Preliminary Environmental and Financial Viability Analysis of Circular Economy Scenarios for Satisfying PV System Service Lifetime

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Executive Summary

PV deployment has grown rapidly in recent decades, and this growth is expected to continue. At the same time, the rapid increase in PV panel efficiencies offers the opportunity to repower/revamp existing installations—replacing operational, lower-efficiency panels before the end of their 30-year service lifetime with newer, higher-efficiency panels. As a result, an increasing volume of PV panels could be decommissioned well before reaching the end of their 30-year service lifetime.

Two broad strategies can be applied to manage the expected increase in decommissioned PV panels: (i) recycle prematurely decommissioned panels, and (ii) prevent recycling of these panels by satisfying the typical service lifetime of 30 years through circular economy strategies such as repair and reuse. Each strategy presents an environmental and economic trade-off. Retaining and satisfying the lifetime of the older, lower-efficiency panels avoids environmental burdens from recycling or landfilling but incurs burdens from additional repair and forgoing the opportunity to install newer panels with greater electricity-generation capabilities.

This study assesses whether satisfying the expected service lifetime of a PV system through circular economy scenarios generates a greater environmental and financial benefit than recycling used panels and installing newer panels with higher efficiencies. The circular economy scenarios include repair and reuse of the PV system. Specifically, the study determines whether it is better for the environment to keep a PV panel in use for its 30-year service life after accounting for potential repair and additional transportation, or to replace older panels with more efficient new ones. In addition, we explore whether satisfying the service lifetime of PV panels proves competitive with the recycling route from a financial perspective.

Part A of this study focuses on the PV system and quantifies the trade-offs between the environmental burdens and benefits of satisfying the lifetime of a prematurely decommissioned PV system through repair or direct reuse. Part B focuses on the market conditions that favour either (i)

a change in ownership (i.e., from the owner who supplies the decommissioned PV system to the next owner who demands the system for reuse), or (ii) recycling of the decommissioned PV system.

The environmental analysis consists of modelled scenarios with different lifetimes of the PV panels (30, 15, and 10 years). The time horizon is 30 years in all scenarios. The maximum service lifetime is 30 years for a panel and 15 years for an inverter. A life cycle assessment approach is used to model the environmental aspects of the PV system. The functional unit is the generation of 1 kWh of electricity. The environmental impact of PV is dominated by its production phase, followed by the end-of-life stage. The impact of the use phase (mainly water used for cleaning) constitutes less than 0.1% of the total life cycle impact (1).

Based on Part A of the study, satisfying a 30-year service lifetime of PV panels appears favourable from an environmental perspective, at least for the cases examined. In other words, it is better for the environment to keep a panel in use for its 30-year lifetime instead of replacing it with new, more efficient panels. Adding repair activities and/or additional transport is unlikely to change this conclusion. Drastic technological revolutions in panel efficiency, production and recycling process efficiency, or both are also unlikely to change this conclusion. This analysis uses a constant system-specific yield. In real life, PV reuse may involve changes in geographical location and thus solar irradiation and performance ratio. In addition, the study analyses multi-crystalline silicon technology, which limits the validity of the conclusions to this technology. Multi-crystalline silicon was chosen because it was the technology with the highest market share at the time of the analysis (2).

Based on analysis of a ground-mount, utility-scale PV system in Part B, satisfying the 30-year service lifetime of PV panels proves financially competitive to the "recycle and acquire new" scenario under certain conditions, from a theoretical levelized cost of electricity (LCOE) perspective. This is the case for relatively young panels (up to around 10 years old) with few or no defects. Although we do not account for testing and recertification costs, these costs could be a determining factor for the success of the reuse business case.

Yet, in practice, satisfying the 30-year service lifetime of PV through reuse in the residential market does not appear to be financially desirable owing to surface-area restrictions as well as the lower remaining power density and limited remaining lifetimes of prematurely decommissioned panels. In addition, our analysis of PV as a utility-scale investment—using net present value as the key performance indicator—suggests that new panels are more attractive than prematurely decommissioned panels in this context as well, without and especially with surface-area limits.

In reality, the financial viability of the reuse business case is influenced by additional country- and case-specific parameters, such as the grid tariffs that drive revenue and can fluctuate substantially. These revenues—together with PV efficiency improvements, price changes, and area restrictions—drive investment decisions.

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