity required	2.5 kVA 48 V DC
Efficiency	**90 % +**
Duty	Continuous
Waveform	**Pure Sine wave**
Ambient	60 deg. C.
Protection	IP under voltage, IP over voltage, OP overload, OP short – circuit
Output regulation	+/- 2.5 %
Input DC bus voltage variation	+/- 25 %
Relative Humidity	98 %
Instrumentation	Output Voltage, current & kWh.
Power Device	MOSFET / IGBT
Control	Pulse Width Modulation
Power Factor	0.85

Master Controller

Solar charge controller for 750WP SPV systems	1 no. Built in
Wind charge controller with dump load for 1no. 48V 1.0 kW wind turbine	1 no. Built in
Metering :- a) Solar generation in Amps. b) Wind generation in Amps. c) Total generation in Amps. d) Grid based AC/DC charger supply in Amps. e) System voltage (D.C) f) Load supply in Amps.	Built in
100 Amps heavy duty battery C.C charger AC 240 volts input from AC Mains to 48 Volts DC output for battery charging	Built in
AC mains /battery AC/DC charger auto start / stop automatic switch.	Built in

Copper Cables: As required

Type	Copper cables of 1.1kV grade PVC insulated

Connection Diagram of the System

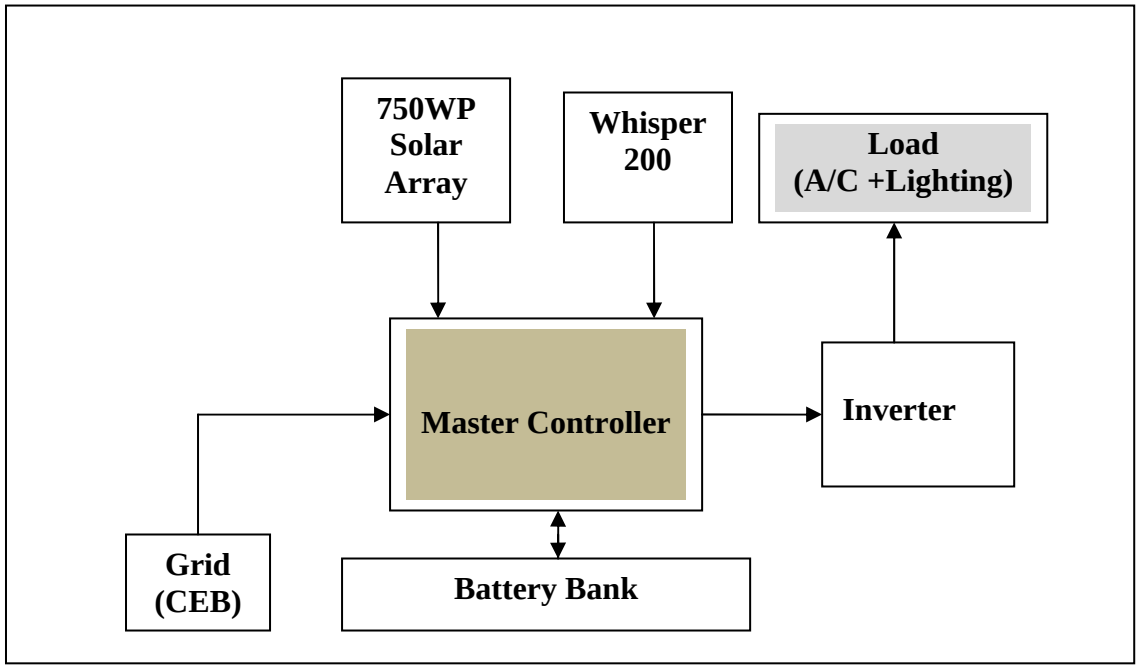


Figure 3: ***Connection Diagram of the System***

[2] , [9]

4 RESULTS AND DISCUSSION

An air conditioner is more likely functioning as a de-humidifier as it maintains indoor temperature of the lodge area around 22 ^{o}C. The energy consumption of the air conditioning system is approximately 3.52 kWh. The minimum power delivered by the wind solar hybrid system is 4.7 kWh and the system has an excess of 1.2 kWh to cater the lighting load of the rooms.

When a wind turbine and an SPV system are interfaced, the power generation from these two is mutually supplemented, and the resultant hybrid system offers a reliable and cost-effective electricity supply in a decentralized mode. The major advantage of solar-wind hybrid system is the enhanced reliability when solar and wind power production is used together. Additionally, the size of battery storage can be reduced slightly as there is less reliance on either method of power production. Often, when there is no sun, there will be plenty of wind. Wind speeds are often low in periods, when the sun resources are there at best. On the other hand, the wind is often stronger in seasons, there are less sun resources. Even during the same day, in many regions worldwide or in some periods of the year, there are different and opposite patterns in terms of wind and solar resources. Such different patterns can make the hybrid system the best option in electricity production. A hybrid wind-solar electric system demands a higher initial investment than single larger systems.

Advantages through green power for an eco lodge:

- Door opening for green certifications and carbon credits
- No net emission of greenhouse gases

- Renewable sources of energy are available in most locations
- Generally, technologies are proven, reliable and require minimal maintenance
- Systems do not require a constant input of consumables (no motoroil, filters, etc)
- Life cycle costs of wind and solar can be very attractive
- Long service life (15-25 years)

General drawbacks of a green energy system in Sri Lanka are as follows.

- High initial cost (especially for photovoltaic systems)
- Lack of soft loan schemes to tackle the high initial cost
- High-tech components in renewable electricity generation systems
- Low power output (except in the areas with large wind and hydropower resources)
- Often needs some type of a non-renewable energy backup system
- High cost and unavailability of high-efficiency appliances in local markets

[3], [6] , [7] , [8]

5 CONCLUSIONS

As it was presented in this paper, practical aspects for hybrid (wind and solar)systems are very feasible application for eco lodges or small hotels located in remote location of Sri Lanka whose location's characteristics give it ability to exploit, not one but two alternative energy sources for the generation of a large part of the necessary energy. Of course, before the installation of a hybrid system, a very good study of the climatic characteristics such as the wind potential and the solar radiation must certainly be one. So, the energy demand for hotels and lodges in the country can be partially or fully covered with the use of wind and solar hybrid system as standalone or grid-connected systems when location characteristics and areas' wind energy potential is good.

This eco lodge will be a model for green energy adopted lodge and it will deliver the message of green concept towards the Sri Lankan hotel industry.

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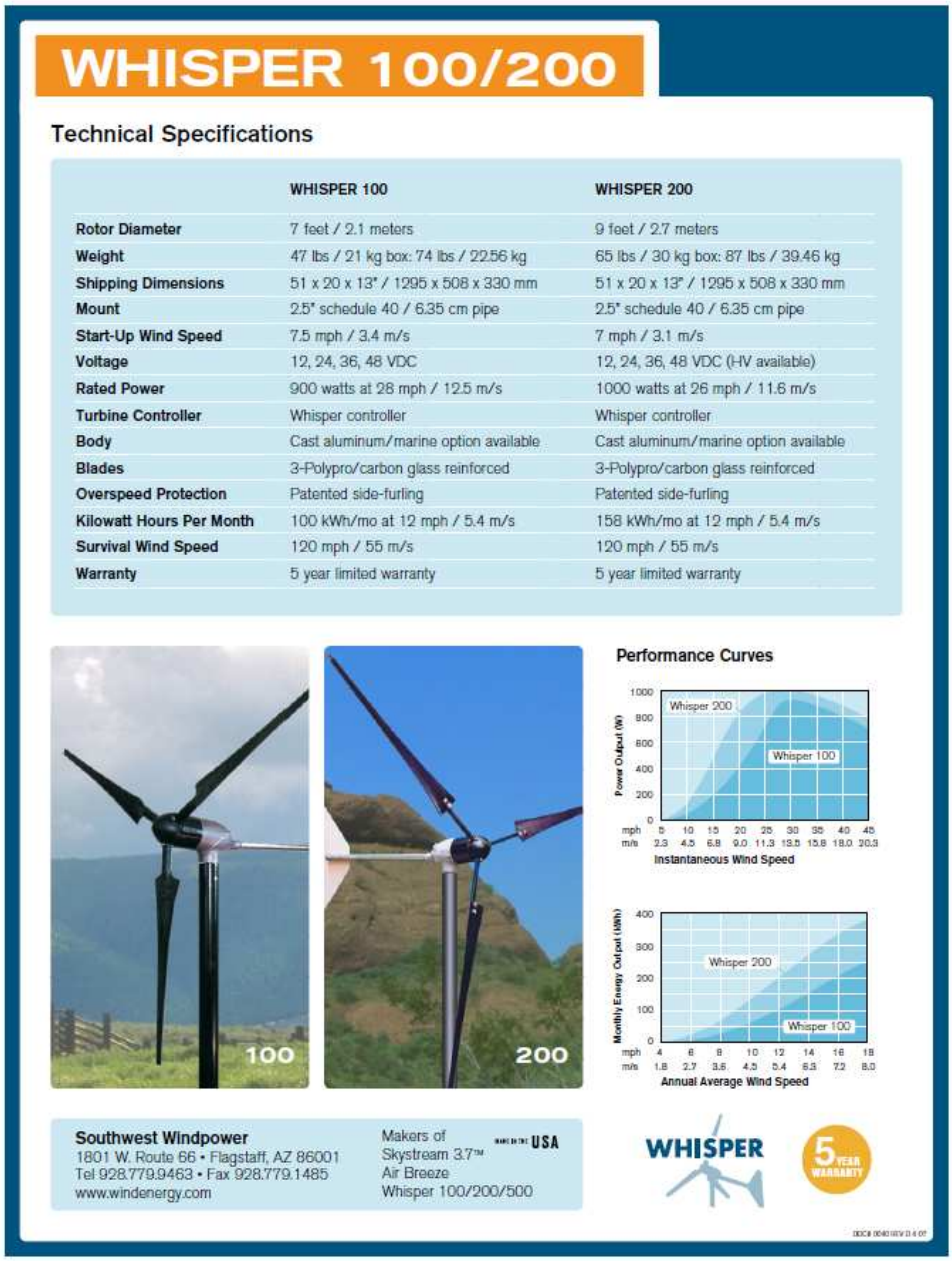
ANNEX



WHISPER 100/200

Technical Specifications

	WHISPER 100	WHISPER 200
Rotor Diameter	7 feet / 2.1 meters	9 feet / 2.7 meters
Weight	47 lbs / 21 kg box: 74 lbs / 22.56 kg	65 lbs / 30 kg box: 87 lbs / 39.46 kg
Shipping Dimensions	51 x 20 x 13" / 1295 x 508 x 330 mm	51 x 20 x 13" / 1295 x 508 x 330 mm
Mount	2.5" schedule 40 / 6.35 cm pipe	2.5" schedule 40 / 6.35 cm pipe
Start-Up Wind Speed	7.5 mph / 3.4 m/s	7 mph / 3.1 m/s
Voltage	12, 24, 36, 48 VDC	12, 24, 36, 48 VDC (HV available)
Rated Power	900 watts at 28 mph / 12.5 m/s	1000 watts at 26 mph / 11.6 m/s
Turbine Controller	Whisper controller	Whisper controller
Body	Cast aluminum/marine option available	Cast aluminum/marine option available
Blades	3-Polypro/carbon glass reinforced	3-Polypro/carbon glass reinforced
Overspeed Protection	Patented side-furling	Patented side-furling
Kilowatt Hours Per Month	100 kWh/mo at 12 mph / 5.4 m/s	158 kWh/mo at 12 mph / 5.4 m/s
Survival Wind Speed	120 mph / 55 m/s	120 mph / 55 m/s
Warranty	5 year limited warranty	5 year limited warranty

Performance Curves

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5 YEAR WARRANTY

Whisper 200 Wind Turbine Details

A Bed Room Similar to Lodges'