# A Review on photovoltaic poverty alleviation projects in China: conjunctures, current status and policy recommendations

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**Abstract.** Photovoltaic-based targeted poverty alleviation (PVPA) has been established for 10 years with the mission of one of "the ten large-scale poverty relief programs" in China. This paper would firstly examine the historical conjuncture of the PVPA, followed by the current status and the analysis of policy instruments. Results show that there are mainly three categories of policy instruments: the supply-type ones, the environment-oriented ones and the demand-type ones, with the previous two emphasized. The three most popular policy instruments that governments prefer to use are goal planning, financial support and infrastructure construction. Despite the great achievements, PVPA also need some improvements to be better implemented, and in the last part of the paper, some policy implementations are made regarding the unbalance distribution of the instruments among three above-mentioned classifications, as well as financial issues and accountability factors. It is suggested that governments should pay more attention to the demand-type policy instruments such as procurement or encouragement of the PV power generated by PVPA projects, and at the same time find better ways to supervise the benefit distribution.

#### **1** Introduction

In the past five years, China has witnessed great progress of the targeted poverty alleviation under President Xi Jinping's poverty relief proposal. The impoverished number has declined over 60 million and the total poverty rate has decreased from over 10% to less than 4%. However, continuously working on targeted poverty alleviation is still a crucial goal for the central government with great difficulties.

China has abundant solar radiation, and more than 66% of the Chinese landscape enjoys over 2000 sunshine hours per year, which provide quite satisfied conditions for the PVPA projects [1]. The Poverty Relief Office of State Council named the PVPA one of the "ten targeted poverty alleviation programs" which is a preferable approach to both central government and local government for its characteristics of income stability, energy saving and Green House Gas emission elimination. Practically speaking, farmers can use the green power generated from the PVPA projects and sell the surplus to the national grid with subsidiaries to earn some extra income. This project could help both the poor families owning the PV stations and the PV manufacturers, since the latter party could earn profit by selling the PV station component and maintenance & operation parts. The win-win situation could finally stimulate the regional GDP.

To successfully realize the PVPA projects, supporting policies plays a crucial role, therefore how to design the policy in a proper way has been a issue of great significance. At present there are mainly three categories of policy instruments namely supply-type, environmentoriented and demand-type policy instruments, with distinguished features and bias, which could be useful in different situations. Thanks to the policy instruments, some PV enterprises have gained great progress in the PVPA projects and there are quite a lot of positive role models. However, the targeted poverty alleviation also faces some noticeable difficulties in its development, especially in the policy-making decisions, including the unbalance development of the different categories of policies and other lack of demand and financial support polices, thus there are some policy implementations at the end of the paper to give some future possibilities.

#### **2 LITERATURE REVIEW**

According to Oh and Yoo, applying and encouraging the green energy in developing countries could be a feasible way to increase the household income of the poverty-stricken population, and at the same time, improve the renewable technologies as well as the local GDP [2,3]. This notion has been widely accepted by a number of

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scholars [4-9]. However, the literatures directly mentioned about PVPA projects are rare with no systematic research so far.

In fact, if any kind of poverty alleviation needs to gain certain achievement, several conditions must be met first including technical support, infrastructure construction, education and support policies. Liu and Li emphasized that to fulfill the previous requirements, some actions shall be taken such as boosting the tourism industry, establishing more educational institutes, continuously improve the local infrastructure and collecting large amount of dataset [10]. Li, at the same time, emphasized the significance of agricultural science in rural areas [11]. According to Jennifer and Smallholder, the popularity of small-sized irrigation technology can noticeably enhance the grain harvest and therefore help the poverty-stricken population out of poverty [12].

Education and labor training are also long-term mechanisms for the poor population to escape poverty. For example in mining industry, Ge and Lei did a study a concluded that education and training could effectively and efficiently enhance the possibility for poor people to increase their household income to meet the poverty-relief benchmark [13].

Evidently, although there are a lot of studies regarding poverty relief, papers directly related to PVPA is still deficient. Therefore, a study regarding PVPA and policy recommendations could be helpful to governments to make further decisions.

#### 3 PVPA : HISTORICAL CONJUNCTURES AND CURRENT STATUS

#### 3.1 Why PVPA now?

To better understand the current status and the political support regarding PVPA projects in China, we should firstly study the historical conjectures and drivers of this particular policy category – why launched PVPA at that specific period of time? In this paper, three factors are illustrated in the following section: the stubborn poor situation in the rural areas in China, demonstrating the demand of extra income for the poverty-stricken people; the crossroad of Chinese PV industry due to the overcapacity and curtailment, leading to the urgent need of distributed PV installation; and last but not least, the poor coverage of electrification in poor areas in China.

#### 3.1.1 The poverty situation in rural areas

Since the market reform and openness policy in 1978, 29 years after the founding of new People's Republic of China, this country experienced a period of remarkable, even unprecedented economic development, witnessing

an average annual growth rate of around 10% over the past 30 years, and the household income as well as the per capita GDP increased dramatically in both urban and suburban areas, lifting more than 800 million people successfully out of poverty [14].

Nevertheless, the uneven development in the household income and other living standard benchmarks between rural areas and urban areas is greater than ever. For example, the average per capita disposable income in urban areas rose from 343 RMB in 1978 to 31,195 RMB in 2015, while the average per capita disposable income in rural areas increased from 134 RMB to 11,422 RMB during the same time span [15]. Throughout the whole process of the reform and openness era, the urban-rural income ratio in China was around 3:1, much higher than the international average ration of around 1.5:1 [16], not mention the non-monetary variances in a lot of other important areas such as education level, industrial level, social welfare, medical care and other gaps. Besides, this urban-rural income gap is not distributed evenly in China as well. The situation is especially severe in western regions where the natural resources are quite limited and the climate is not suitable for the development of most industries. In fact, the urban-rural income gap ratio could reach as high as 4:1 in some western provinces [17]. According to China's official figure for the current poverty standard (2300 RMB of annual per capita income), the poverty population in China was around 56.30 million in rural areas in the year of 2015 [18], most of which were staying in western provinces.

Ever since President Xi Jinping came to power in the year 2012, the poverty issue and the unbalanced development in China had been elevated to one of the highest priorities during the process of development in China [19]. Under Xi's spirit, several policies has been issued after Xi's visits to the poorest areas in China, echoing his determination in the battle of poverty [20]. After a few years' trial and error, the current poverty alleviation projects in China mainly focuses in two major criteria: the so-called "precision" and "industrial" requirements. The former one emphasized that the government should make sure to target the real poor households according to some precise and comprehensive data with multiple-phase re-classification system, and the latter one aimed to help the poor households to improve a certain technique by developing innovative industrial facilities, so that these households could reach a self-sustainable development in the long run. PVPA projects could perfectly match the two requirements simultaneously [19].

### 3.1.2 The current status of China's solar energy industry

The second main reason why the PVPA projects have been launched is the industry itself. China enjoys the relatively low cost of labor and raw material expenditures in the PV industry thus has experienced an incredible boost in the manufacturing section in the PV industry around ten years ago, making China one of the largest export entities in solar PV products [21-23]. However, the unexpected sudden shrink of the global demand thanks to the financial crisis as well as the antidumping and anti-monopoly execution in the year 2011 by the western world pushed the Chinese PV industry into the winter period [24,25].

Therefore, China's central government decided to establish a series of encouraging policies to stimulate the domestic PV market as a rescue strategy including feedin-tariff, subsidies, pilot program, biding projects and so on, as a top-down manner to widen and recover the Chinese PV industry, especially the manufactory sector [26].

This stimulation strategy earned a huge success indeed. By the year 2013, China has surpassed other countries to be the world's leading market in terms of total PV installation, reaching 43.18 GW by the end of 2015 [27,28], with over 15 GW new installation in the single year of 2015 [29]. Nevertheless, the manufacturing capacity grew even faster. As a matter of fact, the domestic newly installation of 15 GW in the year of 2015 only consumed approximately 30% of the national production of PV panels, leading to a serious and persistent over-capacity in the long run [27,28].

Furthermore, and curtailment issue is rampant due to the unbalance development of PV station installation and the grid connection efficiency. Most of the new capacity installation is currently established in the poor western areas where the electricity consumption is low and the transmission cost is high [30]. The curtailment rates had reached as high as 25% in western provinces such as Gansu and Xinjiang in 2015 and this ratio has climbed to as high as 39% over the first half year of 2016 [27,28]. Then the central government adjusted its policy to control the over-development of the centralized PV station installation by stimulating the distributed ones where the electricity generated could be consumed locally at first [31-33]. The distributed PV systems have been welcomed by Chinese government for a long time and viewed as the best model in China. However, from the investor's point of view, the centralized large-scale PV stations is undoubtedly the more favorable one with stable cash flow and remarkable IRR, thus 90% of the investment capital flew into the large scale projects in the year 2015 [33]. The distributed ones, however, are continuously under the government's expectation therefore the PVPA projects could be an idea product under this situation, which can simultaneously receive the support from both the environmental perspective and the poverty-alleviation one.

#### 3.1.3 Rural electrification tendency

To better understand the PVPA projects, not only the poverty alleviation target and the PV stations should be taken into consideration, the development of the electrification history in China should also be demonstrated.

At the founding of the new China in the year 1949, less than 10% of the Chinese residents could access to electricity, thus expanding electrification became one of the most important of the political target for the central government. By the year 2013, this figure had reached as high as 99.8% [34], and the last 39,800 people in the most remote areas in Qinghai Province were reported successfully connected, meaning China has finally reached the 100% electrification standard. But the problem behind the issue is apparent as well: the Chinese central government has spent over US\$4billion on this policy and this is not a efficient and suitable policy in the long run.

To cope with the electrification target as well as the environmental concern, the renewable energy played an increasingly important role in the electrification process in the remote and poverty areas, and the dominant choice was small hydro power (SHP) stations in China for a long time, reaching 73 GW by the end of 2014 thanks to the 47,000 SHP stations in China, occupying more than 25% of the total hydropower capacity of the whole country [35,36]. Different from the PV stations, the SHP stations enjoys bottom-up approach policies so that the local government, investors and local residents had enough intention to build them [37].

However, the construction of the SHP stations has been slowing down since 2012 due to the lack of new suitable spots with hydro potential. As a result, the solar energy has become an ideal substitute for electrification with no limitation of sun radiation and less constrain of location. Apart from the PV thermal system that is traditionally popular in remote and rural areas for a long period of time [38], the PV power generation section could be a future trend in these remote and poor areas as the cost of the PV products has been falling dramatically [39].

In general, this section presented the historical conjuncture of projects, and the following part would mainly focus on the current situation of PVPA projects in China including the developing policies.

#### 3.2 PVPA current status and future plan

China, as indicated in Figure 1, enjoys abundant solar resources, especially in southwestern areas, with the average solar radiation of more than 1100 kWh/m2. The other direction on the graph, the right axis, presents the current situation (number of poor villages) and their distribution in poverty areas in the 12th five-year plan. From the graph we could see that provinces with relatively large population of poverty tend to receive better sun radiation, which provide a suitable condition for the PVPA projects, providing physical feasibility and convenience.

The above-mentioned advantages and physical feasibility catalyzed the PVPA projects and the relevant working program to be established by the central government, thus in 2014, the National Energy Administration (NEA) and the Poverty Alleviation Office of China under the State Council proposed the

PVPA projects for the first time [40]. With careful investigation and picking the poverty information as well as the solar radiation data, the pilot PVPA projects were launched with altogether 5.16 GW, in which 2.98 GW were the ground-mounted centralized large scale systems, spreading in 14 provinces such as Shandong, Hebei, Anhui, and Jiangxi, covering 0.556 million poor residents accordingly where the solar radiation was the priority taken into consideration [41]. In such projects, the supporting policies from both the central government and the local government were crucial, especially the local government. For example, the subsidy in Hebei province was 0.2 RMB/kWh while in Shanxi, this figure was 0.1 million RMB per 20 kW [42,43]. However, the provinces with high solar curtailment ratio were excluded in the PVPA program such as Qinghai and Ningxia, where the limitation of solar curtailment should be achieved first.

## 4 Supporting policies and recommendations

Figures and tables, as originals of good quality and well contrasted, are to be in their final form, ready for reproduction, pasted in the appropriate place in the text. Try to ensure that the size of the text in your figures is approximately the same size as the main text (10 point). Try to ensure that lines are no thinner than 0.25 point.

Fig. 1. Caption of the Figure 1. Below the figure.

#### 4.1 Supporting policies

The supporting policies from either central government or the local government plays one of the most critical roles in the PVPA projects, yet no consensus has been reached on the classification of the policies. One of the classification method presented by Zhang, Chen and Tao is highly praised in the Chinese academic circle, categorizing the PVPA policies into the direct provision of financial loans and services by government, allowances and subsidy, contractual outsourcing and so on [44]. Chen, in 2004, classified the policies into market-oriented instruments, business administration techniques and social measures [45]. And Tao then argued that the policy instruments included five types of instruments: economic, administration, managerial, political and social instruments [46]. Although the above-mentioned policy classifications have widely adopted when studying the PVPA projects, they still seem to be too extensive or unsystematic or overlapping. As a result, we can use the idea which Rothwell and Zegveld first rose in 1985 to classify the basic policies into three categories: a supply type, a demand type and an environmental type [47]. Table 1 illustrates the PVPA policies and Table 2 classified those instruments in those three types. We can see that the demand type is underdevelopment compared to the other two. Detailed speaking, there are altogether 25 supply-type policy instruments, constituting around one third of the total quantity. The second class, the environmental type,

occupies as high as 52% of all the policy instruments, and the exact number is 39 in all. The last one, the demand type, which only contains 11 kinds of PVPA policy instruments, accounts for only 14.67% of the whole policy package. Among all the three categories, an interesting discovery was found that government prefers the following three policy instruments: goal planning (22%), financing support (18.67%) and infrastructure construction (14.66%), which accounts for the three highest proportion among all the policy instrument, followed by three evenly distributed ones namely capital investment, legal regulation and trans-regional/transdepartment cooperation. Apart from these obvious tendencies, there is only one tax-related policy within the environment type policy instruments in 2013. It is indicated that the VAT shall be immediately returned to the taxpayers who self-sale the electric power products using solar energy within the time range of October 1, 2013 to December 31, 2015. This policy considerably reduced the heavy tax burden of those low-income families and at the same time increased their income directly.

Evidently, the current PVPA policies emphasized on the strategic goals and financial support sectors, and the Chinese government has shown a relatively strong preference on the supply type and environment type policy instruments. However, for the supply and environment types, there is room for improvements. The dearth of supply type policy instruments implies that the PVPA in China faces some uncertainties, which the central government should perfect it as soon as possible. While at the same time, the deficiency in supply type instruments indicates that the government's direct production factors into PVPA projects is incomplete.

Table 1. Policy documents related to PVPA projects.

No.	Documents	Agency	Year	Purpose
1	Circular on the VAT Policy of PV- based Power Generation	Ministry of Finance	2013	Tax preference
2	Several Proposals of State Council on Promoting the Healthy Development of the PV Industry	The State Council	2013	Promotin g the healthy developm ent of PV industry
3	Provisional Measures of Administration over Distributive PV projects	NEA	2013	PV Construct ion
4	Circular on Exerting the Function of Prize Leverage to Promote the Healthy Development of PV industry	NEA	2013	Promotin g the healthy developm ent of PV industry
5	Circular on Steadily Boosting Rural	The State Council	2014	Rural Poverty

	Poverty Relief			Relief		construction in 2015			
	Development by								
	Innovative					Proposals on			
	Provisional					Promoting the			Promotin
	Measures for Grid					Application of			g the
6	Connection of	NEA	2014	PV power	16	Advanced PV	NEA	2015	healthy
	Newly-built Power		2014 I V pow		power	Techniques and			developm
	Supply					Products and			ent
	Work Program on					Upgrading of PV			
7	Implementing PV- based Poverty	Implementing PV- based Poverty Relief ProjectNEA2	2014	Construct ion		Implementation			
'						Proposals of			
	Relief Project					National Energy			
	Notice on issuing			Construct ion		Administration on			
o	the annual	NEA	2014			Accelerating the			Poverty
0	of PV power	INLA	2014		17	Energy	NEA	2015	alleviatio
	generation in 2014				1,	Development	11211	2015	n
	Guiding Opinions					Construction of			
	on Offering	Offering				A reas and Boosting			
	Desirable Financial	I ne		Financial		the Storming of			
9	Service to Poverty	bank of	2014	Support		Poverty Elimination			
	Relief Development	China		Support	-	Provisional			
	in an All-round	Cillina				Measures for	Ministry	2015	Capital investmen t
	Way				18	Special Fund			
	Programme for the			Descriter		Management of	of finance		
10	establishment to	NΕΔ	2014	Identificat		Renewable Energy			
10	Poverty Relief	NLA	2014	ion		Program for			
	Development			1011		Compilation of PV-			
		The state			19	based Poverty	NEA	2015	Construct
	The implementation lead	council				Implementation			1011
		leading				Scheme (Trial)			
	Plan for establishing	Plan for establishing group	Poverty	-	Circular on				
11	the Mechanism of	office of	2014	Identificat		Practically Ensuring			
	Precision Poverty	poverty		ion		Desirable	National		
	Alleviation	alleviation				Cooperation	ent and		Financial
		developm			20	between	reform	2016	support
		ent				Government and	commissi		support
	Opinions on					Social Capital in the	on		
	Reforming the					Infrastructures			
	Management	Ministry		Capital		Guiding opinions on			
12	Mechanism of	of Finance	2014	investmen		developing			
	Special Financial	of I manee		t		characteristic	Ministry of	2016	Poverty alleviatio
	Fund to Poverty				21	industries to			
	Alleviation				promote Precision	e		n	
	Mobilizing All					Poverty Eradication	C		
	Social Forces to	The state		Financial		in Poor Areas			
13	Participate in	council	2014	support		Proposals on	China Securities		
	Poverty Relief					Exercing the			Statutory
	Development				22	Market and Serving	Regulator	2016	
	Proposals of					National Strategy of	У	2010	regulation
	improving the					Poverty Relief	Commissi		
	Economic and					Storming	on		
	Social Development			Assessme nt of poverty		Pilot Program for			
14	Assessment of the	The state	2014			Reforming the			
	narty and	council	2014			Asset income from	The State		Income
	government leading			relief	23	Hydropower and	Council	2016	distributio
	bodies and leading					Mineral Resources			n
	cadres in poor					Development in			
	counties					Notice on matters			<u> </u>
	Notice on the					related to the	Ministry		Financial
15	implementation plan	nplementation plan NEA 2015 Constr		Construct	24	Integration of	of Finance 2	2016	support
1.5	of DV nower	111273	2015	ion			or r manee		Support
	of i v power			1011		Agricultural funds			

34

Mode of

Cooperation

between

Government and

Social Capital in the

Energy Field

NEA

2016

support

	in Poverty Counties				Proposals on Implementing 35 Poverty Relief of PV-based Power Generation		National Developm ent and		Sales of	
	Proposals of the CPC Central Committee and the State Council on implementing the New concept of Development to speed up Agricultural Modernization and	The State Council	2016	PV agricultur e			overty Relief of V-based Power Generation	Reform Commissi	2016	electric support
25					36	A Mea Pov C De o	Administrative asures for the PV verty Relief Loan of Agricultural velopment Bank f China (Trial)	Agricultur al Developm ent Bank of China	2016	Financial support
	achieve the goals of a whole well-off society				Table 2. Distribution of basic policy instruments.					
26	National Plan for Agricultural Modernization	Ministry of Agricultur	2016	PV agricultur e	Instrum type	nent e	Instrument	name	Total	Percentage
	(2016-2020) Notice on investing	e			1		technical information		N/A	N/A
27	the construction conditions for PV	NEA	2016	Construct ion	2	Infrastructure co		onstruction	11	14.67%
	Administrative Measures for the			Sales of electric power	3		Capital inve	stment	6	8%
28	Full-amount Indemnificatory Purchase of	Ministry of Finance	2016		4		Educational cultivation		2	2.67%
	Renewable Energy Power Generation	enewable Energy ower Generation		power	5		Public service		5	6.67%
29	Circular on the Thirteenth Five- Year Plan for	The State Council	2016	Goal planning	6		Goal progra	mming	17	22.67%
	Poverty relief Some proposals of				7		Financing s	upport	14	18.67%
30	of the State Council on improving the	The State Council	2016	Farmer's income	8	8 Tax prefe		rence	1	1.33%
	supporting policy to promote the				9		Statutory regulation		7	9.33%
	sustained increasing of farmer's income Work program on				10		Protection of intellectual property right		1	1.33%
31	implementing PVPA project	NEA	2016	Construct ion	12		Governmental p	rocurement	1	1.33%
37	Key points of targeted Poverty	NEA	2016	Construct ion	13		Policy of elect sales	ric power	4	5.33%
52	counterpart support in 2016	NEA	2010		14		Trans-regiona depratmental co	al/trans- opperation	6	8%
	Implementation Opinions on	The			Tota	ıl	N/A		75	100%
33	rinancial Boosting of Poverty Elimination Storming	bank of China	2016	support	4 2 Policy recommendations					
24	Circular of National Energy Administration on Actively popularizing the		2017	Financial	<ul> <li>4.2 Policy recommendations</li> <li>There are several suggestions and implications to the Chinese PVPA policies in order to realize the ambitious goal of eliminating poverty by 2020.</li> <li>Based on the previous analysis, we could safely indicate</li> </ul>					ons to the ambitious

Based on the previous analysis, we could safely indicate the results that: 1) three types of specific policy instruments are currently most popular: goal programming (accounts for 22.67%), financing support (accounts for 18.67) and infrastructure construction (accounts for 14.64%). 2) At present, the government emphasizes on the supply-type and the environment-type policies, with less attention on the demand-oriented policies. Moreover, the supply-oriented ones are not developed soundly.

Therefore, here are some policy recommendations for China:

Firstly, reduce the use of policy instruments regarding goal planning to a moderate level, and increase the economic ones properly. At the same time, the central government should enhance the policies pertaining to the sales of PV-generated power by either government procurement or encouraging the coordination with the traditional thermal power plants.

Secondly, financial incentives and financing support policy instruments should be emphasized to a greater extent as one of the most severe obstacle for the establishment of PVPA projects for the poverty people is lack of capital. China Central Television (CCTV), the main official broadcaster in China, reported in the end of 2016 that Ningxia's pilot PVPA projects faced serious delay in construction due to lack of financing support, and for those who have already established the roof-top PV stations successfully, they received 300 RMB annually from the project developer, or just 10% of the suggested number in the NEA policy indication.

Besides the above-mentioned financial difficulties, the accountability of the PVPA project is another important issue and challenge for the policy-makers to consider. The poor residents from remote and poverty areas tend to have little knowledge and information regarding the PVPA projects as well as the subsidiaries and supporting policies, thus they could be classified as the "passive beneficiaries", the ones that would only get benefit if noticed or informed. They have hardly any negotiation power towards other stakeholders such as local government, project developers, grid companies or policy banks, thus the supervision toward the appropriate distribution of the benefit returns from the PVPA projects within the whole project cycle matters a lot. Since the policy-maker and the initiator of the PVPA projects, the NEA, is not the direct monitor of those powerful parties such as local governments, it is quite a large challenge for them to regulate the benefit distribution so that the goal of the PVPA projects, the poverty alleviation, could implement with satisfied outcome.

#### **5** Conclusion and Discussion

Based on the context analysis, we firstly studied the historical conjuncture of the PVPA projects and the related policies, indicating that the three main reasons of why the PVPA projects are presented now is due to the poverty situation in rural areas in China, the crossroad faced by Chinese PV enterprises and the rural electrification issue. Then the current status of PVPA projects in China, especially the policy instruments, and conclusion could be made that among the three classifications of the PVPA polices in China, namely the supply-type, the environment-oriented and the demandtype, Chinese central government prefers the first two categories, and the three most popular specific instruments are goal planning, infrastructure construction as well as the financing support. However, there are still some difficulties in the PVPA projects and suggestions were made to cope with the obstacles.

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