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Investigation on the Economic Performance of Distributed Building Photovoltaic Systems in the Urban Environment in China

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Abstract

In the urban environment, distributed building PV systems can greatly contribute to the improvement of urban sustainability. Many researchers find high potential of deploying building PV systems in the urban areas for the large areas of building roofs and facades. In China, building PV systems including building-attached photovoltaic system (BAPV) and building-integrated photovoltaic system (BIPV) have been promoted by the government.

Along with the fast economic and social development in China, there are several challenges arising especially in the context of urban environment when adopting building PVs. On the one hand, the economic growth and energy market reform lend to the high uncertainty of electricity price in China. The economic benefit of distributed building PV projects in urban environment is greatly related to the retail electricity price because of the self-consumption policy and high self-consumption ratio as distributed energy resources in cities. On the other hand, due to the rapid urbanization, the density of major cities in China is increasing, bringing a significant challenge of shading effect on the building PVs in the urban environment. The shading loss resulting from the neighbouring buildings and vegetation can influence the performance and energy output of building PVs greatly, which eventually determines the economic feasibility of building PV projects. However, there is limited research associating the impact of changing urban environment with the prediction of electricity price on the economic performance of distributed building PV systems.

Hence, this research aims to bridge the gap regarding the economic performance of building PV projects in increasingly dense urban environment in China, by taking into consideration the prediction of electricity price and urban shading effect. Five different building PV projects representing the most popular distributed building PVs are collected. Twelve cities are selected, covering the most climate zones and policy conditions in China. All selected cities are highly urbanized and population-concentrated, with high GDP and energy consumption.

The shading effect is simulated using solar irradiation data considering the surroundings and adjacent buildings. The electricity price growth rate is estimated using historical market data. The prediction also considers multiple scenarios related to economic growth, population growth and future urban planning.

A lifecycle cost-benefit analysis is conducted through Net Present Value (NPV) per kW, Internal Rate of Return (IRR) and Payback year (PB) as economic indicators. Through the MATLAB program, the dual impacts of electricity price and shading effect on the economic performance of building PVs in the selected cities are investigated. The significance level of both parameters are evaluated and discussed. The findings of the research help in developing a comprehensive understanding of the financial performance of different building PV systems in major urban areas of China under the uncertainty of electricity price and urban environment of high density.

Through the analysis, it is found that although both factors can affect building PV projects' economic performance, the impacts from shading effect are more significant in most of cases compared with the change of electricity price. It is also found that shading effect has uneven impacts among different economic indicators: in one case, the 20% change of shading loss can prolong the payback period for nearly 250%, while the same change only reduces the NPV/KW by less than 20%.

The outcomes of the research can benefit both investors and policy makers. The investors can gain great insight into the investment choice in terms of building PV application type and location by considering the risks in relation to the local conditions. The investors in urban areas of high density such as Shanghai can gain the investment confidence from the results. Although the shading loss affects the economic outcomes of building PVs in Shanghai, the overall economic performance, considering the change of electricity rate growth, is still attractive to investors. when the loss is within a certain range. By contrast, for other cities like Urumqi, the economic performance is heavily affected.

As policymaker, the findings can provide the implications on the incentives for building PV applications projects in cities with different urban environment conditions. It can also provide guidance for the development, deployment and management of building PV systems in the rapidly-changing urban environment.