Decommissioning Photovoltaic Panels- An Environmental Concern

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Abstract

Solar Energy has emerged as one of the most sustainable alternatives to conventional energy resources like coal, natural gas, oil. Global installation of the photovoltaic panels has reached a capacity of 222 gigawatts (GW) by the end of 2015 and is expected to rise further to 4,500 GW by 2050. In India, the total installed capacity has reached 310 GW where the generation of electricity using thermal generation has been 69.4%, hydro electricity generation has been 13.9%, renewable contributed 14.8% to electricity generation and nuclear energy electricity generation was 1.9%.The solar (photovoltaic) panels used in electricity generation have a life span of about 25 years and hence once their life span gets over, their decommissioning adds waste to the Waste from Electrical and Electronic Equipment (WEEE). Waste management and end of life disposal of PV panels is emerging as a pre-emptive measure to counter the e waste to be generated by the PV panels in the coming decades. This paper estimates the requirement of decommissioning of the photovoltaic and end of life recycling of the PV panels.

Introduction

Solar Energy has emerged as one of the most sustainable alternatives to conventional energy resources like coal, natural gas, oil. Global installation of the photovoltaic panels has reached a capacity of 222 gigawatts (GW) by the end of 2015 and is expected to rise further to 4,500 GW by 2050[1]. Solar energy share on the total primary energy demand is expected to reach 9% by 2030 and 40% by 2050[2].In India, the total installed capacity has reached 310 GW where the generation of electricity using thermal generation has been 69.4%, hydro electricity generation has been 13.9%, renewable contributed 14.8% to electricity generation and nuclear energy electricity generation was 1.9%[3]. Renewable power has been able to secure second position in electricity generation (2). There was a compound annual growth rate of 117% in the installation of photo voltaic panels for electricity generation in India since 2013[4]. Harnessing Solar Energy using photovoltaic panels has been one of the most successful means of energy generation. However, one observes that the solar panels used in electricity generation have a life span of about 25 years and hence once their life span gets over, their decommissioning adds waste to the Waste from Electrical and Electronic Equipment (WEEE).

It has been estimated that by the year 2016, photo voltaic waste has been accumulated cumulatively at 43,500-250,000 metric tonnes, globally. This implies cumulative mass of 4 million metric tonnes of solar panels. It is anticipated that large amount of waste due to decommissioning of the solar panels will be added to WEEE by the early 2030s[5].

India's Solar Energy Mission

Taking advantage of the geographical location of the country, India launched an ambitious National Solar Mission in 2010 to harness the solar energy available in abundance. To overcome the energy challenges faced due to the depletion of conventional fossil fuel energy generation, under the brand name of Solar India, a mission has been launched with the ambitious target of deploying 20,000 MW of grid connected solar power by the year 2022[6].

The grid connected solar power generation are where the photo voltaic panels are connected to the main electricity grid and hence can operate parallel to the electric utility grid. The mission has been able to generate solar power of 12.28 Giga Watt by March 2017[7]. In the off grid systems, solar energy is stored in the batteries and it is not connected to the utility grid. Applications such as solar home lighting systems, solar street lighting systems, solar power plants, solar pumps, solar lanterns and solar study lamps are covered under the programme. Table 1 shows the application-wise status of the installations under off-grid and decentralised Solar Photo Voltaic application programme as in the year 2017. While the use of photo voltaic (PV) panels is mitigating the present energy demands, their disposal after the prescribed life span will pose WEEE waste disposal challenge. A pre-emptive effort and preparation in this direction requires intervention of public policy and e-waste aggregators.

Components of a Photovoltaic Panel and the Hazards in its Manufacturing

A Silicon crystalline Photovoltaic panel consists of the following – 1.the front cover, 2. encapsulation, 3. solar cells, 4. back cover. The front cover is either made of glass or polymer.

As a single solar cell output power is limited, many solar cells are adjoined to make a solar panel for meeting the power requirement. Encapsulation is the process which provides adhesion to the solar cells to make a solar panel and also provides adhesion to the top surface and the rear surface of the PV module. The encapsulation is a tool also meant for enhancing the stability of the PV panel by protecting from degradation due to environmental factors like moisture, ultra violet light, oxygen and temperature[8]. Encapsulate are generally made of ethylene-vinyl acetate (EVA). However, other polymer materials like polyvinyl butyral (PVB) are also used.

The solar cell in a silicon-based PV module made from mono-crystalline or poly-crystalline technology[9]. Majority of the solar cells produced are from silicon based crystalline wafers. The first generation of photovoltaic panels were made of crystalline silicon. Monocrystalline solar cells are column ingots grown by the Czochralski (CZ) process while polycrystalline cells are made from square silicon substrates cut from polycrystalline ingots grown in quartz crucibles[10]. The second-generation photovoltaic panels are made using thin film technology which is cost proficient in comparison to the monocrystalline panels. Cadmium Talleride which is a direct semiconductor with very strong light absorption and a bandgap which is well adjusted to the solar spectrum, is used popularly in the second-generation PV panels. CdTe is used in combination with

Cadmium sulphide, CdS, to form hetero junction. They are lower in cost than crystalline solar panels but with lower efficiency.

A basic solar cell design is shown in Figure 1. The back cover of a PV solar panel is a tedlar film which is made from polyvinyl fluoride that provides a durable, weather resistance back sheet. It is the outer layer of the PV panel. Tedlar film is designed to act as an electrical insulator and give protection to the inner components of the PV panel, specifically the photovoltaic cells and electrical components from external stresses[11].In a Solar Panel, the mass of the solar cells constitutes only 4% of the total mass. The outer glass cover has the largest share of the total mass of a finished crystalline photovoltaic module which is about 65%, followed by the aluminium frame ~20%, the ethylene vinyl acetate constitutes ~7.5% of the total mass, the polyvinyl fluoride substrate is ~2.5% and the junction box is 1%.[12] .

As in the case of manufacturing of most of the electronic gadgets, the toxicity of the hazardous elements used in the process of making the PV panels contribute to the perils of the public health. In Crystalline Silicon PV panels, use of HF, SiH_4 fires, Lead solder; in amorphous Silicon PV panels SiH_4 fires/explosions; in CdTe PV panels carcinogenicity and toxicity of cadmium; in GaAs PV modules, toxicity of AsH_3 and arsenide carcinogenicity are the potential environment hazards[13].

Cadmium Telluride, copper indium selenide and gallium arsenide (CIGS) based PV panels are manufactured using thin film technologies that use about 1/100 of the photovoltaic material used on crystalline Silicon.

Decommissioning of Photovoltaic Panels

The annual WEE waste in the year 2014 reached a record 43.8 million tonnes and is expected to reach 50 million metric tonnes by 2018[14]. Solar PV panels though considered under large equipment category, differ from the consumer electronic goods. At present, PV panels account less than 1% of the total annual e-waste volumes but are expected to grow exponentially and a cumulative waste from PV panels is being forecasted to reach 1.7 million t in 2030[1]. An even more drastic rise to approximately 60 million tonnes could be expected by 2050. Figure 2 shows the cumulative waste volumes of the top five countries including India, for the end-of-life PV panels by 2050, both for the early loss scenario and regular loss of the PV panels.

For all type of solar panels, common goals in recycling technology are to maximise recovery yields, minimise impurities in the products of recycling and minimise capital and operating costs to be competitive with other disposal options. Recycling technology can be categorised under bulk recycling and high value recycling. Under bulk recycling, recovery of high-mass fraction materials such as glass, aluminium and copper is executed. Bulk recycling is similar to the laminated glass recycling. It may not be in a position to recover Pb, Cd, Se which are environmentally sensitive materials and can cause toxicity if left in landfills. Valuable elements like Ag, In, Te and solar grade -Si which can be reused may also be lost in the bulk recycling[15].

Under High value recycling, the following three steps are broadly followed – Pre-treatment, Delamination, Glass and Metal Recovery. Pre treatment removes the metal frame and junction box of the solar panel. Delamination removes the module encapsulant and separates it from the glass layer and the back sheet from the solar cell. Delamination applies mechanical, thermal, or chemical processes, or a combination of all three and hence is a challenging process. In glass and Metal Recovery, chemical and electrolytic processes are used to recover precious metals[16].

The waste projection of PV panels in India up to 2050 based on the data in the report of International Renewable Energy Agency (IRENA) and the International Energy Agency Photovoltaic Power Systems (IEA-PVPS)[1] is given in Table 2. Most of the early photo voltaic panels due for disposal post 2020 are crystalline -Si PV panels. The estimate of the steep rise in the waste due to the disposal of existing PV panels post 2030, in India can be observed in the Figure 3. Table 3 shows the estimated cumulative waste volumes of end-of-life PV panels across the globe. Figure 4 shows the comparison between the waste estimate across the globe by the year 2050 in India and across the globe.

Conclusion

It is evident that in the large part of the world, photovoltaic panels have been installed in the early twenty first century as a substitute for the source of energy. Hence it can be concluded that waste generation due the solar panels will become a cause of concern and contributor to the expanding waste generation of WEEE by the end of the year 2030. Figure 3 and Figure 4, projecting the estimate of the steep rise in the waste due to the disposal of existing PV panels post 2030 also corroborate the same. Waste management and end of life disposal of PV panels is emerging as a pre-emptive measure to counter the e waste to be generated by the PV panels in the coming decades. Tailored to specific geographical locations, the enabling framework must be developed to address the challenges of PV panel disposal.

System	No. of units/capacity installed
Solar Lamps/Lanterns	65,17,180
Solar Pumps	2,37,120
Solar Street Lights	6,71,832
Solar Home Lighting Systems	17,15,639
Solar Power Plants/Packs	212 MWpeak

Table 1: Application-wise status of the installations under off-grid and decentralised Solar Photo Voltaic application programme as in the year 2017[7]

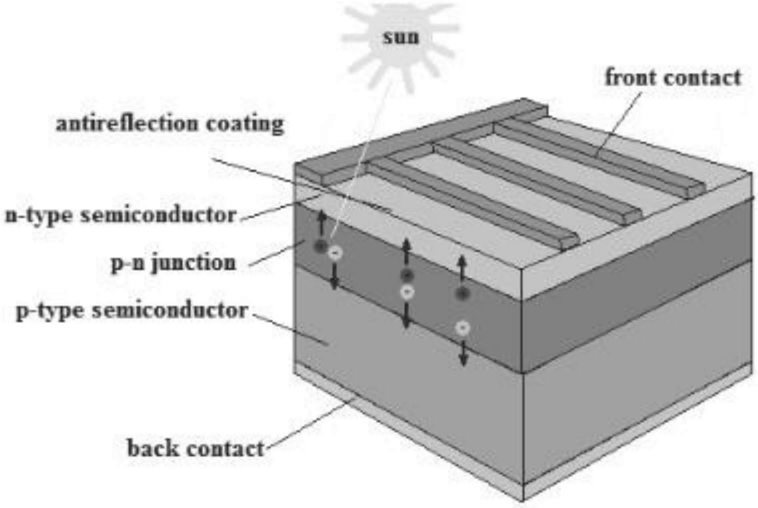

Figure 1: A basic Solar Cell [10]

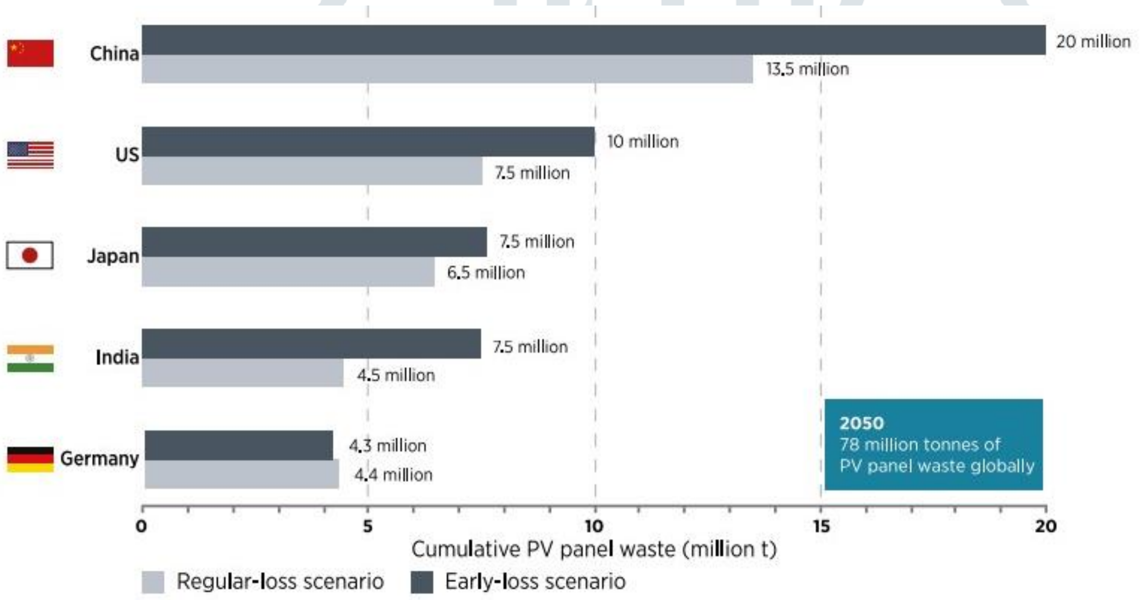

Figure 2: Cumulative waste volumes of the top five countries for the end-of-life PV panels in 2050 (End-of-Life Management: Solar Photovoltaic Panels, International Renewable Energy Agency (IRENA) and the International Energy Agency Photovoltaic Power Systems (IEA-PVPS) June2016ISBN 978-92-95111-98-1 (Print, IRENA).

	2016	2020	2030	2040	2050
Regular Loss	1000	2000	50000	620,000	4,400,000
Early Loss	2500	15000	325,000	2,300,000	7,500,000

Table 2: Based on modelling, estimated cumulative waste volumes of end-of-life PV panels in India in tonnes[1]

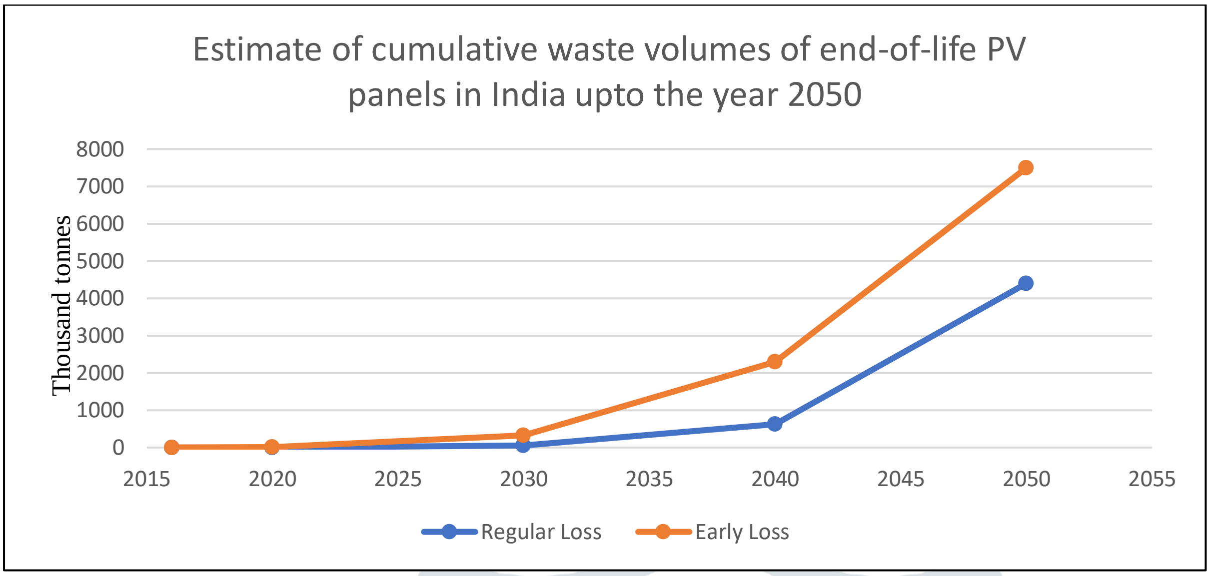

Figure 3: The projection of the increase in the waste volumes of the end-of-life PV panels in India till 2050

Year	2016	2020	2030	2040	2050
Regular Loss*	43,500	100000	1700000	1,50,00,000	6,00,00,000
Early Loss* *Across the globe	250000	850000	80,00,000	3,20,00,000	7,80,00,000

Table 3: Based on modelling, estimated cumulative waste volumes of end-of-life PV panels across the globe in tonnes[1]

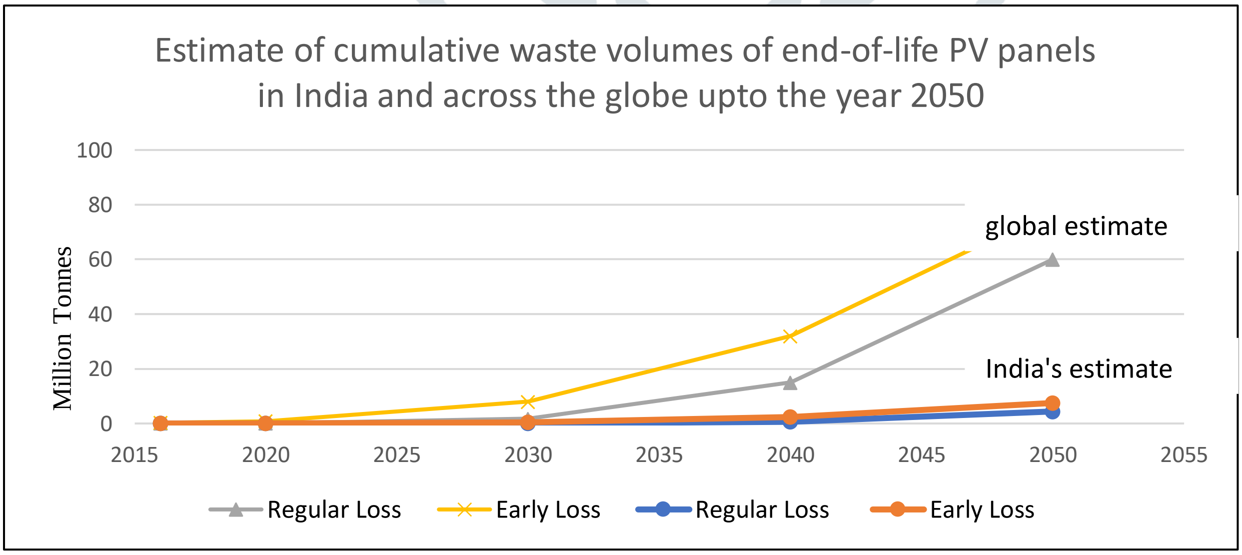

Figure 4: Comparison of the projection of the increase in the waste volumes of the end-of-life PV panels in India and across the globe till 2050

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