


Chapter 1

A Review on the Management of End-of-Life Solar Photovoltaic Panels: Challenges, Opportunities, and Future Directions

Ozan Capraz

 <https://orcid.org/0009-0005-4080-9538>


Pamukkale University, Turkey

Zeynep Ozsut Bogar

 <https://orcid.org/0000-0002-9089-2764>

Pamukkale University, Turkey

Askiner Gungor

 <https://orcid.org/0000-0002-1223-6796>

Pamukkale University, Turkey

ABSTRACT

The rapid increase in the use of solar photovoltaic (PV) panels emphasizes the crucial role of renewable energy sources in meeting energy needs while reducing the environmental impact of fossil fuels. Consequently, managing the end-of-life (EOL) of these panels has gained importance, as the growing number of EOL PV panels brings significant waste management concerns. Major solar energy markets are projected to generate considerable PV waste by 2050; however, recycling infrastructure remains inadequate in many regions. Given the high value of materials

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in PV panels, including base metals like aluminum, critical metals such as indium and gallium, and hazardous metals like lead and cadmium, adopting recycling approaches that align with circular economy is increasingly essential. This chapter provides a comprehensive review of EOL solar PV panel management, examining studies on PV waste estimation, exploring recycling processes, material composition and relevant policies, analyzing key challenges and opportunities, and offering recommendations for sustainable practices.

INTRODUCTION

Throughout history, humanity has continuously worked to meet its energy requirements, which are essential for social development, technological advancement, and the maintenance of daily life (Demir & Yakışık, 2024). Since the beginning of the Industrial Revolution, the demand for energy has significantly increased globally over the years (IEA, 2023). Consequently, due to this increasing global energy demand, fossil fuels such as coal, oil, and natural gas are considered the primary energy source due to their high energy density and ease of access (IEA, 2023). However, this rising demand is rapidly depleting oil and natural gas reserves while also generating environmental problems, particularly greenhouse gas emissions that contribute to global climate change (IPCC, 2023). Studies show that fossil fuels have negative impacts, including air, water, and soil pollution, as well as dependence on energy imports in many regions worldwide (Bertrand, 2021). According to the Global Renewables Outlook: Energy Transformation 2050 report published by IRENA (2020), currently, it is estimated that air pollution results in 7 million premature deaths annually. Furthermore, around 840 million people lack access to electricity, and 2.6 billion lack access to clean cooking fuels (IRENA, 2020). Over the years, global CO₂ emissions have risen significantly, with most of this increase coming from fossil fuels (Ritchie & Rosado, 2022; Ritchie et al., 2023). As illustrated in Figure 1, the continuous increase in fossil fuel consumption use has directly contributed to the increase in CO₂ emissions (Ritchie & Rosado, 2022; Ritchie et al., 2023). Consequently, there has been a global interest in the use of clean and sustainable renewable energy (RE) sources in recent years because of the concerns related to environmental issues and climate change caused by fossil fuels (IPCC, 2023).

The data used in this figure was adapted from the Our World in Data: Fossil Fuels (Ritchie & Rosado, 2022) and the Our World in Data: CO₂ and Greenhouse Gas Emissions (Ritchie et al., 2023).

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