Recycling of Solar Panels in India: Future Challenges and Opportunities

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The renewable energy sector is expected to grow by 48 or 825 GW by 2021 and solar panel deployment at 30,000 panels per hour by 2021. Solar PV installations are going to result in huge solar waste. The present paper aims at providing recommendations to regulators that creates an environment which covers the risk from solar waste into a business opportunity. The study focuses on an assessment of projected solar PV waste generation in India till 2050 developing a policy framework/model for solar PV waste management in India and to study the benefits of solar PV recycling.

Keywords: Solar Panels, Recycling, Renewable Energy, Waste Management, Sustainability

1. Introduction

In quest to achieve a below 2ºC scenario, global efforts are made to reduce GHG emissions. The international platforms foster the idea of discussion among developing and developed world to create solutions to the rising issue of Global warming. The Paris agreement was one such instrument that is now legally binding with Europe and India ratifying the agreement in November 2016. The ambitious commitments of World's biggest emitters will percolate down to strategies that shape the policies on national level. The fact that 60% of GHG emissions come from power sector, it is imperative for the Nations to look at their energy mix. Therefore, there is a trend to move towards a sources of power generation by cleaner technology. Spearheading the clean energy space Solar and Wind has been investment hotspots worldwide. Solar PV installations totaling more than 49 GW in 2015 took global PV power generating capacity to 222 GW by year end. The total share is 1.1% but has doubled in just two years (IRENA: Renewable Energy Statistics, 2016).

The efforts of international communities to mitigate the impacts of climate change has put the clean power generation on the centre stage. The year 2015 has been a remarkable year as the capacity additions of renewables surpassed that of Coal. The capacity addition for power generation from solar photovoltaic has reached new highs year on year, since 2012 and can be accounted to reducing price of solar panels. International Energy Agency suggests an optimistic future for renewable sector, suggesting share of renewables to become 28% by 2021. The global renewable electricity is expected to grow by 48% (or 825 GW) by 2021. The favourable policy framework is expected to accelerate solar panel deployment at 30,000 panels per hour by 2021 (IEA, Renewable Energy Mid-Term Report, 2016). Two-third of this accelerated growth will come from four key markets, i.e. China (37%), United States of America (13%), European Union (12%) and India (9%) of the expected huge solar panel installation (IEA, Renewable Energy Mid-Term Report, 2016).

The high solar PV installations are going to result in huge solar waste. In developed countries like USA and EU, the ratio of waste solar panels new installed panels is almost constant 0.1 % (by the end of 2016- around 43,500 metric tonnes of waste and 4 million metric tonnes of new installations) (IRENA, End-of-Life Management: Solar PV Panels, 2016). The reasons accounted for such a less numbers may be accounted to the following reasons:

1. Solar PV market is still growing and is at a nascent stage.
2. The programs of solar installations began in 1990's in these countries and the estimated life of these panels is expected to be 25-30 years. Hence, we may not even have the first cycle of waste yet.

The numbers projected for the year 2030 and 2050 show the aggressive growth from 4-14% to 80% (IRENA, End-of-Life Management: Solar PV Panels, 2016).

The EU has been pioneer in recognizing this additional waste stream from solar panels by providing a legislative framework for Extended Producer Responsibility (EPR) of PV modules in Europe under recast WEEE (Waste Electrical and Electronics Equipment) Directive 2012/19/EU on July 4th 2012. In the region, Germany and Italy together comprise of 26.4% (by 2015 end) of the total capacity installed globally (Report IEA PVPS T1-29:2016). Thus, it is of vital importance that these two countries have specific waste management regulations. To carry the spirit of the Solar PV WEEE declaration, Germany and Italy laid down regional declaration in October 2015 and March 2014 respectively. The European Union has become the torch bearer on Solar PV waste management regulations in the international forum. The top 5 solar PV nations also include The United States of America and Japan, where the regulations are taking shape and informal frameworks are developing to identifying the risk and opportunities resulting from solar PV waste. Solar Energy Industries Association (SEIA) has started building an understanding how recycling can address the risk arising from ambitious solar PV deployment. SEIA has created a list of panel manufacturers who can use a network of recyclers to use refurbished material. The PV modules have to be disposed in line with the Resource Conservation and Recovery Act, 1976 for characteristic hazardous waste (Press release: "National PV recycling Program aims at discontinuing disposal of panels in Landfills", September 13, 2106). It is important to note here that the key driver for solar PV waste management is not a regulatory push but cost benefits and environmental

performance. Japan is progressively learning and creating a strong knowledge in solar PV waste management. In 2015, Japan's Ministry of Economic Trade and Industry (METI) and Ministry of Environment (MOE) suggested roadmap to handle end-of-life renewable energy equipment. METI and MOE published end-of-life treatment and recycling guidelines on decommissioning, transportation, reuse, recycle and industrial waste disposal. Japan does not have a specific regulation for end-of-life PV panels, therefore must be treated under general regulatory framework for waste management (The Waste Management and Public cleansing Act, 2015). There are two ways a solar PV recycling is developed in solar giants across the world. First, a regulatory approach to mandate the roles and responsibilities at each stage of value chain to monitor and control. Second, voluntary approach where industry associations see solar PV as an opportunity to lower cost or extend it as Corporate Social Responsibility.

The Government of India revamped the solar installation target under Jawaharlal Nehru National Solar Mission (JNNSM) from 20 GW to 100 GW by 2022 in June, 2015 This target comprises of 40 GW from rooftop installations and 60 GW by large scale and mid-scale deployments(Ministry of New and Renewable Energy, GoI,2016). The government walks the talk with providing capital subsidy of ₹ 15,050 Crore for development of solar rooftop in various cities, Viability gap funding through Solar Energy Corporation India (SECI) and through decentralized generation through small solar projects (Press Release: "India surging ahead in the field of Green Energy - 100 GW Solar Scale-Up plan"). The intentions of ambitious targets of solar energy were fuelled by reduced levelized cost of electricity from solar power plants and the country's commitment to reduce GHG emissions. Solar is a part of India's total renewable energy target of 175 GW, presently, India ranks 4th in the installed wind energy capacity globally with 28.7 GW/5.9 % share (GWEC, Global Wind Statistics, 2016). In the past two years the solar capacity additions have doubled and regulations tighter in the country. Post COP 21, the coal plants capacity installations have stopped due to stringent air emission standards. Hence, the government's strategy to reduce GHG is by energy efficiency and renewable energy installations. The nodal agency to execute the target is Ministry of New & Renewable Energy (MNRE) under which financial institutions like Indian Renewable Development Authority (IREDA) and executive body like Solar Energy Corporation India (SECI) operate.

The prolific growth in solar PV deployment since 2014 have an alarming sign of panel waste generation that may create issues of disposal if not addressed in the beginning. India imports most of its solar panels and has very less local manufacturers for panel. Waste management regulations have developed over a period of time and the closest that comes to solar PV is the E-Waste management and handling rules 2011 (Revised in 2016).

The waste management in Indian context have been traditionally a Hazardous waste management and handling rules 1989, which where amended in 2000 and 2003 with final notification coming in 2008 (Revised in 2016), which includes management, handling and trans boundry movement. The central pollution control board (CPCB) has been instrumental in identifying new waste streams like E-Waste. The MoEF CC has notified E-Waste (Management & Handling) Rules 2011 which consists of a basket of products broadly divided in Information and telecommunication equipment and consumer electrical and electronics. These rules have been superseded by E-Waste Management Rules 2016 where producers have been made responsible for collecting and disposal of the waste generated by their products. The rules mandate to maintain the record of the waste at each stage and creates an established structure of handling and management of E Waste. However, these notification does not include waste stream resulting from solar PV. Indian solar program started in 2010 and the first batch of waste stream is expected to come in 2035 to 2040. Though, this is a long shot regulators are expected to work on issues of the present that may give fundamental basis for the problems of the future.

National Solar Mission is a part of Indian renewable energy target of 175 GW that commits installed capacity of 100 GW from Solar. The policy and regulatory framework has made the investments favourable for the sector in India. Thus, there are huge installations of Solar PV modules in progress. Within just two years the installed capacity of solar power generation has doubled to nearly 9 GW (CEA data, 31.01.2017). The life of solar panels is estimated to be 25 years (CEA guidelines). Hence, we must expect panel waste generation spiking after 25 years. The solution in present times must not trigger a problem in future.

The paper aims at providing the necessary recommendation to regulators that creates an environment which covers the risk from solar waste into a business opportunity.

2. Methodology

The researcher plans to make use of three methodologies for gathering information for the paper. The merits and demerits of the methodology has been a guiding factor for the choice. There is an extensive desktop search coupled with document analysis. The researcher plans to take a second opinion along with reassuring the facts with other analysis done and published online.

A very important way of gathering information is to mine secondary data and research done by established institutes and published on trusted forums. Keeping in view the length of time available for the research it is important to utilize the secondary data generated by various government bodies and nodal agencies to create an understanding about the industry. The analysis published by some market research firms give insights that can make significant difference in the project. Secondary survey conducted by market research firms can trigger some pathways to reach the objectives of the project. According to Bloom's Taxonomy, analysing may become an important stage for evaluating which eventually results in creating. The concept of Bloom's Taxonomy is well exercised by the researcher by evaluating the analysis presented by various agencies and thus, evaluate and create to meet the objectives of the paper.

It is of vital importance to engage with stakeholders to understand their needs and understanding on the subject. The researcher will send interview requests to at least two people/organizations that belong to a stakeholder group. The key merit of this method is to get the opinion and suggestions directly from people who are affected by the objectives of this paper. The use of digital tools such as emails will be the priority, since, it is believed that when thoughts pen down are more structured and authentic. However, the researcher completely understands that paucity of time at informants end may delay the process of getting the information in the first place.

3. Objectives

- To develop various scenarios to project solar PV waste generation in India for 2030, 2040 and 2050.
- To study the benefits of solar PV recycling.

4. Results and discussion

There has been some work done in estimating the waste generation resulting from solar PV deployment. The very first step is to build scenarios that estimate the waste generation accurately. The solar capacity installation may follow different trajectory of growth with changes in policy environment. The objective of this paper is to create scenarios that predict the waste generation precisely with the specifics of Indian solar sector. There is a direct correlation between the installed capacity in KW/GW and metric tonnes of the waste generated. The framework adopted by a report of IRENA on End-of-Life Solar Photovoltaic Panels presents a comprehensive structure for prediction of solar PV waste.

To gain deeper insights about the Indian solar sector, the researcher uses two tools to assess the solar market. The tools are used to analyse the prevailing scenario in the sector, bring out the challenges of the sector and the assessment of the policy-vision will help framing the possible solar PV deployment models. To evaluate the micro and macro trends prevailing in the industry, a SWOT analysis is done. It may be inferred that the sector has challenges presently but due to strong policy framework to develop solar PV sector, the Indian solar PV market is progressive. The opportunities present with the sector are growing post COP 21. The market signals grid parity to be achieved by the end of first quarter of 2017, which further strengthens the solar PV deployments across the country. The threat of uncertainty of policy cannot be ignored as precedent in wind power sector presently faces some issues of government slowly taking away the incentives like Accelerated Depreciation and removal of Feed in tariff.

4.1 SWOT Analysis

The industry has recently seen low points by strategic players declaring bankruptcy due to aggressive bidding. The researcher uses PORTER's FIVE FORCES as a tool to study the macro environment of the industry. The analysis shows healthy signs for market, competition driving the prices low and hence supporting the growth of the sector by reaching grid parity. The market has barriers to entry with high capital investment, however, the green banks are supposed to encourage entrepreneurship for the sector and ensures the new players come and keep the market competitive. In response to the tenders floated by NTPC and SECI, the response is fairly good as the number of bidders are increasing and tariff prices are touching new lows. In the basket of renewable energy, there are four options Solar PV, Wind, Waste to Energy and small Hydro.

Table 1 *Drivers & Restraints Matrix for Indian solar energy Industry*

		1-2	3-4	5-7	Remarks
DRIVERS	**Policy framework- UDAY**	H	H	H	Improves the financial health of Discoms
	Debt Financing	H	H	H	Initiatives to introduce Green Banks- IREDA
	Net Metering policy	H	H	H	21 states have come forward with net metering
	Tenders by NTPC & SECI	H	H/M	M	15 GW targeted by Indian PSU and SECI
	Implementation of GST	H	M	M	Attract investors and improve ease of doing business
RESTRAINTS	**Transmission network- RE**	H	H	H	Power outages, harmonics affect considerably as RE
	Ease of doing business	M	M	M	Foreign companies show interest in Solar business in
	Financial crisis of Discoms	M	M	M	Buying power of SEB is compromised
	Reverse bidding-No FiT	M	M	L	Aggressive bidding driving players in losses
	Policy certainty	L	L	L	Support from government on various fronts

The threat of substitute is low, as the feedstock required for waste to energy reduces its ability to fulfil the demand of a country like India. The present FiT's for wind are higher than solar and hence, becomes an uncompetitive player against Solar PV. Small hydro has a capacity constraints and cannot be a contender to achieve an ambitious target of 175 GW. Hence, Solar has a strong position in the market with less variability in comparison with wind, feedstock not required (W2E) and good solar insolation to provide scope for good installed capacity. The major customer for the sector is State Discoms, SECI, PSU and REC's. In all the forums, the power of customer is high as the business is allocated by reverse e-auction. The solar PV

segment shows high market rivalry as the sector shows competition and inclusion of new players with mergers and acquisitions taking the sector to new developments. The matrix above mentions some reasons that show reasons to believe the growth of solar PV in the coming years. However, the challenges that may decelerate the growth of solar PV deployment are also shown.

The government has introduced a carbon less of coal to fund a "Clean Energy Fund" advocating the environmental costs incurred due to the use of such source. The Central governments third intervention since 2004, Ujwal Discom Assurance Yojna (UDAY) aims to improve the financial health of the state owned distribution companies. The policy has tied performance based incentives for the Discoms along with a debt restructuring where most of the debt will be transferred to state in a phased manner and the rest will be converted in bonds. The Indian Renewable Energy Development Agency (IREDA) has volunteered to become the first Indian Green bank to ensure the development of the sector by making requisite funds available keeping in view the needs of the sector.

Since, the revision of JNNSM target, the capacity addition in the successive years have shown a positive effect of the government's efforts to increase solar power in its energy mix. The capacity additions of 1.1 GW in 2014-15, followed by 3 GW in 2015-16 has realised the total capacity of 6.7 GW which is at par with the MNRE target (MNRE data). As per the Central Electricity Agency (CEA), the Indian Installed Solar Power capacity has reached 9.0 GW as on 31st January 2017. The outlook for 2017 remains positive with the year beginning with a project pipeline of 14 GW of utility scale projects, out of which 7.7 GW is expected to be commissioned in the year (growth of around 90% over 2016). Combined with 1.1 GW of expected rooftop solar capacity, India should add a total of 8.8 GW in 2017, ranking it amongst the top three global markets after China and the USA. (Bridge-to-India, Market Outlook, 2017). The Ministry of New and Renewable Energy (MNRE) has projected the milestone achievement in Installed Solar PV capacity which aims at meeting with a total capacity of Solar PV to be 100.7 GW by the end of 2022 (GOI, 30/80/2014-15/NSM).

4.2 Projection of solar PV waste generation

The waste generated by solar PV installations is calculated by converting the PV installed capacity into the resulting waste generated by it.

India is expected to generate 120,000 tonnes of waste from solar PV (most likely case) in 2030. This implies 328 tonnes of solar PV waste generation per day, which is nearly 26% percent of the installed E-waste recycling capacity in India. This becomes an important metric to recognize waste resulting from solar PV. While this number provides a strong argument to have solar PV specific regulations. The projections for 2045 and beyond make the proposition stronger. The waste volumes will grow exponentially after 2045, considering the average life of 30 years. The Ministry of New and Renewable Energy (MNRE) considers the solar PV life only for 25 years (CEA data), which suggests the point of exponential growth will comes faster.

The policy framework in India presently shows positive signs for solar PV industry. To capitalise on the recycling of solar PV, there needs to be a supporting policy for the development of the reverse supply chain, dismantlers and recyclers.

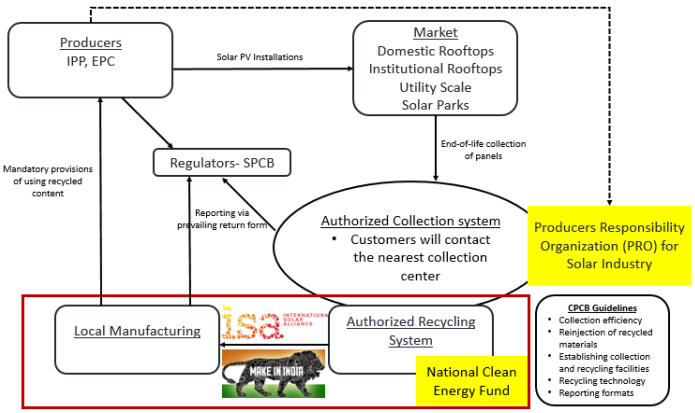

Figure 1 *Suggested Model for solar PV waste management in India*

The above model suggests a producer's responsibility organization (PRO), an independent organization funded by producers that imposes a financial liability on installation of solar PV in view of cost of the take-back mechanism on present fundamentals. PRO will maintain the records of the customers and facilitate the removal and transportation of solar PV. The PRO will decide the take back price of the rooftop PV and utility scale PV and communicate to the players working for these segments. The list of MNRE approved vendors may be referred for the data of the players and projects post 2010. The price of collection of rooftop PV may attract a premium over the price of collection of utility scale PV, since the source of former is distributed and later benefits from economies of scale.

The International Solar Alliance (ISA) based in Gurugram, can address the issue of solar PV waste and create the routes and channels of technology transfer that makes the proposition for recycling all the more beneficial to stake holders. As there

is an infrastructure required to build the facility, the government to encourage entrepreneurship in this area may provide funding from National Clean Energy Fund (NCEF). The responsibilities of Central/State Pollution Control Boards can be continued to be similar to the incumbent E-waste management and handling rules. SPCB will maintain records and data from producers, collection centres and the manufacturers of new solar PV panels.

The prevailing system of annual returns for E-waste must be replicated for solar PV waste and formats specific to PV waste must be developed by CPCB. The annual returns by producers, collectors, manufacturers will be filed in the format.

The resources from nature are exhaustible and will become unsustainable if used the same way. The clean energy space has become very important to guide the human king towards sustainability. The researchers initially focussed on improving the efficiency of these renewable technology to improve the financial viability of such technologies. The commercial deployment of solar PV started in 1980's, with 25 years of life span. The environmental impacts of the waste resulting from solar PV has then surfaced as a problem and the issue is studied by many researchers. Recycling of the waste resulting from solar PV is one of the ways to mitigate the environmental impacts.

4.3 Socio-Economic and Environmental Benefits of recycling solar PV panels

India needs Renewable Energy (RE) for energy security; reducing dependency on energy imports; increasing opportunities in green economy and green employment; fighting climate change; strengthening local economies; and finally providing social justice. In some essence, India needs an energy transition towards Renewable Energy. Solar power has become a strong candidate for meeting the energy needs in India among the other renewable energy sources. The energy mix is evolving with more investments flowing in the renewable energy space in comparison to conventional thermal based power plants. Developing economies jumped ahead of developed countries for the first time in 2015 in terms of total new renewable energy investment. The share of global investment accounted for by developing countries rose from 49% in 2014 to 55% in 2015, with the dollar commitment at $155.9 billion, up from $131.5 billion the previous year. Developed economies invested $130.1 billion, compared to $141.6 billion in 2014. n Within the developing-economy category, the "big three" of China, India and Brazil saw investment rise 16% to $120.2 billion, while "other developing" economies enjoyed a 30% bounce to $36.1 billion (Frankfurt School-UNEP Centre, 2016). India's energy imports have risen sharply from USD 43 bn. in 2005-06 to USD 167 bn. in 2013-14. In comparison India's trade deficit in 2013-14 was USD 139 bn (KPMG, 2015).Solar power is a strategic need for the country as solar power can potentially save USD 20 billion in fossil fuel imports annually by 2030 and domestic manufacturing can save USD 42 billion in equipment imports by 2030. In the absence of manufacturing, India will need to import USD 42 bn. of solar equipment by 2030 corresponding to 100 GW of installed capacity. Solar manufacturing can also create direct employment of more than 50,000 in the next 5 years assuming local manufacturing captures 50% domestic market share and 10% global market share. Another at least 125,000 indirect jobs will be created in the supply chain (KPMG, 2015).

4.3.1 Social benefits

The benefits of recycling to society is that it minimises the risk due to improper handling of hazardous waste. The End-of-life scraps represent a potential source of environmental pollution because they can contain hazardous materials, such as Pb, Cd, Cr and Bi that cause serious illnesses in humans because of their toxicity (Cucchiella, F. et. al., 2015).

An important aspect of recycling is the economic activity generated due to the workforce involved. The International Labour Organization states that the effect of recycling will create new jobs and some of the jobs will shift from landfill to recycling (UNEP, 2012). It was estimated that WEEE recycling will create a 700,000 jobs in China by formal and informal sector (EMPA, 2007). Recycling and waste management in developing countries is done mostly by unorganized sector and driven by poverty. The risk associated with such approach is the health hazards of handling chemicals involved. The solar PV needs decommissioning by skilled work force. Therefore, a rag picker may not be able to take back a solar PV for disposal or recycling. This ensures the involvement of the informal sector will be minimum. In 2009, China now employs 1.3 million in formal waste collection, 1.5 million in informal scrap collection and 10 million in the aspects of recycling, remanufacturing and reuse (ILO, 2009). The recycling based manufacturing is expected to create 25 jobs per ton of the waste material generated (CAFR, 2011). The regulations in solar PV waste management will enhance the green job creation around the management of this new waste stream. It is important to notice the profitability of recycling a thin film solar PV is better than that of the mono/polycrystalline solar PV (McDonald and Pearce, 2010).

4.3.2 Environmental benefits

Recycling can ensure the supply chain sustainability in the long-term by enhancing, from one hand, the recovery of energy and materials embedded in PV modules and, from the other hand, by reducing CO2 emissions.

4.3.3 Landfill

The final argument that supports recycling is the prevailing situation of landfilling in India. The incidents of overflowing landfills has become very common in India (CSE, 2016). The country has a waste profile that that contains more organic matter (TERI, 2014), thus technologies such as biomethanation prove to be commercially viable. The landfill waste disposal of material in solar PV is mostly done by pyrolysis and gasification. These technologies are not yet commercially available in the region. Also, the hazardous chemicals in the solar PV will become a threat (TERI, 2014). Additionally, the pollution

control equipment reduce the commercial viability of these plants. The landfill cost creates an incentive for collecting and recycling and makes a recycling project more viable (McDonald, and Pearce, 2010).

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