Regional photovoltaics circularity under various socio-economic conditions

Julien Walzberg[1], Garvin Heath[1]

[1]National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO, USA 80401

Corresponding author: Julien Walzberg, National Renewable Energy Laboratory julien.walzberg@nrel.gov, (+1) 720 656 2109

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Abstract:

Even when accounting for less favorable conditions (e.g., siting and permitting challenges, higher projected costs of renewable energy technologies), the United States (U.S.) infrastructure investment and jobs act of 2021 (IIJA) and the inflation reduction act of 2022 (IRA) were found to drive the deployment of wind turbines and solar photovoltaics (PV) capacity (44 GW/year) leading to a share of clean electricity of 70% by 2030. Such deployment of solar and wind assets poses end-of-life (EOL) management questions. To reach decarbonization goals, around 1.75 TW of cumulative PV capacity needs to be deployed in the US by 2050, which will generate about 8 million metric tons (Mt) of EOL PV materials. While the quantity and toxicity of PV waste is not as concerning as other type of waste, the recovery of valuable and energy-intensive materials from EOL PV is expected to bring economic and environmental benefits. Indeed, building a circular PV industry would maintain high-value and critical PV materials within the U.S. economy, enhancing its resilience and sustainability. However, the economics are not favorable (with PV recycling costs about one order of magnitude higher than landfill costs). More favorable economics highly depend on the reverse supply chain infrastructure and regulations, which are yet to be optimized for supporting PV circularity.

In this work, we present an analysis of EOL PV recycling rate under various transportation, recycling, and landfill cost conditions and regulatory contexts. Combining the National Renewable Energy Laboratory PV in the Circular Economy (PV ICE) and circular economy agent-based model (CE ABM) models, we increased the accuracy of PV reverse supply chain modeling, better capturing PV materials by vintage, transportation distances, and geographical resolution. Results show that considering PV as hazardous waste would potentially favor recycling since both landfill and transportation costs would significantly increase (Figure 1). However, this is assuming that less stringent transportation and storage regulations applies for recycling. Moreover, results show that halving recycling fees could double the recycling rate up to 80% under the hazardous waste regulation scenario. If Silicon is recovered during recycling, about 200,000 metric tonnes of this material will be recovered between now and 2050 in this scenario. Nearly enough to supply all the domestic Silicon demand from Silumin (aluminum-silicon alloy) manufacturing for that same period.

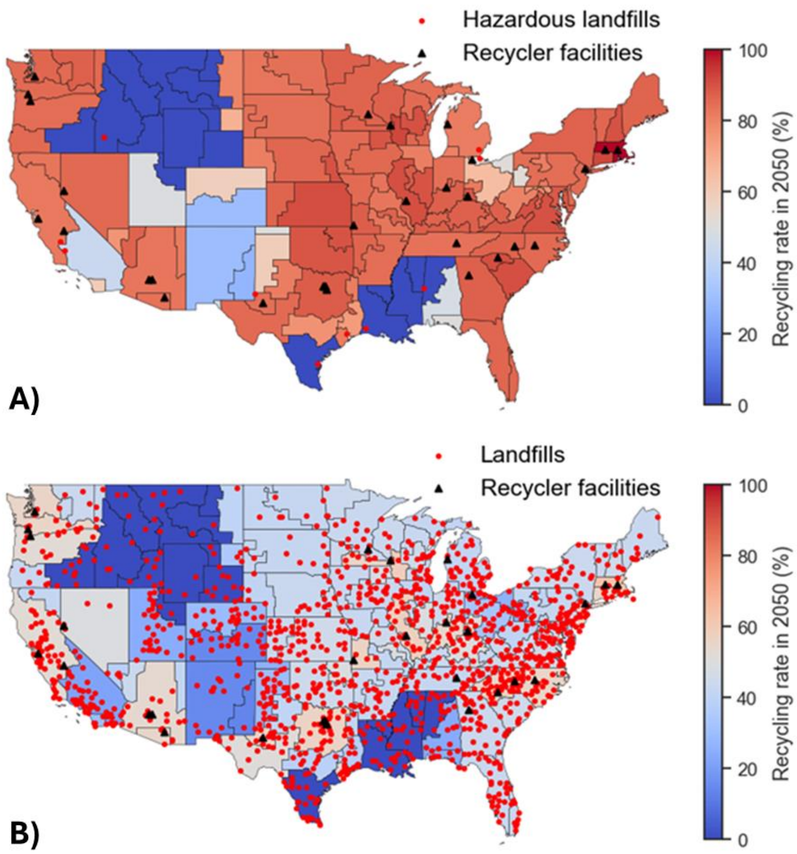

Figure 1: Cumulative recycling rate in 2050 across the U.S. electricity grid balancing areas. In this figure, recycling fees are 0 so that only the effect of various transportation and landfill costs are assessed. A) EOL PV are considered hazardous waste and can only be disposed of in hazardous landfill (red dots on the map). Hazardous landfill costs are $175/tonne. B) EOL PV are not considered hazardous waste and can be disposed of in any landfill (red dots on the map). Landfill costs are $87/tonne. Transportation costs are assumed to be $1.5/t*km for both A) and B).