Current Situation and Challenges of Indian Solar Energy Development

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Abstract

Under the common pressure of global climate change and domestic energy demand, India began to attach importance to the development of new energy. Because of the unique solar energy resources endowment and the lower costs of solar energy construction, solar energy has become the first choice for India in the development of new energy. In order to promote the development of solar energy industry rapidly, the Indian government has put forward the ambitious goal that the solar energy installed capacity reaches 100GW in 2022. Meanwhile, the government also set up a special solar energy management department, which introduced a series of supporting subsidy policies and incentive measures, and strengthened the construction of electric transmission lines. At the same time, the department devoted itself to international cooperation which can improve the development and utilization of solar energy in India. By the end of March 2017, Indian solar energy installed capacity has reached 12.2 GW, which was expected to overtake Japan as the world's third largest solar photovoltaic market in the future. The annual installed capacity of rooftop solar energy also soared from 32MW in 2013 to 227MW in 2016, and the accumulative installed capacity reached 1247MW in end of 2016, and the small size photovoltaic solar systems have also been promoted. At the same time, the solar water heaters, solar cookers, solar photo-thermal power generation, and other photo-thermal utilization have also achieved remarkable results. However, the implementation of the development goals of Indian solar energy in the future is not optimistic. There are some problems such as development planning is out of touch with reality, land expropriation costs are very high, corruption in administrative institutions is prevalent, basic data such as solar radiation is missing, people are lacking purchasing capability and local industries are falling behind, and other real problems have remained to be the major obstacles to the further development of the Indian solar energy industry.

Keywords**:** *India, solar energy, Photovoltaic power generation, Rooftop solar energy, Construction costs of solar energy.*

1. Introduction

Low-carbon development is increasingly becoming important in global development. India is the third-largest economy in Asia, 68% of its electricity is still derived from fossil fuel power station. The high dependence on coal is not conducive to the upgrading and transformation of domestic industries. At the same time, fossil fuel power station also caused a series of environmental problems in India. In recent years, India has been trying to seize the opportunities in the new round of low-carbon revolution to achieve a transformation to cleaner forms of energy. Firstly, India strives to diversify its supply sources and makes up for the long-term power shortages. Secondly, India is committed to reducing the dependence on traditional energy sources. Thirdly, India participates in the process of building a global low-carbon system and strives to have a greater says in the new round of industrial revolution, development revolution, and low-carbon revolution. In that context, developing solar energy resources became an important opportunity for the Indian government to achieve low-carbon development. It is of great significance to effectively strengthen the mutually beneficial cooperation between China and India in the new energy field.

2. Objectives

1. To explore motives and current situation of solar energy development and utilization in India.
2. To analyze the challenges faced by India's solar energy development.
3. To grasp the latest trends of India's energy transformation in the future.

3. The driving force of India's solar industry

3.1 The abundant solar energy resource created the premise for the development of solar energy industry in India

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The development of solar energy has become India's focus in the new energy field, owing to the rich solar resource. India is one of the most solar-rich countries in the world, and most part of India is located in the tropics and subtropics. According to the estimates, most parts of India have about 250 to 300 days of light per year, especially in the central and northwestern regions (GENI, 2013). Average annual solar radiation arriving at India is 20MW/km^2, and the daily sunshine intensity is up to 4 ~ 7kW·h/m^2 (MNRE, 2017).

In addition, the power generation potential of India's solar energy resources (750GW) far exceeds other renewable energy such as wind energy (102GW, 80m altitude, excluding offshore wind resources), small hydropower (20GW) and biomass energy (25GW). It is not hard to find that abundant solar energy resource is an important reason for the Indian government to favor solar energy among other clean energies.

3.2 The Power shortage prompted the Indian government to develop the solar industry

India's economic and social development had long been plagued by power shortages. As far as economic development is concerned, power shortages are a serious constraint to the development of the Indian economy. According to the World Bank, the power shortage caused the Indian economy to lose 7% of the country's gross domestic product (JiRong, 2017). At the end of July 2012, large-scale power outages in India caused power outages in more than 20 states and affected more than 600 million people, even the Indian companies lost hundreds of millions of dollars (Li, 2015).

As far as the level of social development is concerned, although the Indian government has achieved many achievements in solving the people's electricity demand in recent years, the rural areas still face severe challenges of power shortage. According to the International Energy Agency, as of 2013, there were still more than 240 million people in India who have no electricity available (IEA, 2015). In particular, more than 60 percent of remote rural areas still relied on traditional fuels such as wood, diesel, and kerosene. The power shortages in India have severely affected education, health care and development in these parts of India, leaving them far behind central cities and towns.

It can be seen that power shortage become one of the major constraints to India's social and economic development. Therefore, the development of solar energy is not only a popular project that can provide the electricity to the vast remote areas of India, but also alternative energy to alleviate the power shortage in central cities of India.

3.3 The demand of electricity prompted the Indian government to further develop solar energy

India's electricity demand grew from 376 terawatts in 2000 to 897 terawatts in 2013 (IEA, 2015). According to the Planning Commission of India, if the growth rate of India's demand for energy stays at 8%, India's demand for energy will increase three to four times by 2031 as much as it does now, and its need for electricity increase five to six times (Jirong, 2017). In addition, with the development of the economy and the increase in people's income, the demand for indoor refrigeration systems in Indian society also exploded. In recent years, the annual sales growth rate of air conditioners reached 20% in Indian (IEA, 2015). This leads to a rapid increase in the demand for electricity during the summer, which will undoubtedly increase the pressure on the government.

At present, India is in a critical period of economic transformation. And adequate power supply will be an important guarantee for the success of the transition. How to fill a huge gap in power demand will become a major challenge for the Indian government, so solar energy is undoubtedly one of many options.

3.4 The fall in solar costs presents an important opportunity for India to develop solar energy

As a systematic project, the cost of solar energy mainly includes power conversion equipment cost, land acquisition cost, and labor cost. In recent years, although the cost of land acquisition in India increased year by year, with the continued maturity of solar technology (cables, transformers, power conditioners, fixed materials, and solar panels) fallen sharply, the cost of solar energy construction is generally declining in India (Figure 1). Among these, the price of solar panels which is the most critical part of solar equipment had dropped significantly. The average global production cost of solar panels was as

high as $76.67 per watt in 1977 and dropped to $0.613 per watt in 2013 (Wang and Zhao, 2016). In this context, the global construction cost of photovoltaic power generation had also been reduced. According to the research report, the average cost per kilowatt-hour of photovoltaic power globally fell to $122 MW/h in 2015 from $129 MW/h in the first half of the year. And the cost of coal power generation in the Asia-Pacific region rose to $93 MW/h from $85 MW/h in the same period.

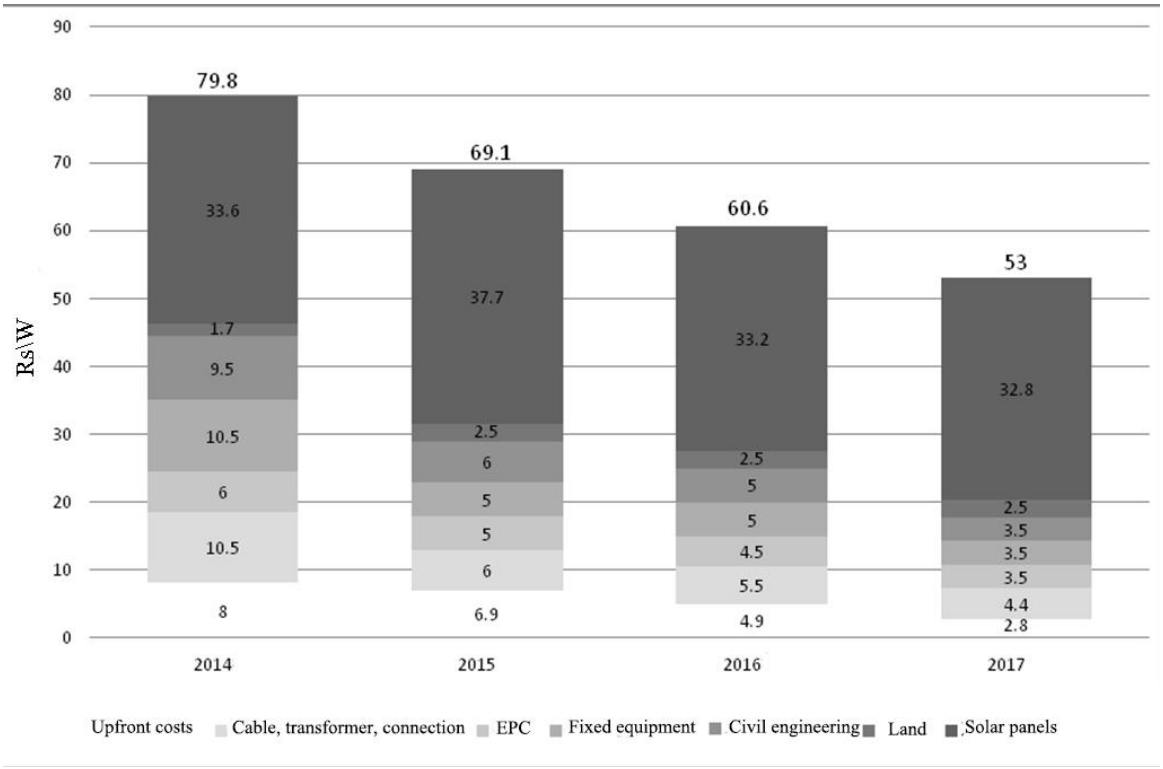

Figure 1 The cost and expenditure of PV construction in India from 2014 to 2017

As global solar equipment prices and PV construction costs continue to fall, Indian solar equipment prices and PV construction costs were also falling. According to data from the Ministry of New and Renewable Energy, the cost of photovoltaic power generation in India dropped to $0.12 (kW/h) in 2015, and the cost of solar thermal power generation dropped to $0.21 (kW/h). India had become one of the countries with the lowest cost of solar grid-connected power generation in the world. In terms of Indian solar equipment prices, the price of solar panel India in 2017 was Rs 22, 8% lower than the previous year. The inverter of solar power was Rs 1.9, down 5% from the previous year. The total price of solar power was Rs 35, downing 8% than the previous year (Bridge to India, 2017). This means that the cost of solar power in India had bottomed out to a level, which closes to the cost of traditional energy generation.

3.5 The pressure of global climate change prompted the Indian government to develop the solar industry

In recent years, climate change has become the focus of global attention. India is the world's fourth-largest greenhouse gas emitters. India always believed that the global warming crisis is nothing more than a "conspiracy of Western countries". About 70% of India's electricity was generated by minerals, mainly coal. Thus, the rapid development of India's economy is accompanied by a large amount of greenhouse gas emissions. According to the Environment and Climate Change Canada, India accounted for 5.1% of the world's greenhouse gas emissions in 2005, emitting 1.97 billion tons of greenhouse gases. In 2013, India's greenhouse gas emissions accounted for 6.4% of the world's total emissions, about a total of

2.909 billion tons. In 2005-2013, India's greenhouse gas emissions increased by 47.6%. While India refused to accept emissions and strut pollutant control indicators, it faced the challenges of increased extreme climate (MOECC, 2017). Therefore, the Indian government was forced to face the domestic and international pressures of energy conservation. At the 21st United Nations Framework Convention on Climate Change conference in Paris in 2015, India pledged to increase the capacity of clean energy power generation to 40% by 2030 (MNRE, 2016). In the future, if India achieves the new goal of 100 GW of solar energy development, it will not only promote India's long-term energy security but also reduce its dependence on fossil fuels and emissions of more than 170 million tons of carbon dioxide (Nilekani, 2011).

4. Initiatives to promote the development of the solar industry was stimulated

As mentioned above, the Indian government had gradually identified the development of solar energy as an important way to achieve low-carbon development. Although the Indian solar industry started late, in order to promote its breakthrough on the existing basis, the Indian government formulated an ambitious solar development plan for the actual situation in the country and introduced a series of supporting measures to promote solar energy promotion.

4.1 Strategy and policy plan for developing solar energy was formulated

India's strategy for developing solar energy first started in India's 11th Five-Year Plan for New Energy and Renewable Energy in 2008. At this meeting, the Indian government introduced the National Action Plan on Climate Change and established a new goal of energy development from 2008 to 2012. It was estimated that solar photovoltaic power generation accounted for 10% of India's electricity demand by 2012. Subsequently, the Indian government had successively issued a series of policy plans to actively invest and develop solar energy.

In August 2009, the Indian government launched the Jawaharlal Nehru National Solar Mission, announcing that the solar grid-connected power generation capacity would be increased to 20 GW by 2022. At the same time, the solar water heater heat collection area reached $2000\times104m^2$. As one of the eight key tasks of India's National Action Plan on Climate Change, the program was committed to creating a favorable policy environment for the development of solar energy in India, making India become a pioneer and even a leader in the global solar industry. The plan was initially divided into three phases (Table 1). Under the guidance of the plan, India's solar energy development had achieved remarkable results. In 2008-09, India's solar capacity was only 3MW, and it reached 2101MW in 2013-14 (Gulati, Manchandaand Kacker, 2016).

Table 2 Phased operation of the "Jawaharlal Nehru National Solar Mission" program

The class type	The first phrase(2010～2013)	The second phrase(2013～2017)	The third Phrase(2017～2022)	Unit
Grid-connected solar system (including rooftop solar)	1100	10000	20000	MW
Off-grid solar system	200	1000	2000MW	MW
Solar collector	700×10^4	1500×10^4	2000×10^4	m^2

After Modi took office in May 2014, he continued to support solar energy development. In October, the Indian government announced that the goal of solar power planning would be greatly increased to 100GW. In December, the Indian government announced that it would build more than 10 large-scale solar power parks in different states. In June 2015, the Indian government approved the development plan, which was to achieve 40GW of rooftop solar power and 60GW of ground solar power (Table 2).

Table 2 Indian grid-connected solar power plant target

Type	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	Total	Unit
Rooftop solar energy	200	4800	5000	6000	7000	8000	9000	40000	MW
Surface solar energy	1800	7200	10000	10000	10000	9500	8500	57000	MW
Total	2000	12000	15000	16000	17000	17500	17500	97000	MW

The development and utilization of solar energy were put on the table in Indian states, including Andhra Pradesh, Chhattisgarh, Haryana, Gujarat, and Himachal. State, Jammu-Kashmir, Karnataka, Kerala, Madhya Pradesh, Rajasthan, Tamil Nadu, Telangana, Uttarakhand, Uttar Pradesh, Jakan Debon, Orissa. At present, 16 states in India have clearly stated their solar energy development goals in accordance with the requirements of the Ministry of New Energy and Renewable Energy (Gulati, Manchanda and Kacker, 2016). In addition, in 2015-16, five states with almost zero solar capacity put forward the solar energy development goals. Bihar, Dammam-Dubub, and Jammu-Kashmir installed solar installations of 5.1MW, 4MW, and 1MW respectively; Himachal Pradesh and Mizoram each added 0.2MW of solar energy equipment (Gulati, Manchanda and Kacker, 2016). In 2016, Tamil Nadu's solar power generation ranked first among all states in India, then the capacity of 1,368 MW was followed by Rajasthan (1307 MW). Gujarat (1112 MW), and Andhra Pradesh (961 MW), Telangana (923MW) and Madhya Pradesh (756MW), which account for more than 80% of India's total solar power generation.

4.2 India introduced relevant supporting measures

Firstly, the Indian government had set up a dedicated solar energy management department to build related databases. In order to achieve a balance between power shortages and power demand, India had been working to explore a new program. In 1992, India established the Ministry of Non-conventional Energy Sources to promote commercial or near-commercial renewable energy technologies. In 2006, India renamed the Department of Unconventional Energy to the Department of New Energy and Renewable Energy. Its main task is to broaden access to energy and meet the country's energy needs. Under the guidance of the Ministry of New Energy and Renewable Energy, the Indian government began to focus on the development of solar energy. In order to better promote solar projects across the country, the Indian government also approved the establishment of the National Institute of Solar Energy in 2013, which will serve as a major hub for the promotion and use of solar energy between governments, industries, and users. The agency also assists the Ministry of New Energy and Renewable Energy to implement the national solar energy plan. The main tasks include solar equipment testing, solar energy resource assessment, and solar technology training. In addition, the Indian government approved the establishment of the Solar Energy Corporation of India. The large-scale projects dedicated to the use of rich solar Radiation resources guarantee national energy security and create "Green India".

Secondly, in order to achieve the development goal of 100 GW of solar grid-connected power generation at the 75th anniversary of India's independence, the Indian government introduced a series of supporting subsidy policies and incentives. In terms of investment, the Indian government expected to invest about 6 trillion rupees to help develop and utilize solar energy. In terms of government subsidies, solar companies decided to support the 4,835 MW solar project with the Adaptive Compensation Fund (VGF), which aims to provide financial support for infrastructure projects. At the end of March 2017, with the support of the Indian Solar Energy Adaptation Compensation Fund, a total of 785MW solar projects were successfully tendered (Bridge to India, 2017). In terms of tax incentives, the Indian government stipulates that fixed assets engaged in solar industry development investment can be calculated at an accelerated depreciation rate of up to 80%. In addition, the Indian government implemented a tax reduction policy for its solar energy companies and projects.

Thirdly, India strengthens the construction of transmission lines. The backwardness of power infrastructure was the main source of power shortages in India. According to the US Energy Agency (EIA), India's transmission and distribution loss rate was 30%, and the average of the world was 9%. Facing such amazing power loss, even if India had strong solar power generation capacity, it is difficult to meet the power demand across the country. Therefore, the Indian government invested 127 billion rupees for the building of transmission lines for solar power. The project was an important part of India's "Green Energy Corridors" project, which delivers electricity from 34 solar parks to the entire country. According to the agreement, 20% of cost came from the government, 40% of it came from the National Clean Energy Fund, and the remaining 40% will be in the form of concessional loans (Upadhyay, 2016).

4.3 India promote international cooperation in solar energy field actively

Firstly, international organizations such as the World Bank, the Asian Development Bank, and the BRICS New Development Bank have become important sources of funding for solar energy development in India. In June 2016, the World Bank announced that it will provide India with a $1 billion loan in 2017 to support the Indian government in its 2022 solar development plan, which will be used primarily for the installation of solar energy in India's rooftop solar energy park. Facility construction and improvement of solar power transmission lines (World Bank Group, 2016). The loan was the largest support loan from the World Bank for solar projects. In addition, the World Bank Board of Directors approved a total of $625 million in grid-connected rooftop solar energy (GRPV) to support the Indian government's accelerated construction of rooftop solar power plants, including the World Bank's $500 million loans, Clean Technology Fund (CTF). Providing $120 million, and the remaining $0.05 billion was provided by the Clean Technology Fund as a donation (The World Bank, 2016). In 2016, the Asian Development Bank approved a $500 million multi-funded Solar Roof Investment Program (SRIP) to fund the construction of rooftop solar energy in India (World Bank, 2016). In 2016, the Asian Development Bank approved a $500 million multi-funded Solar Roof Investment Program (SRIP) to fund the construction of rooftop solar energy in India. The Asian Development Bank also provided a $175 million loan to the Indian Power Company (POWERGRID) to help India diversify its power mix and increase energy security by increasing clean energy, especially solar energy (Asian Development Bank, 2016). The newly established BRICS New Development Bank also placed $250 million of the first $8.11 million in loans to the solar industry in India.

Secondly, the countries with relatively mature solar energy industries such as the United States, Germany, and China have become the main targets for India to seek solar energy cooperation. During the Indian Prime Minister Modi's visit to China in May 2015, he signed 26 agreements with the Chinese government with a total value of up to 22 billion U.S. dollars, four of which are related to strengthening cooperation in the solar energy field. During the German Prime Minister Merkel's visit to India in October 2015, he signed a memorandum of understanding with Modi in the solar industry cooperation field. In the next five years, Germany will be the roof solar energy, solar park and solar off-grid facilities in India. During Modi's visit to the United States in June 2016, he reached an agreement with US President Barack Obama to jointly create a US$20 million US-India Clean Energy Financial Plan (USICEF), which was expected to provide US$400 million in clean energy development to India in the future. The two countries also signed a US$40 million US-India solar financing project, which is expected to achieve financing of up to US$1 billion in the future.

Thirdly, the Indian government was actively promoting the introduction of global initiatives for solar energy development and utilization on the international stage. At the end of November 2015, Modi and French President Hollande jointly launched the International Solar Alliance during the Paris Climate Change Conference, which will become an important part of solar energy cooperation among 121 solar-rich countries. The Platform was committed to improving solar energy utilization through mutual cooperation to achieve mutual benefit (MNRE, 2016). The organization's participating countries are mainly from Latin America and Africa, as well as the United States, China, and France. The Indian government was trying to strengthen cooperation with the world's leading solar energy companies through the International Solar Energy Alliance to break through the technical difficulties and financing challenges of its own solar energy construction; on the other hand, it was also trying to provide solar technology and personnel for the underdeveloped regions of the solar energy industry (such as Africa). At present, although India's strength is sufficient for other countries to pay attention to, it is not enough to play a decisive role in relevant international mechanisms, so it can often only respond to initiatives of other countries. In the future, India's leading international solar energy alliance can play a leading role and drive the generation of new issues in the solar energy field. The prospects are not optimistic.

5. The effectiveness of the development of the solar energy industry in India

After nearly 10 years of development, India's solar industry achieved remarkable results, mainly in the two fields of solar photovoltaic power generation and light and heat utilization.

5.1 The photovoltaic power industry emerged

The development of photovoltaic power generation was extremely rapid. In 2013, India's new solar installed capacity exceeded 1GW for the first time, reaching 1.2GW. And India became the world's seventh largest solar photovoltaic market. By the end of 2016, India ranked fourth in the world with 5GW of installed solar capacity, behind only China, the US and Japan (Bridge to India, 2017). India's solar installed capacity was only 3MW in 2008-09, and growing to 9012MW in 2016-17 (Figure 2). On March 2017, India's solar installed capacity reached 12.2GW. It is expected that India will surpass Japan in the future and become the world's third largest solar photovoltaic market.

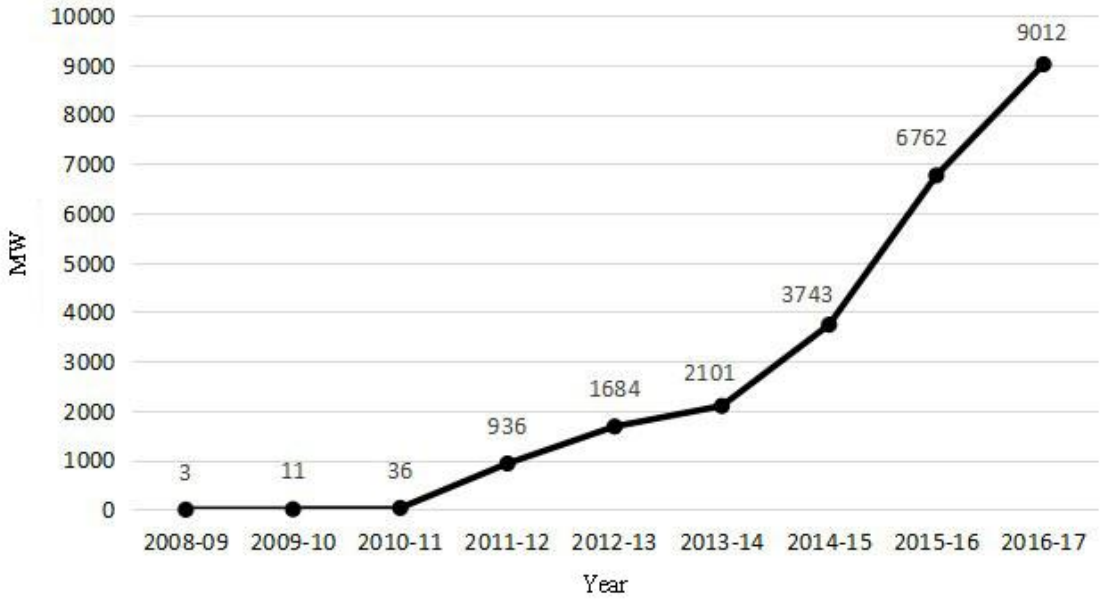

Figure 2 Indian solar installed capacity between 2008-09 and 2016-17

Roof photovoltaic solar growth was significant. By the beginning of 2017, Indian rooftop solar power generation accounted for 10% to 12% in the country (Bridge to India, 2017). And the growth rate was already very impressive. In 2013, the installed capacity of rooftop solar energy was only 32MW in India, and it grew to 227MW in 2016, with a compound growth rate of 92% (Bloomberg New Energy Finance, 2016). At the end of 2016, the cumulative installed capacity of rooftop solar energy in India reached 1247MW. It is estimated that 11.9 GW of rooftop solar power generation capacity will be added by 2021.

Small-scale photovoltaic solar systems were promoted in an orderly manner. With the support of the Indian government and non-governmental international organizations, the installed capacity of solar lights steadily increased in India. In 2013, the installed capacity of solar homes was only 700,000 units in India. By 2016, it grew to 2.3 million units, with a compound annual growth rate of 48% (Bloomberg New Energy Finance, 2016). In addition, the growth of solar water pumps was particularly evident in India. In 2009-10, the installed capacity of solar water pumps for irrigation and drinking were only 7334 in India, and they increased to 19,501 in 2014-15 (Gulati, Manchanda and Kacker, 2016). In 2015-16, the installed capacity of solar water pumps was as high as 31,472 (MNRE, 2017). The widespread use of small-scale solar systems is a boon for the people in many remote rural areas where there is no electricity available in India.

5.2 The thermal energy industry was steadily advancing

Solar water heaters were in the ascendant. As one of the main ways of low-temperature utilization of solar energy, solar water heaters were widely used in Indian households because of their low price, mature technology, and convenient use. In 2009-10, India's cumulative installation of solar water heaters was only $353\times10^4m^2$, which had reached $808\times10^4m^2$ in 2013-14 (Kumarankandath & Goswami, 2015). Moreover, solar water heaters were not limited to family homes and widely used in hotels, hospitals, and industrial sectors.

Solar cookers had been steadily promoted. The high-temperature utilization of solar energy is mainly concentrated on solar cookers. More than 60% of India's population lives in rural areas, and it is difficult to obtain liquefied gas and kerosene fuel. The advent of solar energy stoves effectively solves the cooking problems of rural people. The promotion and use of solar energy stoves not only reduces harmful smoke emissions but also enables women in rural areas to spend a lot of time each day collecting daily fuel. India's solar cookers are mainly divided into box-type solar cookers, dish-type solar cookers, and hybrid solar cookers. In 2015-16, India installed 680,000 box-type solar cookers and 15,000 solar cookers. 700,000 solar stoves (MNRE, 2016).

The project of solar thermal power generation has a broad prospect. The first phase of the "Jawaharlal Nehru National Solar Mission" program set up a 470MW solar thermal power generation installed capacity. However, the projects of solar concentrating power generation were relatively lagging behind due to lack of data, backward technology, and high construction costs. By the end of the first phase of the national solar mission, only 50 MW of Godavari parabolic trough solar thermal power plant was in operation. However, with the increasing attention of the Indian government, a number of solar thermal power generation projects had been launched. Dhursar linear Fresnel reflector solar thermal heat with a capacity of 125MW in Rajasthan. The project, the Abhijeet parabolic trough solar thermal project with the installed capacity of 50MW and the ACME electric tower solar thermal project with the installed capacity of 2.5MW have been started. It is estimated that by 2024, the installed capacity of solar thermal power generation projects in India will reach 1.3GW.

6. The challenges facing the development of India's solar industry

Although India achieved initial results in the development and utilization of solar energy, it still faced some challenges including land acquisition, prevalent administrative corruption, insufficient data, and unstable purchasing power. Their problems will become important factors restricting the further development of its solar energy industry.

6.1 Strategic planning was out of the actual situation

Although the Indian government had formulated a clear solar energy development plan, it is not difficult to find that India's solar energy development plan is too large compared with the world's major solar power countries. In 2014, India's total solar installed capacity was only 3GW, but it was planned to increase it to 100GW by 2022, with a compound annual growth rate of 55%. 100GW was the target of China's solar energy development, but the compound annual growth rate was only 23%, only half of India (Table 3).

Table 3 Solar development goals of the world's major solar power countries

Country	Total installed capacity (2014)	target	Compound Annual Growth Rate
Canada	1.7	6.3 (2020)	24
Britain	5.1	7.2 (2020)	6
France	5.7	15 (2020)	17
Germany	38.2	52 (2020)	5
Italy	18.5	23 (2017)	6
China	28.2	100 (2020)	23
Japan	23.3	65.7 (2020)	19
Thailand	1.3	3 (2021)	12
India	3	100 (2022)	55
Unit	GM	GW	%

In 2016, India's total solar installed capacity stood at 6.7GW, and 93.3GW of solar power projects will be built in the next six years. That means, at least 15.55GW will be built each year. The ambitious goals were placing new demands on the Indian government's ability to coordinate. Therefore, some analysts believed that the plan of India's solar energy development does not rule out the possibility of "high lift, gently put down". According to the International Energy Agency's forecast, India's solar installed capacity can only reach 40GW in 2022, which is far from the policy plan formulated by the Indian government (Gulati, Manchanda and Kacker, 2016). But the implementation of solar energy development in India is not optimistic.

6.2 High cost of land acquisition

Under the current technical conditions, in order to effectively convert sufficient solar energy resources into power resources, it is necessary to level the land to install solar energy conversion equipment. As one of the most difficult countries in the world to recover land, India had been plagued by the high cost of land acquisition. At present, India plans to build 33 solar parks with a total installed capacity of 19,900 MW. If 2 hm^2 of land is required per megawatt of solar equipment installed according to international standards, a total of 39,800 hm^2 of land will be required to complete the construction of these 33 solar parks (Gulati, Manchanda and Kacker, 2016). In the 2011-12 fiscal year, land costs in India's solar project construction costs accounted for only 1% of total costs and rose to 4.7% in 2016-17. In 2011-12, the land cost of solar power in India was 1.5 million rupees per megawatt, and in 2016-17, it was 2.5 million rupees per megawatt, with a growth rate of about 66% (Gulati, Manchanda and Kacker, 2016).

It is not difficult to find that with the rising cost of land acquisition, land acquisition will become a major challenge for India's solar energy development, which is why 40 GW of the 100 GW solar installation target set by the Indian government is roof-type solar energy.

6.3 Prevalent administrative corruption

For a long time, the serious corruption problem not only plagued the smooth development of solar projects in India but also seriously affected the confidence of international investors. According to the 2015 Corruption Perceptions Index published by Transparency International, India's integrity moved up 9 places, from 85 in 2014 to 76. But India's integrity was still in a "failed" state in 168 countries, with a score of 38 points (Yu, 2016). Especially in emerging industries such as the solar industry, which were overly dependent on government policies, was more susceptible to corrupt practices. For example, in the case of Kerala's solar panel bribery in 2013, the bribe amounted to Rs. 55 million. The case caused a large-scale demonstration in Kerala (Shaju, 2015). In addition, the Indian public works and construction market is one of the most serious areas of corruption, especially in the area of major solar projects and project contracting, which caused many investors to stop. International investors worry that corruption would lead to delays in the project.

6.4 Missing related basic data

One of the main constraints in the development of solar energy is the lack of accurate solar radiation data from the Indian government in India. In 2010, in response to the "Jawaharlal Nehru National Solar Mission" program, the National Renewable Energy Laboratory released the Indian solar radiation map, becoming an Indian solar developer and international investor. However, the amount of solar energy indicated by the 2010 version of the solar radiation map was much larger than the actual amount of solar energy available in the local area, it was 15% to 25% higher than the actual measured value (Jennifer Muirhead, 2014). In November 2012, Rajasthan Renewable Energy Corporation released a solar energy assessment report for Rajasthan, in which the solar radiation in Rajasthan was 1676 kW/h (m^2·a), 30% lower than the 2010 version of the Indian solar radiation map. Investors were discouraged due to the lack of data on the location and feasibility of solar energy.

6.5 Unstable purchasing power

The purchasing power of Indians constrained the popularity of solar equipment. Although the Indian economy showed a strong growth trend in recent years, the purchasing power of the people is still very limited. According to the Asian Development Bank, there were still 21.9% of the population living below the national poverty line, and 17.9% of the population had a daily purchasing power of less than $1.9 (Asian Development Bank, 2014). Taking a solar water pump as an example, a solar pump device with a power of 1 HP (1 HP = 745.7 W, the same below) was priced at Rs 200,000 in India, while a 1 HP diesel pump was priced at only Rs 25,000 (Gulati, Manchanda and Kacker, 2016). From what had been discussed above, the purchasing power of the Indian people was very limited. Apart from satisfying basic daily consumer goods, it is impossible to purchase expensive solar equipment.

In addition, most of the solar subsidy funds were subsided for solar panel manufacturers by the Indian government, rather than for people to purchase solar equipment. Thus, it was difficult to promote the solar system in the general public. On the other hand, the solar panels are over-produced in India. These devices did not ensure services for India's people but were cheaply exported to Europe and the United States and Japan.

7. Conclusion

In summary, with the increasing contradiction between global energy supply and demand, India viewed the development of solar energy as an important strategic choice to address climate change and ensuring energy security. Moreover, India also made continued and greater efforts to maintain the initiative and ensure it has its say in the new round of industrial revolution, development revolution, and concept revolution by establishing a global solar energy cooperation organization. Although China has become the world leader in the solar energy industry and the main source of imports of solar energy equipment for India, it remains the biggest shortcoming in the process of participating in the transformation of the international energy system. In the future, there will be a broad prospect between China and India for cooperation in the field of solar energy. The two countries should work together to ensure their say in the new round of low-carbon development and protect the interests of China and India.

8. Reference

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