A Review on Solar Landfills Development in China: Current Status, Policies and Recommendations

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Keywords: Solar landfills, solar PV, land use, policies.

Abstract: Landfilling is the most commonly used option for waste disposal in China but occupies massive land resources and solar landfills could be a win-win solution by installing PV systems on the closed landfills. This paper firstly summarized the current status of PV technologies and policies in China, followed by the analysis of advantages of solar landfills and recommendations for the development of solar landfills in China. Results indicate that the idea of solar landfills could be a good option for the PV industries and waste treatment, and both the technologies and policies could give a good platform for the development of solar landfills in China. Finally, reasons for the underdevelopment of solar landfills in China have been analysed and corresponding recommendations are given from the aspects of policy making, financial support and technical development.

1. Introduction

With the rapid urbanization and the explosion of urban population in China, the increasing municipal solid waste has been a great challenge for the society and government. It is estimated that the annual production of municipal solid waste has been more than 250 million tons in China currently and the number is increasing at a rate of 8% every year[1]. In spite of the disadvantages of landfilling, such as occupying land resources, land pollution, heavy metal pollution, odours emission, etc., this is the most commonly used option for waste disposal because of the low cost and good hygiene[2]. Until 2018, more than 2459 landfills have been constructed in China and about 95% of the municipal solid waste are disposed by landfilling[3].

Although China has the second largest national territorial area, its land resources are relatively limited[4,5]. However, with the rapid development of China and the sharp increase of municipal

solid waste, more and more land has been occupied by landfills. It is reported that among the 668 cities in China, about two thirds of the cities are facing urgent challenges of waste disposal and nearly one forth of them can not built landfills any more because of land limited[6]. As the construction of landfills causes damage on the land geological structure and the garbage decomposing may result in ground settlement, landfills after closing can only be discarded or used for the construction of public leisure places such as parks, squares or golf courses rather than residential or commercial buildings[7], resulting in a huge land wastage.

In recent years, the day after day mature of solar photovoltaic (PV) technologies provides a win-win solution for the land use of landfills after closing. Usually, the installation of solar PV systems possesses a huge demand for land resources, therefore, most of the solar farms located in the western regions of China, which leads to great costs for electricity transportation[8]. Besides, solar farms which are constructed on the rural areas may have negative impacts on the natural landscapes[9]. Moreover, the ground-mounted SPVS may also affect agricultural activities or lead to soil erosion[10]. It is a good idea to build SPVS on landfills after closing because the SPVS is mounted on the otherwise discarded land and occupies less high-quality land resources.

China has a considerable number of landfills, but the solar landfill projects are still rare. In the present work, the authors analyse the current status of solar PV technologies, the advantages of solar landfills and investigate several successful solar landfill projects in the world. And the specific purpose of this paper is to present the great opportunity of solar landfills in China and to propose suggestions for the development of solar landfills accordingly.

2. Current Status of Solar PV in China

To obtain a good understanding of the great opportunity of solar landfills, this paper first analyses the current status of the development of solar PV in China. In this section, three aspects are illustrated: current status of solar PV technologies and industries in China, demonstrating the technical feasibility of solar landfills; the supporting policies of China, leading to an in-depth understand of the

2.1. The Development of PV in China

China is a country of abundant solar energy. Areas where the annual sunshine hours are over 2000 hours accounts for more than two thirds of the total area of China[11]. Besides, China is doing its best to reduce the emission of CO2, therefore, China's current new energy-related market, especially the new energy power industry project, has received special attention and attention. Historically, from 2014, the Chinese government emphasized that in the coming years, China will carry out energy system reforms and introduce relevant energy policy to promote the development of new energy[12]. By the end of 2017, the total capacity of solar PV in China had reached at 131GW, which accounts for 32.8% of the total worldwide solar capacity[13]. As of the end of 2018, the total installed capacity of global photovoltaic power generation was 480.36GW, and the Asian region was 274.6GW, accounting for 57.2% of the world, which makes Asian region the main driving force of global photovoltaic development. Among Asian countries, China has a cumulative installed capacity of 176.1GW, which is three times the installed capacity of Japan (56GW)[14].

In spite of installation of solar projects, China have also made great contribution to the solar technologies and products. With the continuous improvement of the products quality, performance and service, China has been the leader in the domain of high-quality solar PV equipment. In 2019, the global PV equipment industry saw sales grow 4.2% to 5 billion US dollars. At the same time, the market size of China's PV equipment reached 3.57 billion US dollars, with a year-on-year growth of 13.6%, accounting for 71.4% of the global market size[15]. Besides, China also sets a

high value on advanced solar PV technologies. For example, China plans to invest to the production equipment of thin-film solar cells from 2019, which will have significant effects in the global PV markets[11].

In conclusion, the rapid development of solar PV installation and the progress of solar technologies in China provide a great opportunity for the development of solar landfills.

2.2. Policy Support in China

The development of solar PV has made great contribution to environmental protection and energy security, but in return, the rapid growth of solar PV is also inseparable from the strong support of national policy. As early as in 2009, China government proposed "Golden-sun Demonstration Project" to support the Industrialization and scale development of solar PV by providing financial subsidies and technological support[17]. This policy greatly promoted the construction of solar PV projects and attracted a large number of investors to the PV industries[18]. In 2013, new policy was issued to encourage the integration of PV projects to grids. With these encouraging policies, the PV industries in China experienced a sharp growth and its installed capacity and electricity generation ranked the first place in the world for several years. However, with the increment of government subsidies and the explosive growth PV industries, problems such as excess production capacity and plant abandonments have been increasingly acute[19]. Thus, in 2018 the government issued a policy to improve the pricing mechanism and reduce the financial subsidies for solar energy. Although this policy may cause demand reduction in PV markets and affect the development of photovoltaic manufacturing industry, short-term dilemma is helpful to the updating and long-term healthy development of PV industries[20].

From the above analysis, it can be concluded that the government always provides policy supports for the healthy development of PV projects, if the PV enterprise could take advantage of these policies, the PV industry will see a new round of development.

3. Why Landfills: the Advantages of Solar Landfills

Compared to traditional PV projects, the solar landfills projects have several advantages, which makes solar landfills a good solution for the land usage issue after closing of landfills. In this part, the advantages of solar landfills will be introduced and the necessities of it will then be classified.

3.1. Alleviating the Problem of Land Use Issue in PV Project

In traditional PV projects, lots of land resources are needed as the installation of ground-mounted PV equipment occupies lands. One main reason for that most of the solar plants in China are located in the northwest of its terrain is that in the northwest of China where Gobi Deserts are widely spread, the land resources are very cheap for PV installation. However, in the east of China where the land resources are relatively limited, the PV projects may have bad impact on rural environments and cause damages to rural landscapes. Moreover, the PV projects may result in conflicts with agricultural activities or cause soil erosions[21,22].

As mentioned before, the landfill after closing can not be used for construction and its land resource will be wasted. Therefore, solar landfills could be a win-win solution for PV installation and reuse of land resources occupied by landfills because the PV equipment possess a relatively low requirement on the land quality and they can be installed on the landfills rather than occupying other land resources.

3.2. Location Advantage

For the current situation of PV industries in China, most of its solar plants are located in the northwest of its terrain. However, most of the electricity consumers are from the east of China. To fix the location mismatch between solar plants and users, the electricity has to be transported from the west to the east and the construction of electricity transportation infrastructure is time-consuming, material-consuming, and labour-intensive[23].

Figure 1 shows the landfills around Beijing and it can be observed that most of the landfills are distributed in the rural areas of the city. Therefore, the distance between solar plants on landfills and the users could be very short and the cost for electricity transportation could be significantly reduced.

3.3. Developed Infrastructure

In the construction of landfills, the road network should be built first for materials and waste transportation. After closing of landfills, the road network could be preserved and facilitate to the construction of PV projects. The PV equipment such as solar panels, inverters and solar array frames could be transported conveniently. Furthermore, before closing, the landfills must be secured and monitored, which are also necessary for PV projects. Therefore, the remaining security and monitoring systems can be continued to be used by the PV projects, reducing the relevant installation costs[24].

Moreover, before closing, the landfills are usually connected to the grid to obtain necessary power for maintaining and operating. Thus, after closing, the grid can be used by the PV system and the generated electricity can be connect to the grids and delivered to the users directly.

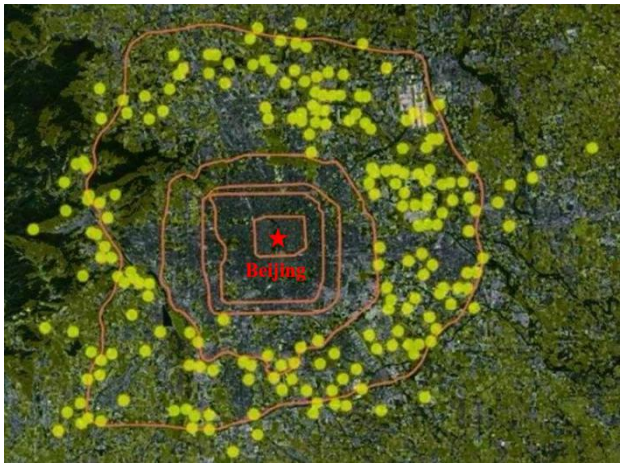

Figure 1: The landfills around Beijing.

4. Recommendation for PV Technologies

With the continuous rapid development and research of solar energy, many PV technologies have been developed for solar energy capturing. Table 1 compares the advantages and disadvantages of different PV technologies, which is helpful for the selection of proper PV technology for solar landfills.

Table 1: The comparation of different PV technologies.

	Polycrystalline silicon PV	Monocrystalline silicon PV	Thin-film PV	Concentrated PV
Technical maturity	Relatively mature	Relatively mature	Being mature	Not very mature
Efficiencies	12%～16%	13%～18%	5%～9%	>20%
Prices	Low	High	Relatively low	High
Environmental suitability	Power increases with radiation, but is easily affected by high temperature.	Power increases with radiation, but is easily affected by high temperature.	Good performance in low radiation environment, less effects by high temperature	Has higher requirements for radiation and tracing technologies and is easily affected by high temperature.
Maintenance requirement	Low	Low	Higher requirement for dust cleaning	High
Service life	About 25 years	About 25 years	About 10-15 years	N/A
Installation	Flat areas	Flat areas	Low requirements for terrain characteristics	High requirements for terrain characteristics

From Table 1, it can be seen that for traditional crystalline silicon PV, the technologies are very mature and have significant advantage on price, maintenance and installation costs. However, for landfills where the surfaces are not flat easy to subside, it is difficult to install traditional crystalline silicon PVs. Therefore, it is suggested to install silicon PVs on flat landfills. Moreover, the thin-film PVs have lower requirements for terrain characteristics and have a balanced performance in power output and costs. Thus, the thin-film PVs could be optimal choice for solar landfills.

5. Discussion and Recommendations

Until now, several solar landfills projects have been constructed in the world, especially in the US. Currently, the US has more advanced technology and progress in the domain of solar landfills. Many solar landfills have been built and more similar projects are in the planning stage. Since 2002, the first solar landfill with a capacity of 276 kWp has been operating in New Jersey. Until 2012, the number of solar landfills in the same state had been 15 and the total capacity had reached 17.15 MWp. Besides, other solar landfills with total capacity 27.5 MWP had also been constructed in other states of the US[25].

There are also several cases of solar landfills in the EU. In France, a 4.1 MWp solar landfill with 54600 panels was built in 2009 and more solar landfill project are being built. In 2011, a 1.9 MWp solar landfill project which is located in Southwest Germany has been proposed and the solar landfill plant is expected to generate 2 GWh of electricity every year. In Italy, a solar landfill which adopted thin-film PV has been built and its capacity is 1 MWp[26, 27].

Actually, several researchers have introduced the idea of solar landfills for certain landfills, for example the Laogang landfill in Shanghai, the Liulitun landfill in Beijing and the Daxin landfill in Shenyang. However, landfills that have been installed with PV systems are still rare. There are several reasons for this phenomenon. Firstly, although the government introduces relevant policies for the development of solar PV industries and technologies, however, policies supporting the development of solar landfills are still rare, the solar projects which are built on landfills should be preferential compared to other normal solar projects from the aspect of policy. On the other hand, the construction of solar landfills is more costly than the normal solar PV projects due to the complex geological condition, however the subsidies from the government in China is reducing gradually, which dampens the enthusiasm of PV companies for solar landfills construction.

Therefore, here are some suggestions for the development of solar landfills in China:

Firstly, the governments should give moderate priority to solar landfills when making policies pertaining to PV industries, showing the supports for solar landfills and attracting the interests of PV companies for the new source for PV installation. At the same time, the government should also enhance the policies regarding to the sales of electricity from solar landfills or encourage the cooperation between solar landfills and factories or villages.

Secondly, financial incentives and financing support should be emphasized on the projects of solar landfills. As mentioned above, the construction of solar landfills is more expensive than traditional solar projects as the supports of PV equipment should be more solid or the projects may select thin-film PV which is a little bit of expensive. Thus, to push the development of solar landfills, one effective way is to support financial subsidy to the PV companies which aims to build solar landfills. Considering the regional government may have no enough budget for the subsidy, the government could provide subsides in other way, for example, providing the land of landfills to PV companies for free in several years or reducing the tax rate of the PV companies which invests to solar landfill projects. Furthermore, the infrastructures such as electricity grids and monitoring system which were established before landfills closing can be used by the PV companies, in this way the operating costs of solar landfills can be reduced.

Last but not least, the development of industries is inseparable from the support of technologies. Thus, the central government should continue to increase investment in research and development of advanced PV technologies, including thin-film PV, solar tracking technology and novel installation technique for solar landfills. Specially, the government should provide more research funding and resources for the research institutions or companies which emphasize their research on solar landfills.

6. Conclusion

Based on the context analysis, we firstly studied the situation of landfills in China and obtained the necessity of building solar landfills. The traditional landfills occupy too much land resources and the occupied can not be used for building construction, thus the solar landfills could be a win-win solution for the sustainable development of landfills. After that, the current status of PV technologies and policies in China was analysed to conclude that both the technologies and policy support give a good platform for the development of solar landfills. In addition, the landfills have inherent advantages for PV projects implement, for example Location advantage and developed infrastructure. By analyzing the current PV technologies, the paper suggested crystalline silicon and thin-film PVs as the optimal PV technologies for solar landfills. Finally, reasons for the underdevelopment of solar landfills in China has been analysed and corresponding recommendations were given from the aspects of policy making, financial support and technical development.

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