2018-10-10

Selection of a 50kW Small Wind Turbine for Calgary

Yan, Tao

UNIVERSITY OF CALGARY

Selection of a 50kW Small Wind Turbine for Calgary

by

Tao Yan

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF ENGINEERING

GRADUATE PROGRAM IN MECHANICAL AND MANUFACTURING ENGINEERING

CALGARY, ALBERTA

SEPTEMBER, 2018

Abstract

The thesis studies the cost efficiency of wind turbines compared to photovoltaic (PV) technologies and develops criteria for the selection of cost-efficient and reliable small wind turbines for sites in Calgary.

The thesis first presents a literature review of wind energy and turbines and describes the technicalities of large versus small turbines. It studies electrical generation, control systems, safety systems and certifications.

This thesis analyzes the performance of PV and small wind turbines, and the economic differences between the two in terms of cost per unit power.

Affordability is another advantage of Chinese turbines; they are usually cheaper than European. Since no Canadian manufacturers are running as Endurance went bankrupt, Chinese turbines are selected because they are relatively inexpensive, certified, and not much is known about them. A detailed framework compares technical and economic performances of turbines from different Chinese manufacturers.

Table of Contents

List of Tables

List of Figures and Illustrations

CHAPTER 1 INTRODUCTION

1.1 Background

Energy is the basis for economic development and it is important to have a reliable supply of energy for the development of any country. Conventional energy sources, such as coal, cause greenhouse gas (GHG) problems. Several energy sources, including nuclear, hydropower, biomass, solar energy, and wind, have been proposed to satisfy the energy demand. Therefore, some renewable energy systems take up a relatively large proportion of electricity generation in many countries. For example, in Canada, the hydropower makes up 59% of electricity generation, wind makes up 4%, and PV makes up 0.5%. (Natural Resource Canada,2018)

Among them, solar photovoltaics have low energy conversion efficiency; however, the manufacturing cost has dropped significantly which threatens the market for wind turbines (Milborrow, 2016). Hydroelectric power, which requires a huge investment, requires construction of dams that submerge considerable areas of land, and large-scale residential migration may add the cost.

The source of wind energy is its motion, which results from the temperature differences caused by uneven heating from the sun. It is estimated conservatively that the world’s available wind resource could be 20,000 TWh/year (Oudah et al., 2014). Both PV and wind turbines can be considered an inexhaustible source of green energy. Unlike locations for hydro dams, wind energy systems and PV may be placed almost anywhere.

1.2 Research Motivation

The City of Calgary owns many Occupational Work Centers (OWCs) and other outdoor sites such as landfills, which may be suitable for the generation of renewable energy through photovoltaic and wind turbines. For example, all landfill and waste facilities in Calgary must maintain an unused space next to a road as buffers (City of Calgary,2018).

Economies of scale achieved in solar PV manufacturing have reduced the cost and increased the availability of PV modules. Recently, the technology has achieved increasing acceptance in the market place (Marigo et al., 2013). Calgary is geographically suitable to utilize PV as well as wind turbines. For example, the yearly photovoltaic potential in Calgary is 1292 kWh/kW compared to Berlin's 848 kWh/kW (Natural Resources of Canada, 2013), this means one kW PV system in Calgary would produce 52% more electricity than the one in Berlin.

Also, The Canadian Wind Energy Atlas calculated the annual average (mean) wind speed in Northwest Calgary as 5.92m/s (50m height) which is plenty for wind turbines.

Hence, customers in Calgary would have interest in buying PV or turbines by considering their power output, space requirements, economics, safety, reliability, availability of the energy source (wind or sun), and other factors relevant to the technologies.

1.3 Research Question

The purpose of this research work is to identify suitable commercial wind turbines for Calgary in terms of performance and cost. Although European companies make wind turbines of suitable capacity, products from China are investigated here because they are certified, and widely utilized in China and African countries, but not largely imported by American countries. Affordability is perceived as another advantage of Chinese turbines; they are usually cheaper than European, and this will be discussed in next Chapter.

Due to the falling prices of photovoltaic cells, smaller turbines (say 1-10 kW) cannot compete with PV; however, PV economics do not change much with scale whereas wind gets considerably cheaper and reach a crossover point where the two technologies are of comparable cost. (Chung,D et al.,2015)

The question is where the point is. The hypothesis of this research is that the point is around 50 kW, but the question can only be answered by a detailed technological analysis to assess the potential power output, cost effectiveness, and safety of turbines in urban settings. More discussion of this crossover point will be presented later in this chapter.

This research work will locate manufacturers and assess their wind turbines to choose the most suitable wind turbines for Calgary. The research work aims to provide further information to determine the point at which PV and wind cost effectiveness are comparable. Such data would be useful for urban applications claiming MW sized turbines are unlikely to be allowed within city limits.

The most experienced and popular Chinese manufacturers have been selected for this study because their products perform well and are likely to be economically feasible.

1.4 Introduction to the Wind Turbines

1.4.1 Wind Energy and Wind Turbines

Among the various renewable energy sources, wind energy is the most promising technology for large scale commercialization, with the advantages of having an inexhaustible supply of clean and safe wind energy. In this project, cost per kWh is the primary concern when evaluating the performance and then the economics of the various technologies.

Wind turbines function by converting the kinetic energy of wind into electrical energy. The main components are blades, gearboxes, and generators. Based on the orientation of the axes of rotation of turbine blades, wind turbines are classified as horizontal and vertical. Horizontal turbines have the main rotor shaft pointed into the wind and vertical turbines have the rotor shaft arranged vertically.

Many important factors must be considered in the selection of wind turbines. Safety is always a primary concern and the manufactures are responsible for testing the turbines before massive production. Performance and cost are always evaluated together. The following chapters will discuss the performance and impact of wind turbines with regard to tower height, wind speed, cost, noise and visibility, safety and warranties.

Wind energy production and consumption have grown tremendously in the last decade, and they are expected to continue this expansion. Global wind energy production in 2011 reached 239GW. This is 3% of the total world energy production (WWEA, 2012). It is projected that by 2020 this share will increase to 10% (WWEA, 2012). According to the International Energy Agency (2010) 12% of global electricity will be generated from wind by 2050. Energy from wind will reach even higher percentages in countries not in the Organization for Economic Cooperation and Development (OECD). The non-OECD economies will have higher global wind energy productions with 17% of global wind energy and this will be 57% in 2050 (WWEA, 2012).]. According to the Canadian Wind Energy Association, Canada has an installed capacity of 6,578 MW (WWEA, 2012). The world's largest wind farm, with 421 turbines covering 47000 acres of land, is in Texas, and rated at 735 MW. The first wind farm was constructed in Alberta in 1993 and the total capacity in Alberta is over 1100 MW (Canadian Wind Energy Association, 2013). Alberta has the strategic advantage of good wind resources for cost effective wind energy production (Canadian Wind Energy Association, 2013).

1.4.2 Selection Criteria for the Power Generation System – PV System vs. Wind Turbine

System

There are always some tradeoffs when selecting a power generation system. In comparing solar with wind technology, reliability, physical installation requirements, cost, and maintenance requirements are the main selection criteria. For example, due to fewer mechanical components, PV produces much less noise; however, it requires much more ground area than turbines for the same size. The costs of these two systems are always comparable.

The 50kW PV installed in 2015 at the Bearspaw OWC owned by the City of Calgary cost $2296 per kW of peak power. This number is from personal communication with Prof.David Wood.

Reliability is a complex issue. Wind turbines should be tested and certificated before sold to customers. Turbines can be either tested by the manufactures or by third-party organizations. For example, the National Wind Technology Center, in Boulder, offers to test the performance and reliability of blades, turbines, and other components in both laboratory and field environments (U.S Department of Energy, 2014).

There are also two other important factors when comparing wind power and PV, but not critical for this project:

Visual and noise impact may be of major concern for the wind turbine. For this project, the potential sites in Calgary are generally industrial areas well away from residences; therefore, visual and noise are not the major concerns.

Comparison of the space required for solar modules and wind turbines, to give equal amount of output is another main factor to consider. Using 200W solar modules requires 250 solar modules to have a rated power of 50kW. However, the land area occupied by one solar module is nearly same as that of one small wind turbine. From Figure 1 and Figure 2, in order to produce 50kW, 250 solar modules have to be used which would cover an area 252 times larger than used by one 50kW wind turbine.

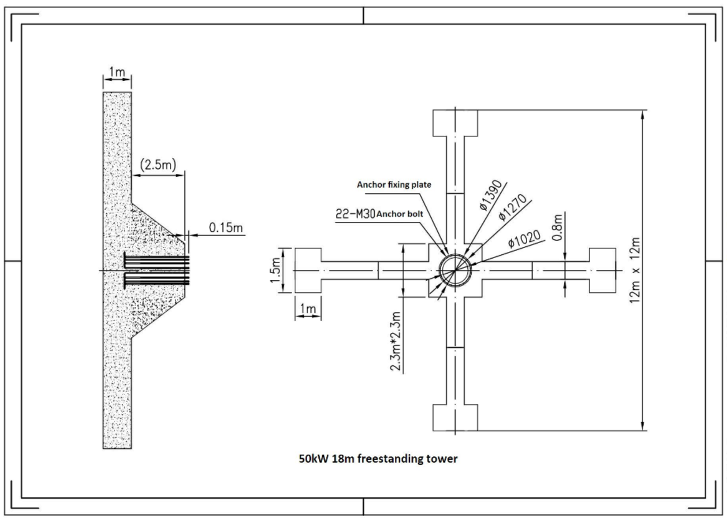


Figure 1 Dimensions of typical Hummer 50kW turbine foundation (see Appendix B Hummer Data Sheets)

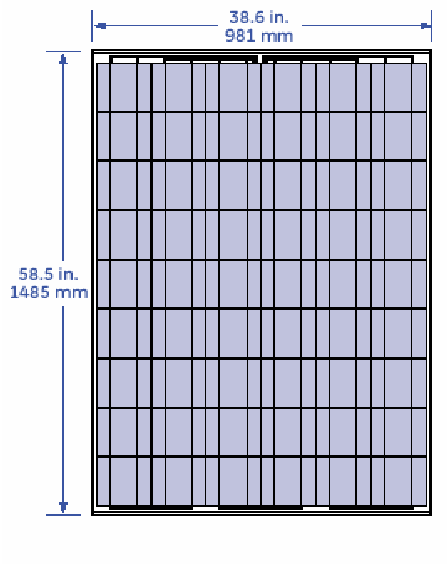


Figure 2 Dimensions of 200W Photovoltaic Module (GEPVp-200 Panel, 2014)

In terms of the rated power, the space requirement of 50kW turbines is nearly 250 times less than the arrays of solar modules. This makes it highly feasible to select a small turbine over the large number of PV arrays to generate 50kW. This comparison is justified as part of a general comparison of the technologies, because space is not necessarily the primary concern for this project.

1.4.3 Capacity Factor of Wind Power System

The capacity factor for any system generating electricity is the ratio of the average power delivered to the rated power (Abed et al., 1997). There is a theoretical maximum efficiency a wind turbine can achieve; this limit is known as Betz's limit which 59.3%. In reality, the capacity factor for large turbines usually ranges between 25-35% depending on the design of the turbines, location and the technology being used (Carbon Trust, 2008). However, for small turbines the capacity factor is found to range between 15-20% or even less (Carbon Trust, 2008).

The coefficient obtained from a wind turbine is given as:

$$\mathbf{C_p} = \frac{\mathbf{2P(\mathit{V})}}{\mathbf{\rho AV^3}} \qquad \mathbf{(1)}$$

Where, C_p is the Coefficient of Power, ρ is the air density, A is the area of the rotor (blades), and V is the wind speed. The coefficient of power (Cp) is a measurement of how efficiently the wind turbine converts the wind energy into electricity, Eq (1) is the expression of definition.

The size of the turbines, their height, and the dimensions of the rotor blades, determines the power output. As the height of the wind turbine increases, the average wind speed increases (Wood, 2011). From Eq (1), it clears that higher average wind speed increases the power output. The output power of a wind turbine varies directly with the cube of wind velocity as described by Eq (1). This equation is only valid for the wind speed range from cut-in to near rated. From rated speed on the power output is constrained as can be seen from any power curve.

The power curve shows the relationship between the turbine power output and hub height wind speed. Turbine manufactures draw the power curve by long testing their turbines in candidate site. (Lydia M et al.,2014)

The height of the tower cannot be increased indefinitely because the ratio of total power output to installed cost will eventually decrease with increasing tower height.

1.4.4 Turbine Selection: 50kW Small Turbine

Wind Turbines are classified into two main categories based on their rated power output: small turbines and large wind turbines.

Types of Wind Turbines

Small wind turbines: According to the international standard for small wind turbine safety, IEC61400-2, small wind turbines are defined as having a rotor swept area of less than 200 m^2 which corresponds to a rated power of around 50 kW (Institution, B. S..2014).

Large Wind Turbines: Wind turbines with capacity above 50kW are defined as large turbines (Institution, B. S..2014).

For usage in OWCs located in cities, large wind turbines are assumed to be unacceptable.

1.5 Research Objective

The overall power extraction capability which is indicated by capacity factor is a critical factor. Generally, large turbines have better CF as mentioned. The hypothesis of this research is that the crossover point is around 50 kW, a detailed technological analysis of each turbine including the potential power output, cost effectiveness, and safety of turbines will be performed. Therefore, this project is to determine whether 50kW wind turbines are an appropriate choice for Calgary.

The research objectives of this study are as follows:

Primary Objectives

- To develop some criteria for selecting 50 kW wind turbines for Calgary considering safety, noise, and cost.
- Determine the cost effectiveness of these wind turbines compared to the PV technologies
- To comparatively study small wind turbines of Chinese Manufacture and solar PV in terms of feasibility and cost efficiency.

Secondary Objectives

- To compare and analyze the performance of different wind turbines.
- To rank available wind turbines based on applicability to Calgary

1.6 Research tools and information

Targeting these research objectives, performance and economic analyses have been performed for a selected 50kW turbine on a nominal project site at Calgary, Canada. Following simulation tools and information have been incorporated order to derive the results as the part of research project.

Tower height and height extrapolation

As the turbine hub height increases, the amount of energy generated increases. Manufacturers produce towers with different heights; a height extrapolation calculation is used to evaluate the turbine performance. To perform a height extrapolation, one of the most commonly used methods is the Hellmann power law expressed as

$$\frac{V}{V_0} = \left(\frac{H}{H_0}\right)^{\alpha} \qquad \textbf{(2)}$$

where V is the wind speed at a given height, H, V_0 is the wind speed at the reference height, H_0.

Most wind speed data have been measured at 10 m (Masters, 2013) whereas the hub height of a 50kW turbine is typically more than 15m. At the Calgary International Airport, this wind speed v_0 is about 4.4 m/s at 10m (Government of Canada, 2017), α is a function of the topography (known as roughness coefficient). For the city of Calgary, 0.3 has been used to calculate the new wind speed (Ragheb, 2015). For all the turbines the wind speeds at various heights and the power generated was computed.

Table 1 Wind extrapolation calculation（Only available heights of turbines are listed.）

H (m)	H/H_0	v(H) [m/s]
16	1.6	5.066
18	1.8	5.248
20	2	5.417
36	3.6	6.462

1.6.1 Weibull Distribution

The Figure 3 shows probability density distribution curve and a typical power curve in steady wind. In this case, small turbines only have flat production after rated power

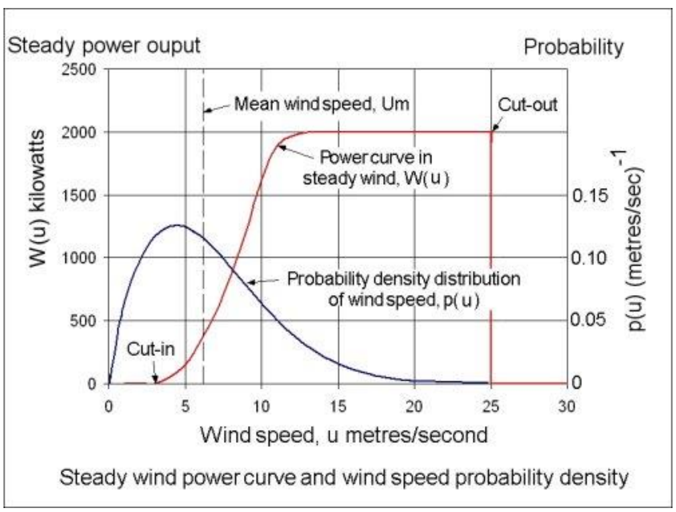


Figure 3 Steady wind power curve and wind speed probability density. (PelaFlow consulting, 2016)

The Weibull probability density distribution function (pdf) is often used to approximate the wind speed (Manwell et al., 2002). The Weibull probability density function is given by (Manwell et al., 2002):

$$p(u) = \left(\frac{k}{c}\right)\left(\frac{u}{c}\right)^{k-1} exp\left[-\left(\frac{u}{c}\right)^{k}\right] \quad \textbf{(3)}$$

where $\boldsymbol{k}$ is the shape factor, $\boldsymbol{c}$ is the scale factor, $\boldsymbol{u}$ is the wind speed.

The cumulative distribution function is given by (Manwell et al., 2002):

$$\boldsymbol{f(u) = 1 - \exp\left[-\left(\frac{u}{c}\right)^{k}\right]} \quad \textbf{(4)}$$

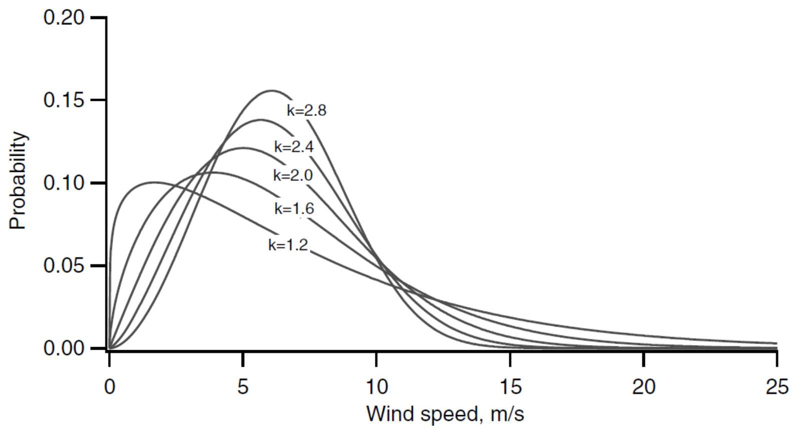


Figure 4 Example of Weibull probability density function for V=6 m/s

From Figure 4， as the k increases, the probability curve has a sharper peak which means wind speed varies less(Manwell et al., 2002).

The average wind speed is derived from Eq (3) as follows (Manwell et al., 2002):

$$\bar{u} = C\Gamma\left(1 + \frac{1}{k}\right) \quad \textbf{(5)}$$

Where $\Gamma(\mathrm{x}) = \int_0^\infty \mathrm{e}^{-\mathrm{t}}\mathrm{f}^{\mathrm{x}-1}\,\mathrm{dt}$. (Manwell et al., 2002)

Weibull distributions will be used along with the manufacturer’s power curves to calculate average power output.

1.6.2 RETSCREEN Analysis of Wind Turbine

RETScreen is a Clean Energy Management Software system for renewable energy and project feasibility for the various power technologies (cogeneration) (Natural Resources Canada, 2016). The tool evaluates the annual electricity costs, production costs, and cost per energy unit. Also, it provides spreadsheets for the financial analysis of a potential installation. To make an analysis, RETscreen requires parameters input (see Figure 5,), such as hub height, power capacity, rotor diameter etc.

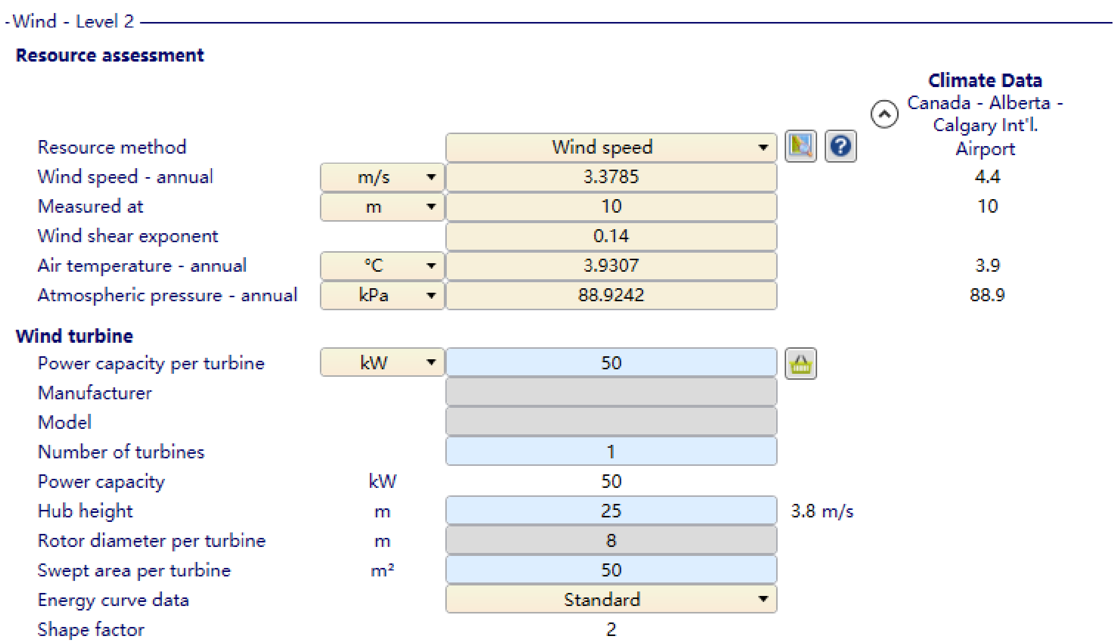
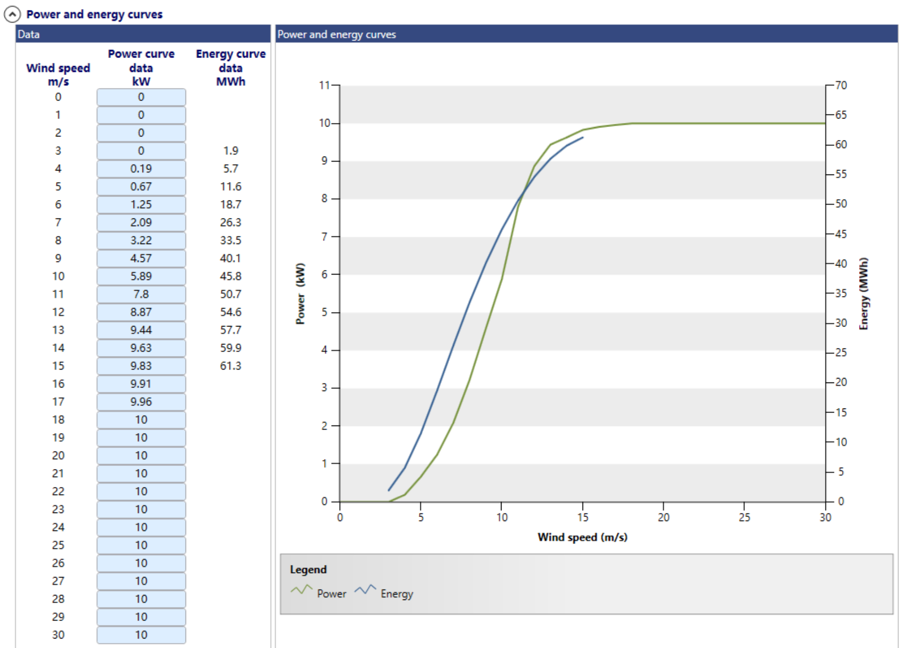


Figure 5 RETscreen Parameters

After input parameters, power and energy curve is generated accordingly (see Figure 6).



Power and energy curves

Data

Wind speed m/s	Power curve data kW	Energy curve data MWh
0	0	
1	0	
2	0	
3	0	1.9
4	0.19	5.7
5	0.67	11.6
6	1.25	18.7
7	2.09	26.3
8	3.22	33.5
9	4.57	40.1
10	5.89	45.8
11	7.8	50.7
12	8.87	54.6
13	9.44	57.7
14	9.63	59.9
15	9.83	61.3
16	9.91	
17	9.96	
18	10	
19	10	
20	10	
21	10	
22	10	
23	10	
24	10	
25	10	
26	10	
27	10	
28	10	
29	10	
30	10	

Figure 6 Power and energy curve generated by RETscreen

RETScreen generates an economic analysis of a project based on various of factors including depreciation and taxes, electricity export revenue etc. Investors can clearly see the profits of the projects. (Natural Resources Canada, 2016).

In this thesis, Financial analysis and cash flow graphs are generated by RETScreen and used to analyze the rate of returns. (see Figure 7)

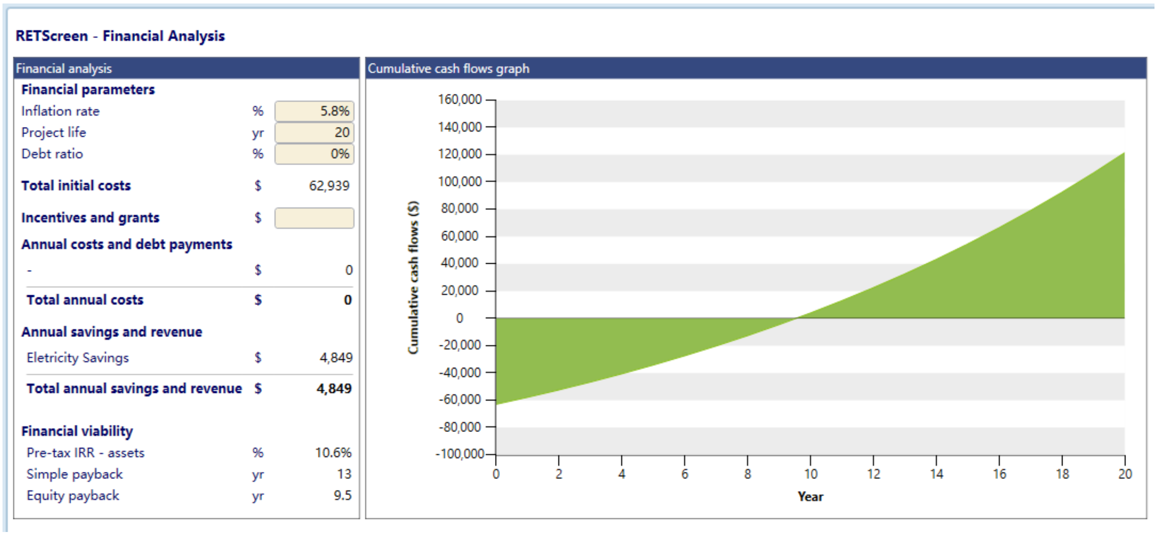


Figure 7 An example of Financial Analysis from RetScreen showing a cash flow analysis

1.7 Research Scope

The technical scope for this paper is to evaluate the power output of 50 kW turbines for typical sites in Calgary and to evaluate their suitability in terms of reliability. Limited by time and materials, only five Chinese wind turbine manufacturers have been selected based on cost and reputation. This study compares wind turbines from these manufacturers and compares them with PV performance.

1.8 Thesis Outline

This dissertation is divided into five chapters. The content of the following chapters I given below.

Chapter 2 provides information on small wind turbines. Technical aspects of wind turbines, types of wind turbines and comparative design aspects of small and large turbines are explained. A detailed discussion is presented on how to select a 50kW small wind turbine for Calgary.

Chapter 3 explains how the selection of five Chinese manufacturers was made. The comparison was based on the technical and commercial features of these companies.

Chapter 4 presents results from probability and software analyses of wind turbine performance and project cost. Weibull analyzes distributions, turbine power curves, assessments of different tower heights for small wind turbines, payback calculations and associated economics.

Chapter 5 provides the overall conclusion based on the research and recommendations arising from the study.

CHAPTER 2 LARGE AND SMALL WIND TURBINES

This section aims to develop a basic understanding of wind turbines of different technical designs.

2.1 Introduction of small and large turbines

To balance performance and cost, the technical designs of small and large turbines are different.

For example, to better utilize the wind flow, yaw control system is needed. There are two types of yaw control system: active yaw system and passive yaw system.

The active yaw systems use software to anticipate the wind direction and rotate the nacelle of the wind turbine against the tower based on automatic signals from wind direction sensors. The passive yaw systems adjust the orientation of the wind turbine rotor by utilizing the wind force. (P Rosenvard et al.,2011)

Large turbines and some small ones use the active yaw control system, which is more precise than the passive yaw system used in other small turbines (All the turbines considered in this thesis use active yaw) (Renewable Energy World, 2008). Furling is a general way to control speed in small turbines whereas brakes are used on the high-speed shaft in large turbines.

Blade pitch adjustment changes the pitch angle of a wind turbine. The turbine's electronic controller checks the power output of the turbine several times per second. When the turbine is overload, the blade pitch mechanism turns the rotor blades slightly out of the wind. The blades are turned back into the wind whenever the power output drops again. (Nielsen et al.,2010)

Blade pitch adjustment is popular on large turbines but has been rarely employed on small turbines because of cost. However, modern 50kW turbines have started to use pitch adjustment to adjust the blade's angle and take greater advantage from the prevailing wind conditions.

The gearbox connects the low-speed shaft to the high-speed shaft and increases the rotational speeds to above 1000rpm, which is required by most generators to produce electricity (Liu, W. et al., 2009). Most small wind turbines use direct drive generators to lower cost (Power cluster. Basic maintenance techniques for wind energy technicians.2011), (Renewable Energy World, 2008).

Small wind turbines come in a great variety of designs, numbers of blades and configurations, which produce different power outputs. Different designs are distinguished in terms of number of blades used, upwind or downwind configurations, vertical axis wind turbines (VAWTs) or horizontal axis wind turbines (HAWTs).

Darrius VAWTs is taken as an example.

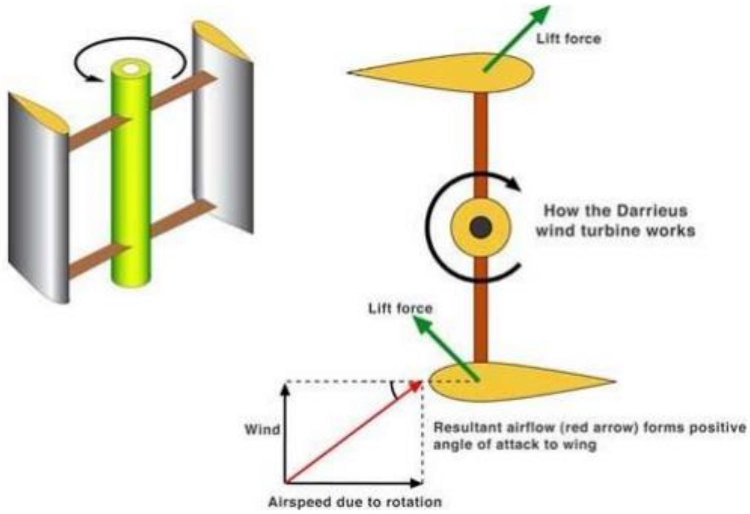


Figure 8 Darrieus vertical axis turbines principle of operation (Jin X et al.,2015)

VAWTs have advantages over HAWTs (C Bracken Meyers,2013):

- No yaw mechanisms are needed.
- Lower rotational speeds which may generate less noise
- Since a VAWT can be located nearer the ground, it takes advantage of locations such as rooftops, mesas, hilltops, ridgelines, and passes funnel the wind and increase wind velocity.

VAWTs are not commonly deployed due to three main reasons (C Bracken Meyers,2013):

- Most VAWTs have an average lower efficiency, because their blades rotate into the wind, and this causes more drag force.
- Due to the lower tower heights, VAWTs do not take advantage of higher wind speeds.
- Lower rotational speeds require (for the same power output) larger generators and brakes.

Currently, only one Chinese manufacture Richuan from Qingdao is exporting 50kW VAWTs on Alibaba. The prices including tower are listed below:

Table 2 Prices of VAWTS (data from personal communication with sales)

Manufactures	Richuan	Hummer
FOB Price (USD)	110000	130000

These prices are higher than average HAWTs. Most manufactures are exporting HAWTs, therefore, this thesis will focus only on HAWTs.

Wind turbines are classified as grid-tied and off grid. Grid-tied systems are those that do not store the power generated and are connected to the main grid. Off-grid systems work in isolation from the electric grid and have their own power storage systems. This project only focuses on grid-tied systems that can be installed in OWCs.

Two turbines considered in this thesis are now described. A 50kW Shenzhou wind turbine is shown in **Figure** 9 while a Ghrepower wind turbine of similar rating has been depicted in **Figure** 10.

Figure 9: 50kW Shenzhou Wind Turbine (Shenzhou, 2014)

Figure 10: 50kW Ghrepower Wind Turbine (Ghrepower, 2014)

2.2 Small and large turbine design

The performance of both small and large wind turbines is affected by many components. The most significant of them are discussed in detail below.

2.2.1 Blades and blade attachment

The rotor consists of the blades and blade attachment; current rotors usually have two or three blades, although there are turbines with four and five blades; these are mainly very small turbines (Lee, 2007).

The only advantage of two-bladed rotors is that the initial price is lower. Even the loads on both 2 bladed and 3 bladed turbines are similar, 3 bladed turbines usually transmit less fluctuating torque to the shaft. Figure 11 shows the Hengfeng 50kW wind turbine rotors. The 3 blades are made from GRP. The blade diameter is 15m.

Figure 11: 50kW Hengfeng Wind Turbine Rotors (Hengfeng Power Generator, 2014)

Turbine blades use airfoil sections to achieve a high lift to drag ratio (Ahmed, 2012). The blades must withstand heavy loads, while the design should lead to optimal energy production and minimize noise. Materials, design and manufacturing procedures and tests are all important to produce good blades.

Blade Materials

The material parameters include minimum and maximum operating temperatures, and ability to withstand other environmental conditions (e.g., strength, toughness, density, cold deformability, ageing characteristics, resistance to rot and sun light).

The material used for the blades is glass fiber reinforced polyester (GRP), carbon fiber and wood, etc. The materials for manufacturing small and large turbine blades are similar. For example, timber is an excellent material for small blades, however, timber has a strong anisotropy and therefore potential variation of its properties (Wood, 2011). The common materials used for both large and small turbines are GRP (Vazquez et al., 1998). The main benefit of GRP is that the reinforcement layout can be adjusted to give maximum strength in the radial direction where it is needed most (Vazquez et al., 1998).

Design and main load

Small and large turbines may have different design goals. For example, minimal noise must be produced by large blades, small blades should be designed to start quickly in low winds. (Wood, 2011)

The driving force of wind turbines is the lift. Lift acts perpendicular to apparent velocity of the wind speed at the blades. lift normally increases with angle of attack, while drag force also increases. The wind turbine will give maximum performance, when lift to drag ratio is maximum. This is the basic design theory (Schubel et al.,2012).

Blades are designed to withstand several loads. For example, wind pressure causes flatwise load, and gravitational forces and torque load cause edgewise load. Rotation causes centrifugal loads. Adequate stiffness is mandatory for all blades to avoid excessive bending under load.

For small turbines, low inertia is more important for starting. For large blades, structural strength is more important (Wood, 2011).

Manufacture:

Due to a high level of centrifugal stress, reinforcement is necessary, but it only gives mainly radial strength. The glass reinforcement in GRP blades is concentrated at the surface is to maximize the distance from the neutral axis, (Wood, 2011).

Moulds are needed if composite materials are used. Vacuum infusion is implemented to make lower and upper surfaces. The upper surface is placed in the mould and after adding the fiberglass layup, resin is vacuumed onto the mould. This manufacturing method needs considerable labor and is suitable for small production (Wood, 2111). A closed-mould process such as resin-transfer moulding (RTM), is suitable for massive production. A core is placed in the mould along with the fiberglass. The mould is then closed and resin injected under pressure (Wood, 2011).

Maintenance:

The faults and damages of wind turbine can be minimized as long as the maintenance work is implemented in stated maintenance time. The failure rate is listed in Figure 12

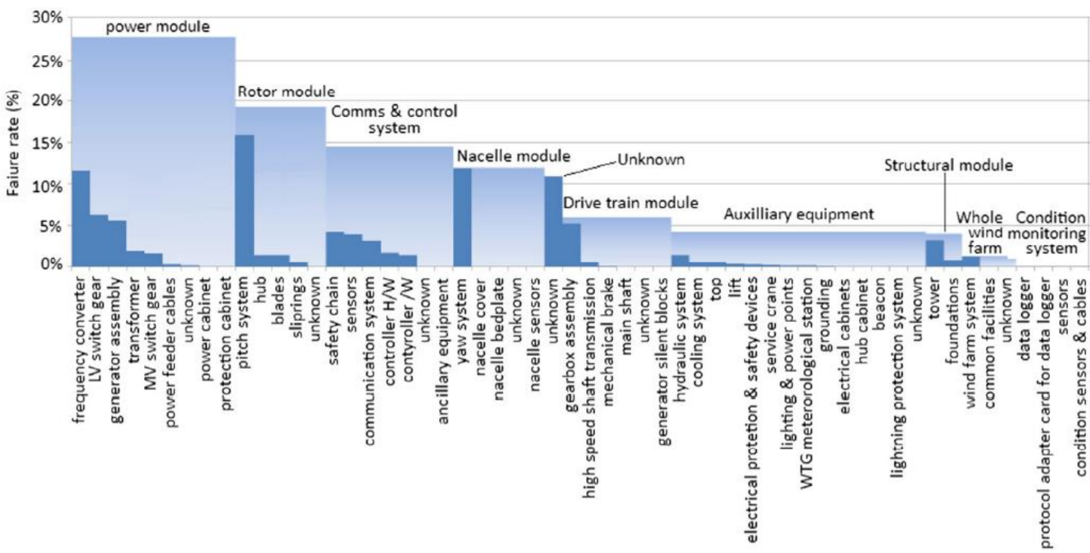


Figure 12 Failure rate proportions attributable to geared-drive onshore wind turbine sub-assemblies. (Yang W et al.,2014)

From Figure 12,power module, rotor module and control system have highest failure rate.

Take Ghrepower turbine as an example, the general maintenance work consists of tower supports, engine room, generator, impeller and control system. 3 persons shall be required for maintenance and they can complete the maintenance within one day without exceptional situation. Maintenance plan should be made to list the maintenance work of 15 years after starting operation of wind turbine. (Ghrepower,2016)

The maintenance time (year) is started from first operation, which can be divided into 4 maintenance periods of A, B, C and X (X1 and X2) according to maintenance contents. (Ghrepower,2016)

Maintenance codes – X1 and X2 express extension: X1 is the items for maintenance per 3 years and X2 is the items for maintenance per 5 years.

All maintenance items with X1 and X2 in maintenance list shall be implemented in this maintenance work. (Ghrepower,2016)

1) Maintenance A is the maintenance of 1-3 months after first operation of wind turbine. It is a single maintenance and will only implement one time in maintenance plan of WTGSs, namely retighten all bolts. Time error for implementation of Maintenance A is one month. (Ghrepower,2016)

2) Maintenance B is the maintenance of half year, which time error is the same with Maintenance A. (Ghrepower,2016)

3) Maintenance C is the maintenance of a year. It is to tighten the bolts as per the numbers required by torque meter and mark for it to avoid repetition. For any bolt loosed found in inspection, tighten all bolts related to the items and make marks on it. The time error for implementation of Maintenance C is the same with maintenance A. (Ghrepower,2016)

4) Maintenance X is the extension of maintenance. (Ghrepower,2016)

All maintenance operations and inspections shall be completely recorded in maintenance records. Please check maintenance list in Appendix H. (Ghrepower,2016)

The cost will be discussed later.

2.2.2 Generators

The broad trend in small turbines is the use of synchronous generators with permanent magnets (PMG) in all existing power ranges. This generator is simple, efficient, and more robust.

Figure 13 shows a 55kW generator of Shenzhou Company. The rpm of this generator varies between 69rpm to 1500rpm. This Permanent magnet generator uses a gear box for its connection with the rotor which is shown in **Figure** 14.

Figure 13: 55kW Shenzhou permanent Generator

Figure 14: Shenzhou Company Gearbox

Figure 15: Hummer direct driven permanent magnetic generators

Figure 15 shows the generator used in Hummer wind turbines. The generator is the direct driven permanent magnetic type.

2.2.3 Yaw Control System

As discussed in Chapter 2.1, passive and active yaw control systems are commonly used on turbines.

A Tail fin is a typical passive yaw control system. The tail fin is placed at the end of an arm and provides a lateral force on the vane, which acts on the arm that yaws the machine to face the wind. This simpler tail fin reduces the overall cost of small turbines, and is easier to maintain, but it is not as efficient as active yaw control system (Wood, 2012).

All the selected turbines use active yaw system to improve their performance. For example, when wind speed exceeds 18m/s, the yaw shaft of Hummer's turbine will deflect 90 degrees from wind and then the turbine stops working. After 5 mins protection, their programmable logic controllers (PLC) module will drive the DC24V regulation motor to seek the wind signal again.

Dogvane is part of active yaw system, and is used to show the direction of wind, usually mounted on the top of the nacelle. For example, **Figure** 16 shows a typical dogvane used by the Hummer 12-50kW wind turbine. **Figure** 17 shows the location of the dogvane on the Ghrepower turbine. The dogvane measures and indicates wind direction. If the angle between dogvane and wind generator axes is more than 10 degrees, the yaw motor will drive the blades into the wind.

Figure 16: 12-50kW Hummer Dogvane

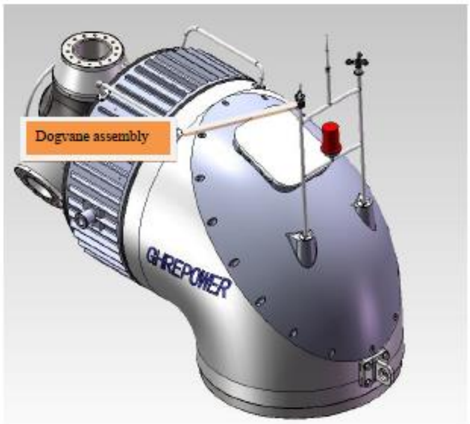


Figure 17: Ghrepower Vane Assembly

2.2.4 Safety System

Brakes

The turbine must be capable of safely parking when emergency events happen. Any emergency, such as loss of rotor balance, an electrical failure, and extremely high speeds leads to an emergency stop.

This braking system consists of a mechanism to slow the rotor to stop, before maximum wind speed is reached.

All the selected turbines use hydraulic brake systems which are activated by hydraulic pressure; it is a mechanical brake system that acts on the main shaft.

The brakes used in Shenzhou wind turbines are shown in **Figure** 18 (high speed shaft brake), **Figure** 19 (low speed shaft break) and **Figure** 20 (Yawing brake).

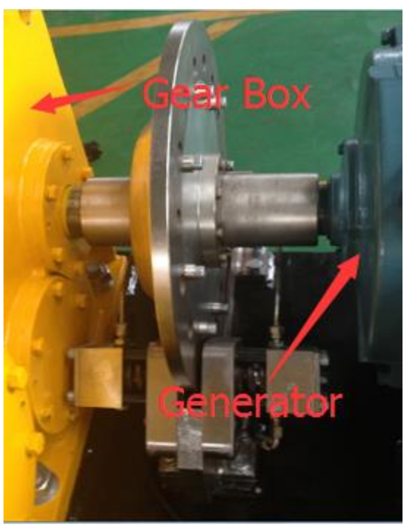


Figure 18: Shenzhou High Speed Shaft Brake (Shenzhou 50kW ON-GRID WIND TURBINE SYSTEM, 2014)

Figure 19: Shenzhou Low Speed Shaft Brake (Shenzhou 50kW ON-GRID WIND TURBINE SYSTEM, 2014)

Figure 20: Shenzhou Yawing Brake(Shenzhou 50kW ON-GRID WIND TURBINE SYSTEM, 2014)

The safety system of large wind turbines is more complex than that of small wind turbines. Many turbines employ active pitch adjustment to protect the turbines from over-speeding and keep the power constant. Pitch changes the angle of attack and therefore changes the lift and drag.

For small wind turbines, when the wind speed increases, the axial thrust force on the rotor also increases, and when this force reaches the value that causes pitch adjustment, the pitch mechanism is activated. all the selected 50kW wind turbines are equipped with pitch adjustment.

Speed regulation

It is not economical to install large electrical generators that can convert all the power contained in high wind speeds to electricity, because from rated speed on the power output is constrained as can be seen from any power curve. When this power cannot be absorbed, over-speed results in high centrifugal forces, excessive and undesirable noise and vibration and electrical damage.

Several methods control the rotational speed in small turbines. Regulation can be achieved by furling the rotor of a turbine with a tail fin: The rotor is furled in the horizontal plane with respect to the wind direction and the rotor collapses towards the tail. Wind flow through the rotor is reduced by decreasing the area that faces it. Thus, the power extracted from the wind is reduced.

Turbine blades have a maximum efficiency at a specific ratio of blade-tip speed to wind speed. Tip/speed ratio (TSR), by definition, is the blade-tip speed divided by the wind speed. For example, if the blade-tip speed is traveling at 100 km/h and the wind speed is 20 km/h, then the TSR is 5 (100/20). (Ragheb et al.,2011)

The actual power of the wind turbine depends on Cp which is the function of the tip speed ratio (λ). The tip speed ratio (λ) is defined to be the ratio between the shaft speed and the wind speed, and is given by:

$$\lambda = \frac{\omega R}{V} \qquad \textbf{(5)}$$

where, ω is the rotor tip speed.

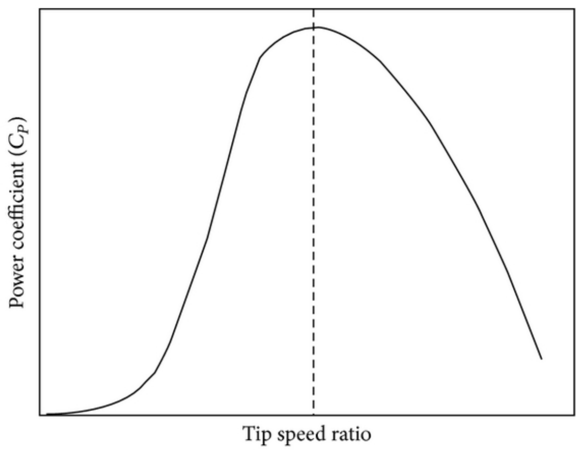


Figure 21 Cp- λ curve for a typical wind turbine. (Kjellin,J et al.,2013)

Figure 21 is an illustration of the Cp- λ curve for a typical wind turbine. Based on this curve, there is only one optimal constant value for tip speed ratio, where Cp is maximum. If the wind turbine is operated at this point, maximum power will be extracted from the available wind.

2.2.5 Towers

The towers can be monopoles or lattice towers. Lattice towers can be self-supporting or supported by guy wires, however, monopoles can only be self-supporting. Self-supporting monopole towers are the most preferred for all selected manufactures,

Examples of towers are shown in **Figure** 22 to **Figure** 24.

Figure 22: A Self-Supporting lattice Tower (Greenheart Energy, 2011)

Figure 23: Guyed Wired Tower (weiku, 2014)

Figure 24: Monopole Tower (youtube, 2010) with hydraulic system for raising and lowering

Table 3 Advantages vs. Disadvantages of each type of tower (Danish Wind Industry Association, Wind Turbine Towers, 2003)

Type	Main advantages	Main disadvantages
Monopole	• Good aesthetic design	• More steel is required More expensive to manufacture and transport
Guyed	• Low manufacturing cost • Guy wire tension helps adjust tower natural frequency • lightning withstands	• Not for urban settings • Not vandal-proof
Sectional lattice	• Low cost to transport • on-site assembly	• Corrosion occurs in joints to shorten the lifetime
Tubular lattice	• Easy to manufacture • Long lifetime without galvanizing	• Protection for electrical cable is minor

It is common for manufacturers to offer different types of towers to suit the needs of the buyers. For example, Hummer and Winpower offer an optional tower (shown in Figure 25 and Figure 26) that is raised and lowered hydraulically (named as “hydraulic towers” by them officially). These towers are freestanding and include tower bases, hydraulic cylinders, and hydraulic pumps.

Hydraulic towers are unique to Hummer and Winpower of the turbines considered here: there will be additional cost, so if this feature is wanted, Hummer and Winpower are the only companies to choose. The following discussion and analysis are based on the basic model without hydraulics.

Figure 25: Hydraulic support for the pole of Wind turbine (Hummer)

Figure 26: Installed Wind Turbine (Hummer)

The towers are also offered in different heights to be selected depending on power output requirements. The towers must withstand the loads from the turbine as well as the tower self-weight and the wind load. (Danish Wind Industry Association, Manufacturing Wind Turbine Towers, 2003)

Towers are assembled from tapered subsections which are cut and rolled into shape, and then welded together. Each subsection is small, so it is usually transported by rail or road. The transportation cost will be discussed later.

Typical 50m towers, which can mount a turbine with a 44m rotor diameter (600 kW), weigh 40 metric tons; 60 m towers, capable of mounting a 72m rotor diameter (2000 kW), weigh 80 metric tons (Danish Wind Industry Association, Manufacturing Wind Turbine Towers,2003).

2.3 Economic Comparison of Small Wind Turbines vs. Large Wind Turbines

Detailed descriptions of small turbines and large turbines are presented in the above section. These main criteria are considered for making economical comparisons. In the section, three turbines from Hummer manufacturer including 10kW,50kW,100kW are compared in terms of overall cost and cost per average power. USD is the standard currency for following calculation. All prices are Free on board (FOB) price. Free on board (FOB) is a trade term that indicates whether the seller or the buyer take responsibility for goods damaged during shipping. "FOB shipping point" (or FOB) means that the buyer takes responsibility. "FOB destination" means that the seller takes responsibility until the goods reach the buyer. (Coon J et al.,2016)

2.3.1 Cost of Components

The distribution of cost of apparatus for a typical 1.5 MW wind turbine is shown in **Figure 27**. It gives a brief cost summary of each component and this figure is also comparable in the following comparison.

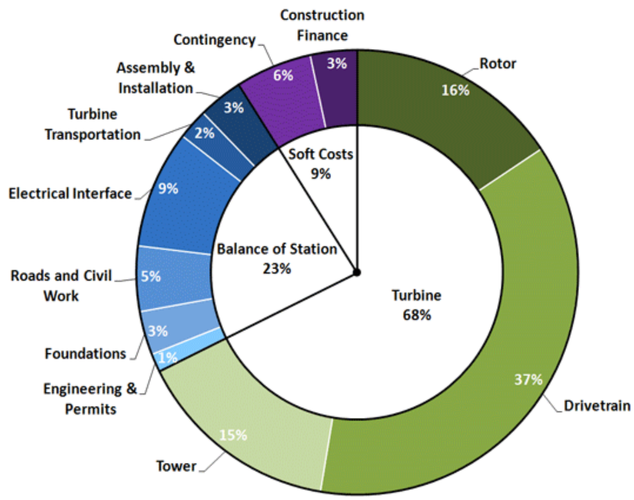


Figure 27: Installed capital costs for the land-based 1.5MW wind reference turbine. (NREL, 2014)

The price comparison from one of the selected manufacturers for the commercial types of turbines is shown in Table **4** below:

Table 4 Hummer 10kW, 50kW and 100kW Wind Turbine System，FOB price(USD) (without on-grid inverter)(personal communication with Hummer Sale representative)

Hummer 10kW, 50kW and 100kW Wind Turbine System(without on-grid inverter)				
S/N	Item	10kW	50kW	100kW
1	Wind turbine	8,170	45,710	105,325
2	SIEMENS PLC controller	800	1,640	1,920
3	Rectifier controller	590	3,390	7,665
4	Metal dumping load	750	2,935	4,365
5	Free standing tower	4,080	10,485	21,810
6	Hydraulic tower	7,345	27,540	42,620
7	Total with freestanding tower	14,390	64,160	141,085
8	Total with hydraulic tower	17,655	81,215	161,895

Transportation is an important part of the overall cost. Wind turbines are transported in both 20ft and 40ft containers. The overall transportation cost of a container from Shanghai to Calgary, is 3950USD and 4600USD, respectively (data from Hummer sales). For 10kW turbines, only a 20ft Container Load is required. For 50kW turbines, one 20ft and one 40ft container are needed. For 100kW, two 40ft units are required (data directly from Hummer).

Wind turbines are imported duty free but incur the 5% GST. So, the total landed cost, excluding installation, is the turbine price, to which must be added transportation cost and a 5% local sales tax.

Table 5 Landed cost comparison

Turbines	**10kW**	**50kW**	**100kW**
Overall FOB cost	$14,390*105%+$3950=**19059.5USD**	$64,160*105%+$3950+$4600=**75918USD**	$141,085*105%+$9200=**157339.3USD**

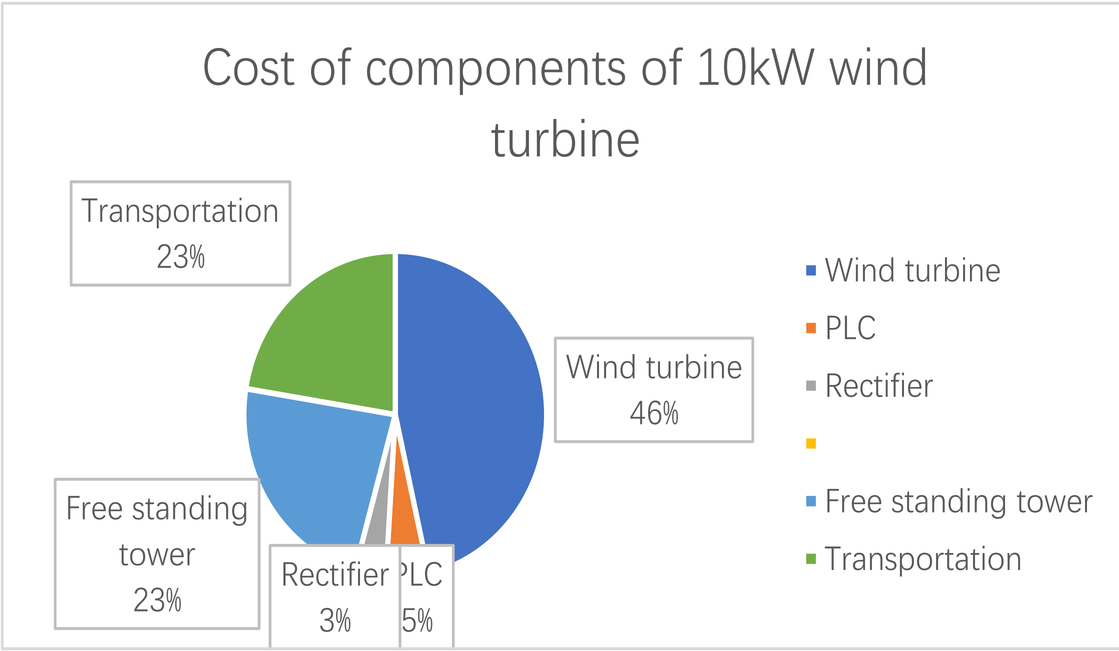


Figure 28: Cost of components of 10kW. Anhui Hummer Dynamo Co. Ltd (Prices in USD.)

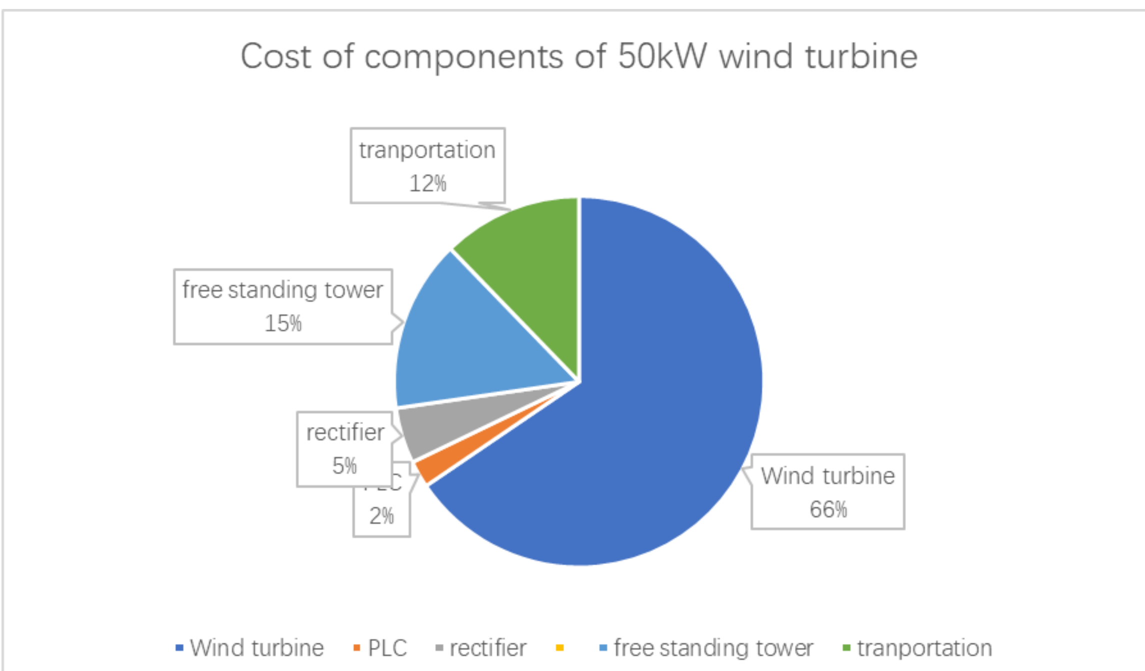


Figure 29: Cost of components of 50kW. Anhui Hummer Dynamo Co. Ltd (USD is used as the currency, as the followings.)

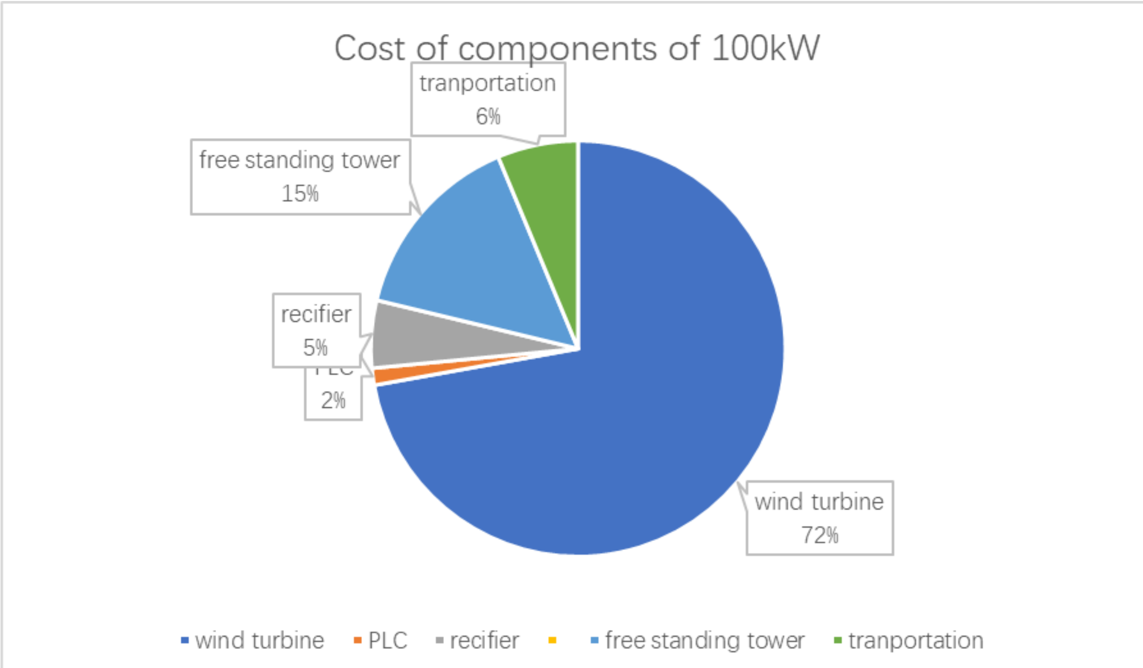


Figure 30: Cost of components of 100kW. Anhui Hummer Dynamo Co. Ltd (USD is used as the currency, as the followings.)

The price of a 10kW turbine is only 46% of the total cost; transportation cost of 10kW turbine takes 23% of the overall cost. This is much higher than that of 50kW and 100 kW. As the capacity of the turbine increases, everything except the turbine itself contributes less to the total cost. With increasing capacity, turbines cost more. However, when the capacity is larger than 50kW, the percentage of cost of each component does not change very much. The cost per unit power is discussed later.

2.3.2 Cost of Installation and Maintenance

Small turbines require less installation space compared to large turbines. Cranes are not always needed for installation of small wind turbines; for example, guyed wired towers can be erected with a winch, and as shown before, some manufactures have hydraulic erectors to raise the tower. Take Hummer's 50kW wind turbines as an example. All data is directly from Hummer's agent. Local engineers and crane are also required. A professional engineer is required for 2-4 days to particularize the foundation design to the specific site conditions, train the local engineers and complete the installation. After the foundation is finished. If an engineer from the Chinese manufacturer is hired, the cost will be around 200USD/day (all data comes from the manufacturers). One flight ticket costs about 1000USD. The hotel is assumed to cost 100USD/day. All turbine installation needs a professional engineer from manufacture to work for 2-4 days (4 is used to calculate). Besides that, other expense including crane rental , local engineers, and other equipment cost should also be considered.

From personal communication with Hummer agent, the total installation cost for a 50kW with 30m freestanding tower is about 7000 USD from the foundation construction to the end of installation. A 10kW turbine costs 4000 USD to install. A 100kW turbine costs 10000 USD to install. These costs are based on a project in US (directly from communication with Hummer representative). The vary significantly with different locations, soil types etc. The overall cost of each turbine is listed in Table 6.

Table 6 Overall Cost of each turbine (including installation and transportation cost)

	10kW	50kW	100kW
Overall Cost (USD)	23059.5	82918	167339.3

Local wind turbine manufacturers, such as Endurance, include the installation cost in the product cost. They are currently installing new turbines in the UK but not in the North American market. The E3120-50kW model from Endurance cost totals 245000 pounds, about 391,623USD. Even with extra installation costs, the Chinese wind turbines still have a cost advantage.

Maintenance is discussed in Chapter 2.2.1. The maintenance of 50kW wind turbines usually takes 3-4 days and need 3 engineers. Chinese manufactures charge the labor at 200-300USD/day as well as the flight ticket and hotel.

2.3.3 Performance and cost assessment of 10kW, 50kW, 100kW Turbines.

Data from the manufacturer (Hummer) was used compare the ratios of cost to rated power. Cost/ Power of Hummer Wind turbines with freestanding tower is shown in **Table** 7.

Table 7 : Rated Cost/ Power Comparison of 10kW, 50kW, 100kW Wind turbines

Turbine	Cost (USD)(installation included)	Cost/ Rated Power (USD/kW)
10 kW	23059.5	2305.95
50 kW	82918	1658.36
100 kW	167339.3	1673.39

Table 7 indicates that 50kW small turbines will produce power 26% cheaper than 10kW turbines. 50kW and 100kW turbines perform similarly.

2.3.4 Cost/Average Power in Calgary

The cumulative equation is introduced in Eq (4). If Shape factor k is not known, use k = 2 for inland sites, use 3 for coastal sites, and use 4 for island sites and trade wind regimes. In Calgary, k=2 is used. (Manwell et al., 2002). Height extrapolation is used to obtain the average wind speed of each turbine.

Table 8 Height Extrapolation calculation base on the average wind speed of 4.4m/s at 10m

Turbine Size	10kW	50kW	100kW
Tower Height (Standard tower type) (m)	15	18	24
New wind speed (reference:4.4m/s at 10m)	4.97	5.26	5.72

The average power is obtained by the method described in Section 1.6 combine as followings:

Table 9 Average power of 10kW turbines

10kW			
wind speed(m/s)	W(V)(kW)	P(V)	W(V)P(V)
3.00	0.40	0.17	0.07
4.00	0.90	0.17	0.15
5.00	1.80	0.15	0.26
6.00	3.00	0.11	0.34
7.00	4.30	0.08	0.34
8.00	6.20	0.05	0.30
9.00	8.00	0.03	0.22
10.00	10.00	0.01	0.14
		Average power	1.82

Table 10 Average power of 50kW turbines

50kW			
wind speed(m/s)	W(V)(kW)	P(V)	W(V)P(V)
3.00	6.42	0.16	1.01

4.00	11.80	0.16	1.92
5.00	14.60	0.15	2.14
6.00	19.01	0.12	2.24
7.00	25.11	0.09	2.16
8.00	30.00	0.06	1.71
9.00	40.00	0.03	1.38
10.00	50.00	0.02	0.96
		Average power	13.51

Table 11 Average power of 100kW turbines

100kW			
wind speed(m/s)	W(V)(kW)	P(V)	W(V)P(V)
3.00	10.80	0.14	1.50
4.00	17.60	0.16	2.86
5.00	25.20	0.15	3.69
6.00	35.20	0.12	4.15
7.00	46.80	0.09	4.02
8.00	59.60	0.06	3.39
9.00	72.50	0.03	2.50
10.00	85.50	0.02	1.65
		Average power	23.76

Table 12: Power Output of Turbines (Manufacturer: Anhui Hummer Dynamo Co. Ltd) (Hummer wind, 2014)

Turbine Size	10kW	50kW	100kW
Power(kW)	1.82	13.51	23.76
cost/average power (USD/kW)	12665.81	6136.81	7042.78
differences	2.06	1	1.15

From **Table** 12, both 50kW and 100kW wind turbines from Hummer have cost/ unit power advantages over 10kW. 50kW is the best.

Table 13: Wind Turbine Specifications for Different Commercially Available Sizes (Manufacturer: Anhui Hummer Dynamo Co. Ltd) (Hummer wind, 2014)

Parameter	**10kW Turbine**	**50kW Turbine**	**100kW Turbine**
Cut in Speed	3 m/s	3 m/s	3 m/s
Rotor Diameter	8m	16m	20.8m
Generator Weight	287kg	1,237kg	2196kg
Rated Wind Speed	10m/s	10m/s	11.5 m/s
Generator Efficiency	>85%	>92%	>93%
Rotor Blade Material	Glass Reinforced Plastics	Glass Reinforced Plastics	Glass Reinforced Plastics

From **Table** 13, generator efficiency is size related. The generator efficiency of 50kW is 7% greater than that of 10kW, but the efficiency of a 50kW generator is only 1% less than that of a 100kW generator. However, generator efficiency is not the main reason for differences in performance; the rotor diameter is the principle factor causing performance differences. 16m diameter rotors enable 50kW turbines to utilize 4 times more wind energy than 10kW turbines.

Table 12 reveals that the 10kW is the most expensive turbine by unit performance, 10kW costs 2.06 times than 50kW, 100kW costs 1.15 times than 50kW.

2.4 Conclusion

Manufacturers offer many designs for small and large turbines. Designs offering greater structural strength is desired for large turbines. To avoid using a gearbox, small turbines use PMG. Tail fin is a cost-effective solution to orient small turbines, but for large turbines, active yaw systems are usually used to improve productivity. However, all selected turbines use active yaw system to improve their performance.

Performance is always the primary concern when choosing small wind turbines, which are designed differently compared to large turbines. Currently however, small wind turbines are starting to employ some of the features usually found on large turbines, such as pitch adjustment.

By comparing 10kW, 50kW, 100kW turbines from one manufacturer, 50kW has the best cost/unit power. In summary, 50kW small turbines are more cost effective than 10 kW turbines, and closely approach the performance of 100kW turbines. Therefore, this thesis chooses 50kW turbines from 5 Chinese manufactures for future analysis.

CHAPTER 3 COMPARE THE MANUFACTURES OF SMALL WIND TURBINES

3.1 Introduction and Objective of the Chapter

A market and performance comparison have been performed. Following is the list of small wind turbine manufacturers that have been selected for this work.

- ***Ghrepower Manufacturing Company:*** http://www.ghrepower.com/en/
- ***Hummer Manufacturing Company:*** http://www.chinahummer.cn/
- ***Hengfeng Manufacturing Company:*** http://www.hengfeng-power.com/intro.asp?id=2
- ***Shenzhou Manufacturing Company:*** http://www.china-swtgs.com/en/
- ***Winpower Manufacturing Company:*** http://www.chinawinpower.com/

The Chinese have been manufacturing small wind turbines (50kW) for several years, and representatives of Asian companies have experience in foreign countries. These manufacturers are listed and certified by Alibaba.com, which means they can export products to Canada. This thesis ranks these manufacturers based on their turbine's performance and cost at a representative site in Calgary.

Wind data for Calgary have been collected from RetScreen database. Technical details of the wind turbines are directly collected from their manufacturer's data sheets (reproduced in Appendix A to E). The product reviews and the details of commercial features have been collected by interviewing the technical representatives of each manufacturer.

Customer feedback has also been taken into consideration. A letter from Iron customer has also been taken into consideration with respect to the performance of the 50kW Winpower Turbine (see Appendix E Winpower Data Sheets).

3.2 Technical Specifications comparison for Selected Turbine Manufacturers

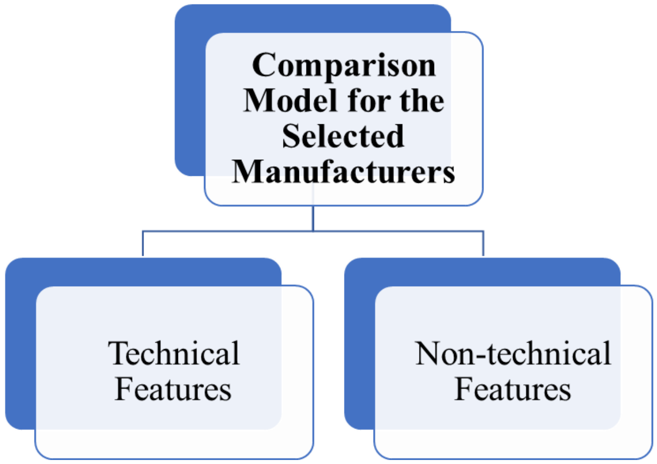


Figure 31 Comparison Model for the Selected Manufacturers

To compare the turbines for this research, technical features, and non-technical features for the 50kW small wind turbine are studied and analyzed in detail. The certification of the turbines is checked and studied. This provides a sound ground for their performance and provides confidence about their safety. The manufacturers are analyzed, to define a ranking among them and select the best option for the considered installation.

The following aspects of products from the selected manufacturers have been compared and analyzed. This study has been performed to specifically rank the turbine manufacturers regarding safety concerns associated with the mechanical and electronic design of the wind turbines.

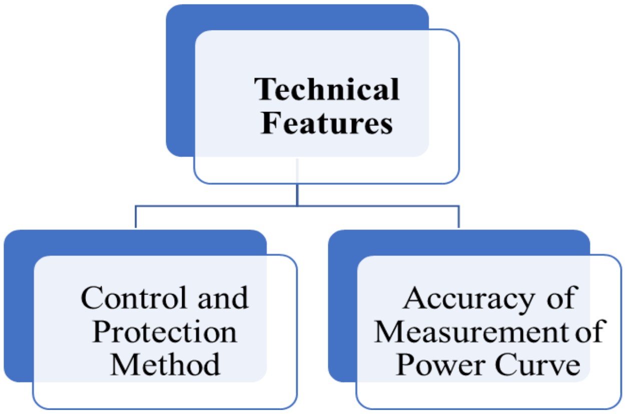


Figure 32 Technical Features for Model Evaluation

Control and Protection Method: Turbines are controlled either manually or automatically. As discussed in 2.2.4, the turbines must be controlled to deliver maximum efficiency.

All selected turbines are equipped with PLC. As discussed in 2.2.3, PLC protect the turbine by controlling yaw shaft to deflect.

"Yaw brake" is also a protection method, but it does not affect the blades directly. The yaw brake is a passive friction brake (see Figure 20)(Park et al.,2011). This system is also used to park turbines for maintenance.

Cut-out speed is the speed at which the turbine blades are brought to stop to avoid damage. When cut-out speed is reached, protection mode is activated.

For example, there are three protection modes for Hummer's turbine: over wind speed, over generator temperature, over RPM of generator. When RPM reaches the limit(180RPM), the rotor is yawed out from the wind by 30 degrees. If the RPM is still higher than that, the yaw shaft will deflect another 60 degrees from wind and then the turbine stops rotating. It is working similar for other alarms. All these are controlled by the PLC control module and do not need any operation of human. These include two sets of hydraulic speed limit brakes on the main shaft and high-speed shaft.

Accuracy of Measurement of Power Curve: Power curves are provided by the manufacturers and are often determined by a third-party independent test.

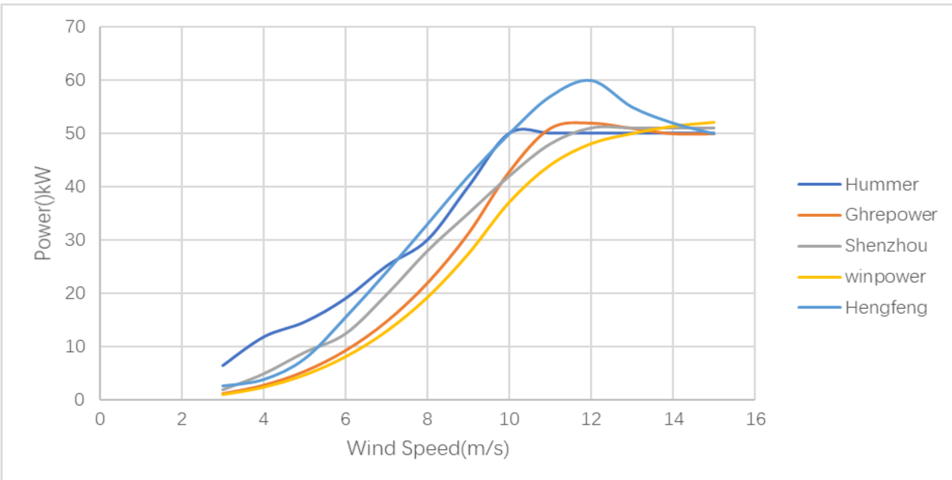


Figure 33 Output Power Curves of Selected Chinese Wind Turbines Manufactures

To determine the power curves and make sure the specification is accurate, each manufacturer should test the turbine before mass production. All power curves in Figure 33 are directly from manufacturers and determined by third party. Ghrepower tested their 50kW turbines in Scotland for over 1 year and certified by Intertek. Hummer tested their turbines for 1 year in Inner Mongolia wind farm and record the data themselves. Hengfeng, Shenzhou test their turbine in Winpower tested their turbines in their factory for over 1 year.

The problem is only Ghrepower has certified power curve. Other four manufactures draw the power curves themselves. They only guarantee the accuracy of power curves on paper.

Here is a case. During 2007-2008, a project called Encraft Warwick Wind Trials Project tested turbines from five manufacturers across the UK (Encraft,2009). The results show that the uncertified power curve data some manufactures provided is not accurate. Significant differences could happen (see Figure 34). Buyers should beware.

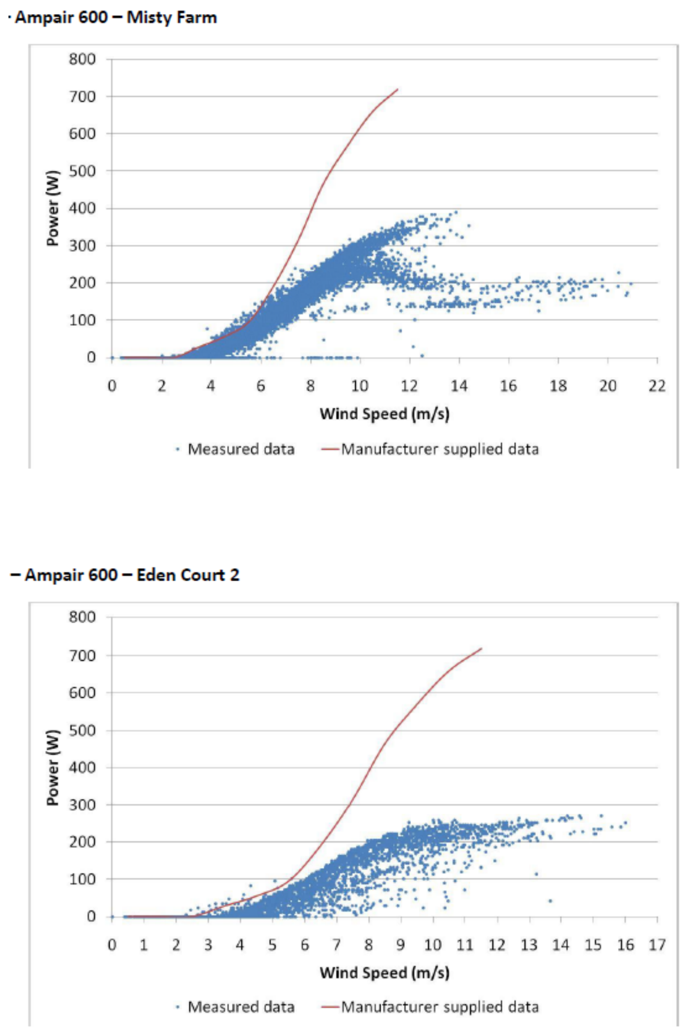


Figure 34 Measured data VS. manufacturer supplied data in Encraft Warwick Wind Trials Project (Encraft,2009)

The comparison of the technical features of wind turbines is given in Table 14.

Table 14 Comparison Table for the Assessment of Technical Features of Manufactures

Technical Feature	Ghrepower	Hummer	Hengfeng	Shenzhou	Windpower
Control System	Controller & Inverter (Supervisory Control and Data Acquisition - SCADA optional)	Siemens Programmable Logic Controller with Touch screen	Siemens,Delta Programmable Logic Controller Control System	Mitsubishi Programmable Logic Controller	Intelligent Control
Yaw System	Electrical yaw system Pitch adjustment	Electrical Yaw control system Pitch adjustment	Electrical Yaw control system	Electrical Yaw control system	Electrical Yaw control system
Cut – Out speed Protection Methods	Hydraulic braking,	Hydraulic Braking,	Hydraulic braking system,	Hydraulic braking,	Hydraulic braking,
Blade Material	Fiber Reinforced Plastics	Fiber Reinforced Plastics	Fiber Reinforced Plastics	Fiber Reinforced Plastics	Fiber Reinforced Plastics
Rated Wind Speed	9m/s	11.5 m/s	10m/s	12m/s	12m/s
Tower Height (m)	36	18	18	18	20
Blade diameter (m)	21.5	16.5	15	16	16
Wind speed (m/s) (4.4m/s at 10m)	6.46	5.25	5.25	5.25	5.42
Maximum C_P	0.43	0.42	0.48	0.42	0.42
FOB Price (USD)	215140	87,380	62939(394000RMB)	57507(360000 RMB)	64,780.00

From Table 14, the Ghrepower FD21-50kW has significant advantages over other turbines, including higher tower height, longer blade diameter. higher tower helps turbine to capture faster wind flow. Hengfeng turbines promised the highest Cp. Winpower turbines have slightly higher tower height compared to Hummer, Shenzhou, and Hengfeng.

3.3 Non-technical features

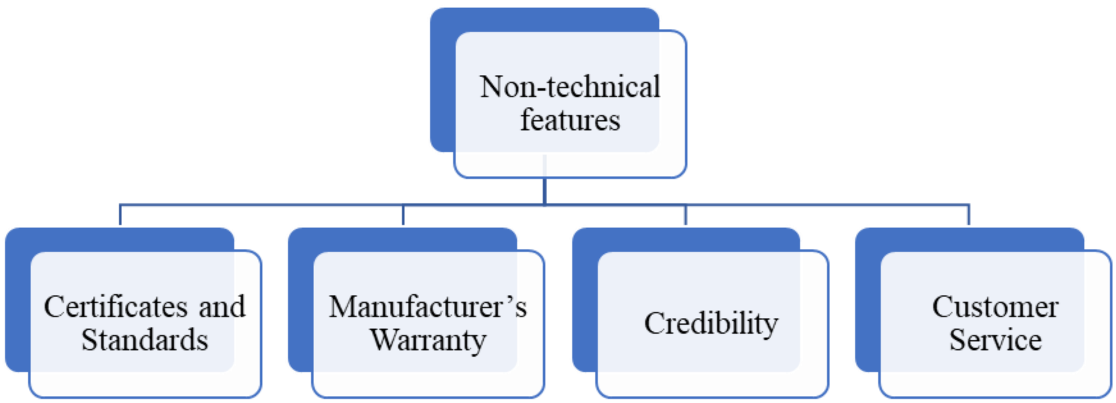


Figure 35 Commercial Features for Model Evaluation

The following commercial features are assessed to rank the selected manufacturers:

1. ***Certificates and Standards:*** Certificates and Standards are issued by third parties to ensure the products meet specific quality requirements or assurance.
2. ***Manufacturer's Warranty and Maintenance Contract:*** Warranties of various lengths are offered to guarantee results claimed. Maintenance Contract is defined either by the parent company or the local vendor for maintenance of wind turbines and accessories.
3. ***Market Price:*** It's the manufacturer's price for a complete turbine system. Prices stated by the manufacturers are always FOB. The transportation costs for the selected turbines are similar. Each of their installation cost is almost identical.

4. ***Customer Service:*** For international business, communications are important. Every customer support team of selected manufactures is different. Responding time and quality of answer are the two criteria used to evaluate the customer service.

3.3.1 Wind Turbine Certificates and Standards Overview -

For the buyers to evaluate the safety issues, it is the best to check the certification of the turbines.

The IEC 61400 Series are the most common wind turbine standards and include IEC 61400-1, IEC 61400-2, IEC 61400-11, IEC 61400-21, etc. IEC 61400-2 defines the design requirements for small wind turbines. (American National Standards Institute,2016). IEC 61400 is also basis for Canadian CAN/CSA C61400-2 and other nationalized versions of the SWT standard

IEC Safety Standards

The International Electrotechnical Commission (IEC) 61400 is an International Standard and has defined specific safety standards for wind turbines. This commission has standardized design requirements, performance measurements, power performance evaluations, mechanical load, simulation models and many other concerns for the safe installation and workings of wind turbines (Institution, B. S..2014).

IEC 61400-2 addresses the safety of small wind turbines. It permits the examination of turbine safety through the “Simple Load Model” (SLM) which provide simple and approximate equations enable SLM to test for the main turbine loads such as the root bending moment of the blade, the turbine shaft load, and the turbine and wind force on the tower (Institution, B. S..2014).

In Canada, IEC61400-2 is adopted by CSA, “CAN/CSA-C61400-2 Wind turbines — Part 2: Design requirements for small wind turbines” is the same as IEC61400-2.

UL (Underwriters Laboratories)

UL is a global independent safety science company. UL has certified small wind turbines under the product category Small Wind Turbine Generating Systems (ZGEN), located on page 466 in the 2012 UL White Book. (UL,2012)

This category covers small wind turbine generating systems (WTGS) investigated for risk of fire and shock, including safety-related control system electrical performance and utility (grid) interconnection performance for Utility Interactive models. (UL,2012).

Hummer and Ghrepower uses POWERONE inverter which was certified by UL.

ISO 9001: 2008

ISO 9001: 2008 is an international standard related to quality management system and it is based on eight quality management principles (all fundamental to good business practice). All requirements of ISO 9001:2008 are generic and are intended to be applicable to all organizations, regardless of type, size and product provided.

For wind turbine, the process usually takes about 1 year and it includes the implementation of a formal quality management system, robust employee training on formal operating procedures, and implementation of measurement systems related to quality. Many third part offers this certification. Most selected turbines are certified by IQnet and CQM.Ghrepower turbines are certified by Sira.Hengfeng turbines are certified by Beijing Zhongliantianrun Certification center.

CE Certificates

'CE' stands for 'Conformité Européenne'. CE is a certification mark required for many products sold in Europe. This mark ensures that the products are certified and meet standards of EU (European Union) safety, health, and environmental protection, before being placed on the market. CE is not required for products in North American markets, however, in this case, all manufacturers already have these certificates since they have done business in Europe for many years (Ec Europa, 2014).

Table 15 Organizations issued CE

	Ghrepower	Hummer	Hengfeng	Shenzhou	Winpower
Organizations	European Ceprom	China CEPREI	APRAGAZ,Belgium/Italian Ente Certificazione Macchine Srl	SGS	LNMC

ROHs (Restriction of Hazardous Substances)

ROHs is a standard in the European Union. It restricts the use of hazardous substances in electrical and electronic equipment, and it promotes the collection and recycling of such equipment (Marrapese et al.,2016). Only Hengfeng has ROHs certification.

Intertek

Intertek offers a wide array of certification and performance testing services for all types of power conversion equipment used in power generation, including traditional standby generators with integrated inverters, PV inverters, energy storage systems, as well as wind turbine and fuel cell inverters. Ghrepower's inverter and power curve have been certified by Intertek. (Intertek,2018)

Medium Wind Turbine Certification (MWT)

Medium Wind Turbine Certification (MWT) is issued by small turbine certification council. Unlike other certifications, this certificate represents that the turbine has been evaluated by small wind certification council (SWCC) concerning Acoustic testing. Only Ghrepower turbines are certificated by MWT.

Table 16 Certificates comparison

	Ghrepower	**Hengfeng**	**Hummer**	**Shenzhou**	**Winpower**
Certificates	European CE, ISO9001:2008. Medium Wind Turbine Certification (MWT) Intertek (UL)	European CE. ROHs, ISO9001:2008.	European CE, USA UL, ISO9001:2008	European CE, ISO9001:2008	European CE, ISO9001:2008

3.3.2 Assessment of warranty and maintenance contracts

This section is based on data collected from all manufacturers. All data are the latest from the representatives of each manufacturer.

Ghrepower 50kW Wind Turbine

All components of the system come with a five-year limited warranty. Ghrepower offers five-year maintenance contracts, but buyers have to pay for travel expenses.

Hummer 50kW Wind Turbine

Hummer offers a two-year guarantee for the turbine generator and a 1-year guarantee for the other components of the turbine. As discussed in Chapter 2.3, the vendor offers free maintenance for the product, but buyers must pay all travelling expenses.

Hengfeng 50kW Wind Turbine

Hengfeng offers a warranty of 1 year for the whole wind turbine. They claim a product life span of 20 to 25 years.

Shenzhou 50kW Wind Turbine

Shenzhou claims its 50kW Wind Turbine has an operating life of 15 to 20 years and they offer a 3-year warranty for the whole turbine.

WinPower 50kW Wind Turbine

Winpower also claims a service-life of 15 – 20 years for their 50kW small turbine but offers only a 1-year warranty for the whole turbine.

A summary is shown in Figure 17.

Table 17 warranty comparison

Technical Feature	Ghrepower	Hummer	Hengfeng	Shenzhou	Windpower
Manufacturer's Warranty	5-year	2-year Generator and 1-year other parts	1-year	3 years	1 year
Maintenance Contract	5-year	Free Maintenance	No Warranty	No Warranty	No Warranty

From Table 17, Ghrepower offers the longest warranty. Regarding with maintenance, only Ghrepower and Hummer offer maintenance. Hummer offers lifelong free maintenance. Since none of the companies have engineers in Canada, buyers must pay for travel expenses.

3.3.3 Credibility Evaluations of the Manufacturers

Safety and credibility are critical concerns for customers. Safety evaluation is based on the certificates companies have and credibility is based on the experience and history of the manufacturers.

Table 18 Credibility Assessment on Ghrepower

Credibility Assessment on GHREPOWER(Source: Ghrepower, 2013b)	
Experience and history	Registered capital: 68000000￥ The company began in 2006. Its workshop covers more than 20000 square meters, and it annual production of wind turbines is over 10MW. To date, the company has produced and sold more than 15,000 units, from 300 watts to 50kW, in China, the UK, France, Canada, Korea and African countries. Applications include on-grid/off-grid power systems, which offer utility connections, battery back-up in homes, water pumping, water heating and a variety of other uses. The company employs over 40 engineers for the research and design processes. It owns over 30 technical patents on wind turbine parts.
Products	300W-50kW small wind turbines

Table 19 Credibility Assessment on Hengfeng HF15.0-50kW

Credibility Assessment HF15.0-50kW	
Experience and History	Registered capital: 10000000￥ 8 years as an Alibaba "trusted company." Total number of turbines produced to date: 1689 Company started in 2004. Workshop covers more than 5000 square meters. 7 years' experience in small turbine field. Export to more than 43 countries for example, Europe, Middle East, Southeast Asia, Australia etc.
Products	15kW to 200kW wind turbines and solar panels (rated power from 2-280w)

Table 20 Credibility Assessment of the Anhui Hummer Dynamo Company (Anhui Hummer Dynamo Co., Ltd., 2015)

Credibility Assessment of the Anhui Hummer Dynamo Company (Source: Anhui Hummer, 2013)	
Experience	Registered capital: 11000000￥ Company began 1993 Its workshop covers about 10000 square meters. The wind power department was founded in 1998 and mass production of 50kW turbines started in 2010. The company has about 200 employees. Over 200 50kW turbines have been installed since 2010. Hummer products have been exported to 112 countries and areas, since 2005.
Product Range	400W to 100kW wind turbines. Wind-solar power systems

Table 21 Credibility Assessment on the Yangzhou （Shenzhou）Company

Credibility Assessment on the Yangzhou （Shenzhou）company (Source Yangzhou, 2013)	
Experience	Registered capital: 11000000￥ The company entered the field of wind and solar energy in 1996 Workshop covers about 35000 square meters. In addition to small and medium wind turbines, Yangzhou also manufactures wind-solar hybrid street lighting systems, wind/solar hybrid home power systems, wind-diesel hybrid systems, etc.
Product Range	300W to kW50kW wind turbines. Solar systems (panel 50-250w, inverter)

Table 22 Credibility Assessment on the WinPower Group Co

Credibility Assessment on the WinPower Group Co (Source: Winpower, 2013)	
Experience	Registered capital: 120000000￥ The company, established in 2003, specializes in the R&D, manufacture and application of small and medium size wind turbine generators. It is also a provider of wind-solar hybrid power supply systems. The workshop covers about 5000 square meters. Winpower exports products to Germany, Italy, France, Hungary, Poland, Finland, USA and Brazil. Iran, which imported Winpower products, offers positive feedback and data.
Products	300kW-50kW horizontal and vertical wind turbines 50W-300W Solar modules. Indoor LED series. Controller & inverter

Credibility assessments are often biased if based on information only from the manufacturers. Therefore, certification is the most reliable assessment. Ghrepower has the largest registered capital, 68000000￥, which seems more reliable.

3.3.4 Customer service

It is important to have a responsive and effective customer service.

Hummer probably has the best customer service among the five. They provided lots of useful information and fast responses (usually within 2hrs via email). They also send update emails regularly. The most important thing is their representatives are professionals, they can answer questions immediately. For example, I asked how their protection system works, the representative replied me with 3 protection modes including over speed protection, over generator temperature protection, over RPM protection and she explained them in details. Only the representative in Hummers can answer such questions fast and detailed.

Ghrepower provides good customer service as well, but their representatives are not professionals. Normally, the technical questions will be given to manager or other technicians, and this takes a day or more. The information they give is accurate and professional. For example, I sent them a questions sheet about control method and certifications, and the representative said he must pass this to a technician. I waited several days for the answers.

Winpower provides good customer service. They respond fast and provide accurate and sufficient information. They answer questions professionally and detailed. The response time is usually less than a day which is acceptable.

Hengfeng provides average customer service. They provide accurate and professional answers, but it is very hard to reach the technicians. Their technicians are always busy. Once a technical question is submitted, it usually takes more than 1 day to receive the answers.

Shenzhou provides less than average customer service. They refused to provide some technical details before offer is made. They usually answer technical questions within 1 day. The answer quality is less than average. They barely provide very detailed information; however, they prefer to explain them in a few sentences.

Table 23 Customer Service of each manufacture

Manufactures	Hummer	Ghrepower	Winpower	Hengfeng	Shenzhou
Customer Service	Best	Good	Good	Average	Below Average

CHAPTER 4 PERFORMANCE ANALYSIS AND RESULTS

4.1 Average power calculation

To finalize the selection for a site in Calgary, the average power output is calculated to evaluate the performance. As discussed in Chapter 1.6, average power is calculated by combining the power curve and PDF.

The five selected manufacturers of 50kW wind turbines were subjected to the same statistical analyses to compare unit power (kW/s).

4.1.1 Description of Weibull Input Parameters

Wind Speed and Solar radiation data:

The wind speed data is directly from Retscreen database.

Month	Air temperature	Relative humidity	Precipitation	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days 18 °C	Cooling degree-days 10 °C
	°C	%	mm	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-9.6	59.8%	28.75	1.34	88.8	4.5	-12.1	856	0
February	-6.3	59.0%	20.02	2.31	88.8	4.2	-10.3	680	0
March	-2.5	61.4%	27.68	3.59	88.7	4.5	-4.8	636	0
April	4.1	54.3%	41.10	4.96	88.9	4.7	3.8	417	0
May	9.7	55.8%	61.91	5.67	88.9	5.0	9.9	257	0
June	14.0	61.9%	105.24	6.38	89.0	4.7	13.9	120	120
July	16.4	62.4%	70.08	6.34	89.2	4.2	16.4	50	198
August	15.7	61.6%	62.92	5.36	89.2	3.9	15.4	71	177
September	10.6	61.0%	55.79	4.02	89.1	4.2	9.2	222	18
October	5.7	58.0%	30.85	2.70	89.0	4.2	2.3	381	0
November	-3.0	63.2%	27.15	1.54	88.8	4.2	-6.1	630	0
December	-8.3	59.1%	28.97	1.06	88.8	4.5	-11.4	815	0
Annual	**3.9**	**59.8%**	**560.46**	**3.78**	**88.9**	**4.4**	**2.3**	**5,135**	**513**
Source	Ground	Ground	NASA	Ground	Ground	Ground	NASA	Ground	Ground
Measured at					m	10	0		

Figure 36 Average Wind Data and solar radiation for Calgary Canada from Retscreen database

From Figure 36,The average wind speed in Calgary is 4.4m/s at height of 10m.

4.1.2 Average Power Output for Calgary

Input parameters:

Average Wind Speed = 4.4m/s at 10m

Shape factor k = 2

Table 24 Weibull Power Output Estimation for Calgary

Wind Speed(m/s)	Weibull Probability density function
0.000	0.000
1.000	0.098
2.000	0.168
3.000	0.195
4.000	0.181
5.000	0.142
6.000	0.097
7.000	0.058
8.000	0.030
9.000	0.014
10.000	0.006
11.000	0.002
12.000	0.001
13.000	0.000
14.000	0.000
15.000	0.000
	0.991

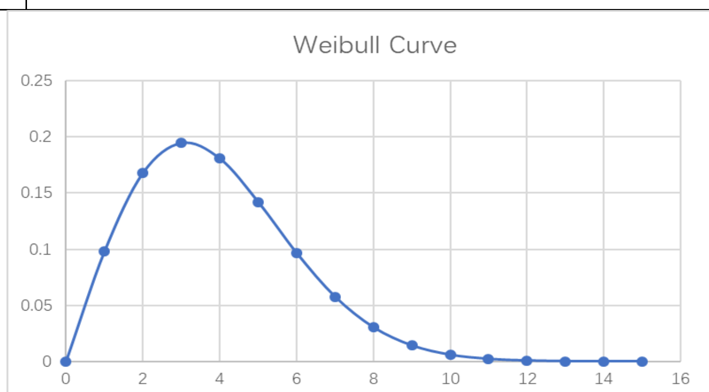


Figure 37 Weibull Power Output Estimation for Calgary

4.1.3 Wind Speed Probability and Average Power Output for All Manufacturers

The five turbines are analyzed based on standard conditions at the height of the various towers.

4.1.3.1 Statistical Analysis and Performance Calculations for Ghrepower

Weibull statistical analysis and performance calculations for the Ghrepower 50 kW turbines are presented below. These calculations are based on a tower height of 36m.

Table 25 Weibull Statistical Analysis for Ghrepower

Ghrepower			
H/H0	3.600		
reference height(m)	10.000		
New wind speed(m/s) at 36m	6.462		
Wind Speed(m/s)	Power(kW)	Weibull Probability density function	Average Power(kW)
0.000		0.000	0.000
1.000		0.047	0.000
2.000		0.087	0.000
3.000	1.150	0.116	0.133
4.000	2.740	0.131	0.358
5.000	5.350	0.132	0.704
6.000	9.260	0.121	1.124
7.000	14.700	0.104	1.524
8.000	21.950	0.083	1.816
9.000	31.250	0.062	1.936
10.000	42.870	0.044	1.872
11.000	51.000	0.029	1.482
12.000	52.000	0.018	0.950
13.000	51.000	0.011	0.555
14.000	50.000	0.006	0.307
15.000	50.000	0.003	0.164
Total		0.993	12.925

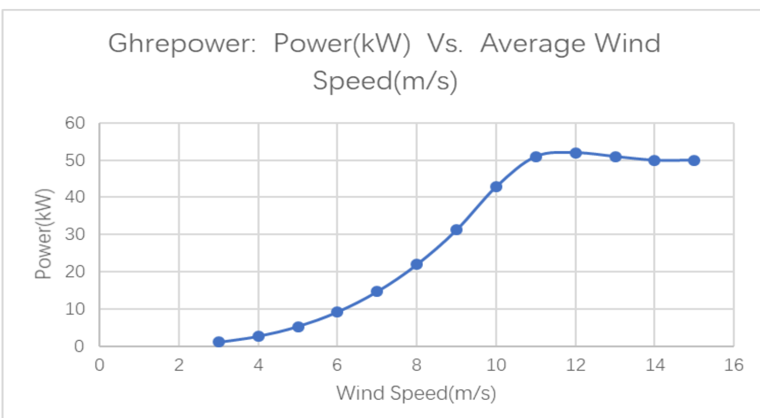


Figure 38 Ghrepower: Power (kW) Vs. Average Wind Speed (m/s)

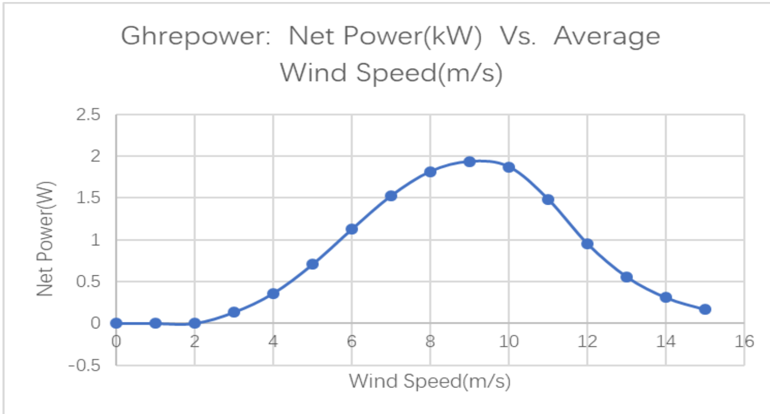


Figure 39 Ghrepower: Average Power（kW）Vs. Average Wind Speed (m/s)

4.1.3.2 Statistical Analysis and Performance Calculations for Hummer

Weibull statistical analysis and performance calculations for Hummer 50 kW turbines are presented below. These calculations are based on a tower height of 18m.

Table 26 Weibull Statistical Analysis for Hummer

Hummer			
H/H0	1.800		
reference height(m)	10.000		
New wind speed(m/s) at 36m	5.248		
Wind Speed(m/s)	Power(kW)	Weibull Probability density function	Average Power(kW)
0.000		0.000	0.000
1.000		0.070	0.000
2.000		0.126	0.000
3.000	6.421	0.157	1.009
4.000	11.804	0.162	1.918
5.000	14.600	0.146	2.139
6.000	19.007	0.118	2.241
7.000	25.114	0.086	2.155
8.000	30.000	0.057	1.707
9.000	40.000	0.035	1.381
10.000	50.000	0.019	0.962
11.000	50.000	0.010	0.494
12.000	50.000	0.005	0.234
13.000	50.000	0.002	0.102
14.000	50.000	0.001	0.041

15.000	50.000	0.000	0.015
Total		0.994	14.398

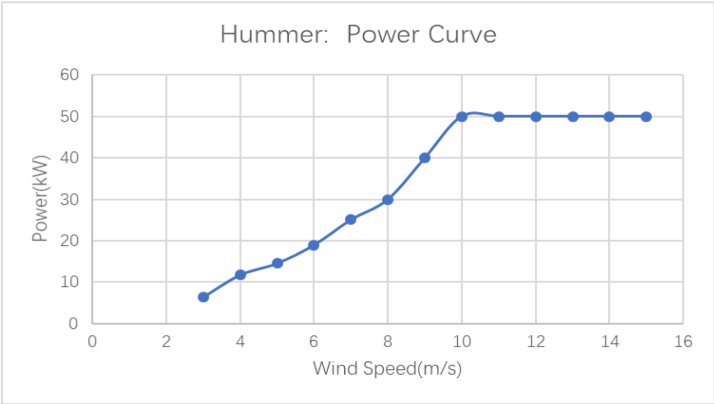


Figure 40 Hummer: Power Curve

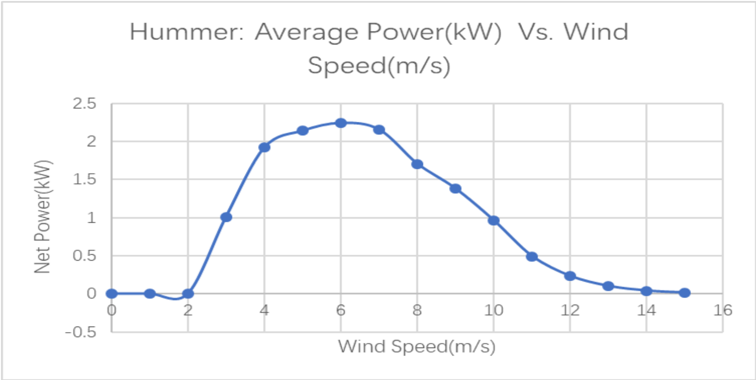


Figure 41 Hummer: Average Power (kW) Vs. Wind Speed (m/s)

4.1.3.3 Statistical Analysis and Performance Calculations for Hengfeng

Weibull statistical analysis and performance calculations for the Hengfeng 50 kW turbine is presented in Table 25. These calculations are based on a tower height of 18 m.

Table 27 Weibull Statistical Analysis for Hengfeng

Hengfeng			
H/H0	1.800		
reference height(m)	10.000		
New wind speed(m/s) at 36m	5.248		
Wind Speed(m/s)	Power(kW)	Weibull Probability density function	Average Power(kW)
0.000	0.000	0.000	0.000
1.000	0.000	0.070	0.000
2.000	0.000	0.126	0.000
3.000	2.600	0.157	0.408
4.000	3.800	0.162	0.617
5.000	7.700	0.146	1.128
6.000	15.500	0.118	1.828
7.000	24.000	0.086	2.059
8.000	33.000	0.057	1.877
9.000	42.000	0.035	1.450
10.000	50.000	0.019	0.962
11.000	57.000	0.010	0.563
12.000	60.000	0.005	0.281
13.000	55.000	0.002	0.112
14.000	52.000	0.001	0.043
15.000	50.000	0.000	0.015
Total		0.994	11.345

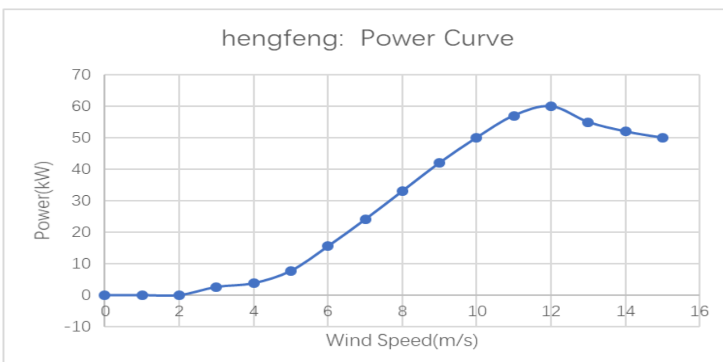


Figure 42 Hengfeng Power Curve

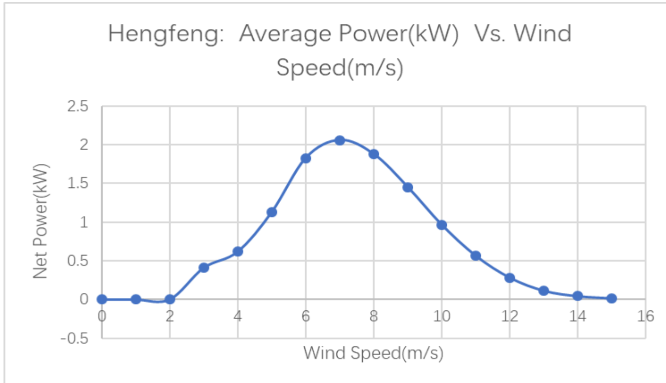


Figure 43 Hengfeng: Average Power (kW) Vs. Wind Speed (m/s)

4.1.3.4 Statistical Analysis and Performance Calculations for Shenzhou

Weibull statistical analysis and performance calculations for Shenzhou 50 kW turbines are presented below. These calculations are based on a tower height of 18 m.

Table 28 Weibull Statistical Analysis for Shenzhou

Shenzhou			
H/H0	1.800		
reference height(m)	10.000		
New wind speed(m/s) at 36m	5.248		
Wind Speed(m/s)	Power(kW)	Weibull Probability density function	Average Power(kW)
0.000	0.000	0.000	0.000
1.000	0.000	0.070	0.000
2.000	0.000	0.126	0.000
3.000	2.000	0.157	0.314
4.000	5.000	0.162	0.812
5.000	9.000	0.146	1.318
6.000	12.500	0.118	1.474
7.000	19.800	0.086	1.699
8.000	28.000	0.057	1.593
9.000	35.000	0.035	1.208
10.000	42.000	0.019	0.808
11.000	48.000	0.010	0.474
12.000	51.000	0.005	0.238
13.000	51.000	0.002	0.104
14.000	51.000	0.001	0.042

15.000	51.000	0.000	0.016
Total		0.994	10.102

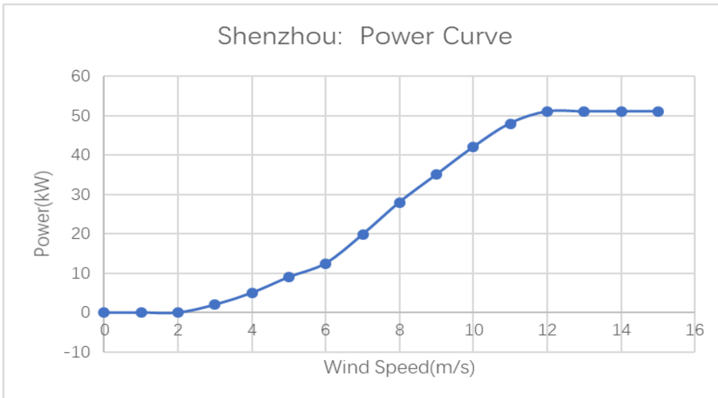


Figure 44 Shenzhou: Power Curve

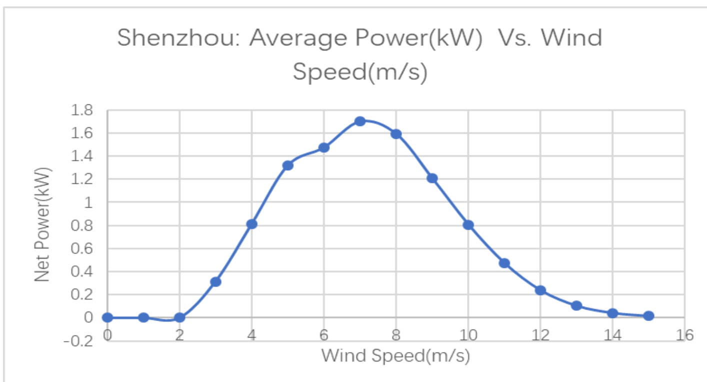


Figure 45 Shenzhou: Average Power（kW）Vs. Wind Speed (m/s)

4.1.3.5 Statistical Analysis and Performance Calculations for WinPower

Weibull statistical analysis and performance Calculations for the Winpower 50 kW turbines are presented below. These calculations are based on a tower height of 20 m.

Table 29 Weibull Statistical Analysis for Winpower

Winpower			
H/H0	2.000		
reference height(m)	10.000		
New wind speed(m/s) at 36m	5.417		
Wind Speed(m/s)	Power(kW)	Weibull Probability density function	Average Power(kW)
0.000		0.000	0.000
1.000		0.066	0.000
2.000		0.119	0.000
3.000	1.014	0.150	0.153
4.000	2.404	0.158	0.380
5.000	4.696	0.145	0.683
6.000	8.114	0.120	0.973
7.000	12.885	0.090	1.157
8.000	19.234	0.062	1.184
9.000	27.385	0.039	1.063
10.000	37.066	0.023	0.837
11.000	44.000	0.012	0.534
12.000	48.000	0.006	0.290
13.000	49.900	0.003	0.139
14.000	51.273	0.001	0.061
15.000	52.003	0.000	0.025
Total		0.994	7.479

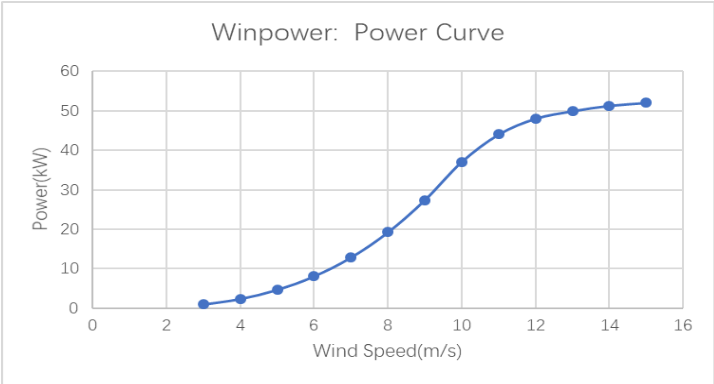


Figure 46 Winpower: Power Curve

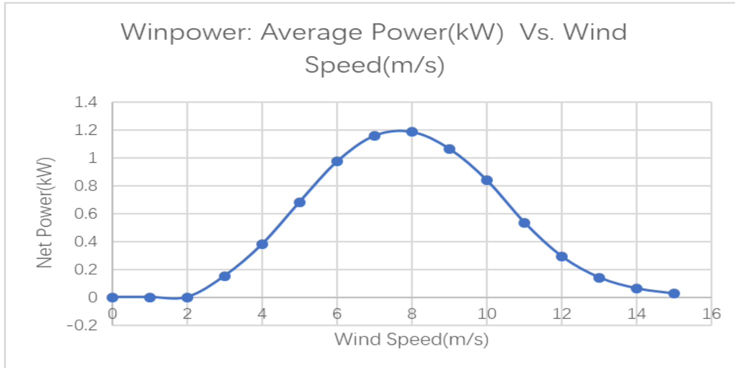


Figure 47 Winpower: Average Power (kW) Vs. Wind Speed (m/s)

4.1.3.6 Summary

Table 30 the power output of five turbines (w)

Wind Speed(m/s)	Ghrepower Power(kW)	Hummer Power(kW)	Hengfeng Power(kW)	Shenzhou Power(kW)	Winpower Power(kW)
0.000	0.000	0.000	0.000	0.000	0.000
1.000	0.000	0.000	0.000	0.000	0.000
2.000	0.000	0.000	0.000	0.000	0.000
3.000	1.150	6.421	2.600	2.000	1.014
4.000	2.740	11.804	3.800	5.000	2.404
5.000	5.350	14.600	7.700	9.000	4.696
6.000	9.260	19.007	15.500	12.500	8.114
7.000	14.700	25.114	24.000	19.800	12.885
8.000	21.950	30.000	33.000	28.000	19.234
9.000	31.250	40.000	42.000	35.000	27.385
10.000	42.870	50.000	50.000	42.000	37.066
11.000	51.000	50.000	57.000	48.000	44.000
12.000	52.000	50.000	60.000	51.000	48.000
13.000	51.000	50.000	55.000	51.000	49.900
14.000	50.000	50.000	52.000	51.000	51.273
15.000	50.000	50.000	50.000	51.000	52.003

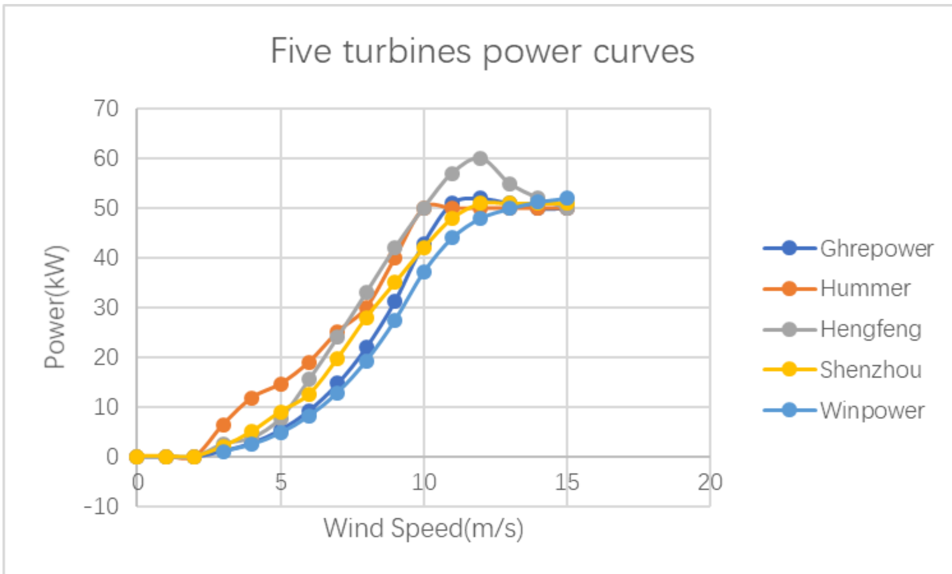


Figure 48 the power curves of five turbines

Table 31 Summary of cost and average power output (kW)

	Hengfeng	**Shenzhou**	**Hummer**	**Winpower**	**Ghrepower**
FOB Price (USD)	62939.00	57507.00	87380.00	64780.00	215140.00
Transportation Cost	9200.00	9200.00	9200.00	9200.00	9200.00
Average Power Output(kW)	11.34	10.10	14.39	7.47	12.92
Average Unit price (USD/kW)	6358.54	6603.08	6707.75	9891.36	17357.62
Unit price Differential	0.000	0.04	0.01	0.47	0.75

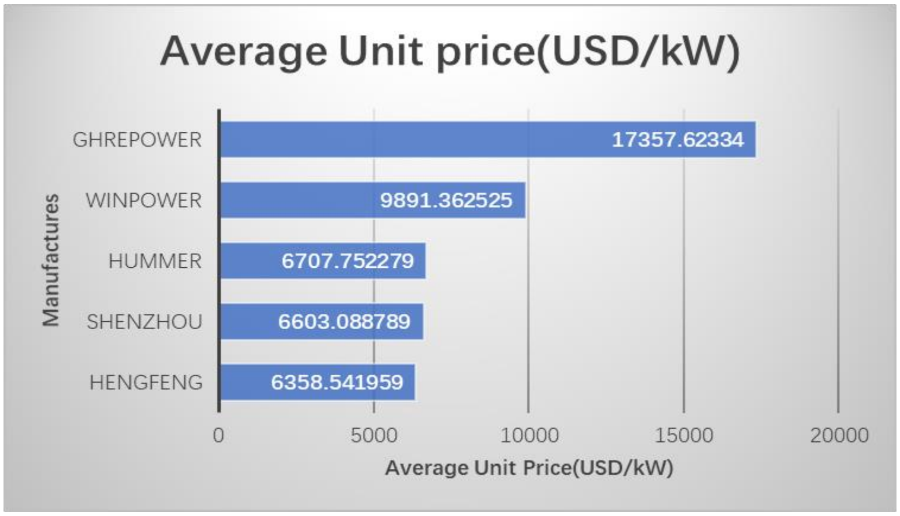


Figure 49 Cost per Average Power Output (USD/kW)

From Figure 48, Hummer performs best at wind speed from 3 to 7 m/s. Hengfeng performs best at from 10m/s to 15m/s. Ghrepower,Shenzhou,and Winpower perform similarly.

In Calgary, from Table 31, Hummer wind turbine has the best power output in the average wind conditions of Calgary. The average unit power price is slightly higher than Hengfeng(+9.3%) and Shenzhou(+6.7%), but much lower than Ghrepower(-63.5%) and winpower(-29.9%).

Hengfeng and Shenzhou performs similarly. Their performance ranks in middle, but due to the lower cost, their average unit prices are lowest.

Winpower performs worst, and this is unexpected. Winpower turbines have second tallest tower which give them wind speed advantage. Its average power output (7.48kW) is not competitive and only half that of Hummer (14.40kW). Due to its low performance, the average unit power price is much higher than Hummer, Hengfeng and Shenzhou.

Ghrepower turbines are disappointing in this regard. They sell at almost triple the price of the other turbines. They have much higher towers and longer blades. They are even rated at

60kW in China, but the performance is worse than Hummer. The average unit power price (17357.62USD/kW) is much higher than others.

In summary,Hummer,Shenzhou,Hengfeng are good choices based on the average unit power price. Ghrepower has second best performance, but worst average unit price, because the price is almost tripled than other turbines. Winpower has the worst performance as well as the average unit price.

4.2 Payback Calculations for all Turbine Manufactures

To evaluate the economic performance of the turbines, the time it takes for investors to recover their costs is calculated.

The calculations include data obtained from a personal communication with an Enmax manager about projected electricity costs over the next 20 years. Existing Wires Cost is the cost of grid use when turbines are connected on grids.

Simple formulas:

$$S_{electricity} = h * P * C_{electricity}$$

$$S_{wires} = h * P * C_{wires}$$

$$S_{total} = S_{electricity} + S_{wires}$$

where $S_{electricity}$= Electricity savings

S_{wires}= Wires savings

S_{total}=Total savings

$C_{electricity}$=Electricity price (Forward curve)

C_{wires}=Cost of grid use (Existing Wires Cost)

h=operation hours

U=Average Power of each turbine

Internal Rate of Return (IRR) is important in payback calculation. It is defined as “the rate at which the project breaks even”. (Berman,K et al.,2013) In this section, the initial FOB cost of each turbine and the annual electricity savings are used to calculate the IRR.

It is assumed that the lifetime of these turbines is 20 years. The IRR calculation is based on the period from 2015 to 2034. To minimize the bias, 5.8% inflation is assumed base on the variation of predicted electric prices from 2015 to 2034.The results are listed in Appendix G Payback Calculations

Table 32 Summary of IRR

	Ghrepower	Hummer	Hengfeng	Shenzhou	Winpower
IRR(on grid)	0.273%	10.811%	11.997%	11.651%	6.589%

The IRRs of Hengfeng and Shenzhou rank the best overall, and Hummer’s IRR is slightly behind. All these three turbines are worth to invest with IRRs over 10%. Ghrepower’s high capital investment make the turbine hard to pay even.

Table 33 Summary for Cumulated Savings for All Manufacturers, Over the Period of 20 years (2015-2034)

	Ghrepower	Hummer	Hengfeng	Shenzhou	WinPower
Total saving（USD）	222096	247419	206455	183839	136104
How many years to pay even	20	9	9	9	13

Hummer,Hengfeng and Shenzhou buyers are expected to get their money back within 9 year; Ghrepower buyers are going to be the last to recover their investments.

4.3 Analysis for PV Technologies in Calgary

Trina Solar TSM-PA05.082-250W is selected to compare to five turbines. (see Appendix F Trina Solar Data Sheets) Trina is a Chinese manufacture that has expanded into Ontario,Canada since 2012.200 units are used to have a peak power of 50kW.

Cost per unit average power

From Figure 36, the average solar radiation in Calgary is 3.78kWh/m^2/d. From Appendix F, annual power production is 64972kWh, then the average power is 7.41kW. The total initial cost is 55738 USD. The average unit price is 7522USD/kW.

Table 34 Cost per unit average power

	Hengfeng	Shenzhou	Hummer	PV	Winpower	Ghrepower
Average Unit price (USD/kW)	6358.54	6603.09	6707.75	7521.99	9891.36	17357.62

Table 35 Payback calculation

	Photovoltaic	Hengfeng	Hummer	Shenzhou	Winpower	Ghrepower
payback years	11.7	9.5	10.2	9.7	13.2	>project

It takes approximately 11.7 years for Trina solar to break even which is longer than Hengfeng, Hummer, Shenzhou. From economic perspective, Trina solar TSM-PA05.082-250W is competitive with 50kW wind turbines based on rate of returns.

Space used is another concern. It takes 1.56 m2 for individual PV module, the total area is 518.2 m2. For comparison, Hummer 50kW wind turbines, the free tower base will only use 144 m2. (see Appendix B Hummer Data Sheets). If space is limited, 50kW wind turbines are better choices.

CHAPTER 5 CONCLUSION

The aim of this thesis was to select a small wind turbine for Calgary, where “small” was defined as power rated less than 100 kW. Many areas of Calgary are ideal to use these small turbines to generate electricity, for example, in Calgary, an unused space is required between a road and a landfill.

Chinese turbines are cheaper than local turbines, such as Endurance E3120-50kW model. When comparing with 10kW, 100kW turbines, it is shown that 50kW turbines generally have the lowest cost/unit power. This project evaluated the cost-effectiveness of 50 kW wind turbines made in China for use within the City of Calgary. The turbine and manufacture information were found from Alibaba as this is considered the best online platform for Chinese turbine purchase. Most data were retrieved from the follow-up direct contact with all manufacturers. PV is a popular renewable energy technology. In comparison to PV, small scale wind is considered expensive and unreliable. However, many Chinese manufactures are selling similar capacity turbines at competitive price so far. Therefore, a significant part of this thesis was to evaluate the power curved, reliability and warranties provided by wind turbine manufactures.

From specifications data sheet provided by manufacturers, Ghrepower has significant advantages over other turbines, resulting from higher tower height, longer blade diameter. In addition, the company has the largest registered capital of all those considered, which adds attributes when dealing with future maintenance and related issues. All the chosen turbines have both European Conformité Européenne and ISO9001:2008 certifications. Besides that, Ghrepower has Intertek (UL) certification. For warranty, Ghrepower offers the longest 5-year warranty and 5-year maintenance and Hummer offers life-long free maintenance.

It should have noted that all manufactures provided power curves, but only the Ghrepower power curve has been certified by Intertek.

By using Weibull statistical analysis, it is shown that Hummer has an average power output of 14.4 kW which is the best among the five.

The overall cost includes turbine cost, transportation cost, installation cost and foundation cost. A standard height extrapolation is used to calculate the wind speed at tower height for each turbine. From Table 34, Hummer, Shenzhou, and Hengfeng turbines have similar average unit power price at from 6000 to 7000 USD/average kW of power output, and Hengfeng costs the least at 6358 USD/kW. In Chapter 4.3 it is shown that typical PV costs are 7522 USD/kW which is higher than Hummer, Shenzhou, and Heng Feng, but lower than Winpower and Ghrepower. Ghrepower costs the most at 17357 USD/kW.

The average unit price of PV is 7522 USD/kW which ranks in middle among the turbines. The payback of PV (11.7 years) is slightly longer than Hengfeng (9.5), Hummer (10.2), Shenzhou (9.7), but shorter than Winpwer (13.2). Comparing with PV, turbines use much less land space to generate renewable energy. In this case, Hummer 50kW wind turbines used 4 times more space than 200 Trina solar TSM-PA05.082-250W (50kW total) modules.

Hengfeng, Hummer, Shenzhou turbines are better choices in terms of average unit power price (USD/kW) and payback time. However, Shenzhou's customer service refused to provide all the certificates they claim their turbines have been certified to, and detailed information before offer made. Hummer has provided the most detailed certificates information. In summary, Hummer is the first choice.

References

Abed, K., & El-Mallah, A. (1997). Capacity factor of wind turbines. *Energy*, 22(5), 487--491.

Ahmed, M. (2012). Blade sections for wind turbine and tidal current turbine applications-current status and future challenges. *International Journal of Energy Research*, 36(7), pp.829-844.

American National Standards Institute. (2016) *Wind Turbine Standards*. Retrieved on: https://webstore.ansi.org/energy/wind-turbine/

Anhui Hummer Dynamo Co., Ltd. (2015).*Hummer introduction*, retrieved from: http://www.chinahummer.cn/index.php/index/list_m/s_id/1001

Berman, K., Knight, J., & Case, J. (2013). *Financial intelligence, revised edition.*

C Bracken Meyers,(2013) *Types of Wind Turbines*, retrieved 09 December 2013, from: http://centurionenergy.net/types-of-wind-turbines

Canadian Wind Energy Association. (2013). *WindVision 2025 - A Strategy for ALBERTA.* Retrieved 21 September 2014, from http://canwea.ca/pdf/canwea-alberta-windvision-FINAL.pdf

Carbon Trust. (2008). Small-scale wind energy: policy insights and practical guidance. Carbon Trust, London, UK.

Chung, D., Davidson, C., Fu, R., Ardani, K., & Margolis, R. (2015). *U.s. photovoltaic prices and cost breakdowns: q1 2015 benchmarks for residential, commercial, and utility-scale systems.*

City of Calgary, (2018), *Landfill and Waste Management Facilities Setbacks*, retrieved from: http://www.calgary.ca/PDA/pd/Pages/Landfill-Setbacks.aspx

Conservation Services Group, Inc. (2014). *Types of Clean Energy and Renewable Energy Technologies.* Retrieved 21 September 2014, from http://www.csgrp.com/homeowners-renters/home-energy-efficiency-tips-energy-info/renewable-energy/

Coon, J., & Stewart, H. (2016). *Investopedia*. Utah Business.

CSA Group, (2016),*Wind Power Generating Systems* , retrieved from: http://www.csagroup.org/industries/energy-and-resources/renewable-energy/wind-power/

Danish Wind Industry Association, *Manufacturing Wind Turbine Towers*,Sep 19,2003,retrived from: http://drømstørre.dk/wp-content/wind/miller/windpower%20web/en/tour/manu/towerm.htm

Danish Wind Industry Association, *Testing Wind Turbine Rotor Blades*, Sep 19,2003,retrived from: http://drømstørre.dk/wp-content/wind/miller/windpower%20web/en/tour/manu/bladtest.htm

Danish Wind Industry Association, *Wind Turbine Towers*, Sep 19,2003,retrived from: http://drømstørre.dk/wp-content/wind/miller/windpower%20web/en/tour/wtrb/tower.htm

Ec Europa, (2014). *CE marking - Basics and FAQs - European Commission.*Available at: http://ec.europa.eu/enterprise/policies/single-market-goods/cemarking/about-ce-marking/index_en.htm

Encraft, (2009). *The Warwick Wind Trials report.* Available at: http://www.microwindturbine.be/Rapportering_files/Warwick+Wind+Trials+Final+Report+%281%29.pdf

Endurance Windpower, (2014). *50kW Wind Turbine - Endurance E-3120.* Available at: http://www.endurancewindpower.com/e3120.html.

Endurance Windpower, (2014). *Endurance Windpower | X-29 225kW Wind Turbine.* Available at: http://www.endurancewindpower.com/x29.html

GEPVp-200 Panel. (2014). *GEPVp-200 200W 18V Solar Panel. Altestore*. Retrieved 31 August 2014, from http://www.altestore.com/store/Solar-Panels/150-Watts-Up-Solar-Panels/GEPVp-200-200W-18V-Solar-Panel/p3843/

Ghrepower, (2016). *Maintenance Manual of FD16 Series WTGS*

Ghrepower. (2014). *50kW Wind Turbine - GHREPOWER - Power Your Future*. Retrieved 31 August 2014, from http://www.ghrepower.co.uk/50kW-wind-turbines.asp

Government of Canada, (June 1st ,2017), *Canadian Climate Normals 1981-2010 Station Data*, retrieved from: http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?stnID=2205&autofwd=1

Government of Canada, Natural Resources Canada, Energy Sector, *CANMET Energy Technology Centre – Varennes, RETScreen International. Retscreen international home.*

Greenheart Energy,(2011),*Wind Turbine Previous installations*, retrieved from: http://www.greenheart.co.uk/wind-turbines/previous-installations/

HengFeng Power Generator, (2014). *50KW wind turbine Manufacturer and Supplier*. Retrieved 31 August 2014, from http://www.china-wind-turbines.com/50kW-wind-turbine/9.html

HSBC (2011). *Climate investment update: Japan's nuclear crisis and the case for clean energy*. HSBC Global Research

http://www.ebay.com/itm/Apollo-MAX-550-W-Watt-12-V-DC-Magnet-PMA-Wind-Turbine-Generator-Kit-0-5-5-kW-New-/200787169559

Hummerwind. (2014). *100KW Wind Power System: Anhui Hummer Dynamo Co. Ltd.* Retrieved 31 August 2014, from http://hummerwind.manufacturer.globalsources.com/si/6008846411596/pdtl/Wind-turbine/1078924381/100kW-Wind-Power-System.htm

Hummerwind. (2014). *10kW Wind Turbine Generator Anhui Hummer Dynamo Co. Ltd.* Retrieved 31 August 2014, from http://hummerwind.manufacturer.globalsources.com/si/6008846411596/pdtl/Wind-turbine/1079709818/10kW-Wind-Turbine-Generator.htm

Hummerwind. (2014). *50kW Wind Turbine Generator: Anhui Hummer Dynamo Co. Ltd.* Retrieved 31 August 2014, from http://hummerwind.manufacturer.globalsources.com/si/6008846411596/pdtl/Wind-turbine/1065896529/50kW-Wind-Turbine-Generator.htm

Institution, B. S. .(2014). Bs en 61400-2. wind turbines. part 2. small wind turbines.

Intertek, (2017), *ETL Certification, the end to end process,* retrieved from: http://www.intertek.com/uploadedfiles/intertek/divisions/commercial_and_electrical/media/pdf/certifications_and_marks/etl_end_to_end_process.pdf

Intertek, (2018), *About us*, retrieved from: http://www.intertek.com/about/

Jin, X., Zhao, G., Gao, K. J., & Ju, W. (2015). *Darrieus vertical axis wind turbine: basic research methods. Renewable & Sustainable Energy Reviews*, 42, 212-225.

Kjellin, J., Eriksson, S., & Bernhoff, H. (2013). *Electric control substituting pitch control for large wind turbines.* Journal of Wind Energy, 2013(1–3).

Lawal Nadabo, S. (2010). *Renewable energy as a solution to nigerian, energy crisis.* Vaasan Ammattikorkeakoulu.

Lee, M. (2007). *Rotor for wind turbine,* U.S. Patent Application 11/975,821.

Liu, W., & Lund, H. (2009). *Comparative study of the potential of renewable energy sources and solutions between denmark and china.*

Lydia M, Kumar S S, Selvakumar A I, et al. *A comprehensive review on wind turbine power curve modeling techniques[J]. Renewable & Sustainable Energy Reviews*, 2014, 30(2):452-460.

M.Ragheb, (2015),*Wind Shear Roughness Classes and Turbine Energy Production.*

Manwell, J. F., Mcgowan, J. G., & Rogers, A. L. (2002). *Wind energy explained.* Wiley John + Sons, 30(2), 169-170.

Marigo, N., & Candelise, C. (2013). *What is behind the recent dramatic reductions in photovoltaic prices? the role of china.* Economia E Politica Industriale, 40(3), 5-41.

Marrapese, M. E., & Walker, J. C. (2007). *Restriction of the Use of Hazardous Substances (RoHS) in Electrical and Electronic Equipment.Encyclopedia of Magnetic Resonance.*

Masters, G. (2013). *Renewable and efficient electric power systems.* Wiley & Sons(8), 55 - 62.

Natural Resource Canada. (2018). *Electricity facts*, retrieved from: https://www.nrcan.gc.ca/energy/facts/electricity/20068

Natural Resources of Canada, Government of Canada, (2013). *Photovoltaic potential and solar resource maps of Canada.* Retrieved 21 August 2014, from http://pv.nrcan.gc.ca/index.php?m=r

Nielsen, T. S. B., & Spruce, C. J. (2010). *Wind turbine, a method for damping edgewise oscillations in one or more blades of a wind turbine by changing the blade pitch and use hereof.* US, US7854589.

NREL, (2014). Up to Wind Speed. Available at: http://www.nrel.gov/emails/wind/utws_newsletter_2012-06.html

Oudah, A., Mohd, I. I., & Hameed, A. (2014). *Wind turbines control: features and trends.* Modern Applied Science, 8(6), 272-295.

Park, J. H., Park, S. S., Yoon, Y. I., Yoo, C. H., & Hwang, J. G. (2011). *Design for yaw brake system in wind turbine.* 한국윤활학회 2010 년도 제 51 회 추계학술대회, 27(4), 204-208.

Ragheb, M., & Ragheb, A. M. (2011). *Wind Turbines Theory - The Betz Equation and Optimal Rotor Tip Speed Ratio. Fundamental and Advanced Topics in Wind Power.*

Renewable Energy World, (2008). *Survey Says 60% of US Wind Turbines May Be Behind in Maintenance.* Available at: http://www.renewableenergyworld.com/rea/news/article/2008/09/survey-says-60-of-us-wind-turbines-may-be-behind-in-maintenance-53502.

RETScreen, (March 20th, 2017),Natural Resources of Canada, retrieved from: http://www.nrcan.gc.ca/energy/software-tools/7465

Rosenvard, P., & Christensen, L. B. (2011). *Yaw system for a nacelle of a wind turbine and wind turbine.* US, US7944070.

Schubel, P. J., & Crossley, R. J. (2012). *Wind turbine blade design review.* Wind Engineering, 36(4), 3425-3449.

Shenzhou，(2014). *Yangzhou Shenzhou Wind-driven Generator Co,Ltd.* Retrieved from http://wind-turbine.com/anbieter/237/yangzhou-shenzhou-wind-driven-generator-co-ltd-jiangdu.html

Tian, J., (2012). *Integrated Optimal Design of Wind Turbine Systems. Open Access Dissertations.* Paper 909.Retrieved 21 September 2014, from http://scholarlyrepository.miami.edu/oa_dissertations/909

U.S Department of Energy. (2014). *Wind Testing and Certification | Department of Energy.* Retrieved 28 August 2014, from http://energy.gov/eere/wind/wind-testing-and-certification

Ul, (2012). GUIDE INFORMATION FOR ELECTRICAL EQUIPMENT THE WHITE BOOK 2012. Available at:

https://www.ul.com/global/documents/offerings/perspectives/regulators/2012%20WB%20FINAL.pdf

Vazquez, J., Silvera, A., Arias, F., & Soria, E. (1998). *Fatigue properties of a glass-fibre-reinforced polyester material used in wind turbine blades.Journal of Strain Analysis for Engineering Design*, 33(3), 183-193.

Weather Statistics for Calgary, Alberta. (2014). *Current Weather in Calgary.* Retrieved 3 August 2014, from http://calgary.weatherstats.ca

Weiku, (2014), *Guy wire tower for wind turbine 5.5m-30m,* retrived from: http://www.weiku.com/products/5662971/guy_wire_tower_for_wind_turbine_5_5m_30m.html

Yang, W., Tavner, P. J., Crabtree, C. J., Feng, Y., & Qiu, Y. (2014). *Wind turbine condition monitoring: technical and commercial challenges.* Wind Energy, 17(5), 673–693.

Youtube,*Coemi-Skywing Wind Turbine - Raising the Tower,* March 29,2010,retrived from: https://www.youtube.com/watch?v=z0d6oQj8wdE

Zobaa, A., & Bansal, R. (2011). *Handbook of renewable energy technology (1st ed.).* Singapore: World Scientific

Appendix A Ghrepower Data Sheets

		Ghrepower	
		FD16 50KW	
Power			
a	Rated Output	50	kW
b	Rated Voltage	DC460	V
c	Rated Current	108	
Generator		Permanent magnetic generator	
Blades			
a.	Material	FRP	
b	Number of Blades	3	
c.	Rotation Direction	ClockWise	
Blade/Rotor Diameter		16.0	M
Tilt Angle of Rotor Shaft		3	
Rated RPM		75	
Swept Area		198	
Wind Factors			
a	Start-Up Wind Speed	3	
b	Rated Wind Speed	11	m/s
c	Cut-Out Wind Speed	25	
d.	Cut-In Wind Speed	3	m/s
e.	Security/Survival Wind Speed	59.5(3s wind speed)	
f	Work Speed	3-25m/s	
Turbine Type		horizontal axis	
Control Mode		Active pitch	
Generator Utilization Ratio/Efficiency/		0.94	
Protection Mode		active pitch	
		mechanical brake	
		dumpload	
Tower Height		36	m
Power Curve			
a.	Wind Speed 3m/s	1.15	kW
b.	Wind Speed 4m/s	2.74	kW
c.	Wind Speed 5m/s	5.35	kW
d.	Wind Speed 6m/s	9.26	kW
e.	Wind Speed 7m/s	14.7	kW
f.	Wind Speed 8m/s	21.95	kW
g.	Wind Speed 9m/s	31.25	kW

h.	Wind Speed 10m/s	42.87	kW
i.	Wind Speed 11m/s	51	kW
j.	Wind Speed 12m/s	52	kW
k.	Wind Speed 13m/s	51	kW
l.	Wind Speed 14m/s	50	kW
m.	Wind Speed 15m/s	50	kW
Annual Energy Production		169000	kWh(7m/s)
Noise Level		<55	dBA

Certificate：

EUROTEST Laboratori S.u. - Società Unipersonale
Via G. Marconi, 25 - 35030 Mestrino - Padova (Italia)
Tel (+39) 049.9930145 - Fax (+39) 049.9730747
P.IVA e Cod.Fisc. 02344070286 - Cap. Soc. € 99.800 i.v.
La società è soggetta all'attività di direzione e coordinamento di CAIBI S.p.A.

LAB N° 0192

CEI 0-21

Fascicolo prove

/ Tests report file

Rapporto di prova n° CEI0-21 01 25304-130115 */Test report No.*

Prodotto in prova */Product under test*	Inverter eolico */Wind inverter*
Costruttore */Manufacturer*	Shangai Ghrepower Green Energy Co., Ltd No. 1281 Ronghua Road Shangai 201611 - China
Tipo - Modello */Type - Model*	GNW60K3G

EMC, Electrical Safety and Renewable Energies Testing Laboratory
Accredited by ACCREDIA
In compliance with UNI CEI EN ISO/IEC 17025
Accreditation number: 0192

NOVA CERTIFICATION

CERTIFICATE OF ADEQUACY

Certificate Number :	GR2107/009068C2
Date of Issue :	October 20, 2011
Manufacturer :	SHANGHAI GHREPOWER GREEN ENERGY CO., LTD. No.1281, Ronghua Rd, Songjiang, Shanghai, China
Certificate Holder :	SHANGHAI GHREPOWER GREEN ENERGY CO., LTD. No.1281, Ronghua Rd, Songjiang, Shanghai, China
Product Description :	WIND TURBINE
Product Type or Model :	FD12-20/11, FD12-30/11, FD13-30/12, FD13-40/12, FD13-50/12, FD14-30/12, FD14-40/12, FD14-50/12, FD21-50/12, FD21-60/12, FD21-70/12, FD21-80/12, FD21-90/12, FD21-100/12, FD28-150/12, FD28-200/12, FD32-300/12
European Union Directive :	Machinery Directive 2006/42/EC, Annex VIII Low-Voltage Directive 2006/95/EC, Annex IV
European Standards :	EN ISO 12100:2010, EN 61400-2:2006, EN 60204-1:2006+A1:2009
Report Number :	ZY-11001002 / October 20, 2011

Statement

This certification **declares** that the manufacturer or his authorised representative established in the EU, has draw up and submit the Technical File referred to in Annex VII.A of Directive 2006/42/EC and Annex IV §3 of directive 2006/95/EC, for the mentioned above product type (as described in Annex VIII of the Directive 2006/42/EC).

The Certification Body received and keeps the Technical File for specified period (until **October 19, 2016**).

Additional information – Remarks

The certification body should be informed (revision of technical file) for any modification or alterations made to the aforementioned product type(s), including design and manufacture and/or extension to the existing scope of application.

The manufacturer is responsible (within internal production control procedure) for certifying the product and ensuring that all manufactured products are in compliance with the specifications declared in the technical construction file.

The CE mark as shown below can be used under the responsibility of the manufacturer (other EC directives should be considered).

The manufacturer should accompany the product with EC Declaration of Conformity and appropriate operation and maintenance instructions.

This certificate may be reproduced only in a complete form.

NOVA CERTIFICATION

INSPECTION • CERTIFICATION NOVA CERTIFICATION www.novacert.com

For Third Party Inspection Body

General Director

NOVA CERTIFICATION LTD
Ag. Dimitriou Street No 163, GR-54636 Salonica, Greece
Tel. +30-23410-70380 email info@novacert.com
China Tel.: 400-882-8600

Certificate data can be validated at our website (www.novacert.com).

009068C2 LVD & MD SHANGHAI GHREPOWER GREEN ENERGY CO., LTD., CHINA

Page 1 of 1

TEST REPORT
Engineering Recommendation G59
RECOMMENDATIONS FOR THE CONNECTION OF GENERATING PLANT TO THE DISTRIBUTION SYSTEMS OF LICENSED DISTRIBUTION NETWORK OPERATORS

Report Reference No. ....:	SH12060654-001
Tested by (name + signature)..........:	Sleif Sui
Approved by (name + signature) ......:	Robin Xu
Date of issue ....:	2012-08-16
Contents ....:	25 pages
Testing Laboratory ....:	Intertek Testing Services Shanghai.
Address ....:	Building No.86, 1198 Qinzhou Road (North), Shanghai 200233, China.
Testing location / procedure............:	TL ☒ SMT ☐ TMP ☐
Testing location / address...............:	Same as above
Applicant's name.............................:	Shanghai Ghrepower Green Energy Co., Ltd
Address ....:	No.1281 Ronghua Road Shanghai 201611 China
Test specification:	
Standard...:	ER G59_2_2010
Test procedure.................................:	G59_testing
Non-standard test method...............:	N/A
Test Report Form/blank test report	
Test Report Form No. ....:	TTRF_G59_2_2010_V1.1_2011-12
TRF Originator ....:	Intertek Shanghai
Master TRF ....:	2011-12

RetScreen Data

Wind - Level 2

Resource assessment

	Unit	Value	Climate Data Canada - Alberta - Calgary Int'l. Airport
Resource method		Wind speed	
Wind speed - annual	m/s		4.4
Measured at	m		10
Wind shear exponent			
Air temperature - annual	°C		3.9
Atmospheric pressure - annual	kPa		88.9

Wind turbine

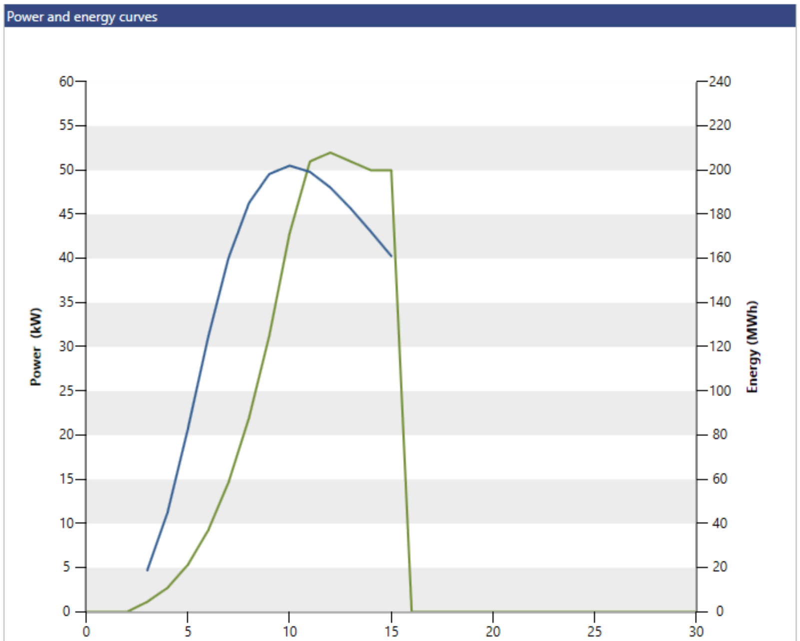
	Unit	Value
Power capacity per turbine	kW	50
Manufacturer		Ghrepower
Model		FD16 50KW
Number of turbines		
Power capacity	kW	
Hub height	m	36
Rotor diameter per turbine	m	16
Swept area per turbine	m²	
Energy curve data		Standard
Shape factor		2

Power and energy curves

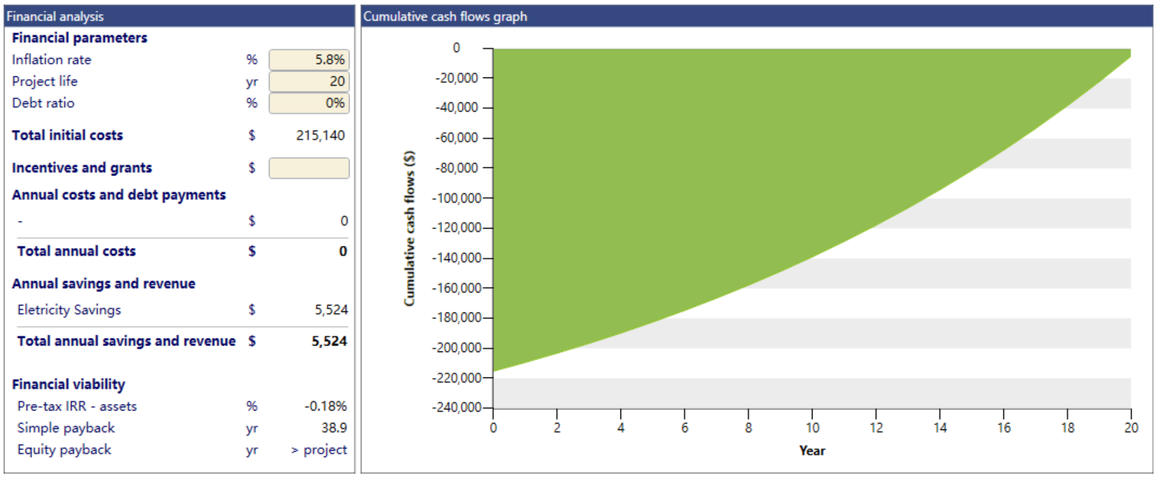
Data

Wind speed m/s	Power curve data kW	Energy curve data MWh
0		
1		
2		
3	1.15	18.8
4	2.74	45.2
5	5.35	83
6	9.26	125
7	14.7	160
8	21.95	185
9	31.25	198
10	42.87	202
11	51	199
12	52	192
13	51	183
14	50	172
15	50	161
16		
17		
18		
19		
20		
21		
22		
23		

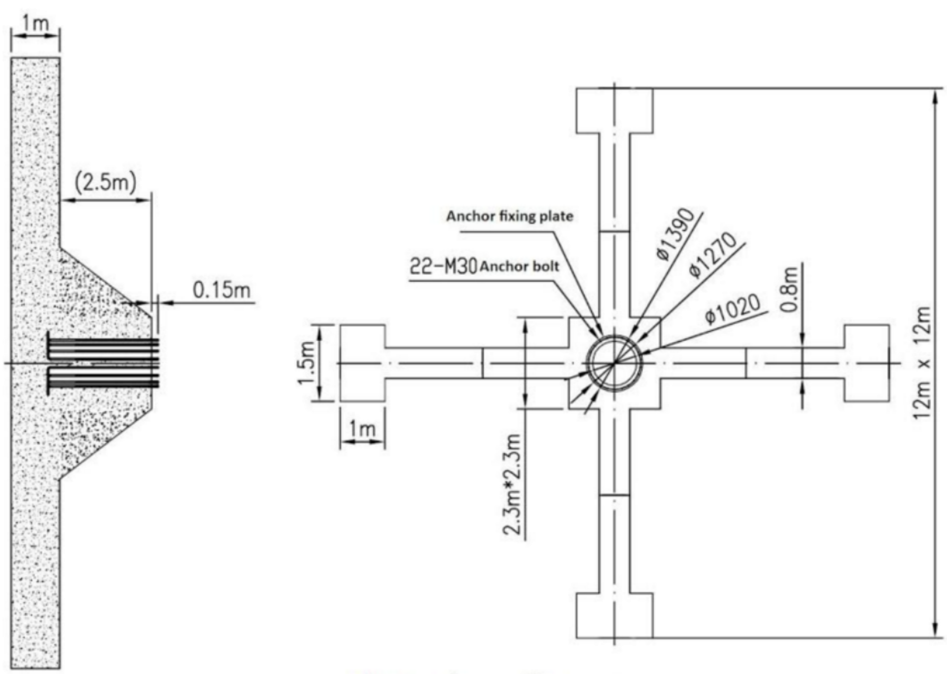
Power and energy curves



RETScreen - Financial Analysis



Foundation dimensions:



50kW 18m freestanding tower

Appendix B Hummer Data Sheets

	Hummer 50kW
	H12.0-50000W
Power	
a. rated output	50000W

c. rated voltage	400V
d. rated current	125A
Generator	direct driven permanent magnet generator with single phase output
Blades	
a. material	GRP
b. number of blades	3
c. rotation direction	clockWise
Rotor diameter	16m
Rated RPM	160
Swept area	200.96m^2
Wind factors	
rated wind speed	11m/s
cut-out wind speed	18m/s It is factory default value and users can reset it by themselves with Touch Screen of SIEMSN PLC.
cut-in wind speed	2m/s
security/survival wind speed	50m/s
work wind speed	2.5-25m/s
Turine type	Upwind
Control mode	Manual & Automatic
Generator utilization ratio	＞0.92
Protection mode	Yawing + Electromagnetism braking + Hydraulic braking
Standard tower height	18m
Nacelle weight	Generator weight: 1200kg Yaw shaft wight: 1250kg
Annual KWH production	KWH
3m/s	56250
4m/s	103400
5m/s	127900
6m/s	166500
7m/s	220000
8m/s	262800
9m/s	350400
10m/s	438000
Annaul energy production	
Noise level	Described noise report

Price(Updated on 2015/03/11)(from direct communication with sales):

Right now the rotor diameter of 50kW is 16.5m.
And there is upgrade of 50kW wind turbine, with pitch control.
The price of new version of 50kW wind turbine is as following:
Wind generator: USD65,850
SIEMENS PLC controller: USD4,720
Rectifier controller: USD3,390
Metal dumping load: USD2,935
18m freestanding tower: USD10,485
19.5m hydraulic tower: USD31,105
Total with freestanding tower: USD87,380
Total with hydraulic tower: USD108,000

Noise Report:

Noise report.pdf

Documents:

HUMMER parameters-50KW

Certificates:

EPREI

CHINA CEPREI (SICHUAN) LABORATORY

DECLARATION OF CONFORMITY

DECLARATION OF CONFORMITY is hereby issued to certify the following equipment

Certificate Holder: Anhui Hummer Dynamo Co., Ltd.
Address: Lujiang County Economic Development Zone, Anhui Province, China

Manufacturer: Anhui Hummer Dynamo Co., Ltd.
Address: Lujiang County Economic Development Zone, Anhui Province, China

Certification Marking: CE

Product Type: Wind generator
Product Model: H1.25-400W, H2.7-500W, H1.25-600W, H3.1-1000W, H3.8-2000W, H4.6-3000W, H6.4-5000W, H8.0-10KW, H9.0-20KW, H10.0-30KW, H12.0-50KW, H13.0-100KW
Parameters: Rated Voltage: 12V~480V DC
Rated Power: 400W~100 KW
Output Rated Frequency: 50Hz & 60Hz

Certificate Number: E2 032113 05
Report Number: 252336200
Date of Issue: September 17, 2011

Complied with the requirements set out by the Council Directive 2006/95/EC (Low Voltage Directive). The following standards were applied:

EN 50308: 2004, EN 61400-1: 2005+A1: 2010/ IEC 61400-1:2007
EN 61400-2: 2006/ IEC 61400-2:2006, EN 61400-12-1: 2006/ IEC61400-12-1: 2005

WESTCEPREI

Signature: Oliver Deng

Title: Vice-General Manager

Tel: 800-886-7323 Fax: 0086-28-8522 4532 www.westceprei.com

THE INTERNATIONAL CERTIFICATION NETWORK

CERTIFICATE

IQNet and CQM
hereby certify that the organization

Anhui Hummer Dynamo Co.,Ltd.

Domicile: Industrial Park, Lucheng Town, Lujiang County, Chaohu City, Anhui, P.R.China
Certification Add.: Industrial Park, Lucheng Town, Lujiang County, Anhui, P.R.China

Postcode.:231500

is in conformity with

ISO 9001:2008 Standard

This certificate is valid to the following product(s)/service:

The design & manufacture of wind turbine generator system, wind-solar hybrid street light system

Issued on: 2010-12-08
Validity date: 2013-12-07
Registration Number: CN-00210Q16719R0S

Michael Drechsel
President of IQNet

Zhang Wei
President of CQM

IQNet Partners*:

AENOR Spain AFNOR Certification France AIB-Vinçotte International Belgium ANCE Mexico APCER Portugal CCC Cyprus CISQ Italy CQC China CQM China CQS Czech Republic Cro Cert Croatia DQS Holding GmbH Germany DS Denmark ELOT Greece FCAV Brazil FONDONORMA Venezuela ICONTEC Colombia IMNC Mexico Inspecta Certification Finland IRAM Argentina JQA Japan KFQ Korea MSZT Hungary Nemko AS Norway NSAI Ireland PCBC Poland Quality Austria Austria RR Russia SII Israel SIQ Slovenia SIRIM QAS International Malaysia SQS Switzerland SRAC Romania TEST St Petersburg Russia TSE Turkey YUQS Serbia

IQNet is represented in the USA by: AFNOR Certification, CISQ, DQS Holding GmbH and NSAI Inc.

** The list of IQNet partners is valid at the time of issue of this certificate. Updated information is available under www.iqnet-certification.com* the standard in safety

Underwriters Laboratories

File E320011 Vol 1 Issued: 2008-06-26
Revised: 2008-10-17

FOLLOW-UP SERVICE PROCEDURE
(TYPE L)

COMPONENT - APPLIANCE WIRING MATERIAL
(AVLV2,AVLV8)

Manufacturer: SICHUAN STAR CABLE CO LTD
(100406-492) 18 YINGBIN AVE
HI-TECH DEVELOPMENT AREA
LESHAN,
SICHUAN 614001 CHINA

Applicant: SAME AS MANUFACTURER
(100406-492)

Recognized Company: SAME AS MANUFACTURER
(100406-492)

This Procedure authorizes the above manufacturer to use the marking specified by Underwriters Laboratories Inc.(UL), or any authorized licensee of UL, only on products covered by this Procedure, in accordance with the applicable UL Services Agreement.

The prescribed Mark or Marking shall be used only at the above manufacturing location on such products which comply with this Procedure and any other applicable requirements.

The Procedure contains information for the use of the above named Manufacturer and representatives of Underwriters Laboratories Inc. and is not to be used for any other purpose. It is lent to the Manufacturer with the understanding that it is not to be copied, either wholly or in part, and that it will be returned to Underwriters Laboratories Inc. (UL) or any authorized licensee of UL, upon request.

This PROCEDURE, and any subsequent revision, is the property of Underwriters Laboratories Inc.(UL) and the authorized licensee of UL and is not transferable.

Underwriters Laboratories Inc.

Stephen Hewson
Senior Vice President
Global Follow-Up Service Operations

William R. Carney
Director
North American Certification Program

EPREI

VERIFICATION

of conformity with European Directives

Order No	LC090109-60-CE
Type of equipment	GRID-TIED INVERTER
Applicant /Manufacturer	Anhui Hummer Dynamo Co.,LTD
Manufacturer site	Lucheng Town Industrial Zone, Lujiang County, Chaohu City, Anhui Province, China.
Type designation	HG-1KW、HG-2KW、HG-3KW、HG-5KW、HG-10KW、HG-20KW、HG-30KW、HG-50KW
Technical data	Input voltage:DC230V-400V ， Output voltage: AC180-260V Rated Power: 5KW ， AC Frequency:47-51.5HZ/57-61.5HZ

The submitted sample of the above equipment has been tested for CE marking according to the following European Directive:

The European Electromagnetic Compatibility Directive 89/336/EEC amended by 92/31/EEC

Standard(s) used for showing compliance with the essential requirements in the specified directive(s):

Standard(s)	*Test report(s)*	*Issued by*	*Date(s)*
EN61000-6-1:2007、EN61000-6-2:2006 EN61000-6-3:2007、EN61000-6-4:2007 EN61000-3-2:2006、EN61000-3-3:2006 EN55022:2008 ， EN55024:2002	LC090109-60-CE	China Ceprei (Sichuan) Compliance Lab.	2009-01-09

The referred test report(s) show that the product complies with standard(s) recognized as giving presumption of compliance with the essential requirements in the specified EU Directive(s).

After preparation of the necessary technical documentation as well as the conformity declaration the CE marking as shown below can be affixed on the equipment. Other relevant Directives have to be observed.

Note: This verification is only valid in connection with the reference test report(s).

Signature: Andrew Li Title: Chief Engineer Date: Jan 9. 2009

CE

CHINA CEPREI (SICHUAN) COMPLIANCE LAB.

EPREI

CHINA CEPREI (SICHUAN) LABORATORY

DECLARATION OF CONFORMITY

DECLARATION OF CONFORMITY is hereby issued to certify the following equipment

Certificate Holder: Anhui Hummer Hynamo Co., Ltd.
Address: Room 302, No. E2 Building, Huayi Industrial Park, High And New Technology Industrial Development Zone, Hefei, Anhui Province, China
Manufacturer: Anhui Hummer Hynamo Co., Ltd.
Address: Room 302, No. E2 Building, Huayi Industrial Park, High And New Technology Industrial Development Zone, Hefei, Anhui Province, China

Certification Marking: CE

Product Type: GRID-TIED INVERTER
Product Model: H1.25-400W, H1.35-500W, H1.45-600W, H2.7-500W, H3.1-1KW, H3.8-2KW, H4.6-3KW, H6.4-5KW, H8.0-10KW, H8.1-15KW, H9.0-20KW, H9.1-25KW, H10.0-30KW, H12.0-50KW, H13.0-60KW, H14.0-70KW, H15.0-80KW, H16.0-90KW, H18.0-100KW
Parameters: Rated Voltage:12V ~ 480V DC
Rated Power: 400W~100 KW
Output Rated Frequency: 50Hz & 60Hz

Certificate Number: E2 032113 03
Date of Issue: September 2, 2011

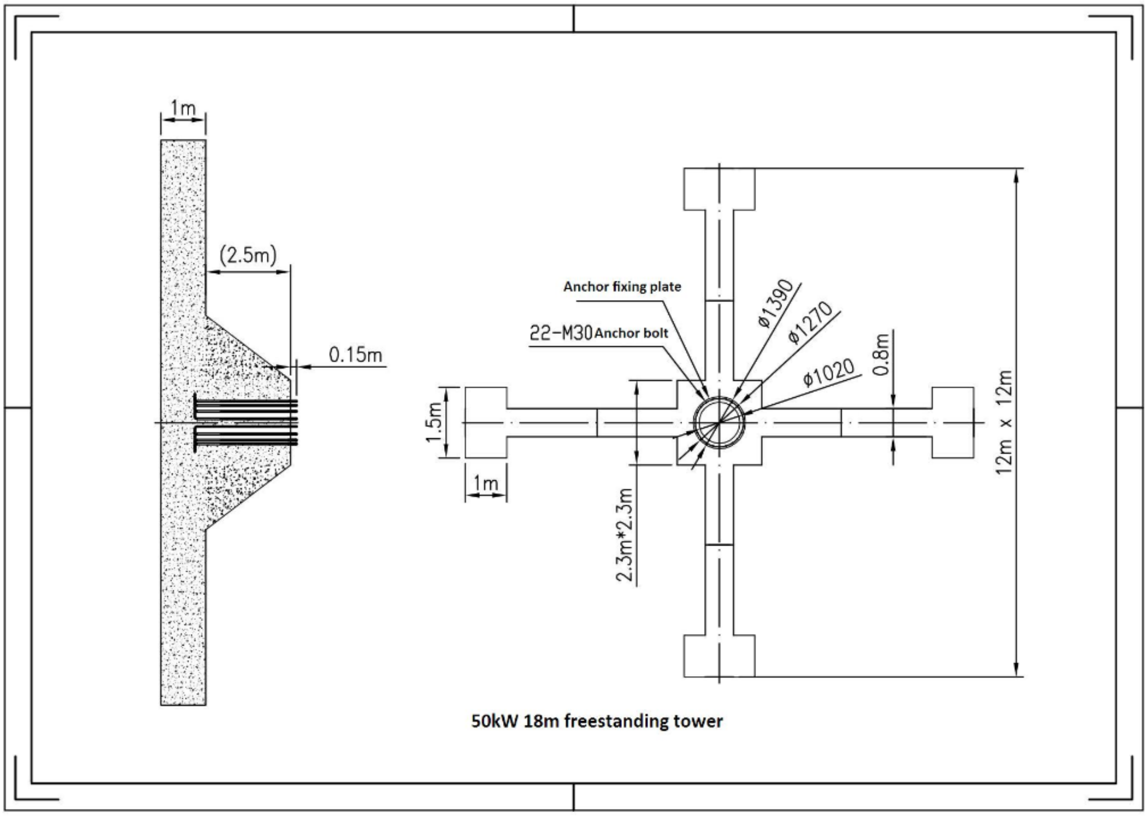
Complied with the requirements set out by the Council Directive 2006/95/EC (Low Voltage Directive). The following standards were applied:

EN 50178: 1997, EN60146-1-1: 2010

Signature: Oliver Deng   Title: Vice-General Manager

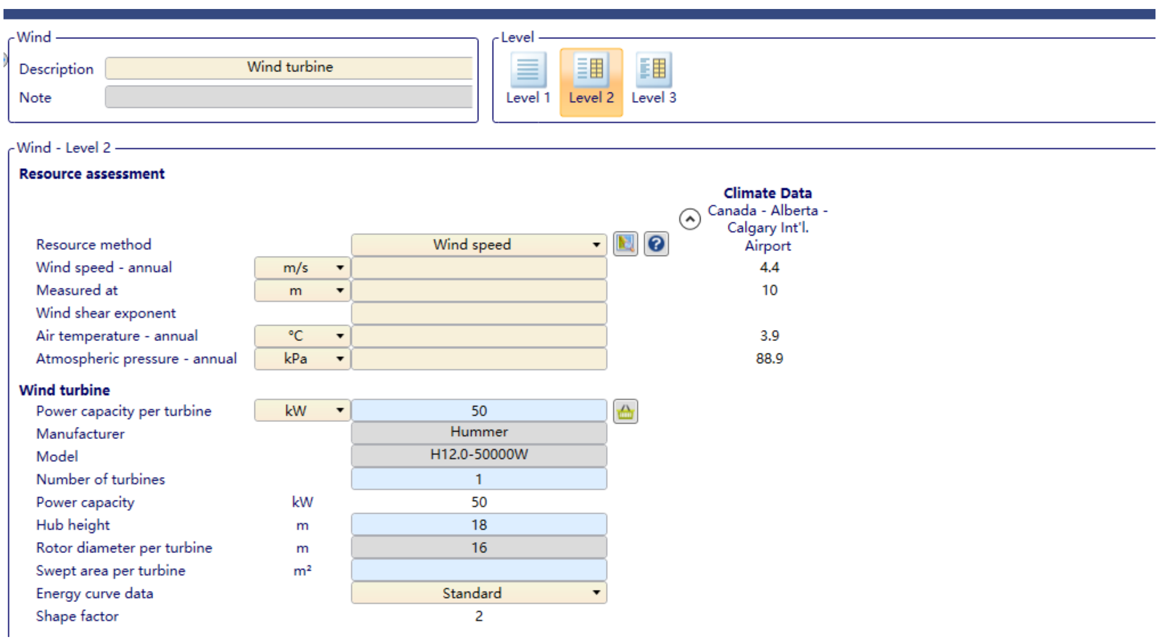
Tel: 800-886-7323 Fax: 0086-28-8522 4532 www.westceprei.com

Tower base dimension



50kW 18m freestanding tower

RetScreen Data:



Wind
Description: Wind turbine
Note:

Level
Level 1 | Level 2 | Level 3

Wind - Level 2

Resource assessment

	Unit	Value	Climate Data Canada - Alberta - Calgary Int'l. Airport
Resource method		Wind speed	
Wind speed - annual	m/s		4.4
Measured at	m		10
Wind shear exponent			
Air temperature - annual	°C		3.9
Atmospheric pressure - annual	kPa		88.9

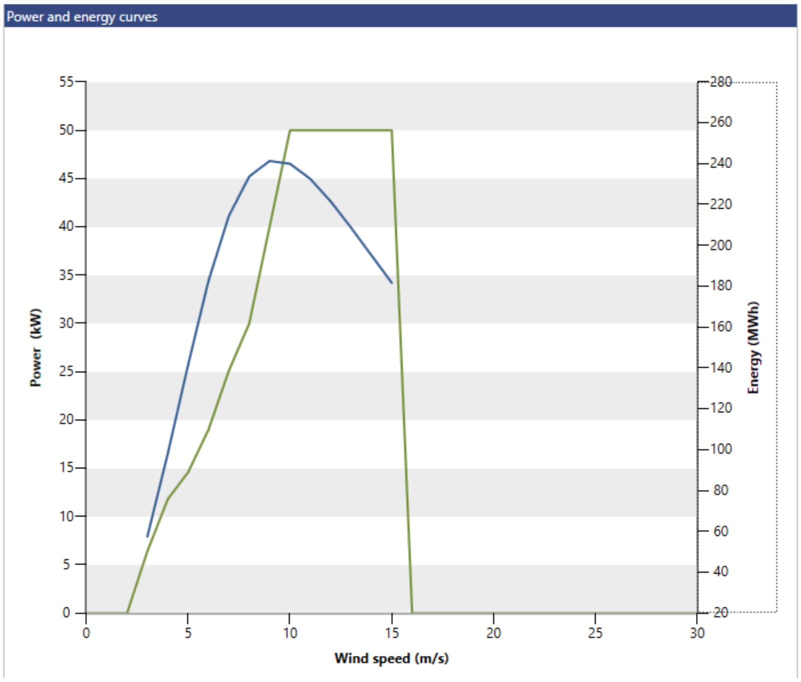
Wind turbine

	Unit	Value
Power capacity per turbine	kW	50
Manufacturer		Hummer
Model		H12.0-50000W
Number of turbines		1
Power capacity	kW	50
Hub height	m	18
Rotor diameter per turbine	m	16
Swept area per turbine	m²	
Energy curve data		Standard
Shape factor		2

Power and energy curves

Data

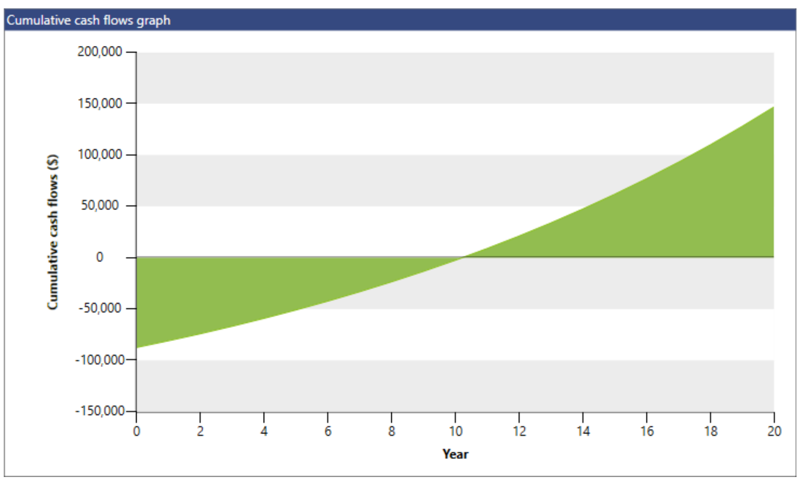
Wind speed m/s	Power curve data kW	Energy curve data MWh
0		
1		
2		
3	6.4212	57.6
4	11.8037	98
5	14.6005	142
6	19.0068	183
7	25.1142	214
8	30	234
9	40	241
10	50	240
11	50	233
12	50	222
13	50	209
14	50	195
15	50	182
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		



RETScreen - Financial Analysis

Financial analysis

Financial parameters		
Inflation rate	%	5.8%
Project life	yr	20
Debt ratio	%	0%
Total initial costs	$	87,380
Incentives and grants	$	
Annual costs and debt payments		
-	$	0
Total annual costs	$	**0**
Annual savings and revenue		
Eletric Savings	$	6,154
Total annual savings and revenue	$	**6,154**
Financial viability		
Pre-tax IRR - assets	%	9.5%
Simple payback	yr	14.2
Equity payback	yr	10.2



Appendix C Hengfeng Data Sheets

		Hengfeng HF50KW	
Power			
a.	Rated Output	50,000	w
b	Rated Voltage	380	V
c	Rated Current	76A	

Generator		direct drive	
Blades			
a.	Material	glass fiber reinforced plastics	
b	Number of Blades	3 pcs	
c.	Rotation Direction	clockWise	
Blade/Rotor Diameter		15.0	M
Tilt Angle of Rotor Shaft		6	
Rated RPM		100	r/min
Swept Area		177 ㎡	
Wind Factors			
a.	Rated Wind Speed	12	m/s
b	Cut-Out Wind Speed	30m/s	
c	Cut-In Wind Speed	3.5m/s	
d.	Security/Survival Wind Speed	50	m/s
Turbine Type		updraft	
Control Mode		Micro-computer intelligence controller	
Generator Utilization Ratio/Efficiency/		0.85	
Power Factor			
Protection Mode		yawing, automatic brake and Manual brake protection	
Tower Height		≤18	m
Power curve(kW)			
a.	Wind Speed 3m/s	2.6	
b.	Wind Speed 4m/s	3.8	
c.	Wind Speed 5m/s	7.7	
d.	Wind Speed 6m/s	15.5	
e.	Wind Speed 7m/s	24	
f.	Wind Speed 8m/s	33	
g.	Wind Speed 9m/s	42	
h.	Wind Speed 10m/s	50	
i.	Wind Speed 11m/s	57	
j.	Wind Speed 12m/s	60	
k.	Wind Speed 13m/s	55	
l.	Wind Speed 14m/s	52	
m.	Wind Speed 15m/s	50	
Noise Level		≤40dB	

Certificates:

APRAGAZ

Member of CEOC

Chaussée de Vilvorde, 156
Vilvoordsesteenweg 156
B-1120 Bruxelles/Brussel
Tel.: 32 (0)2 264 03 60
Fax: 32 (0)2 268 89 58
http://www.apragaz.com
info@apragaz.com

APRAGAZ-UTS
(Representative Office)
Room 812-813,JiaoNeng
International Mansion,No.79,
Aona Road,Pudong District,
200131 Shanghai China
Tel.:+86 2151099699
Fax.:+86 2151156186
http://www.utsce.com
e-mail:utsce@utsce.com.cn

CERTIFICATE OF COMPLIANCE Review of Manufacturer's Technical File		Certificate N° 09/CN/1661-1-REV 0
Manufacturer	Name	QINGDAO HENGFENG WIND POWER GENERATOR CO.,LTD.
	Address	N° 226 TAISHAN ROAD,JIAONAN CITY QINGDAO,CHINA

Concerned Equipment: **WIND POWER GENERATORS**

MODEL: 150W, 200W, 300W, 600W, 1000W ,2000W, 3000W ,5000W, 10KW ,15KW, 20KW ,30KW, 50KW, 100KW, 200KW

As described in the Technical Construction File ref. :**HENGFENG-081209– Issue date 04/01/2010**

This is to declare that the Technical File issued by QINGDAO HENGFENG WIND POWER GENERATOR CO.,LTD. concerning the above mentioned equipment has been prepared according to the essential safety requirements of the Machinery Directive 2006/42/EC and the Low Voltage Directive 2006/95/EC.

The manufacturer is allowed to affix the "CE" mark, under its own responsibility, to the concerned equipment, in the conditions described in the Directive, providing all measures described in the Technical File ref.: HENGFENG-081209– Issue date 04/01/2010 have been applied to the product put on the European Market.

All modifications to the Technical File should be first submitted to the Third Party Inspection Authority to ensure further validity of this compliance certificate.

Date : **04/06/2010** Name : **Ch. Leplat** Position **General Manager**

Signature

Third Party Authority stamp : APRAGAZ Belgium Inspecting Authority

Third Party Authority reference : 0901/P10835/LVD01/MD01

CE

RP197 rev 0

山 东 省
企业产品执行标准登记证书

（证书编号： 370284-1026 ）

青岛恒风风力发电机有限公司：

依据《山东省实施＜中华人民共和国标准化法＞办法》，本证书副本所列你单位产品执行标准符合要求，予以登记。

证书有效期至 2011年 03月 17日

登记部门（章）
2008年 3月 16日

山东省质量技术监督局

Certificate of Approval
Awarded to
Qingdao Hengfeng Wind Power Generator Co., Ltd.
ISO 9001
IAF
Beijing Zhongliantianrun Certification Center
质量管理体系认证证书
授 予
青岛恒风风力发电机有限公司
2014/03/04 12:46


Made-in-China.com
Audited Supplier
中国制造网 认证供应商
AUDITED SUPPLIER
Presented To
Qingdao Hengfeng Wind Power Generator Co., Ltd.
青岛恒风风力发电机有限公司
www.hengfeng-power.com
Made-in-China.com
中国制造网
SGS


Supplier Assessment
Supplier Assessment Certificate
Certification No. 7176393_P+T
Qingdao Hengfeng Wind Power Generator Co., Ltd.
青岛恒风风力发电机有限公司
http://hengfeng-energy.en.alibaba.com
Onsite assessment of the following areas was conducted by Bureau Veritas :
Company Overview
Human Resources
Current Export Situation
Export Business Capacity
Production Capacity
Quality Assurance
Production Process Management
R & D Capacity
Company Development / Expansion Plans
Production Flow
Certification & Photos
Company and Product Samples
www.hengfeng-power.com
Issued by: Alibaba.com
Date of Issue: 01 Jan 2014
Assessed by:
Certificate No. 7176393_P+T
Signature:
Title: Director for Bureau Veritas Certification Greater China


Alibaba.com Assessed Supplier
Supplier Assessment
Certificate Number: 7176393_P+T
Presented to
Qingdao Hengfeng Wind Power Generator Co., Ltd.
www.hengfeng-power.com
Assessed by Mr. Peak Wan on 31 Dec 2013.
Valid until: 31 Dec 2014.
Signature:
Title: Director for Bureau Veritas Certification Greater China
Alibaba.com
BUREAU VERITAS

APRAGAZ

T U S

Member of CEOC

Chaussée de Vilvorde, 156
Vilvoordsesteenweg 156
B-1120 Bruxelles/Brussel
Tel.: 32 (0)2 264 03 60
Fax: 32 (0)2 268 89 58
http://www.apragaz.com
info@apragaz.com

APRAGAZ-UTS
(Representative Office)
Room 812-813 JiaoNeng
International Mansion, No.79,
Anna Road, Pudong District,
200131 Shanghai China
Tel.:+86 2151099699
Fax.:+86 2151156186
http://www.utsce.com
e-mail:utsce@utsce.com.cn

CERTIFICATE OF COMPLIANCE Review of Manufacturer's Technical File		Certificate N° 09/CN/1661-1-REV 0
Manufacturer	Name	QINGDAO HENGFENG WIND POWER GENERATOR CO.,LTD.
	Address	N° 226 TAISHAN ROAD,JIAONAN CITY QINGDAO,CHINA

Concerned Equipment: WIND POWER GENERATORS

MODEL: 150W, 200W, 300W, 600W, 1000W ,2000W, 3000W ,5000W, 10KW ,15KW, 20KW ,30KW, 50KW, 100KW

As described in the Technical Construction File ref. :HENGFENG-081209– Issue date 04/01/2010

This is to declare that the Technical File issued by QINGDAO HENGFENG WIND POWER GENERATOR CO.,LTD. concerning the above mentioned equipment has been prepared according to the essential safety requirements of the Machinery Directive 2006/42/EC and the Low Voltage Directive 2006/95/EC.

The manufacturer is allowed to affix the "CE" mark, under its own responsibility, to the concerned equipment, in the conditions described in the Directive, providing all measures described in the Technical File ref.: HENGFENG-081209– issue date 04/01/2010 have been applied to the product put on the European Market.

All modifications to the Technical File should be first submitted to the Third Party Inspection Authority to ensure further validity of this compliance certificate.

Date : 04/06/2010 Name : Ch. Leplat Position General Manager

Signature

Third Party Authority stamp : APRAGAZ Belgium Inspecting Authority

CE

Third Party Authority reference : 0901/P10835/LVD01/MD01

RP197 rev 0

Project case:

project case.ppt

Company introduction

TEL：0086-532-89055077 FAX：0086-532-89055066
http://www.hengfeng-power.com E-mail:power@hengfeng-power.com

Hi, nice to talk with you, we are leading manufacturer in china, we have 7 years experience in this field. Export to more than 63 countries. We can provide you with the most reliable quality and best price. Our products have been certified by CE, SGS, BV.

15KW 20KW 30KW 50KW 100KW 200KW wind turbine controllers are based on microcomputer control, PLC programmable logic control, man-machine interface, 256 color touch screen, operation more intuitive and convenient, rectifier components with temperature detection function, controller power acceptable input voltage range of 24-600V, in order to ensure the controller and the yaw motor can normal operation regardless of the circumstances, signal sensor is shielded cable connection, make sure signal transmission uninterrupted, more reliable.

Detection internal voltage and current sensor is use of the 12 high-precision, the controller controls the generator yaw according to wind speed, wind direction, current, voltage etc combined effects. yaw of the minimum angle is1 degree (Note: do not like other manufacturers yaw minimum angle is 30 degrees), so that we can make more effective use of wind energy to obtain the maximum output power.
Add or delete control content based on customer requirements, it is possible to additional monitoring communications.

Direct drive permanent magnet generator: contains: Motor Stamping disk used is 470 silicon steel sheet, generator winding is pure copper wire which can be resistant to 160 degrees high temperature, high insulation properties, high permeability and high efficiency, high power generation efficiency, low-speed performance. In the light breeze wind speed the generator can generate electricity. Using advanced circuit automatic control system can automatically run reliably under adverse weather conditions, state-of-the-art technology, reliable unit performance, easy installation and maintenance. Controls, inverters, unloading blend.

Blade: propeller, wing style, aviation materials, hand mold making, flange pad connector ,convenient connection to install them without correction, the degree of balance is good . Airfoil blades, strength, fatigue resistance, and high efficiency.

Price:

hengfeng Price
of 50KW WIND TI

RETScreen:

- Wind - Level 2

Resource assessment

	Unit	Value	Climate Data Canada - Alberta - Calgary Int'l. Airport
Resource method		Wind speed	
Wind speed - annual	m/s		4.4
Measured at	m		10
Wind shear exponent			
Air temperature - annual	°C		3.9
Atmospheric pressure - annual	kPa		88.9

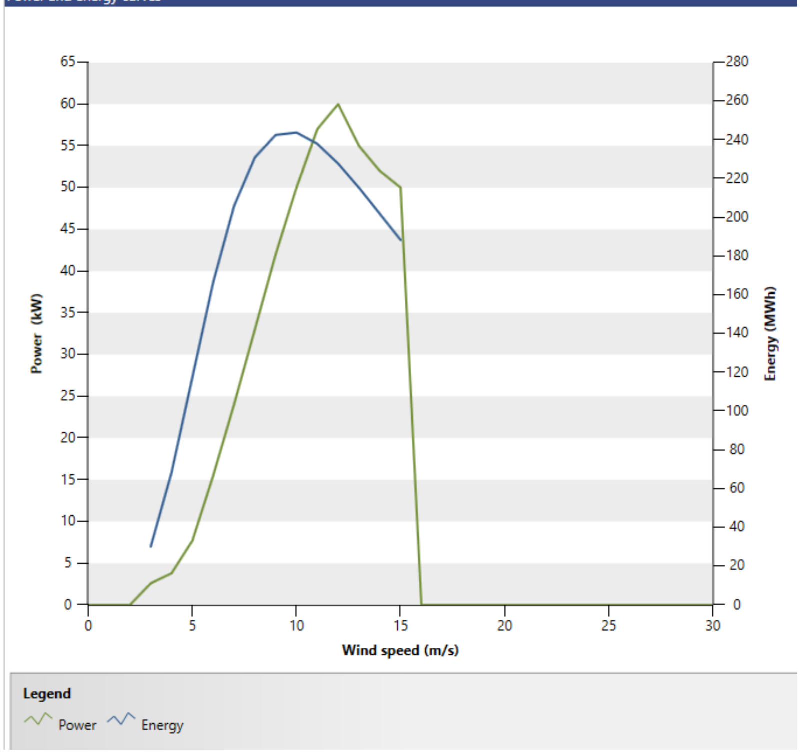
Wind turbine

	Unit	Value
Power capacity per turbine	kW	50
Manufacturer		Hengfeng
Model		HF50KW
Number of turbines		
Power capacity	kW	
Hub height	m	18
Rotor diameter per turbine	m	15
Swept area per turbine	m^2	
Energy curve data		Standard
Shape factor		2

Power and energy curves

Data

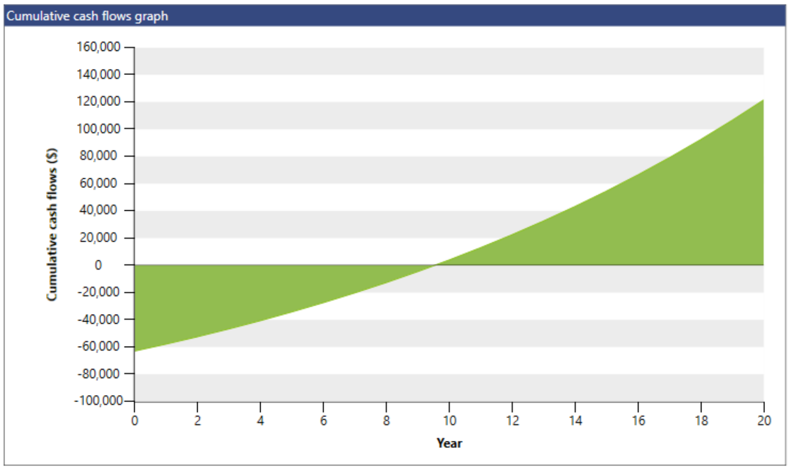
Wind speed m/s	Power curve data kW	Energy curve data MWh
0		
1		
2		
3	2.6	30.1
4	3.8	68.4
5	7.7	118
6	15.5	167
7	24	206
8	33	231
9	42	243
10	50	244
11	57	238
12	60	228
13	55	215
14	52	202
15	50	188
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		



RETScreen - Financial Analysis

Financial analysis

Financial parameters		
Inflation rate	%	5.8%
Project life	yr	20
Debt ratio	%	0%
Total initial costs	$	62,939
Incentives and grants	$	
Annual costs and debt payments		
-	$	0
Total annual costs	**$**	**0**
Annual savings and revenue		
Eletricity Savings	$	4,849
Total annual savings and revenue	**$**	**4,849**
Financial viability		
Pre-tax IRR - assets	%	10.6%
Simple payback	yr	13
Equity payback	yr	9.5



Appendix D Shenzhou Data Sheets

PARAMETERS		Shenzhou 50kW FD16.0-50000
1	Power	

	a.	Rated Output	50,000	w
	b	Rated Voltage	360	DCV
	c	Rated Current	138	DCA
4	Generator		Permanent Magnet	
5	Blades			
	a.	Material	GFRP	
	b	Number of Blades	3	
	c.	Rotation Direction	ClockWise	
6	Rotor Diameter		16.0	M
8	Rated RPM		60	r/min
9	Swept Area		200	m^2
10	Wind Factors			
	a	Rated Wind Speed	12	m/s
	b	Cut-Out Wind Speed	20	m/s
	c	Cut-In Wind Speed	3	
	d.	Security/Survival Wind Speed	60	m/s
11	Turbine Type		Upwind	
12	Control Mode		Manual/Auto	
13	Generator Utilization Ratio/Efficiency		0.9	
14	Protection Mode		Yawing/Dump;	
			Load/Brake	
			(fail-safe type)	
15	Standard Tower Height		18	
16	Nacelle Weight		3	
17	Off-Grid		could be off-grid use with different controller and inverter	
18	Power Curve (kW)			
	a.	Wind Speed 3m/s	0	
	b.	Wind Speed 4m/s	13140	
	c.	Wind Speed 5m/s	30660	
	d.	Wind Speed 6m/s	56940	
	e.	Wind Speed 7m/s	83220	
	f.	Wind Speed 8m/s	109500	
	g.	Wind Speed 9m/s	157680	
	h.	Wind Speed 10m/s	245280	
	i	Wind Speed 11m/s	367920	
	j	Wind Speed 12m/s	420480	
	k	Wind Speed 13m/s	446760	

	l	Wind Speed 14m/s	446760
	m	Wind Speed 15m/s	446760
19	Annual Energy Production(kWh)		56940
20	Noise Level		55db

Certificates:

IQNet

THE INTERNATIONAL CERTIFICATION NETWORK

CERTIFICATE

IQNet and CQM
hereby certify that the organization

Anhui Hummer Dynamo Co.,Ltd.

Domicile: Industrial Park, Lucheng Town, Lujiang County, Chaohu City, Anhui, P.R.China
Certification Add.: Industrial Park, Lucheng Town, Lujiang County, Anhui, P.R.China

Postcode.:231500
is in conformity with

ISO 9001:2008 Standard

This certificate is valid to the following product(s)/service:
The design & manufacture of wind turbine generator system, wind-solar hybrid street light system

Issued on: 2010-12-08
Validity date: 2013-12-07
Registration Number: CN-00210Q16719R0S

Michael Drechsel
President of IQNet

Zhang Wei
President of CQM

IQNet Partners*:

AENOR Spain AFNOR Certification France AIB-Vinçotte International Belgium ANCE Mexico APCER Portugal CCC Cyprus CISQ Italy CQC China CQM China CQS Czech Republic Cro Cert Croatia DQS Holding GmbH Germany DS Denmark ELOT Greece FCAV Brazil FONDONORMA Venezuela ICONTEC Colombia IMNC Mexico Inspecta Certification Finland IRAM Argentina JQA Japan KFQ Korea MSZT Hungary Nemko AS Norway NSAI Ireland PCBC Poland Quality Austria Austria RR Russia SII Israel SIQ Slovenia SIRIM QAS International Malaysia SQS Switzerland SRAC Romania TEST St Petersburg Russia TSE Turkey YUQS Serbia

IQNet is represented in the USA by: AFNOR Certification, CISQ, DQS Holding GmbH and NSAI Inc.

** The list of IQNet partners is valid at the time of issue of this certificate. Updated information is available under www.iqnet-certification.com*

CERTIFICATE No. : 0433/IN-IST-10
IS1050-0248/MKE/AKC

SGS

EC-ATTESTATION CERTIFICATE OF MACHINE SAFETY

Date/Place of Issue	: 20.05.2010 / İstanbul
Valid Until	: 19.05.2015
Client (Name & Address)	: YANGZHOU SHENZHOU WIND-DRIVEN GENERATOR CO., LTD XINHE INDUSTRIAL PARK, XIANNV TOWN, JIANGDU CITY, CHINA
Manufacturer (Name & Address)	: YANGZHOU SHENZHOU WIND-DRIVEN GENERATOR CO., LTD XINHE INDUSTRIAL PARK, XIANNV TOWN, JIANGDU CITY, CHINA
Description of Product(s)	: WIND TURBINE GENERATOR SYSTEM
Model(s)	: # FD Series, Aeolus Series #
Assessment Performed	: Conformity to Annex I's Applicable Paragraphs of 2006/42/EC Machinery Directive
Standard(s) Referenced	: # EN ISO 12100-1:2003+A1:2009, EN ISO 12100-2:2003+A1:2009 # # EN 61400-2: 2006, EN ISO 14121-1: 2007 #
Conditions Subject to Issue	: Acceptance of information detailed in technical file MD-TCF-100422-208 and referenced against job file IS1050-0248
Declaration	: In the opinion of SGS the submitted technical file MD-TCF-100422-208 satisfies the requirements of the Machinery Directive 2006/42/EC Annex-VII
Assessor ID No	: TR-IND-S21
Date/Place of Assessment	: 15.04.2010 / Jiangdu City – China

Test reports in technical file MD-TCF-100422-208 and referenced against job file IS1050-0248 are reviewed and found to be acceptable. The CE mark as shown below can be used, under the responsibility of the manufacturer, after completion of an EC Declaration of Conformity and compliance with all relevant EC Directives.

CE

This EC-Attestation Certificate is only valid for the equipment and configuration described in conjunction with the data detailed above. It refers only to the sample submitted to SGS Supervise Gözetme Etüd Kontrol Servisleri A.Ş. for testing and certification. Any modifications made to the product shall immediately be reported to SGS Supervise Gözetme Etüd Kontrol Servisleri A.Ş. office in order to examine whether this certificate remains valid. This certificate shall not be reproduced except in full without the written approval of SGS Supervise Gözetme Etüd Kontrol Servisleri A.Ş.

For and on behalf of
SGS Supervise Gözetme Etüd
Kontrol Servisleri A.Ş.

SGS Supervise Gözetme Etüd Kontrol Servisleri A.Ş.
Abide-i Hürriyet Cad. Geçit Sokak
NO:4 K:1-2-3-4 34381 Şişli İstanbul- TURKEY
t: 90.212.3684000 (Pbx)
f: 90.212.2964782-83
e: sgs_turkey@sgs.com

Page 1 of 1

S-IND-F-32/ Rev.3

SGSPAPER
09551322

Honors:


高新技术企业认定证书

企业名称：扬州神州风力发电机有限公司

统一编号：2006YGQ025

扬州市科学技术局

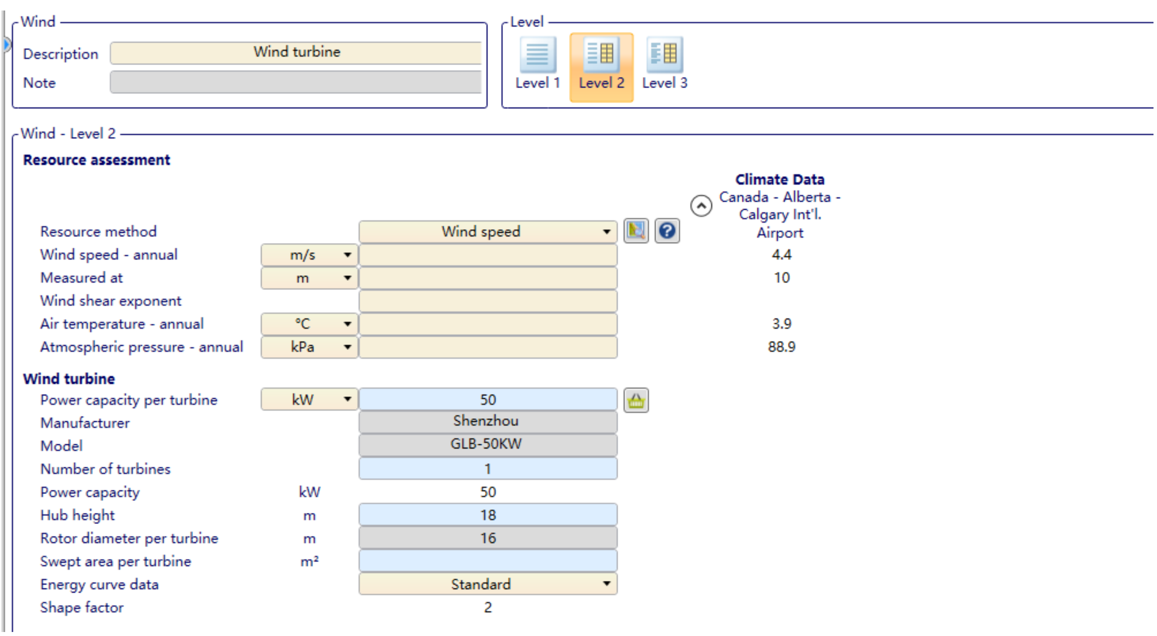
二〇〇六年四月十二日

(High-tech industry certificate, issued by Yangzhou Science and technology bureau)

(designated manufacture for "shi wu" event. Issued by State Ethnic Affairs Commission, China's Ministry of Finance, People's Bank of China)

(National Engineering Research Center for small size wind turbines. Issued by Yangzhou Science and technology bureau)

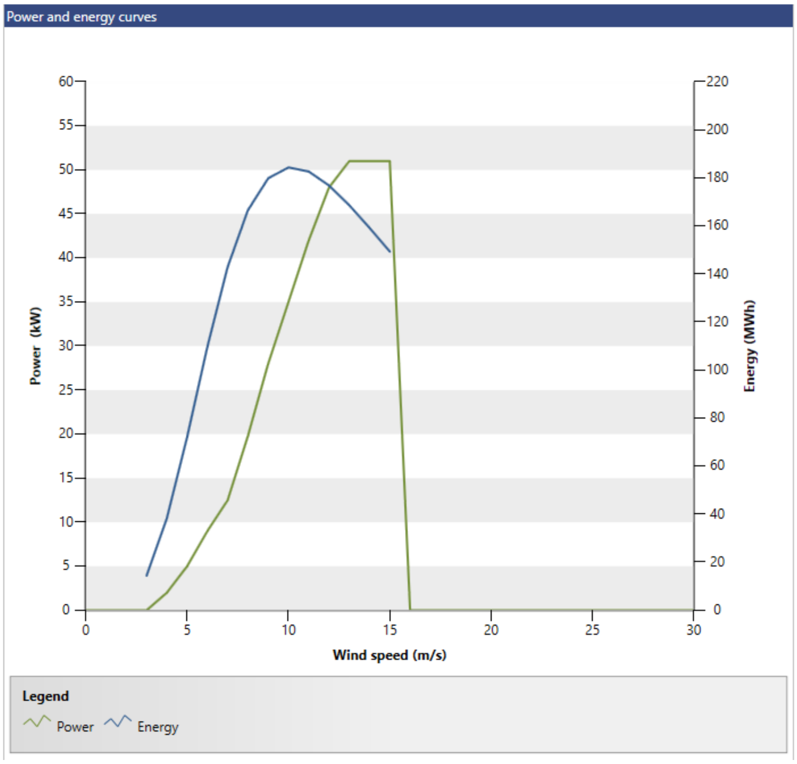
RETScreen Data:



Power and energy curves

Data

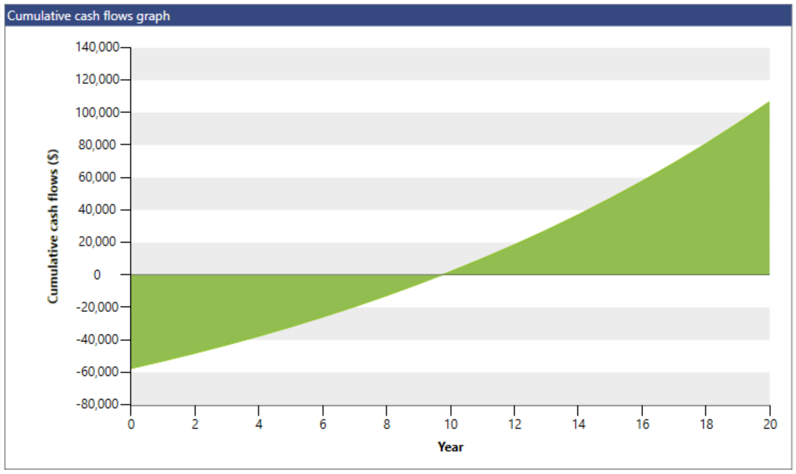
Wind speed m/s	Power curve data kW	Energy curve data MWh
0		
1		
2		
3	0	14.4
4	2	38.3
5	5	72.2
6	9	110
7	12.5	143
8	19.8	167
9	28	180
10	35	184
11	42	183
12	48	177
13	51	169
14	51	159
15	51	149
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		



RETScreen - Financial Analysis

Financial analysis

Financial parameters		
Inflation rate	%	5.8%
Project life	yr	20
Debt ratio	%	0%
Total initial costs	$	57,507
Incentives and grants	$	
Annual costs and debt payments		
-	$	0
Total annual costs	**$**	**0**
Annual savings and revenue		
Eletricity Savings	$	4,318
Total annual savings and revenue	**$**	**4,318**
Financial viability		
Pre-tax IRR - assets	%	10.3%
Simple payback	yr	13.3
Equity payback	yr	9.7



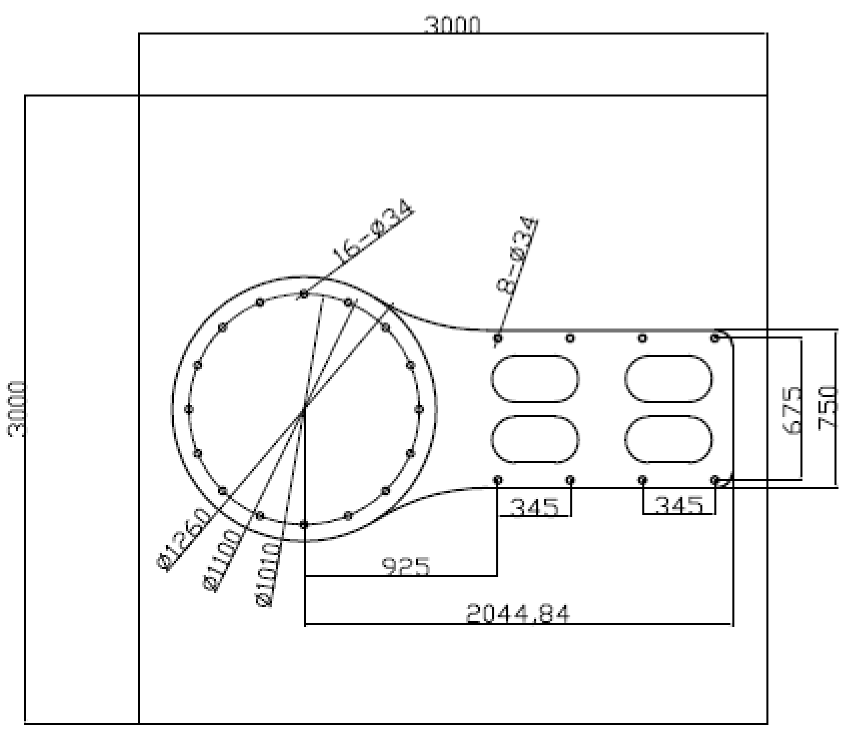
Appendix E Winpower Data Sheets

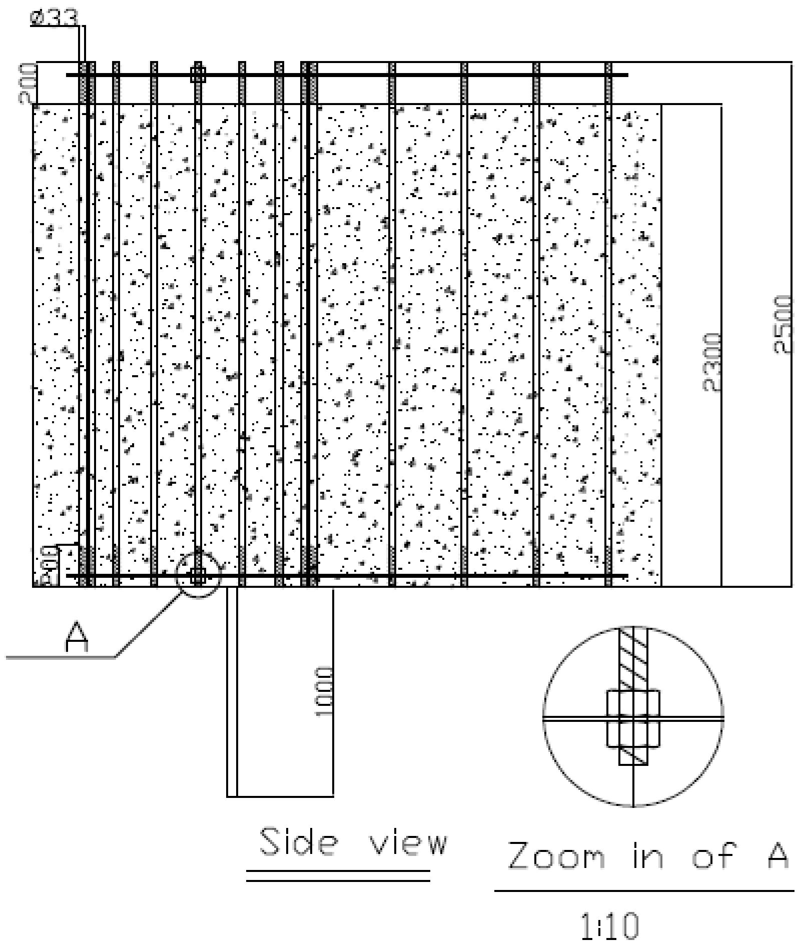
	Winpower	
	GLB50KW	
Power		

a.	Rated Output	50,000	w
b	Rated Voltage	380	V
c	Rated Current	131	
Phases		3	
Blades			
a.	Material	GFRP	
b	Number of Blades	3	
c.	Rotation Direction	clockWise	
Blade/Rotor Diameter		16	M
Rated RPM		59	r/min
Swept Area		$201m^2$	
Wind Factors			
c	Rated Wind Speed	12	m/s
d.	Cut-Out Wind Speed	20m/s	
e.	Cut-In Wind Speed	3.5m/s	
f.	Security/Survival Wind Speed	45	m/s
Control Mode		high technology with intelligent	
Generator Utilization Ratio/Efficiency/		0.9	
Power Factor			
Protection Mode		hydraulic yaw and hydraulic brake keep the security.	
Tower Height		20	m
Nacelle Weight		800KG	
Off-Grid		do not off-grid,on-grid	
Annual KwH Production			
a.	Wind Speed 3m/s	8,883	kWh
b.	Wind Speed 4m/s	21,059	kWh
c.	Wind Speed 5m/s	41,137	kWh
d.	Wind Speed 6m/s	71,079	kWh
e.	Wind Speed 7m/s	112,873	kWh
f.	Wind Speed 8m/s	168,490	kWh
g.	Wind Speed 9m/s	239,893	kWh
h.	Wind Speed 10m/s	324,698	kWh
i.	Wind Speed 11m/s	385,440	kWh
j.	Wind Speed 12m/s	420,480	kWh
k.	Wind Speed 13m/s	437,124	kWh
l.	Wind Speed 14m/s	449,151	kWh
m.	Wind Speed 15m/s	455,546	kWh
Annual Energy Production		72000KWH	

Noise Level	≤70	dBa

Tower Base:





Certificates：

Registration Certificate

BM TRADA
CERTIFICATION

BM TRADA certify that the quality management system of

Ningbo Feng Shen Feng Dian Science and Technology Co., Ltd.
No.6, Dongyi Road, Meixu Industrial Zone, High-Tech & Science Develop District, Ningbo
Zhejiang
China

meets the requirements of ISO 9001:2008
and is registered within the BM TRADA certification scheme

The client agrees to maintain their management system to continually meet the requirements of ISO 9001:2008 and use the logo and certification mark in accordance with BM TRADA regulations

Scope of Certification

Design and Development, Manufacture and Sales of Wind-Solar Photovoltaic Hybrid Generating Electricity System

Within validation of the certificate, the status sticker of surveillance should be pasted in following squares. The certificate will be invalid without required stickers.

From Oct.2010 to July.2011	**The first Surveillance sticker**		**From Aug.2011 to May.2012**	**The second Surveillance sticker**		**From June.2012 to Mar.2013**	**The third Surveillance sticker**

Signed on behalf of BM TRADA Certification Ltd
Stocking Lane, Hughenden Valley, High Wycombe, Buckinghamshire. HP14 4ND
Further clarifications regarding the scope of this certificate and the applicability of ISO 9001:2008 requirements and verification of this certificate is available from BM TRADA at the above address or by enquiries through www.bmtrada.com

This certificate remains the property of BM TRADA Certification Ltd to whom it must be returned on request

Page 1 of 1

Certificate Number
PRC004985

Date of Initial Registration
8 March 2010

Date of Last Issue
8 March 2010

Date of expiry
7 March 2013

UKAS
QUALITY MANAGEMENT
012

The use of the accreditation mark indicates accreditation in respect of those activities covered by the accreditation certificate 012

Izdošanas datums: 21.09.2011
Date of issue
Derīgs līdz: 21.09.2014
Valid until

Atbilstības Sertifikāts Nr.ScD1080S11

CERTIFICATE OF CONFORMITY

Produkts: *Product:*	*Vēja turbīnas ģenerātora sistēma* *Wind turbine generator system*
Pieteicējs: *Applicant:*	SIA "NATURE POWER" reģ Nr: 40103409815 *„NATURE POWER"ltd, R/N* 40103409815
Pieteicēja adrese: *Address of applicant:*	Austuves iela3a, Rīga, Latvija Austuves st. 3a, Riga, Latvia
Ražotājs: *Manufacturer:*	*NingBo Winpower Energy Technology Co,Ltd*
Ražotāja adrese: *Address of manufacturer:*	Address: No.6 DongQing Road,High-tech Industrial Zone, NingBo,China
Modelis/tips: *Model/ type:*	*X- XXXX- XXXX, modeļu sarakstu skatīt sertifikāta pielikumā* *X- XXXX- XXXX, please look annex for model list*
Produkta paraugs(-i) testēts(-i) un tam konstatēta atbilstība prasībām: *A sample(s) of the product was tested and found to be in conformity with:*	***DIRECTIVE 2006/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits DIRECTIVE 2004/108/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC*** ***Standards: EN61000-6-1:2007; EN61000-6-3:2007; EN60947-1; IEC 61400-22***
Apliecinājuma dokumenti: *Documents of Conformity:*	*Testēšanas pārskats*: SGS test report Nr. 0433/IN-IST-10

PIEZĪME: Sertifikāts satur tikai produkta drošības aspektus un neattiecas uz tā kvalitāti, pielietojumu, eleganci utml.
NOTE: This Certificate concerns only safety aspects of the product, it does not concern any other matters, such as style, performance or quality.

Apstiprinātājs:
Approved by: *Inese Janševska*

SABIEDRĪBA AR IEROBEŽOTU ATBILDĪBU "LATVIJAS NACIONĀLAIS METROLOĢIJAS CENTRS" Sertificēšanas centrs

CE

LATVIJAS NACIONĀLAIS METROLOĢIJAS CENTRS SIA
Reģ.Nr.40003435328, K. Valdemāra iela 157, Rīga, LV-1013, Tālr. +371 67378165, Fakss: +371 67362805, www.lnmc.lv

ANNEX TO CERTIFICATE Nr. **Nr.ScD1080S11**
Pielikums sertifikātam Nr.

MODEĻU SARAKSTS, UZ KURIEM ATTIECAS SERTIFIKĀTS
MODEL LIST UNDER SCOPE OF CERTIFICATE

MODEL NUMBER	ITEM
A-400W-24V	A-Series number, 400W-CAPACITY (400W),24V-DC Voltage
E-1KW-24V/48V	E-Series number, 1KW-CAPACITY (1KW),24V/48V-DC Voltage
E-2KW-48V/120V	E-Series number, 2KW-CAPACITY (2KW),48V/120V-DC Voltage
E-3KW-48V/120V	E-Series number, 3KW-CAPACITY (3KW),48V/120V-DC Voltage
E-5KW-240V	E-Series number, 5KW-CAPACITY (5KW),240V-DC Voltage
D-10KW-240V	D-Series number, 10KW-CAPACITY (10KW),240V-DC Voltage
D-20KW-240V	D-Series number, 20KW-CAPACITY (10KW),240V-DC Voltage
D-30KW-240V	D-Series number, 30KW-CAPACITY (10KW),240V-DC Voltage
G-10KW-380V	G-Series number, 10KW-CAPACITY (10KW), 380V-DC Voltage
G-20KW-380V	G-Series number, 20KW-CAPACITY (20KW), 380V-DC Voltage
G-30KW-380V	G-Series number, 30KW-CAPACITY (30KW), 380V-DC Voltage
G-50KW-380V	G-Series number, 50KW-CAPACITY (50KW), 380V-DC Voltage

Approved by:

Inese Jansevska
Head of Certification centre

SABIEDRĪBA AR IEROBEŽOTU ATBILDĪBU "LATVIJAS NACIONĀLAIS METROLOĢIJAS CENTRS"
Sertificēšanas centrs

Customer's feedback from the "International Center for Science, High Technology and Environmental Science" Iran:

شرکت مهندسی نماد نیرو (سهامی خاص) - شماره ثبت ۹۲۳۷- ارائه خدمات مهندسی در زمینه انرژی

NAMAD Niroo

Namad Niroo Company (PJS) - Registration no: 9237 - Representing engineering services for energy

To: Winpower group Co.LTD

Attention : Mr. Bruce

C.C : -

Tel : +86 574 8788 4338

Fax : +86 574 8788 4853

Email : winpower11@winpower.cc

Date : 2011/12/15

Our reference : NN.90.153

Your reference : -

Number of pages : 1 page

Attachment : No

Subject: Bill of 10 KW wind turbine electricity

Dear Sir,

Hereby it is confirmed that the 10 KW wind turbine installed at the "International Center for Science, High technology and Environmental Sciences" by that company has been operating as the following table.

Sincerely yours

Mahmoud Reza Rezaei

Managing Director

Kerman NAMAD Niroo
ثبت: ۹۲۳۷
شرکت مهندسی نماد نیرو

10 KW Wind turbine energy output data		
Item	2011/12/4	2011/12/15
DC Voltage	244 V	124 V
DC Current	30 A	0 A
AC Voltage	414.6 V	0 V
AC Current	8.7 A	0 A
Input Power	7466 W	0 W
Output Power	6247 W	0 W
Frequency	50.1 Hz	0 Hz
Temperature	25.2 C	25.2 C
Energy Today	0.349 KWh	0.350 KWh
Energy Total	88 KWh	95 KWh
Time Today	28 min	11 min
Time Total	149 hours	161 hours
CO_2 Reduced	85 Kg	92 Kg

Typical Iranian Electricity Tariff (1 USD = 11000 IRR)							
Monthly Energy Consumption (KWh/Month)	0-100	100-200	200-300	300-400	400-500	500-600	>600
Base Price Per KWh (IRR)	300	350	750	1350	1550	1950	2150

Head office:
No. 3, 4th floor, Kerman science & technology park Building , 26th ABNOS St. , Kerman , Iran
Postal code: 7613999573
Tel : +98 (0341) 2461462 Fax : +98 (0341) 2461462
Tehran office:
No. 34 , 6th floor , Trading and official building ,VALIASR Square , Tehran , Iran
Postal code:1593733469
Tel : +98 (021) 88931045,6 Fax : +98 (021) 88931044

دفتر مرکزی :
کرمان، خیابان آبنوس ۲۶ ، ساختمان پارک علم و فن و آوری ، طبقه ۴ ، واحد ۳
کد پستی : ۷۶۱۳۹۹۹۵۷۳
تلفن : ۲۴۶۱۴۶۲-۰۳۴۱ فاکس : ۲۴۶۱۴۶۲-۰۳۴۱
دفتر تهران :
تهران، میدان ولی عصر ، ساختمان تجاری و اداری ولیعصر ، طبقه ششم واحد ۳۴
کد پستی : ۱۵۹۳۷۳۳۴۶۹
تلفن : ۶ و ۸۸۹۳۱۰۴۵-۰۲۱ فاکس : ۸۸۹۳۱۰۴۴-۰۲۱

Email : info@namadniroo.ir
www.namadniroo.ir

RETScreen Data:

Wind - Level 2

Resource assessment

	Unit	Value	Climate Data: Canada - Alberta - Calgary Int'l. Airport
Resource method		Wind speed	
Wind speed - annual	m/s		4.4
Measured at	m		10
Wind shear exponent			
Air temperature - annual	°C		3.9
Atmospheric pressure - annual	kPa		88.9

Wind turbine

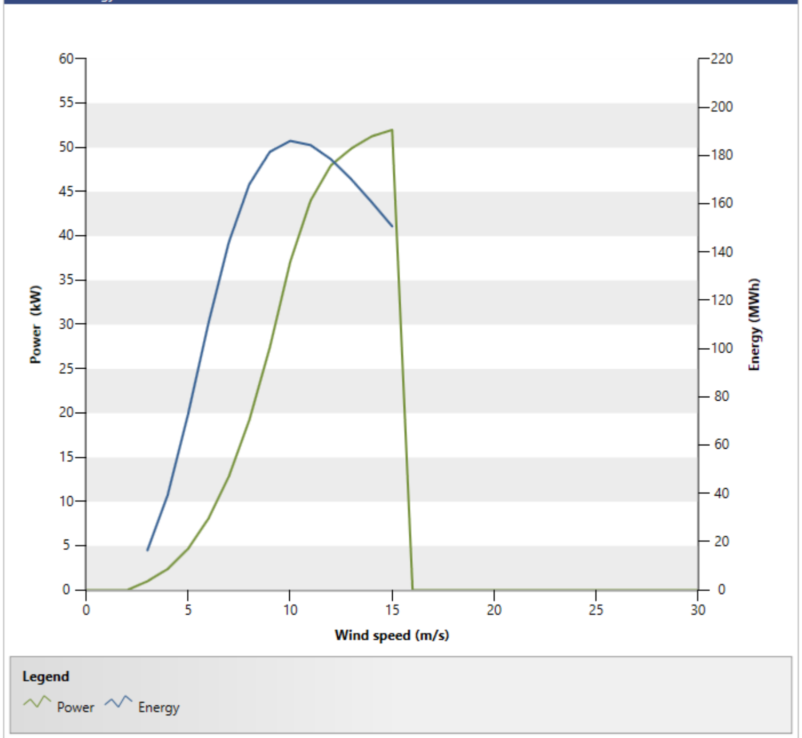
	Unit	Value
Power capacity per turbine	kW	50
Manufacturer		Winpower
Model		GLB50KW
Number of turbines		
Power capacity	kW	
Hub height	m	20
Rotor diameter per turbine	m	16
Swept area per turbine	m²	
Energy curve data		Standard
Shape factor		2

Power and energy curves

Data

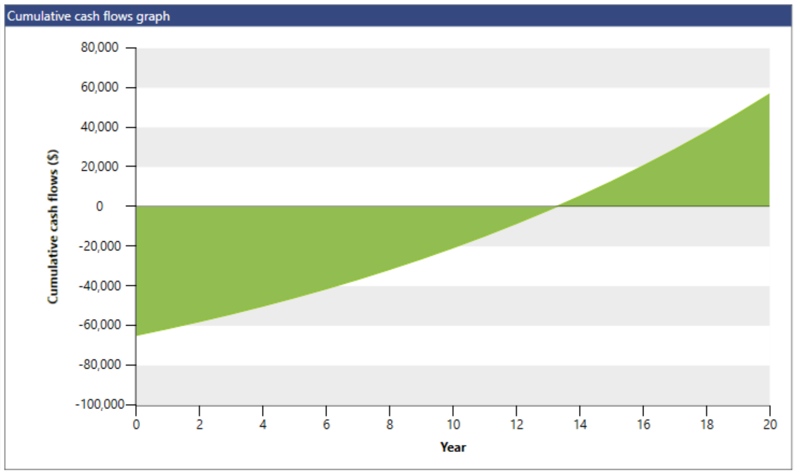
Wind speed m/s	Power curve data kW	Energy curve data MWh
0		
1		
2		
3	1.014	16.5
4	2.404	39.6
5	4.696	73.1
6	8.114	111
7	12.885	144
8	19.234	168
9	27.385	182
10	37.066	186
11	44	184
12	48	178
13	49.9	170
14	51.2729	161
15	52.003	151
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		

Power and energy curves



RETScreen - Financial Analysis

Financial analysis		
Financial parameters		
Inflation rate	%	5.8%
Project life	yr	20
Debt ratio	%	0%
Total initial costs	$	64,780
Incentives and grants	$	
Annual costs and debt payments		
-	$	0
Total annual costs	$	**0**
Annual savings and revenue		
Eletricity Savings	$	3,197
Total annual savings and revenue	$	**3,197**
Financial viability		
Pre-tax IRR - assets	%	5.7%
Simple payback	yr	20.3
Equity payback	yr	13.2



Appendix F Trina Solar Data Sheets

Data for Trina Solar TSM-PA05.082-250W, 250 Watt Solar Panel, 60 Cell Poly, Black

Photovoltaic

Type		poly-Si
Power capacity	kW	50
Manufacturer		Trina Solar
Model		poly-Si - TSM - PA05.08 / 250 W
Number of units		200
Efficiency	%	15.3%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m²	327
Miscellaneous losses	%	

Inverter

Efficiency	%	94%
Capacity	kW	
Miscellaneous losses	%	

Summary

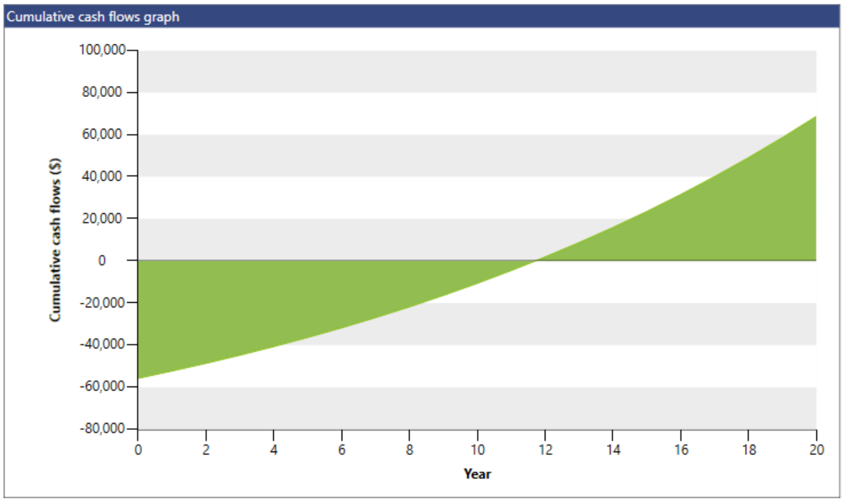
Capacity factor	%	14.8%
Initial costs	$	55,738
O&M costs (savings)	$/kW-year	44
	$	2,200
Electricity export rate		Electricity exported to grid - annual
	$/kWh	0.049
Electricity exported to grid	kWh	64,972
Electricity export revenue	$	3,184

RETScreen - Financial Analysis

Financial analysis

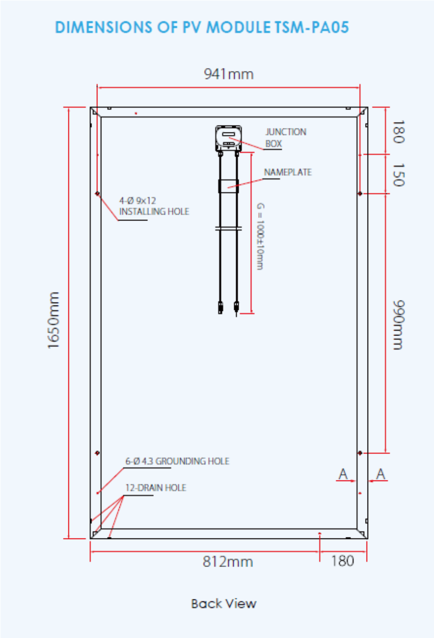
Financial parameters		
Inflation rate	%	5.8%
Project life	yr	20
Debt ratio	%	0%
Total initial costs	$	55,738
Incentives and grants	$	
Annual costs and debt payments		
-	$	0
Total annual costs	$	0
Annual savings and revenue		
Electricity export revenue	$	3,270
Total annual savings and revenue	$	3,270
Financial viability		
Pre-tax IRR - assets	%	7.5%
Simple payback	yr	17
Equity payback	yr	11.7

Cumulative cash flows graph



Go to: Risk

Dimension:



Product Description:

Certificates

The Universal Solution

Currently Trina Solar's most popular panel. Versatile and adaptable, with power output ranging from 225 to 245Wp, the TSM-PA05.08 is perfect for largescale installations, particularly ground-mounted and commercial rooftop systems. Using reliable and carefully selected components that are tested at the Trina Solar Center of Excellence, this panel comes with a 25-year performance guarantee of 80% power production.

Features

- Module can bear snow loads up to 5400Pa and wind loads up to 2400Pa
- Guaranteed power output (0~+3%)
- High performance under low light conditions (Cloudy days, mornings and evenings)
- Independently certified by international certification bodies
- Manufactured according to International Quality and Environment Management System (ISO9001, ISO14001)

- Black frame provide aesthetic module appearance.

Trina Solar, the best $/kWh value under the sun

Founded in 1997, Trina Solar is a vertically integrated PV manufacturer, producing everything from ingots to modules, using both mono and multicrystalline technologies. At the end of 2010, the company will have a nameplate module capacity of 950MW. Trina Solar's wide range of products are used in residential, commercial, industrial and public utility applications throughout the world.

Electrical Data @ STC

Peak Power Watts-PMAX (WP)	250
Power Output Tolerance-PMAX (%)	0/+3
Maximum Power Voltage-VMAX (V)	31
Maximum Power Current-IMPP (A)	8.6
Open Circuit Voltage-VOC (V)	37.4
Short Circuit Current-ISC (A)	8.59
Module Efficiency ηm (%)	15.3

Values at Standard Test Conditions STC (Air Mass AM1.5, Irradiance 1000W/m², Cell Temperature 25°C)

Mechanical Data

Solar cells	Multicrystalline 6 inches (156 x 156mm)
Cells orientation	60 cells (6x10)
Module dimension	64.95 x 39.05 x 1.57inches (1650 x 992 x 40mm)
Weight	43.0lb (19.5kg)
Glass	High transperancy solar glass 0.13inches (3.2mm)

Frame	Anodized aluminium alloy
J-Box	IP 65 rated
Cables/Connector	Photovoltaic Technology cable 0.006inches² (4.0mm²), 39.4inches (1000mm), MC4

Temperature Ratings

Nominal Operating Cell Temperature (NOCT)	46°C (±2°C)
Temperature Coefficient of Pmpp	- 0.45%/°C
Temperature Coefficient of Voc	- 0.35%/°C
Temperature Coefficient of Isc	0.05%/°C

Maximum Ratings

Operational Temperature	-40~+85°C
Maximum System Voltage	600VDC
Max Series Fuse Rating	15A

Packaging Configuration

Modules per box	25 pcs
Modules per 40' container	650 pcs

Warranty

10 years workmanship warranty
25 years linear performance warranty

Appendix G Payback Calculations

Table 36 Pay back Calculations for Ghrepower for 20 years (on-grid)

Pay back Calculations for Ghrepower for 20 years(on-grid)						
years	forward curve($/kWh)	Existing Wires Cost($/kWh)	Hours per year	Average Power(kW)	Total Savings	Cumulated Savings
2015.00	0.05	0.00	8760.00	12.92	5523.97	5523.97
2016.00	0.06	0.00	8760.00	12.92	6308.58	11832.55
2017.00	0.06	0.00	8760.00	12.92	7052.43	18884.98
2018.00	0.08	0.00	8760.00	12.92	9116.42	28001.40
2019.00	0.09	0.00	8760.00	12.92	9863.67	37865.07
2020.00	0.10	0.00	8760.00	12.92	11773.68	49638.75
2021.00	0.11	0.00	8760.00	12.92	12198.25	61837.00
2022.00	0.08	0.00	8760.00	12.92	9547.79	71384.78
2023.00	0.09	0.00	8760.00	12.92	10025.57	81410.35
2024.00	0.09	0.00	8760.00	12.92	10515.81	91926.16
2025.00	0.10	0.00	8760.00	12.92	11053.60	102979.77
2026.00	0.10	0.00	8760.00	12.92	11606.11	114585.88
2027.00	0.11	0.00	8760.0	12.92	11983.	126569.1

			0		31	9
2028.00	0.11	0.00	8760.0 0	12.92	12372. 77	138941.9 6
2029.00	0.11	0.00	8760.0 0	12.92	12774. 88	151716.8 4
2030.00	0.12	0.00	8760.0 0	12.92	13190. 07	164906.9 1
2031.00	0.12	0.00	8760.0 0	12.92	13618. 74	178525.6 5
2032.00	0.12	0.00	8760.0 0	12.92	14061. 35	192587.0 1
2033.00	0.13	0.00	8760.0 0	12.92	14518. 35	207105.3 6
2034.00	0.13	0.00	8760.0 0	12.92	14990. 19	222095.5 5

Table 37 Internal rate of return calculation for Ghrepower for 20 years

Internal rate of return calculation
(215140.00)
5523.97
6308.58
7052.43
9116.42
9863.67
11773.68
12198.25
9547.79
10025.57
10515.81
11053.60
11606.11
11983.31
12372.77
12774.88
13190.07
13618.74
14061.35
14518.35
14990.19
0.00

Table 38 Pay back Calculations for Hummer for 20 years (on-grid)

Pay back Calculations for Hummer for 20 years(on-grid)						
years	forward curve($/kWh)	Existing Wires Cost($/kWh)	Hours per year	Average Power(kW)	Total Savings	Cumulated Savings
2015.00	0.05	0.00	8760.00	14.40	6153.83	6153.83
2016.00	0.06	0.00	8760.00	14.40	7027.90	13181.73
2017.00	0.06	0.00	8760.00	14.40	7856.57	21038.29
2018.00	0.08	0.00	8760.00	14.40	10155.89	31194.19
2019.00	0.09	0.00	8760.00	14.40	10988.34	42182.53
2020.00	0.10	0.00	8760.00	14.40	13116.14	55298.67
2021.00	0.11	0.00	8760.00	14.40	13589.12	68887.79
2022.00	0.08	0.00	8760.00	14.40	10636.45	79524.24
2023.00	0.09	0.00	8760.00	14.40	11168.71	90692.95
2024.00	0.09	0.00	8760.00	14.40	11714.85	102407.79
2025.00	0.10	0.00	8760.00	14.40	12313.96	114721.75
2026.00	0.10	0.00	8760.00	14.40	12929.47	127651.22
2027.00	0.11	0.00	8760.00	14.40	13349.68	141000.90
2028.00	0.11	0.00	8760.00	14.40	13783.54	154784.44
2029.00	0.11	0.00	8760.00	14.40	14231.51	169015.94
2030.00	0.12	0.00	8760.00	14.40	14694.03	183709.97
2031.00	0.12	0.00	8760.00	14.40	15171.59	198881.56
2032.00	0.12	0.00	8760.00	14.40	15664.66	214546.22
2033.00	0.13	0.00	8760.00	14.40	16173.76	230719.98

2034.00	0.13	0.00	8760.00	14.40	16699.41	247419.39

Table 39 Internal rate of return calculation for Hummer for 20 years (on-grid)

Internal rate of return calculation
(87380.00)
6153.83
7027.90
7856.57
10155.89
10988.34
13116.14
13589.12
10636.45
11168.71
11714.85
12313.96
12929.47
13349.68
13783.54
14231.51
14694.03
15171.59
15664.66
16173.76
16699.41
0.11

Table 40 Pay back Calculations for Hengfeng for 20 years (on-grid)

Pay back Calculations for Hengfeng for 20 years(on-grid)						
years	forward curve($/kWh)	Existing Wires Cost($/kWh)	Hours per year	Average Power(kW)	Total Savings	Cumulated Savings
2015.00	0.05	0.00	8760.00	11.35	4848.95	4848.95
2016.00	0.06	0.00	8760.00	11.35	5537.68	10386.63
2017.00	0.06	0.00	8760.00	11.35	6190.63	16577.26

2018.00	0.08	0.00	8760.00	11.35	8002.40	24579.66
2019.00	0.09	0.00	8760.00	11.35	8658.34	33238.00
2020.00	0.10	0.00	8760.00	11.35	10334.95	43572.94
2021.00	0.11	0.00	8760.00	11.35	10707.64	54280.58
2022.00	0.08	0.00	8760.00	11.35	8381.06	62661.64
2023.00	0.09	0.00	8760.00	11.35	8800.46	71462.09
2024.00	0.09	0.00	8760.00	11.35	9230.79	80692.88
2025.00	0.10	0.00	8760.00	11.35	9702.86	90395.75
2026.00	0.10	0.00	8760.00	11.35	10187.86	100583.60
2027.00	0.11	0.00	8760.00	11.35	10518.96	111102.57
2028.00	0.11	0.00	8760.00	11.35	10860.83	121963.40
2029.00	0.11	0.00	8760.00	11.35	11213.81	133177.20
2030.00	0.12	0.00	8760.00	11.35	11578.26	144755.46
2031.00	0.12	0.00	8760.00	11.35	11954.55	156710.01
2032.00	0.12	0.00	8760.00	11.35	12343.07	169053.08
2033.00	0.13	0.00	8760.00	11.35	12744.22	181797.30
2034.00	0.13	0.00	8760.00	11.35	13158.41	194955.71

Table 41 Internal rate of return calculation for Hengfeng for 20 years (on-grid)

Internal rate of return calculation
(62939.00)
4848.95
5537.68
6190.63
8002.40

8658.34
10334.95
10707.64
8381.06
8800.46
9230.79
9702.86
10187.86
10518.96
10860.83
11213.81
11578.26
11954.55
12343.07
12744.22
13158.41
0.12

Table 42 Pay back Calculations for Shenzhou for 20 years (on-grid)

Pay back Calculations for Shenzhou for 20 years(on-grid)						
years	forward curve($/kWh)	Existing Wires Cost($/kWh)	Hours per year	Average Power(kW)	Total Savings	Cumulated Savings
2015.00	0.05	0.00	8760.00	10.10	4317.77	4317.77
2016.00	0.06	0.00	8760.00	10.10	4931.05	9248.81
2017.00	0.06	0.00	8760.00	10.10	5512.47	14761.29
2018.00	0.08	0.00	8760.00	10.10	7125.77	21887.06
2019.00	0.09	0.00	8760.00	10.10	7709.85	29596.92
2020.00	0.10	0.00	8760.00	10.10	9202.80	38799.71
2021.00	0.11	0.00	8760.00	10.10	9534.66	48334.37
2022.00	0.08	0.00	8760.00	10.10	7462.95	55797.32
2023.00	0.09	0.00	8760.00	10.10	7836.40	63633.72

2024.00	0.09	0.00	8760.00	10.10	8219.60	71853.32
2025.00	0.10	0.00	8760.00	10.10	8639.96	80493.27
2026.00	0.10	0.00	8760.00	10.10	9071.82	89565.09
2027.00	0.11	0.00	8760.00	10.10	9366.66	98931.75
2028.00	0.11	0.00	8760.00	10.10	9671.07	108602.82
2029.00	0.11	0.00	8760.00	10.10	9985.38	118588.20
2030.00	0.12	0.00	8760.00	10.10	10309.91	128898.11
2031.00	0.12	0.00	8760.00	10.10	10644.98	139543.09
2032.00	0.12	0.00	8760.00	10.10	10990.94	150534.03
2033.00	0.13	0.00	8760.00	10.10	11348.15	161882.17
2034.00	0.13	0.00	8760.00	10.10	11716.96	173599.13

Table 43 Internal rate of return calculation for Shenzhou（on-grid）

Internal rate of return calculation
(57507.00)
4317.77
4931.05
5512.47
7125.77
7709.85
9202.80
9534.66
7462.95
7836.40
8219.60
8639.96
9071.82
9366.66
9671.07
9985.38
10309.91

10644.98
10990.94
11348.15
11716.96
0.12

Table 44 Pay back Calculations for WinPower for 20 years for WinPower (on-grid)

Pay back Calculations for winpower for 20 years(on-grid)						
years	forward curve($/kWh)	Existing Wires Cost($/kWh)	Hours per year	Average Power(kW)	Total Savings	Cumulated Savings
2015.00	0.05	0.00	8760.00	7.48	3196.64	3196.64
2016.00	0.06	0.00	8760.00	7.48	3650.68	6847.31
2017.00	0.06	0.00	8760.00	7.48	4081.13	10928.45
2018.00	0.08	0.00	8760.00	7.48	5275.53	16203.98
2019.00	0.09	0.00	8760.00	7.48	5707.95	21911.93
2020.00	0.10	0.00	8760.00	7.48	6813.24	28725.17
2021.00	0.11	0.00	8760.00	7.48	7058.94	35784.11
2022.00	0.08	0.00	8760.00	7.48	5525.15	41309.26
2023.00	0.09	0.00	8760.00	7.48	5801.64	47110.90
2024.00	0.09	0.00	8760.00	7.48	6085.34	53196.24
2025.00	0.10	0.00	8760.00	7.48	6396.55	59592.79
2026.00	0.10	0.00	8760.00	7.48	6716.28	66309.06
2027.00	0.11	0.00	8760.00	7.48	6934.56	73243.62
2028.00	0.11	0.00	8760.00	7.48	7159.93	80403.55
2029.00	0.11	0.00	8760.00	7.48	7392.63	87796.17

2030.00	0.12	0.00	8760.00	7.48	7632.89	95429.06
2031.00	0.12	0.00	8760.00	7.48	7880.96	103310.01
2032.00	0.12	0.00	8760.00	7.48	8137.09	111447.10
2033.00	0.13	0.00	8760.00	7.48	8401.54	119848.64
2034.00	0.13	0.00	8760.00	7.48	8674.59	128523.23

Table 45 Internal rate of return calculation for Winpower （on-grid）

Internal rate of return calculation
(64780.00)
3196.64
3650.68
4081.13
5275.53
5707.95
6813.24
7058.94
5525.15
5801.64
6085.34
6396.55
6716.28
6934.56
7159.93
7392.63
7632.89
7880.96
8137.09
8401.54
8674.59
0.07

Appendix H Maintenance list

No	Content of checking and standard	Method of checking	Maintenance period				Referred chapter	Data record of phenomenon	Treatment measure
			A	B	C	X			
1	**Overhaul of the whole WTGS（no need to stop when running）**						**2**		
1.1	Whether there is damaged, crack, weld failure, massive painting peel off, rust or corrosion on the appearance of the WTGS	Visual inspection	A	B			2.1	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
1.2	Whether there is abnormal noise for the devices in the control room or cables or burns, deformation, electrical sparkle or damaged	Visual inspection	A	B			2.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
1.3	Do noise inspection when the WTGS is running and find no abnormal noise	Inspection by listening	A	B			2.3	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
1.4	Whether the human-machine interface is damaged or displays vague; whether the operating button is flexible	Visual inspection	A	B			2.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
1.5	Record running status of the system: working wind speed, direction of wind, voltage, current, rotating speed, voltage, yaw power, variable pitch power, angle of hook and generating capacity of date, month and year	Visual inspection	A				2.5	Whether it is working when maintaining: yes□ no□ WPpeS:_____ WDirS:______ Udc :______ Idc :______ Rpm :_____ TwistA:______ Yield : D___ M____ Y____	
1.6	Whether the LCD screen of the inverter is damaged or displays vague	Visual inspection	A	B			2.6	Normal: □ abnormal: □ Abnormal phenomenon: _____ _____________________	
1.7	Check whether the inverter shows alarm fault information and review the record of the historic alarm information	Visual inspection	A	B			2.7	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________________	
1.8	Turn off the turbine to carry out insulation test of the generator;	instrument		B				A/B/C grounding condition	
2	**Bottom of tower barrel and foundation (it must be stopped before checking)**						**3**		
2.1	Check whether the tower door, seal ring and door lock are rust, damaged or leakage.	Visual inspection	A		C		3.1	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
2.2	Check whether the foundation is ponding, leakage, damaged or corrosion	Visual inspection	A	B			3.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
2.3	Fastening anchor bolt or flange connection bolt according to the Torque Table and make marks	Torque spanner Marking pen	A		C		3.3	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	

2.4	Check the connecting resistance value of foundation grounding and connection cable; Check whether the joint is loose or corrosion	Multimeter	A		C		3.4	Normal: □ abnormal:□ Connecting resistance value ： __________________ Abnormal phenomenon：____ ____________	
2.5	Measure the connecting resistance value of foundation grounding	Earthing resistance tester	A		C		3.5	Grounding resistance value: ________ Normal: □ abnormal: □ Abnormal phenomenon: ____ ____________	
2.6	Measure the resistance value of unloader	Multimeter	A	B			3.6	Unloading resistance: P2+/DB：________ Normal: □ abnormal: □ Abnormal phenomenon: ____ ____________	
2.7	Check the color of the indication color of lightning arrester	Visual inspection	A	B			3.6	Normal: □ abnormal: □ Abnormal phenomenon: ____ ____________________	
2.8	Check whether the capacitor has cracks or leakage	Visual inspection	A	B			3.6	Normal: □ abnormal: □ Abnormal phenomenon: ____ ____________________ _	
2.9	Check whether the diode, IGBT or unloading plate in the main control room is yellowing, crack or charred	Visual inspection	A	B			3.6	Normal: □ abnormal: □ Abnormal phenomenon: ____ ____________	
2.10	Check the seal and connection status of the revos under the control cabinet of the tower	Visual inspection	A	B			3.6	Normal: □ abnormal: □ Abnormal phenomenon: ____ ____________	
2.11	Check whether the lock catch for the safety belt of the ladder stand under the	Visual inspection	A	B			3.7	Normal: □ abnormal: □ Abnormal phenomenon: ____	

	tower is reliable and record the trial result	On trial						______________	
2.12	Fastening the connecting bolt of the first-stage ladder stand	Spanner M12	A		C		3.8	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
2.13	Check whether the first stage of cable of tower barrel is crushing, abnormal connection and stranded cable	Visual inspection	A	B			3.9	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
2.14	Check whether the first stage of headlamp is light	Visual inspection	A		C		3.10	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
3	**Midcourse and head check of the tower barrel**						**4**		
3.1	Fastening the connecting bolt of flange of the midcourse and the head of the tower barrel by torque spanner	Torque spanner with M20 cover	A			X 1	4.1	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
3.2	Fastening the mounting bolt of each platform	Spanner M12	A		C		4.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
3.3	Fastening the connecting bolt of the midcourse and the head of the ladder stand	Spanner M12	A		C		4.3	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
3.4	Check whether the cable on the midcourse and the head of the tower barrel is stranded, broken or abnormal connection	Visual inspection	A		C		4.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
3.5	Check whether the headlamp in the midcourse and the head is light	Visual inspection	A			X 1	4.5	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4	**Examination of engine room**						**5**		
4.1	Check whether the internal components and the surface of the internal wall is rust, corrosion, loose or leakage	Visual inspection	A	B			5.1	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.2	Fastening anemometer, wind indicator, aeronautical light and its bracket bolt	Adjustable spanner	A	B			5.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.3	Check appearances of the anemometer, wind indicator, aeronautical light and its bracket, if find damages, repair it	Visual inspection	A	B			5.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.4	Check whether the anemometer and wind indicator are jammed	Rolling by hand	A	B			5.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.5	Check the connection status of lightning rod and grounding cable	Visual inspection	A	B			5.2	Normal: □ abnormal: □ Abnormal phenomenon: _____	

4.6	Check the outgoing cable and junction box of the generator	Visual inspection	A	B			5.3	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.7	Fastening the mounting bolts of junction box, speed measurement mechanism, brake disc, air compressor, lubricant pump, heater, locking system on the brake disc, yaw motor, variable pitch motor, beam and control cabinet	Cross screwdrivers Spanner	A	B			5.3	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.8	Whether the pump body is deformation or crack	Visual inspection	A	B			5.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.9	Fastening the bolts of drainer, compressor, accumulator and brake block	Spanner	A	B			5.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.10	Check whether the shock pad of the compressor is damaged	Visual inspection	A	B			5.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.11	Check whether the connection of the air tube is reliable or leakage	Visual inspection	A	B			5.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.12	Check whether the brake block has cracks, scratches or damages; Measure the thickness of brake block; Measure the clearance between brake block and brake disc	Visual inspection Feeler gauge Vernier caliper	A	B			5.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________ Thickness of brake block： __________ Clearance between brake block and brake disc:__________	
	Examination of lubrication mechanism								
4.13	Check whether the appearance of the oil pump has cracks or leakage oil	Visual inspection	A	B			5.5	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.14	Check the oil level of the oil pump and if less than 1/4, need to add oil Mobil/SH lubricating grease /460WT	Visual inspection	A	B			5.5	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.15	Check whether the nipple and oil channel and oil pipe are loose or leakage	Visual inspection	A	B			5.5	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
4.16	Replace battery of oil pump (four pieces of 7# batteries)。	Replace by hand		B			5.5	Normal: □ abnormal: □ Abnormal phenomenon: _____ ______________	
	Examination of variable pitch mechanism								
4.17	Fastening the mounting bolt of the	Hex	A	B			5.6	Normal: □ abnormal: □	

	travel switch and proximity switch	wrenches						Abnormal phenomenon: ______	
4.18	The lead screw is painted with lubricating grease	Painting plate	A	B			5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______	
4.19	Fastening the foundation bolt of variable pitch reducer	Torque spanner	A	B			5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______	
4.20	Fastening the connecting bolt M12 between the support of lead screw and beam; Fastening the mounting bolt M8 between the support of lead screw and the bearing cap 2; Fastening mounting bolt between the gear and proximity switch; Fastening connecting bolt M8 between follower plate and nut; Fastening connecting bolt M10 between follower plate and drive retainer	Hex wrenches	A	B			5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______	
4.21	Check the wear pattern of Linear guideway without oil at the sides of the follower plate and measure the thickness of guideway.	Visual inspection	A	B			5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______ Thickness of sliding rail______	
4.22	Check whether the inside of the support of lead screw has welding or scratches. If any, please clean	Visual inspection Scraper plate	A	B			5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______	
4.23	Check whether the junction box of the yaw motor is loose, charred, deformation or the cable marker is vague	Visual inspection Screw driver	A	B			5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______	
4.24	Clean the dust on the variable pitch motor and its cooling fan	Dusting brush	A	B			5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______	
4.25	Observe the oil hole of the variable pitch reducer; if lower than the oil level, add lubricant	Refuel fixture lubricating oil	A		C		5.6	Normal: □ abnormal: □ Abnormal phenomenon: ______	
	PLC control cabinet and check of Variable frequency counter								
4.26	Check whether the appearance of PLC cabinet has phenomenon such as seriously painting off, deformation, rust or leakage	Visual inspection	A	B			5.7	Normal: □ abnormal: □ Abnormal phenomenon: ______	

4.27	Check the revos and its label	Visual inspection	A	B			5.7	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.28	Check whether the components in the cabinet is deformation, loose, charred or label peels off	Visual inspection	A	B			5.7	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.29	Check the connection status of the grounding cable of the two cabinets	Cross screwdrivers	A	B			5.7	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.30	Fastening the mounting bolt of the two cabinets	Spanner	A	B			5.7	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
	Institution inspection of yaw								
4.31	Clean the leakage oil and dust on the surface of yaw reducer	Dusting brush	A	B			5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.32	Add lubrication oil for yaw pivotal bearing; Mobil/SHC lubricating grease/460WT	fuel truck nozzle Oil	A	B		X 1	5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.33	Fastening the mounting bolt of the reducer	Torque spanner	A		C		5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.34	Check whether the junction box of the yaw motor is loose, charred, deformation or the cable marker is vague	Visual inspection	A	B			5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.35	Fastening the mounting bolt M6 of the stranded-proof device	hex wrenches	A	B			5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.36	Fastening the mounting bolt M6 of the proximity switch by fastening a number of gear and check the connection cable	Visual inspection hex wrenches	A	B			5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.37	Observe the oil level of the yaw reducer; if lower than the oil hole, please add lubrication oil	Refuel fixture Oil	A		C		5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.38	Fastening the damper	Torque spanner	A	B			5.8	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.39	Check the bearing lubrication nozzle of the rear main shaft	Visual inspection	A	B			5.9	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
4.40	Check the connecting status of the two grounding brushes in the engine room	Visual inspection	A	B			5.10	Normal: □ abnormal: □ Abnormal phenomenon: ______ ________________	
	Power-on test								

5.1	Test the anemograph and record data Test wind indicator and record data	Visual inspection Operative text	A	B			6.1	1. WSpeS:______, ______,______,______, 2. WDirS:______, ______,______,______,	
5.2	Test the pump under low pressure and record the air pressure data	Visual inspection					6.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
5.3	Check whether the brake disc has the phenomenon of jamming when starting braking and releasing the brake	Visual	A		C		6.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
5.3	Check whether the solenoid valve and air tube have the phenomenon such as the joint is loose or leakage	Visual	A	B			6.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
5.4	Check whether the pipe joints and the pipeline are leakage	Visual	A	B			6.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
5.5	Observe whether the air pump is frequently autoinflation	Visual inspection	A	B			6.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
	Yaw system								
5.6	Record the yaw power	Visual inspection Operating record	A	B			6.3	Working power of yaw motor： Py：______	
5.7	Manually record the gear number of yaw when yawing one circle in the direction of clockwise; Manually record the gear number of yaw when adverse yawing one circle;	Visual inspection Operating record	A	B			6.3	Gear number of yawing in the direction of clockwise：______ ______ Gear number of adverse yawing ：____________	
	Variable pitch system								
5.8	Record the power of variable pitch; Record the current range of the angle	Visual inspection Operating record	A	B			6.4	Motor power：Pp：______W Angle range of variable pitch： BladeCurA_____	
5.9	Observe the action of proximity switch when variable pitch is in the distance of 0°-90°.	Visual inspection	A	B			6.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
5.10	Check whether the fan of the heater is working	Visual inspection Operating record	A	B			6.5	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
5.11	Fastening the mounting bolt of measurement device of rotating speed of the generator	Spanner	A	B			6.6	Normal: □ abnormal: □ Abnormal phenomenon: _____ _______________	
5.12	Measure sensing distance of proximity switch; Test proximity switch	feeler gauge	A	B			6.6	Proximity switch 1 distance：__ _ Proximity switch 2 distance：_	

								______ Proximity switch 1 test: normal :□ Abnormal :□ Proximity switch 2test: normal :□ Abnormal :□	
6	**Wind turbine generator system**						**7**		
6.1	Check whether the appearance of the blade is crack, deformation or damaged and clean the blade	Visual	A	B	C		7.1	Normal: □ abnormal: □ Abnormal phenomenon: _____ __________	
6.2	Check whether the wheel is crack, damaged or corrosion	Visual	A	B			7.2	Normal: □ abnormal: □ Abnormal phenomenon: _____ __________	
6.3	Fastening the connecting bolt between the blade and the root flange of the blade	torque wrench	A			X 1	7.3	Normal: □ abnormal: □ Abnormal phenomenon: _____ __________	
6.4	Fastening the connecting bolt between the foundation bearing of the blade and the connecting flange	torque wrench	A			X 1	7.4	Normal: □ abnormal: □ Abnormal phenomenon: _____ __________	
6.5	Fastening the mounting bolt of the wheels handrail	torque wrench	A			X 1	7.5	Normal: □ abnormal: □ Abnormal phenomenon: _____ __________	
6.6	Refueling the foundation bearing of the blade	fuel truck nozzle lubricating grease	A			X 1	7.6	Normal: □ abnormal: □ Abnormal phenomenon: _____ ________________	
6.7	Refueling the bearing of the front main bearing of the generator	fuel truck nozzle lubricating grease	A			X 1	7.7	Normal: □ abnormal: □ Abnormal phenomenon: _____ ________________	
6.8	Check whether the lightning air terminal falls off	Visual	A		C		7.8	Normal: □ abnormal: □ Abnormal phenomenon: _____ __________	
6.9	Please clean it if there is some ice on the surface of the blade in winter	Manual	A		C		7.9	Normal: □ abnormal: □ Abnormal phenomenon: _____ ________________	
6.10	Check whether the bearing seal ring on the foundation of the blade is broken	Visual	A		C		7.10	Normal: □ abnormal: □ Abnormal phenomenon: _____ ________________	