Comprehensive cost-effectiveness study of distributed photovoltaic projects in Jiangsu

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Abstract. Cost-benefit analysis is to analyze the relationship between costs and benefits, measure the gains and losses of economic behaviors, and obtain the optimal combination of costs and benefits. It is one of the most effective methods to evaluate investment plans. This paper takes a distributed photovoltaic power generation project in Jiangsu as the object, analyzes its investment cost and operating cost, power generation income and other economic benefits, and accordingly establishes a cost-benefit analysis model, evaluates the economy of the project, and carries out sensitivity analysis. In addition, the environmental benefit of distributed photovoltaic project is calculated. It is concluded that distributed pv can not only achieve good economic benefits, but also have good emission reduction benefits.

1. Introduction
Cost-benefit analysis is a method to evaluate the value of a project by comparing the total costs and benefits of the project. It is one of the means of economic system analysis. As a kind of economic decision-making method, its purpose is to take decisions and all kinds of possible alternative solutions, study their constraints, list their benefits and costs, a quantitative calculation by using modern scientific methods. Then by the corresponding evaluation index, evaluate proposed implementation plan. And finally select an optimal scheme of relative economic benefit, which is how to obtain the biggest benefit with the minimum cost. Cost-benefit analysis is one of the most effective methods to evaluate investment plans and the most powerful tool for investment decisions.

To be specific, cost-benefit analysis is to analyze the relationship between cost and benefit, to measure the gains and losses of economic behavior, so as to get the optimal combination of cost and benefit. In practice, cost-benefit analysis can be expressed in two basic forms: net benefit and effective rate. The net benefit form reflects the feasibility of a project or feasibility plan by the difference between the benefit and the cost. If the difference is greater than zero, the expected value has been reached, and all the evaluation indexes can meet the requirements, then the project or program is feasible. On the contrary, if the difference is less than zero, the input of the project or program is greater than the output, which is not feasible. The efficiency rate reflects the feasibility of a project or programme through the proportional relationship between benefits and costs. If the quotient value divided by benefit and cost is greater than 1, the project or program is feasible, otherwise, it is not. These two basic forms of analysis, whether the consumption rate value is greater than 1 or the net efficiency value is greater than 0, are consistent from the economic feasibility conclusion. That is, for the same project scheme, two forms of cost-benefit analysis, the feasibility of the scheme discrimination results are the same. Therefore, both expressions are basic criteria for decision-making and evaluation of the evaluated project or program, and can be applied in practice.
This paper will carry out technical and economic evaluation of photovoltaic distributed power generation project, take a rooftop photovoltaic project in Jiangsu as an example, and make an empirical analysis of the economic benefits, social benefits and environmental benefits of photovoltaic distributed power generation project.

2. Basic data
The total installed capacity of this project is 9MWp. According to the sunlight intensity meter, it is estimated that the power station can generate 10,866,000 kWh a year and 271.65 million kWh a year in total. However, due to the attenuation of conversion efficiency of solar photovoltaic modules, the conversion efficiency of crystalline silicon solar photovoltaic modules will decline after long-term use in light and conventional atmospheric environment. According to the performance of photovoltaic modules used in this project, the maximum limit is calculated by 20% output attenuation of the system in 25 years, that is, the total power generation in 25 years is 217.32 million kWh, and the average annual power generation is 869.28 million kWh. This paper takes the construction project financial evaluation methods and parameters for reference, reviews project profitability and loan repayment ability, detailed analysis of benefit and cost of the project. According to the national current fiscal and taxation system and price system and reasonable data comprehensive prediction and evaluation of financial situation, for the project is feasible and can be financially profitable provide judgment basis.

2.1. Investment
The construction period of this project is 1 year, the operation period is 25 years, and the calculation period is 26 years. The total static investment of this project is 67.518 million yuan. According to the relevant laws and regulations, the domestic power project investment capital ratio of 20%. The project construction investment is 67.518 million yuan, which plans to apply for a long-term bank loan of 55.05 million yuan, the rest of the funds are all from the enterprise's own capital solution. Construction period interest is 199.1 million yuan. In addition, the current capital ratio of the project shall be 30% of the annual operating cost of the project, being 307,000 yuan.

The total dynamic investment of this project is 69.816 million yuan, among which the construction investment is 67.518 million yuan, the interest rate over the construction period is 199.1 million yuan, and the working capital is 300.7 million yuan.

2.2. Cost
The power generation cost of this project mainly includes wages and benefits, repair cost, depreciation and amortization expense. The above costs are calculated as follows.

Depreciation cost is equal to fixed asset value minus item salvage value, divide again depreciation fixed year. In this paper, the depreciation life of houses and buildings is calculated by 25 years, and the net salvage value rate is 10%. Depreciation life of machinery and equipment is calculated by 25 years, salvage value rate is 10%.

Maintenance fee shall be considered at 0.5% of the original value of fixed assets (excluding interest).

Worker salary takes 60000 yuan/year, welfare funds takes 14% of gross wages, and the number of employees is considered as 4.

Financial expenses in the operating period are interest expenses, and the effective interest rate is calculated according to 7.24%.

Other intangible assets in intangible assets are amortized by 10 years, and deferred assets are amortized by 5 years.

The roof rental cost is about 315,000 yuan/year.

To sum up, the average annual total cost and expense of the production period in the calculation period of this project is 5.4715 million yuan, and the annual operating cost is 1.023 million yuan.
2.3. Estimation of power generation revenue and sales taxes and surcharges

2.3.1. Sales revenue of power generation. Power generation revenue = self-use electricity × industrial electricity price × 90% + on-grid electricity × on-grid electricity price + government subsidies. 90% of the electricity generated by this project is consumed locally and 10% is put on the grid. According to the electricity price 0.9795 yuan/kWh of industrial enterprises in Jiangsu province, the project gives the enterprise an electricity price discount of 10% as economic return (namely: 0.9795×0.9=0.8816 yuan/kWh). The online electricity quantity refers to the electricity quantity after deducting each loss in the design electricity quantity. The feed-in tariff of this project is 0.4523 yuan/kWh (tax included) and 0.3866 yuan/kWh (tax excluded) of the benchmark feed-in tariff of coal-fired power plants. In addition, according to relevant documents, the state subsidies for distributed photovoltaic power generation are listed as 0.42/kWh. The average annual power generation of the project is 8,692,800 kWh, the sales revenue is 9.3516 million yuan after deducting VAT.

2.3.2. Sales taxes and surcharges and income taxes. The VAT rate is 17%. After the VAT transformation is considered in this paper, the VAT on equipment purchase expenses of fixed assets will be returned year by year with the output tax of the operating period. The sales tax surcharge includes the city maintenance and construction tax and the education fee surcharge, which are levied by 7% and 5% of the value-added tax (output item) respectively. The enterprise income tax shall be paid at the rate of 25%. According to the calculation, the VAT of project income in a normal year is 1,589,800 yuan, the sales tax and additional tax in a normal year is 190,800 yuan, and the enterprise income tax is 1,415,600 yuan.

2.3.3. Operating costs. Operating cost of power generation refers to all other expenses excluding depreciation expense, amortization expense and interest expense. Accordingly, operating cost is equal to total cost cost to subtract depreciation cost, amortize cost and interest expenditure.

2.3.4. Profits. Total profit is equal to generating revenue minus total costs, sales taxes and surcharges. Profit after tax is equal to total profit minus income tax. The principle of profit distribution is that the total amount of profit is to make up for the previous annual losses within five years, pay income tax and draw the legal surplus reserve (draw 10%) for distribution.

3. Analysis of financial indicators

3.1. Profitability analysis
The pre-tax financial internal rate of return of all investment in this project is 9.18%, the pre-tax investment return period is 10.68 years, the after-tax financial internal rate of return is 6.64%, and the after-tax investment return period is 13.04 years. The investment profit rate is equal to the annual average net profit divided by the total investment, which is 8.3%. Net profit rate of capital is equal to annual average net profit divided by capital, which is 29.26%; The total return on investment is equal to the annual average ebit divided by the total investment, which is 10.33%.

3.2. Repayment ability analysis
In this paper, the long-term loan is repaid according to the agreed long-term loan terms, and the domestic long-term loan is calculated according to the repayment period of 20 years. The loan repayment funds of photovoltaic power stations mainly include loan repayment profit, loan repayment depreciation and amortization. Through balanced calculation, the interest payment rate and debt service provision ratio of this project are above 1 from the 11th year. In addition, the asset-liability ratio of the project is appropriate during the construction period. In the second year of the project, the asset-liability ratio is the highest and then decreases year by year, so the project has a good solvency.
3.3. Break-even point analysis
Break-even analysis refers to the break-even analysis of the balance between project costs and benefits when the project reaches the designed production capacity. By calculating the utilization rate of production capacity, the utilization rate of the break-even rate of production capacity in the 12th year is 118.3%. During the 11th to 12th year of operation period, the break-even rate is basically achieved. After the 11th year of operation period, the project has a greater ability to adapt to the changes of electricity generation and an enhanced risk resistance capacity.

3.4. Sensitivity analysis
Uncertain factors affecting photovoltaic power station projects are usually composed of feed-in tariff, power generation, total construction investment and other factors. When the variation range is ±10%, the changes of electricity generation, electricity price and static total investment have a greater impact on the financial internal rate of return. Therefore, the project income level can be improved by controlling the project cost well in the project bidding and construction stage, striving for a higher electricity price and strengthening the operation and management of the project to improve the power generation of the project.

It can be seen from the analysis that among all kinds of sensitive factors, the most influential factors on the project investment pre-tax financial internal rate of return are the electricity price, construction investment and project operation cost. The degree of influence is shown in table 1.

### Table 1. The influence degree of construction investment, electricity price and operation cost

| Project       | Movement | IRR (%) | NPV   | Payback period(year) | Sensitivity coefficient |
|---------------|----------|---------|-------|----------------------|-------------------------|
| Investment    | 10%      | 8.07    | 2390  | 11.61                | -1.21                   |
|               | 5%       | 8.60    | 2711  | 11.17                | -1.26                   |
|               | -5%      | 9.81    | 3355  | 10.21                | -1.37                   |
|               | -10%     | 10.49   | 3676  | 9.74                 | -1.43                   |
| Electricity   | 10%      | 10.80   | 4316  | 9.55                 | 1.76                    |
| prices        | 5%       | 10.02   | 3688  | 10.06                | 1.83                    |
|               | -5%      | 8.40    | 2430  | 11.32                | 1.70                    |
|               | -10%     | 7.56    | 1801  | 12.09                | 1.75                    |
| Operation     | 10%      | 9.01    | 2895  | 10.82                | -0.19                   |
| cost          | 5%       | 9.09    | 2964  | 10.75                | -0.20                   |
|               | -5%      | 9.27    | 3102  | 10.61                | -0.20                   |
|               | -10%     | 9.34    | 3157  | 10.56                | -0.17                   |

3.5. Financial evaluation conclusion
This financial evaluation adopts the method of dynamic analysis and implements the current financial accounting system for calculation. The pre-tax financial internal rate of return of all investment in the project is 9.18%, which is higher than the wind power benchmark rate of return of 5%, indicating that the project has better profitability.

Through the sensitivity analysis of this project, it can be known that in the construction and operation process of the project, if the owner can fully consider the sensitive factors of the project and make full use of the preferential policies of the project, the income level of the project will be greatly improved.
4. Environmental benefit analysis

4.1. Energy-saving benefit
After photovoltaic power generation is connected to the grid, photovoltaic power generation replaces thermal power generation and reduces the coal consumption of the system, resulting in obvious energy saving benefits. According to the future construction plan of Jiangsu power supply and the technical and economic indicators of various types of power supply, through system operation simulation analysis, the average coal consumption of thermal power generation in Jiangsu power grid in 2015 was 323 g/KWH without considering the grid-connection of photovoltaic power generation. After the completion of this project, the grid-connected photovoltaic power station of 9MWp will be installed. Within 25 years, the average annual power generation of this system is about 8,692,800 kWh, the annual coal consumption can be saved by 2,807.77 tce, and the total coal consumption can be reduced by about 7,0194.36 tce.

4.2. Emission reduction benefits
According to the regulations of "provincial greenhouse gas inventory compilation guidelines (trial)" in east China, the corresponding CO2 emission coefficient of each emission point in China is 0.928kg/kWh. Based on this, it can be calculated that compared with traditional thermal power, this project is expected to reduce carbon dioxide emissions by 8066.92t per year, and 201673t per year in 25 years.

It is estimated that the installed photovoltaic power generation capacity of this project will reach 9MWh, and the annual online electricity capacity will reach about 8,692,800 kWh. According to the emission performance index of major pollutants in the power industry, the project can reduce the emission of pollutants and save energy, as shown in table 2.

| Indicators                        | Effects       |
|----------------------------------|---------------|
| Installed photovoltaic power generation capacity(MWp) | 9             |
| Photovoltaic power generation(10000KW·h/year)       | 869.28        |
| Soot emission reductions(t)       | 260.78        |
| Sulfur dioxide emission reduction(t) | 1303.92      |
| Nitrogen oxide emission reduction(t)  | 977.94       |

According to the environmental planning institute of the state environmental protection administration's "China's power generation environment space research", the economic losses caused by pollutant emission per unit power generation in different regions of China are different. Generally speaking, the economic losses in the eastern region are much higher than that in the northwest region. As the photovoltaic power generation project is put into production, it can replace coal-fired power and reduce the corresponding pollutant emission loss to the planned level.

5. Conclusion
This paper mainly carries out technical and economic evaluation of distributed photovoltaic projects, and summarizes the following conclusions through theoretical research and empirical analysis.

In terms of economic benefits, the investment payback period of photovoltaic distributed power generation projects is long, while the annual decline of power generation is large, and the investment benefits are easily affected by the external environment. Photovoltaic distributed projects have shown good social and environmental benefits, especially in terms of energy conservation and emission reduction. Investment in distributed photovoltaic projects can focus appropriately on the development of carbon trading to improve economic efficiency.
The after-tax financial internal rate of return of all investment in photovoltaic projects is 9.91%, higher than the wind power benchmark rate of return of 5%, with better profitability. In the construction and operation process of the project, if the owner can fully consider the sensitive factors of the project and make full use of the preferential policies of the project, the project income level will be greatly improved.

Photovoltaic power generation has good emission reduction benefits. This project can reduce carbon dioxide emissions by 249,569.36t, and also generate additional revenue of 2.5 million yuan through carbon trading. Meanwhile, it can reduce sulfur dioxide emission by 1613.6t, nitrogen oxide emission by 1210.2t and soot emission by 3227.2t per year.

In a word, future changes in energy prices and stricter requirements for energy conservation and emission reduction will gradually broaden the way of commercialization of distributed power supply system, and gradually highlight its energy conservation value and economic benefits.

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