PV RECYCLING

Fulfilling Solar's Green Promise

By Otto Gunderson

Over the last two decades, the expansion of solar photovoltaics (PV) in the U.S. has created immense benefits in the form of green jobs, economic development, and climate action. However, this success story does not address the fundamental fact that PV, like any other electronic product, does not last forever and is in fact experiencing early end-of-life (EOL) decommissioning. These early decommissionings are primarily due to manufacturing defects, installation mistakes, tax-motivations, system upgrades, forest fires, and weather-related events including hail, tornadoes, and hurricanes fueled by climate change. These EOL panels offer an opportunity for private industries, government agencies, and non-profit organizations to work together to create a PV circular economy to combat the tsunami of PV e-waste that has begun to enter the US waste stream.

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Solar module laminates awaiting final processing.

Between 1990 and 2020, approximately 400 million PV panels have been installed in the U.S. In 2020 alone, between 65 to 70 million PV panels will be installed. Even with the effects of COVID-19, the solar industry is expected to set a record with 18 gigawatts of solar installed in 2020, breaking the previous record of 15 gigawatts set in 2015. However, there is a major misconception within the solar energy community about the longevity of PV panels. Prior to the 1990s, PV manufacturers mainly engineered and manufactured panels in the U.S. or Europe. These PV panels were built under stringent engineering standards and practices developed for NASA's space program and were expected to last 25 to 30 years.

Starting in about 2000, thousands of new companies around the world began to manufacture PV panels. These companies face tremendous competition and market pressure to drive down manufacturing costs to compete. In order to achieve this, many of these companies have cut corners by switching to questionable materials, suppliers, and manufacturing practices. The result, as we are now beginning to see, are less durable PV panels with shorter lifespans and fewer valuable materials.

Based on The International Renewable Energy Agency's (IRENA) 2016 End-Of-Life Management: Solar Photovoltaic

Laminates are cut into 5 inch squares before glass, silicon, polymers and metals are extracted.

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Panels report, the US could see approximately 94 thousand US tons (roughly 4.2 million PV panels) of cumulative PV e-waste in 2020, increasing to 1.1 million U.S. tons by 2030 (approximately 48.9 million PV panels), and 11 million U.S. tons (approximately 489 million PV panels) by 2050. This is the equivalent of 6,462; 75,231; and 752,308 fully loaded U.S. semi-trailers respectively. IRENA acknowledges that its projections are conservative and RPVS's internal research and field experience are projecting significantly higher decommissioning volumes. Based on this internal research and field experience, RPVS estimates that in the US today that less than 10% of decommissioned panels are recycled, with the remaining 90% going to landfills or sent to developing countries with weak environmental protection and product safety enforcement for reuse or possibly dumped as e-waste. With no national U.S. PV reuse-recycling program, states are struggling to create practical PV product stewardship legislation without objective and up-to-date PV decommissioning data. In California, which makes up about 50% of US PV installations, PV system owners are unaware of the financial burden of properly disposing of their PV panels under present Department of Toxic Substances Control (DTSC) regulations. There is no labelling or notification requirement to alert these consumers and disclose hazardous or potentially hazardous materials for PV panels or the hazardous waste status of a PV panel under law.

Currently, every PV system in California, including over 1 million residential rooftop PV systems, is classified as potentially hazardous waste by the DTSC, yet many system owners often do not learn of this until they go to decommission their systems. This lack of consumer awareness and industry preparation for EOL PV panels was revealed in a 2020 California Product Stewardship Council survey that found 97% of San Mateo County residential solar system responders did not receive information on responsible

recycling from installers and 86% of surveyed installers did not have a policy or process for PV management. In response to growing awareness around PV e-waste, a few states have either enacted or proposed PV product stewardship legislation, while several others are in various stages of developing their own. In 2017, Washington State passed the first PV product stewardship law in the US with bipartisan support. This legislation was revised in 2020 to address ambiguous language which delayed its implementation until 2022 with enforcement beginning in 2023.

In 2019, North Carolina passed legislation that requires the owner or operator of a utility-scale installation to responsibly decommission projects, establish financial assurance to cover decommissioning costs, and reuse or recycle all possible EOL equipment. Many county governments require the same of solar farms in their jurisdiction. This law also requires manufacturers of non-utility scale PV panels and energy storage batteries sold within the state to implement programs to recycle their EOL products. The law also prohibits the disposal of EOL PV panels and energy storage system batteries in landfills. In February 2020, Arizona legislators proposed a similar bill that requires solar panels be recycled at an approved facility and would require a $5 per-panel fee on all PV panels sold by manufacturers without their own recycling facilities. However, with the lack of comprehensive PV reuse/recycling at the federal level, many panels are finding their way into local landfills, sowing the seeds for a recycling crisis at the county level.

Further complicating efforts for states preparing for the management of PV waste is that there is no manufacturing materials database with details on materials used in the manufacturing of PV panels. This includes "critical materials", which are considered vital to the economic and national security of the US due to scarcity and geopolitical relations. Some PV technologies are fairly benign, but others are considered highly toxic. Without this information, PV system owners and waste management companies are not alerted to hazardous materials (e.g., lead, cadmium, indium, gallium, etc.) that may be in these panels. This can be especially problematic and expensive for PV system owners that discover at the time of decommissioning that materials used in their PV panels are considered hazardous and require special handling and processing. Additionally, the environmental impact of concentrating potentially hazardous materials in landfills has not been fully addressed. In contrast, the EU's Waste Electrical and Electronic Equipment Directive requires proper recycling of solar panels to avoid human health and environmental impacts such as groundwater contamination. Establishing an effective US PV reuse-recycling program does not have to be this hard. The success of PV Cycle in the European Union (E.U.) offers a roadmap and a quick-start opportunity through a collaborative effort for the US. The E.U. uses a system of extended producer responsibility: to manufacture or distribute panels within the EU the manufacturer must provide a plan for EOL. Solar producers in the E.U. market must follow certain requirements, including a financing responsibility that covers collection and recycling. All producers must report on panels sold, returned, and sent to the recycling processors, as well as label their products regarding EOL processes and collection points. Conversely, it is the responsibility of system owners within the U.S. to dispose of their panels, despite being limited by a lack of knowledge or resources.

Furthermore, the E.U.'s WEEE Directive required that by 2018, 85% of solar waste must be recovered and 80% must be recycled or reused. Such legislation reduces environmental harm while also recovering valuable materials, including those considered "critical" to economic security, for reuse in other products, including solar panels. Since its opening in 2010, PV Cycle, a non-profit PV Recycling organization in Europe, has processed 35,773 metric tons of PV waste. In 2019 alone, PV cycled recycled 11,514 tons of waste, demonstrating their growth over the last decade. Proof of PV Cycle's success can be found in their cost to recycle per panel, at roughly $1 per panel, while in the United States there is an estimated cost of between $15-45 per panel. South Korea has begun addressing solar recycling by requiring an extended producer warranty which is expected to be enforced in South Korea by 2023. The South Korean government has even begun construction on a new 3,600 ton module recycling facility expected to become operational by 2021.

> "There's some infrastructure...I wouldn't say it's especially well established at this point.
>
> – Garvin Heath, Senior Scientist at the National Renewable Energy Laboratory (NREL)

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Junction boxes are ground into small pieces to be used as plastic feedstock.

In order to reach this level of success in the U.S., collaboration between organizations is critical. In the words of Sam Vanderhoof, CEO of Recycle PV Solar, "[t]he importance of collaborative action, especially between recycling processors, panel manufacturers, and system owners is paramount to the success of the PV recycling." Recycle PV Solar, one of several solar recycling companies that processes panels in the U.S., has worked with legislators, non-profit organizations, and system owners to encourage proper EOL processes. However, as Sam Vanderhoof points out, "[t]he U.S. is simply far less organized than the E.U. and there are conflicting interests that need to be ironed out."

The cheap cost to landfill panels and the decommissioning responsibility falling on the shoulders of system owners result in only 10% of panels being recycled today. Garvin Heath, a senior scientist at the National Renewable Energy Laboratory (NREL) is quoted as saying "[t]here's some infrastructure…I wouldn't say it's especially well established at this point." This lack of infrastructure means there is no tracking of where panels are being sent. Electronic recyclers, transfer stations, and landfills are all receiving panels, but there is no clear source of information. PV panel manufacturer First Solar currently operates solar recycling facilities for their panels in the United States, as well as Malaysia and Germany. With up to a 90% recovery rate, they are one of the few manufacturers with a system of producer responsibility operating in the United States. Creating this extended producer responsibility is critical to the success of the PV recycling industry and requires government agencies, recycling corporations, and non-profit organizations to work together.

Approximately 11 million U.S. tons of PV waste (approximately 489 million PV panels) is expected to enter the U.S. waste stream over the next three decades. A comprehensive plan for EOL PV panels will result in $10.1 billion in market value by 2050 as well as the raw materials capable of creating 2 billion new PV panels. The opportunity to do well by doing good is before the American solar industry and US environmental and economic policymakers. Together, we can develop a PV circular economy with comprehensive PV recycling legislation including practical extended producer responsibility requirements that will protect our environment, inject critical recycled PV materials back into the US economy, generate billions of dollars in economic activity, and create thousands of clean industry jobs. Let's make solar green by keeping it out of landfills in the U.S. and around the world. ■

About the Author

Otto Gunderson is a student at the University of Virginia who is studying history with a focus on entrepreneurship. He has been working as a research associate at Recycle PV Solar for six months. He expects to graduate from the University of Virginia in 2023 and enter the clean energy sector.

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