2.1.6. The Waste Framework Directive

The Waste Framework Directive 2008/98/EC sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. It explains when waste ceases to be waste and becomes a secondary raw material (so called "end-of-waste" criteria), and how to distinguish between waste and by-products. As such, it is an essential piece of legislation that must be considered in the context of recycling and treating any type of waste, including PV modules.

This Directive introduces the "polluter pays principle" and the "Extended Producer Responsibility" (EPR). It incorporates provisions on hazardous waste and waste oils, and includes two new recycling and recovery targets to be achieved by 2020: 50% preparing for re-use and recycling of certain waste materials from households and other origins similar to households, and 70% preparing for re-use, recycling and other recovery of construction and demolition waste. This Directive requires as well that Member States adopt waste management plans and waste prevention programmes.

The European Commission adopted in 2020 an ambitious Circular Economy Package, which includes revised legislative proposals on waste to stimulate Europe's transition towards a circular economy which will boost global competitiveness, foster sustainable economic growth and generate new jobs.

The revised legislative proposal on waste sets clear targets for reduction of waste and establishes an ambitious and credible long-term path for waste management and recycling. To ensure effective implementation, the waste reduction targets in the new proposal are accompanied by concrete measures to address obstacles on the ground and the different situations across EU Member States.

Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030;
- A ban on landfilling of separately collected waste;
- Promotion of economic instruments to discourage landfilling;
- Simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU;
- Concrete measures to promote re-use and stimulate industrial symbiosis –turning one industry's by-product into another industry's raw material;

Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

2.1.7. Battery Directive

The EU legislation on waste batteries is embodied in the Batteries Directive 2006/66/EU and amended in 2013. It intends to contribute to the protection, preservation and improvement of the quality of the environment by minimising the negative impact of batteries and accumulators and waste batteries and accumulators. It also ensures the smooth functioning of the internal market by harmonising requirements as regards the placing on the market of batteries and accumulators. With some exceptions, it applies to all batteries and accumulators, no matter their chemical nature, size or design. Thus, also the batteries used for the storage of energy generated by PV systems are under the scope of this European legislation.

To achieve these objectives, the Directive prohibits the marketing of batteries containing some hazardous substances, defines measures to establish take-back schemes aiming at high level of collection and recycling, and fixes targets for collection and recycling activities. The Directive also sets out provisions on labelling of batteries and their removability from equipment.

It also aims to improve the environmental performance of all operators involved in the life cycle of batteries and accumulators, e.g. producers, distributors and end-users and, in particular, those operators directly involved in the treatment and recycling of waste batteries and accumulators. Producers of batteries and accumulators and producers of other products incorporating a battery or accumulator are given responsibility (EPR) for the waste management of batteries and accumulators that they place on the market.

2.2. Overview of the Indian regulatory framework for WEEE and RoHS

2.2.1. E-Waste (Management and Handling) Rules[5]

India's e-waste regulation (for both management and handling) was crafted in 2011 and became effective from 1 May 2012. Prior to the enactment of this rule, e-waste was covered under the Hazardous Waste Management (HWM) Rules. Under the ambit of Environmental Protection Act 1986, the E-Waste (Management and Handling) Rules, 2011 were enacted which brought into force to enable recovery and/or reuse of useful material from e-waste, thereby reducing the hazardous wastes destined for disposal, to ensure the environmentally sound management of all types of e-waste and to address the safe and environment friendly handling, transporting, storing, and recycling of e-waste. This 2011 act was the first time, where the Extended Producer Responsibility (EPR) as a concept was introduced in India manufacturers liable for safe disposal of electronic goods.

[5] *http://greene.gov.in/wp-content/uploads/2018/01/EWM-Rules-2016-english-23.03.2016.pdf*

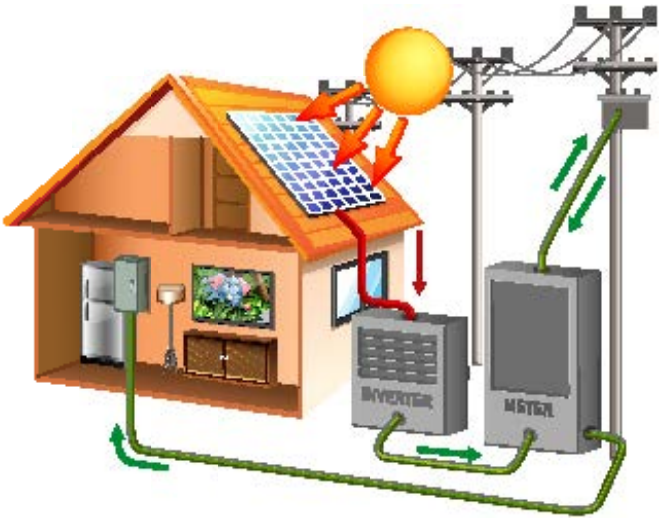
In supersession of the 2011 Rules, the E-Waste (Management) Rules, 2016 were enacted and came into effect from 1 October 2016. Through this supersession, the Manufacturers, dealers, refurbishers and Producer Responsibility Organisations (PRO) were also brought under the ambit of these Rules. An option was given for setting up of a PRO as an additional channel for implementation of EPR by Producers. Further, collection mechanism-based approach was adopted for collection of e-waste by Producers under EPR. Furthermore, the applicability of the Rules was expanded to cover components, consumables, parts and spares of EEE in addition to the equipment covered under the Rules.

In March 2018, the E-Waste Rules were amended by the Ministry of Environment, Forest and Climate Change to facilitate and streamline the implementation of an environmentally sound management of e-waste in India. The objective of these amendments is to formalize the e-waste recycling sector by channelizing e-waste generated in the country towards authorized dismantlers and recyclers. To undertake the activities prescribed for PROs under these new Rules, the PROs were to apply for Central Pollution Control Board (CPCB) registration. This amendment is considered as a progressive one in India's journey of handling e-waste as the requirement of PROs to register with CPCB would ensure continuous monitoring by CPCB thereby ensuring accountability from PROs.

As per these revised targets, 10% of the quantity of waste generated shall be collected during 2017-2018 and there shall be a 10% increase every year until the year 2023. After 2023, the E-Waste collection target is fixed at 70% of the quantity of waste generation.

The responsibilities of the various entities, producers; consumers (including bulk consumers); collection centres; dismantlers and recyclers, are defined, together with the procedures for obtaining registration and authorisation from the pollution control entities including sample forms. For producers, collection centres, dismantlers and recyclers, an application for a Grant of Authorisation must be made within three months of the start of the Rules, (i.e.) by 31st July 2012, with the authorisation having a five year validity being made up to 90 days later.

In the E-Waste (Management and Handling) Rules "e-waste" is defined as "electrical and electronic equipment (EEE), whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment and repair processes". EEE is defined as "equipment which are dependent on electric current or electro-magnetic field in order to become functional". This EEE definition includes inverters.



PV modules and inverters are currently outside the scope of the E-waste Rules. The E-Waste Rules apply to the two e-waste categories defined in Schedule I of the Rules: (i) information technology and telecommunication equipment and

(ii) consumer electrical and electronics. Neither PV modules nor inverters are listed among the identified EEE categories.

Even though the components of a solar PV system – PV modules and inverters – are currently not included in the E-Waste Rules, this piece of legislation could be considered as a reference legislation by both the Indian authorities as well as the Indian solar industry. For example, MNRE's Guidelines for setting up grid-connected solar power plants state that "the developers will ensure that all solar PV modules collected from their plant after their end-of-life are disposed-off in accordance with the "E-waste (Management and Handling) Rules". However, today, there are neither any regulations nor any standards for PV waste management in India.

The E-Waste Rules also cover the restriction of hazardous substances (RoHS) in electronic and electrical components and equipment. It is applied on producers and distributors involved in the manufacture, sale, and processing of electronic and electrical equipment or components. Under the RoHS provisions, cost for sampling and testing shall be borne by the government for conducting the RoHS test. If the product does not comply with RoHS provisions, then the cost of the test will be borne by the Producer.

Similarly to the European RoHS Directive, the Indian E-Waste Rules restrict the use of lead (Pb), cadmium (Cd), mercury (Hg), hexavalent chromium (Cr6+) and certain flame retardants (PBB, PBDE) in EEE appliances. The thresholds are the same as in the EU RoHS Directive.[6] Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages, is exempted. This means that if PV modules were included under the scope of the E-Waste Rules, crystalline silicon PV modules would be significantly below the thresholds. However, Cadmium-Telluride (CdTe) PV modules may present a cadmium concentration above the cadmium concentration threshold of 0.01% by weight.

In the European Union, PV modules, being a key sustainable technology for the decarbonisation of the energy system, are exempted from the requirements related to the use of hazardous substances in electrical and electronic equipment.

Regarding E-waste storage, the E-waste law has no definition of this notion and it requires that every relevant actor (manufacturer, producer, bulk consumer, collection center, dealer, refurbisher, dismantler and recycler) may store the e-waste for a period not exceeding one hundred and eighty days and shall maintain a record of collection, sale, transfer and storage of wastes and make these records available for inspection.

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

2.2.2. Hazardous and Other Wastes (Management and Transboundary Movement) Rules

The Hazardous and Other Wastes Rules[7] is a complex legislation because it combines the former Hazardous Waste Rules of 1998 and the Transboundary shipment of Non-Hazardous and Hazardous Waste into and towards countries outside India.

The latter is simply the logical implementation of the International Basel Convention; in Europe, this is implemented by the Waste Shipment Regulation 1013/2006.

"Other waste" means waste specified in Part B and Part D of Schedule III for import or export and includes all such waste generated originally within India.

Examples of "other waste" are:

Waste electrical and electronic assemblies or scrap (including printed circuit boards) not containing components such as accumulators and other batteries, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or not contaminated with Schedule II constituents (such as cadmium, mercury, lead, polychlorinated biphenyl) or from which these have been removed, to an extent that they do not possess any of the hazardousness characteristics

Glass wastes in non-dispersible form: Cullet and other waste and scrap of glass except for glass from cathode-ray tubes and other activated glasses

The Hazardous and Other Wastes (Management and Transboundary Movement) Rules define hazardous waste as any waste which by virtue of any of its physical, chemical, biological, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or in contact with other wastes or substances and include wastes generated mainly from the 36 industrial processes (e.g. oil and pharmaceutical industry) referred under Schedule I of these Rules. In addition, some wastes become hazardous by virtue of concentration limits as well as hazardous characteristics listed under Schedule II whereby the defined concentration limits are based on the Toxicity Characteristic Leaching Procedure (TCLP) (Class A) and based on Total Threshold Limit Concentration (TTLC) (Class B).[8]

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[7] *http://iwma.in/HWM%20Rules.pdf*
https://vikaspedia.in/energy/environment/waste-management/hazardous-waste/environment-ministry-notifies-hazardous-waste-management-rules-2016

[8] *https://en.wikipedia.org/wiki/Toxicity_characteristic_leaching_procedure*

The hierarchy in management of hazardous waste is to reduce, reuse, recycle and re-process and final option of disposal of wastes having no potential for value addition, in disposal facilities in an environmentally sound manner. The disposal facilities may only have a secured land fill (SLF) or may have an incinerator alone for organic wastes or combination of secured landfill and incinerator.

Crystalline silicon PV modules, which compose the great majority of the Indian installed PV fleet, are classified as non-hazardous waste when tested applying the USEPA TCLP Method 1311 in line with the testing requirements imposed by the Hazardous and Other Waste Rules.[9,10] In state-of-the-art PV modules concentration levels of relevant metals, including mercury, arsenic, barium, cadmium, chromium, lead, selenium and silver are below the limits defined by the Hazardous and Other Waste Rules Schedule II (Class A).

Solar glasses containing antimony create a potential environmental risk when disposed improperly. Antimony containing solar module glass is used globally to improve the stability of the solar performance of the glass upon exposure to ultraviolet radiation and sunlight. An advisory study conducted by MNRE indicated that the antimony concentration in solar glass was in the range of 0.13 and 0.29 mg/l (TCLP), while the threshold set by the Hazardous and Other Waste Rules is 15 mg/l[11]. Therefore, the tested antimony containing solar glass waste does not fall in the category of hazardous waste. However, waste antimony glass has potential to leach antimony in wet conditions including wet landfill conditions. In 2019 MNRE issued a draft blueprint[12] in which the issue was addressed, highlighting that antimony leaching would take place when waste solar glass is disposed on land through unsecured manner. Still, the leaching of antimony from solar glass would occur only in a worst-case end-of-life management scenario in which modules are dumped in an uncontrolled landfill and the solar glass is completely crushed.

For CdTe PV modules, the TCLP values may be above the concentration limits. However, the results obtained in a study from 2017 indicate that a high fraction of the Cd and Te in CdTe modules could be potentially released if non-encapsulated CdTe solar modules are discarded in municipal landfills.[13] Leaching of Cd and Te is expected to occur mainly during the acidic phase of a landfill in which low pH values are dominant. The actual Cd concentrations in a given landfill would depend on the amount of PV modules disposed, module design, module fragment size, climatic conditions, landfill management and design, etc.

For CIGS PV modules, aluminum, copper and selenium were the most abundant materials while gallium – which is said to have apoptotic (cell-fatal) and carcinogenic properties if present in compound form – was found to make up 2.4% of the metal composition, with indium having

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[9] *https://repository.asu.edu/attachments/191176/content/Krishnamurthy_asu_0010N_17317.pdf*

[10] *https://www.epa.gov/sites/production/files/2015-12/documents/1311.pdf*

[11] *MNRE (2017): Concept Note/ Blue Print on Management of Antimony Containing Glass from End-of-Life of the Solar PV Panels.*

[12] *https://mercomindia.com/mnre-recycling-solar-panel-glass/*

[13] *Ramos-Ruiz et al. (2017): Leaching of cadmium and tellurium from cadmium telluride (CdTe) thin-film solar panels under simulated landfill conditions; Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5607867/*

a 13.14% share.[14] This reference to a scientific paper is only a reference. Taking into account the waste legislation and the classification of what is hazardous or non-hazardous waste, we notice in general that CIGS PV Panels are classified as non-hazardous waste. To classify a waste as hazardous waste, the threshold for Selenium is usually 3% weight and the average amount of Selenium in a CIGS panel is 0,020% weight.

It is relevant to highlight that, were a landfill ban on solar PV modules implemented, the risk of leaching of antimony and other hazardous substances would be minimised.

Other PV system equipment, including inverters[15], wiring and other BoS components, are not considered as hazardous waste.

The Hazardous and Other Wastes Rules (HOWR) also defines an "Occupier" in relation to any factory or premises as a person who has, control over the affairs of the factory or the premises and includes in relation to any hazardous and other wastes, the person in possession of the hazardous or other waste.

A "(treatment) facility" In the HOWR means any establishment wherein the processes incidental to the generation, handling, collection, reception, treatment, storage, reuse, recycling, recovery, preprocessing, co-processing, utilisation and disposal of hazardous and, or, other wastes are carried out;

The occupiers of facilities may store the hazardous and other wastes for a period not exceeding ninety days and shall maintain a record of sale, transfer, storage, recycling, recovery, pre-processing, co-processing and utilisation of such wastes and make these records available for inspection.

in the HOWR, "Storage" is defined as storing any hazardous or other waste for a temporary period, at the end of which such waste is processed or disposed. The occupiers of facilities may store the hazardous and other wastes for a period not exceeding 90 (ninety) days and should duly maintain a record of sale, transfer, storage, recycling, recovery, pre-processing, co-processing and utilisation of such wastes and these records should be made available for inspection.

Main conclusion is that the HOWR is only related to hazardous waste and how this needs to be stored, treated and – when applicable – how hazardous waste and a list of so-called other (non-hazardous) waste must be shipped into and outside India.

2.2.3. Batteries (Management and Handling) Rules (2001)

The Batteries (Management and Handling) Rules of 2001 is only applicable to lead-acid batteries.

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[14] *https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5607867/ and Initial metal contents and leaching rate constants of metals leached from end-of-life solar photovoltaic waste: An integrative literature review and analysis, PreetiNain,ArunKumar, 2019.*

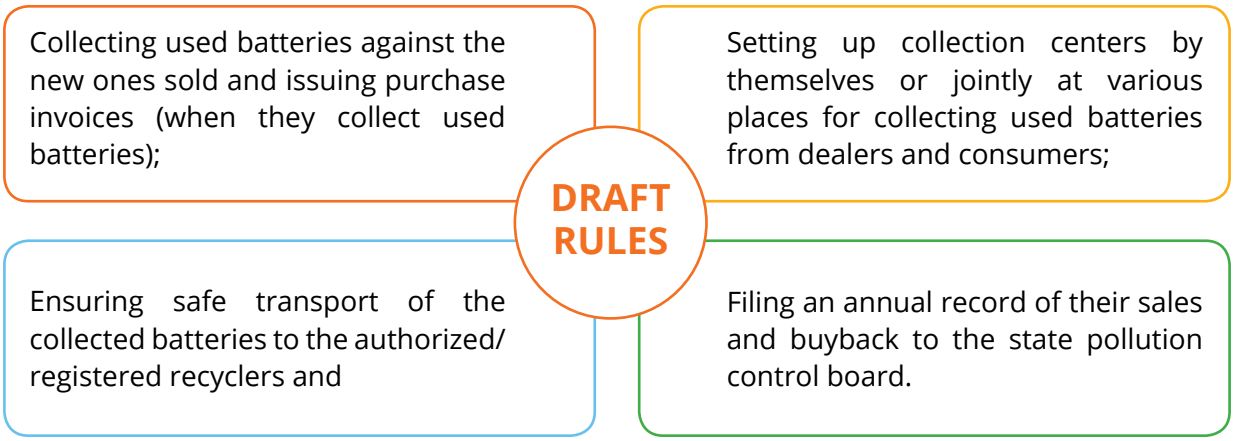
[15] *https://susproc.jrc.ec.europa.eu/solar_photovoltaics/docs/Draft_Report_Task4%20Master%20REV%20-%20to%20publish.pdf*

End of February 2020, the Ministry of Environment, Climate and Forest Change released the Draft Battery Waste Management Rules, 2020.

The draft Rules will be applicable to various stakeholders involved in the life of batteries or its components, consumables, and spare parts which make the product operational. These include every manufacturer, producer, collection center, importer, assembler, dealer, recycler, consumer, and bulk consumers.

The Draft Rules will cover all types of batteries. It will also apply to all appliances into which a battery is, or maybe incorporated. As the storage of energy generated from PV systems is usually stored through lithium-ion batteries, the batteries used within a PV system might within a certain timeframe covered by Indian Extended Producer Responsibility legislation.

The responsibilities of manufacturers and dealers under the Draft Rules can be summarized as follows:



2.2.4. Solid Waste Management Rules[16] and Construction and Demolition Waste Management Rules[17]

These Solid Waste Management Rules apply to solid or semi-solid domestic waste, sanitary waste, commercial waste, institutional waste, catering and market waste and other non-residential wastes, street sweepings, silt removed or collected from the surface drains, horticulture waste, agriculture and dairy waste and treated bio-medical waste.

Excluded are industrial waste, bio-medical waste and e-waste, lead-acid battery waste and radio-active waste.

The Construction and Demolition Waste Management Rules of 2016 apply to waste comprising of building materials, debris and rubble resulting from construction, re-modeling, repair and demolition of any civil structure.

[16] *https://c40-production-images.s3.amazonaws.com/other_uploads/images/1939_SWM-Rules-2016.original.pdf?1536934757*

[17] *https://dpccocmms.nic.in/SPCB_DOCUMENTS/MSW.pdf*

Neither PV modules nor other equipment of a PV System are covered by one of these two Rules.

2.2.5. Industrial Solid Waste

A true legislation dedicated to only Non-hazardous Industrial Solid Waste does as such not exist in India. Only for Hazardous Industrial Solid Waste, there is the reference to the HOWR of 2016.

Today, without any specific legislation in place for photovoltaic modules, and being non-hazardous waste, the only reference for waste management could have been rules related to Industrial Non-hazardous Solid Waste.

Moreover, for arriving at an appropriate solution for better management of industrial solid waste, assessment of nature of waste generated is also essential.

Management of Industrial Solid Waste (ISW) is not the responsibility of local bodies. Industries generating solid waste have to manage such waste by themselves and are required to seek authorizations from the respective State Pollution Control Boards (SPCBs).

Assessment of industrial solid waste management problem greatly varies depending on the nature of the industry, their location and mode of disposal of waste.

Moreover, for arriving at an appropriate solution for better management of industrial solid waste, assessment of nature of waste generated is also essential.

Industries are required to collect and dispose of their waste at specific disposal sites and such collection, treatment and disposal is required to be monitored by the concerned State Pollution Control Board (SPCB) or Pollution Control Committee (PCC) in Union Territory.

The following problems are generally encountered in cities and towns while dealing with industrial solid waste

- There are no specific disposal sites where industries can dispose their waste;
- Mostly, industries generating solid waste in city and town limits are of small-scale nature and even do not seek consents of SPCBs/PCCs;
- Industries are located in non-conforming areas and as a result they cause water and air pollution problems besides disposing solid waste;
- Industrial estates located in city limits do not have adequate facilities so that industries can organise their collection, treatment and disposal of liquid and solid waste;

- There is no regular interaction between urban local bodies and SPCBs/PCCs to deal such issues relating to treatment and disposal of waste and issuance of licenses in non-conforming areas.

2.3. Current PV waste management practices in India

As PV waste management is not regulated in India, different players take different approaches when dealing with PV module waste.

2.3.1 Developers: Storage of the PV modules

As the disposal of the PV modules waste generated during the installation and operation have a financial impact on the developer, a majority of them store the damaged PV modules within their premises, waiting for an economical solution to carry out the disposal.

Today, there is a risk that waste PV modules end up in uncontrolled or not environmentally sound disposal operations such as uncontrolled or illegal landfills or in open land.

2.3.2 Developers: Treatment, recycling, recovery or disposal on a voluntary basis

A minority of producers owing to their internal environment management systems manage their organisations responsibilities including the end of life management of their products.

For e.g. ISO 14001 describes the principles and framework for life cycle assessment (LCA) of the company's products and operation. Under such frameworks a few organisations including the module manufacturers and the installers in association with other waste recyclers are working towards the disposal of the damaged and the "end of life" PV modules.

These installers collect and store the discarded PV modules on site until they reach a predefined number, which is required for enabling the treatment process. Hereby, the holders of PV modules waste dispose these PV modules with the assistance of environmentally sound waste treatment plants.

As PV modules are "as such" in India not included in any of its waste management rules unless the rules applicable of industrial solid waste, the waste treatment plants sometimes classify themselves these PV modules waste as hazardous or e- waste.

The cost of collection, transportation and disposal is borne by the owner or holder of the waste and depends on the quantity of the PV modules Waste being disposed. Due to the absence of volume of PV modules waste , the treatment capacity and infrastructure and limited experience, the treatment plants in India are or not interested in creating capacity and infrastructure (see the notion of no volume !) or are able to extract only a portion (20% by weight) of the PV module, i.e. the aluminium frames and the junction box. The remaining part of the PV modules is disposed of in the TSDFs on payment of the TSDF stated fees, which ranges around Rs. 20-35 per kg.

2.3.3 The approach of PV module manufacturers on PV modules damaged during transportation

NSEFI has conducted interviews with the eight module (and cell) manufacturers in India to understand the storage, treating, recovery & recycling of PV module waste. Many of them expressed the concern that there is no policy for dealing with the waste generated by PV modules as they are neither included in e-waste, nor in hazardous waste. Currently when modules get damaged during the transportation and installation phase they are not dumped into landfills and the module waste is dealt in the following way where approximately 50% of the total material is revived back:

01 Part of frame that is taken down is sold in the form of scrap (by weight).

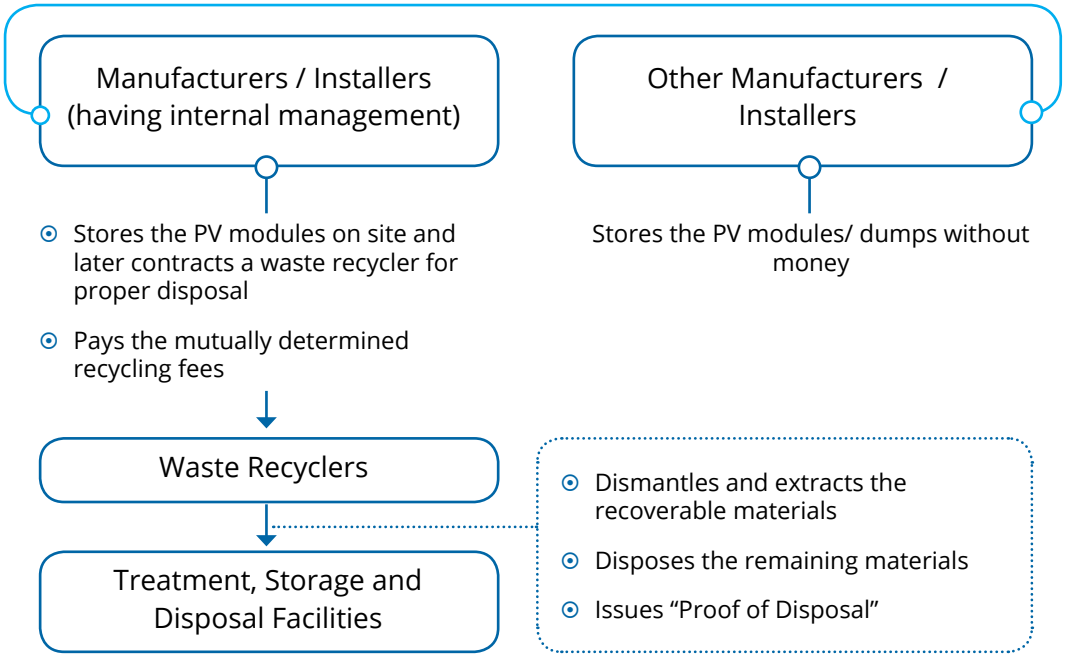
02 Junctions and cables, since they fall in the category of e-waste and are recycled as per the e-waste regulations.

03 Glass laminate is recycled to some extent or is disposed as general waste mostly.

04 Most of the times the silicon cells are used as cut cells for modules with lower ratings

Economically speaking, the best way to get the value back of modules damaged will be to set up the infrastructure for recycling and enabling policies through the help of government of India and in this regard, they were also open about considering business models like of PV CYCLE.

Figure 1 – PV waste management existing scenario. Source: PV Rooftop Cell.



2.3.4 Observations

1 A part of the owners or holders of the PV modules waste still bear the cost involved in disposing, storing the damaged PV modules within their premises.

2 The fee for dumping and disposing the waste in India is not properly defined and due to the lack of rules and inspection, the PV modules waste have a risk ending up in uncontrolled landfills or in open land.

3 A few holders or owners of PV modules waste having their internal environment management system, follow an informal practice to manage the PV modules waste.

4 The treatment facilities classify the PV module waste (or its components) as hazardous waste or e-waste in India. In general, around 20% of the waste is recovered and the remaining part is treated by TSDFs upon payment of disposal fees. This results in cost implications to the owner or holder of the PV modules waste. However, there is also the "Polluter Pays'-principle which is enacted to make the party responsible for producing pollution responsible for paying for the damage done to the natural environment. It is regarded as a regional custom because of the strong support it has received in most Organisation for Economic Co-operation and Development (OECD) and European Union countries. It is a fundamental principle in US environmental law.

5 The manufacturers opined that it is very often difficult for them to get the modules back to the manufacturing unit. In this contrast, they would like the government to look into distributing collection points across the country, especially at the locations where solar installations are highly concentrated to optimize the cost of transportation & enable efficient recycling mechanism. This according to them will de-stress their logistical involvement and will also help generate more jobs.

6 The interviewees expect the government to explicitly specify in its policies the responsibility of manufacturers & developers, so that process of collection, transport, storage & treatment goes on seamlessly.

2.4. Conclusions

There are important similarities and differences between both regions for waste treatment regulations relevant for waste generated from PV systems.

- Main drivers for the environmentally sound waste management of equipment related to PV systems in the European Union are:
    - Landfill ban for unsorted waste and for waste which can be recycled;
    - Extended Producer Responsibility requirements for inverters;
    - Extended Producer Responsibility requirements for PV modules. For PV modules the WEEE Directive is not the best legislation to be part of due to the fact that the WEEE Directive is originally a "consumer waste driven legislation focusing on