Accepted Manuscript
Renewable and Sustainable Energy Reviews
Article in Press
http://dx.doi.org/10.1016/j.rser.2016.10.077

Solar-PV energy payback and net energy: Meta-assessment of study quality, reproducibility, and results harmonization.

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Abstract

Numerous analyses of mono- and polysilicon Solar-Photovoltaic (PV) modules provide an Energy Payback Time (EPT) or Net Energy Ratio (NER) value. Few are directly comparable due to differences in annual solar radiation, supply-chain technologies, life-cycle boundaries, and system specifications. The purpose of this paper is to reproduce and harmonize twenty-nine studies, and to examine the influence of data age, system boundaries, and technological configurations.

The results include:

The study harmonization yielded a mean EPT for mono- and polysilicon solar-PV of 3.9 and 2.9 years, and a mean NER of 8.6 and 9.2 times, as expressed in solar energy output gain per unit of energy input, respectively.

The average time between study publication and sourced data was established at 7 years within a 2–18 year range, due to which energy input costs are typically overestimated as recent technological improvements are not captured.

When filtering for studies with manufacturing data collected after 2008, the harmonized average EPT for mono- and polysilicon was found to be approximately half (e.g. 2.0 instead of 3.9) and NER double (e.g. 14.4 instead of 7), relative to studies with data from 2008 or older.

An input correction with recent technological improvements for all studies resulted for mono- and polysilicon solar-PV in an adjusted mean harmonized EPT of 3.5 and 2.4 years and NER of 9.7 and 11.4 times, respectively.

Few studies in their system boundaries considered energy costs for embodied material, maintenance, decommissioning, and auxiliary services.

It is recommended in future studies to use recent data reflecting up-to-date technological standards and include the collection year of any used datasets. And to strictly follow existing ISO14040, ISO14044, and IEA-PVPS T12 standards, especially by transparent reporting of: solar module specifications, energy inputs for individual facilities and non-module components, technology assumptions, and electric/thermal conversions.