Allow the Indian PV industry to propose a sustainable and long-term solution for the waste generated by a PV system taking into account that PV modules have a very long lifetime and today's generated waste is by far not attractive to enable big industrial waste treatment capacity for PV modules.

The development of such a piece of legislation can supported by the current study taking into economic, technological, social and environmental characteristics of India, including technologies of material recovery, market price of recyclables, collection and recycling business models (deposit systems, subsidy systems etc), recycling fees and cost implications for electricity costs and Indian solar businesses, and an implementation roadmap.

Once this preparatory study has been conducted, a separate piece of Indian legislation for the end-of-life management of PV modules should be developed. The new legislative framework should include in the scope inverters and other PV system components. While it is too early to determine whether inverters and other PV components should be part of the same legislation for PV modules or rather be part of the E-Waste Rules, it will be key to ensure synergies across the different pieces of legislation and to optimise the economic, social and environmental dimensions in waste collection and treatment.

The Indian PV recycling legislation could be inspired by lessons learned in Europe. Therefore, it is important to remember that the European WEEE Directive (similar to its Indian counterpart) is legislation, which was originally established for purely household appliances and consumer electronics. The WEEE legislation is not specifically designed for PV appliances or commercial or industrial electrical and electronic equipment. Therefore, it is recommended to invite first the Indian PV Industry to propose a management plan for the end-of-life phase of their products such as PV modules, inverters and batteries, to allow its assessment by the MNRE and to conclude based upon the accompanying discussions if and how legislative support would benefit for the Indian society.

## 5.2. PV waste scenarios in India – main conclusions

Looking at the PV capacity annually installed in India from 2010 to 2020, it can be noted that the PV market effectively started in 2012, and boomed only in 2017. Compared to current installation levels, the annual PV market is expected to grow significantly across all three scenarios investigated in the study. By 2030, cumulative installed capacity experiences a multi-fold growth across all scenarios. Under the Low and Medium scenarios cumulative capacity reaches 187 and 287 GW respectively, up from 40 GW in 2020. The High scenario capacity reaches 400 GW by 2030, in line with government ambition. Assuming that PV systems installed in 2020-2030 have a lifetime of at least 30 years, any capacity installed during this period will reach the end-of-life stage not before 2050.

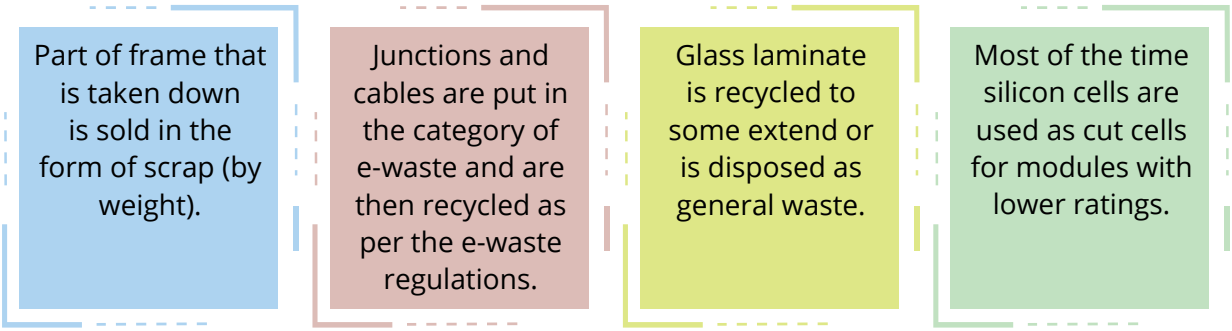
Given that ground-mounted solar constitutes the vast majority of PV capacity, and that the residential segment is only a fraction of rooftop installations, it can be concluded that the greatest bulk of end-of-life PV waste will be deriving from B2B relations.

According to the analysis carried out in the context of this study, by the year 2030 India will generate a cumulative mass of PV module waste of 11 kilo tonnes (kt) in the Low scenario,

21 kt in the Medium scenario, and 34 kt in the High scenario. The waste generated due to the end of life of the PV modules would start accumulating only around after the year 2040 and will become rapidly the most relevant waste source.

## 5.3. PV practices in India – main conclusions

In India there is no policy in respect to dealing with the waste generated by PV modules as they are neither included in e-waste, nor in hazardous waste regulations. Presently the module waste is treated in the following ways: -




In this process approximately 50% of the total material is revived back today from recycling.

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. 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.

However, 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.

## 5.4. Possible business models for PV waste management in India – main conclusions

### 1. Preferred approach for PV waste management and possible EPR business models

As described in Chapter 5, compared to a BAU scenario or to an improved BAU scenario whereby a landfill ban is introduced, the authors of this study recommend the Extended Producer Responsibility approach as the best one for the Indian context, as it constitutes the most effective means to perform sound PV waste management. It is advised to implement an EPR law for PV modules which sets the principle of a Producer Responsibility for PV modules and – where required – other products of a PV system, such as inverters and batteries.

Several EPR policy instruments and measures are available to governments to help them meet their stated goals and objectives: product take-back, deposit/refund, advanced disposal fees, product/material taxes, combined upstream tax and subsidy and minimum recycling requirements. Policymakers should review these different instruments to identify which might best meet their particular needs. An instrument's applicability depends on policy goals, or the influence or pressure necessary to reduce environmental impacts of concern. Several types of supportive measures can be used to enhance the effectiveness of an EPR policy. Such measures should be selected in light of the policy goals. Selection criteria can help policymakers select an EPR policy instrument that best suits their needs. These criteria are environmental effectiveness; economic efficiency; political acceptability; administrability (ease of administration); and innovative advancement.

Governments need to select the responsibility model and assign precise responsibilities to both physical and financial responsibility. The level or degree of producer responsibility (full or partial for physical and/or financial activities) for the EPR program is a crucial decisional point in EPR policy design. Decisions on the allocation of responsibility should be made in view of the policy goals, product characteristics, market dynamics, actors in the product chain and resources needed to implement the policy. The national government, state and local authorities, the retailer, the consumer and the final owner of the waste all play important roles under EPR – measures should take into account all these stakeholders. In several cases, a producer responsibility organisation (PRO) could be a useful option for managing and collecting products in lieu of each producer establishing its own separate system.

It is plausible that complete removal of free rider behaviour – the one of actors in an EPR system who do not pay for the benefits they receive – may not generate sufficient environmental benefits to justify the administrative costs to minimize 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 (as far as possible) 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.

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 (near) future. A draft financing model for an Advanced and Visible Disposal Fee is therefore very recommendable.

## 2. Recommendations for the setting of an EPR system

a. Set up a five-year Management plan. The Plan should define the strategical vision and contain information including prevention, communication, sensitize and financial plans.

b. Do not set any collection target in the first phase of the EPR system. As PV modules are an investment product instead of a consumer product, a collection target can be set later on.

c. Set clear, realistic and appropriate treatment targets. We recommend to recover target of 70%, of which preparation for reuse and recycling of 55%. Material-specific targets are included in paragraph 5.8.

d. There is no single "right" approach. Both voluntary and mandatory approaches have been used in the past.

e. The visible fee approach seems the best fit to the Indian context. It drastically limits free riders, saves the cash of the Producers/Importers and put the financial responsibility on at the Polluter whilst the legal responsibility is and remains at the Producer/Importer.

f. Ensure neutrality to competition. Lifting regulatory barriers to entry will decrease costs.

g. One solution for all photovoltaic modules. All PV modules sold on the Indian market should be within the scope of the EPR, irrespective of the size of the PV system.

h. Promote R&D on product design and material substitution. One way forward to stimulate this is through R&D funding programs towards the industry and the academic world, under the responsibility of the Indian government.

i. Encourage competition in the waste management sector. Lack of competition can lead to high costs for collection, sorting and treatment.

j. Boost consumer participation. A communication plan will help to inform the purchasers of PV modules and PV systems of their roles and responsibilities under the program.

k. Use life cycle analysis. LCA can help increase the acceptance of a program and lead to products' environmental optimisation.

l. Establish monitoring systems. Governments and industry should cooperate to establish an effective, adequately resourced monitoring system, possibly through an independent body

m. Take into account the operational waste management infrastructure. The EPR program should not hinder the operation of existing efficient recycling programs.

n. Ensure dialogue among stakeholders. A specific dialogue mechanism must be established which shall result in contentious relationships among stakeholders.

o. Implement measures to enhance environmental effectiveness. Target setting and proper enforcement are among the approaches to do so.

p. Ensure strong transparency. Mandatory EPR systems should be required to report regularly on the technical and financial aspects of their operations, audits should be regularly conducted, while reporting should be harmonised.

q. Define a clear framework for possibility of reuse. Stakeholders should know upfront when and how a PV module can be "prepared for reuse" and under which conditions such a "prepared for reuse PV module" can be sold again as a second-hand product.

## 3. Proposal for a mechanism of fee calculation

A draft of financing model for an Advanced and Visible Disposal Fee for PV modules is provided below.

The following assumptions are taken into account at the end of the year 2019:

- Managed by an industry-led PRO
- 50% of market share in Year 1
- A 10 GW Market forecast per year for the first five years (2020 – 2024)
- Weight per module of 18 kg
- Average Watt per module of 375 W
- Average transport and treatment costs of 9,825 INR/ton or 115 EUR/t
- Foresee costs for Historical Waste or PV capacity installed until end of 2019: 34 GW
- Return rate of 0,01% + only 80% of total returns
- Waste to collect during Year 1: 1262 tons
- Potential waste installed during Year 1 to return the next 30 years: 227,000 tons (rounded)
- Unknown today: profit of the materials? Which materials?
- Recycling fee: 3.95 INR/piece (0,05 EUR/piece)

The following cost structure is taken into account (in EUR):

1. **Administration (total: 20,022k INR (236,000 EUR))**

    a) Marcom: 6,957k INR (82,000 EUR)

    b) Staff: 8,484 k INR (100,000 EUR)

c) Office

d) Financial

e) Data management and reporting

f) Other

**2. Operations (total):**

a) Transport: 7,635 INR (90 EUR/ton)

Treatment: 2,120 INR (25 EUR/ton) (note: landfill cost in India: 5,344 INR (63 EUR/t)

The following revenues are generated through the advanced and visible recycling fee of 0,0110 INR/W or 3,95 INR/piece (0,00014 EUR/W or 0.05 EUR/piece): 53,704k INR (633k EUR)

Result end of Year 1: 21,125k INR (249k EUR)

Provisions for future costs at the end of the year 2024 for sold PV modules since start of 2020: 5,8%

No provisions for historical waste are yet built up.

## 4. Proposal for the organisational structure

The organizational structure for a collective system which implements and executes the Extended Producer Responsibility could have the following components, represented by two legal entities with their powers and responsibilities.

1) Not for profit association “PRO Circular”

Owners are the PV Companies putting PV modules, inverters and batteries on the Indian market.

- Responsibilities:
  - Define the Strategy
  - Define the Financial plan
  - Define the fee
  - Management financial assets

- Tasks:
    - Communicating and Informing about PV Energy and the Circular Solar Economy of a Take-Back and Recycling Programme for the PV System" waste (modules, inverters, batteries, BOS products);
    - Advisor to the national and State Authorities;

2) Purchase of services through private company "PRO INDIA"

- Responsibility:
    - Executes the strategy and the decisions in the name of, on behalf of and under control of the Management Organization

- Tasks:
    - Purchases the services of collection, shipment and treatment (re-use, recycling and final treatment) in order to achieve a zero-cost service for PRO CIRCULAR.
    - Services for all PV systems, residential and B2B PV Power plant

## 5.5. Key takeaways from stakeholder survey on PV waste management in India

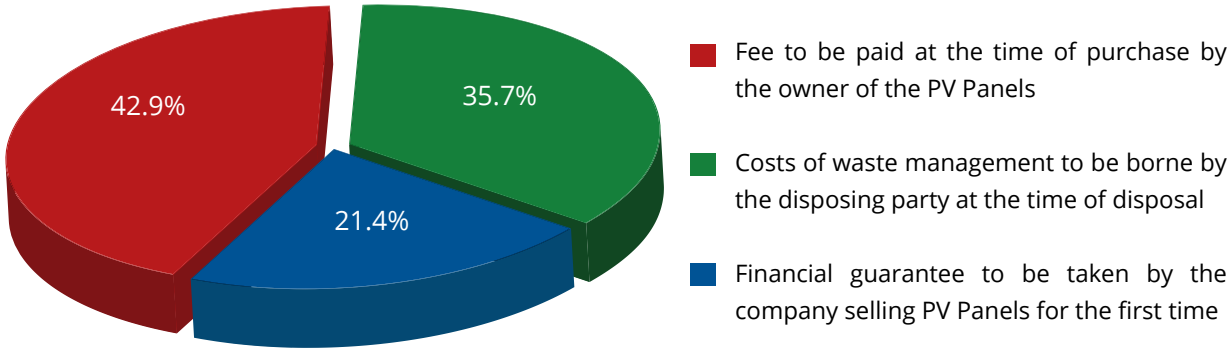
EU India TCP, NSEFI, SolarPower Europe and PV cycle designed a questionnaire to understand the notion of Indian stakeholders (especially manufacturers and developers) on different aspects of PV waste management mechanism. 13 key questions were posed to the stakeholders to seek their inputs. Around 71% of the stakeholders were willing to take the responsibility for the end-of-life phase of PV modules, inverters and batteries sold into the Indian market. Among the manufacturers who participated in this survey almost 80% of them were willing to take this responsibility.

When asked about the ideal method to finance the end-of-life phase of PV modules around 43% of the stakeholders preferred that the Fee to be paid at the time of purchase by the owner of the PV Modules while around 36% of the respondents felt that these costs should be borne by the disposing party(in this case mostly developers) at the time of disposal. The rest of them expressed that they would prefer a financial guarantee to be taken by the manufacturer of PV modules.

**Figure 6 – Response to stakeholder survey – question 1: Who should bear the costs of waste management?**

2) What will be the ideal method to finance the end of-life phase of PV Panesl sold as - for example - from 1 January 2021?

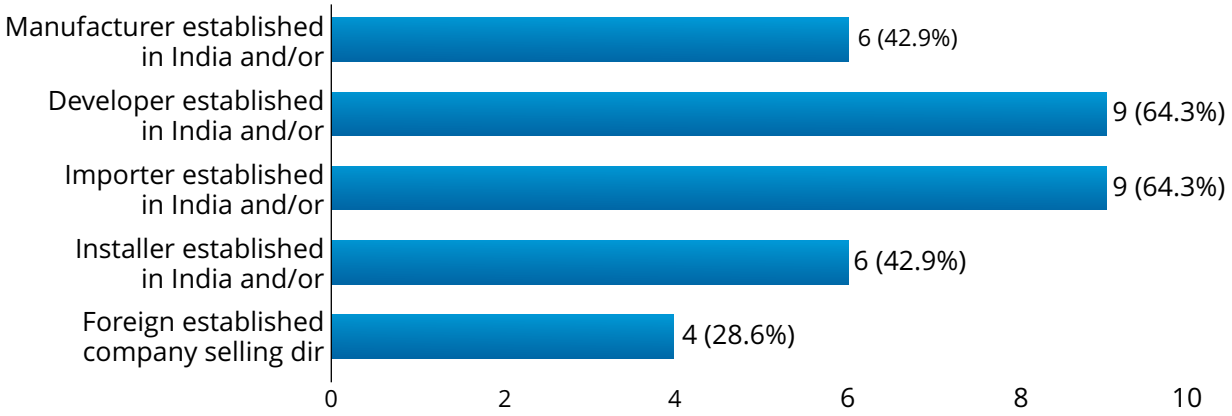
14 responses




Majority of the respondents felt that both the developer and the manufacturer/importer are equally responsible for producer responsibility related to the end-of-life phase of modules in India. A resounding majority of around 93% of the respondents were willing to accept a recycling to be paid by the final customer. 92.9% of the stakeholders agree with setting up a limited fund for future waste management of PV modules sold in India and they recommend this fund as an important solution to address the challenge of the future waste management of PV modules that are already installed in India before 2021 (or before a comprehensive policy evolves) and the same percentage of stakeholders believed a Management Organization steered by the PV industry itself is the best way to handle this fund.

**Figure 7 – Response to stakeholder survey – question 2: Who should be legally responsible for Producer Responsibility related to the end-of-life phase of PV modules sold on the Indian territory?**

3) According to you, who is the legally responsible for Producer Responsibility related to the end-of-life phase of PV Panels sold on the Indian ter...urerestablished in India and selling in India, etc)?



100% of the respondents accepted the notion of a recycling fee which takes into account the level of recyclability of a PV module.

Only half of the stakeholders questioned believed that PV recycling will be profitable in the coming years. Most of them cited the scale, market for the recycled materials, and incentives for recycling, diversity of PV modules and collection cost as the possible reasons of non-profitability.

According to 50% of the stakeholders, the cost of technology in the initial years may be high until an optimum size and efficiency is established and In a country of India's size, transport costs are also significant if materials have to be moved from one corner of the country to another. Until PV dismantling and recycling units are set up in different corners (or hotspots) of the country, it is difficult to bring financial efficiency to the PV recycling model. In the long run, this has a definite potential to be profitable.

Stakeholders expressed that profitability of recycling of PV modules will depend on a lot of different factors. The decommissioning of large-scale PV power systems today offers the possibility for a positive return from salvage values of recovered materials as well as the value of the land, hence the overall business case for high-value recycling according to them is positive. When it comes to the collection and recycling of distributed installations at small scale, the logistic costs for the reverse logistic chain play an important role, as well as the amount of waste becoming available for central processing in treatment facilities. They felt that the economies of scale will most likely improve over the next couple of years and lead to the possibility to also generate a profit from high-value recycling of PV modules. Advance techniques required for dedicated PV recycling facilities focusing on high value recovery and supply chain will play a critical role.

Around 71% of the stakeholders interviewed felt that recycling inverters is economically viable in India while only 35% felt recycling Lithium Ion batteries is viable in India. Imposing Landfill ban and taxes on it along with enforcing stricter Extended Producer Responsibilities are the two main factors the stakeholders felt should be enforced by the government to push the market for a circular economy. Finally, a majority (86%) of the respondents felt that setting targets for a minimum amount of recycled content to be included while manufacturing of new modules will help in realizing recycling goals.

**Figure 8 – Response to stakeholder survey – question 3: What practices of government do you think will push the market for a circular economy?**

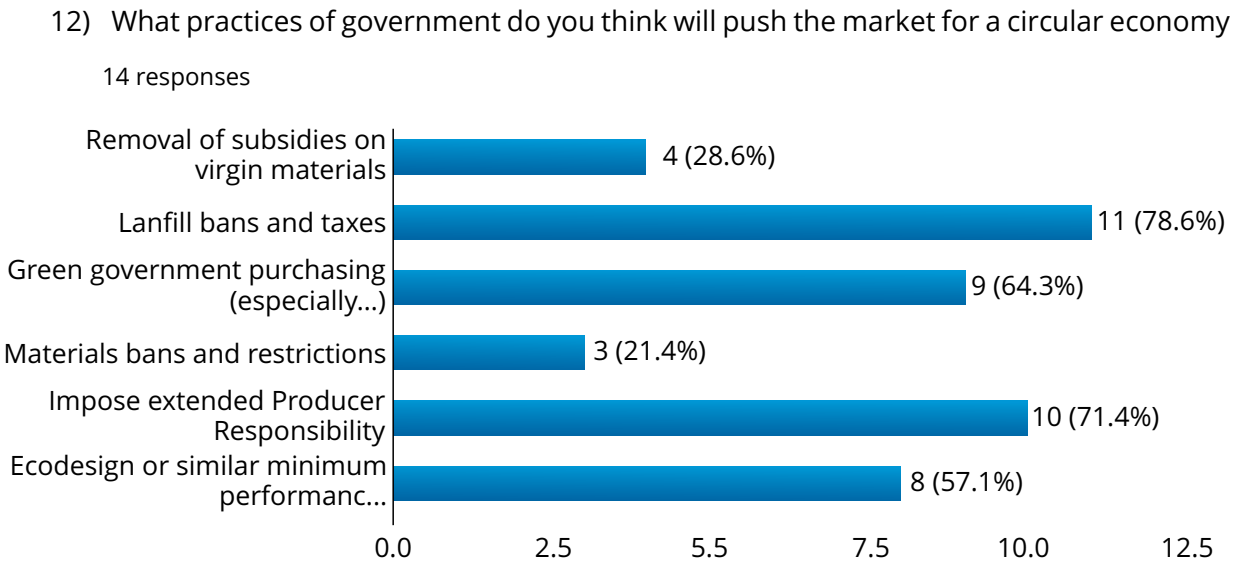
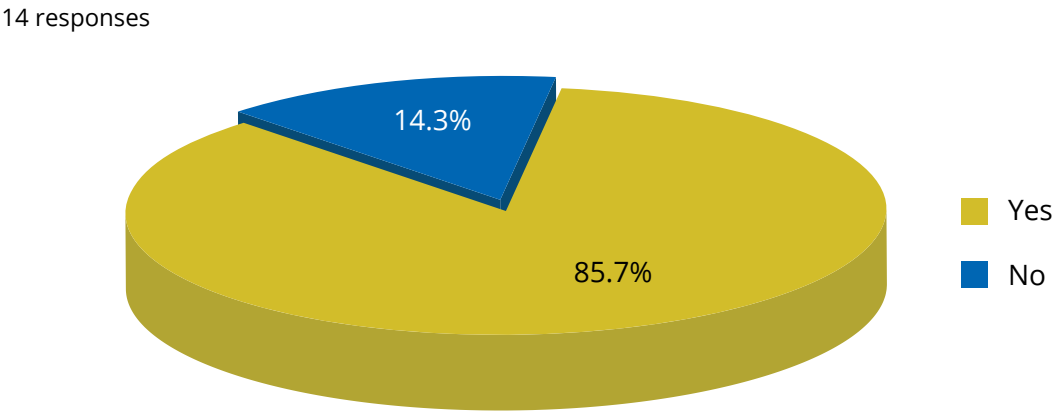



**Figure 9 – Response to stakeholder survey – question 4: Would setting up a standard, i.e., a target of a minimum amount of recycled content to be included while manufacturing of new modules, improve PV waste management in India? (Blue: yes; red: no)**




Overall, from the survey it can be concluded that stakeholders in India are concerned about the PV waste and it's 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. This report encompasses the measures and strategies that have been proposed or suggested by majority of stakeholders in terms of Landfill ban, EPR enforcement and centralized fund.