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ECONOMIC BENEFIT ANALYSIS OF HOUSEHOLD DISTRIBUTED PHOTOVOLTAIC UNDER DIFFERENT FINANCING MODES

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ABSTRACT

In recent years, the development of household distributed photovoltaic is accelerating. However, the initial investment cost is relatively unaffordable for users, and the distributed photovoltaic financing is of characteristics like high threshold, few channels, low quota, high cost and short term, so China is actively promoting the corresponding financial supporting measures, like "photovoltaic loan" and finance lease. That's makes the choice of proper financing terms very important. This paper first establishes the evaluation model of economic benefits based on NPV method and different financing characteristics, and then changes interest rate, loan proportion and repayment mode, to analyze their impact on economic benefits, and finally arrives at conclusion that with proper financing mode, economic benefits and investors' investment confidence can be improved. Furthermore, It also suggests government should perfect existing photovoltaic financing policies, as well as enhance financial institutions' confidence that provide loans.

Keywords: household distributed photovoltaic, photovoltaic loan, finance lease, economic benefits

NONMENCLATURE

Abbreviations

DPV	Distributed Photovoltaic
IRR	Internal Rate of Return
PBP	Payback Period
NPV	Net Present Value

Symbols

n	Year of DPV project
p_{use}	Residential electricity price
P_{sale}	Desulfurized coal price
P_{sub}	Subsidy per kWh
K_{use}	The internal consumption proportion
M	Installed capacity of the DPV
C_o	Initial investment cost
H	Annual peak sunshine hours
$\mu_{(t)}$	Annual DPV generation decay rate
K_{debt}	Loans proportion
$C_{debt(t)}$	Annual repayment for loans
K_{ope}	Annual operation cost proportion
K_{scrap}	Residual value proportion
I_{int}	Interest Rate
m	Actual repayment period for loans
n'	Lease Term

1. INTRODUCTION

Household distributed photovoltaic develops rapidly in recent years. In 2020, the cumulative installed capacity of household photovoltaic is estimated to be 36 GW in China. Household DPV has eminent investing attributes and the current annual return on investment can reach more than 9%. However, because the initial investment cost is still relatively high to rural residents, along with the high threshold of financing, China has been making great efforts to promote matching financing support. According to the "China Household Photovoltaic Market Survey Report 2018" issued by China New Energy Network, 41.33% of users use their own fund to install DPV system, while nearly 55% depend on loans, as the following Fig. 1. Financing has been playing an increasingly important role in household distributed photovoltaic.

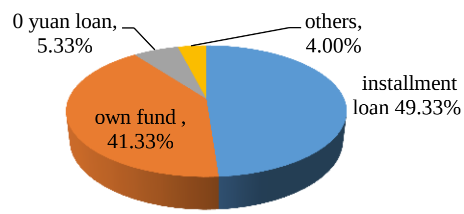

Fig 1 Payment method selected by users in 2018

So far, scholars at China and abroad have done a lot of research on the economic benefit analysis of household distributed photovoltaic. He et al. [1]

analyzed the IRR under different types of users in different regions if initial investment subsidies and subsidies for carbon emission reduction exist. Rodrigues et al. [2] analyzed Economic analysis of photovoltaic systems for the residential market under China's new regulation. Yang and Zhao [3] explored policies and economic efficiency of China's DPV, showing that economic efficiency is highly dependent on industrial policies. Shuai et al. [4] studied how government and users share the investment cost and benefit. To sum up, few scholars compare the impact on economic benefit brought by different financing methods from the user's point of view. Therefore, this paper build an economic benefits analysis model based on NPV method and different financing characteristics, and then elects an example in Jinan, Shandong Province, to calculate and compare its economic benefits. Finally, this paper arrives at conclusions and suggestions that proper design of financing terms will help to increase their investment value and promote further development of household DPV.

2. ECONOMIC BENEFITS ANALYSIS MODEL

2.1 Income model

The annual total income of DPV is mainly composed of three parts: electricity sales $I_{sale(t)}$, subsidy income $I_{sub(t)}$ and electricity saving income $I_{use(t)}$, as Eq.1, Eq.2, Eq.3, and Eq.4.

$$\mathrm{I}_{total(t)}=\sum_{t=1}^{n} I_{sale(t)}+\sum_{t=1}^{n} I_{\mathrm{sub}(t)}+\sum_{t=1}^{n} I_{\mathrm{use}(t)} \quad (1)$$

$$I_{sale(t)}=\mathrm{Q}_{total(t)}\times P_{sale}\times(1-K_{use}) \quad (2)$$

$$I_{sub(t)}=\mathrm{Q}_{total(t)}\times P_{sub} \quad (3)$$

$$I_{use(t)}=\mathrm{Q}_{total(t)}\times P_{use}\times K_{use} \quad (4)$$

$Q_{total(t)}$ represents the annual electricity generation. The annual power generation is determined by installed capacity, peak sunshine hours, system efficiency and annual DPV generation decay rate. The formula is as following Eq.5.

$$Q_{total(t)}=M\times\lambda\times H\times(1-\mu_{(t)}) \quad (5)$$

2.2 Cost model

2.2.1 Photovoltaic loan

When part of the initial investment cost is funded by bank loans, the cash outflow $C_{out(t)}$ of each year is expressed by the Eq.6, Eq.7, and Eq.8.

$$\mathrm{C}_{out(t)}=\mathrm{C}_0\times(1-K_{debt})(t=0) \quad (6)$$

$$\mathrm{C}_{out(t)}=\mathrm{C}_0\times K_{ope}+\mathrm{C}_{debt(t)}(1\leqslant t\leqslant n\text{-}1) \quad (7)$$

$$C_{out(t)}=\mathrm{C}_o\times K_{ope}-C_0\times K_{scrap}(t=\mathrm{n}) \quad (8)$$

In the way of repayment of equal principal, the user needs to repay the same amount of principal every year. Interest is determined by the remaining outstanding principal, and that is as Eq.9.

$$C_{debt(t)}=\mathrm{C}_0\times K_{debt}\div m+[\mathrm{C}_0\times K_{debt}-(\mathrm{m}\text{-}1)\times(\mathrm{C}_0\times K_{debt}\div m)]\times \mathrm{I}_{\mathrm{int}} \quad (9)$$

In the repayment way of equal principal and interest, users are required to repay the same amount every year, part of which is capital and part of which is interest, and that is as Eq.10.

$$C_{debt(t)}=\left[k_{debt}\times C_0\times I_{\mathrm{int}}\times(1+I_{\mathrm{int}})^m\right]/\left[(1+I_{\mathrm{int}})^m-1\right] \quad (10)$$

m is generally less than *n* and can be negotiated between lenders and borrowers.

2.2.2 own fund

When K_{debt} and $C_{debt(t)}$ equal "0", the annual cost of DPV funded by own money is the same as Eq.6, Eq.7, and Eq.8.

2.2.3 finance lease

Finance lease mainly aims at the equipment part, accounting for about 80%. Here we assume 100%. In addition, the project term of distributed photovoltaic projects is longer, usually 20-25 years, while the Contract Law stipulates that the lease term should not exceed 20 years. During the lease period, the equipment maintenance work is undertaken by the leasing company, so the annual operating cost is not considered here. After the expiration of the lease period, the ownership of the equipment belongs to the leasing company, that is, no residual value. The financial leasing company should determine the annual leasing cost of users. Here, we assume that the annual leasing fee consists of two parts, one is the depreciation of equipment, and the other is the cost of capital.

Therefore, when the DPV user chooses the financial lease mode, the cash outflow of each year is expressed by the Eq.11.

$$C_{out(t)}=C_0\times(1-K_{scrap})/n'+C_o\times I_{\mathrm{int}} \quad (11)$$

2.3 Economic Benefit Index Model

2.3.1 Internal rate of return

IRR is a discount rate that makes the NPV of an investment equals zero, which can be expressed as Eq.12.

$$\sum_{t=1}^{n}\frac{I_{total(t)}-C_{out(t)}}{(1+IRR)^{t}}-C_{out(t=0)}=0 \tag{12}$$

2.3.2 Payback period

The payback period refers to the time required for the total cumulative income of an investment project to cover the total investment cost, which can be expressed by Eq.13.

$$PBP=t'-1+\left|\sum_{t=0}^{t'-1}NPV_{t}\right|/NPV_{t'} \tag{13}$$

Where *t'* is the year in which the cumulative net cash flow begins to appear positive.

3. CASE STUDY

3.1 Data sources

Taking a distributed photovoltaic system with 8 KW installed capacity in Jinan, Shandong Province as an example. The average effective sunshine time of the area is 4.28 hours daily and 1562.2 hours yearly respectively. Assuming that the system efficiency is 85% and decreases by 3% in the first year, and then maintains a decline rate of 0.7% annually. The state subsidy for Shandong area lasts for 20 years and is 0.37 yuan per kilowatt-hour. Other specific data are assumed in the following Table1.

Table 1. Basic data values

Symbol	unit	value
K_{ope}	/	2%
K_{scrap}	/	2%
m	year	5
P_{use}	yuan/kWh	0.5969
P_{sale}	yuan/kWh	0.3949
C_0	yuan/kWh	8
n	year	20

3.2 Discussions and results

3.2.1 Assuming that the self-use ratio is 30%, the repayment of bank loan is made in the form of equal principal, and the lease term *n'* is 10 years, the results of economic benefits under the annual interest rate of 6% and 10% are shown as Fig. 2.

When the initial investment cost is fully self-paid, the user will obtain an IRR of 9.18%. Under the situation that the investment return rate is higher than the loan interest rate(6%), the higher the loan proportion is, the higher the IRR will be. So the IRR will be increased from 9.18% to 10.30% if the loan proportion rises from 0 to 70%. However, if the interest rate is 10%, higher than the investment return rate, the IRR will decrease as the proportion of loans increases. When the proportion of loans rises from 0 to 70%, IRR will be down from 9.18% to 8.91%. As to payback period, it will increase with the increase of the loan proportion regardless of the interest rate. For the household distributed photovoltaic system, the difference in PBP is not significant, so when the bank provides a more favorable interest rate, users can appropriately increase the loan proportion.

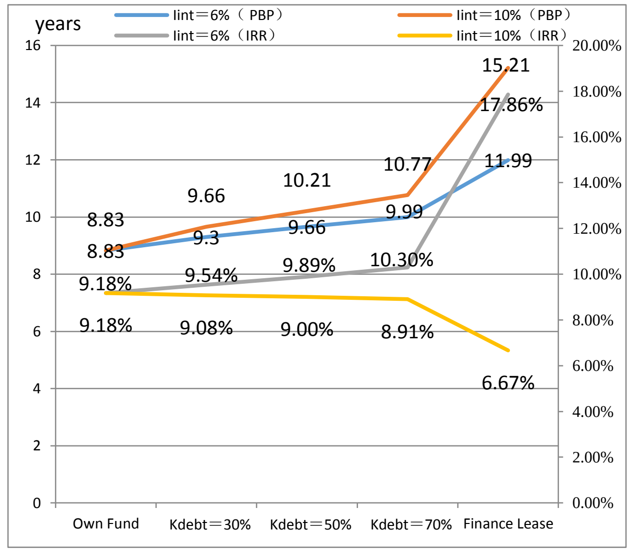

Fig 2 IRR and PBP under the first situation

In addition, the IRR and PBP under the finance lease mode fluctuate more intensely than any other financing mode with the changes of interest rate. That's because the lease term of 10 years is longer than loan terms of 5 years. The longer the term is, the greater the change of economic benefits will be. Adding that the longer the lease term is, the lower the annual lease fee is, so the annual revenue can cover the annual lease fees in ideal conditions, which can reduce the financial pressure of PV users to the greatest extent. The combination of "financial lease + distributed photovoltaic" has broad market prospects in the future.

3.2.2 Assuming that the self-use ratio is 30%, the annual interest rate is 6%, and repayment is made in two different forms - equal principal and interest, equal principal. The results are shown in Table 2

Table2. IRR and PBP under the second situation

Financing Mode	Equal Principal	Equal Principal and Interest
Own Fund	8.83 years 9.18%	8.83 years 9.18%
K_{debt} =30%	9.3 years 9.54%	9.81 years 9.58%
K_{debt} =50%	9.66 years 9.89%	10.69 years 9.92%
K_{debt} =70%	9.99 years 10.30%	10.04 years 10.35%

Under equal principal and interest repayment mode, the users generally get higher internal rate of return and longer payback period than the equal principal repayment mode. In the way of equal principal repayment, the monthly principal repayment has remained unchanged, but the interest is gradually decreasing, so the amount of total monthly repayment is becoming smaller and smaller. This method of repayment can quickly reduce borrowers' liabilities level, but the pressure of early repayment is very high and not suitable for young people. While in the other way, the total monthly repayment remains unchanged, which is more suitable for families with normal expenditure plans. However, this relative lower repayment pressure is at the expense of higher total interests. Users can choose the appropriate way of repayment according to their family routines.

3.2.3 Assuming annual interest rate is 6%, repayment is in the form of equal principal and interest, and lease term is 10 years, the results of IRR and PBP are as Fig.3. if the self-use ratio is 30%, 70% respectively.

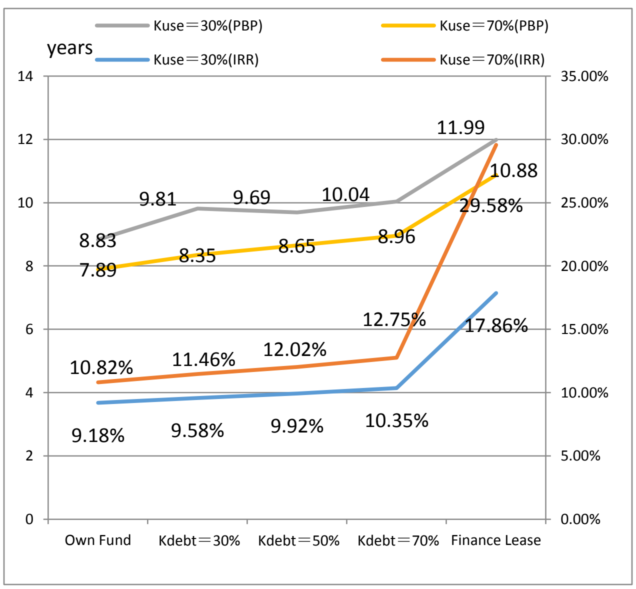

Fig 3 IRR and PBP under the third situation

From the above table, it can be seen that the higher the self-use proportion, the better the economic benefit will be. When the proportion of self-use is 30% and investors use their fund, the IRR is 9.18%; while when the proportion of self-use is 70%, and the loan accounts for 70% of total initial investment cost, the IRR is 12.75%. From 9.18% to 12.75%, nearly 40% increase rate, we can see that proper financing mode added higher self-use ratio will greatly contribute to the increase of project's intrinsic rate of return, and greatly enhance the attraction to investors.

4. CONLUSIONS AND SUGGESTIONS

This paper concludes that at the present stage (IRR is around 9% without loan), users can increase the IRR by increasing the proportion of loans with favorable interest rate (lower than 9%), but at the same time, the payback period of investment will be prolonged. Users need to balance the PBP and IRR. Financial leasing mode will further improve the economic benefits, and the annual revenue can even almost cover the annual rental fees, greatly reducing the financial pressure, but users should pay attention to the corresponding risks and the stability of subsidies .As to repayment mode, the equal principal and interest way of repaying loan will bring higher internal rate of return and longer payback period than equal principal, and is more suitable for families with normal expenditure plans. In addition, increasing the proportion of self-use will also improve the economic efficiency and the effect will be more obvious if it is combined with a proper financing mode at the same time.

Government plays a crucial rule in this process .On the one hand, government should speed up the construction of financial infrastructure, cultivate third-party rating agencies, introduce big data, cloud computing and other technologies, so as to strengthen data analysis and projects' rating and to increase financial institutions' investment confidence in the photovoltaic industry. On the other hand, the government should improve the existing photovoltaic financing policies, and actively explore new financing channels for small-scale household distributed photovoltaic systems, so as to further promote distributed photovoltaic among household users.

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