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Considerations for the calculation of greenhouse gas reduction by photovoltaic solar energy

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Abstract

A CO_2 comprehensive balance within the life-cycle of a photovoltaic energy system requires careful examination of the CO_2 sinks and sources at the locations and under the conditions of production of each component, during transport, installation and operation, as well as at the site of recycling. Calculations of the possible effect on CO_2 reduction by PV energy systems may be incorrect if system borders are not set wide enough and remain on a national level, as can be found in the literature. For the examples of Brazil and Germany, the effective CO_2 reductions have been derived, also considering possible interchange scenarios for production and operation of the PV systems considering the carbon dioxide intensity of the local electricity grids. In the case of Brazil also off-grid applications and the substitution of diesel generating sets by photovoltaics are examined: CO_2 reduction may reach 26,805 kg/kW$_p$ in that case. Doing these calculations, the compositions of the local grids and their CO_2 intensity at the time of PV grid injection have to be taken into account. Also possible changes of the generation fuel mix in the future have to be considered: During the operation time of a PV system, different kinds of power plants could be installed that might change the CO_2 intensity of the grid. In the future also advanced technologies such as thin films have to be considered.

Keywords: Carbon dioxide reduction; Solar energy; Photovoltaic; Dislocation; Life-cycle analysis

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Nomenclature

a-Si	amorphous silicon
BR	Brazil
D	Germany
GJ_{el}	electrical energy in 10^9 J
kW_p	electrical power output of PV generator under Standard Test Conditions (irradiance of 1000 W/m^2, solar spectrum equivalent to a relative air mass of 1.5, solar cell temperature 25 °C)
kWh	energy (equivalent to 3.6 MJ)
kWh_{el}	electrical energy (equivalent to 3.6 MJ_{el})
kWh_{prim}	primary energy (equivalent to 3.6 MJ_{prim})
MJ	energy in 10^6 J
m-Si	mono-crystalline silicon
p-Si	multi-crystalline silicon (formerly known under the name of 'poly-crystalline' silicon)

1. Introduction

Several authors have discussed the energy requirements for the production of photovoltaic (PV) solar energy conversion systems and their energy pay-back-time [1–3]. Some publications also mention the reduction of CO_2 emissions by using PV systems to substitute conventional energy generating sets [4]. System borders of the life-cycle analysis (LCA) of energy systems are very often set to national borders (as Tahara et al. [5]). These results may be helpful to improve national CO_2 balances, but they often will not meet concerns about suitable measures in order to reduce the Earth's atmosphere carbon dioxide contents on a global scale.

With very few exceptions (e.g. Komiyada et al. [6]), all of the CO_2 balances made are neglecting the fact that the locations of production, of operation, and of recycling of a PV system are rarely the same in a global market. This could lead to vast deviations of calculations from the actual effect of PV on the reduction of greenhouse gases.

2. Calculations

2.1. Production

While the specific electrical energy requirements do not vary notably for most of modern manufacturing facilities of PV components all over the world, the specific CO_2 emissions depend very much on the power plants (nuclear, hydro, fossil etc.) producing the electricity to operate production facilities of PV and system compo-