It is plausible that complete removal of free rider behaviour may not generate sufficient environmental benefits to justify the administrative costs to minimise free riders. Policymakers and PROs need to analyse the incentives they create for the various actors operating in an EPR system through different pricing structures and legal liabilities, to ensure that these are consistent with the ultimate goals and objectives of the EPR program and with overall economic efficiency. Under mandatory EPR programs, government enforcement against free riders may be needed to assure fairness to producers that carry out their EPR responsibilities. Decisions with regard to orphan and existing products must be also taken into account.

Most EPR schemes cover partly or fully the net costs for the management of waste that has been separately collected, as well as administrative, reporting and communication costs relative to the operation of collective schemes. For photovoltaic modules, the administrative costs shall be similar as in each EPR-environment. The challenge is the operational costs, where almost no waste occurs whilst the fixed administrative costs exist. The creation of provisions or funding for future waste management is crucial in order to be able as solar industry to manage the upcoming waste environmentally sound in the future. A draft financing model for an Advanced and Visible Disposal Fee is therefore very recommendable.

Recommendations for the setting of an EPR system, the proposal for a fee calculation, as well as the proposal for the organisational structure of a PRO are included in the report.

From a stakeholder survey carried out during the drafting of this study it can be concluded that stakeholders in India are concerned about the PV waste and its management in the country in coming years and are willing to consider a fee to create a fund which is managed by an industry body to facilitate this process and manage India's PV waste. Among the manufacturers who participated in this survey almost 80% of them were willing to take PV end-of-life responsibility. Over 90% of stakeholders believed a Management Organization steered by the PV industry itself is the best way to handle a fund for future waste management of PV modules.

Looking at the medium- and long-term time horizon (5-10 years), the following actions should be explored:

1. Develop sustainable product policies for PV modules, inverters and systems, such as Ecodesign and Ecolabel, based on globally recognised standards and a methodology that take into account the full product lifecycle;
2. Consider including sustainability criteria in national renewable energy auctions, based on a point-based system, to reward products with the lowest environmental impact;
3. Periodically re-assess rules on PV waste recycling to keep pace with the evolution of the sector;
4. Set up joint EU-India Horizon 2020 calls for R&D projects on PV recycling technology or innovative equipment.

CHAPTER 01

INTRODUCTION

1.1. Context

The last few years have witnessed a major global shift towards renewable and sustainable modes of energy generation. With increasing focus on solar energy and subsequent capacity addition, the PV solar sector is growing rapidly. In India, solar energy and its implementation was first addressed during the 6th Five Year Plan (1980-85). However, solar energy in India did not receive the desired momentum until recently when the National Solar Mission was launched as one of the several measures under the National Action Plan on Climate Change in 2010. The mission was launched initially with a target of 20 GW by 2022 which was later revised to 100 GW. Under the revised targets, the ground mount solar systems of 60 GW and 40 GW of solar systems on rooftops are proposed to be installed by the year 2022. By the end of 2019, India has installed around 35 GWAC of solar PV capacity on ground and rooftops across the country[1].

As everywhere else in the world, the prodigious penetration of PV technology in India will generate waste. Solar PV modules are durable and long-lasting products and are expected to last 30 years or even longer. Thus currently, PV module waste generation as a result of end-of-life has very limited effects in the short and medium term, considering the fact that majority of PV systems have been installed after 2010. However, PV waste is not only generated once the expected end-of-life stage of the PV module is reached but also during transportation, installation and operation of the PV system. It is therefore important to carry out an assessment of PV waste generation over the next decades to provide solutions for a sustainable energy economy and to prevent adverse environmental impacts which could arise from the wrong practices of disposal of end-of-life PV modules and their components.

1.2. Objectives

This report has the following key objectives:

- Comparison of the EU and Indian regulatory settings and main policy drivers
- Analysis of the PV module waste market in India, including the amount of waste generated, current waste treatment practices
- Short-term (2020-2025) policy recommendations for India for setting up a PV module waste collection and financing mechanism based on the Extended Producer Responsibility (EPR) approach, adapted to the Indian context

[1] *Differently from most of the EU countries, installed capacity in India is always expressed in GWAC. The DC/AC conversion rate used in this study is 1.2.*

- Proposal of the deposit fee and financing for management of PV waste – how much, where, who?
- Medium to long-term (2025-2030) recommendations for improving the EPR policy, proposals of R&D policy and programs between India and EU in relation to for example eco-design, improving treatment of PV modules waste etc.The report can thus be a starting point for the design and the implementation of a lean and mean legislative framework for Renewable Energy Equipment and its post-consumer waste.

1.3. About the Project

This report is developed in cooperation among the EU India Technical Cooperation Project (IDOM), SolarPower Europe, PV CYCLE & National Solar Energy Federation of India.

IDOM (Consortium leader) is an international firm of independent professional services in the fields of engineering, consulting and architecture, backed by an experience that goes back to 1957. In a global world, IDOM has become a global and multidisciplinary firm made up of over 3,500 professionals, located in 40 permanents and various project offices distributed 40 countries across 5 continents. With projects in 125 countries, it has offices in 20 countries, Algeria, Argentina, Brazil, Chile, Colombia, UAE, Slovenia, Spain, United States, India, Mexico, Poland, Portugal, United Kingdom, Senegal, Malaysia, Peru, Turkey, Canada. IDOM's journey in India started in 2012, the New Delhi office has more than 100 multidisciplinary professionals who share common goals and work practices. IDOM Indian experts counts on vast experience in successfully, delivering and providing services in all disciplines of engineering, consultancy and architecture.

IDOM is an association of professionals linked by work and the common ownership of the firm (100% of the capital is distributed between the staff currently working in the company), cooperating to achieve greater human and professional development, while offering the best service to the Client.

The EU-India Technical Cooperation Project Energy is formed under the joint collaboration of European Union and Government of India. The project is operational since September 2014 and has provided its assistance to Bureau of Energy Efficiency (Ministry of Power), Solar Energy Corporation of India (SECI) and the Ministry of New and Renewable Energy (MNRE). The project provides beneficiaries and participants with the opportunity to enhance their technical and institutional capacity. The major aim is to create enabling environment for implementation of climate friendly energy efficient technologies through increasing awareness amongst public and private sectors. You may know more about the project by clicking the link: https://faqs.solar/about-the-programme/

SolarPower Europe is the voice of the Solar industry in Europe, with more than 200 members active along the whole solar PV value chain. SolarPower Europe's mission is to shape the regulatory environment and enhance business opportunities for Solar in the European market providing its -global membership with a strong voice towards European decision makers. It develops award winning business intelligence and best practices reports on markets, industry

and technologies, informing its members and external stakeholders on the latest trends of the PV industry. The association is acknowledged as an essential content provider for European political stakeholders – including EU institutions and opinion leaders. SolarPower Europe is registered as an international non-profit making organisation under Belgian law.

NSEFI is an umbrella organization of all solar energy stakeholders of India. This apex solar organization works in the area of policy advocacy and is a National Platform for addressing all issues connected with solar energy growth in India. It consists of leading international, National and regional companies and includes Solar Developers, Manufacturers, EPC Contractors, Rooftop Installers, System integrators, and Balance of Plant suppliers and manufacturers, Small and Medium Enterprises and works in a complimentary manner with the Central and State Governments for achieving India's national solar target of 100 GW by 2022. NSEFI Covers all activities: Solar PV, solar thermal (Both Small and big) off-grid, Rooftop solar, Micro and Mini grids, Rural electrification, solar agricultural Pumps, encouragement to R&D, capacity building, spreading awareness etc-with an avowed goal of Making Solar Energy Affordable for all.

PV CYCLE is a non-for-profit member-based organization which offers both collective and tailor-made waste management and legal compliance services for companies and waste holders around the world. With the mission in mind to always offer members and their customers best-in-class solutions, PV CYCLE has become the preferred waste management partner for companies with extensive sustainability needs. Solutions are known for setting the benchmark and include all aspects of waste management. PV CYCLE offers members and waste holders better access to take-back and can ensure recycling rates above the industry standards. The organization includes a broad range of electrical and electronic equipment, batteries, packaging and industrial waste in its portfolio, and has national representations and partnerships throughout the globe.

The recommendations of the study are based on the authors' best knowledge at the time of publication and do not necessarily reflect the position of EU-India Technical Cooperation Project: Energy Solar Power Europe, NSEFI, PV CYCLE or their respective members.

Meeting with MNRE to discuss the work plan for the effective management of PV waste in India

From the left: Mrinal Madas (Member, EU India TCP), Marek Zaborowski (Team Leader, EU India TCP), Dr. Rajesh Kumar (Scientist E, MNRE), Shri. Amitesh Sinha (Joint Secretary, MNRE), Máté Heisz (Head of International Cooperation, SPE), Subrahmanyam Pulipaka (CEO, NSEFI)

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Jan Clyncke joined PV CYCLE as Managing Director as of April 1, 2008. He graduated with a Bachelor of Law from the University of Ghent (Belgium) in 1991. He continued his studies at Ehsal (Logistics Management) and Vlerick Management School (Management). In his early career he worked as a Manager of Production & Logistics in the meat industry before moving into the waste management sector. He was employed by the Dutch AVR-Van Gansewinkel Group (currently RENEWI) where he worked as Project Manager, Legal Environment and Government Affairs Manager Benelux. In the last three years before joining PV CYCLE, he was in this Dutch company responsible for Health, Safety and Environment at 20 waste treatment locations. He has experience in setting up of voluntary and mandatory take-back schemes in Belgium and the Netherlands in household and industrial packaging waste, tyre waste, vegetable oil & fat waste, waste oil (lubricants), waste on electrical and electronic equipment, empty paint tin waste, flat glass waste, photochemical waste, etc.

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Subrahmanyam Pulipaka is the youngest chief executive officer of National Solar Energy Federation of India (NSEFI). He is the recipient of BRICS Energy for Thought - Young Scientist award - 2018. He is an alumnus of BITS Pilani and is also the founding chairman of India Africa Youth Energy Forum (IAYEF), a platform dedicated to nurture future energy leaders in the Indian subcontinent and African continent. He also started series of Youth Energy Dialogues for carrying forward the youth centric energy revolution dialogues in different cities in India as well as different countries in Africa. He has been involved in active research on the reliability of solar photovoltaics since last 4 years and was one of the youngest researchers to represent India at many international forums. Apart from this, he has also been actively involved in solar skill development and policy deliberation activities and addressed various intergovernmental sessions in India, Russia and Rwanda.

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CHAPTER 02

THE REGULATORY FRAMEWORK IN INDIA AND THE EUROPEAN UNION

2.1 Overview of European Waste and Extended Producer Responsibility regulatory framework for PV modules, inverters and batteries

2.1.1. The Waste Electrical and Electronic Equipment (WEEE) Directive

The WEEE Directive 2012/19/EU entered into force in each Member State on 14 February 2014. This recast Directive is the successor of the original WEEE Directive 2002/96/EC, which entered into force on 13 August 2005 in each Member State. The WEEE Directive imposes the responsibility for the disposal of Waste Electrical and Electronic Equipment (WEEE) on the manufacturers or distributors of such equipment or more precisely on the companies, which are putting for the first time such equipment on the territory of a Member State of the European Union (referred to as "producers" in the WEEE Directive's terminology).

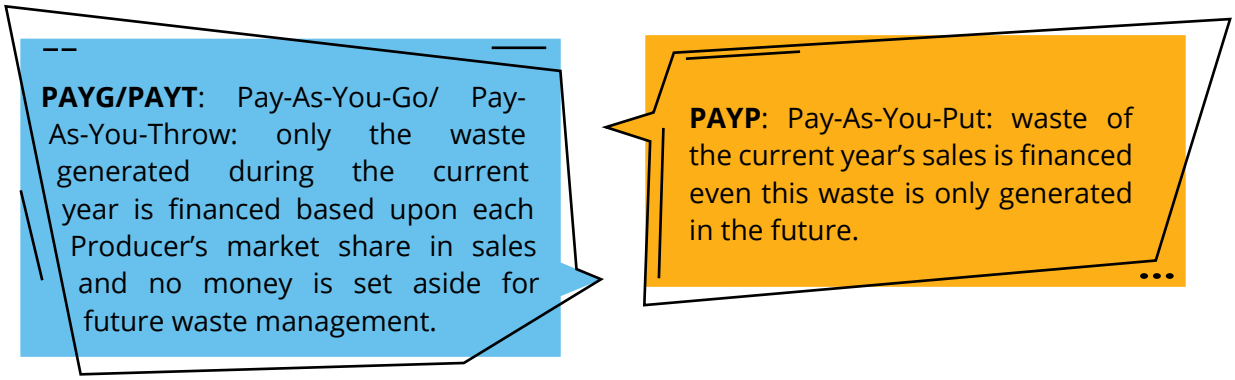
The WEEE Directive is an example of the Extended Producer Responsibility (EPR) principle, which is "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle".[2]

In practice, EPR implies that the first put-on-the-market companies (producers, importers) take over the responsibility for collecting or taking back used goods and for sorting and treating their post-consumer waste. This requires that those companies establish an infrastructure for collecting WEEE, in such a way that "Users of electrical and electronic equipment from private households should have the possibility of returning WEEE at least free of charge". The directive saw the formation of national "producer compliance schemes", into which manufacturers and distributors paid an annual fee for the collection and recycling of associated waste electronics from household waste recycling centres.

The WEEE Directive distinguishes between historical and new WEEE. The distinction between the financial mechanism to be applied for new WEEE and historic WEEE is that producers bear individual financial responsibility for new WEEE. Meanwhile, as producers could not influence the design of products placed on the market before the directive came into force, the WEEE Directive assigns collective responsibility for this historic WEEE on all producers on the market when the costs to manage it will arise.

[2] *OECD (2001) Extended Producer Responsibility: A Guidance Manual for Governments, OECD, March, Paris, 164p*

The financing mechanisms for Extended Producer Responsibility consist mainly of two options or a combination of these options:



Historical waste, i.e. waste generated today of products sold before the starting date of the EPR, is collectively financed by all actors on the market today; this is the result of the International Accounting Standards Board and their IFRIC 6 decision of 2005.

Besides defining the parties that are responsible of financing, reporting and information on end-of-life management, the Directive outlines, for the various WEEE categories, recovery and recycling targets, requirements on how to handle waste, as well as provisions on waste classification, labelling and registration.

In order to comply with all the obligations of the WEEE Directive, this legislation allows that the Producer or Importer can choose how to solve all these challenges: either individually or by joining a collective scheme such as PV CYCLE (see below).

Even though the WEEE Directive has initially been construed for Electrical and Electronic Equipment (EEE) consuming electricity, the 2012 Directive has put since 2014 for the first time EEE under its scope which generates electricity, i.e. photovoltaic modules.

Besides PV modules, also inverters are under the scope of the WEEE legislation.

PV modules are part of Category 4 in the WEEE Directive. This Category has the following treatment target: 85% of the WEEE shall be recovered, and 80% shall be prepared for re-use and recycled.

As from the year 2019, there are two options to calculate the collection rate for all WEEE in each Member State:

- Minimum percentage of 65% of the average weight of EEE placed on the market in the three preceding years in the Member State concerned, OR
- Alternatively, 85 % of WEEE generated on the territory of that Member State.

The latter – WEEE Generated Target – is an important calculation method for PV modules due to very low return rate during the first 12 to 20 years.

For this WEEE Generated target the European Commission has published the Regulation 2017/699 establishing a common methodology for the calculation of the weight of electrical and electronic equipment (EEE) placed on the market of each Member State and a common methodology for the calculation of the quantity of waste electrical and electronic equipment (WEEE) generated by weight in each Member State.

Additionally, the Commission has published a WEEE calculation tool (for WEEE Generated) – in fact a Macro Excel - which is customized for each Member State and is set up and made available by the Commission.

Implementation of the WEEE Directive at EU Member State level

It is important to understand the value of a "Directive" in the European legal context. A Directive is binding to each Member State of the European Union; each country of EU-28 must transpose the European law into national legislation and only then this national WEEE Law is addressed to the companies (producers or importers).

Hereby the Member States must respect the minimum requirements imposed by the European Directive. However, each Member State is allowed to "gold-plating', a term to characterise the process where an EU directive is given additional powers when being transposed into the national laws of member states.

In relation to WEEE, we notice for example differences in the transposition and the execution of the financing obligation mechanisms across all Member States. Presenting this for some EU-countries is outside the scope of this study.

PV CYCLE

PV CYCLE is a collective take-back and recycling scheme meaning that it organises the registration, the reporting of the amount of PV modules put on the market of each EU-28 country and the collected waste amounts towards public authorities (upstream WEEE-compliance) and the organization of the collection, recycling and final recovery of PV modules and inverters (downstream WEEE-compliance) on behalf of its participants.

PV CYCLE's operations are financed through monthly or quarterly fees depending on the reporting obligations in each Member State.

2.1.2. The Restriction of Hazardous Substances (RoHS) Directive

The Directive on the Restriction of the use of certain Hazardous Substances (RoHS) in electrical and electronic equipment (Directive 2002/95/EC), introduced in 2003, recast in 2013 (Directive 2011/65/EU) and last amended in 2017, complements the provisions laid out in the WEEE Directive. Objective of the RoHS Directive is to reduce and substitute certain hazardous substances used in EEE – lead (Pb), cadmium (Cd), mercury (Hg), hexavalent chromium (Cr6+) and certain flame retardants (PBB, PBDE) – with safer alternatives. The RoHS Directive sets maximum concentration levels of these substances.[3]

[3]*The maximum concentration level is set at 0.1%, except for cadmium (0.01%) by weight.*

Since 2013 and still at present state, PV modules are permanently excluded from the scope of the RoHS Directive.

2.1.3. The Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)

The Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (EC 1907/2006) is the EU Regulation overseeing the use of chemicals, addressing the production and use of chemical substances and their impacts on human health and the environment.

This legislation mandates that all companies manufacturing or importing relevant quantities[4] of chemical substances in the EU, register such substances with the European Chemical Agency. In the registration, they must identify the risks connected to the substances they produce and import, and illustrate how these risks are managed.

The Regulation also addresses the use of a number of substances of very high concern (SVHC). These substances, identified in a Candidate List, cannot be used unless the company is given an authorisation.

2.1.4. Sustainable product policies

The European Commission is currently considering the implementation of a number of sustainable product policies for PV modules, inverters and systems. These measures include both mandatory instruments (Ecodesign, Energy Label) and voluntary instruments (EU Ecolabel, Green Public Procurement), which are undergoing a process assessing their impact on market and product sustainability. Some of the criteria provisionally laid out in the draft measures include performance requirements and information disclosure on material content, dismantlability, repairability, recyclability and presence of hazardous substances. The expected timeframe for entry into force of the first set of these provisions is 2023-2024.

2.1.5. Landfill Directive

The Landfill Directive 1999/31/EC has the objective to prevent and reduce as much as possible the negative effects on the environment, in particular on surface water, groundwater, soil, air, and on human health from the landfilling of waste by introducing stringent technical requirements for waste and landfills.

The Landfill Directive defines the different categories of waste (municipal waste, hazardous waste, non-hazardous waste and inert waste) and applies to all landfills, defined as waste disposal sites for the deposit of waste onto or into land. Landfills are divided into three classes: landfills for hazardous waste; landfills for non-hazardous waste; landfills for inert waste.

Most of the EU Member States have introduced a landfill ban for untreated waste (including PV modules), separately collected waste such as the products covered by EPR-regulations (such as PV modules).

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[4] *1 tonne or more per year per company.*