Updated sustainability status of cadmium telluride thin-film photovoltaic systems and projections

Vasilis Fthenakis[1], Enrica Leccisi[1], and Parikhit Sinha[2]

[1]Columbia University
[2]First Solar Inc

July 28, 2023

Abstract

This paper provides a comprehensive assessment of the up-to-date life-cycle sustainability status of cadmium-telluride based photovoltaic (PV) systems. Current production modules (Series 6 and Series 7) are analyzed in terms of their energy performance and environmental footprint and compared with the older series 4 module production and current single-crystalline-silicon (sc-Si) module production. For fixed-tilt systems with series 6 modules operating under average US irradiation of 1800 kWh/m ^{2}/yr, the global warming potential (GWP) is reduced from 16 g CO2 $_{eq/}$kWh in Series 4 systems to 10 CO2 $_{eq/}$kWh in Series 6 systems. For operation in US-SW irradiation of 2300 kWh/m2 the GWP is reduced from 11 CO2eq/kWh to 8 CO2eq/kWh and for 1-axis tracking systems operating in Phoenix, Arizona with point-of array irradiation of 3051 kWh/m ^{2}/yr the GWP is reduced to 6.5 CO2 $_{eq/}$kWh. Similar reductions have happened in all environmental indicators. Energy payback times (EPBT) of currently installed systems range from 0.6 years for fixed-tilt ground-mounted installations at average U.S. irradiation at latitude tilt installations, to 0.3 years for one-axis trackers at high US-SW irradiation, considering average fossil-fuel dominated electricity grids with fuel to electricity conversion efficiency of 0.3. The resulting energy return on energy investment (EROI) also depends on the conversion efficiency of the electricity grid and on the operation life expectance. For a 30-year operational life and grid conversion efficiency of 0.3, EROI ranges from 50 (at US average irradiation) to 70 for US-SW irradiation. The EROI declines with increased grid conversion efficiency; for CdTe PV operating in south California with grid conversion efficiency of 49% the EROI is about 50 and is projected to fall to 30 when the state's 2030 target of 80% renewable energy penetration materializes. Material alternatives that show a potential of further reductions in degradation rates and materials for enhanced encapsulation that would enable longer operation lives are also been investigated. A degradation rate of 0.3%/year, which has been verified by accelerated testing, is assumed in 30-year scenarios; this is projected to be reduced to 0.2%/yr in the near-term and potentially to 0.1%/yr in the longer term. With such low degradation rates and enhanced edge-sealing, modules can last 40- to 50-years. Consequently, all impact indicators will be proportionally reduced while EROI will increase.

Hosted file

`pip-23-299-File001.docx` available at https://authorea.com/users/644286/articles/657238-updated-sustainability-status-of-cadmium-telluride-thin-film-photovoltaic-systems-and-projections