

# Increasing Solar Waste, Increasing Concerns

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**W**ITH the global need for electrical energy growing at an exponential rate and limited reserves of conventional fuel as well as environmental degradation issues efforts are on to increase the share of renewables. Solar energy is a renewable energy source with numerous benefits. It is a dependable, non-polluting, safe, and efficient source of energy that is widely disseminated around the world.

The use of solar photovoltaics (PV) has expanded globally in the last few decades with increasing demands for clean energy generation and rising environmental concerns. Solar PV is predicted to supply a large share of total energy consumed globally in the next decades. Solar energy is being used in different sectors for different types of work such as generating power, heating, and desalinating water all around the world.

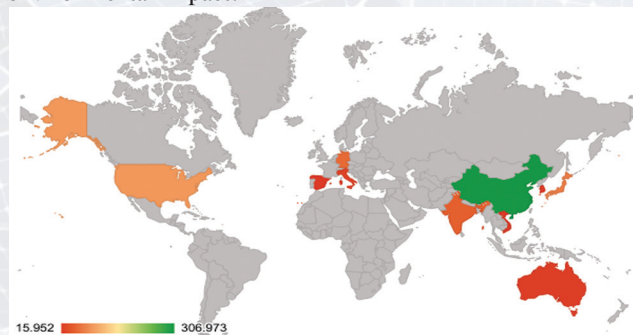
Energy transitions are not always simple or rapid; the earlier energy shifts happened over long periods of time. For instance, it took around 70 years for the proportion of oil as primary energy source to climb from about 1% in the 1890s to eventually replace coal as the most common source of energy. However, given the urgency of climate change, the next transition must be completed far more quickly than the earlier ones.

Coal and oil have long aided in the country's economic progress. But this has also led to increasing emissions. The increasing usage of solar energy decreases emissions. Therefore, the government is also encouraging investments into the solar energy business. Solar energy is predicted to make up for and replace a big portion of traditional energy sources around the world. Prime Minister Shri Narendra Modi has set an ambitious target for 2030, including the installation of 500 gigawatts (GW) of renewable energy capacity, a 45 percent reduction in the economy's emissions intensity, and a billion tonnes of CO<sub>2</sub> reduction. The statement by India that it plans to achieve net zero emissions by 2070 and fulfill half of its electricity needs with renewable energy sources by 2030 is a watershed moment in the global fight against climate change.

Global Solar PV installed capacity rose from 23.18 GW in 2009 to 849.47 GW in 2021 and it is expected to rise further to more than 8000 GW by 2050. A worldwide study by International Renewable Energy Agency (IRENA) indicates that the top five countries for cumulative installed capacity are China with deployment of 306.97 GW till 2021 accounting for 36.1% of the global market and becoming the top leader in solar PV energy, production followed by United States (95.20 GW), Japan (74.19 GW), Germany (58.46 GW)

and India (49.68 GW). The overall number of solar panels placed around the world is rapidly increasing, and this trend is projected to continue in the future years. India's solar energy business is exploding, and the country has set an ambitious goal of 300 GW of solar energy by 2030.

However, as the global solar PV market increases, it will also increase the volume of decommissioned PV panels. In fact, the issue of solar PV panel End of Life (EOL) waste management is an evolving field that requires further research and development and calls for a need to formulate regulatory framework to limit the negative influence of the persistent growth in PV waste volume and to implement solar module recycling. In the absence of any regulatory framework, the entire waste would go to landfills and cause deteriorating environmental impact.



Top 10 countries for cumulative installed capacity in 2021

## Solar PV Panels

The process of converting light (photons) to electricity (voltage) is called photovoltaic effect. This phenomenon was first exploited in 1954 by scientists at the Bell Laboratories who created a working solar cell made from silicon that generated an electric current when exposed to sunlight.

Solar panels can be classified into three generations: (i) Crystalline Silicon (Mono-crystalline or poly-crystalline); (ii) Thin film (copper indium gallium selenide-CIGS, cadmium telluride-CdTe, amorphous silicon); and (iii) concentrator photovoltaic and emerging technologies (dye-sensitized solar panels, CPV solar panels, hybrid panels, and organic solar panels).

Around 90% of the world's photovoltaics are made of some kind of silicon. Crystalline silicon cells are used in around the same percentage of household solar panel systems, which provides both low costs and high efficiency. These cells are typically integrated into bigger modules that can be installed on the rooftops of homes or businesses, or deployed on ground-mounted racks to generate massive, utility-scale systems.

The silicon used in solar cells comes in a variety of shapes and sizes. The purity of the silicon is an important factor as it has a direct impact on its effectiveness.

Thin-film solar cells, another widely used photovoltaic technology, are produced from very thin layers of semiconductor material, such as cadmium telluride (CdTe) or copper indium gallium selenide (CIGS). A typical solar panel consists of Aluminum frames, tempered glass, battery piece, EVA (ethylene vinyl acetate copolymer) and backboard (TPT - Tedlar Polyester Tedlar, Topotecan Hydrochloride, etc.).

As they reach the end of their useful lives, solar panels become toxic garbage. Solar panels have around 25-30 year lifespan in case of regular loss and a few panels are also damaged much before 25 years due to natural calamities, material defects, transport, midlife, wear-out failures, etc. In the coming years, as significant numbers of panels from the initial batches of installed PV panels are decommissioned, PV panel end of life waste management would become a serious environmental concern.

The proper management of end-of-life PV modules is essential not only to enable recycling and recovery for other production processes of limited natural resources but it is also essential to properly dispose off the hazardous substances like lead present in c-Si modules and cadmium present in thin film modules.

The excessive accumulation of cadmium causes chlorosis in plants, and toxicity, necrosis or death in animals. In humans, the main effects of intoxication are fever, weakness and vomiting while the effect of chronic intoxication leads to kidney dysfunction, pulmonary emphysema, etc. Lead has different physiological and biochemical effects as it interferes with enzymes and can cause damaged peripheral paresis and central nervous system problems like headache, irritability, memory loss, hallucination, as well as to the cardiovascular system, kidney, etc.

As per IRENA, decommissioned panels will increase as the global cumulative solar power installation capacity rises to around 3000 GW by 2030, led by China, United States, Japan, India and Germany. According to an IRENA estimate, global estimated cumulative waste volumes of end-of-life PV panels is predicted to reach 1.7 to 8.0 million tonnes by 2030. By 2050, global estimated cumulative waste volumes of end-of-life PV panels will have increased to more than 78 million tonnes per year led by China (13.5 to 20 million tonnes), US

(7.5 to 10 million tonnes), Japan (6.5 to 7.5 million tonnes), India (4.4 to 7.5 million tonnes) and Germany (4.5 to 7.5 million tonnes).

## Managing PV Waste

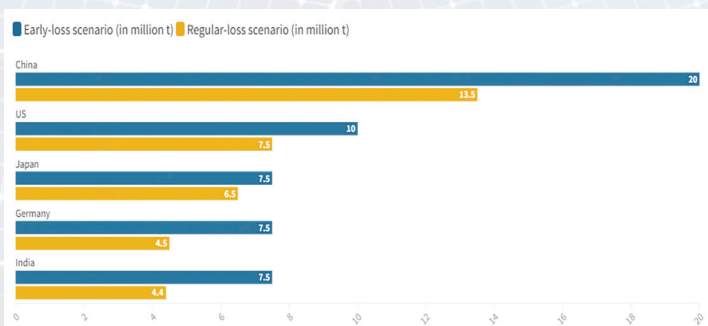
Globally the European Union has taken the lead with their WEEE policy for allocating liability, setting recovery and recycling targets, and requirements for treatment and consumer awareness. The European Union has a strong policy on PV solar waste, where priority is given to the recovery and recycling of materials and export of the waste is strictly prohibited. The United Kingdom was the first country within the EU to adapt the WEEE directive on the processing of waste solar PV panel components, followed by Germany. Germany amended its waste electrical and electronic equipment (WEEE) legislation, and all solar PV panel manufacturers and importers need to register their goods and accept end-of-life treatment obligations, or face severe penalties. Now, all the 28 member states of EU have initiated the regime for PV module collection and recycling as per the WEEE directive. Europe is also focusing on research and development related to solar module recycling.

There are no specific federal statutes, law or regulations followed by USA for the collection, gathering, handling and use of end-of-life PV modules. However, some states and industry-led policies have started to address the end-of-life solar PV module concern. California, Washington, New Jersey, and North Carolina are the only states in USA having laws or regulations that address the PV solar panel waste generated directly.

*PV Cycle*, a European organization responsible for PV module collecting and recycling, and *Retina*, a photovoltaic waste processor, have formed a joint venture in the Czech Republic to recover and recycle waste solar panels. *PV Cycle* provides collective and tailored waste management as well as legal compliance services to businesses and waste processors all over the world. Private companies and public research institutes are doing a great job of setting up laboratory scale or pilot industrial processes to achieve the goal of sustainable development and economic viability. Another organization *First Solar* has recently launched a program that includes the collection and recycling of environmentally hazardous materials for PV modules.

There are no specific laws or regulations for PV solar waste management in China and India. Growing solar PV panel waste creates a new environmental challenge. But it also provides an unprecedented opportunity to create value and pursue economic avenues. This includes recovery of raw materials and the emergence of new solar PV end-of-life (EOL) waste management industries. PV recycling sectors will be essential in the global transition to a sustainable, economically viable and increasingly renewable energy based future.

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Estimated cumulative waste volumes of EOL PV panels by top five countries in 2050 by early-loss scenario and regular-loss scenario