

Governance Challenges and Solutions of the Solar Energy for Poverty Alleviation Program in China: The Case of Jinzhai County

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Abstract

This paper discusses one of China's targeted poverty alleviation programs, namely the Solar Energy for Poverty Alleviation Program (SEPAP). SEPAP is an important and innovative policy that enables poor households to earn additional income by installing solar panels and selling the generated electricity to the grid. However, there are still some doubts regarding the actual effects of SEPAP. Based on the results of 30 semi-structured interviews with village leaders and local government officials in Jinzhai County, China, we explore in-depth the development stages and the types of SEPAP. In addition, we discuss the governance challenges of SEPAP implementation in Jinzhai County, including poor construction quality, maintenance difficulties, inadequate maintenance service, and delays in the payment of government subsidies. We also discuss how the local government has worked together with both the upper levels of government and the poor households to address some of these challenges.

Keywords: Solar Energy for Poverty Alleviation Program (SEPAP), solar photovoltaic (PV), extreme poverty, local government, Jinzhai County, China

1. INTRODUCTION

The 2030 Agenda for Sustainable Development, which was endorsed by all UN Member States in 2015, lays out a clear path for advancing human well-being that should not be at the expense of the environment and future generations. The first Sustainable Development Goal aims to reduce extreme poverty to less than 3% of the global population by 2030 [1]. According to the United Nations *b1*, even though the proportion of the world's population living in extreme poverty fell to 10% in 2015, down from 16% in 2010 and 36% in 1990, the rate of poverty reduction has slowed down, and that proportion was 8.6% in 2018. Even worse, as a consequence of the Covid-19 outbreak, the number of people living in extreme poverty increased for the first time since 1997 [2]. Although China has been remarkably successful in reducing poverty after the start of its market reforms in 1979, 55.75 million people in rural China remained under the extreme poverty line in 2015 *b3*. The entire population was 1,370 million, out of which 600 million people lived in rural areas. Therefore, the percentage of poor people living in rural areas in 2015 was 9.38 percent. In

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2010, China's extreme poverty line was set at 2,300 Chinese yuan (approximately \$337 USD) per capita, and the line was changed to 2,855 Chinese yuan (approximately \$458 USD) in 2015 [3].

In 2014, China launched an ambitious policy to reduce rural poverty by implementing distributed solar photovoltaic (PV) systems in remote rural areas. This policy is known as the Solar Energy for Poverty Alleviation Program (SEPAP). There were four primary options that we call here individual-level SEPAP, village-level SEPAP, joint village-level SEPAP and utility-scale SEPAP. The government helped the poor to decide which kind of SEPAP they would join. Under the individual-level SEPAP, the Chinese government and solar PV companies assisted the poor in installing solar panels on their rooftops or lands. The second and third alternatives were to build solar power plants in the designated counties or villages. The fourth option was to build centralized solar power plants in the vicinity of the designated counties or villages.

Poor households, as well as the designated counties or villages, could sell the electricity generated by the solar panels to the grid company. The expected results were an increase of 3,000 Chinese yuan in the annual income of each poor household and a new collective income for the county or village. By 2020, the Solar Energy for Poverty Alleviation Program (SEPAP) aimed to add more than 10 gigawatts of capacity and help over 2 million households from roughly 35,000 villages [4]. Only people in rural areas that were under the extreme poverty line could participate in the program. The SEPAP was funded by government subsidies as well as by company donations, which were decided as part of their corporate social responsibility (CSR). According to the National Energy Administration [5], as of July 2020, China had built and put into operation 26.49 gigawatt of solar PV power systems for poverty alleviation, benefiting 1,472 counties, 138,091 villages, and 4.18 million poor households, averaging more than 6 kilowatts per poor household.

In 2020, China's President Xi Jinping officially announced that China had eliminated extreme poverty. The Chinese government argues that SEPAP has made a substantial contribution to the process of poverty alleviation. However, the academic debate reveals some doubts regarding the actual effects of SEPAP. In some cases, poverty alleviation was hindered by problems in the SEPAP implementation. Therefore, it is vital to examine in more depth both the actual effects of SEPAP and the process of its implementation.

The idea of using solar PV to alleviate poverty is not new. Solar home systems (SHS) have been installed to provide off-grid access to electricity for poor households in the rural areas of many developing countries, particularly in some of the world's least developed countries in Africa and South Asia. A number of researchers have discovered positive social and economic effects of using solar PV to provide access to electricity [6–11]. The SEPAP, on the other hand, differs from SHS in several ways, including the grid connection, financial model, and distribution of income. As a result, it has received much attention from the Chinese academic circles [12–16]. The difference between SEPAP in China and similar solar PV programs around the world is discussed in the literature review section (Section 2.1).

Because China is a very large country with substantial regional disparities, the SEPAP implementation process has also been distinctive. Using a single method to fully understand the situation in different regions is problematic. In this paper, we develop a case study of SEPAP implementation in Jinzhai County. There are three reasons for our choice of the case study of Jinzhai County. Firstly, Jinzhai County is Anhui Province's most impoverished county, with the largest area and population. At the end of 2013, Jinzhai County had 45,687 low-income families or 147,723 poor people out of a total population of 680,000, resulting in a poverty rate of 21.72% [17]. The second reason is that as the pioneering case of SEPAP, the experience of Jinzhai County has significantly impacted the SEPAP at the national level. Jinzhai County has been selected by the central government as the pilot county to conduct the SEPAP experiment considering its high poverty rate and successful experience with SEPAP in 2013. It has been promoted by the Chinese

government as a successful model for SEPAP development. Finally, during the period of SEPAP implementation (2014-2020), Jinzhai County developed all four types of SEPAP mentioned above.

In general, prior research is limited to explaining the Chinese government's role in SEPAP planning and implementation. This paper answers the following research questions that have not been addressed in previous academic studies. First, how did SEPAP develop over time and what were the similarities and differences between the four types of SEPAP in Jinzhai County? Second, what were the main problems that arose during the implementation of SEPAP, and what actions has the local government taken to solve those problems.

In this paper, we first review the various stages of SEPAP development and the main stakeholders involved in its implementation. Next, we highlight the main problems that have arisen during the process of SEPAP's implementation. In addition, we explain that what looks like a top-down policy process operates as a multi-level governance system. The contribution of the paper derives from the results of 30 semi-structured interviews that we conducted in July 2021 in Jinzhai County. The interviewees included village leaders and government officials at the town and county levels. A total of 30 interviews were conducted (19 with government officials and 11 with village leaders). The interviews focused on understanding different stakeholders' experiences and opinions regarding the challenges of SEPAP's implementation in Jinzhai County.

The paper is structured into seven sections. Section 2 includes a literature review of SEPAP in China in the context of the literature on the role of governance in poverty alleviation. Section 3 outlines the role of the main stakeholders in SEPAP implementation. Section 4 overviews the development of SEPAP in Jinzhai County since its official launch in 2014. Section 5 discusses the main problems of SEPAP implementation in the county and the efforts of the local government to find solutions. Section 6 is the discussion on SEPAP implementation and provides recommendations for policymakers. Section 7 concludes the paper.

2. LITERATURE REVIEW

2.1. Literature review on SEPAP

SEPAP was launched in 2014 and officially ended in 2020, but the implementation of SEPAP has recently piqued the interest of a rising number of Chinese scholars. The existing literature on SEPAP can be classified into four types.

The first type of study is policy review. Zhang et al. [12], Geall et al. [13], Li et al. [18], Zhang et al. [19], and Liao et al. [20] outlined the current state and policies of using solar PV for poverty alleviation from a macro viewpoint. In addition to eliminating rural poverty, Geall et al. [13] pointed out the following reasons for the launch of the SEPAP: narrowing the urban and rural income gap, boosting the domestic solar industry, and offering an alternative for rural electrification. Zhang et al. [12] conducted a content analysis on SEPAP policies and found that the Chinese central government emphasized goal planning, financing support, and infrastructure construction. Li et al. [20] summarized major supporting policies for SEPAP, including government subsidies.

The second type is financial analysis. A stable funding structure for SEPAP is essential for its long-term development. Zhang et al. [21] compared three different financial models or ways of providing capital for initial investment under SEPAP. The first model was full financing by the government, the second one was borrowing by the poor households plus partial financing by the government, and the third one was partial financing by the government plus investment by the solar PV companies. They found that the third way (partial financing by the government plus investment by the solar PV companies) was superior to the other two in terms of both the average

level of income and the income growth of solar PV companies and poverty-stricken families. Furthermore, the results of the cost-benefit analysis by Zhang et al. [19] indicate that lowering the installed capacity cost per unit was the best strategy for increasing the profitability of solar energy poverty alleviation projects and for minimizing government subsidies. Also, the village level and the joint-village level SEPAP were the most effective models according to the results of the cost-benefit analysis done by calculating the net cash flow, the net present value, and the payback period [13].

The third type of study focuses on empirical analysis with multi-criteria evaluation. Wang et al. [22] found that SEPAP had good energy efficiency and environmental benefits due to the adoption of the Life Cycle Assessment (LCA) and the Net Energy Analysis (NEA) methods. Zhang et al. [23] developed a poverty index incorporating six dimensions to evaluate 30 SEPAP pilot counties. According to them, the multidimensional poverty index of solar PV-based pilot counties showed a general decreasing trend from 2014 to 2016. Among the six dimensions, finance and social production were the most significant contributors to the reduction of poverty, followed by income and social security. Zhang et al. [24] further conducted difference-in-difference (DID) regressions showing that the effect of solar PV investment was positive and significant and that the poverty alleviation effect was stronger in the poorer regions, particularly in Eastern China. Liu et al. [25] used the same methodology to find that SEPAP has effectively improved the economic conditions and social capital of low-income poor families, but that the expected gains in human and natural capital have yet to materialize. Hua et al. [16] conducted a social impact evaluation of SEPAP by combining four categories (Human life, Safety guarantee, Social resources, and public participation) with 13 indicators. They came to the same conclusion as Liu et al. [25]. SEPAP improved low-income families' economic conditions and social capital, yet the expected increases in human and natural capital did not happen.

Lo [26] discussed the evaluation of SEPAP based on distributional and procedural justice principles. The evidence gathered from interviews and surveys indicates that the SEPAP has achieved a just energy transition in two ways. First, there were institutionalized processes in place to ensure procedural justice, such as public consultation at the village level and information disclosure regarding the distribution of benefits. Second, in terms of the just outcome perspective, the solar poverty alleviation program has had a favorable material impact on poor households.

The fourth type of study focuses on the problems of SEPAP implementation. Geall et al. [13] discovered four specific issues in their case study of SEPAP in Guinan County, located in the Tibetan Plateau. To begin with, solar projects typically last more than 20 years, but the pilot project barely lasted a year. This left regulators little time to assess the pilot project's accomplishments and failures before SEPAP was promoted to the national level. Second, financial and post-construction maintenance arrangements were lacking. Neither the central nor the local government allocated additional money to fund the post-construction maintenance. Third, a monitoring system to supervise the distribution of benefits to poor households was lacking too. Fourth, although national energy regulators had a supply-side management ability and could push through the development of utility-scale solar PV, they often had little knowledge of the local context or the poverty and development issues at the grassroots (village) level [12].

Li et al. [18] divided SEPAP into three stages: startup stage, construction and operation stage, and appraisal stage. They also pointed out some problems. At the startup stage, the following three problems were identified: (1) difficulties in obtaining relevant data, (2) shortage of startup funds, (3) vicious competition, low prices, and inferior quality products. At the construction and operation stage, more manpower and material resources were required, and the capacity of the grid infrastructure to integrate solar PV electricity was low. At the appraisal stage, there was a lack of a comprehensive indicator system to evaluate the SEPAP results.

The review of the literature on SEPAP shows that SEPAP differs from similar solar PV programs around the world in at least three ways (Table 1). First, their goals are different. In many developing countries in Africa and South Asia, solar PV programs are designed to provide access to electricity. However, SEPAP aims to raise poor people's income. Second, SEPAP comes in a variety of formats. Solar home systems (SHS) and mini-grids are the most common off-grid projects in Africa and South Asia. In addition, SHS and mini-grids are developed in remote areas where grid extension is a major challenge. Individual-level SEPAP, village-level SEPAP, joint village-level SEPAP, and utility-scale SEPAP are all examples of solar PV systems connected to the grid, allowing the poor households to sell the generated electricity to the grid company. Third, the funding sources are also different. SEPAP is a government-subsidized program that is sometimes combined with donations from solar PV companies and with low- or zero-interest bank loans. In contrast, most worldwide solar PV programs rely heavily on funding from international organizations and NGOs or are market-based.

In conclusion, although there are many papers discussing the outcomes of SEPAP, research that examines in more depth the types of SEPAP, as well as the problems of its implementation, is still insufficient. In addition, from the voluminous literature on governance, we know that the quality of governance is of utmost importance for the effectiveness of poverty alleviation programs around the world. In the following section, we make a brief review of the literature on the role of governance in poverty alleviation programs. We argue that SEPAP is an illustration of the "experiment under hierarchy" approach that is defined by bottom-up experimentation and top-down control.

Table 1: *The differences between SEPAP and other similar solar programs in developing countries*

	SEPAP	Other solar programs in developing countries
Aims	Poverty reduction	Rural electrification
Grid connection	On-grid	Off-grid
Funding	Government and donation from solar PV companies	International organizations and NGOs

Sources: Constructed by authors.

2.2. Literature review on the role of governance in poverty alleviation programs

The term "governance" should not be confused with "government". Government is a social control system in which a specific group of people has the power to make and enforce laws [27]. Governance on the national level refers to how political and administrative authority is exercised to manage a country's affairs [28]. Furthermore, governance is an important theme in the public sector, where governments must be accountable and transparent while effectively implementing policy [29].

Scholars have been studying the relationship between governance and poverty alleviation programs for a long time. According to the World Development report published by the World Bank in 1992 [30], there are four key dimensions of governance. These are "Public Sector Management", "Accountability", "Legal framework for Development", "Transparency and Information". UNESCAP [31] defines eight major characteristics of good governance. It is participatory, consensus-oriented, accountable, transparent, responsive, effective and efficient, equitable and

inclusive, and follows the rule of law. These factors are critical for human development and poverty eradication since ineffective institutions disproportionately affect the poor and vulnerable [28].

Many studies have shown that good governance leads to poverty reduction, whereas bad governance has the opposite effect [32–35]. Sobhan [32] stated that the poverty reduction program in Bangladesh was ineffective, because in reality the government deprived many poor of access to the services to which they were entitled. Shylendra [34] used the case of Swarnjayanti Gram Swarozgar Yojana in India to show that governance problems like faulty selection, improper identification of viable schemes, sidelining of capacity building and, above all, lack of integration among different agencies involved in the implementation of the scheme disturbed the program's effectiveness. Damayanthi [35] studied the Samurdhi program in Sri Lanka and found that the program is suffering from serious governance issues such as mistargeting, lack of transparency, accountability, efficiency and effectiveness, equity and social justice as well as informed citizenry.

In recent decades, when it comes to governance for poverty alleviation, participatory or democratic governance has become a buzzword that encourages the participation of citizens in the process of policy-making and policy implementation so that the voice of the poor people can be heard. The governance system should be responsive to these voices. In reality, participatory governance has also been introduced in many developing countries. However, a number of studies [36–38] criticize the decentralized and participatory approaches to development [39,40] because of the failure to achieve the poverty alleviation goal.

China has a long history of combating poverty. The first Rural Poverty Alleviation and Development Plan (2001-2010) was adopted at the start of the 21st century. The State Council's Leading Group Office for Poverty Alleviation and Development (LGO-PAD) positioned participatory poverty reduction and the Integrated Village Development Program as the two underlying strategies for poverty reduction [41]. In 2011, the State Council promulgated and implemented the second Rural Poverty Alleviation and Development Plan (2011-2020). This plan proposed to eliminate absolute poverty by 2020 and to implement ten targeted poverty alleviation programs. SEPAP was one of the ten programs.

Although China has been combating poverty under an authoritarian political system in which the central government leads the process of policy formulation and implementation, China's post-1978 reforms have shown a tendency toward decentralization, particularly in the economic and administrative areas. "Experiment under hierarchy", according to Heilmann [42], is a distinctive Chinese approach defined by bottom-up experimentation and top-down control. In other words, local governments are encouraged to experiment with specific poverty reduction programs. Local governments are often willing to start the experiment because of the perceived personal, institutional, and local benefits of experimentation, individual preferences for innovation and the existing supportive policies [42]. If the results are positive, the central government will consider expanding the experimental program from the local to the national level. In our view, SEPAP is an example of an "experiment under hierarchy" program that needs to be evaluated for its benefits for poor households. Through a case study of SEPAP, Lo and Castán Broto [43] found that China's multi-level experimentation approach allows for not only the adaptation of national-level models to specific locations but also for the incorporation of local implementation lessons into national policy-making.

3. ROLE OF THE MAIN STAKEHOLDERS INVOLVED IN THE SEPAP IMPLEMENTATION

China's administrative management system is hierarchical and has six levels. Apart from the central government, China's administrative organs are divided into five levels: provincial level, prefecture level, county level, town level, and basic level autonomy, including village and commu-

nity. There are various departments at each level of government. Each department has its unique tasks and rules. The horizontal departments and combination of the same level of departments to form a coordinated parallel relationship between each other is referred to as the departmental structure of the administrative organs.

At the central government level, the National Energy Administration (NEA) and the State Council’s Leading Group Office of Poverty Alleviation and Development (LGO-PAD) have initiated and led SEPAP. The decision-making power primarily resides in the NEA, particularly its Renewable Energy Department, since most of the implementation organizations (state grid companies, solar PV companies, and policy banks) are directly or indirectly regulated by this department. The LGO-PAD plays a supporting and monitoring role [13].

While central government entities are more concerned with macro-level policy development, prefectural and county governments are in charge of SEPAP implementation on the ground. Three government agencies have been involved in SEPAP implementation in Jinzhai County: the State Grid Corporation of China (Jinzhai County), the Jinzhai Development and Reform Commission (DRC), and the Poverty Alleviation and Development Bureau (PADB)¹ (Jinzhai County). The roles of the main stakeholders in the three stages of SEPAP (application, construction, and post-construction) are explained in Table 2.

Table 2: *The roles of the main stakeholders in the three stages of SEPAP*

	Development and Reform Commission and Poverty Alleviation and Development Bureau	Solar PV companies (for example, Sungrow Power Supply Co., Ltd, XINYI Solar, etc.)	State Grid
Application stage	Formulate the plan and determine the goals	N/A	(1) Analyze and evaluate the electricity distribution network in the rural area; (2) Upgrade the rural power grids.
Construction stage	Record and report the installation data to the upper-level government body	Install the solar PV modules	Connect the solar power generation to the grid
Post-construction stage	Conduct project acceptance review	Maintenance (before 2019)	(1) Maintenance (after 2019); (2) Distribute the government subsidies.

Sources: Constructed by authors.

Village-level self-governance is also vital for the implementation of SEPAP. Several stages must be completed prior to the launch of SEPAP. First, support from village committees and party-member assemblies must be obtained. The village committee, whose members are elected by the villagers, is a self-governing body responsible for managing village affairs. The party-member assembly refers to the members of the Chinese Communist Party. Formally, these are two different

¹The role of the Development and Reform Commission (DRC) on the national level is to formulate policies for economic and social development, maintain the balance of economic development, and guide the restructuring of the economic system. As for the DRC in Jinzhai County, it cooperates with PADB to manage SEPAP. The PADB focuses on poverty alleviation programs in Jinzhai County.

organizations, but in reality, there are many overlapping points between them and it is difficult to differentiate their roles.

Second, depending on the size of the village, the start of SEPAP must be discussed at either village assemblies or village-representative assemblies. Village assemblies are meetings of all villagers, whereas village-representative assemblies are composed of representatives elected from village groups. In addition, once SEPAP is approved, the assemblies further discuss the issue of who is qualified to join SEPAP. Then, the information about SEPAP is disclosed to the public to check if there is any disagreement. Also, the village leader often visits the poor people's houses to persuade them to join SEPAP. In addition, after the SEPAP implementation, the village assembly or village-representative assembly must approve the annual income distribution of the village-level SEPAP.

4. RESULTS OF OUR FIELD STUDY ON SEPAP TYPES AND IMPLEMENTATION

4.1. Field study

We conducted 30 semi-structured interviews by using a questionnaire with officials at different government bodies and administrative levels in July 2021. We interviewed a total of 19 government officials from the State Grid (SG), the Development and Reform Commission (DRC) and the Poverty Alleviation and Development Bureau (PADB). Among the interviewees, ten were from the PADB, five from the SG and four from the DRC. In particular, at the SG, we interviewed the deputies of the sales and construction departments. At the DRC and the PADB, we interviewed the SEPAP's project managers. In addition, we interviewed 11 village-level government officials, including the village chiefs from three villages. Apart from the basic information, during the interviews we asked specific questions about the four types of SEPAP, the problems in SEPAP implementation, and about their evaluation of SEPAP outcomes.

4.2. Development stages and types of SEPAP

4.2.1 Pilot phase (2013-2014)

Almost all interviewees mentioned that the start of SEPAP in Jinzhai County could be attributed to the former secretary of the communist party in Jinzhai County, Mr. Pan Dongxu. He holds a doctoral degree in management and engineering science. He launched many solar power construction projects and attracted investments to Jinzhai County during his tenure (2012-2020). In 2014, during the construction of a photovoltaic agro-ecological park project, he realized that the solar PV industry had tremendous potential for local industrial development. Solar PV is relatively simple to operate, and it can provide stable income and other long-term benefits to the local people.

At the end of 2013, there were 45,687 poor households or 147,723 poor people in Jinzhai County out of a total population of 680,000 [17]. The incidence of poverty was 21.72%. Among the poor people, more than one-fourth were disabled people and people who had some chronic disease. The poverty alleviation task was arduous. Solar PV projects, however, were perfectly suitable for the disabled and the sick people as these people could not find work or have stable job. As an experiment, the Jinzhai local government implemented eight solar PV projects for eight disadvantaged households in different areas of the county. All projects were fully funded by the local government. Each of the solar PV projects had a capacity of 3 kilowatt. Each poor household

could gain 3,000 Chinese yuan on average per year by selling the generated electricity to the grid company for 20 years.

4.2.2 Large-scale installation stage (2014-2015)

The Jinzhai local government promptly began large-scale installation once the pilot projects proved to be beneficial for the eight disadvantaged households. The project type was individual-level SEPAP. Each solar PV project had a capacity of 3 kilowatts and was funded by a total investment of 24,000 Chinese yuan, of which the local government provided 8,000 yuan, another 8,000 yuan came from solar PV company donations, and the remaining 8,000 yuan from poor households. Most poor households could not afford to pay the initial investment of 8,000 yuan but could get interest-free loans from the local banks. The bank loans could be repaid by the annual income gained from selling the generated electricity. In 2014 and 2015, 2,008 and 5,795 poor people in Jinzhai County installed their solar PV modules, bringing the total number of individual-level SEPAP to 7,803.

4.2.3 Installation of village-level, joint village-level and utility-scale SEPAP (2015-2017)

In 2015, the Jinzhai local government also started building village-level, joint village-level and utility-scale SEPAP. In 2015, the county had a total of 218 village-level solar power systems with a total installed capacity of 23,480 kilowatt. To help build the solar power systems (each with a capacity of 60 kilowatt), village welfare companies were established by the village collectives. The village welfare companies made an initial investment of 740,000 yuan with financial support from the local government and the local banks. Thanks to SEPAP, the village could earn a guaranteed income by selling electricity to the state grid company for 20 years. The income was used for village-level public welfare initiatives such as public welfare jobs and temporary financial assistance to poor households.

To solve the problems caused by the scattered installation of household solar PV modules and to lower the operation and maintenance costs, the Jinzhai local government decided in 2015 to use the joint village-level option of SEPAP. The projects were again financed by the local government, the solar PV companies, and poor households. The county government owned the property rights of the solar power systems. The net revenue was obtained after paying the land transfer fees and the operation and maintenance expenditures. The net revenue was then distributed to poor households. Each poor household had to pay 5,000 yuan as an initial investment. For that investment, they could borrow money from the local bank. They would earn 3,000 yuan each year over the next four years (2017-2020) and return the bank loan.

To save land resources and cover more poor households, the Jinzhai local government decided in 2015 to build another 100,000 kilowatt of utility-scale solar power systems. For that construction, 170 million yuan was invested by the county's government and poor households, while another 630 million yuan came from low-interest bank loans. The net revenue was obtained after paying the operation and maintenance expenditures, as well as the loan servicing costs. Part of the net revenue was then distributed to poor households. The capacity in kW of utility-scale SEPAP was higher than that of joint village-level SEPAP (see Table 3).

4.2.4 Adjustment and maintenance stage (after 2016)

The construction of most of the solar power systems under SEPAP was completed after 2016. The county government then started a capacity expansion project. The capacity of 68 village-level solar power stations was expanded from 60 kilowatt to 100 kilowatt. Another 150 village-level solar

power stations adopted a county-based, centralized construction method to increase their capacity to 100 kilowatt. Moreover, the central government designated 24 model villages and raised their capacity to 170 kilowatt. In addition, some villages received donations from solar PV companies to expand the capacity of the solar power systems even further.

When all the construction and capacity expansion were finished, the county government finally aggregated all SEPAP data and created a SEPAP archive for better project management. Since then, the county government's work has shifted from construction to maintenance and income distribution, as good maintenance directly affects the operational stability and the actual power generation of a solar PV plant. In addition, equitable and timely income distribution is at the core of the county government's efforts to help the poor benefit from SEPAP.

Table 3: *Four types of SEPAP in Jinzhai County*

	Individual-level	Village-level	Joint village-level	Utility-scale
Capacity (KW)	3	>100	240-6,000	>1,000
Starting year	2013	2015	2015	2015
Who pays the initial investment	Local government + solar company + poor households (each poor household pays 8,000 yuan)	Local government	Local government + solar company + poor households (each poor household pays 5,000 yuan)	Local government + solar company + poor households (each poor household pays 5,000 yuan)
Initial installation cost	24,000 yuan	Varies according to the capacity of the solar power system		
Property rights	Households	Village collectives	Local government	Local government
Distribution of income	All income goes to the poor households	Income used for public welfare initiatives at the village level such as creating public welfare jobs and temporary financial assistance for poor households	Poor households and local government	Poor households and local government
Lifetime of the solar PV modules	20-25 years			
Selling price of electricity (yuan/Kwh)	1.00 (2013-2015), 0.98 (2016-2017), and 0.85 (2018-2020)			

Sources: Constructed by authors.

5. GOVERNANCE CHALLENGES IN SEPAP IMPLEMENTATION AND THE SEARCH FOR SOLUTIONS

5.1. Challenges in SEPAP implementation

During our interviews with government officials, they admitted the existence of some challenges in SEPAP implementation. The problems hampered the achievement of SEPAP's positive effects on poor people. The key challenges raised during the interviews are discussed below.

5.1.1 Poor construction quality

The poor construction quality hampered the achievement of the positive poverty alleviation effect. At the start (2014-2015), there was a boom in individual-level SEPAP installations. About 8,000 individual-level SEPAP projects were constructed in the first two years. Following instructions from the upper levels of government, the village-level government officials visited the houses of poor households and tried to persuade them to install solar PV modules.

SEPAP was undeniably appealing to the majority of poor households. They could get an interest-free bank loan to pay for the initial investment. They could also receive a stable income over the next 20 years. The poor households had, on average, an annual income below 2,800 yuan (approximately 455 US dollars) in 2014. After joining SEPAP, their annual income could double in a couple of years. Most of the poor trusted the local government and accepted to join the SEPAP.

The Chinese government authorized a large number of solar companies to supply solar PV modules for SEPAP. However, at that time, there were no construction standards in place, and the government did not apply strict requirements for the entire installation procedure, which included a pre-construction approval and a post-construction review. Due to the low installation fee and the sharing of one-third of the initial investment cost, some smaller solar PV companies supplied solar PV modules of low quality. This caused huge problems for operations and maintenance later.

5.1.2 Maintenance difficulties

Jinzhai County is the largest (in terms of area and population) mountainous county in Anhui Province, with a total area of 3,814 square kilometers. For comparison, Jinzhai County is approximately three times larger than New York City and 1.5 times larger than Tokyo. Furthermore, Jinzhai county is made up of 23 towns and over 200 villages, some of which are located in the Dabie mountain. The majority of poor households live in mountainous areas where there were no modern roads in 2014. Transportation and road conditions have substantially improved in the past seven years. However, when the authors conducted the field study in July 2021, some isolated settlements could not yet be reached by bus or car. If maintenance work is required, it will take more than 3 hours to travel from the central section of Jinzhai county to the farthest or most remote houses of the poor households. The round trip for a regular maintenance job would take a whole day.

5.1.3 Inadequate maintenance service

The problems discussed above in (5.1.1) and (5.2.2) have resulted in inadequate maintenance service. Until 2019, Jinzhai County's maintenance service was handled by Sungrow Power Supply Co., Ltd. The company is one of China's largest private solar PV firms. But the local maintenance team had only 11 employees and four cars. According to government documents

and our interviews, this team did troubleshooting 2,975 times and changed 787 modules and 710 inverters in 2014-2019.

Nevertheless, the maintenance service provided by Sungrow Power was insufficient. They were unable to do proper maintenance in a timely manner due to the remote location, high costs, and the lack of qualified personnel. There were some additional problems when they had to replace the old, defective solar panels with new ones. As some of the solar PV modules were not manufactured by Sungrow Power, the new ones had to be supplied by the original manufacturer. In the case that the original manufacturer could not supply the new solar panels, Sungrow Power had to replace the old panels with their own products that were much more expensive. The price of replacement was out of reach for the poor. This elevated the financial burden of the local government and the solar PV company even further.

5.1.4 Difficulties for households to maintain the solar systems

In comparison with other cities or counties, Jinzhai County has a low level of education. As shown in Table 4, only 8.62 percent of the overall population have received a university degree. Nearly 70% of the population only attended middle and elementary school, while 8.26% of the population is uneducated. When it comes to poor people, the number is even higher. Most of the poor only went to elementary school or remained uneducated. They had neither any knowledge of solar PV modules nor the desire to learn about them. The majority of the poor merely knew that they could receive some money, most likely 3,000 Chinese yuan every year. Most poor households were unaware of how to do simple maintenance and how to determine whether their solar panel is working or not. The government’s work was taken for granted by the majority of the poor. They assumed that paying money to them was all part of the government’s job.

According to the government officials we interviewed, some poor people have relocated to other places as a result of a government-funded relocation program. These poor people had previously resided in the mountain areas where disaster risk was high. In addition, many young people moved to large cities and worked part-time jobs to supplement their income. As a result, poor households found it difficult to return to their original living locations where the solar PV modules were installed. Thus, they were not able to take care of their own solar equipment.

Table 4: Number of people with all types of educational attainment per 100,000 population in 2020

	University or higher	High school	Middle school	Elementary school	Uneducated
Jinzhai County	8,618	14,687	36,656	31,783	8,259

Source: [44]

5.1.5 Delays in the payment of government subsidies

Last but not least, the government subsidies for SEPAP were not paid on schedule for two main reasons. First, there was a shortage of funds within the central government. The Finance Ministry was responsible for distributing the subsidies to the local governments. However, it is estimated that the shortage reached over 45.5 billion Chinese yuan in 2018 and this number is still getting bigger [45]. Without subsidies from the upper levels of government, the State Grid in Jinzhai County could not distribute the subsidies to poor households. Second, there was a data

inconsistency between the poor household archive in the poverty alleviation and development bureau (PADB) and the user information archive in the State Grid. PADB reported its own data on who should be subsidized to the central government. The State Grid was responsible for distributing the subsidies to the poor people and knew the actual number of poor people who should be subsidized. Unfortunately, as these two data sets did not match, the subsidies could not be paid to some poor households on time. These two data sets did not match because the actual SEPAP construction was slightly different from the original SEPAP construction plan.

5.2. Efforts to address the challenges in SEPAP implementation

Although a number of serious problems occurred during the process of SEPAP implementation, some of them have been solved due to subsequent government actions.

5.2.1 Development of standardized SEPAP design plans and management regulations

In the process of SEPAP implementation, the central government released a number of SEPAP policy documents. Figure 1 below summarizes and categorizes the policy documents related to SEPAP implementation until 2021.

Documents such as "SEPAP Management Methods" and "Village-level SEPAP Income Distribution Management Measures" adopted in 2018 specified how SEPAP should be managed and how SEPAP benefits should be distributed to poor households. In addition to the central government's efforts to improve SEPAP implementation, Jinzhai County formed its own design plan and management regulations from 2015. "The SEPAP Grid Connection Engineering Design", for example, sought to establish guidelines for connecting the solar electricity to the grid at 220/380 V, 10 kV, 35 kV, and other voltage levels. "The SEPAP Photovoltaic Enterprise Operation Guidelines" simplified operating procedures, reduced grid connection time, and improved the efficiency of solar PV power generation for poverty alleviation. "The User's Settlement Process for Distributed Photovoltaic Poverty Alleviation" created a one-stop rapid service, a streamlined business process, a shorter working time frame, and improved service efficiency. All of these documents have contributed to the creation of a better SEPAP management system, allowing the entire process to be standardized and based on formal rules and regulations.

5.2.2 Transfer of the maintenance responsibility to the State Grid

As discussed above, the difficulties of maintenance by Sungrow Power have impeded the efficiency of solar electricity generation and, thus, the equitable distribution of benefits to poor households. In 2019, the responsibility to maintain the solar PV modules constructed under SEPAP was transferred from Sungrow Power to the State Grid in Jinzhai County.

The transfer of the maintenance responsibility was done because of the following advantages of the State Grid (SG). First, the SG had its own office and technical staff in each small town and was responsible for all electrical work, including SEPAP maintenance work. In case of trouble, the SG employees could get to the poor people's houses quicker. Second, the local government provided SG's technical workers with maintenance training. Being a state-owned enterprise was the third advantage. As maintenance work does not produce large profits, private companies such as Sungrow Power and their employees had a relatively low motivation to provide high-quality maintenance work. Fourth, the SG employees were typically locals who were also more familiar with the local situation.

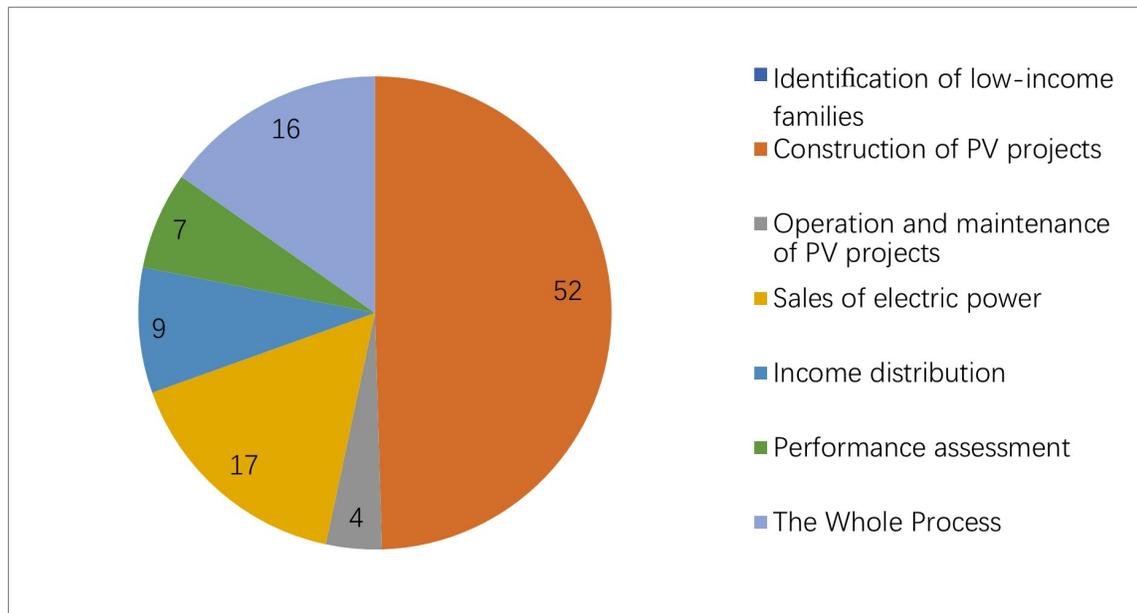


Figure 1: Number and categories of political texts related to SEPAP's implementation until 2021

5.2.3 Training and knowledge dissemination

Poor households are SEPAP's most significant stakeholders and beneficiaries. They should learn the basics of how to take care of their own solar PV modules. The Jinzhai government launched various initiatives to disseminate knowledge to poor households. For instance, the local government developed and distributed solar power generation pamphlets to low-income families. According to an interviewee at the State Grid, almost 20,000 pamphlets were given to the poor. In addition, the local government provided training for village-level government officials. Then, the village-level government officials taught what they had learned to the poor households in their respective villages.

Not only the village-level government officials were involved in poverty alleviation, but the upper-level government officials were also responsible for taking care of the poor people. Each upper-level government official was in charge of three poor households. The government official visited these poor households once a month. The purpose was to keep track of the situation of low-income families. If the poor needed something, the government official would soon be aware of it and would try to help them. When upper-level government officials visited poor households' houses, they also checked whether their solar PV modules were working and advised the poor on how to maintain the modules on a regular basis.

5.2.4 Development of a remote monitoring system for SEPAP projects

The local government partnered with the National Electric Power Science Company to establish a distributed PV regional monitoring system based on big data, which integrated the data into an intelligent dispatching technology support system via wireless technology. The system allowed the local government and poor households to monitor the current and the voltage of the solar PV modules in real-time. If any anomalous data was discovered, the government would send technical personnel to the field. As a result, they were able to resolve solar panel malfunctioning

issues quickly and diminish the amount of lost income for poor households.

6. DISCUSSION

Given the characteristics of China's political regime, it is not a surprise to observe poverty alleviation in a top-down manner. As discussed by Li et al. [46], the main driver of SEPAP was the desire to end extreme poverty at the national level. Nevertheless, we find that SEPAP was an innovative program in which both top-down and bottom-up governance modes were important. In particular, the local governments played the role of a bridge between the upper levels of government and the poor households. In addition, the local governments were allowed to make decisions based on the local context, their capacities, and limitations. Through the local experiments the central government could gather information and receive feedback about what was beneficial for the poor.

China's experimentation approach allowed for a quick launch and implementation of SEPAP. As a result, poor households managed to increase their annual income by a large percentage. The poor had an average annual income of only 2,800 yuan in 2014 (approximately 455 US Dollars). If we assume that they received the expected 3,000 yuan per year, the poor people's income could be doubled in just one year. In reality, since many had to pay back the bank loan, most of the poor received half of the income, or about 1,500 yuan per year, which was more than half of their 2014 annual income.

However, SEPAP also has some disadvantages. First, as discussed in section 2.1, some Chinese scholars [16,25] found that SEPAP did not lead to improvements in human and natural capital. Second, SEPAP is a government-led program in which government subsidy plays a very important role. The poor households did not learn any new skills to improve their living standards. Most of the new jobs created by SEPAP did not go to the poor people in the villages. In our view, SEPAP has led to an increasing reliance of the poor on government subsidies.

Furthermore, we have some doubts about whether the income increases achieved by SEPAP can be sustained over the long run. As for individual-level SEPAP, what will happen after the end of the period (20 years) of guaranteed government subsidies? Will the formerly poor households fall back into poverty? In addition, the government does not have to pay subsidies to the poor in the case of village-level, joint village-level and utility-scale SEPAP after 2020. Under those types of SEPAP, can the poverty alleviation effects of SEPAP be sustained over time?

After the launch of SEPAP, it took some time for the local governments to fully understand the intended and unintended impacts of the four different options. Our case study shows that many problems existed in the initial period of SEPAP implementation in Jinzhai County. However, the local government improved most of its policies over time. In our opinion, there were three major improvements. First, the shift from individual-level to village-level SEPAP. Compared to the individual-level SEPAP, the village-level SEPAP had a lower initial cost (average cost per kilowatt) and the maintenance was much easier. Second, the central and local governments adopted new policy documents that significantly improved the SEPAP management process. Third, the local government's efforts to educate poor households about SEPAP encouraged them to participate actively in the program and have their voices heard.

Even though some of the problems in SEPAP implementation have been solved as a result of the learning process over time, efforts to solve other problems have been less successful. According to our interviewees, there is still a lack of effective coordination between the different government bodies at the local government level. Although regular monthly meetings are held between the leaders of the Energy Bureau, the State Grid, and the Poverty Alleviation and Development Bureau, there is still insufficient communication among those departments.

In particular, many difficulties arise when the project requires coordination among various parties. For example, how to deal with the solar PV modules left at the original site when the residents have relocated to urban areas? The solution of the problem requires the involvement of the State Grid, the Poverty Alleviation and Development Bureau and the Energy Bureau. The Energy Bureau must work first with the State Grid to determine whether construction at the new location is feasible, or whether maintenance at the original site is preferable. Then it should discuss with the Poverty Alleviation and Development Bureau on how to enter the data. The entire procedure is lengthy and inefficient, thereby impacting poverty alleviation efforts. Therefore, the problem of coordination between the different departments at the local government level is a factor affecting negatively SEPAP outcomes.

Finally, our results lead us to the following policy recommendations regarding maintenance. First, we suggest that the local governments should develop an evaluation framework (including reward and punishment measures) for SEPAP maintenance. At the time of our interviews (July 2021), there was no specific evaluation framework for SEPAP maintenance work in Jinzhai County. However, good maintenance is the most crucial task for SEPAP after 2020. Without an evaluation framework that leads to reward and punishment measures, the effectiveness of SEPAP may be diminished.

In our view, reward and punishment measures should be set for the maintenance work based on indicators such as complaint rate, maintenance rate and actual power generation efficiency. In addition, it is necessary to develop a detailed task list and assessment rules for maintenance workers and include it in the annual poverty alleviation assessment. The poor households could also be rewarded or punished if they manage (or fail) to do some basic maintenance of their solar PV modules. In a nutshell, developing an evaluation framework is essential to ensure a higher quality of maintenance work and increase the benefits from SEPAP.

Second, we propose that the local governments should establish solar equipment replacement funds. In our view, this could largely solve the problem of fund shortage when the solar PV module's replacement is needed. Due to the low quality of the solar panels provided at the time of installation, some poor households had to replace their solar panels. However, they could not afford to pay for the replacement of the malfunctioning solar panels. To establish solar equipment replacement funds, the local governments could mobilize part of the revenues received from utility-scale SEPAP electricity generation. In addition, the local governments should also set clear and transparent rules for fund usage, i.e., specify the circumstances in which the poor households can use the replacement funds.

7. CONCLUSION

By critically exploring the problems of SEPAP implementation in Jinzhai County, this paper contributes to a deeper understanding of the outcomes of SEPAP in rural China. Jinzhai County has been hailed by the Chinese government as a success story. Furthermore, Jinzhai County has been dubbed the "living fossil" of SEPAP since it employed all four options with various capacities and funding models. However, we have shown that in Jinzhai County, the process of SEPAP implementation was far from easy. During the initial construction period, SEPAP implementation created serious problems such as poor construction quality, maintenance difficulties, poor people's lack of awareness about maintenance, and unfair income distribution. At a later stage, the local government made some efforts to solve some of the problems. Those efforts have led to better poverty alleviation outcomes in Jinzhai County. Nonetheless, some other problems remain unsolved. In this paper, we attempt to contribute to the search for solutions. In particular, we suggest establishing an evaluation framework that includes reward and punishment mechanisms

for maintenance, and creating a solar equipment replacement fund for future SEPAP management.

Declaration of interest: None

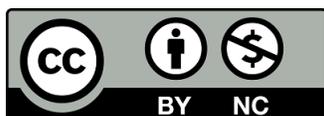
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