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Study on Energy Payback Time of Building Integrated Photovoltaic System

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Abstract

Building Integrated Photovoltaic system (BIPVs) is a measure of utilizing renewable energy, and has received great attention from researchers and powerful financial support by government.This paper use life cycle assessment to calculate the energy payback time of three different photovoltaic System, namely single-crystalline silicon, multi-crystalline silicon and amorphous silicon. Energy payback time of three systems is 3.0-7.4 years,which is far less than the PV system's life cycle, hence theoretically three photovoltaic systems are all sustainable and environmentally friendly renewable energy systems from the perspective of energy consumption.

Keywords: Life cycle assessment, Energy payback time, Building-integrated photovoltaics(BIPV), Renewable energy

1. Introduction

Building-integrated photovoltaics (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. The advantages such as low space, installation and electricity transmission cost make BIPV one of the fastest growing segments of the photovoltaic industry. It is usually considered that photovoltaic systems convert the sun's radiation into usable electricity during system operation without consuming other forms of energy, do not produce greenhouse gases, so it appears that it is a renewable energy technology of no pollution and zero energy consumption. However,

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in the whole life cycle of photovoltaic system, from silicon purification, battery manufacturing, photovoltaic module assembly, to the production of subsidiary system production (Balance of System), transportation, installation, assembly and recycle process will all consume a certain amount of energy and with greenhouse gas emissions.

In order to objectively evaluate the sustainability of photovoltaic system and its impact on the environment, the researchers used life cycle assessment method to assess the environmental benefits and energy gain of PV systems. Three common indicators of sustainability, namely, energy payback time(EPBT), greenhouse gas emission payback time and greenhouse gas emission rates were used to evaluate the sustainability and environmental friendliness of PV systems.

The energy payback time can be defined as the time necessary for a photovoltaic panel to generate the equivalent amount of energy used to produce it during its life cycle. The energy payback time of photovoltaic system is influenced by many factors, such as production technology, component installation, solar radiation rate, system installation angle, components efficiency and so on, so to accurate calculate the energy payback time is quite difficult. Type 1 gives the calculation formula of energy payback time.

$$EPBT = \frac{E_{input} + E_{BOS,E}}{E_{output}} \tag{1}$$

In the formula, E_{input} is the primary energy consumed by the PV modules in the life cycle, It includes the production of components, raw material transportation, component installation, operation and maintenance, as well as the energy consumption of dispose and recycle processes. $E_{BOS,E}$ is the energy consumption for balance of system components, which includes support structure, cable, power electronics, inverter and battery. E_{output} is the average annual output of the PV system as the primary energy.

Previously published estimates for the energy payback time of present day crystalline silicon modules vary considerably. Alsema[1] estimate the EPBT for roof mounted thin film module is 2.5 years and the roof mounted multi-crystalline silicon module is 3.1 years. Jester[2] estimate the EPBT for 150W/55W peak power multi-crystalline silicon module are 3.2 and 5.2 years. Jungbluth. N.[3] studied a multi-crystalline silicon module with and without emissions consideration, the results are 25.5 years if emissions are taken into account and 4 years if not. Other studies, however, claim that the energy payback of PV cells is much lower than Alsema. For example, Howard Odum[4], Nieuwlaar E. and Kazmerski L.L. claim that the energy production of photovoltaic system in its life cycle is not enough to cover the huge consumption of its life cycle, that is to say the the energy payback time of PV modules exceeds their lifetime.These studies are all based on different assumptions, and evaluate different types of modules, and therefore cannot be directly compared. These differences can partly be explained by different assumptions for process parameters, but they mostly appear to arise from estimates for the silicon purification and the crystallisation process.

To evaluate life cycle environmental impact of building integrated photovoltaic system is very important for the application of solar photovoltaic panels and improvement in the production process. This paper will use life cycle assessment to calculate the energy payback time of 3 different solar cells, namely single-crystalline silicon, multi-crystalline silicon and amorphous silicon.

2. Life Cycle Energy Consumption of PV System

In the production process of the PV module, it is necessary to consume a certain amount of electric energy and heat energy and release the greenhouse gas for the purification, crystallization, slicing of the silicon, the production of the battery and the assembly of the components. In addition to energy consumption for PV module production, there are still many other energy consumption of subsidiary system including mounting materials and structures, inverters, cables, control electronic devices, transportation, installation, maintenance and recycle.

The author summarized previous literature[1-7] and combined with the actual production data of enterprise, get the energy consumption list for photovoltaic systems. Assume the transportation energy consumption of raw materials and components is about 100MJ, photovoltaic cells are roof mounted. Figure 1,2,3 show the overall energy consumption and percentages of each sections for single-crystalline silicon, multi-crystalline silicon and amorphous silicon systems. The single-crystalline silicon has the largest energy consumption 7460MJ/㎡,