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Review on life cycle assessment of energy payback of solar photovoltaic systems and a case study

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Abstract

This paper aims to examine the environmental performance of the multi-crystalline (multi-Si) photovoltaic installations by conducting a life cycle assessment (LCA) of a typical 1-Megawatt on-grid ground-mounted solar power station in China. An energy payback time calculation will be presented with some further suggestions. After a thorough study of the LCA of solar power station, the boundary of the goal is clearly presented, making it feasible to study the total input and the annual output of the system. Specifically speaking, the total energy input, including the energy input of the module manufacturing and the energy input of balance of system (BOS) is 19.5548 x10^6 MJ, while the annual energy output is calculated to be 8.328 x 10^6 MJ. Thus the energy payback time (EPBT) is 2.3 years, revealing the conclusion that the establishment of the solar power station would contribute to a clean usage for more than 27 years, given the assumption of a 30-year operation period. Therefore, the solar power station is much more environmental friendly compared to the traditional fossil fuel systems.

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Keywords: Photovoltaic system, Multi-Si, Life cyle assessment, Energy payback time.

1. Introduction

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The accelerating development of the economics and the exponential growth of the world population have witnessed the increasing demand of the energy, catalyzing the speed of burning of traditional fossil fuels. At the same time, the vast consumption of fossil fuels could also cause a series of serious environmental problems such as global warming, air pollution, acid rain and so on [1]. Therefore, people have been seeking for the alternative sustainable and renewable energy technologies, especially photovoltaic (PV), to cope with the challenges of energy shortage and environmental pollution [2].

Solar power, no matter using photovoltaic (PV) directly or using concentrated solar power (CSP) indirectly, is the conversion of sunlight into electricity, in which photovoltaic convert light into an electric current using the photovoltaic effect [3]. There is no fossil energy consumption and greenhouse gas (GHG) emission during its operations, theoretically, thus solar power seems to be environmental friendly comparably [4]. However, when the whole life cycle assessment is taken into consideration, including the solar cell manufacturing processes, PV module assembly, balance of system (BOS) production, material transportation, PV system installation and retrofitting, and system disposal or recycling, it actually incurs significant amount of energy input. As a result, a life cycle assessment (LCA) is often introduced at such situation to scientifically investigate the whole picture of the environmental impact of such a PV system installation, elaborating by the commonly used factor of energy payback time (EPBT) [1].

According to the Handbook of Life Cycle Assessment, LCA is usually defined as the “compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life time”, meaning that it aims to evaluate the whole environmental burden with consideration of the entire input and output process at all stages over a product’s life time [5-8]. The methodology of LCA generally consists of four main sectors: the goal and scope definition, inventory analysis, impact assessment and interpretation as shown in the following figure 1 to form an entire framework [9].

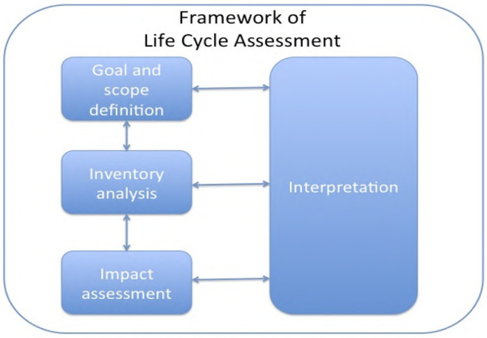

Figure 1
Framework of Life Cycle Assessment

Some scholars have already conducted the LCA analysis on the PV application of solar power installations, and results could be found that PV-based electricity generation systems generate significantly lower GHG emissions than the traditional fossil fuel stations, and the difference could be as high as 89% if the PV-based electricity generation systems are connected to the grid [10]. To further investigate the environmental impact of the PV stations, a closer study of LCA will be conducted, and this paper would primarily use the EPBT indicator to demonstrate the issue.

EPBT is defined as the years a PV system has to operate in order to recover the energy input, both from the manufacturing of modules and the energy requirement of the balance of system (BOS). The calculation of EPBT can be presented as Eq. (1):

$$EPBT = E_{input} / E_{output} = (E_{PV} + E_{BOS}) / E_{output} \quad (1)$$