

# **Solar and Wind Power in Hybrid Energy Systems in China**

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## SYMBOLS AND ABBREVIATIONS

DC	Direct Current
AC	Alternating Current
PV	Photovoltaic
CSP	Concentrated solar power
HAWT	Horizontal-axis wind turbines
VAWT	Vertical- axis wind turbines
PWM	Pulse Width Modulation
HRES	Hybrid Renewable Energy Systems

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<p>Abstract</p> <p>In order to solve problems created by traditional energy, reducing the amount of usage of traditional energy and enlarging the range of usage of new energy, particularly some renewable energy should be developed immediately. In the recent years, China has been paying more attention to the utilization of renewable energy resources. Wind energy and solar energy are particularly popular due to lower cost and high economic effectiveness. As the development of wind energy and solar energy, scientists are trying to combine the applications and have made some breakthroughs in this field.</p> <p>The objective of this thesis was to demonstrate a series of serious environmental problems caused by traditional energy resources – fossil fuel. This has been proven by some relevant statistics and data has been collected from some literature, internet, authorities and government's reports. In accordance to the sustainable development strategy made by Chinese government the speed of utilization and related technical researches of wind energy and solar energy have accelerated in the recent years. Nevertheless merits of these two renewable energy resources are really apparent.</p> <p>The conclusion of this thesis is to show that renewable energy can gradually influence human behavior and how applications operate in daily life. This has a good profound meaning to sustainable development of society.</p>			
Keywords Solar Energy, Wind Energy, Hybrid Energy systems			

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Appendix 1 Standard Solutions of Wind Solar Hybrid Street Lighting

## 1 INTRODUCTION

With the speed of global economic growth, the amounts of consumption of energy resources have increased significantly. There is no doubt that all types of energy resources have made a great contribution to the development of human beings and they will be playing absolutely necessary role in any field in the future. However, at the same time, some inevitable problems have been brought by natural energy resources especially those fossil fuels which have had great negative influence on our surrounding environment. It seems that the environmental contamination can be more easily found in developing countries such as China. The reason for that is the problem in their domestic structure of utilization of energy resources which are not advanced enough. Optimizing the structure of energy resources and speeding the utilization rate of new renewable energy and relevant technical innovations are the emergent tasks for human beings.

By reviewing the human beings' history of the energy resources usage, fossil fuels with high percentage of carbon including coal, petroleum, natural gas and so on have been accounting for the biggest part until now that really proves no one can live without them. The importance of them is also self-evident. Nevertheless that does not mean that there are no disadvantages. On the contrary, many serious problems have been caused by them. For instance, Pollution is the major disadvantage which is formed because of fossil fuels. When burnt, carbon dioxide is released, a greenhouse gas which is the main compound of global warming is created. This has caused the rising of earth temperature, melting polar ice caps, flooding, rising sea levels. Acid Rain is another severe problem. Besides, human health and aquatic life will be sacrificed for it.

In order to solve these problems created by traditional energy, it should be considered as reducing the amount of usage of traditional energy and enlarging the range of usage of new energy. In the recent years, many countries have been paying more attention to the utilization of these renewable energy resources. Wind energy and solar energy are particularly popular due to their lower cost and high economic effectiveness. As the development of wind energy and solar energy, scientists are trying to combine the applications and have made some breakthroughs in this field.

### 1.1 Objectives of Thesis

The aim of this thesis was to research and analyze the past and current structure of all types of energy resources, consumption share of them and their geographical distribution in China by dividing them into two groups – fossil fuels and renewable energy resources. The main function of this thesis is to introduce situation of wind energy, solar energy, and combination of them and their relevant applications. With the popularity of solar, wind and hybrid applications, there will be less environmental pollution caused by the use of fossil resources.

Obviously the usage of traditional energy resources particularly fossil fuel is really big in China. Actually China has a long history of using fossil fuel as their main energy resources. The fact is that coal has become the main energy resources and this situation will continue for few years. The fossil fuel will destroy environment by emitting plenty of greenhouse gas. Every country's government now is regarding the acceleration of transition of energy resources structures and enlargement of renewable energy as the current most important strategic plan and goal. At the moment, there is no doubt that China is also no exception.

Since the 1990s, Chinese government has gradually become aware of the importance of development of renewable energy specially wind energy and solar energy in China. This thesis mainly forces on the situation of and development of these two energy resources by researching and collecting the relevant statistical data which comes from Chinese government and some related authorities. Under the circumstances of innovation of wind energy technology and solar energy, numerous applications of them have come up. Some are at the experimental stage and some have been taken in to service. Most applications such as Photovoltaic cells and Photovoltaic power stations have brought respectable economic benefits. The combination of application of these two renewable energy resources is another new scientific and technological area which has a wide application and developing prospect.

## 1.2 Structure of Thesis

At beginning of this thesis, some basic information of Chinese energy is introduced. Some problems of Chinese energy development and Chinese energy strategy are presented.

Solar energy, wind energy, and the hybrid energy systems in China are the main focus of the thesis. Some applications with sophisticated technology are introduced, for example, photovoltaic power station, photovoltaic cells and wind turbine.

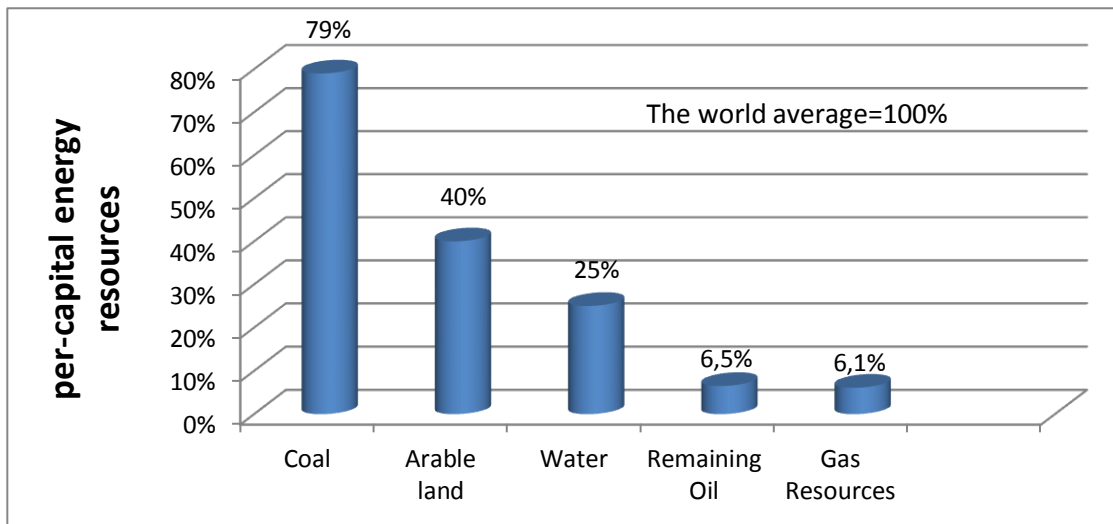
In the thesis, the future development of solar energy and wind energy power in the hybrid energy system in China are also introduced. The technique is applied in the area of world; hopefully there will be a mass of usage in the near future.



## 2 THE CURRENT SITUATION AND PROBLEMS of CHINESE ENERGY DEVELOPMENT

### 2.1 The Characteristics of Natural Resources

There are many kinds of energy resources in China. The first characteristics of natural resources: various types, big total volume with small per-capita occupancy. Water and coal are relatively abundant, they are on the 1th and 3rd place in the world; While there is not enough high quality fossil energy, remaining oil and gas resources rank 13th and 17th in the world. From the figure 2.1, it can be seen that all kinds of per-capital energy resources are lower than the world average level because of the numerous population. From the different resource type, the real output of hydropower is 402 million kW power, but annual output is 1750 billion kW · h, mainly distributed in the southwest. The development level is relatively low and it is difficult to develop with the higher costs. There are remaining coal resources about 184.2 billion, mostly distributed in the Midwest. The area is arid and far away from the centre of consumer. Overall the conditions for mining are bad. There are only 20400 million t remaining oil resources, the reserve-production ratio is low and has a great potential, but the productivity growth is limited. The remaining economic recoverable reserves of gas resources are 2.39 trillion m<sup>3</sup>. With the possibility of increasing production, there is a great potential possibility for improving the output.



*Figure 2.1 Comparison of per capita possession of main resources in China and the average in the world [W1]*

In Contrast to the traditional resources, there is a huge development in on the renewable energy resources such as wind power and solar energy resources. The development and utilization mostly depend on technical and economic factors.

## 2.2 Visible Pressure of Ecological Environment

Driven by the rapid growth of demand, the Chinese energy production is growing fast as well, particularly in coal consumption. Over the past six years, the raw coal consumption rose by nearly 1.2 billion t. In 2007, annual output of 2.54 billion t, accounted for about 40% of global production. At the same time, the over production and use of coal produced a series of problems, such as low rate of resource recovery, serious waste, safety accidents, high mortality, damaging the ecology of earth's surface and underground water system. In addition, there is a remarkable rise in gas emissions, like SO<sub>2</sub>, dust, smoke,

NO<sub>x</sub> and CO<sub>2</sub>. This brings bottleneck for ecological environment governance. China as a developing count still faces the pressure of reducing greenhouse gas discharge, although per capita CO<sub>2</sub> emissions are below the world average. [W1]

### 2.3 The Energy Structure Needs to Be Optimized

In reform and opening-up stage, especially since the 1990s, Chinese energy structures lay in optimized development stage. In the energy consumption, the proportion of coal consumption was from 76.2% in 1990 fell to 66.3% in 2002. While this share in developed countries is only about 21% on average. China was the largest coal producer and consumer in the world. In the primary energy consumption structure, the share of coal was higher than the world average about 41%, the share of oil lowed than the average approximately 36%, the proportion of water electricity and nuclear power lowed than average about 5%.

Nowadays, there is not sufficient utilization of clean energy and renewable energy. The development of wind, solar and biomass energy is still in primary stage. Still adjustment and improvement for optimizing energy structure has to be done. [W1]

## 2.4 The Strategy of Energy Development

China will be the world's largest energy consumer and supplier in the next decade.

Therefore, China needs a new energy development road with Chinese characteristics that uses smaller energy resources and causes lower environmental cost. As a big energy system, it needs a long cycle for adjusting, so this requires a long-term strategic energy development. And it also needs to seek the optimal or better development path.

Multiple developments: The energy structure can be optimized to meet the energy needs of future, when energy resources can only be sufficiently used. The developed countries have finished the optimization of fossil energy. Now they begin to develop the low carbon energy for promoting the optimized energy to a higher level. Chinese energy also needs adjustment into new direction. The remarkable point is improving the proportion of natural gas, nuclear energy and renewable energy in energy consumption.

### 3 SOLAR ENERGY IN CHINA

Solar energy generally refers to radiant energy of sunlight, nowadays it is used to generate electricity .China produces 63% of the world's solar photovoltaic energy, which means China has become the world's largest manufacturer of solar panels in the years from 2007 to 2010. So doing the research of solar energy in China has profound meaning.

#### 3.1 Solar Energy Resources in China

In the vast fertile land of China, there are very rich solar energy resources. The annual radiation of sunlight is from 3340MJ/m<sup>2</sup> to 8400MJ/m<sup>2</sup> across the country in China, the median is about 5852 MJ/m<sup>2</sup>. From the distribution of China's total solar energy, there is a great amount of solar radiation in the western region due to the good location. The table below shows distribution of solar energy resources in different provinces. [W2]

*Table 3.1 Distribution of solar energy resources in different provinces in China [W2]*

Region	Amount of radiation	Distribution
I region	6680 – 8400 MJ/m <sup>2</sup>	The north of Ningxia and Gansu, the east of Xinjiang, the west of Tibet and Qinghai, etc.
II region	5850 – 6680 MJ/m <sup>2</sup>	The northwest of Hebei, the north of Shanxi, the south of Inner Mongolia, Xinjiang and Ningxia, the centre of Gansu, the east of Qinghai, the southeast of Tibet, etc
		The southeast of Shandong, Henan, Gansu and Hebei, the south of Shanxi, the

III region	5000 – 5850 MJ/m <sup>2</sup>	north of Xinjiang, the north of Jilin, Liaoning, Yunnan, Jiangsu, Anhui and Shanxi, the south Guangdong and Fujian, the southwest of Taiwan
IV region	4200 – 5000 MJ/m <sup>2</sup>	The north of Hunan, Hubei, Jiangxi, Guangxi, Zhejiang, Guangdong, Suzhou and Fujian, the south of Shanxi and Anhui, the northeast of Heilongjiang and Taiwan, etc
V region	3350 – 4200 MJ/m <sup>2</sup>	Sichuan and Guizhou province

The main features of the distribution of solar energy resources in China are:

- The centre of high value and low value are at the north latitude of 22° - 35°. In this area, the centre of the Tibetan Plateau is a high-value area, the low centre of Sichuan Basin is low-value area.
- In the total annual solar radiation, the western region is higher than the eastern region, and besides the two autonomous regions of Tibet and Xinjiang, normally the south lower than the north.
- Due to rainy and cloudy weather in most parts of the south at the north latitude of 30° to 40°, there is a difference in the distribution of solar energy. It does not follow solar energy in general variation of latitude law. Solar power radiation does not decrease with increasing latitude. However, with increasing latitude, it will grow.

### 3.2 Relevant Applications of Solar Energy

The applications of solar energy are very wide. It can be converted into electricity, thermal and chemical energy. Solar power is the conversion of sunlight into electricity, either directly using photovoltaic power (PV), or indirectly using concentrated solar power (CSP). Solar photovoltaic power becomes more popular and plays an important role in solar power. Photovoltaic cells and solar photovoltaic power plants use photovoltaic effect.

#### 3.2.1 Photovoltaic Cells

Photovoltaic cells include monocrystalline silicon cells, polycrystalline silicon cells and amorphous silicon cells. There is a diagram that shows how crystalline silicon solar cells run.

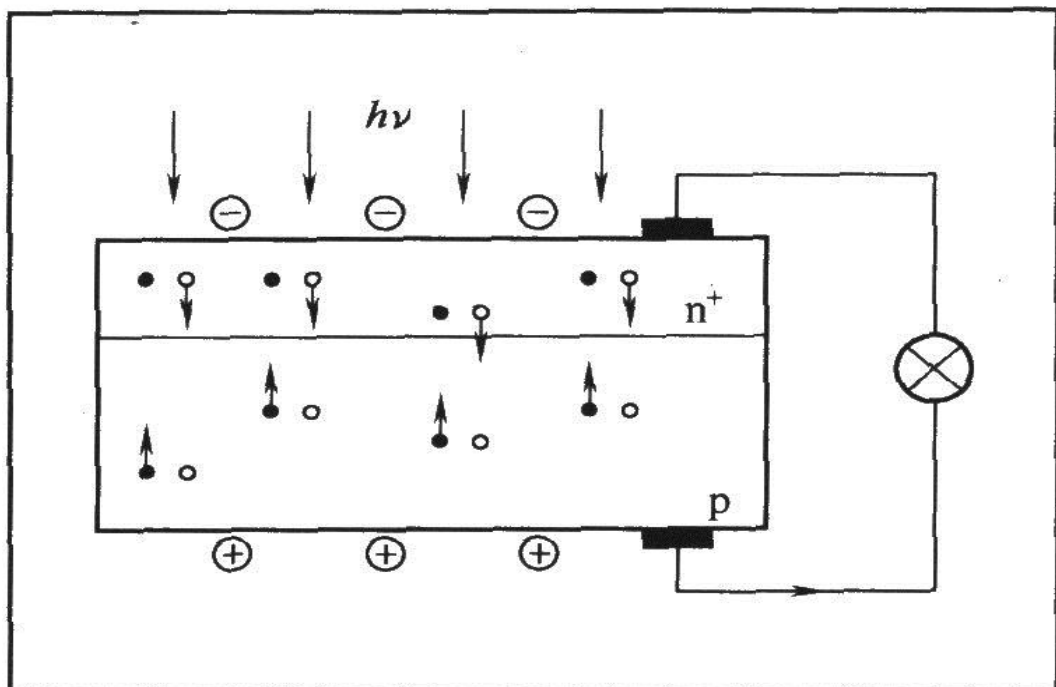


Figure 3.1 a schematic diagram of crystalline silicon solar cells principle

(• represents the electron; o represents hole; photon energy  $h\nu$ )[W3]

Semiconductors are used in photovoltaic cells. They are special resources which include some elements, such as silicon, which is currently most commonly used. It is based on a principle, when light strikes the cell, the semiconductor material will absorb a part of light sources. It means that semiconductor will get the energy of the absorbed light. The energy knocks electrons and lets them separate, allowing them to flow freely into different directions.

Due to light absorption, the electrons follow into certain electric field which is created by PV cells. The current is formed by flow of electrons, and by placing metal contacts on the top and bottom of the PV cell, we can understand extra use of the current, for example, to power a calculator. This current, together with the cell's voltage, which is based on the electric field in PV cells, can be defined as a power from solar cell. [W4]

This is basic process of how PV cells work and it is a cost effective way to convert the sun's energy directly into electricity.

### 3.2.2 Photovoltaic Power Stations

Huanghe Hydropower's Golmud Solar Park is located in Golmud, Qinghai Province, China, which has 200 MWp of PV power. It is one of the world's largest solar parks, and it provides large amount electricity. The construction began in 2009, and the project won the 2012 China Quality Power Project Award. The annual output is expected to be 317.2 GWh. [W5]





*Figure 3.2 Huanghe Hydropower Golmud Solar Park [W5]*

A solar power system includes solar modules, controllers, batteries, inverters, load and other components. In this system, the solar cell module and a battery act as a power supply, controller and inverter controller system prevent the load of the system terminal.

A photovoltaic power plant needs huge investment and long construction time, it requires complex control and distribution equipment, and will occupy large tracts of land. As for the price, the price of electric energy is much higher than the market price of electricity.

### 3.3 The Future Development of Solar Energy

There are broad prospects for solar energy applications, which are the mainly linked to solar thermal and solar photovoltaic energy. Solar thermal applications include electricity, hot water, dry, air-conditioning and greenhouses, etc. And power generation, battery and electric cars can be categorized to Photovoltaic applications. However, the solar water heater is the only commercially available solar technology application.

#### 3.3.1 The Prospects of Solar Thermal Energy

After many years of effort, with the rapid development of China's solar market, the use of solar energy has gained big improvement. Solar water heaters have been used in different areas, such as apartments, hotels, shopping malls, agriculture, forestry, farming and so on. With the gradual improvement of products and public awareness of civilization, there will be a potential market of 900 million people in rural areas. The application of solar water heaters will have substantial growth. In the near future, this situation that solar water heaters, air conditioners, refrigerators, colour televisions and other appliances products will occupy important position will emerge.

China has become the world's largest solar water heater producer and user. The cumulative area of the users has exceeded 90 million square meters, and there is still 20 % -30 % annual rate of increasing. China's production of the world's total production of solar water heaters accounted more than 76%. It is estimated that the country will fully promote the use of solar thermal work. If only considering a solar water

heater, the country will have a total market demand for more than 10,000 billion Yuan in the next decade, and it still contains enormous potential market.

### 3.3.2 The Prospects of Solar Photovoltaic Systems

The prospects of solar photovoltaic technology is relatively mature, safe and reliable, it has no noise and pollution. Energy is available everywhere because it does not have geographical restrictions and fuel consumption. The time of establishment is short, and it is not necessary to erect transmission lines. It is convenient to connect the technology with buildings, too. These advantages make the other conventional power generation methods falling behind. Chinese solar cell production had hovered around 1% of global production before 2002, but since 2004, with strong demand in Germany and Japan in the international PV market, Chinese PV industry has been pushed to develop rapidly, especially in 2006. Now it has reached more than 10% share of the world, following Japan and Europe, ranking third in the world.

## 4 WIND ENERGY IN CHINA

Wind resources are very rich in China, which is a good qualification for development of wind power. On the other hand, China has chosen wind power as an important alternative source for rebalancing the energy structure. So China encourages technological innovation and market expansion for wind energy.

By the end of 2012, wind power installed capacity had reached 45GW, increasing about 10 % compared the previous year. Global cumulative installed capacity of wind power had reached 282.5GW, increased of about 19%. The development in 2012 outstripped the expectations of many people; the global wind power industry achieved a new milestone. Although the growth of 2012 had a slight decline compared with the average annual growth of 22% over the past decade, in the current context of global economic development, the 2012 wind power industry still is an industry at high speed of growth. [B1]

### 4.1 Wind Energy Resources in China

China has wide ground and long coastline, so there is a rich resource for wind power development. South-eastern coastal areas distribute the richest wind energy resources in China, and the locations include adjacent island. There are also some parts of inland which are rich in wind resources as well as off-shore.

The provinces of Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan have the most abundant wind resources along their coastline

and in the islands near them. Those areas within 10 km of the coast have an annual wind power density above  $2000\text{W}/\text{m}^2$ . [B2]

The provinces with most abundant wind resources in the north of China include Heilongjiang, Jilin, Liaoning, Hebei, Inner Mongolia, Gansu, Ningxia and Xinjiang; this area is about 200 km wide. The wind power density ranges from  $200\text{W}/\text{m}^2$  up  $300\text{W}/\text{m}^2$  and sometimes even reaches above  $500\text{W}/\text{m}^2$ . [B2]

Wind resources off-shore is also rich along with the eastern coast, such as Jiangsu, Fujian, Shandong and Guangdong. In some special areas in inland, like lakes or other geographic conditions, the wind resources also need to be considered.

#### 4.2 Relevant Applications of Wind Energy

Wind power is a typical application of wind energy. It is the conversion of wind energy. It is a process that converts wind into electricity by some advanced techniques. Wind turbine is a common way for converting the kinetic energy created by the wind into mechanical power. There are many applications by using mechanical power such as grinding grain or pumping water or building power station to supply electricity to suburbs, city centers, schools, factories and some facilities with electricity. [W6]

#### 4.2.1 Wind Turbine

Wind turbine is a rotating machine which converts the kinetic energy coming from wind into mechanical energy, and then changes it into electricity with special equipment. They have developed quickly recently, and are much less heavier than in the past. The setting of wind turbine usually starts with designing and testing an example randomly in many times. After those steps, the wind turbine can be produced formally. The energy output of a wind turbine is determined by the length of the blades which must follow the standards and pass the quality guarantee commitment. [W6]

#### 4.2.2 Wind Turbine Types

There are two different types of wind turbines according to their structure. One is Horizontal-axis wind turbines (HAWT) with blades like airplane and the other is Vertical-axis wind turbines (VAWT), which looks like an egg-beater. The picture below shows the main differences about these two types.

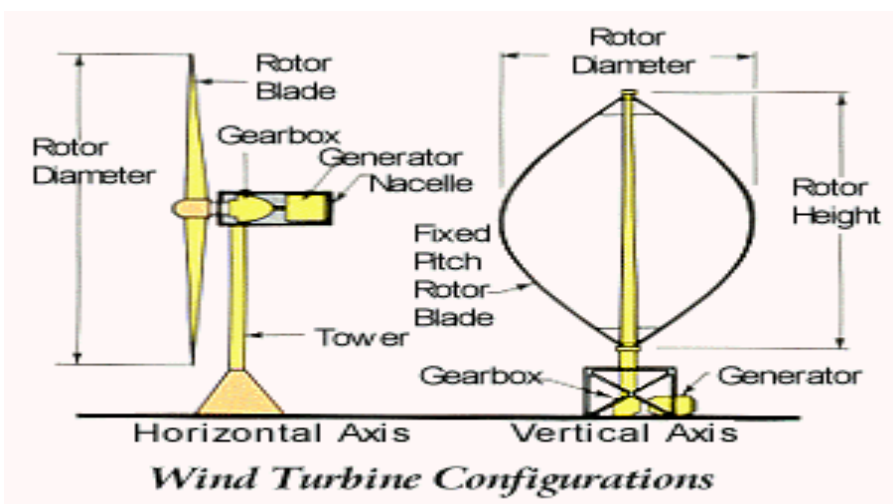


Figure 4.1 Wind Turbine Configurations [W7]

#### *4.2.2.1 Structure of HAWT*

Horizontal-axis wind turbines (HAWT)'s axis of wind wheels is parallel to the ground floor and the wheels are placed on the vertical tower, and HAWT is currently the most widely used model.

The horizontal-axis wind turbines can be divided into the two models of upwind and downwind. In upwind wind turbine system, turbine wheels should face the wind and be placed in front of the tower. Upwind units require active steering mechanism to ensure that the wind turbine can be readily aligned with the wind. In downwind units, the wheels are back to the wind and placed in the rear of tower. The current large-scale grid wind turbines are almost always upwind type.

Downwind wind turbines only appear in medium and small power models. The characteristics of downwind wind turbines are:

- 1) The wind wheels are passive to the wind and do not need to yaw drive mechanism system. Because the wind wheels in downwind of the tower is static equilibrium. In fact, due to the yaw making the cable twist, twist measures still need to be solved. Slip ring mechanism can be used in principle to avoid twisting, but it is not reliable.
- 2) Due to the wind direction and influence of the tower shadow, these aspects will decide wind energy utilization coefficient. At the same time, its fatigue amplitudes will increase, and the same blade fatigue life compared to the upwind model ma-

chine is also low, so downwind units currently are rarely used. But recently, in order to reduce the weight of the wind turbine, and reduce the cost of wind turbines, someone has proposed designing a downwind flexible structure. But so far there are no product models.

For upwind horizontal-axis wind turbine, three-bladed wind turbine is the mainstream of contemporary large electricity producer; two blade products are relatively common. But if two wind turbine blades were in the same situation of wind wheel diameter (swept area); they should have faster speed to get the same power output, also require blade life (cycles) higher than the three-bladed models. Due to the fast speed, the noisy level of wind turbine is high and therefore there is a large impact on the surrounding environment. It is more difficult for two blades to have relative mass balance and aerodynamic balance as the same as the three blades, so the power and load will fluctuate all the time. The advantages of two wind turbine blades are fewer blades and relatively low-cost. In addition, the two blades are more appropriate for less noise requirement.

#### *4.2.2.2 Structure of VAWT*

The vertical-axis wind turbines are divided into resistance type and lift type by the torque mechanism. Aerodynamic efficiency of resistance type is much smaller than the lift type, so today's large-scale vertical-axis wind turbine grids are all lift type.



Resistance-type wind turbine blade torque is formed by the resistance of different sides of the object and a typical representative product is the wind cups, but not large-scale wind turbine.

Lift-type wind turbine blade torque is provided by the lift, and it is the mainstream of vertical-axis wind turbine, especially (as) the Darrius wind turbine is the most popular. When this wind turbine blade centrifugal load is dominant, the blade axis only has force and not moment, it is the lightest blade structure.

The main features are as follows:

- 1) Security. With a vertical blade and triangular double pivot design, and the main point of focusing on the force wheels, and therefore leaves fall off, break and blade-out and other issues have been got a better solution.
- 2) Low noise. Using a horizontal rotating blade design principles and design of aircraft wings, so it will reduce the noise in the condition that it cannot be measured in the natural environment.
- 3) Wind resistance. Due to the horizontal rotation and triangles dual pivot design principles , it has a small wind pressure resistant and is possible to against 45 meters per second of super typhoon ;
- 4) Radius of gyration. Due to their different structures and operating principles of the design than other forms of wind power, it has a smaller turning radius, and it also saves space, improving efficiency as well.

- 5) Power curve characteristics. Wind speed is lower than other forms of wind turbines, the power generation more gentle rise, so in the wind speed range of 5 to 8 m , a higher amount of power will be input than that other types of wind turbine that is about 10% ~ 30%.
- 6) Using wind speed range. Using a special control theory, making it suitable for running wind speed range extended to 2.5 ~ 25m / s, the maximum utilization of wind resources while gaining a greater amount of electricity, and it also improves the economy of wind power equipment.
- 7) Brake device. Reconfigurable manipulator and electronic automatic brakes are two kinds of brake devices. In the absence of typhoon and strong wind area, it is necessary to set hand brake device.
- 8) Operation and maintenance. The permanent direct-drive magnet generator does not have gearbox and steering mechanism, regularly (generally every half of year) the movable parts should be connected to check.

#### 4.3 The Future Development of Wind Energy

Wind energy has an advantage because of its large energy context. It is more than all the oil, gas and coal reserves. According to the theory, only 1% of the wind will be able to meet human energy needs. With the future of energy depletion and institutional reforms as well as the survival of the fittest equipment manufacturing, wind power will still have a good development, but this development should go a long way. As for wind power, it has occupied the major market in this century. It has an ad-

vantage that other resources do not have, because when the capability is double, the cost will reduce 15%. With the drop of cost, Wind power has started to become the goal of more gold diggers.

Now the wind energy has been commercialized. But not so many investments have a profound influence. We can easily get a conclusion that it will encounter a bright future that no one can imagine. It has woken up the public interests, even the notice of government. It is good to advocate that wind power can replace the coal power in some area. It is economical and sustainable, which gives the government a good solution to the lack of energy. Now it is a new round for wind energy.

## 5 SOLAR AND WIND POWER IN HYBRID ENERGY SYSTEMS

Hybrid system usually consists of two or more renewable energy sources provide higher efficiency than the system with one energy resource only. Systems combining wind and solar energy have been made possible by recent technological developments. It can have many benefits due to taking advantage of solar and wind energy, and both of these energy forms are rich which ensures the hybrid system to have enough resource to generate power. Hybrid energy systems often yield greater economic and environmental returns than wind or solar stand-alone systems by themselves. The system has a good performance and cheap price, and now it is popular in different countries that acquiring a better application.

### 5.1 Wind Solar Hybrid Electricity Systems

Hybrid wind and solar electric system consists of wind turbines, solar photovoltaic batteries, controllers, batteries, inverters, AC-DC load, etc. The system combines the electricity generation systems of wind, solar and battery and artificial control system together to create a new renewable energy generation electric systems.

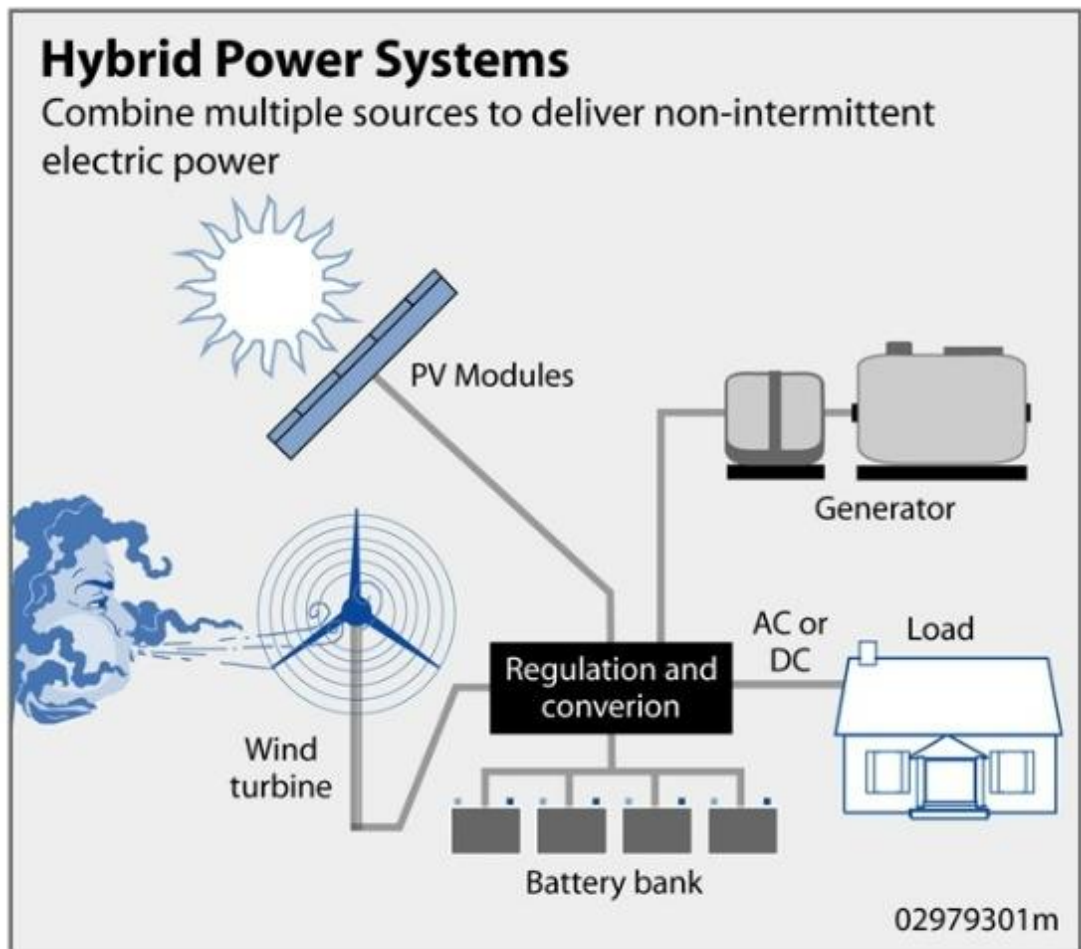


Figure 5.1 Structure of hybrid wind and solar electric system [W8]

- 1) The wind turbine converts wind energy into mechanical energy by the wind turbine. Next, mechanical energy will be converted to electrical energy, and then the battery is charged by the controller, the power supply to the load through the inverter.
- 2) The photovoltaic system uses the photovoltaic effect of photovoltaic solar panels to convert light energy into electrical energy, and charges the battery through the inverter by converting DC to AC power for the load;
- 3) Inverter system is composed of several inverters. The system makes the DC batteries become standard 220V AC, as to ensure the normal use of the AC load

equipment. It also has an automatic voltage regulator function at the same time; it will improve the quality of hybrid supply and solar electricity systems supply.

- 4) As for control part, according to changes in sunlight intensity, wind speed and change of load, it could constantly work to switch and regulate the state of the battery pack. On the one hand, the energy-adjusted will directly send to DC or AC load. On the other hand, the excess energy will be stored in the battery pack. When the load cannot meet the needs of power generation, controller sent electricity of battery into the load, in order to ensure the continuity and stability of the entire system;
- 5) The multi-block battery composes the battery partially and the system also plays an important role in balanced energy regulation and the battery is ready for use when power is low.

Hybrid wind and solar electric system can run in three modes based on wind and solar radiation changes: single wind turbine will input power to the load; single photovoltaic system supply power to the load; Hybrid wind and solar electric system supply power to the load.

## 5.2 Wind and Solar Controller

Solar photovoltaic, wind power controllers adjust and control power for photovoltaic panels and wind turbines generating electricity, respectively. On the one hand, the adjusted energy is sent to DC load or AC load; on the other hand, the excess energy will release and prevent overloading. When the electric generated cannot meet the

need of load, the controller will sent the battery power to the load again. After the battery is fully charged, the controller must care about whether the battery is over-charged or not. When the battery energy has been stored is done, the controller must prove that the battery is not over-discharged so as to protect the battery.

Controller uses PWM mode to control fans and solar battery to have an intelligent charging. When the solar panels and wind power generators emit power more than the amount of storage batteries, a control system must consume the excess energy. Common control is connected to the unloading of all, when the battery is generally not full, but the energy is consumed in the unloading, which results in a waste of energy. Others use a phased connect unloading, the more stages, the better control, but generally only do about five or six, so the effect is still not ideal. The best control method is to use PWM (pulse width modulation) mode, which can prevent the voltage unloading. Therefore, under normal unloading case, it can ensure that the battery voltage has been stabilized at float voltage point, but only the excess energy is released to the unloading. Thus it ensures optimum battery charging characteristics and makes full use of power.

Because the battery can only withstand a certain charge current and float voltage, over-current and over-voltage battery charging will cause serious damage. Wind and solar controller is detected by real-time microcontroller battery to care about charging voltage and charging current, which controlling the turbine and photovoltaic battery charge current within the limit, so as to ensure that both the battery fully charged and it will not be damaged. Thereby it can ensure the battery life.

### 5.3 Relevant Applications of Hybrid Energy Systems in China

Hybrid renewable energy systems (HRES) are becoming popular in remote areas due to progresses of renewable energy technologies and subsequent rise in prices of petroleum products. A hybrid energy system usually consists of two or more renewable energy sources used together to provide effective system as well as greater balance in energy supply. One example of wind solar hybrid street lighting will show the superior advantage than the single energy system.

#### 5.3.1 Wind Solar Hybrid Street Lighting

Street lights are the most common application in our daily lives, and it brings us bright light at night. The city's night becomes more beautiful with its decoration. Today, whether cities or towns in rural areas, street lights are everywhere. They have become an indispensable part of Modern people's life. For instance, the remaining number of street lights in China is between 28million and 30 million; recently, the annual increased number is 15%~20%. [W9] But (for) the streetlights' power consumption is high and low-voltage transmission lines are long, power loss greatly when it passes through the transmission line. Especially in the suburbs and highways, the annual consumption is also high.





*Figure 5.2 Wind Solar Hybrid Street Light LED [W10]*

Energy has become the most important issue related to human survival and development, with the rapid development of the economy, the demand for energy is also increasing. For the huge power shortage, coal, oil, natural gas and other non-renewable resource consumption soars are used for this urgent case thus these resources reserves are less and less. Energy crisis is becoming more serious. New energy development has become one of the major problems all over the world. There are pressing needs for some methods to solve this problem in every country.

The continuous development of science and technology of solar energy has gradually come into our ordinary lives and the application of solar photovoltaic streetlights has decreased the power consumption and high construction cost. With the use of wind turbines, more power and convenience are for streetlight. Wind solar hybrid system, solar panels and the wind turbine transform electric energy to be stored in bat-

tery, when the street lighting is shining at night, the battery stored in the inverter's DC will be changed into AC power to support lighting. Wind solar hybrid system, in a word, is that wind turbines and solar panels together are generating power for battery. Due to the limited battery storage of electricity, the biggest advantage of Wind solar hybrid system that it is full of power all the time. At night and rainy days, generating power will belong to the wind turbines; on sunny days the duty will pass to the solar panel. On windy and sunny days both of them will generate power. So wind and solar streetlights fully adapt to changes in the natural environment, for instance, in summer, wind is weak, but the sunshine is scorching; in winter, the sunshine is weak, but the wind is strong. During cloudy days, wind is high but there is lack of sunshine; during sunny days, sunshine is ample but wind is weak. They have a good complementary, and wind and solar energy are inexhaustible renewable energy sources. Wind solar hybrid system has achieved generating power capacity per day; it is more scientific and practical than single wind or solar system.

### 5.3.2 Wind Solar Hybrid Street Lighting System

Wind turbines apply natural wind as power. Wind wheels absorb wind energy and drive wind wheels and wind turbines rotate. Then the wind energy is converted to electrical energy by controlling equipment to lie in batteries. The energy of battery stored by the controller can be directly used for DC appliances, or can be inverted into 220V/50Hz (110V/60Hz) 380V/50Hz AC for AC appliances using.

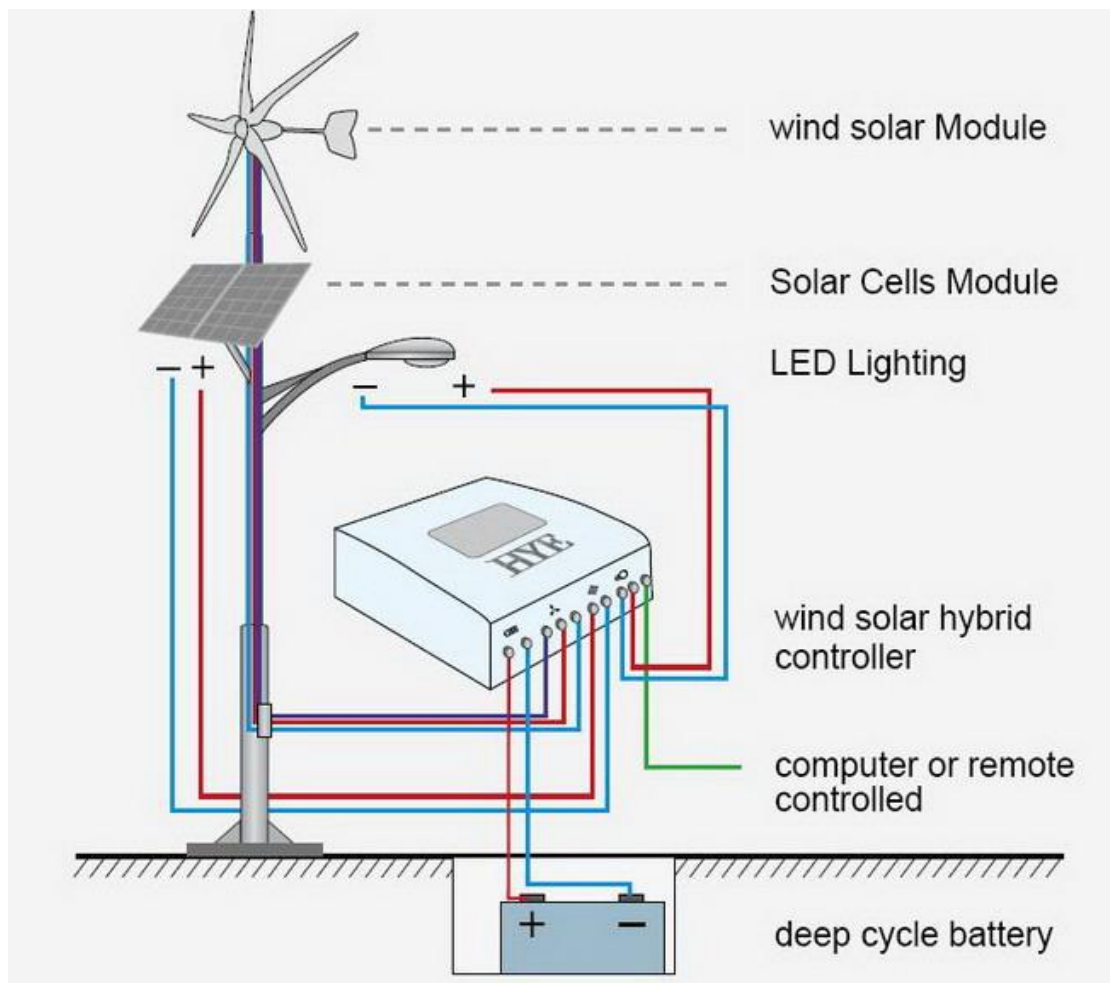


Figure 5.3 System Circuit Diagram [W11]

Wind turbines adopt permanent magnet direct drive generators, Wind turbines consist of the host, blades, wheels, spindles, and shroud and rudder plates. The main features are such as the whole simple structure, light weight, low power with good performance, high reliability, easy to install and maintenance, easy to relocate and so on.

Solar Panel is the generating device that directly converts solar energy into electrical. It mainly consists of crystal cells, high light transmittance tempered glass, high-quality film, film back, anodized aluminium frame and waterproof insulated junction box. It has high efficiency, long life, can resist hail storm, and is easy to install. The power of solar modules in street lighting systems typically is 60W-120W.

Equipped with solar modules, controller / inverter, batteries, lamps light source, light poles, electric control box on the basis of the wind turbine, they can form together wind + solar hybrid street light system, which also is known as wind and solar street lighting system.

### 5.3.3 The Advantages and Disadvantages of Wind and Solar Street Lighting System

The advantages of wind solar street lighting system:

- Economic benefits: traditional lighting system needs underground cables to supply power. Electricity supply lines need to be built even if there is a long distance from the original place. So high expenses is needed when building traditional light in suburbs. However, the wind solar street lighting system does not need transmission lines, does not consume electricity when using natural wind and light. Its maintenance is easy and the lifetime of it is long.
- Environmentally friendly: The wind solar street lighting system does not generate gas emission, pollution or radiation. It is environmentally friendly.
- Safe: it provides the safest power since it uses wind energy and solar energy to convert low DC voltage to charge the battery.
- Outstanding specific technology: automatic controllers will change depending on the light and wind speed in the environment; it can control the light on and off to reduce the loss of energy. Technical workers only take care of the condition whether it is working.

- Beautiful appearance: windmill in Chinese traditional culture is a mascot which is believed to bring people good luck. When the light system is on at night, the road will look great and spectacular. It may attract people to stop and enjoy the night scene.

The disadvantages of wind solar street lighting system:

- Expensive investment: some precise equipment needed has very high price. Professional workers are also needed due to the less knowledge in this area.
- Big noise: when wind turbines are turned on at the night, it will disturb the people's sleeping. Also it will cause resonance which has bad influence. But with some technical solutions, this problem seems not very obvious.
- Weak lights: when it is raining, the system is hard to get more sunshine; it will make the lights become weak. Storage reverses cannot provide enough electricity for light because it needs electricity to operate and keep it running.

## 6 THE FUTURE DEVELOPMENT OF SOLAR AND WIND POWER IN CHINA

It is estimated that the annual solar radiation on the earth is 173000 TW. [W12] Available solar radiation that can be developed for using is about 500 to 100 billion degrees. However, because the distribution is fragmented, there is minimal energy using in the world. The potential wind energy in the world is about 350 TW, due to intermittent and dispersed of wind, and it is difficult to get economical use. Once there is a significant improvement on energy storage technologies for future loss, it will increase the use of wind power. [B3]

In 2009, the Chinese domestic solar cell production capacity was about 2.4 GW, but the domestic solar power generation capacity was only 120 MW, and 95 percent of the capacity was exported. The most important market was Europe. Over the past few years, Europe has been the centre of the world's solar photovoltaic power generation. In 2009, Germany, Spain, Italy and the Czech Republic's newly installed capacity was over 4.2 GW, accounting for 60% of the world. [B3]

Wind energy is formed by the current solar radiation. Wind energy has obvious advantages compared with other energy sources. Its reserves are about 10 times more than water sources, and it is widely distributed and inexhaustible. It is particularly important to the areas like isolated islands and remote countryside where transportation is difficult and it is far away from the main power grid. The most common use of wind energy is generating electricity over the wind. There are two formats of wind power, the horizontal axis and vertical axis wind turbine fan. The horizontal axis wind turbines are currently widely used and they have become the main models of wind power.

By the end of 2009, the global cumulative installed capacity had reached 159 million kilowatts. New installed capacity was over 30 million kilowatts in 2009, increasing 31.9%. From the cumulative installed capacity, the United States had a total installed capacity of 35.16 million kilowatts, ranking first; China was 26.1 million kilowatts, ranking second in the world. [B3]

Wind, solar miniaturized integrated application space is huge, but the current problem is that there are no special measures to promote the application. The government does not pay enough attention to the large-scale application of wind, solar miniaturized integrated application system. In addition, China's off-grid new energy companies are mostly small and medium scale enterprises, they have low capability of independent innovation, and related industries do not have high degree of support, concentration, and they have not yet formed an influential industry clusters. Besides, social recognition is not high, either. According to existing policy and market rules, wind, solar miniaturized integrated application cannot be treated equally and got policy support for large-scale wind power, photovoltaic power plant construction.

The demand of energy is increasing but there has been a serious shortage of conventional energy reserves. Contrarily, wind energy and solar energy always have overcapacities. It means the maximum utility of solar and wind power is a new subject in every country. And wind, solar miniaturized integrated application has become popular. Hybrid energy is low-cost and can have different functions which exceed single energy. In electricity market, a new market about hybrid solar and wind power has attracted people's curiousness because of its benefits. However, Hybrid wind and solar electric system is not popular, it only appear in some test places.

Hybrid wind and solar electric system has a huge market in future, due to the reducing emission police has been published, it seems that every country is seeking for new method to follow this rule. When applying this system into normal equipment, it can reduce the people's dependence on the normal electricity. With the input of hybrid wind and solar electric systems, it will bring 1.8 million potential markets in next decade; it will also pull up the growth of GDP, which can be evaluated about 0.39 up than before. [B3]

With the development of hybrid and solar electric system, it will be gradually applied in the world because of its less gas emission and energy waste. The technique has been completed gradually. Hopefully in the near future, it will appear in every country and in wider areas.



## 7 CONCLUSIONS

The objective of this thesis was to demonstrate a series of serious environmental problems caused by traditional energy resources – fossil fuel. This has been proven by some relevant statistics and data collected from some literature, internet, authorities and government's reports. The geographical distribution of fossil fuel and consumption amount of them in China also can be found from this thesis.

Besides, no one suspects the functions of these traditional fossil fuels and the contribution made by them to Chinese economic development in recent decades. Indeed, fossil fuels play an indispensable role in the Chinese long developing history. However we have to admit that when they create the huge value for society, they absolutely bring some tough and avoidable problems for our environment and most of them cannot be solved immediately. The international environment protection organizations and Chinese government are trying their best to change the energy structure and encourage more usage of renewable energy.

In accordance to the sustainable development strategy made by Chinese government, the speed of utilization and related technical research of wind energy and solar energy have been accelerated in the recent years. Due to the unremitting efforts from the Chinese government for extending the use of renewable energy, ordinary persons in China start realizing many advantages of renewable energy, which is apparently good for further applications of them. Some applications with sophisticated technology have been put into use for example photovoltaic power stations, photovoltaic cells and wind turbines.

Because of the huge economic effectiveness created by the wind energy and solar energy, the theory of using combination of two energy resources naturally was came up with by experts. Now it has become true. Wind solar hybrid street lighting system described by this thesis is an important and sophisticated application. Many this types of applications will be put into service in near future.

As it can be found, some technical innovations and hybrid systems have a long way to go in the future. Nevertheless merits of these two renewable energy resources are really apparent. No one can neglect this point. The more value and more convenience will be brought by them for the human beings. And the future of applications of the two renewable energies is promising.

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## Appendix 1 Standard Solutions of Wind Solar Hybrid Street Lighting

Unicorn Series - one power source one Light				
Major Component	HY-SWL60A	HY-SWL80A	HY-SWL90A	HY-SWL120A
Wind turbine	HY-400 24V	HY-400 24V	HY-600 24V	HY-600 24V
PV module	60W 12V x 2	90W 12V x 2	100W 12V x 2	140W 12V x 2
Light source	60W LED	80W LED	90W LED	120W LED
hybrid charge controller	12V/10A controller	24V/10A controller	24V/10A controller	24V/15A controller
battery	100AH 12V x 2	120AH 12V x 2	150AH 12V x 2	200AH 12V x 2
Main pole(with power system)	10M, lamp height 6-8M	10M, lamp height 8-10M	12M, lamp height 8-10M	12M, lamp height 8-10M



### Pegasus Series - one power source two Lights

Major Component	HY-SWL30B	HY-SWL40B	HY-SWL60B	HY-SWL80B	HY-SWL90B
Wind turbine	HY-400 24V	HY-400 24V	HY-600 24V	HY-600 48V	HY-1000 48V
PV module	60W 12V x 2	90W 12V x 2	140W 12V x 2	180W 24V x 2	180W 24V x 2
Light source	30W LED x 2	40W LED x 2	60W LED x 2	80W LED x 2	90W LED x 2
hybrid charge controller	12V/10A controller	24V/10A controller	24V/15A controller	48V/10A controller	48V/10A controller
battery	100AH 12V x 2	120AH 12V x 2	200AH 12V x 2	120AH 12V x 4	150AH 12V x 4
Main pole(with power system)	10M, lamp height 4-6M	10M, lamp height 4-6M	12M, lamp height 6-8M	12M, lamp height 8-10M	12M, lamp height 8-10M
Regular light pole	4-6M steel pole	4-6M steel pole	6-8M steel pole	8-10M steel pole	8-10M steel pole



one power source two Lights

### Triad Series - one power source three Lights

Major Component	HY-SWL20C	HY-SWL30C	HY-SWL40C	HY-SWL60C
Wind turbine	HY-400 24V	HY-600 24V	HY-600 24V	HY-1000 48V
PV module	60W 12V x 2	100W 12V x 2	140W 12V x 2	180W 24V x 2
Light source	20W LED x 3	30W LED x 3	40W LED x 3	60W LED x 3
hybrid charge controller	12V/10A controller	24V/10A controller	24V/15A controller	48V/10A controller
battery	100AH 12V x 2	150AH 12V x 2	200AH 12V x 2	150AH 12V x 4
Main pole(with power system)	10M, lamp height 4-6M	10M, lamp height 4-6M	10M, lamp height 4-6M	12M, lamp height 6-8M
Regular light pole	4-6M steel pole x 2	4-6M steel pole x 2	4-6M steel pole x 2	6-8M steel pole x 2



one power source three Lights

### Sky Driven Series - one power source several Lights

Major Component	HY-SWL40D	HY-SWL60D	HY-SWL80D	HY-SWL90D	HY-SWL120D
Wind turbine	HY-3000 48V	HY-3000 48V	HY-3000 48V	HY-3000 48V	HY-3000 48V
PV module	900W of round panel	900W of round panel	900W of round panel	900W of round panel	900W of round panel
Light source	40W LED x 15	60W LED x 10	80W LED x 7	90W LED x 6	120W LED x 5
hybrid charge controller	12V/10A controller	12V/10A controller	12V/10A controller	12V/10A controller	12V/10A controller
pure sine wave inverter	800W 220/230V	800W 220/230V	800W 220/230V	800W 220/230V	800W 220/230V
battery	200AH 12V x 8	200AH 12V x 8	200AH 12V x 8	200AH 12V x 8	200AH 12V x 8
Main pole(with power system)	15M with round panel in 3 parts	15M with round panel in 3 parts	15M with round panel in 3 parts	15M with round panel in 3 parts	15M with round panel in 3 parts
regular light pole	4-6M steel pole x 15	6-8M steel pole x 10	8-10M steel pole x 7	10-12M steel pole x 6	10-12M steel pole x 5