Investigation of solar energy utilization in China

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Abstract

With the development of human beings, and the earth's natural resources are used by human application, more and more environmental problems come out. World surface temperature is increasing very fast during these years. the carbon dioxide emissions is also increasing. Green house effect is getting more and more worse. The ecological destruction and desertification are becoming more and more serious. Make use of renewable energy instead of non-renewable energy into the human and energy a common development goal.

Among the all the renewable energy, because of having no geographical restrictions and faster conversion speed into other energy as well as its high-value, solar energy can be directly developed and used without mining and transport. Development and utilization of solar energy does not pollute the environment, besides, the annual solar radiation on the earth's surface is enormous, so it is now one of the world's largest and cleanest energies that can be developed.

As a developing country with a large population, China should more focus on the use of resources, the use of solar energy, saving energy and resources, to reduce the environmental pollution and at the same time to improve people's quality of life. This paper describes the significance of the Chinese solar energy, the use of a variety of solar energy equipment in China principle and the development and usage.

Key words: renewable energy, Solar energy, Solar water heaters, Passive solar house, Photovoltaic system
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CHAPTER 1
INTRODUCTION

1.1 Why should we increase the solar energy

Energy development history can trace back to ancient times’ making fire by rubbing sticks, and since then, humans began the development and use of energy. Today, all types of energy have become a necessity of human. The energy can be divided into non-renewable energy and renewable energy. In the past, human used a lot of non-renewable energy to meet the needs of human life, such as fossil fuels (coal, petroleum, natural gas), nuclear power (uranium). These non-renewable energy cannot be reproduced, grown and generated, faster than the growth rate of non-renewable energy. Human being’s development and utilization of it can exhaust the energy resource and lead to serious consequences such as climate changes.

1.1.1 climate change

Due to human’s rapid development, especially after the Industrial Revolution, greenhouse effect happened because of the burning of fossil fuels, population increasing and other issues.

$\text{CO}_2$

Table 1.1 $\text{CO}_2$ Emissions for some countries[1]

<table>
<thead>
<tr>
<th>Country</th>
<th>$\text{CO}_2$ Emissions average annual growth(%)</th>
<th>Total Emissions (million metric tons)</th>
<th>Per Capita Emissions (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>1.8</td>
<td>24688</td>
<td>30649.4</td>
</tr>
<tr>
<td>China</td>
<td>5.9</td>
<td>3402.3</td>
<td>6533</td>
</tr>
<tr>
<td>India</td>
<td>5.1</td>
<td>1185.7</td>
<td>1611</td>
</tr>
<tr>
<td>Japan</td>
<td>0.5</td>
<td>1228.8</td>
<td>1253.5</td>
</tr>
<tr>
<td>American</td>
<td>1.1</td>
<td>5737.2</td>
<td>5832.2</td>
</tr>
<tr>
<td>France</td>
<td>-0.4</td>
<td>365.3</td>
<td>371.5</td>
</tr>
<tr>
<td>Germany</td>
<td>-1.3</td>
<td>831.4</td>
<td>787.3</td>
</tr>
<tr>
<td>Italy</td>
<td>0.4</td>
<td>447</td>
<td>456.1</td>
</tr>
</tbody>
</table>
The world carbon dioxide emissions average annual growth are increase 1.8% from 1990 to 2007. It's increase very fast in the Asia area. It's even decrease in Europe. This means people in the developed countries already realized high carbon dioxide emissions will destroying the natural environment long time ago. They already trying to control the carbon dioxide emissions. In another hand, carbon dioxide emission increasing very fast during these years in the developing countries, especially the country with the overpopulated. Because in these countries, they always have a large number of the population, they are entered a period of rapid economic growth. The carbon dioxide emissions will due to the over-exploitation in urban development and also because they still use lots of fossil fuels.

So the CO₂ emissions are still increasing during these years. The global greenhouse effect are increasing due to the increasing of carbon dioxide emissions.

![CO₂ Emissions from 2003 to 2009](image)

Figure 1.1 CO₂ Emissions from 2003-2009(World, Euro area, China)[2] Source: World Bank WDI Database.

Compare the carbon dioxide emissions in whole world, euro area and China from 2003 to 2009. In the beginning, Euro area (The Euro area with a lot of countries, this is the average data) with a high carbon dioxide emissions. But after that, it is decreasing all the times. That's because they are more and more focus on the sustainable development. They Strictly control the emissions of carbon dioxide. And the result is also based on the population. So it seems the carbon dioxide in the euro is higher than China. But in fact it's a bad situation in China, the problem is getting worse and it's the unsustainable development.
1.1.2 Temperature

From 1906 to 2005, the global average surface temperature has increased by 0.74 °C (0.56 ~ 0.92 °C), and from 1901 to 2000 the average annual increased by 0.6 °C (0.4 ~ 0.8 °C), the former’s increasing speed is faster than the latter by 0.14 °C. In the last 50 years, the increasing speed is almost twice the past 100 years. Since 1850, among the warmest 12 years, 11 years is in this period (1995 - 2006, 1996 excluded). Warming caused seawater to expand, thus leading to rising sea level. The global sea level of the 20th century rises about 0.17m[3].

![Global Land–Ocean Temperature Index](image)

Figure 1.2 Global Annual Mean Surface Air Temperature Change This is an update of Hansen(2006)[4].

From the figure 1.2, the temperature increasing very fast after 1980. Because after 1980, with the development of the human economy and population increasing, carbon dioxide emissions also increased. In addition, the emissions from human activities also include a lot of methane, nitric oxide, chlorofluorocarbon compounds that can warm the globe. Warming effect of methane among the gases is next to carbon dioxide. Methane emissions from human activities mainly include the following ways: increases of rice fields, reservoirs, organic waste, biomass burning, coal mining and natural gas leaks, and so on. The burning of fossil fuels produces hydrocarbons and nitrogen oxides, which can generate ozone under the solar radiation because photochemical reaction occurs, so over the past century, ozone concentration in the atmosphere near the ground doubled. The ozone in the lower atmosphere may cause greenhouse effect and damages to buildings, plants and human health. In order to develop urban areas, the destruction of forest vegetation is another cause of rising temperatures.
As individuals, we should reduce our reliance on fossil fuels, use less electricity and adopt lifestyles that minimize the degradation of natural resources.

### 1.1.3 Sustainable

In nowadays society, every state generates electricity through water, thermal, nuclear, wind, solar, ocean energy, etc.

Table 1.2 shows the electric energy production for some countries and area.

<table>
<thead>
<tr>
<th>Electric energy production (million kilowatt hours)</th>
<th>Country</th>
<th>Total</th>
<th>Thermal</th>
<th>Hydro</th>
<th>Nuclear</th>
<th>Wind</th>
<th>Solar</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>11551944</td>
<td>12415034</td>
<td>2548574</td>
<td>2452741</td>
<td>178857</td>
<td>12876</td>
<td></td>
</tr>
<tr>
<td>China</td>
<td>3496111</td>
<td>2829279</td>
<td>585187</td>
<td>68394</td>
<td>13079</td>
<td>172</td>
<td></td>
</tr>
<tr>
<td>US</td>
<td>4352085</td>
<td>3174140</td>
<td>281995</td>
<td>837804</td>
<td>55696</td>
<td>2450</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>574868</td>
<td>60832</td>
<td>68325</td>
<td>439468</td>
<td>5689</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Japan</td>
<td>1082014</td>
<td>732965</td>
<td>83295</td>
<td>148495</td>
<td>40574</td>
<td>2251</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>637232</td>
<td>416762</td>
<td>26963</td>
<td>148495</td>
<td>40574</td>
<td>4420</td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>389366</td>
<td>320509</td>
<td>9257</td>
<td>52486</td>
<td>7097</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

From the table 1.2 All countries have different ways of generating electricity according to their own resources and conditions. But fossil fuel generation is still the generation produce the mostly electricity. Then it's the hydro power station and the nuclear power station.

Among all of the factors that affect the environment, the use of non-renewable energy has great impact on the environment, such as fossil fuel generation. We should pay more attention to environmental protection for sustainable human development. So looking for and using new energy has become the world's common goals.

China is a developing country with a large population. The sixth national census on November 1, 2010 showed: China's total population is about 14 million. The large population causes enormous pressure on economic and social development, land, forests and water resources. Mining of non-renewable energy sources causes ecological and environmental degradation, which will undoubtedly jeopardize the rudimentary living conditions of people and socio-economic sustainable development. The rapid expansion of China's energy consumption, the increase in exports of heavy industrial products and construction boom leads to great growing demand for energy. Chinese government’s not limiting the energy consumption and seeking more energy
exacerbates energy demand. In China the most widely used non-renewable energies are oil, coal and natural gas.

**Oil**

Oil has many important uses in people's lives, so it has improved people's lives significantly. But the oil has much pollution to the environment. Volatile oil and gas pollutes atmosphere, mainly reflected in the performance that when volatile gas and oil as well as other harmful gas are utilized by solar ultraviolet irradiation, it will cause physical and chemical reaction to produce photochemical smog, which can cause cancer, greenhouse effect and ozone depletion, etc.

**Coal**

China is the world's largest coal producer and consumer, in China, coal is taken as the key primary energy. The uses of coal are wide, but coal mining, transportation, combustion will emit a lot of harmful substances such as CO₂, SO₂ and dust, resulting in deterioration of air quality in cities and large-scale rain falls, especially global warming effect will cause very serious pollution to environment.

**Natural gas**

The best one is natural gas. As a clean energy, natural gas can reduce emissions of sulfur dioxide and dust nearly by 100%, reduce carbon dioxide emissions by 60 percent and nitrogen oxide emissions by 50%; it can also reduce the use of coal and oil, help reduce the formation of acid rain and relieve global warming[6].

Human’s development and utilization of non-renewable energy resources can exhaust the energy and lead to serious consequences such as climate changes, global warming, increased pests and diseases on the planet, rising sea level, erratic weather, increased ocean storms, drought land, increased desertification area. Eventually it will have great bad impacts on economics, agriculture and marine ecology.

So we have to seek the energy in nature which can be endlessly renewable, sustainable, inexhaustible, environmentally friendly, widely distributed, and of high-value and low-cost. We can replace non-renewable energy with the new energy, which is the renewable energy: wind energy, hydro energy, tidal energy, solar energy, etc.

**Wind energy**

Wind energy is the energy which is converted into electricity, heat, mechanical energy and other forms of energy by wind turbines. Wind power is the main form of development and utilization. According to Relevant data of the National
Meteorological Services[7], wind energy resources that can be developed and utilized in China's land reach 253 million kilowatts, mainly in the southeast coast and islands, Xinjiang, Gansu, Inner Mongolia and Northeast regions. In addition, China is also very rich in offshore wind resources, which is about three times the land wind energy resources based on the initial estimate; the total amount of energy resources that can be developed and utilized reach 750 million kilowatts[8]. It seems from the above that wind energy in China has obvious geographical limits according to the geographical conditions around China. Many cities in China cannot get wind energy. Wind energy is considered as clean energy without pollution and can reduce the threat of global warming, but excessively used wind can also affect the natural environment. Wind power grid will affect the system's voltage fluctuations and power quality; also it may cause harmonic pollution. Turbine noise is also a form of pollution.

**Tidal energy**

Tidal energy can indirectly slow the increases of CO2 in atmosphere. It is a worldwide phenomenon of cyclical changes in sea level. The tidal energy can generate electricity by the differences between the rising and falling of water level.

The geographical distribution of tidal energy resources in China is quite uneven, and the utilization rate is not very high. Most Chinese coastlines which are composed of sand or silt are straight and have flat terrain and smaller tidal range. Although Zhejiang and Fujian provinces have rich tidal energy resources, there are more difficulties in developing it. We need to focus on studying and solving the reservoir sedimentation problem. What’s worse, the cost of the tidal power generation facilities is high.

**Hydro energy**

Hydroelectric power does not produce carbon dioxide and is environmentally friendly. But hydroelectric generation in China has obvious geographical limits and may seriously damage the ecological environment of the river, and it is ecological disaster for aquatic life. Meantime, if the reservoir cannot be controlled well, it may cause serious flooding to downstream.

**Geothermal energy**

Although geothermal energy is inexhaustible and has no pollution, China's geothermal energy utilization has geographical limits; so many cities cannot mine and use it.

**Solar energy**

Among the all the renewable energy, because of having no geographical restrictions and faster conversion speed into other energy as well as its high-value, solar energy can be directly developed and used without mining and transport. Development and
utilization of solar energy does not pollute the environment, besides, the annual solar radiation on the earth's surface is enormous, which is equivalent to 130 trillion tons of coal, so it is now one of the world's largest and cleanest energies that can be developed. What’s more, solar energy is inexhaustible for us[9].

1.2 Applies of solar energy

Human life is inseparable from the sun, and the vast majority of energy human need is directly or indirectly from the sun. A variety of plants convert solar energy into chemical energy through photosynthesis, which is stored in plants. Coal, oil, natural gas and fossil fuels are also formed by ancient plants and animals buried in the ground after a long geological time. It is essentially solar energy which is formed by the ancient biology.

Solar energy can be generally divided into:

Indirectly used solar energy: fossil energy (luminous energy ----- chemical energy) biomass (luminous energy----- chemical energy)

Directly used solar energy: solar collector (flat plate collectors, concentrating collectors) (luminous energy----- internal energy)

Solar cell: (luminous energy-----electric energy)

Photovoltaic power: Today, solar photovoltaic power generation is an important form; it can directly convert solar energy into electricity via solar cells.

The development and application of solar energy in China is mainly reflected in the following areas:

Solar water heaters, The wall type solar water heater, Refrigeration and heating systems assisted by solar absorption, Solar heating system, Solar construction—Passive solar houses, Solar light, Photovoltaic system.

1.3 Purpose

This purpose for this thesis is to know the distribution of solar energy in China. The principle of solar equipment, development and its usage in China
CHAPTER 2
METHOD

Literature review

Discussion with classmate and teacher

Book knowledge and lecture note
CHAPTER 3
RESULT

3.1 Distribution of solar energy in China

China is rich in solar energy resources. It is estimated that annually the land surface receives solar radiation about $5 \times 10^{22}$ J, which is equivalent to the energy about 1.7 trillion tons of standard coal.

According to the solar total radiation, China's land can be divided into four areas of solar energy resources.

Figure 3.1 Solar energy resource region in China

1. First-level resource region. This region with extremely abundant solar energy resource: Annual solar radiation exceeds 1750kwh/m$^2$, annual change rate is relatively stable, and therefore it is the best areas of solar energy resources utilization. The annual sunshine time is about 3000h, the land area of this resource makes up 17.4% of the total area.

2. Second-level resource region. This region with abundant solar energy resource:
Annual solar radiation is around 1400—1750kwh/m², Because of the terrain problem, there are some Hengduan Mountains where solar energy utilization rate is not high. The annual sunshine hours are 2400 to 3000 hours. The land area of this resource makes up 42.7% of the total area.

3, Third-level resource region. This region with rich solar energy resource: Annual solar radiation is1050—1400kwh/m². These areas are located in the hilly area of Hanjiang River and the coastal areas, so solar energy utilization changes with seasonal variations. The annual sunshine hours are 1200-2400h or so and it is not conducive to solar energy utilization. The land area of this resource makes up 36.2% of the total area.

4, Forth-level resource region. This region with moderate solar energy resource: Annual solar radiation less then 1050kwh/m². The annual sunshine hours are under 1200 hours. The land area of this resource makes up 3.7% of the total area.

The area which the total annual radiation than 2200h has the economic value of utilization for solar energy. Therefore, most of the areas in China are suitable for promotion of solar energy utilization.

3.2 Developed of energy

There is a figure 3.2 shows the World total solar power capacity (million kilowatt hours) in 2008

![World total solar power capacity](image)

Figure 3.2 World total electric energy production of solar power (million kilowatt hours) in 2008  
Source: UN ESD Database

World total solar power capacity (million kilowatt hours) in 2008 is 12876 million kilowatt hours. There are 17 countries use the solar energy in 2008. The solar power
capacity details for all of these countries shows in figure 3.2. The percent of solar power capacity in Germany is 34%, Spain is 20%. United States is 19%, Japan is 17%, China is only 1% of the total.

Although the Chinese solar power currently accounts for only one percent of the world, but China is the leading country in using solar heating. Solar heating, mostly for water and space heating, is estimated to provide 25 times more power than PV systems and has been growing rapidly[10].

In the 1980s, the shortages of energy aroused the attention of the state and society, many domestic research institutes and universities began to engage in research in solar thermal utilization.

In 2005, China adopted a Renewable Energy Law that requires electric utilities to purchase renewable energy from other producers and offers discount loans and tax preferences for renewable energy projects. The purpose is to promote the development of renewable energy in China, trying to increase the share of renewable energy, such as solar heating, PV, wind energy and other renewable sources. The goal is to make these renewable sources to 10% of total energy consumption by 2020, up from 3% in 2003[11]. This policy accelerated the solar energy development and utilization in China.

Currently, the development of solar energy equipment in China mainly concentrated in several areas:
- Solar water heaters, The wall type solar water heater, Refrigeration and heating systems assisted by solar absorption, Solar heating system, Solar construction—Passive solar houses, Solar light, Photovoltaic system.

3.3 The principle of solar equipment and its usage in China

3.3.1 Solar water heaters

Operating principle
The collector surface of solar water heater has a special coating, when the absorption of solar energy, due to the coating of the thermal radiation reflectivity wavelength of the radiation is low, thus preserving the solar heat is through this heat to heat the water was gradually heated water. Because of the specific gravity in cold water is greater than in hot water, cold water sink, hot water rise, forming a natural convection circulation, so that water in the tank to warm gradually until the water temperature reaches the set temperature.
Process: cold water through a pipe into the solar water heaters, pass the collector plates, and the collector plates can collect solar energy, make the solar energy into the heat, then rise the water from low to high temperature. As the specific gravity in cold water is greater than in hot water, hot water rise automatically, and then form a cycle power, the water in the collector plate that gradually warming up, when reach a certain temperature can into a thermal storage tank, at the same time the cold water get down into the collector for heating, In this cycle way. Able to provide hot water when you need. Shows in figure 3.3

![Figure 3.3 Operating principle of solar water heater](image)

Solar hot water system in China is mainly used to provide water for showers. China's first solar water heater was invented in 1958. Since 1990s, China has established a full glass vacuum tube, which greatly promoted the development of the application of solar water heaters.

Because China has a large number of people that living in rural areas. In recent years, with the rapid development of the rural economy, people’s living standards have been greatly improved. If we use a lot of gas and electric water heaters, we will
certainly increase energy consumption and bring the greenhouse effect and environmental problems. According to compare the gas water heaters, electric water heater and the solar water heater (shows in table 3.1), solar water heater has no pollution, and the characters of being cheap and safe it's became the best choice for human being [12].

Table 3.1 Economic benefits of three kinds of water heater [12].

<table>
<thead>
<tr>
<th>Equipment</th>
<th>electric water heater</th>
<th>gas water heaters</th>
<th>solar water heater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat got</td>
<td>100 L hot water/day</td>
<td>100 L hot water/day</td>
<td>100 L hot water/day</td>
</tr>
<tr>
<td>Equipment investment/ yuan</td>
<td>1200</td>
<td>1000</td>
<td>1800</td>
</tr>
<tr>
<td>Annual operating cost /yuan</td>
<td>500</td>
<td>350</td>
<td>5</td>
</tr>
<tr>
<td>Longevity / years</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Annual average for investment/yuan</td>
<td>650</td>
<td>650</td>
<td>185</td>
</tr>
</tbody>
</table>

In the past 11 years since we came to the 21st century, China's cumulative total savings of solar water heater is equivalent to 136.47 million tons of standard coal and 3195.68GWh electricity. Chlorine dioxide emissions reduction accumulated 4,466,700 tons and 2,011,200 tons of nitrogen dioxide; the energy saving effect is remarkable.

Table 3.2 Market share of gas water heaters, electric water heater and the solar water heater from 2001 to 2012 [12].

<table>
<thead>
<tr>
<th>Years</th>
<th>Electric water heater (%)</th>
<th>Gas water heaters (%)</th>
<th>Solar water heater (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>30.00</td>
<td>54.80</td>
<td>15.20</td>
</tr>
<tr>
<td>2003</td>
<td>44.23</td>
<td>37.57</td>
<td>22.20</td>
</tr>
<tr>
<td>2005</td>
<td>45.20</td>
<td>26.57</td>
<td>28.23</td>
</tr>
<tr>
<td>2007</td>
<td>42.30</td>
<td>19.20</td>
<td>38.5</td>
</tr>
<tr>
<td>2008</td>
<td>49.20</td>
<td>50.80</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>43.30</td>
<td>56.70</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>42.80</td>
<td>57.20</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>42.30</td>
<td>57.70</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td>42.00</td>
<td>58.00</td>
<td></td>
</tr>
</tbody>
</table>
The annual conference of the China Solar Thermal Industry Federation (CSTIF), 2001 gives the data for the energy saving and emission reduction from 2000 to 2010 due to use the solar water heat shows in table 3.3 [12]

Table 3.3 Energy saving and emission reduction from 2000-2010 due to use solar water heat in China[1].

<table>
<thead>
<tr>
<th>Years</th>
<th>Equivalent to standard coal (Megaton)</th>
<th>CO2mitigation (megaton)</th>
<th>NO2mitigation (megaton)</th>
<th>SO2mitigation (megaton)</th>
<th>Dust mitigation (megaton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>3.90</td>
<td>8.37</td>
<td>0.06</td>
<td>0.13</td>
<td>0.10</td>
</tr>
<tr>
<td>2001</td>
<td>4.80</td>
<td>10.30</td>
<td>0.07</td>
<td>0.16</td>
<td>0.12</td>
</tr>
<tr>
<td>2002</td>
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<td>0.19</td>
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<tr>
<td>2006</td>
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<td>28.98</td>
<td>0.20</td>
<td>0.44</td>
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<tr>
<td>2007</td>
<td>16.20</td>
<td>24.78</td>
<td>0.24</td>
<td>0.52</td>
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<td>2008</td>
<td>18.75</td>
<td>40.25</td>
<td>0.28</td>
<td>0.61</td>
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<td>2009</td>
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<td>46.69</td>
<td>0.32</td>
<td>0.70</td>
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<td>2010</td>
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<td>0.37</td>
<td>0.81</td>
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<td>136.47</td>
<td>292.92</td>
<td>2.01</td>
<td>4.47</td>
<td>3.45</td>
</tr>
</tbody>
</table>

3.3.2 The wall type solar water heater

At present, most families still use gas or electricity for heating, and solar water heaters are not often used. One of the important reasons is that solar water heaters will affect the appearance of the building. The wall type solar water heater has significantly improved utilization rate of solar water heaters. Wall-type solar collector design is based on flat plate collectors. The luminous energy is converted into heat energy through Wall-type solar collector.

Since the collector is also part of the wall, thus it requires sufficient strength, appearance beautifying effect and heat preservation efficiency. Wall-type solar collector made by Solar Energy Research Institute of Tianjin University can gain high efficiency of 90% under the conditions of fewer temperature differences. Even under the conditions of greater temperature difference temperature, it can also meet the water needs of the residents. So it has a certain value of promoting[13].
3.3.3 Refrigeration and heating systems assisted by solar absorption

After 1970s, our country began to study the solar refrigeration and air conditioning, in Guangdong and Shandong, the key scientific and technological projects of solar air conditioning are organized and implemented. In 1998 and 1999, 100kw solar air-conditioning systems were separately completed in Jiangmen and Shandong. Due to its high cost and long payback period, its wide range of use is greatly limited[14].

3.3.4 Solar heating system

Operating principle
The solar heating system concept refers to the solar heating system as a heat source. Through the use of solar energy collector(eg: flat plate solar collector, solar vacuum tube and other absorb solar energy collection devices) focuses distributed solar energy into heat energy, Used for building heating in winter and other seasons of the year heating system.

The operating principle of solar heating system is evacuated tube heat collectors to heating the water, and then through the circulatory system to the heat storage thermal storage tank. When the water temperature reached a certain value, the heat exchange through the heat exchanger coil or the geothermal heat sink, then the ground / heat sink to the indoor radiant heat evenly.
Several years ago our Solar Energy Heating engineering application has been in its infancy only, single demonstration buildings are built, such as the Tianpu of new energy demonstration building[15] and Beijing Tsinghua Solar company office building[16] so on. District heating solar heating project is not yet applied practice.

Through the solar industry expert’s appraisal. There is an application(Solar office building) of solar energy heating is declared successful in the Northeast region, March 2013. This solar office building has six floors, the overall area is nearly 5120 square meters, for winter heating, summer cooling and non-potable hot water, all by solar thermal systems to achieve, make the solar heating, cooling simultaneously.

### 3.3.5 Solar construction—Passive solar houses

There are several types of the passive solar house.

**1. Directly benefit**

The principle of the directly benefit solar house is like this, the south window must be built in a larger area, in winter, during the daytime the sun through this large area of glazing to the south then the exposure to the interior wall, floor and the furniture, they absorb a lot of heat, so rise the temperature. The wall, floor and furniture absorb the heat, some of which in the pattern of radiation, convection in the interior space to pass, and others to get into storage, and then gradually release the heat at
night, so that the room can maintain a certain temperature at night or the cloudy.

But due to the large area of the glass to the south, especially in the summer this kind of solar house has certain disadvantage, airtight glass must be superior in quality, and very thick curtains are needed to prevent the heat from the loss of the night, the biggest drawback is that in the summer, even with sun visor, it still causes the temperature get too high in the room.

Figure 3.6 Operating principle of passive solar house—directly benefit

Wall Collecting

First, this kind of solar room to the south side of the building need to build a special wall, perpendicular to the south side of the wall surface of the Solar collector to the heat storage painted black or certain dark colors, this can be more effectively absorb sunlight. In order to achieve the effect of warm in winter and cool in summer, the wall top and bottom are needed to open a vent separately. In the top of the north wall will usually open a vent for using in the summer (in the winter this vent completely closed).

The working principle is through the use of wall absorption of sunlight through the glass. In the winter, when the sun radiation to the wall, the wall is heated while the south wall of the air between the glass and is also heated, then the hot air will form the updraft through the air into the room, the interior of the cold air enters through the lower outlet mezzanine space continue to be heated, forming a virtuous circle. In the summer, when open the north to vent, the cold air from the vent into the indoor, is strengthen the indoor ventilated effect. Using this solar house, though the fluctuation of the temperature indoor is small, but the efficiency is lower, often used in conjunction with other methods.
**Figure 3.7 Operating principle of passive solar house—Wall Collecting**

**Attached sunspace**

Attached sunspace is similar to the Solar collector, building exterior protected construction are composed of pervious to light material such as glass. It will widen the distance between the south glass window and the inside wall, and provide a larger temperature range for the interlayer.

The sun to the additional solar house on the floor, wall and the object, these objects absorbed a part of the heat in the form of radiation and convection, together with the additional room in heated hot air through uptake into indoor, and the indoor air will continue to be through the tuyere into the interlayer space heating and circulation. Another part is stored in the object, released when be needed without the solar. The additional solar house can reduce the heat loss of the building. Due to the temperature in the additional solar house is higher than the outdoor, so we can plant some plants in the buffer room.
The passive solar house widened the air gap between wall and glass, provides an additional used space for additional solar house, This space is that generated the large fluctuation in temperature due to direct solar gain of space.

Besides that the winter heating, and the summer cooling is also very important, the solar house used a solar thermal effect to enhance natural ventilation in summer.
The first passive solar house in China was built in 1977. After 20 years of efforts, passive solar house research has achieved fruitful results[17].

In 2007, a passive solar house was built in Tibet. Passive Solar House is a kind of building which can collect, store and distribute solar energy by rationally arranging orientation and the surrounding environment, processing appropriately the internal space and the external shape, materials, proper selection of structures. It is made up of the glass envelope, thermal storage wall, attached sun room, etc., thus becoming a new landscape among the quaint buildings. It is cool in summer and warm in winter in such houses. The indoor temperature can be increase 8 °C in winter and decrease 2—3°C in summer without auxiliary heat source.

In Tibet, the processes of building a passive solar house include: thermal calculation, determining reasonable ratio (in Tibet is around 1/4) of south-facing light transmittance and floor heating to obtain the most suitable amount of daylight. Through thermal calculation, heat preservation material and thickness of palisade structure of the buildings should be determined. Double or triple sealed glass windows are to be installed and heavy insulation curtains are to be chosen, during the day the sun shines directly through the south window to the interior walls, floors and furniture so that their temperature rise and heat is stored; at night, temperature drops, you can shut the window curtains and pull down the interior walls, the heat stored in floors and furniture will slowly release to achieve the purpose of warming.

They often use a solar thermal storage wall, which consists of a fixed glass cover, the air space, hot-press plate, load-bearing walls and the like. During the day the sun heats the air space and the collector plate through the glass cover. The black heat collection coating on the collector plate makes the steel sheet temperature rise, and steel sheet radiation heats the air space while passing on the heat to the outside wall through exterior surface. After heating, the ratio of air decreases so that it flows upward by the upper windward side into the room, but the indoor cold air flows into the air space which is in negative pressure condition from the down-wind, so that the flow of hot air can heat the chamber. The heated exterior side radiates heat to indoors so that it can improve the temperature while storing part of heat to release in the evening.

Solar houses have been widely utilized in many parts of Tibet. Passive solar houses solve the problem of heating in winter in Tibet, it can not only save energy, time and labor but it is clean, so that the residents' quality of life and students’ learning environment have been greatly improved.
In 2007, Tibet's energy research centers conducted experiment ‘applied research of passive solar house in the pastoral schools’, combining passive solar technology and precautionary measures in buildings. Experimental results showed that after using the techniques above, the indoor temperature of the passive solar houses is 10 °C higher than traditional building indoor temperature, and it can basically meet the classroom heating requirements in winter. Meanwhile, the cost of transforming the passive solar houses does not exceed 20% of the cost of school construction[18].


<table>
<thead>
<tr>
<th>Years</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (ten thousand square meter)</td>
<td>1395.2</td>
<td>1467.8</td>
<td>1590.46</td>
<td>1700</td>
<td>2000</td>
</tr>
</tbody>
</table>

The area of solar house is increase around 30% from 2006 to 2010. In the future, it will prioritize hybrid solar house which is combined both active solar house and passive solar house.

### 3.3.6 Solar light

**Operating principle**

The solar light consist of the solar module, solar lighting controller, battery, LED lamp, light pole and structural parts.

The working principle is when the sunlight irradiate on the solar panels, the luminous energy can translate into electrical energy. The current through the diode transmit to the rechargeable battery and bulb unit at the same time, During the daytime, the solar panel charged the battery; the battery provide the power to the street lamp at night.
3.3.7 Photovoltaic system

Operating principle

The photovoltaic power generation is based on the principle of photo-voltaic effect, the use of solar cells to solar energy directly into electricity. Photovoltaic system is used for grid or used independently, mainly by the controller, solar panel modules and inverter three major components. The key of the technology is the series after the solar cell can be formed after the package to protect a large area of solar components, and then use the power controller and other components to form a photovoltaic device.
Solar photovoltaic (PV) systems will need the batteries to store power for use when the resource is not available (e.g., at night for solar equipment)[19].

Since 1958, China developed the first block of silico
First used successfully on the launched by China Eastern Red II satellites, 1971.
In 1975, in Ningbo, Kaifeng had set up the solar-cell factory successively, the solar cell applications began to descend to the ground from the space.

Photovoltaic industry before 1980 was still in embryonic form in China, the annual production of solar cells has been hovering at 10KW or less, and the price was very expensive. Due to the constraints of the price and yield, the market development was very slow, besides as a satellite power, only used for same certain small power systems.

1981-1990, the state began to give the support to the development of photovoltaic industry and PV market, the central and local governments to invest in pv field, making the solar battery industry got great development.

In 1990s, with the initial formation of China's photovoltaic industry and the cost reduction, the application began to develop in the industrial areas and rural electrification, and the market is expanding steadily, and be included in the national and local government’s programs.

In 1998, the Chinese government proposed the first set of the 3MW polysilicon battery and its application system demonstration project.
Enter into the 21st century, the state has invested 2 billion, for installing 20MW, to solve the electricity problem for the nearly 800 townships in our country, also promoting Chinese PV market to get the quickly and substantial growth. At the same time, The grid-connected power generation demonstration project began rapid development, from 5kW, 10kW grown to more than 100kW.

In 2004, 1MW combined to the grid project in Expo Park of Shenzhen becomes the highlight in domestic photovoltaic application field. The installed gross capacity of domestic photovoltaic system reaches approximately 65MW by the end of 2004.

Nowadays some cities in China have owned the well set up large photovoltaic combined to the grid power station. Until 2012, 70 photovoltaic power stations exist just in more than ten cities of western China, and the scale of power station reaches hundreds of megawatt. Now almost every city has at least one photovoltaic power generation park in Qinghai, Gansu, Xinjiang, and most of photovoltaic power generation parks are set up based on the scale of GW level. According to the statistical data from NPD Solorbuzz, installed gross capacity of China photovoltaic goes to 4.7GW and capacity combined to the grid is 1.49GW in 2012. Qinghai, which has the installed capacity of close to 1GW, is still the biggest province from this field in China, and Qinghai is followed by Gansu, Xinjiang, Inner Mongolia, Jiangsu and Ningxia; these six areas totally occupy more than 60% share[20]. Kumul area of Xinjiang is the most centralized area for installed photovoltaic. Kumul promotes Shichengzi photovoltaic industrial park from the early phase. It was started in 2010, built 35MW at the end of 2011, and accumulative installed capacity reached 138MW by the end of 2012. Golmud of Qinghai realized the target of 1GW installed capacity at the end of 2012 and went to 1.03GW. The output capacity of Wuwei Golden Sun Park from Jiangsu province reaches 480MW and the built accumulative photovoltaic projects go to 1.5GW. Now Dunhuang has set up the power station with more than 100MW etc.

In January 2013, many provinces have already owned, the large photovoltaic (pv) grid power generation concession projects, all of their project is over 20 megawatts[21].

In addition to the national large-scale photovoltaic grid power station, some residents individual photovoltaic power stations have been built in our country. In Fujian, Beijing, Shanghai, Shaanxi etc. areas, resident individual photovoltaic power stations have been built. And there are many users in grid applications currently being self-built power station stage.
CHAPTER 4
Analysis and Discussion

From the chapter 3. After years of effort, China has achieved fruitful results in solar water heaters and passive solar fields and has basically formed solar thermal technology with Chinese characteristics, at the same time it has had the necessary conditions of solar application and dissemination. Solar water heating systems have become a necessity in family life; solar heating system has been basically technically mature. About the problems of unitary and expensive features of the built solar houses, multi-functional solar houses should be developed according to the actual situation to meet the needs of different users. (The importance of solar heating has often been neglected as it has not been included in energy databases due to lack of data).

Solar lamps have become the new favorite of urban street lighting industry. However, due to constraints such as raw material price and technology, solar street lamp power system has been known for a high price and even higher cost in later maintenance and replacement. In addition to the low photovoltaic conversion efficiency of the solar panel, which is a great obstacle for the promotion of solar street lamp.

Although the cost of generating electricity using solar PV system is still higher than the cost of fossil fuel generation, The solar PV system is still the a good choice for the sustainable development, China is able to develop large-scale photovoltaic power generation with good solar energy resources and sufficient building roofs as well as desert/wilderness resources. Photovoltaic will play an important role in the future power supply of China. It's estimated that China photovoltaic industry will increase with the speed of more than 40% every year[22].
CHAPTER 5
Suggestion

Here is some suggestion of the future work on solar energy in China.

- **Build large power station**
  According to solar energy resource distribution in China. Tibet, Qinghai, Gansu and west Inner Mongolia, south Xinjiang are rich in direct solar energy. Land vacancy rate in the fixed and semi-fixed sand dunes and desert areas is high, so it is well suited to build large solar power station.

![Figure 5.1 Suggest land to build solar power station in China](image)

It is suggested large solar power plants be built in the following regions according to solar energy resource distribution in China.

1. **Hunshandake sandy land**
   Cover an area of 21400 km². Fixed, half fixed sand dune accounted for 98% of the total area. Solar radiation resources are very abundant, the accumulative total solar direct radiation is 5573 mj/m² per year, water resources condition is very good. Precipitation is good. The linear distance to Beijing is about 180 km, as Beijing desertification is very serious, so the desert is became one of the national key development.

2. **Keerqin sandy land**
   These areas cover 42,300 km² and have less quicksand; they are near the ocean and have abundant rainfall, the annual rainfall is 300-400mm. The solar radiation
resources are relatively abundant; the annual total direct normal solar radiation is 5443MJ/m$^2$.

3. Hulun buir sandy land

These areas cover 7200 km$^2$, most of which are fixed and semi-fixed sand dunes and are rich in solar radiation resources; the annual total direct normal solar radiation is 5000MJ/m$^2$.

4. Zhungeer sandy land

These areas cover 7200 km$^2$, most of which are fixed and semi-fixed sand dunes and are rich in solar radiation resources; the annual total direct normal solar radiation is 5000MJ/m$^2$.

- Publicity, training and information dissemination should be increased. And great significance of solar energy to sustainable economic and social development should be spread through a variety of forms.

- Currently solar energy still has a high investment and long payback period problem, so the government should develop and implement certain policies to encourage the enterprises.

- Improve the efficiency of solar energy equipment. The use and promotion of the solar energy products, only relying on policy and environmental awareness is not enough, the most important is depending on technological innovation, increasing the technology content, only make the price down, and the quality to go up, at the same time the cost control within the acceptable range, the solar products will have the market competitiveness.
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