SPATIOTEMPORAL FORECASTING AND SUSTAINABLE RECYCLING PATHWAYS OF PHOTOVOLTAIC WASTE IN CHINA USING GEOSPATIAL DATA

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Overview

The rapid expansion of photovoltaic (PV) installations in China has positioned the country as a global leader in PV capacity. However, this growth has also introduced significant challenges in managing decommissioned PV panels, with current data limitations at the provincial level impeding effective waste recycling strategies. To address this issue, this study utilized high-resolution satellite remote sensing data to map PV installations across 1,593 county-level administrative units from 2010 to 2022. By integrating Weibull distribution functions, life-cycle assessment (LCA) models, and spatial correlation analyses, the research projects that China will generate approximately 800 GW of PV waste by 2050, predominantly in Shandong and Hebei provinces. The findings highlight the optimal recycling period between 2030 and 2036 and propose strategies for optimizing waste management pathways and facility placement. This study provides critical insights for policymakers and industry stakeholders to mitigate environmental risks and maximize the economic potential of PV waste recycling.

Methods

To address data limitations, this study utilized high-resolution satellite remote sensing data to accurately map the spatial distribution of PV installations across 1,593 county-level administrative units from 2010 to 2022. Weibull distribution functions were employed to predict PV waste generation based on China's photovoltaic roadmap, incorporating multiple uncertainty scenarios and degradation pathways. A life-cycle assessment (LCA) model was used to calculate the economic benefits of PV systems throughout their lifecycle at the county level. Additionally, spatial correlation models were applied to analyze the relationships between PV installations in different counties, revealing regional clustering effects and inter-county dependencies.

Results

Projections indicate that China will generate approximately 800 GW of PV waste by 2050, with the highest concentrations mainly in Shandong and Hebei provinces. The assessment of recyclable materials within decommissioned PV modules revealed a significant resource recovery potential. The optimal period to initiate large-scale PV recycling activities was identified as 2030–2036, during which an annual generation of 5 GW of PV waste can sustain economically viable recycling operations. Spatial analysis showed strong correlations of waste generation among counties within the same city, while significant disparities were observed across different cities. These findings provide valuable insights for optimizing recycling pathways and facility placement.

Conclusions

This study underscores the urgent need for high-resolution PV installation data to support effective waste management strategies. By projecting PV waste generation, identifying the optimal recycling timeline, and analyzing spatial correlations, this research provides actionable guidance for policymakers and industry stakeholders. The findings highlight the importance of coordinated regional planning and resource optimization to mitigate environmental risks and unlock the economic potential of PV module recycling.