BBChina

Master Program
on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Solar Energy in China

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Summary

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1.Background

1.1 Brief introduction of solar energy resources

Solar energy is the energy from the earth's outer bodies. The sun is a huge energy body, energy mainly derived from the fusion reaction of hydrogen into helium, the capacity power (i.e. the energy generated per second) is about 3.8 x 10^{23} kW. The earth receives only 1-2.2 billionth of the total solar radiation, but it also has about 1.7 x 10^{14} kW. This part of the radiation is absorbed by the atmosphere about 23%, by atmospheric molecules and dust reflected back to space solar radiation is about 30%, the remaining about 47% can reach the ground, about 8.1 x 10^{13}kW, which equals to the world's electricity generation hundreds of thousands of times. The solar radiation that is projected to Earth every year is 6 x 10^{17} kWh, or 74 trillion tons of standard coal. At the current rate of mass consumption of the sun, it can last 60 billion years, so it can be said that it is "inexhaustible" energy.

Most of the energy we need comes directly or indirectly from the sun. Plants release oxygen through photosynthesis, absorb carbon dioxide, and convert solar energy into chemical energy to store in plants. Most of the energy on earth comes from solar energy. According to relevant data, the area with more than 2200 hours of sunshine per year accounts for more than 2 / 3 of the land area. Therefore, solar energy resources have good development conditions and application prospects. Distribution of solar energy resources in China: solar energy resources are widely distributed in China. According to the division standard of wind energy and solar energy assessment center of National Meteorological Administration, solar energy resources in China can be divided into the following four categories[1-3]:

Class I area: the annual solar radiation is large, ranging from 6700 to 8370 MJ/m^2. Such areas mainly include the northwest of China, such as the north of Gansu and the north of Ningxia.

Class II area: the annual solar radiation is large, in 5400-6700 MJ/m^2. Such areas mainly include the northeast of China, such as Shandong, Jilin and so on.

Class III area: the annual solar radiation is generally in the range of 4200-5400 MJ/m^2. Such areas mainly include southern China, such as Zhejiang and Guangdong.

Class IV area:the annual solar radiation is very small, below 4200 MJ/m^2. These areas are mainly distributed in Sichuan and Guizhou.

1.2 Advantages and disadvantages of solar energy resources

1.2.1 Advantages of solar energy resources

As a clean renewable energy, solar energy has incomparable advantages compared with conventional energy：

(l) Solar energy resources are widely distributed and can be directly developed and utilized without regional restrictions.

(2) Solar energy resources are huge, and its total amount is the largest exploitable energy.

(3) Solar energy resources belong to clean energy, and the development and utilization of solar energy will not pollute the environment.

(4) To some extent, solar energy resources are inexhaustible. According to the current total power of solar radiation, solar energy resources can be maintained for about 60 billion years[4, 5].

1.2.2 Disadvantages of solar energy resources

(l) At present, the development level of solar energy utilization is limited, and some aspects are feasible in theory, but in fact, some solar energy utilization devices are restricted by certain economy due to their low efficiency and high cost.

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(2) Although the total amount of solar radiation reaching the earth's surface is large, the energy density is very low. Therefore, the use of solar energy, often need a considerable area of conversion equipment, high cost.

(3) Solar power generation is not stable and continuous, which is greatly affected by the weather conditions such as season, day and night, cloudy and sunny, which makes the large-scale continuous application of solar energy more difficult.

In China, photovoltaic industry faces many problems:

(1) Backward core technology.

(2) High energy consumption and pollution in production. China's photovoltaic manufacturing industry occupies the first place in the world, but it comes at the expense of the environment. The waste treatment in the photovoltaic production process has become one of the bottlenecks restricting the development of China's circular economy.

(3) Overcapacity.

(4) High external dependence of demand market.

(5) Trade protectionism spread.

1.3 Application of solar energy resources

With the shortage of fossil energy supply and the increasing attention to environmental protection, the application of solar energy is expanding. Next, we will introduce several major applications of solar energy.

1.3.1 Solar collector

Solar collector is a kind of equipment which can convert the radiant energy of the sun into heat energy. The most common device is the solar water heater. Its basic principle is to collect the solar radiation energy and convert it into heat energy through the interaction with materials for people's production and life. According to the structure, it can be divided into vacuum tube type and flat plate type solar water heaters, mainly vacuum tube type solar water heaters. It has good heat preservation performance, strong frost resistance and long service life,It is popular in the market. With the continuous breakthrough of the key technology of solar water heater, solar water heater has been widely used in hotels, factories, villas, duplex rooms and other places.

1.3.2 Solar thermal power generation

Solar thermal power generation is a kind of power generation method that first converts solar energy into heat energy, and then converts heat energy into electric energy. The use of solar thermal power has become an important field of global venture capital. The first tower solar thermal power plant in China which is the largest one in Asia, Badaling solar thermal power experimental plant, successfully generated electricity in 2012 and officially put into use. Solar thermal power generation is particularly suitable for remote areas and areas where power transmission is difficult, especially in the west of China.

1.3.3 Solar air conditioning

Solar energy is the energy of refrigeration and air conditioning. Considering the application of heating and cooling, solar energy and renewable biomass fuel are the main energy sources in heating, and a small amount of electric energy is used in refrigeration to utilize the low temperature of ground source, and superconducting energy transmission system is used for direct refrigeration. Solar driven air conditioning system has good seasonal adaptability, and it is of great significance for saving conventional energy and protecting the natural environment. It has been widely used in schools, hospitals and comprehensive office building and other places.

2.Description of the technologies

As a rapidly expanding emerging industry, the solar energy industry is also expanding its scope. But "at present, the use of solar energy in China mainly includes solar thermal energy and solar photovoltaic power generation[6].

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Therefore, two major industries are formed: solar thermal utilization industry and solar photovoltaic industry. Solar thermal applications mainly include solar hot water systems (commonly known as water heaters, etc.), solar heating/cooling systems, solar thermal power generation technologies, etc.; solar photovoltaic application technologies (photovoltaics) mainly include off-grid power generation systems, grid-connected power generation systems and hybrids System etc[7]. At present, with the continuous expansion of solar energy application fields, the scope of solar energy industry has continued the trend of expansion and marginalization. For the healthy development of the solar energy industry, it should extend the solar energy industry chain in a healthy manner, forming a coordinated development of upstream, middle and downstream.

2.1 Solar thermal utilization industry

The research and development of China's solar photovoltaic technology began in the 1970s and was initially mainly used in extraterrestrial space. After the mid-1970s, photovoltaic applications gradually began to expand to the ground and formed a photovoltaic industry with a certain scale today. Photovoltaic power generation and solar cells have played an important role in improving people's quality of life, and will play a greater role in the sustainable development of country's national economy in the 21st century. The solar thermal utilization industry is mainly engaged in the direct conversion of solar radiation energy into thermal energy for utilization. Through a series of industrial systems such as processing raw materials, developing new products, engineering design and providing marketing services, it has greatly driven the development of related industries such as the electronics industry, steel industry, and chemical industry. At present, it is mainly used in the field of solar water heaters in China.

The solar heat utilization industry includes three utilization methods: low temperature utilization(<100℃), medium temperature utilization(100℃-500℃) and high temperature utilization(>500℃). Among them, low temperature utilization including solar water heaters, solar houses, solar stoves and other medium temperature utilization is mainly used in industrial production fields, such as chemical distillation, wood drying and high temperature utilization is mainly used in the field of power generation. Among the three utilization methods, the widest application range and the most mature technology development in China are in the field of low-temperature solar energy utilization, especially the vigorous promotion and use of solar water heaters. The research on high-temperature utilization of solar energy in China started late, but it has achieved a breakthrough in core technology, and the technology in the field of thermoelectricity is currently at the forefront of the world.

2.2 Solar photovoltaic industry

Photovoltaic is a new application technology that uses the photovoltaic effect of solar cell semiconductor materials (such as monocrystalline silicon, polycrystalline silicon, gallium arsenide, etc.) to directly convert solar radiation energy into electrical energy. The photovoltaic industry refers to the industrial chain formed by the application and development of silicon materials, including the production of crystalline silicon materials, silicon wafer ingot manufacturing, solar cell production, module packaging, and photovoltaic power generation system applications. According to the application form of solar photovoltaic system, the scale of application and the type of load, the photovoltaic power supply system will be divided more carefully. The photovoltaic system can also be subdivided into the following six types: small solar power system (Small DC); simple DC system (Simple DC); large solar power system (Large DC); AC, DC power supply system (AC/DC); Grid-connected system (Utility Grid Connect); Hybrid power supply system (Hybrid); Grid-connected hybrid system.

Photovoltaic power generation, that is, solar cell technology or photovoltaic utilization. Therefore, the trend of technological innovation in the field of photovoltaics lies in improving the conversion efficiency of solar cells, thereby effectively reducing costs. The United Kingdom and Norway jointly announced that they have discovered the basic principles of the fourth generation of solar cell technology. The first generation is crystalline silicon solar cells and the second generation is thin film solar cells. It is a representative of amorphous silicon solar cells. The third generation is dye-sensitized nanocrystalline solar cells. At present, polycrystalline silicon cells are still the mainstream products in the photovoltaic industry, but their cost is too high. Quartz stone is the material used to

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produce solar cells, and China is very rich in quartz stone, from which a large amount of industrial silicon is extracted and exported to Europe, America and other countries. Countries such as Europe and the United States then sold crystalline silicon materials purified by industrial silicon to our country at high prices. This phenomenon occurs because China has not yet mastered the core technology of processing industrial silicon into polysilicon. Moreover, China will cause high pollution and high energy consumption in the process of refining polysilicon, which seriously pollutes the environment. China cannot currently produce thin-film solar cells on a large scale. However, thin-film batteries can become technologies vigorously developed by Chinese solar energy companies by improving performance and improving processes. Because it is not restricted by raw materials, the cost advantage is obvious. At present, the competitiveness of China's photovoltaic industry is increasing year by year, and the photovoltaic industry chain is developing in a coordinated and rapid manner, and it is showing a trend of continuous innovation and development.It is manifested in the mastery of the key technologies of the corresponding industry chain, such as silicon material technology, batteries Technology, etc.

2.2.1 Polysilicon production

The production and refining of polysilicon requires a large amount of capital, more energy consumption (every kilogram of polysilicon produced requires 200-500 ℃) and a higher technical threshold. The main traditional processes of polysilicon production in the world are: improved Siemens method, silane method and fluidized bed method. Among them, the polysilicon production capacity of the improved Siemens process accounts for about 80% of the world's total production capacity. In the short term, the situation of industrial technology monopoly blockade will not change. However, the photovoltaic industry has recently emerged several new technologies specializing in the production of solar-grade polysilicon, mainly including: low-cost process of improved Siemens method, direct preparation of high purity SiO2, Vaper to iquid Deposition, Thermal decomposition process, Al-Si solution low temperature preparation of solar-grade silicon, molten salt electrolysis, etc. The core technology of polysilicon production process is mainly in the hands of most international polysilicon suppliers such as Hemlock, MEMC, Wacker, REC, SGS, Tokuyama, Mitsubishi, etc[8].

2.2.2 Cutting of silicon rods (ingots) and silicon wafers

The purified polysilicon material needs to be further converted into a monocrystalline silicon rod or polycrystalline ingot before it can be processed into silicon wafers, batteries and mounting components. Among them, the most commonly used process for the production of single crystal silicon rods is the Czochralski method and the area melting purification method; the most commonly used production process for polycrystalline silicon ingots is the ingot method. The silicon wafer cutting process basically uses multi-wire cutting technology. The thickness of silicon wafers has grown from the mainstream thickness of 270um in 2004 to 180um in 2009. The thickness of silicon wafers in mass production by some international manufacturers has even reached 120um. The crystal pulling furnace and the crystal casting furnace are relatively cheap, and the manufacturing process is relatively simple, which has basically achieved localization.

2.2.3 Solar cell manufacturing

The next step in slicing is to produce solar cells. Solar cells are divided into crystalline silicon cells and thin-film coated batteries. Crystal silicon batteries can be subdivided into single-crystal silicon batteries and polycrystalline silicon batteries; thin-film batteries can be subdivided into amorphous silicon batteries and other compound batteries, mainly including CIGS, GaAs, CdTe, etc. Among them, crystalline silicon batteries account for more than 90% of the market. From the point of view of commercial battery conversion efficiency, monocrystalline silicon batteries are the highest, polycrystalline silicon batteries are second, and thin-film batteries are the lowest. However, in terms of manufacturing cost, single-crystal silicon batteries are the highest, polycrystalline silicon batteries are second, and thin-film batteries are the lowest. With the continuous improvement of manufacturing technology, amorphous silicon thin film solar cells are expected to become the mainstream of the future development of the photovoltaic industry.

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2.2.4 Component package

In order to meet the actual use requirements of solar cells, several single cells must be processed in series and parallel, and packaged to form a minimum unit that can be used independently as a power source. This independent minimum unit is a battery module. The solar cell assembly is composed of a photovoltaic cell and a metal frame, a glass cover sheet, a cable lead, and an adhesive. The crystalline silicon solar cell package is generally formed by sequentially stacking toughened white glass-EVA (ethylene vinyl acetate copolymer)-cell sheet-siphon glass-EVA-PVF (polyvinyl fluoride) composite film. In the entire photovoltaic industry chain, the funding requirements and technical thresholds for the packaging of photovoltaic modules are the lowest. Most packaging equipment has been localized and the prices are relatively cheap. The module packaging business is the most convenient and fastest way to enter the photovoltaic industry.

2.2.5 Photovoltaic power generation system

Photovoltaic power generation system is the core function value of solar cells in the industrial cluster downstream of the photovoltaic industry chain. The photovoltaic power generation system is divided into three forms: off-grid, grid-connected and hybrid power generation. The downstream enterprises of the photovoltaic industry chain, in addition to specific applications such as solar cell grid-connected power generation projects, also include solar photovoltaic cells and electromechanical industries, BIPV (Building Integrated Photovoltaic), wind-solar complementary systems, and other aspects. The market access threshold for photovoltaic power generation systems is relatively low. However, due to high power generation costs, the overall market size is very small.

In addition to the above five main links, the photovoltaic industry chain also includes the production of supporting products related to the integration of photovoltaic power generation systems, which are mainly the balancing components (BOS) of the photovoltaic system, such as controllers, inverters, maximum power trackers, Storage batteries, monitoring systems, power distribution systems, brackets and cables, etc. The production of balanced components has relatively low technical requirements. Except for some large-scale grid-connected photovoltaic power generation systems that use imported equipment, most of the components have basically been localized.

3.The present status of solar energy

3.1 Global photovoltaic research status

In 2018, the new installed capacity of global photovoltaic exceeded 100 GW for the first time, reaching 102.4 GW. So far, the cumulative installed capacity of global photovoltaic has exceeded 0.5tw, with a year-on-year increase of 25% . Among them, China, the United States and India account for 61% of the global market share. It is still the core country that dominates the scale of global photovoltaic industry. Compared with the photovoltaic market in some countries or stagnation or depression, the photovoltaic industry in Mexico, Australia, South Korea, Egypt and other countries and regions has developed rapidly. In addition, more and more developing countries begin to attach importance to photovoltaic power generation technology, and a large number of emerging markets are emerging, especially in Africa, the Middle East and South Asia. In 2018, it is the vigorous development of these emerging photovoltaic markets that makes up for the impact of the slowdown in the growth of photovoltaic markets in China, the United States, Japan and so on, so that the global photovoltaic market maintains an overall upward development trend[9, 10].

3.1.1 European PV market:

From 2017, the European photovoltaic market began to show signs of recovery. Since 2012, the new installed capacity of photovoltaic industry in Europe has declined. Driven by the EU's 2020 renewable energy binding target, the photovoltaic industry in Europe has changed form.Since 2017, it has maintained steady growth year by year. In 2017, the new installed capacity of European photovoltaic market was 9.3 GW, a year-on-year increase of 30%; in 2018, the new installed capacity of Europe was 11.3 GW, a year-on-year increase of 21% . Among them, the new

installed capacity of the Netherlands exceeds 1 GW, reaching about 1.5 GW; the new installed capacity of Germany reaches 2.9 GW, up 67% from 1.8 GW in 2017, becoming the largest photovoltaic market in Europe again.

3.1.2 Photovoltaic market in the Americas:

The overall development of photovoltaic market in America is relatively stable, especially in South America. As the second largest photovoltaic market in the world, the U.S. photovoltaic market stagnated in 2017-2018 due to the impact of import tariffs on solar cells and components, and the installed capacity in these two years was about 10.6 GW. With the slowdown of the U.S. photovoltaic market, the photovoltaic industry in Mexico, Brazil and other countries has risen rapidly. Compared with 285 MW of new photovoltaic installed capacity in 2017, in 2018, Mexico's new photovoltaic installed capacity exceeded 1 GW for the first time, reaching 2.8 GW, nearly 10 times higher than the same period last year, while in 2016, the figure was only 143 MW , making Mexico the seventh largest photovoltaic market in the world. This strong growth is mainly due to the three bidding activities of renewable energy projects held by the Mexican government in 2016 and 2017, making photovoltaic power generation the biggest winner; at the same time, the government also lifted the restrictions on distributed roof photovoltaic power generation system. In 2017 and 2018, the new installed capacity of photovoltaic in Brazil exceeded 1 GW, and in 2018, the new installed capacity was about 1.2 GW, an increase of 13% year on year. In addition, Chile, Argentina, Colombia and Peru are also actively accelerating the construction of photovoltaic power generation system.

3.1.3 Photovoltaic market in Asia Pacific:

The leading position of photovoltaic industry in Asia Pacific region (including China) is further expanded. For six consecutive years, China's new installed capacity of photovoltaic industry has ranked first in the world, from 10.6 GW in 2013 to 52.8 GW in 2017, which has created a new record and promoted the rapid development of global photovoltaic industry. In 2018, due to the influence of the "531" new photovoltaic subsidy policy, China's new installed capacity of photovoltaic fell to 44.4 GW , but it did not affect its leading position in the global photovoltaic market. According to solar power Europe's forecast, in 2018, India's new installed capacity of photovoltaic will surpass that of the United States, making it the second largest photovoltaic market in the world. However, due to factors such as commodity service tax and protectionist policies, India's photovoltaic market has shrunk, with only 8.3 GW of new installed capacity, 16% less than that of 2017's 9.6 GW. In addition, the development of photovoltaic industry in Australia and South Korea is particularly prominent. In 2017, the new installed capacity of photovoltaic in Australia was 1.3 GW, compared with 5.3 GW in 2018, a year-on-year increase of 295%. Driven by the renewable energy portfolio standards, South Korea's photovoltaic market expanded rapidly, with new installed capacity exceeding 1 GW and 2 GW in 2017 and 2018, respectively. The renewable energy portfolio standard is intended to replace the feed in tariff policy, requiring utilities with an installed capacity of more than 500 MW to generate 6% and 10% of the total electricity demand by 2019 and 2024, respectively. The development of photovoltaic industry in Taiwan region of China is stable. The newly added installed capacity increased from 523 MW in 2017 to 971 MW in 2018, with an increase rate of 86%, and the cumulative installed capacity reached 2.7 GW. Taiwan, China plans to have a total installed capacity of 20 GW by 2025. The photovoltaic industry in the Philippines, Vietnam, Indonesia and other countries has great potential. In comparison, Japan's photovoltaic industry shrank for three consecutive years, with the newly increased installed capacity from 7.8 GW in 2016.Down to 7.2 GW in 2017 and 6.6 GW in 2018. According to the report of Japan Photovoltaic Energy Association (jpea), due to the restructuring of the power industry implemented by the Japanese government, Japan's photovoltaic industry will be in a period of time in the future.The industry will continue to shrink. In general, although the growth of photovoltaic industry in China, India, Japan and other countries slowed down, resulting in the reduction of installed demand in the Asia Pacific region in 2018 and the reduction of the photovoltaic market by 4%, the total market volume is still rising steadily, with an accumulated installed capacity of 295.7 GW, accounting for more than half of the global installed capacity again, and the photovoltaic market in the Asia Pacific region has become the leader of the global photovoltaic market.

3.1.4 Photovoltaic market in the Middle East and Africa:

The development of photovoltaic industry in the Middle East and Africa has great potential. In the Middle East, Israel, the United Arab Emirates and Jordan are the larger photovoltaic markets. Due to the political environment and other reasons, the new installed capacity of photovoltaic in Israel decreased significantly from 2015 to 2017, but it changed in 2018, and achieved the highest new installed capacity in many years, reaching 432 MW. Since the UAE issued its 2050 energy strategic plan in 2017, it has promoted the bidding and construction of a series of photovoltaic projects. In 2018, its new installed capacity of photovoltaic is 239 MW, which is significantly higher than before. Limited by geographical factors, the Jordanian government has also begun to vigorously develop photovoltaic technology.In 2017, the new installed capacity of PV was only 185 MW. In the future, there will be 5 billion US dollars worth of photovoltaic projects in the Middle East to be put into operation, and another 15 billion US dollars worth of photovoltaic projects to be built. In Africa, the development of photovoltaic industry in South Africa is not stable and fluctuates greatly. In 2014, South Africa became the first country with an installed photovoltaic capacity of 1 GW. Since then, South Africa light.The volt industry suddenly stopped growing and shrank (503 MW in 2016 and 172 MW in 2017).In 2018, the South African government urged Eskom, the national utility company, to sign an enterprise power purchase agreement for the 2.3 GW renewable energy project. The demand for photovoltaic installation has slightly recovered, with an additional installed capacity of 373 MW. In 2018, Egypt became the largest photovoltaic market in the African continent for the first time, with an additional installed capacity of 581 MW, and almost all of these installed capacities were installed in the solar Park of Benban, Egypt. Other countries, such as Ethiopia, Madagascar, Senegal, Zambia, Tunisia and Mozambique, have announced photovoltaic bidding projects, but there are relatively few projects actually started.

3.2 The present status in China

From 2010 to 2017, the cumulative installed capacity of solar photovoltaic power generation in China is on the rise, especially since 2013, the rate of increase is fast. In 2017, the cumulative installed capacity of solar energy photovoltaic power generation in China was 130.25 GW, an increase of 68.24% YoY. In recent years, with the " impose stringent emission control measures " slogan put forward, the role of China's solar power industry is becoming more and more obvious, in order to promote the health and sustainable development of the solar power industry, the country issued a series of related development plans.

As an important part of China's strategic emerging industries, in recent years, under the strong guidance of national policy, showing a "flowering everywhere" development trend, installed capacity to "blowout" development model has been multiplied, for three consecutive years the world ranked first. However, while achieving remarkable results, a series of problems such as overcapacity, off-grid, and abandonment of light are also becoming more and more serious. In 2015-2018, the cumulative amount of photovoltaic abandonment in the five northwest provinces reached 18.428 billion kilowatts, and the annual waste rate in some provinces reached 32.2%, resulting in serious waste of energy.

The installed PV capacity of China increased from 100,000 kW in 2007 to 77.42 GW in 2016, which is an increase of more than 700 times, with an average annual growth rate of 103%. 2010 and 2011 were the fastest-growing years, with growth of more than 200 per cent. By the end of 2016, China's total installed PV capacity was 77.GW, of which 34.54 GW was added, the largest cumulative and new installed capacity in the world. The total installed capacity of photovoltaic power plants is 67.1 GW, and the total installed capacity of distributed PV plants is 10.32 GW. In 2016, photovoltaic power generated 66.2 billion kWh, accounting for 1% of the country's total power generation.

As the largest province in the country, xinjiang had installed 8.62 GW by the end of 2016, exceeding the total installed capacity of the country's power stations by 12.85 percent, and in 2016, Xinjiang added 3.29 GW, accounting for about 10% of the total new amount in the country, up from 2.1 GW in 2015 and 590,000 kW in 2014. Qinghai is the second largest photovoltaic installed province after Xinjiang, with a cumulative installed capacity of 68.2 GW in photovoltaic power plants by the end of 2016, accounting for 10.2% of the total installed capacity of

the whole country. In the past three years, Qinghai's annual installed capacity exceeded 1 GW, and in 2016 it added 1.18 GW, accounting for about 4% of the country's total new additions in the year, a slight decrease from the 1.51 GW increase in 2015. Gansu was the largest province in the country in 2014 and 2015 with the largest installed PV capacity of photovoltaic power plants, but in 2016 it was overtaken by Xinjiang and Qinghai, making it the third largest in the country. In Inner Mongolia, the construction of ground photovoltaic power plants has grown steadily in the past 3 years, with the annual installed capacity exceeding 1.5 GW.

By 2011, there are about 115 photovoltaic companies in China, with a total capacity of 36.5gw, and the annual photovoltaic cell output reached 20GW, accounting for about 65% of the global total. Since 2005, driven by the substantial growth of international market demand, a large number of domestic enterprises have entered this field through the methods of production transformation, capacity expansion, new establishment, etc., which has promoted the domestic photovoltaic module industry to enter the fast lane of growth. There are more than 400 photovoltaic module enterprises in China, and the total output of photovoltaic modules has increased from 200MW in 2005 to 43gw in 2015. Also in 2015, China continued to become the world's largest photovoltaic application market, with an additional installed capacity of about 15gw and a cumulative installed capacity of 43gw, ranking first in the world. In 2015, the output of polycrystalline silicon exceeded 165000 tons; the output of silicon wafer exceeded 10 billion pieces, with high industrial concentration; the output of battery chip exceeded 41gw, and polycrystalline was still mainstream; the annual output of components exceeded 43gw. China has ranked first in global photovoltaic cell / module production for 8 consecutive years. In 2015, China's export of solar photovoltaic cells is expected to reach US $14.5 billion. A number of institutions predict that the global photovoltaic market will continue to maintain high-speed growth in 2016, among which Bloomberg new energy finance forecasts that the global photovoltaic market will add 64-68gw of installed capacity in 2016.

At present, china's photovoltaic industry continues to expand, the overall development of the industry is improving. By the end of 2017, China's cumulative installed PV capacity reached 130.25GW, compared with the previous solar "13th Five-Year Plan" target of only 105GW, has been ahead of schedule and exceeded the "13th Five-Year Plan" target. According to the current development trend, the market capacity of the photovoltaic industry will show a year-on-year growth trend. It is predicted that by 2023 China's cumulative installed capacity of solar energy will exceed 23 billion KW[11].

4.Strength and weaknesses of solar energy

4.1 The strength of solar energy

Under the world's resource-strapped environment, solar energy as the most economical, the cleanest, the most environmentally friendly renewable energy, will certainly be in the next few decades or even hundreds of years of energy structure is an indispensable part. The popularization and application of photovoltaic power generation will not only alleviate the world's energy shortage, but also improve the serious ecological pollution. In terms of socio-economic development, the increase in photovoltaic power generation will promote employment opportunities, manufacturing opportunities, construction opportunities will expand, China and the world economic recovery has an important role.

The development of solar photovoltaic industry in China is relatively slow at the beginning. However, with the adjustment of national policies and the extensive development and utilization of emerging energy, the development of photovoltaic power generation industry also ushered in a golden period. By 2005, the solar cell capacity required for photovoltaic power generation in China has exceeded that of developed countries, ranking first in the world. Since 2005, the polysilicon industry has gradually developed under the promotion of the development of China's photovoltaic industry. China also has a huge team of researchers for this research, including not only specialized researchers, but also highly effective graduate students, who are engaged in the research of this project. During the

11th Five Year Plan period, China's solar cell production has accounted for most of the world's share, and its growth rate is far faster than other countries in the world. More than 90% of China's solar cell products are exported[12].

4.2 The weaknesses of solar energy

(1) Dispersion: Although the total amount of solar radiation reaching the earth's surface is large, the energy density is very low. On average, near the Tropic of cancer, when the weather is relatively clear in summer, the irradiance of solar radiation is the largest at noon, and the average solar energy received on an area of 1 square meter perpendicular to the direction of sunlight is about 1000W; if the annual average is day and night, it is only 200W left and right. In winter, it's only about half, and in overcast days, it's only about 1 / 5, so the energy density is very low. Therefore, in the use of solar energy, in order to get a certain conversion power, it often needs a set of collection and conversion equipment with a large area and high cost.

(2) Instability: due to the limitation of natural conditions such as day and night, season, geographic latitude and altitude, as well as the influence of random factors such as sunny, cloudy, cloudy and rainy, the solar irradiance reaching a certain ground is both intermittent and extremely unstable, which increases the difficulty of large-scale application of solar energy. In order to make the solar energy become a continuous and stable energy, and finally become an alternative energy that can compete with the conventional energy, we must solve the problem of energy storage, that is, to store the solar radiation energy in sunny days as much as possible for use at night or rainy days, but energy storage is also one of the weak links in solar energy utilization.

(3) Low efficiency and high cost[13]: the development level of solar energy utilization is feasible in theory and mature in technology. However, because of the low efficiency and high cost of some solar energy utilization devices, the current laboratory utilization efficiency is no more than 30%. In general, the economy cannot compete with conventional energy. In the near future, the further development of solar energy utilization is mainly restricted by economy.

(4) Solar panel pollution: at present, the solar panel has a certain life span. Generally, the solar panel needs to be replaced once in 3-5 years at most, and the replaced solar panel is very difficult to be decomposed by nature, resulting in considerable pollution.

4.3 the weaknesses of photovoltaic industry

4.3.1 Analysis from the perspective of photovoltaic industry chain[14].

(1) The core technology is backward. There is a big gap between China's photovoltaic industry and developed countries in terms of core technology. Although China's Silicon ore, especially high-quality quartz silicon ore, is rich in reserves, it faces technical monopoly in the production of high-purity polysilicon, the core technology link. The key technologies and equipment in domestic polysilicon production process are still not fully mastered. The core technologies and production capacity of polysilicon raw materials are mainly concentrated in the hands of seven major international manufacturers. Compared with foreign polysilicon manufacturers, the quality of polysilicon produced by domestic manufacturers is poor due to backward core technology and small scale, and the production cost is generally higher than that of foreign enterprises. Therefore, despite the rapid increase of polysilicon production in recent years, domestic enterprises still need to import silicon materials. As the United States, Japan and other countries have the core technology of manufacturing silicon materials, which can determine the supply of polysilicon materials, Chinese photovoltaic enterprises can only carry out subsequent production after importing silicon materials from these countries, and they are in a low profit processing link in the international division of labor in the photovoltaic industry chain.

(2) High energy consumption and pollution in production.We all know that the production of industrial silicon materials is a link of high energy consumption and high pollution in the industrial chain. What is little known is that in the production process of polycrystalline silicon in China, each ton of polycrystalline silicon is purified, and the

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waste produced can be up to 14 tons. Under normal circumstances, silicon tetrachloride, a by-product of polysilicon production, should be recycled. However, at present, Chinese photovoltaic enterprises only purchase this technology at a high price from foreign enterprises that monopolize polysilicon tail gas recovery technology. Most of the manufacturers feel that the cost is too high, and they are unwilling to install the tetrachloride recovery system. At present, only a few large photovoltaic enterprises in China have installed the equipment under various pressures. If silicon tetrachloride can not be recovered in time, a large amount of silicon tetrachloride will cause air pollution in dozens or even hundreds of square kilometers once overflowed. Although China's photovoltaic manufacturing industry occupies the first place in the world, it comes at the cost of the environment. The waste treatment in the photovoltaic production process has become a bottleneck restricting the development of China's circular economy.

4.3.2 Analysis of market supply and demand of photovoltaic industry

(1) Excess capacity. China's photovoltaic industry is under the shadow of "overcapacity", photovoltaic output and application development is still seriously unbalanced. On the one hand, China has become a major country in solar photovoltaic products manufacturing. Local governments continue to regard solar energy as a priority industry and introduce various fiscal, tax, land and other preferential policies. The supply of photovoltaic products in China continues to increase as conditions permit. On the other hand, the high price of photovoltaic power generation products and the slow construction of power grid infrastructure restrict the development of photovoltaic industry in the domestic market.

(2) High external dependence of the demand market. As a photovoltaic manufacturing country, China's performance in photovoltaic application is not dazzling. Although China's photovoltaic application market has been developed with the launch of a series of photovoltaic application projects such as "Golden Sun Demonstration Project" and "large-scale power station bidding", there are no specific industrial policy rules in China to encourage residents and enterprises to use solar power generation, and compared with Europe and the United States, its market capacity is still small. More than 95% of China's photovoltaic products are exported to foreign countries. Under the background that the domestic market has not been opened yet, the unfavorable factors such as foreign markets, policies and commercial trade barriers will bring huge impact to the industry.

Trade protectionism is spreading. Driven by the interest of high yield growth space, some local governments and large enterprises and institutions in China turn to the field of photovoltaic. With continued investment in the photovoltaic industry, the huge capacity will inevitably lead to more trade protection measures. Especially in recent two years, due to the impact of the financial crisis in the United States and the debt crisis in Europe, some Countries in Europe and The United States have reduced their financial support for photovoltaic and other new energy industries. As a result, the demand for photovoltaic cells has decreased significantly and the installed market has shrunk, which makes the photovoltaic trade frictions facing China tend to turn white-hot.

5.A description of the solution proposed

5.1 environmental problem

With the development of solar energy development, the natural law should be followed, the location of solar energy collection devices such as the roof should be reasonably installed, and the relationship between the building layout should be well coordinated. In the production process of solar energy equipment, solid waste, waste liquid and waste gas emissions need to be avoided, so it is necessary to adopt more green and environment-friendly production technology. Solar cells are the main devices to collect solar energy. The production of solar cells involves the acquisition of crystalline silicon, which will produce organic compounds containing chlorine and fluorine as well as acid and alkali waste liquid[15]. If the treatment technology of these pollutants doesn’t meet the standard, serious environmental problems will be caused. The installation of solar panels needs to occupy a certain land area, which may affect the ecological environment such as soil, vegetation and climate. In addition, discarded solar panels are also an environmental problem for the development of the solar industry.

After the Chinese government encouraged the development of solar energy, a large number of factories were built, but the production process did not meet the standards, resulting in many environmental problems. Therefore, the state should formulate complete production operation standards and reward and punishment system for enterprises, and ban those highly polluting enterprises. On the other hand, money should be invested in waste treatment technology to make the production process harmless and waste solar panels can be reused[16].

5.2 Technology innovation

According to the research, solar power generation and solar heat generation are the current industrialized utilization methods of solar energy. Their advantages include high energy efficiency and mature technology. However, the total amount of solar energy radiated to the earth is extremely objective, but the low average energy density makes the energy utilization efficiency of solar panels not high. So technically, we think we can do it in two ways.

Solar power generation and heat generation, as mature technologies in research, face the challenge of how to use them in conditions of low solar energy such as cloudy days and winter. Therefore, in addition to inorganic silicon panels, we should turn our attention to the field of organic solar cells to promote the development of this field. Compared with inorganic silicon solar cells, there are more methods to improve the quantum efficiency of organic solar cells, and the production process is more conducive to realizing the sustainable goal.

In addition to the common utilization methods of power generation and heat generation, many novel utilization methods such as solar cars, solar houses[17], solar farming, solar seawater desalination and solar hydrogen production have been proposed[1819]. Although the introduction of these concepts is conducive to the diversified development of solar energy, technological breakthroughs have always been the key to practical applications. Among them, the research field pay attention to solar energy hydrogen production. Many advanced materials have been developed, but due to various reasons such as cost and hydrogen production efficiency, the practical application is still far away. But solar hydrogen production is also the most interesting application.

5.3 National policy

With the promulgation of the Renewable Energy Law of the People's Republic of China, the development of Chinese photovoltaic industry has been effectively promoted. In Chinese sustainable development, energy issues and environmental issues are very remarkable. In terms of the current international situation, solar energy has a good opportunity for development. Feed-in tariff and financial subsidy can be an effective incentive policy to promote the development of solar energy[20]. The development of solar energy in the world is extremely uneven. Among them, developing countries started lately, so they should conduct more technical exchanges and cooperation with other fully developed countries. The country should balance the distribution of solar energy. In developed areas, the proportion of solar energy is relatively low, and the use of solar energy in areas with high energy consumption should be increased, rather than being used as auxiliary energy in poor areas[21].

Currently, Chinese photovoltaic industry relies on imports for raw materials and various devices and lacks independent capabilities[22]. The country should establish national labs for basic experimental research and establish a complete photovoltaic industry chain. In addition, the photovoltaic industry demonstration base can be established to avoid the blind expansion of the photovoltaic industry[2324].

As a major producer and exporter of solar panels, the development of the photovoltaic industry depends on foreign demand, while the domestic market is in urgent need of development. China has a vast territory, sparsely populated western regions, where abundant renewable solar and wind energy resources is rich. The present situation of Chinese energy demand is that the west is rich in energy and low in energy consumption, while the east is high in energy consumption and low in energy reserves, which cannot meet the needs of social development. Therefore, the country

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should build solar and wind power plants in the western region, and then transmit the electricity to the eastern region through the transportation network.

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Master Program on Bio-Based Circular Economy

Course of Renewable Energy Technologies

Solar Energy in China

Students: Huirui_Yang, Wenli_Wang, Shanshan_Feng Xiaomei_Lei, Ping_Hu

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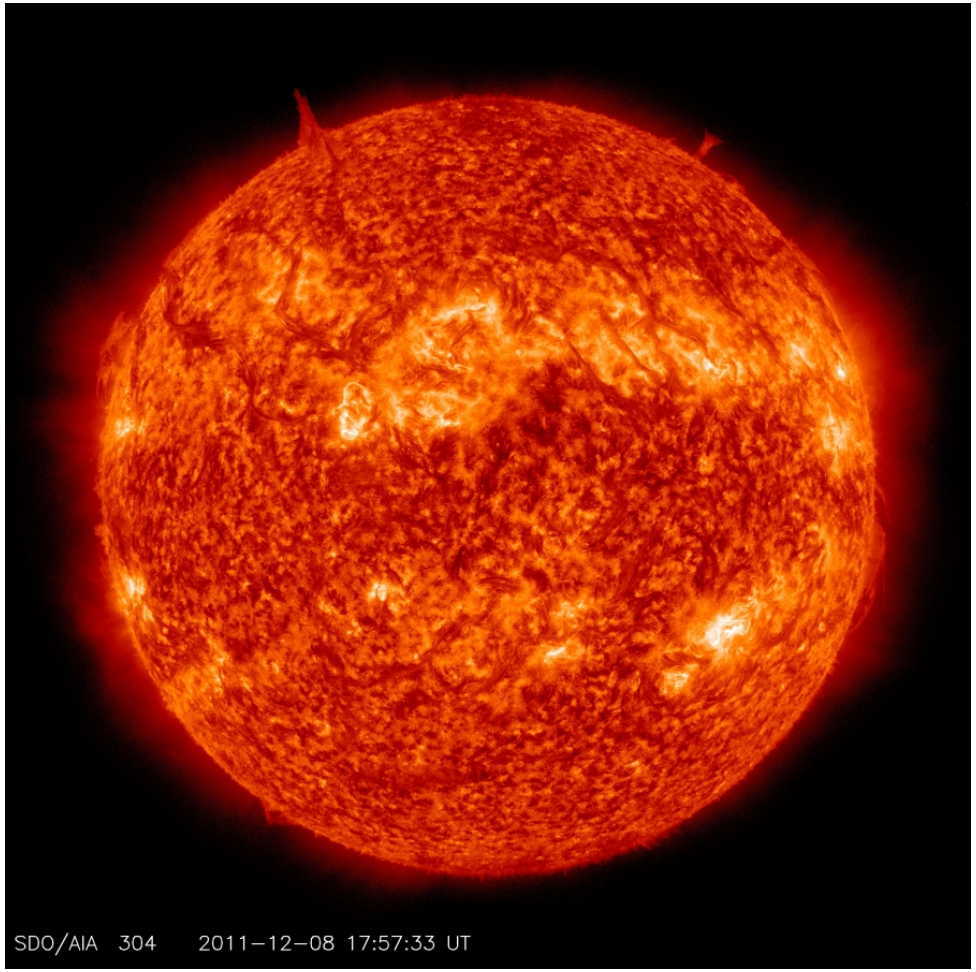
CONTENTS

- Background
- Description of the technologies
- The present status of solar energy
- Strength and weaknesses of solar energy
- A description of the solution proposed

Background

Huirui_Yang

1.1 Brief introduction



Solar energy is the energy from the earth's outer bodies. The sun is a huge energy body, energy mainly derived from the fusion reaction of hydrogen into helium, the capacity power (i.e. the energy generated per second) is about 3.8 x 10^{23} kW. The earth receives only one-2.2 billionth of the total solar radiation, but it also has about 1.7 x 1014 kW. Most of the energy we need comes directly or indirectly from the sun.

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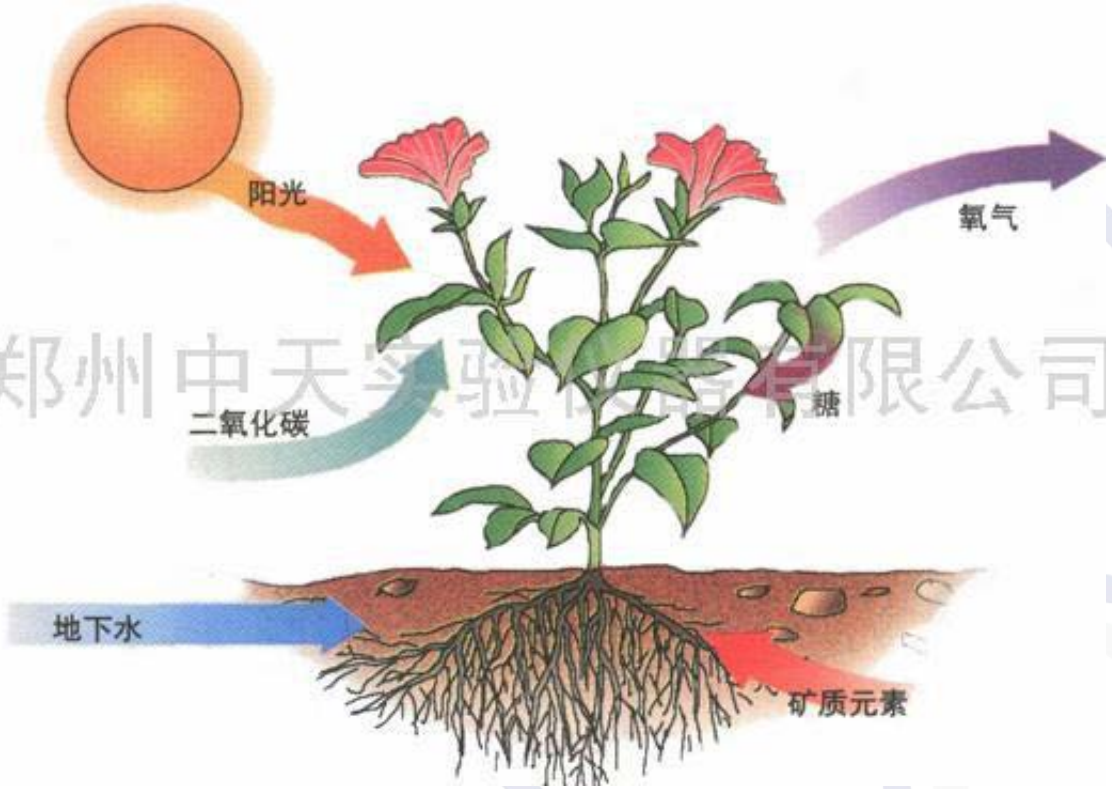
1.1 Brief introduction

- Plants release oxygen through photosynthesis, absorb carbon dioxide, and convert solar energy into chemical energy to store in plants. Most of the energy on earth comes from solar energy.
- solar energy resources have good development conditions and application prospects



1.1 Brief introduction

Distribution of solar energy resources in China: solar energy resources are widely distributed in China. According to the division standard of wind energy and solar energy assessment center of National Meteorological Administration, solar energy resources in China can be divided into the following four categories

Class Ⅰ area: the annual solar radiation is very large

Class II area: the annual solar radiation is large

Class IV area:the annual solar radiation is very small

Class III area: the annual solar radiation is in medium scale

1.2 Advantages and disadvantages

1.development level of solar energy utilization is limited

2. energy density is very low

3. not stable and continuous

1. widely distributed and utilized without regional restrictions

2. total amount is the largest exploitable energy

3. clean energy

4. Inexhaustible

In China
(1) Backward core technology.
(2) High energy consumption and pollution in production.
(3) Overcapacity.
(4) High external dependence of demand market.
(5) Trade protectionism spread.

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1.3 Application of solar energy resources

Solar collector is a kind of equipment which can convert the radiant energy of the sun into heat energy. The most common device is the solar water heater.

Solar thermal power generation is a kind of power generation method that first converts solar energy into heat energy, and then converts heat energy into electric energy.

Solar energy is the energy of refrigeration and air conditioning. Solar driven air conditioning system has good seasonal adaptability.

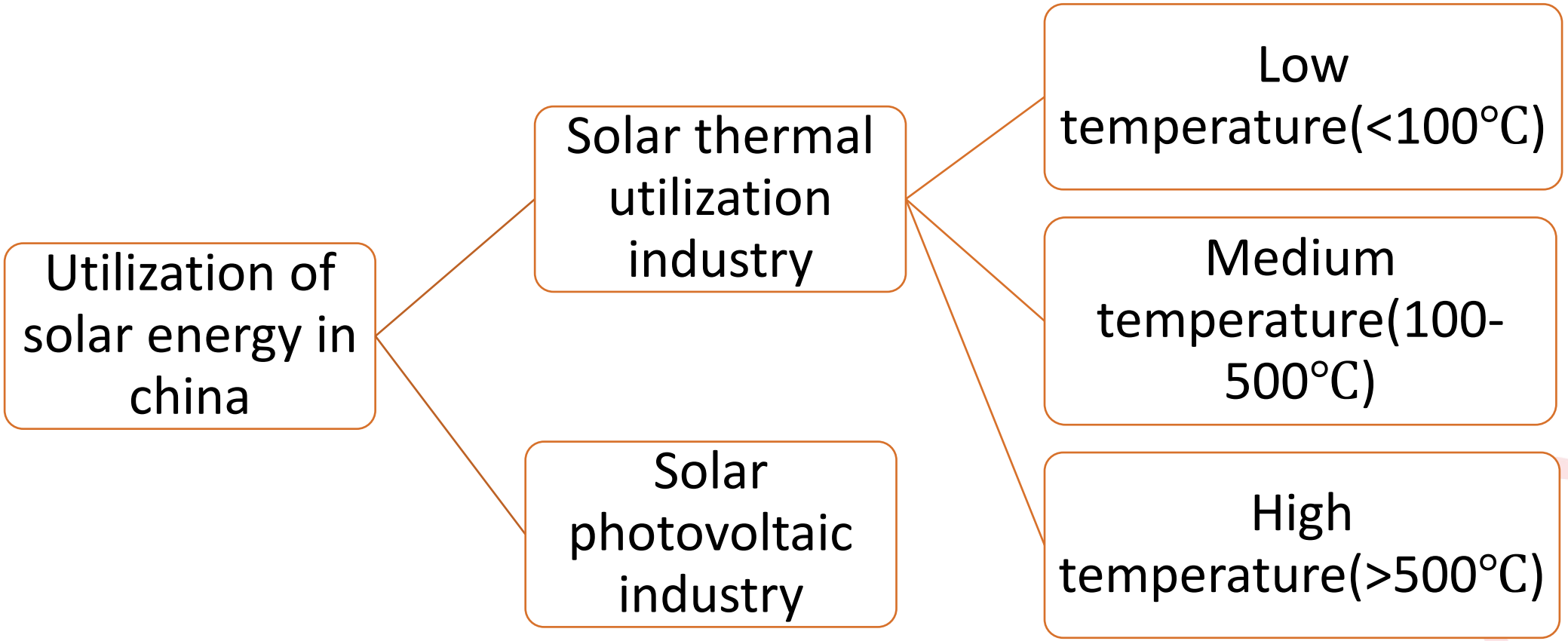
Description of the technologies

Wenli_Wang

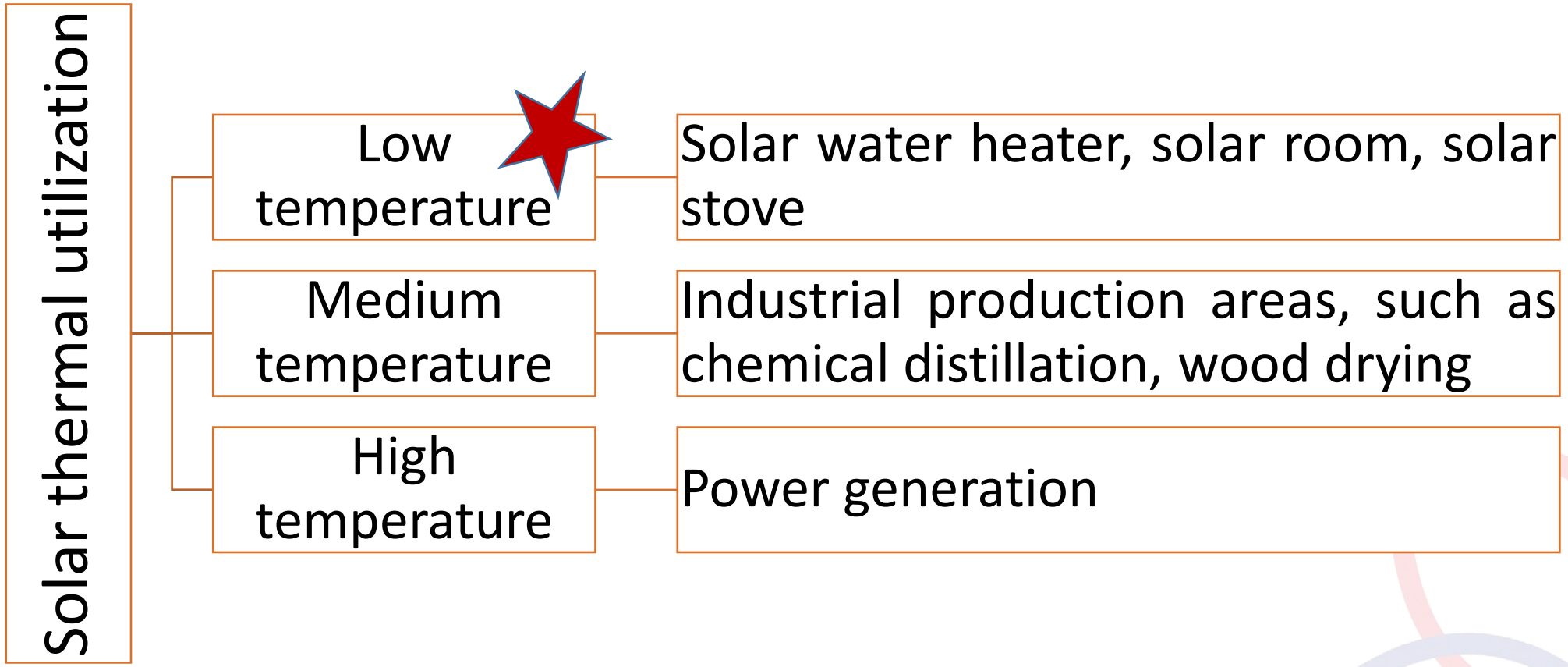
2.1 Seven technical fields of solar energy utilization

The way of utilization	Technology and principles
photothermal utilization	Directly through the focus of the sun's radiant energy to generate heat and use it.
photothermal power generation	Large-scale condensers are used to condense the solar thermal energy to heat the medium in the receiver and convert it into mechanical energy through the heat exchange device, and then drive the generator to generate electrical energy.
Direct use of thermoelectricity	Using thermoelectric conversion materials by Seeback and Peltier, directly converts thermal energy into electrical energy.
photoelectric utilization	Using the principle of photovoltaics to generate direct current, directly convert solar radiation energy into electrical energy, and store the electrical energy in the battery pack to provide stable DC power when needed.
Actinic utilization	Direct decomposition of solar radiation energy to form a photochemical conversion method of water to hydrogen.
Photobiological utilization	A method of using plant photosynthesis to convert solar energy into biomass energy.
Photo-thermal photoelectric comprehensive utilization	Integrate technologies such as splitting, concentrating, and combined heat and power, and comprehensively utilize the full-band energy of solar energy.

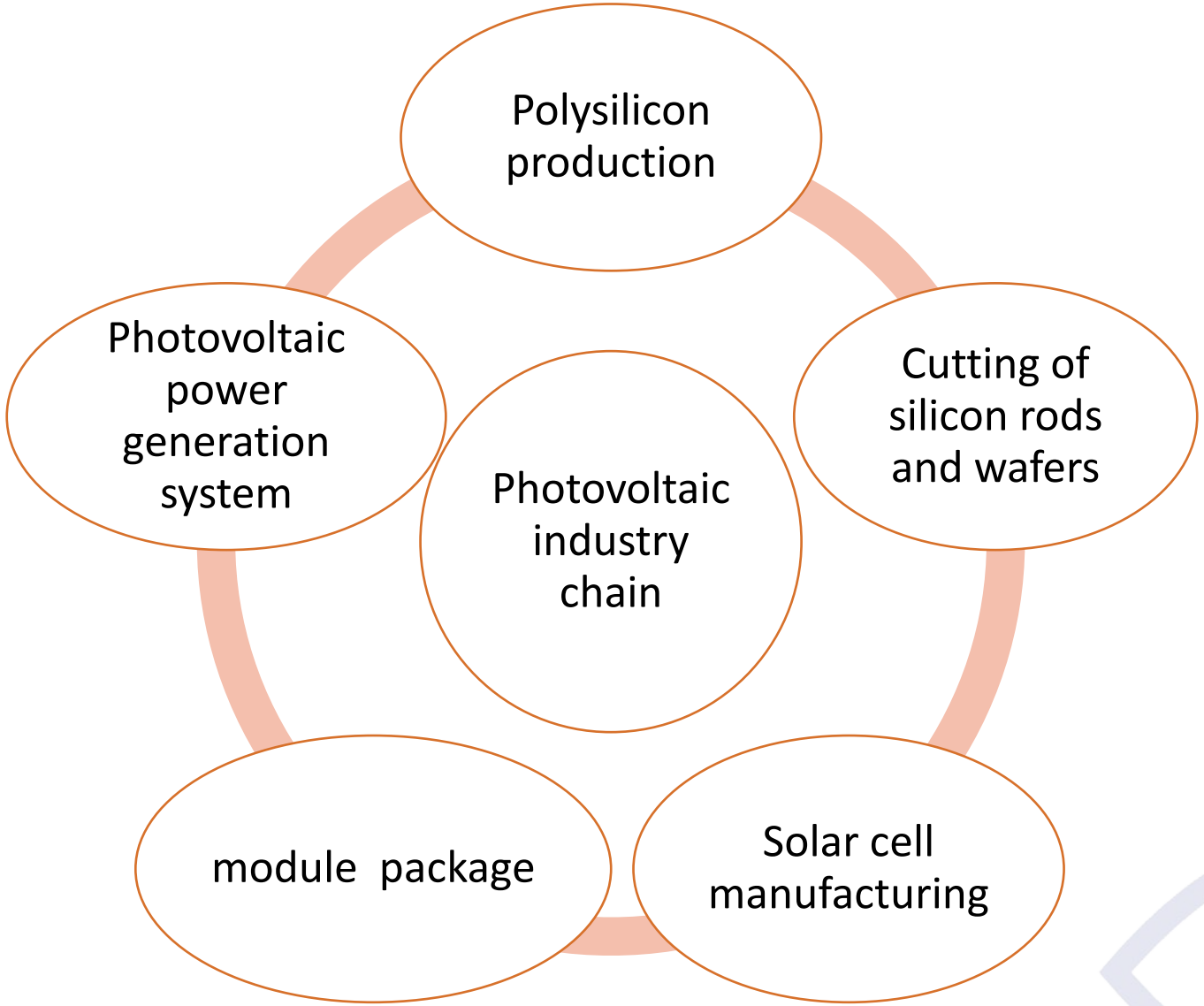
2.2 Utilization of solar energy in china



2.3 Solar thermal utilization industry



2.4 Solar photovoltaic industry



The present status of solar energy

Shanshan_Feng

3.1 Global photovoltaic research status

From 2017, the European photovoltaic market began to show signs of recovery, and has maintained steady growth year by year.

European PV market

America PV market

The overall development of photovoltaic market in America is relatively stable, especially in South America.

The leading position of photovoltaic industry in Asia Pacific region (including China) is further expanded, and from 2018, it has become the leader of the global photovoltaic market.

Middle East and Africa PV market

Asia Pacific PV market

The development of photovoltaic industry in the Middle East and Africa has great potential. In 2018, Egypt became the largest photovoltaic market in the African continent for the first time.

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3.2 The present status in China

From 2010 to 2017, the cumulative installed capacity of solar photovoltaic power generation in China is on the rise, especially since 2013, the rate of the increase is very fast.

In 2017, the cumulative installed capacity of solar energy photovoltaic power generation in China was 130.25 million kW, with an increase of 68.24% YoY.

It is predicted that by 2023 China's cumulative installed capacity of light will exceed 23 billion KW.

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3.2 The present status in China

- By 2011, there are about 115 photovoltaic companies in China, with a total capacity of 36.5 million kW, and the annual photovoltaic cell output reached 20 million kW, accounting for about 65% of the global total.
- In 2015, China continued to become the world's largest photovoltaic application market, with an additional installed capacity of about 15 million kW and a cumulative installed capacity of 43 million kW, ranking first in the world.
- By the end of 2016, China's total installed PV capacity was 77.42 million kW, of which 34.54 million kW was added, became the largest cumulative and new installed capacity in the world.
- The installed PV capacity of China increased from 100,000 kW in 2007 to 77.42 million kW in 2016, which is an increase of more than 700 times, with an average annual growth rate of 103%. 2010 and 2011 were the fastest-growing years, with growth of more than 200%.

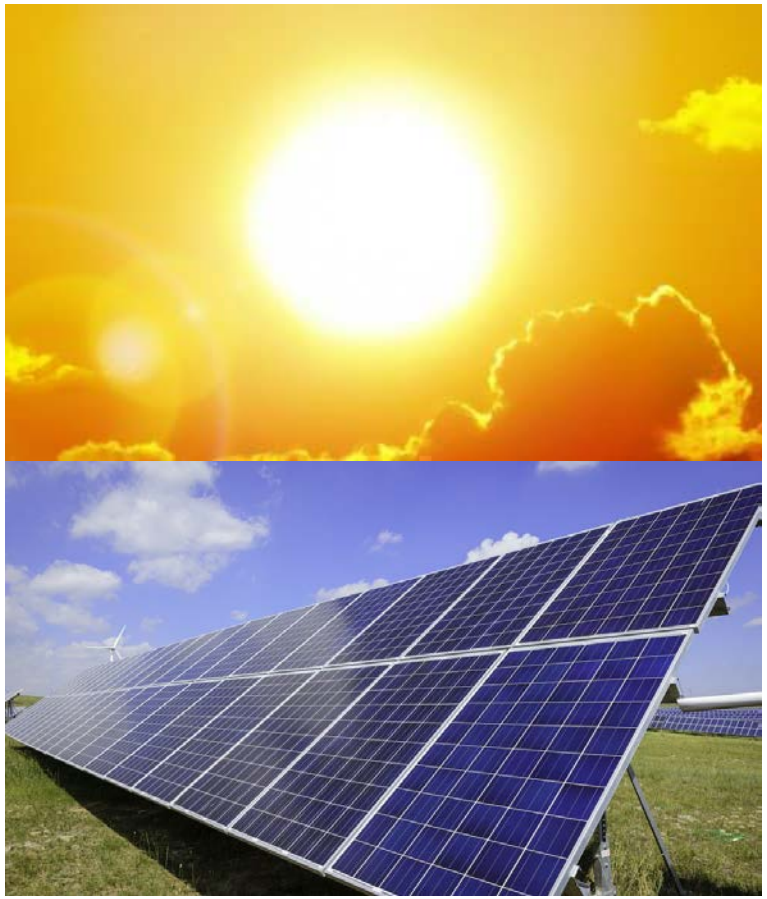
3.2 The present status in China

- As an important part of China's strategic emerging industries, in recent years, under the strong guidance of national policy, PV capacity showing a “blossom everywhere" development trend, and ranked first all over the world for three consecutive years.
- However, a series of problems has appeared while achieving remarkable results, such as overcapacity, off-grid, and light abandonment.
- In 2015-2018, the cumulative amount of PV abandonment in the five northwest provinces reached 18.428 billion kW, and the annual waste rate in some provinces reached 32.2%, resulting in serious waste of energy.

Strength and weaknesses of solar energy

Xiaomei_Lei

4.1 The strength of solar energy



- As the most economical and clean renewable energy, solar energy will become an indispensable part of the energy structure in the future.
- The popularization and application of photovoltaic power generation can not only alleviate the energy shortage in the world, but also improve the serious ecological pollution. From the perspective of social and economic development, the increase of photovoltaic power generation will promote employment opportunities, promote the development of manufacturing industry and construction industry, and play an important role in the recovery of China and even the world economy.

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4.1 The strength of solar energy

Development of photovoltaic industry in China:

In 2002, China's photovoltaic industry started. During the "Tenth Five Year Plan" period, China has carried out research on key technologies such as crystalline silicon high-efficiency battery in the research and development of photovoltaic power generation technology, greatly improving the level of photovoltaic power generation technology and industry, and shortening the gap between photovoltaic power generation manufacturing industry and international level.

After 2010, under the background of European photovoltaic industry demand slowing down, China's photovoltaic industry rose rapidly and became the main driving force of global photovoltaic industry development. In 2017, China's new grid connected installed capacity reached 53gw, with a year-on-year growth of more than 50%, and the cumulative grid connected installed capacity reached 131gw, ranking first in the world. With the photovoltaic power generation industry has entered the era of affordable access to the Internet, the domestic photovoltaic industry still has a huge development space in the future.

4.2 The weaknesses of solar energy

Dispersion

Although the total amount of solar radiation reaching the earth's surface is large, the energy density is very low.

Instability

Due to the limitations of weather, day and night, season, geographic latitude, altitude and other natural conditions, the solar radiation reaching a certain ground is intermittent and extremely unstable.

Low efficiency and high cost

Solar energy utilization is feasible in theory, but some solar energy utilization devices are low efficiency, high cost, and can not compete with traditional energy economically.

Solar panel pollution

The solar panel has a certain life, and the replaced solar panel is difficult to be decomposed naturally, causing considerable pollution.

4.2 The weaknesses of solar energy

Analysis from the perspective of photovoltaic industry chain

- The core technology is backward
- High energy consumption and pollution in production

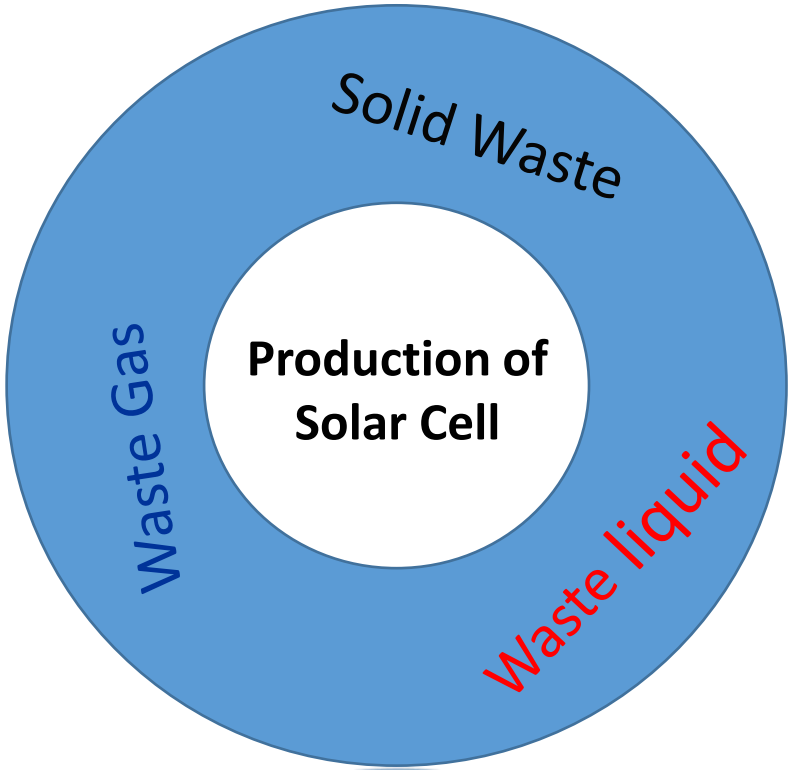
Analysis of market supply and demand of photovoltaic industry

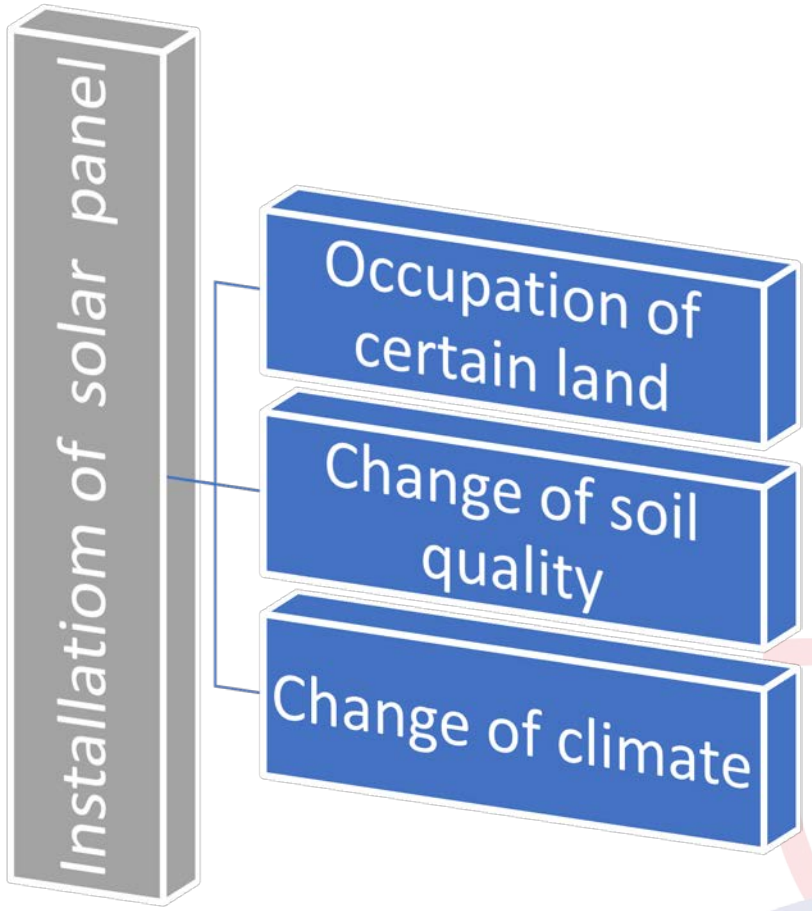
- Excess capacity
- High external dependence of the demand market
- Trade protectionism is spreading

A description of the solution proposed

Ping_Hu

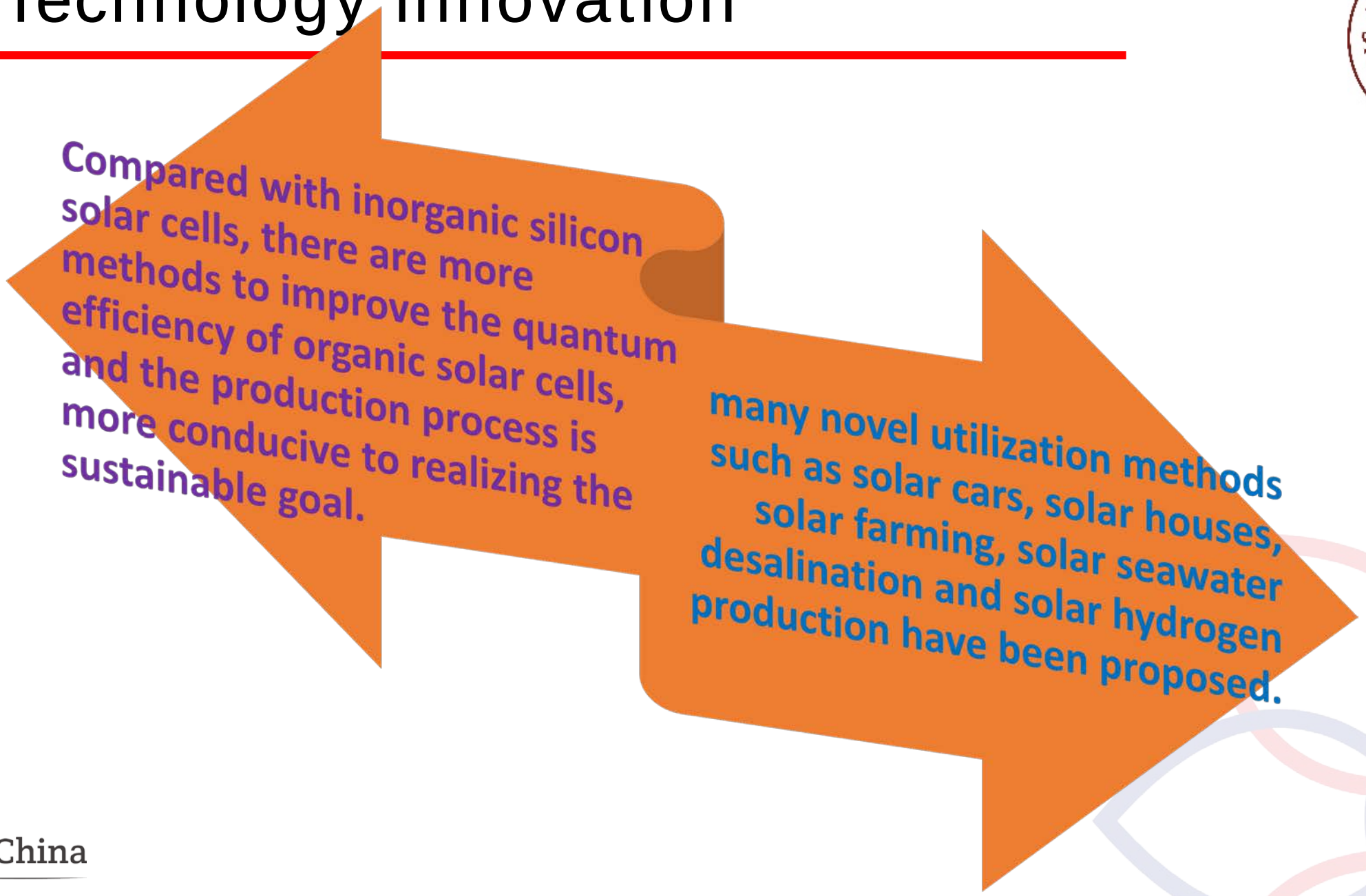
5.1 Environment Problem





5.1 Environment Problem

5.2 Technology innovation



5.3 National policy

The technology is not mature in the developing country	• More technical exchanges and cooperation with other fully developed countries • Feed-in tariff and financial subsidy can be an effective incentive policy to promote the development of solar energy
Chinese photovoltaic industry relies on imports for raw materials and various devices and lacks independent capabilities	• The country should establish national labs for basic experimental research and establish a complete photovoltaic industry chain
As a major producer and exporter of solar panels, The development of the photovoltaic industry depends on foreign demand	• the domestic market is in urgent need of development

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Thanks for listening