



TRADE AND DEVELOPMENT BANK GROUP  
GROUPE DE LA BANQUE DE COMMERCE ET DE DÉVELOPPEMENT

# GUIDANCE NOTE FOR MANAGEMENT OF E-WASTE IN TDB'S FINANCED PROJECTS NOVEMBER 2025

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## ACRONYMS

Abbreviation	Term
As	Arsenic
Ba	Barium
Be	Beryllium
Ca	Calcium
Cd	Cadmium
Cr	Chromium VI
CPU	Central Processing Unit
CITES	Convention on International Trade in Endangered Species
COMESA	Common Market for Eastern and Southern Africa
DFI	Development Finance Institution
EEE	Electrical and Electronic Equipment
E&S	Environmental and Social
EPR	Extended Producer Responsibility
GHG	Greenhouse Gas
ESIA	Environmental and Social Impact Assessment
ERM	Enterprise Risk Management
ESAP	Environmental and Social Action Plan
ESMS	Environmental and Social Management System
FI	Financial Intermediaries
Hg	Mercury
ICT	Information and Communication Technologies
IFC	International Finance Corporation
ITU	International Communication Union
Li	Lithium
Ni	Nickel
ODS	Ozone Depleting Substances
OHS	Occupational Health and Safety
Pb	Lead
PCB	polychlorinated biphenyls
PRO	Producer Responsibility Organization
PV	Photovoltaic
PVC	Polyvinyl Chloride
Se	Selenium
Si	Silicon
SEDD	Social and Environmental Due Diligence
SHS	Solar Home System
TDB	Trade and Development Bank Group
Te	Tellurium
ToR	Terms of Reference
WEEE	Waste from Electrical and Electronic Equipment
Zn	Zinc

## GLOSSARY

### **Amorphous silicon**

Non-crystalline form of silicon formed using silicon vapour which is quickly cooled.

### **Borrower (Client)**

A company that has received capital or debt directly from TDB

### **Electrical and electronic equipment**

The term electrical and electronic equipment (EEE) is defined as equipment designed for use with a voltage rating not exceeding 1,000 Volts (V) for alternating current and 1,500 V for direct current, or equipment dependent on electric currents or electromagnetic fields in order to work properly, or equipment for the generation of such currents, or equipment for the transfer of such currents, or equipment for the measurement of such currents.

### **Extended Producer Responsibility**

Extended Producer Responsibility (EPR) 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. An EPR policy is characterised by (1) shifting responsibility (physically and/or economically; fully or partially) upstream towards the producers and away from governments and (2) the provision of incentives to producers to take into account environmental considerations when designing their products.

### **E-Waste**

Electronic waste or E-waste, also called Waste Electrical and Electronic Equipment (WEEE), , as per EU directive (WEEE Directive, EU, 2002a), is defined as "Electrical or electronic equipment which is including all components, subassemblies and consumables, which are part of the product at the time of discarding; E-waste is also as any end-of-life or end-of-use piece of "equipment which is dependent on electrical currents or electromagnetic fields in order to work properly". It covers a broad range of electronic devices, ranging from large household appliances, information technology and telecommunications equipment, lighting equipment, medical devices, monitoring and control instruments, automatic dispensers, and consumer electronics, such as electrical and electronic tools, toys, leisure and sports equipment, and mobile phones to computers. Components of electric and electronic equipment (EEE), such as batteries, obsolete and/or broken solar panels, electric cables from end-of-life vehicles (ELVs), printed circuit boards (PCBs), plastic casings, cathode-ray tubes (CRTs), activated glass, and lead capacitors are also classified as e-waste.

### **Monocrystalline silicon**

Silicon manufactured in such a way that it forms a continuous single crystal without grain boundaries.

### **Pay-as-you-go**

In a pay-as-you-go (PAYG) approach, the cost of collection and recycling is covered by market participants when waste occurs. By contrast, a pay-as-you-put (PAYP) approach involves setting aside an upfront payment of estimated collection and recycling costs when a product is placed on the market.

### **Poly- or multicrystalline silicon**

Silicon manufactured in such a way that it consists of a number of small crystals forming grains.

### **Partner Financial Intermediary (PFI)**

Financial intermediary refers to an entity that acts as an intermediary between the TDB and its clients or projects, facilitating the flow of funds for investments or activities

**Raw material**

Basic material which has not been processed, or only minimally, is used to produce goods, finished products, energy or intermediate products which will be used to produce other goods.

**Sub borrower**

Means a private firm/entrepreneur who has obtained funding from Partner Financial Intermediary

**Thin film**

Technology used to produce solar cells based on very thin layers of PV materials deposited over an inexpensive material (glass, stainless steel, plastic)

## 1 INTRODUCTION

TDB Group seeks to play a leading role in financing green industrialisation in a responsible manner that pro-actively supports sustainable, inclusive, and resilient development, including investing in clean energy following principles of just transition and circular economy. In this regard, the Bank acknowledges that investment in the energy transition can deliver a range of longer-term benefits by enhancing competitiveness, improving access to energy, and facilitating industrialization, and export development while reducing greenhouse gas emissions.

While TDB is well-positioned to assist its Member States in realizing their NDCs, NAPAs, and ushering in a low-carbon transformation, addressing energy demand financing gap through investments in renewable energy sources requires a prudent approach to support the management of E-waste – for instance, despite the substantial social and environmental benefits of PV and off-grid solar systems (including improved electricity access and reduced greenhouse gas emissions from traditional, polluting lighting sources) concerns arise regarding waste management, especially concerning end-of-life products like batteries.

This Guidance Note therefore, offers guidance on promoting safe and responsible e-waste management practices among TDB's borrowers and sub-borrowers, including those financed through financial intermediaries. All TDB's PFIs engaged in PV and SHS systems are required to comply with the requirements of this guidance note.

The Guidance Note draws from global association for the off-grid solar energy industry (GOGLA) e-waste toolkit, which supports companies in the development and implementation of responsible e-waste policies and procedures.

## 2 GAPS IN E-WASTE MANAGEMENT IN THE REGION

Most of African countries lack formal governance structures to support e-waste management. This is aggravated by the fact that not all the producers nor local authorities are taking sufficient ownership of this issue, and although e-waste volumes continue to rise, recycling facilities (where available) are not operating at capacity due to poor collection systems.

Most of the existing Hazardous Regulations do not mention E-waste, rather different hazardous chemicals are mentioned which can be the part of the E-waste or released during dismantling, burning, chemical processing or disposing on the land. Enforcement of these provisions is weak due to lack of enforcement infrastructure and resources. There are no specific rules and guidelines to regulate E-waste recyclers and their facilities and their disposal.

The retailers and producers are not under any compulsion to take back the post-consumer products. Generally, E-waste recycling is carried out informally without taking environmental safeguards.

E-waste is collected by the scrappers or street waste collectors from homes and offices or by scavengers from streets. This E-waste is mixed with other general waste and treated as waste without any special attention to it. These scrappers and scavengers sell this waste to small waste collectors. The small waste collectors segregate the waste into different categories and sell each category of waste to the specific waste contractor. The waste contractor sells this waste to the recyclers. The recyclers either repair electrical and electronic equipment and resale these in the market as second-hand equipment or recycle it to recover valuable materials. The valuable materials are sold to specific buyers/market.

### 3 OCCURRENCE OF HARMFUL SUBSTANCES IN E\_WASTE

#### Hazardous E-Waste Management

Hazardous e-waste refers to electric and electronic devices that contain toxic materials such as mercury, lead, arsenic, cadmium, or brominated flame retardants, etc., beyond threshold quantities or known to harm human health and the environment.

Hazardous e-waste should always be segregated from non-hazardous e-wastes. If the generation of hazardous e-waste cannot be prevented through the implementation of the general e-waste management practices, its management should focus on the prevention of harm to health, safety, and the environment, according to the following additional principles:

- (i) Understanding potential risks and impacts associated with the management of any generated hazardous e-waste during its complete life cycle;
- (ii) Ensuring that contractors handling, treating, and disposing of hazardous e-waste are reputable and legitimate enterprises, licensed by the relevant regulatory agencies and following good international industry practice for the e-waste being handled;
- (iii) Ensuring compliance with applicable local and international regulations, WB ESHG, and GIIP.

Table 1 below illustrates the presence of some harmful substances listed above in E-waste products:

*Table 1: Harmful substances found in E-waste products*

TOXIC SUBSTANCE	O CCURANCE IN EEE
<b>Halogenated compounds</b>	
PCB (polychlorinated biphenyls)	Condensers, Transformers
TBBA (tetrabromo-bisphenol-A) PBB (polybrominated biphenyls) PBDE (polybrominated diphenyl ethers)	Fire retardants for plastics (thermoplastic components, cable insulation) TBBA is presently the most widely used flame retardant in printed circuit boards
Chlorofluorocarbon (CFC)	Cooling unit, Insulation foam
PVC (polyvinyl chloride)	Cable insulation
<b>Heavy metals and other metals:</b>	
Arsenic	Small quantities in the form of gallium arsenide within light emitting diodes
Barium	Getters in cathode ray tubes (CRTs)
Beryllium	Power supply boxes which contain silicon-controlled rectifiers and x-ray lenses
Cadmium	Rechargeable computer batteries, fluorescent layer (CRT screens), printer inks and toners, photocopying-machines (printer drums)
Chromium VI	Data tapes, floppy-disks
Lead	CRT screens, batteries, printed wiring boards, television sets, PC monitors, light bulbs, lamps
Lithium	Li-batteries
Mercury	Fluorescent lamps that provide backlighting in LCDs, in some alkaline batteries and mercury wetted switches
Nickel	Rechargeable NiCd-batteries or NiMH-batteries, electron gun in CRT
Rare Earth elements (Yttrium, Europium)	Fluorescent layer (CRT-screen)
Selenium	Older photocopying-machines (photo drums)
Zinc sulphide	Interior of CRT screens, mixed with rare earth metals

## 4 ADVERSE IMPACTS ON HUMAN HEALTH AND ENVIRONMENT BY TOXIC SUBSTANCES CONTAINED IN E-WASTE

Inadequate management and recycling of e-waste can have serious health consequences, particularly for individuals working in unregulated recycling sectors as discussed below:

### ➤ Arsenic

Arsenic is a poisonous semi-metallic element which is present in dust and soluble substances. Chronic exposure to arsenic can lead to various diseases of the skin and decrease nerve conduction velocity. Chronic exposure to arsenic can also cause lung cancer and can often be fatal.

### ➤ Barium

Barium is a metallic element that is used in sparkplugs, fluorescent lamps and "getters" in vacuum tubes. Being highly unstable in the pure form, it forms poisonous oxides when in contact with air. Short-term exposure to barium could lead to brain swelling, muscle weakness, damage to the heart, low blood potassium, cardiac arrhythmias, respiratory failure, gastrointestinal dysfunction, paralysis, muscle twitching, and elevated blood pressure, liver, and spleen. Animal studies reveal increased blood pressure and changes in the heart from ingesting barium over a long period of time.

### ➤ Beryllium

Beryllium has recently been classified as a human carcinogen because exposure to it can cause lung cancer. The primary health concern is the inhalation of beryllium dust, fume, or mist. Workers who are constantly exposed to beryllium, even in small amounts, and who become sensitized to it can develop what is known as Chronic Beryllium Disease (berylliosis), a disease that primarily affects the lungs. Beryllium can also affect organs such as the liver, kidneys, heart, nervous system, and lymphatic system may develop beryllium sensitization or chronic beryllium disease. Exposure to beryllium also causes a form of skin disease that is characterized by poor wound healing and wart-like bumps. Studies have shown that people can still develop beryllium diseases even many years following the last exposure.

### ➤ Brominated Flame Retardants (BFRs)

The 3 main types of BFRs used in electronic and electrical appliances are Polybrominated biphenyl (PBB), Polybrominated diphenyl ether (PBDE), and Tetrabromobisphenol - A (TBBA). Flame-retardants make materials, especially plastics and textiles, more flame resistant. They have been found in indoor dust and air through migration and evaporation from plastics. Combustion of halogenated case material and printed wiring boards at lower temperatures releases toxic emissions, including dioxins, which can lead to severe hormonal disorders. Major electronics manufacturers have begun to phase out brominated flame-retardants because of their toxicity.

### ➤ Cadmium

Cadmium components may have serious impacts on the kidneys. Cadmium is adsorbed through respiration but is also taken up with food. Due to the long half-life in the body, cadmium can easily be accumulated in amounts that cause symptoms of poisoning. Cadmium shows the danger of cumulative effects in the environment due to its acute and chronic toxicity. Acute exposure to cadmium fumes causes flu-like symptoms of weakness, fever, headache, chills, sweating and muscular pain. The primary health risks of long-term exposure are lung cancer and kidney damage. Cadmium also is believed to cause pulmonary emphysema, possibly reproductive damage, and bone disease (osteomalacia and osteoporosis).

## CFCs (Chlorofluorocarbons)

Chlorofluorocarbons are compounds composed of carbon, fluorine, chlorine, and sometimes hydrogen. Used mainly in cooling units and insulation foam, they have been phased out because when released into the atmosphere, they accumulate in the stratosphere and have a deleterious effect on the ozone layer. This results in an increased incidence of skin cancer in humans and in genetic damage in many organisms.

### ➤ Chromium

Chromium and its oxides are widely used because of their high conductivity and anti-corrosive properties. While some forms of chromium are nontoxic, Chromium (VI) is easily absorbed in the human body and can produce various toxic effects within cells. Most chromium (VI) compounds are irritating to the eyes, skin, and mucous membranes. Chronic exposure to chromium (VI) compounds can cause permanent eye injury unless properly treated, human carcinogens, impacts on neonates, and reproductive and endocrine functions. Chromium VI may also cause DNA damage.

### ➤ Dioxins

Dioxins and furans are a family of chemicals comprising 75 different types of dioxin compounds and 135 related compounds known as furans. Dioxins are taken to mean the family of compounds comprising polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). Dioxins have never been intentionally manufactured but form as unwanted by-products in the manufacture of substances like some pesticides as well as during combustion. Dioxins are highly toxic to animals and humans because they bio-accumulate in the body and can lead to malformations of the foetus, decreased reproduction and growth rates and cause impairment of the immune system, among other things. The best-known and most toxic dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD).

### ➤ Lead

Lead is the fifth most widely used metal after iron, aluminum, copper, and zinc. It is commonly used in the electrical and electronics industry in solder, lead-acid batteries, electronic components, cable sheathing, in the glass of CRTs etc. Short-term exposure to high levels of lead can cause vomiting, diarrhoea, convulsions, coma or even death. Other symptoms are appetite loss, abdominal pain, constipation, fatigue, sleeplessness, irritability, and headache. Continued excessive exposure, as in an industrial setting, can affect the kidneys. It is hazardous for young children because it can damage nervous connections and cause blood and brain disorders.

### ➤ Mercury

Mercury is one of the most toxic yet widely used metals in the production of electrical and electronic applications. It is a toxic heavy metal that bio-accumulates, causing brain and liver damage if ingested or inhaled. In electronics and electrical appliances, mercury is highly concentrated in batteries, some switches and thermostats, and fluorescent lamps.

### ➤ Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) are a class of organic compounds used in various applications, including dielectric fluids for capacitors and transformers, heat transfer fluids and additives in adhesives and plastics. PCBs have been shown to cause cancer in animals. PCBs have also been shown to cause a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous system, endocrine system, and other health effects. PCBs are persistent contaminants in the environment.

Due to the high lipid solubility and slow metabolism rate of these chemicals, PCBs accumulate in the fatrich tissues of almost all organisms (bioaccumulation).

### ➤ **Polyvinyl Chloride (PVC)**

Polyvinyl chloride (PVC) is the most widely used plastic, used in everyday electronics and appliances, household items, pipes, upholstery etc. PVC is hazardous because it contains up to 56 per cent chlorine. When burned, it produces large quantities of hydrogen chloride gas, which combines with water to form hydrochloric acid and is dangerous because when inhaled, it leads to respiratory problems.

### ➤ **Selenium**

Exposure to high concentrations of selenium compounds causes selenosis. The major signs of selenosis are hair loss; nail brittleness, and neurological abnormalities (such as numbness and other odd sensations in the extremities).

## **5 PROCEDURE FOR MANAGEMENT OF E-WASTE**

### **Procurement of Electronic Items of High Quality from Reputable Retailers/Sources**

The first mitigation measure is to ensure that all electronic devices are procured from retailers and sources that are credible, that all devices will have a clear date of manufacture and warranty, and the item is of a high quality. This will avoid procurement of poor quality, refurbished, or used second hand electronic devices with a shorter life cycle that leads to a rapid generation of E-waste. All items should be purchased where applicable, with protective covers and insurance. If possible, retailers or source of electronic items should be engaged where a repair, renewal, recycling or take back scheme option is offered. If the retailer or source does not offer some or all of these options, then the project is to locate legally licensed facilities that do repair or recycle electronic items. If such options do not exist, then disposal in licensed disposal facilities for hazardous wastes should follow the Environmental Management Regulations as prescribed by the National or Local Authorities.

### **5.1 E-Waste Management Hierarchy**

#### **5.1.1 E-Waste Prevention Processes**

TDB financed project should be designed and operated to prevent, reduce, or minimize, the quantity of e-waste generated, and hazards associated with the e-waste generated in accordance with the following strategy:

- (i) Substituting raw materials or parts with less hazardous or toxic materials or with those where processing generates a lower e-waste volume.
- (ii) Adopting and implementing good housekeeping and operating practices, including inventory control to reduce the amount of e-waste resulting from materials that are out-of-date, off-specification, contaminated, damaged, or are excess to operational needs; and
- (iii) Reducing/minimizing hazardous e-waste generation by implementing stringent e-waste segregation to prevent the commingling of non-hazardous and hazardous e-waste from been managed.

#### **5.1.2 Recycling and Reuse**

In addition to the implementation of e-waste prevention strategies, the total amount of e-waste may be significantly reduced through the implementation of reuse and recycling plans, which should consider the following elements:

- (i) Identification and reuse/recycling of products that can be reintroduced into the operational processes

- (ii) Investigation of external markets for recycling by other industrial processing operations located in the neighborhood or region of the facility (e.g., e-waste exchange);
- (iii) Establishing reuse/recycling objectives and formal tracking of e-waste generation and recycling rates; and
- (iv) Providing training and incentives to employees in order to meet objectives.

### 5.1.3 E-Waste Storage

Hazardous e-waste should be properly stored to prevent or control accidental releases to air, soil, and water resources in areas where:

- (i) E-waste is stored in a manner that prevents the commingling or contact between incompatible e-waste and allows for inspection between containers to monitor leaks or spills. Examples include sufficient space between incompatible or physical separation such as walls or containment curbs;
- (ii) Store in closed containers (some could be radioactive proofed), away from direct sunlight, wind and rain;
- (iii) Secondary containment systems should be constructed with materials appropriate for the e-waste being contained and adequate to prevent loss to the environment;
- (iv) Provision of readily available information on compatibility to employees, including labelling each container to identify its contents;
- (v) Limiting access to hazardous e-waste storage areas to only employees who have received proper training;
- (vi) Clearly identifying (labelling) and demarcating the area, including documentation of its location on a facility map or site plan; and,
- (vii) Conducting periodic inspections of e-waste storage areas and documenting the findings.

### 5.1.4 Transportation of E-Waste

All e-waste containers designated for off-site shipment should be secured and labelled with the contents and associated hazards. This must be properly loaded and secured into transportation vehicles before leaving the site and accompanied by a shipping paper (i.e., manifest, record, etc.) that describes the load and its associated hazards, which is consistent with the Transport of Hazardous Materials good practices and guidance. When preparing for shipment the following should be implemented:

- Name and identification number of the material(s) composing the e-waste.
- Physical state (i.e., solid, liquid, gaseous or a combination of one, or more, of these)
- Quantity (e.g., kilograms or liters, number of containers)
- Waste shipment tracking documentation to include, quantity and type, date dispatched, date transported, date received, record of the originator, the receiver, and the transporter
- Method and date of storing, repacking, treating, or disposing at the facility, cross-referenced to specific manifest document numbers applicable to the e-waste.
- Location of each e-waste within the facility, and the quantity at each location.

### 5.1.5 Treatment and Disposal

If e-waste materials are still generated after the implementation of feasible e-waste prevention, reduction, reuse, recovery, and recycling measures; then, e-waste materials should be treated and disposed of following all measures to avoid potential impacts to human health and the environment. Selected

management approaches should be consistent with the specifications of e-waste characteristics and local regulations and may include one or more of the following:

- (i) On-site or off-site chemical or physical treatment of the e-waste material to render it non-hazardous prior to final disposal;
- (ii) Treatment or disposal at permitted facilities specially designed to receive the e-waste;
- (iii) Permitted and operated landfills or disposal facilities designed for the respective type of e-waste or other methods known to be effective in the safe, final disposal of e-waste materials.

## 6 MANAGEMENT OF END-OF-LIFE (EOL) PV AND SHS TECHNOLOGIES

TDB Group in partnership with World Bank are implementing the Regional Infrastructure Finance Facility (RIFF), Africa Green, Resilient and Inclusive Housing De-Risking (GRIHD) Facility and Accelerating Sustainable and Clean Energy Access Transformation (ASCENT) aimed at expanding long-term finance to private firms in selected infrastructure sectors, accelerating access to and financing of sustainable, reliable, and affordable Housing and Scaling-up Energy Access in Eastern and Southern Africa. Achieving global goals for access to energy and mitigation of climate change will require a quadrupling of present levels of solar photovoltaic (PV) generation in the developing world by 2025 to reach around 950 gigawatts (GW)<sup>1</sup>. As TDB lays out a path to finance sustainable solar projects, the Bank recognizes that growing PV and SHS presents a new environmental challenge on e-waste management, but also unprecedented opportunities to create value and pursue new economic avenues in its Member States. This section provides specific guidance for TDB borrowers on the management of EOL PV and SHS Technologies.

### 6.1 Materials in PV Systems

A PV system is comprised of modules, racking structures, and inverters that connect it to the grid. Modules, which are composed of approximately 90% glass and Aluminium (Al) by mass, contribute about half of the materials by mass of a system. The remainder of the system materials include steel for racking, piles, and trackers; copper (Cu), Al for wiring and plastics for electronics and wire housing.

In the most of TDB's Member States, recycling companies in scrap metal markets can accommodate Steel, Al, and Cu. Solar glass, which is clearer than the majority of glass, can be recycled or used for secondary products, such as reflective paints. However, the glass still needs to be separated from the rest of the module laminate.

While the majority of module system component materials can be sold to the scrap metal market, the module, batteries and inverter are the components that are considered electronic waste (e-waste) and do not have as robust recycling and secondary materials markets as steel, Al, and Cu in the region. However, module EOL and batteries volumes will be far larger than inverter EOL volumes due to their respective mass proportions in a system, and the recycling will be different from other e-waste recycling due to differences between consumer electronics and module designs. Therefore, module EOL handling will be the main priority

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<sup>1</sup> According to the World Bank's estimates, based on the International Energy Agency's Sustainable Development Scenario

## 6.2 MATERIALS IN PV MODULES

As technological advances, today, two-thirds of globally manufactured PV panels are crystalline silicon (c-Si). A silicon module is made of silicon solar cells, which are electrically connected with silver (Ag), sandwiched between glass and plastic sheets, and framed in Al.

Modules are categorized as e-waste because they contain electrical components, but they are typically composed of more than 90% glass, polymer and aluminium, which are classified as non-hazardous waste. However, the same panels also include such hazardous materials as silver, tin and lead traces. Thin-film panels, by comparison, are over 98% non-hazardous glass, polymer and aluminium, combined with around 2% copper and zinc (potentially hazardous) and semiconductor or other hazardous materials. These include indium, gallium, selenium, cadmium, tellurium and lead. Precious metals, such as silver, are valuable materials in solar modules that could be recovered and reused for multiple purposes.

However, silver, silicon is also difficult to recover with sufficient purity for reuse. While the silicon embodied in a PV cell could be valuable, other materials are intentionally added to the silicon to make it into a solar cell. This makes the recovered silicon lower quality than is needed for electronic applications, although it may be useful for metallurgical applications.

The market also offers cadmium telluride (CdTe) thin film modules which are made by depositing CdTeSe absorber materials directly on the glass of the module, using plastic encapsulant and edge seals, and Al and Molybdenum (Mo) contacts, and an Al frame. Tellurium (Te) is a rare element in the earth's crust, with an abundance on par with platinum. The amount of CdTeSe absorber in the module is below 0.1% by mass.

## 6.3 EOL HANDLING PATHWAYS FOR PV MODULES

The module recycling process starts with mechanically removing the aluminium frames, if applicable, and shearing off the junction box. The commercial process for silicon then shreds the module into small pieces, grinds them into fine particles, and then uses eddy currents and sifting to separate the glass, polymers, interconnect ribbons, and cells. Other silicon module recycling techniques use heat to remove the polymers from the glass and chemical treatments to separate the metals from the silicon.

For CdTe modules, after mechanical removal of the frame and junction box the commercial recycling process then proceeds to shred the laminate, grind it into small pieces in a hammermill, mechanically separate the glass and laminate pieces, and then immerse in a series of chemical baths to recover the Cd and Te.

The PV module reuse/resale market is currently small but has been established in most African countries. Some modules that are decommissioned still output a useful amount of power which can be sold to buyers looking for pre-owned modules or a particular module product. Companies have been established that take care of both these useable decommissioned modules along with EOL modules for system owners.

### 6.3.1 MANAGEMENT OF EOL BATTERIES

Environmentally, when batteries are improperly discarded with household waste, they often end up in landfills, leading to the corrosion of battery casings and the leaching of harmful chemicals into groundwater, contaminating water bodies. This process also results in soil pollution, as acid and lead particles become airborne when dry, posing significant health risks.

Solar system batteries mainly come in two types, lead acid and lithium-ion, both of which carry risks in the recycling and storage process. If mishandled, they can harm the environment and people's health, each presenting unique challenges in disposal and recycling.

Lead acid batteries, commonly used in solar systems, are hazardous due to their primary components: lead and battery acid. Transportation of undamaged batteries to recyclers is generally safe, but lead becomes hazardous when disturbed, as it can create lead dust during disassembly, which is harmful when inhaled. Additionally, lead is easily absorbed by living organisms, accumulating over time, causing various health issues such as miscarriages, neurological development problems, and cognitive function deterioration.

Battery acid, composed of sulfuric acid, is harmful to ecosystems, polluting groundwater when improperly disposed of, and causing harm to humans. Moreover, lead particles within these batteries also contaminate the environment and are difficult to clean up.

Lithium-based batteries, including LFP (Lithium-iron-phosphate) and LMO (Lithium-manganese-oxide), have a risk of fire during storage due to uncontrolled thermal runaways. While LFP and LMO batteries carry a lower fire risk than other compositions, proper discharge and storage procedures are essential.

In more developed markets, e-waste management companies and recyclers accept various battery components and their fractions, including plastics, glass, aluminum, copper, PCBs, etc. However, the absence of service providers in many countries hinders improved recycling efforts. GOGLA's e-waste toolkit<sup>2</sup> offers information on management companies and guidance for selecting a service provider through their e-waste hub.

### Guidance on Appropriate Storage of Batteries

Proper battery storage is crucial for both regulatory compliance and safety. To mitigate risks, it's essential to follow these best practices:

- (i) **Ensure Proper Training and PPE:** All personnel handling batteries should undergo appropriate training, and they should be provided with adequate personal protective equipment (PPE) in compliance with the MSDS.
- (ii) **Address Lithium Battery Fire Risks:** Lithium-based batteries, such as Lithium-Iron-Phosphate (common in off-grid solar), pose a fire risk. To prevent fires, discharge lithium batteries fully before storage, as uncontrolled "thermal runaways" can result from deep discharging, short-circuiting, or overcharging.
- (iii) **Storage Protocols:**
  - **Avoid Battery Dismantling:** Do not attempt to dismantle battery packs.
  - **Insulate Battery Poles:** Cover the poles of batteries with insulated tape.
  - **Sheltered Storage:** Store batteries in an area sheltered from heat and rain.
  - **Separate Storage:** Keep lithium batteries in a designated section of the warehouse to reduce the risk of fire spread.

- **Safe Discharge:** Discharge batteries and store them in plastic containers covered with sand. The sand absorbs thermal runaway and forms a protective glass layer around the battery to prevent fire spread.
- (iv) **Lead-Acid Battery Storage:**
- **Avoid Sunlight:** Keep lead-acid batteries out of direct sunlight.
  - **Wet Batteries:** Drain wet batteries that require distilled water during their lifespan and store the acid in secure containers.
  - **Sealed Batteries:** Do not open sealed batteries and place them on impermeable surfaces.
  - **Pallet Storage:** Store and transport lead-acid batteries on pallets, positioning similar-sized batteries next to each other.
  - **Use Cardboard Separators:** Insert a layer of thick cardboard between each battery layer to absorb any acid leakage.
  - **Limit Stacking Height:** Stack batteries no higher than three layers.
  - **Secure Pallets:** Wrap and seal pallets with plastic wrap, criss-crossing for load stability, and ensure that pallets are stacked no higher than two meters.

Adhering to these practices will help maintain the safe storage of batteries while minimizing associated risks.

### Guidance on Transportation of Spent Batteries

In general, e-waste management companies are responsible for the transportation of e-waste, collecting it from off-grid solar logistics hubs. However, it is crucial to assess waste management partners to understand the hazards and best practices associated with transportation.

**Domestic Transportation:** For the safe transfer of e-waste, best practices are consistent with those for handling other hazardous waste. It should be transported in a sealed truck dedicated exclusively to hazardous waste transportation to contain any potential leaks. The truck should display appropriate signage and possess the necessary permits for hazardous waste transportation. Drivers and accompanying staff should be equipped with suitable safety gear. It's also important to be aware of local regulations, which may specify specific requirements and responsibilities.

**Transboundary Movement:** When waste crosses international borders, it falls under the category of Transboundary Movement, subject to international conventions (such as Stockholm, Rotterdam, and Basel) and local regulations. Compliance requirements may include the use of specific vehicles and permits, similar to those required for domestic transportation. Failure to adhere to regulations and policies, like the Basel Convention, when shipping e-waste can result in the waste being stranded at the destination port or returned to the departure port for reprocessing. In some cases, this could lead to the improper disposal or incineration of waste, causing unknown environmental harm and financial penalties. Therefore, borrowers and sub-borrowers must comply with the relevant international conventions when transporting e-waste across borders.

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### Guidance on Recycling

Borrowers and Sub-borrowers should actively explore and identify recycling opportunities, wherever feasible, to minimize the risk of inadequate treatment of spent products.

In general, there's no universally applicable "best practice" or one-size-fits-all approach to managing a company's e-waste. The decision regarding the selection and number of partners hinges on factors such as the availability of service providers, the specific components or fractions earmarked for recycling, operational and financial requisites, as well as environmental and safety standards. Off-grid solar companies often opt to engage a single e-waste management company that serves as a collector, dismantler, transporter, and is responsible for choosing recyclers and overseeing this relationship. However, an exception arises for companies using lead-acid batteries, where it is advisable to directly engage with recyclers for this component. This approach offers advantages in terms of finance and logistics and ensures compliance with environmental, health, and safety standards. The process of selecting a waste management partner is distinct for each company, involving conformity with local regulations and a rigorous safety assessment.

For additional guidance, please consult GOGLA's e-waste briefing note, specifically Chapter 1, which outlines how to choose suitable recyclers.

### **Guidance on Consumer Awareness on E-waste and Take Back and Collection**

In addition to addressing defective products returned by customers, borrowers and sub-borrowers are strongly encouraged to implement proactive take-back programs that allow customers to return spent products. As per the GOGLA code of conduct, it is essential to inform consumers about proper end-of-life product disposal, with a particular emphasis on batteries. Companies should consider establishing collection schemes or informing consumers about alternative collection options, such as those offered by other agencies.

Take-back and collection initiatives are integral components of a company's e-waste management strategy and present opportunities to engage with both new and existing customers, reinforcing brand value. These efforts also serve as risk mitigation measures, reducing health and environmental concerns for consumers and communities and preventing brand damage that could result from products entering the informal repair sector and re-entering the market with questionable quality. By extending the customer relationship beyond the warranty period and encouraging repeat purchases, companies can maximize the positive impact of providing access to clean and affordable electricity. For further details on best practices, please refer to GOGLA's e-waste briefing note 6.

Regarding disposal, lead-acid batteries are classified as hazardous waste, and lithium-ion batteries may also qualify as household hazardous waste. Solar companies must ensure that these batteries are disposed of in designated areas, following World Bank E&S standards and the Environmental, Health, and Safety Guidelines of the World Bank Group to maintain environmental and occupational health and safety standards. Additionally, compliance with government regulations, if applicable, pertaining to the disposal of battery components is essential. In general, batteries should be disposed of at authorized facilities that operate in accordance with national e-waste requirements.

## 7 AWARENESS AND SENSITIZATION

Awareness and sensitization of project developers and contractors (as applicable, at borrower or sub-borrower levels) who will use or install electronic devices on the proper disposal once they become damaged, irreparable or at their end of life is vital. The awareness material should include in the sensitization the usefulness and significance of E-waste recycling, and the need for returning back all electronic items procured by the project to a collection Centre that should be established.

TDB financed companies must ensure that they implement an awareness program aimed at its consumers, informal sector waste collectors and transporters (if the company plans to use them in their waste management activities). The awareness should focus on the following aspects:

- i. Awareness about the E&S risk involved in unsafe disposal of e-waste.
- ii. Company supported e-waste collection and recycling activities.
- iii. Awareness about incentives for safe disposal of e-waste.

Financed companies should prepare a do's and don'ts for consumers with focus on e-waste.

Sample do's and don'ts

Do's:

- Ensure that only Authorized Recyclers/dismantler handle your products and e-waste
- call us at our toll-free number regarding any questions on product, and e-waste
- Always drop your e-waste such as batteries, CFL bulbs, etc. when they reach the end of their life at your nearest e-waste collection points.

Don'ts:

- Do not dismantle or open your solar products on your own
- Do not give e-waste to informal and unorganized sectors like scrap dealers/ rag pickers.
- Do not dispose your product in garbage bins along with municipal waste that ultimately reaches landfills.

The elements of the awareness program should be defined in the e-waste management procedure, as part of the company Integrated Waste Management Plan.

## 8 EMERGENCY PROCEDURES

TDB's borrowers or sub-borrowers are required to develop and implement procedures to respond in the event of an imminent or actual emergency situation, (a release, fire, electrocution, explosion, etc.) related to e-waste management, and immediately identify the character, exact source, amount, and a real extent of the emergency.

The Emergency Preparedness and Response Plan for E-waste Management must be commensurate with the risks, and at the minimum include the following elements:

- Administration
- Pre-emergency planning,
- Emergency recognition and prevention,
- Emergency medical and first-aid treatment,
- Methods or procedures for alerting on-site employees,
- Safe distances and places of refuge,
- Site security and control
- Personal protective and emergency equipment,
- Evacuation routes and procedures. And
- Training and Awareness

In addition to the above requirements, the plan must include site topography, layout, prevailing weather conditions, and procedures for reporting incidents to local authorities.