PV for PV to accelerate carbon neutrality

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Abstract. The cost of carbon neutrality is too expensive. How to find a cheaper and more feasible approach to realize it? This paper studies the innovative development mode of PV for PV-Max speed. Through the three-stage "PV for PV" development plan, After 2023, China's annual capacity can reach 400 GW, with a total investment of about $96 billion. After 2032, China's PV installation can reach 4000 GW, annual power generation is 5200TWh, and annual CO2 emission reduction is 4.4 Gt. After 2033, it will be an export period, with an annual export revenue of $54 billion. By 2046, it will be able to export a total of 5300 GW, with an annual power generation of 6890 TWh. It will reduce the CO2 emissions of 10.2 Gt for the world every year. If the PV plant is built in the three northern regions of China, combined with desertification control, the western desert will become a "green valley".

Keywords: Carbon neutrality; PV for PV; Desertification; Green revolution.

1 Introduction

The 120 member states of the United Nations Framework Convention on Climate Change (UNFCCC) are striving to achieve carbon neutrality by 2050[1]. China's CO2 emissions in 2019 was 10.5 GTon[2]. China is already the world's largest energy consumer and largest emitter of CO2, and is also the world's largest emitter of non-CO2 greenhouse gases (GHGs) emissions[3]. China accounts for the majority of the 48% of global emissions from countries that have pledged carbon neutrality (in law, in proposed legislation andin proposed policies)[4]. If China meets its 2060 emissions reduction commitments, it will avoid a quarter of a degree Celsius of global warming this century[5].

Nowadays more and more countries had taken steps to make renewable targets and create policies supporting renewable energy[6,7]. It is a major development task of all countries in the world to implement the new energy strategy and construct a clean, safe and efficient modern green energy system.

But the cost of carbon neutrality is expensive. According to the reports, China needs to invest $5~15 trillion if it is to realize carbon neutral[8,9]. China's electricity system would need to reach net-zero CO2 emissions by 2050,with more than 85% of all energy and more than 90% of electricity coming from non-fossil sources. Investment in the power sector alone needs to increase by $4 trillion[10]. So the conventional way of development will takes long time, costs too much money, and is hard to implement.

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2 The analysis of PV for PV plan

At present, the supply of photo-voltaic(PV) industry chain is mainly concentrated in the Chinese mainland. In 2019, China accounted for 67%, 97%, 79%, 71% and 59% of the global output of polysilicon, silicon wafer, battery, components and inverter.

PV is an industrialized product, with the possibility of large-scale self-replication. If the mode of PV for PV is adopted, the PV power generation is used to produce PV products. In this way, the rapid replication of PV can be utilized and the production can be rapidly increased. At present the energy consumption of all processes of the polycrystalline silicon PV is 1.2 kWh/W. According to the average Chinese PV power generating capacity of 1.3 kWh/W.a, so It can be calculated that 1W solar cells can be produced from 1W PV power generation capacity every year, so the annual total PV production capacity will be doubled, and it is "zero carbon" and "zero pollution".

According to the projections, After 2050 China's total primary energy demand is 6 Gtce, and the proportion of clean energy consumption is 74%. The total electricity demand is 14.1 trillion KWh (equivalent to 1.73 billion tce), and clean energy power generation is 13 trillion KWh[11,12]. If one third of China's electricity (4700TWh) will be generated by PV in 2050. it will be calculated based on the average annual PV panel generation of 1.3kwh /W. China need to install PV 3616 GW, by the end of 2019 China PV power grid capacity is 204 GW, as a base, the PV doubled every year, 5 years later PV can grow up to 3200 GW.

The price of PV dropped 90% in the past ten years [13]. At present PV module market price has dropped to 1.3 yuan/W, according to the component price of 1.5 yuan/W, PV factory installed cost is 2.5 yuan/W (due to produce their own can save costs by more than 10%). energy consumption of PV production is 1.2 kWh/W, so the energy cost is about 0.7 yuan/W, so the cost of PV module is 0.6 yuan/W, the profit is up to 0.9 yuan/w. 1 yuan RMB is calculated to 0.15$. According to the PV module service life is 25 years, the max speed development expectation of the three stages from 2020 to 2050 can be obtained as shown in Table 1 as follows.

Table 1. Development expectation of three stages of PV for PV-Max speed mode (2020-2050).

Year	PV Product Capacity GW	PV Installation in China GW	PV Installation abroad GW	China annual CO_2 emission reduction GT	Toatal annual CO_2 emission reduction GT	The balance of payments ($billion)	China annual PV power generating Twh	Foreign annual PV power generatin Twh
2020	100					-24		
2021	200					-48		
2022	400					-96		
2023	400	400		0.4	0.4	-42	520	
2024	400	800		0.9	0.9	12	1040	
2025	400	1200		1.3	1.3	66	1560	
2026	400	1600		1.7	1.7	120	2080	
2027	400	2000		2.2	2.2	174	2600	
2028	400	2400		2.6	2.6	228	3120	
2029	400	2800		3.1	3.1	282	3640	
2030	400	3200		3.5	3.5	336	4160	
2031	400	3600		3.9	3.9	390	4680	
2032	400	4000		4.4	4.4	444	5200	
2033	400	4000	400	4.4	4.8	498	5200	520
2034	400	4000	800	4.4	5.2	552	5200	1040
2035	400	4000	1200	4.4	5.7	606	5200	1560
2036	400	4000	1600	4.4	6.1	660	5200	2080
2037	400	4000	2000	4.4	6.6	714	5200	2600

2038	400	4000	2400	4.4	7.0	768	5200	3120
2039	400	4000	2800	4.4	7.4	822	5200	3640
2040	400	4000	3200	4.4	7.9	876	5200	4160
2041	400	4000	3600	4.4	8.3	930	5200	4680
2042	400	4000	4000	4.4	8.7	984	5200	5200
2043	400	4000	4400	4.4	9.2	1038	5200	5720
2044	400	4000	4800	4.4	9.6	1092	5200	6240
2045	400	4000	5100	4.4	9.9	1134	5200	6630
2046	400	4000	5300	4.4	10.2	1164	5200	6890
2047	400	4000	5300	4.4	10.2	1170	5200	6890
2048	400	4000	5300	4.4	10.2	1224	5200	6890
2049	400	4000	5300	4.4	10.2	1278	5200	6890
2050	400	4000	5300	4.4	10.2	1332	5200	6890

It can be seen that the development of the three stages of max speed mode is as follows:

1. The first three years (2020-2022) are the closed expansion period. Through PV for PV can rapid expand the production capacity .The annual PV capacity increased from 100GW to 400GW, and the PV investment in this stage also increased rapidly. The investment in the first year was 24 billion dollars, the output of the year was 100GW, and the profit was 13.5 billion dollars. After 3 years, the accumulative total investment was about 96 billion dollars.

2. The fourth year to the thirteen year (2023-2032) are the domestic expansion period. The annual production capacity is stable at 400GW, and the installation can be promoted from areas with solar energy resources category 1 to areas with category III, with an annual net profit of 54 billion dollars. After 2032, the domestic PV installation will reach 4,000 GW. In the following years, the annual generating capacity will be 5200TWh, equivalent to 640 million tce, accounting for 10.7% of the national energy consumption and 36.9% of the electricity consumption.

3. After the 14th year (2033-2048) are the export period. The net profit of export sales is 360 billion dollars every year. Since PV modules have 25-year life span, it will be necessary to replace 100GW of old equipment in 2045, and so on, until the completion of 400GW of PV equipment in 2047. By 2046, a total of 5300GW of pv can be sold to foreign countries, with an annual power generating as high as 6890TWh, equivalent to 850 million tce.

4. Due to 400GW of equipment be replaced every year after 2047, So the PV installation has remained stable since then. It will be a balance between supply and demand, and annual net income of 54 billion dollars. By 2050, the cumulative net income has reached 1332 billion dollars, about 13.9 times the maximum cumulative investment.

5. In addition, the annual CO2 emission reduction by PV power generation is huge. After 2023, the annual emission reduction of domestic PV power generation will increase by about 0.3GT every year, and after 2032, the annual emission reduction of domestic PV power generation will increase by 4.4GT. The emission reduction of total PV power generation will increase continuously until 10.2GT in 2046, and the annual CO2 emission reduction will be maintained stable thereafter. This plan will reduce China's emissions by 102.6 GT and word's emissions by 171.2 GT by 2050. So this plan will not only benefit China, but also benefit the world.

3 The region selection of PV plant

According to the results of the fourth national desert survey completed in 2011, by the end of 2009, the desertified land area in China was 263.62×10^4 km^2, and the desertified land area was 173.11×10^4 km^2, accounting for 27.43% and 18.03% of the total land area

respectively[14]. Desert areas have harsh climate, heavy wind and dry sand, little precipitation, little vegetation, sparsely populated, abundant sunshine, and solar radiation greater than 1700kWh/m^2. Solar radiation belongs to category 1 resource area, making it a good place to build PV plants.

The wind energy density in the three northern regions is generally above 150W/m^2, and the annual cumulative wind speed of 3m/s is more than 4000h. In particular, the wind energy density in northern Inner Mongolia and Gansu is as high as 200-300w/m^2, and the annual cumulative wind speed of 3m/s is more than 5000h. According to the average annual power generation of 1W wind turbines in the region, the annual installed wind power capacity of 1W can produce 2W PV products. In addition, Wind and solar power are complementary in northwest China: the wind is usually stronger in the early morning and night than during the day, and stronger in winter and spring than in summer and autumn, while solar power is the opposite. Secondly, wind power and PV power are intermittent power generation, while the three north areas of China is rich in natural gas resources, which can be supplemented by the construction of distributed natural gas power stations to realize the stable production of PV plants. Therefore, if wind-solar complementary power generation is adopted to produce PV locally, the annual pv output will be greatly improved.

The combination of PV power station and vegetation can not only prevent wind and fix sand, but also greatly improve solar energy utilization rate. The energy conversion efficiency of local PV power generation is hundreds of times that of vegetation in desert areas. It is estimated that the solar energy converted by 1m^2 PV panels is equivalent to the solar energy utilization of 260.8m^2 desert vegetation in Minqin sand area[15]. In 1982~2015, Shanxi, Qinghai, Ningxia, Gansu, Chongqing (Zhejiang), Xizang, Jiangsu and Xinjiang (Shaanxi and Sichuan) are the fastest annual average temperature rise in China, with the average temperature rising by 0.57^{0}C, 0.53^{0}C, 0.49^{0}C, 0.48^{0}C, 0.46^{0}C, 0.42^{0}C, 0.40^{0}C, 0.39^{0}C per 10 years. Among the top 11 provinces with the fastest warming in China, only Chongqing, Zhejiang and Jiangsu are not in the three northern regions[16]. So the development of PV in the three northern regions is conducive to reducing the local fossil energy exploitation and anthropocentric thermal emissions, mitigating local climate warming, and protecting the ecology and environment of China's border areas.

PV plants can also be combined with desertification prevention and control, ecological agriculture, ecological tourism and poverty alleviation. At present, the ratio of sand control area and PV installation area in China's desert PV industrial parks is generally between 3.8-13.3. The 400GW PV module covers an area of 2,000 km^2. If calculated according to the PV power generation area and desertification control area of 1:6, it can promote the desert control of 12,000 km^2, only accounting for 2.3% of the treatable area of China's desertification land (about 530,000 km^2), which is equivalent to two times of Shanghai . Due to the electricity price in western China is cheaper, at present the production capacity of crystal silicon and silicon wafer in China is shifting to northwest and southwest of China, which is completely consistent with the region selection of this plan. The construction of PV plants in the three northern regions can turn local resources into gold, and the western Gobi desert can be turned into a "green valley".

4 Conclusion

In view of the investment difficulties faced by China and the world in achieving carbon neutrality. This paper studied the innovative development mode of PV for PV. After 2022, China's annual PV capacity can reach 400GW, with the largest cumulative total investment of about 96 billion dollars, and the annual profit of 54 billion dollars thereafter. After 2032, China PV installation can achieve 4TW, with 5200TWh of electricity generation, and 4.4 billion tons of CO2 emission reduction annually. After 2033, it will be available for export.

By 2046, it will be available for 5.3TW of foreign PV installations, generate 6890TWh of electricity annually, and reduce emissions by 10.2 billion tons of CO2 1.2 billion tons annually. By 2050, the total CO2 emission reduction will be 102.7 billion tons for China and 171.2 billion tons for the world. By 2050 the accumulative net income will be 1332 billion dollars, which is about 13.9 times of the largest accumulative investment. The economic and ecological benefits of PV for PV are huge. If the PV plant is built in the three northern regions of China, combined with desertification control, the western Gobi desert will become a "green valley".

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