# E-Waste Policy Handbook

Africa Clean Energy Technical Assistance Facility

Africa Clean Energy
Catalysing Africa's Solar Markets

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A TETRA TECH COMPANY

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**Department for International Development (DFID)**
**Africa Clean Energy Technical Assistance Facility**

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**Coffey International Development Ltd**

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# Abbreviations

| | |
|---|---|
| **ACE TAF** | African Clean Energy-Technical Assistance Facility |
| **CPCB** | Central Pollution Control Board |
| **DFID** | Department for International Development |
| **EPR** | Extended Producer Responsibility |
| **EU** | European Union |
| **E-waste** | Electronic waste |
| **GEC** | Green Electronics Council |
| **IRENA** | International Renewable Energy Agency |
| **ITU** | International Telecommunication Union |
| **Li** | Lithium |
| **MoEFCC** | Ministry of Environment, Forest and Climate Change |
| **NGO** | Non-governmental organisation |
| **OECD** | Organisation for Economic Co-operation and Development |
| **Pb** | Lead |
| **PRO** | Producer Responsibility Organisation |
| **PV** | Photovoltaic |
| **SHS** | Solar home systems |
| **SPCB** | State Pollution Control Board |
| **SPL** | Solar portable lanterns |
| **SRI** | Sustainable Recycling Industries |
| **StEP** | Solving the E-waste Problem Initiative |
| **WEEE** | Waste Electrical and Electronic Equipment |
| **WHO** | World Health Organization |



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# Executive Summary

## Benefits of the Off-grid Solar Sector

The societal benefits of off-grid solar solutions are undeniable: 120.3 million people now have improved energy access, 18.6 million sources of traditional lighting have been phased out and USD 192 of savings achieved, on average, per household. Off-grid solar is a healthier, safer and cheaper alternative to kerosene, batteries and candles. It also has the potential to lead to job creation both within the off-grid solar value chain, and for people using solar home systems in small businesses. At the same time, access to energy enables broader societal benefits including improved education and healthcare.

## End-of-Life Challenges

There are challenges when assessing the life cycle of off-grid solar products [Chapter 5], especially in ensuring proper collection and recycling of waste [Chapters 5, 6], considering that infrastructure to manage e-waste is lacking in many African countries, particularly in rural areas. The main source of e-waste is the battery of the off-grid solar product, which has a defined lifespan.

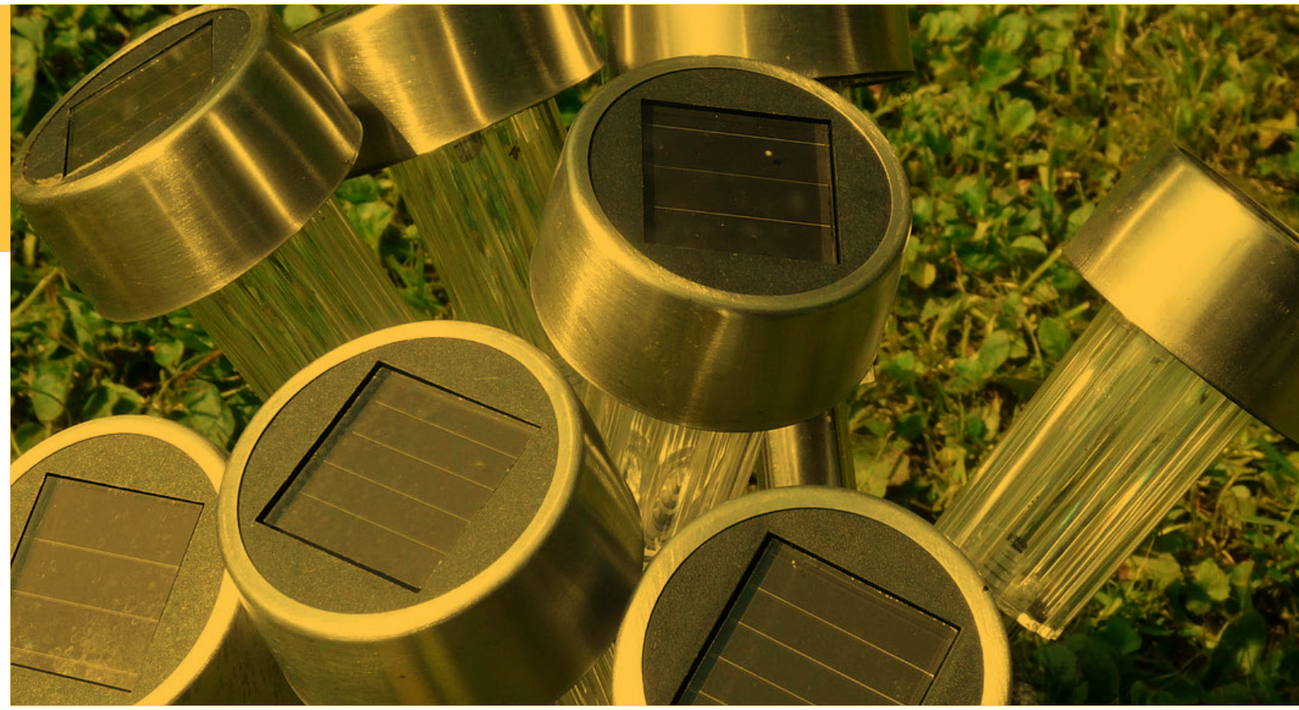
While policymakers and the industry strive to ensure sustainability of the off-grid system, key questions remain on how this can be achieved: can it be addressed through mandatory legal obligation? Or are there alternative approaches that are effective[Chapter 1]? Which is the most engaging process to ensure stakeholders are effectively involved in developing local solutions [Chapter 6]? How will the policies impact the adoption of off-grid solutions as viable clean energy alternatives for rural off-grid households [Chapter 3]?

## Local Context and Developments in Africa

In the last decade, some African countries have started to develop policies and regulations to manage hazardous waste, particularly e-waste [Chapter 2]. This process has been challenging, especially since examples of existing systems and legislations have been taken from developed countries where: (i) challenges of informal collection and recycling are less relevant, (ii) basic infrastructure for waste management is present, (iii) consumers and industry are generally aware of waste management practices, and (iv) off-grid solar products are hardly present.

## Policy Options for Industry

Irrespective of legal obligation for take back and recycling, alternative models exist, including voluntary – individual or collective – approaches, and incentives to encourage return of products from consumers [Chapter 3].



## Recycling Operations

There are three fundamental elements in designing and implementing sustainable solutions for e-waste management:

**Volumes and flows** [Chapter 4]: What quantities of waste are generated annually? What are the main routes of disposal from consumers? How can the volumes be best estimated? Modelling, surveys and literature can be combined to develop national baselines. Volumes and flows have direct impact on the dimensioning of proper collection and recycling infrastructure at national or regional level.

**Economics** [Chapter 5]: The main fractions resulting from recycling processes need to be identified, including what happens to them downstream. The intrinsic economic value of various product types and the economics of collection and recycling also need to be considered. The key question to ask is: how can the financials of the system be calculated to estimate the baseline for proper collection and recycling, and which are the main leverages for cost-effectiveness of the system?

**Engagement of consumers** [Chapter 6]: Off-grid solar companies have revolutionised the distribution of solar products, creating new business models to tackle the challenges of various customer segments. Although some of these models include important assets when it comes to end-of-life products, ultimately customers are the key interface between waste generated and any formal or informal collection and recycling system. Therefore, the engagement of consumers through proper campaigns and messages is crucial.

# Policy Development Cycle and Drivers for change

**This chapter looks at the various processes through which policymakers can increase their awareness about the various drivers for policy, and how they can work in partnership with other public and private stakeholders. The chapter also looks at the trade-off between presence of regulations, impact of end-of-life fees and adoption of off-grid solution, compared with other forms of incentives.**

## Chapter Objectives

- Familiarise policymakers with key terms, concepts and definitions
- Present an overview of common challenges and trade-offs
- Indicate key milestones in the roadmap for policy development and implementation
- Illustrate country/ regional experiences in developing e-waste policy and legislation.

## 1.1 Key terms, concepts and definitions for policymakers

This section presents the key terms, concepts and definitions that are frequently encountered in the larger system of e-waste management.

**Extended Producer Responsibility (EPR)** is a policy approach that allocates a significant role to the producers, specifically the responsibility for their products in the post-consumer phase. The important features of this approach are:

- It shifts the responsibility (fully/partially, financially/physically) up the value chain towards the producer and away from the municipalities
- It provides incentives to producers to factor environmental aspects into their product design and manufacturing. This encourages prevention or reduction of waste at source, better selection of materials, and support of public recycling and material management. Thus, EPR integrates environmentally beneficial characteristics throughout the product chain(See Figure 1).

The Development of Guidance on Extended Producer Responsibility (EPR) document[1] provides a good overview of compliance schemes or Producer Responsibility Organisations (PROs) and experience from its implementation in Europe across various waste streams. The OECD[2] also provides a useful analytical framework to evaluate the costs and benefits of EPR programmes.

## Objectives of EPR-based policy

Clear objectives should steer the entire process of adopting an EPR-based policy approach. Various aspects to consider include: diversion of waste from landfills; greater recovery of secondary raw materials, prevention of pollution from the current methods of handling e-waste or managing and disposing e-waste that is hazardous to human health and the environment. An effective and efficient e-waste policy precisely defines the objectives of the policy and the concerns that it addresses.

## Determining who is the producer

Under EPR regulation, legal obligation for compliance is with the producer, which makes it important to provide clarity in the definition of the producer. The most common definition of 'producer' is the manufacturer or importer or brand owner of the product. In some countries, producers and manufacturers are defined separately, as are distributors and importers (e.g. in India), but they all carry the EPR obligations if they are putting a product on the market. In practice though, leadership is vested in the producer. Shared responsibility is the essence of a successful EPR policy.

[1]Extended Producer Responsibility: A Guidance Manual for Governments, OECD, 2001
[2]Analytical Framework for Evaluating the Costs and Benefits of Extended Producer Responsibility Programmes, 2005



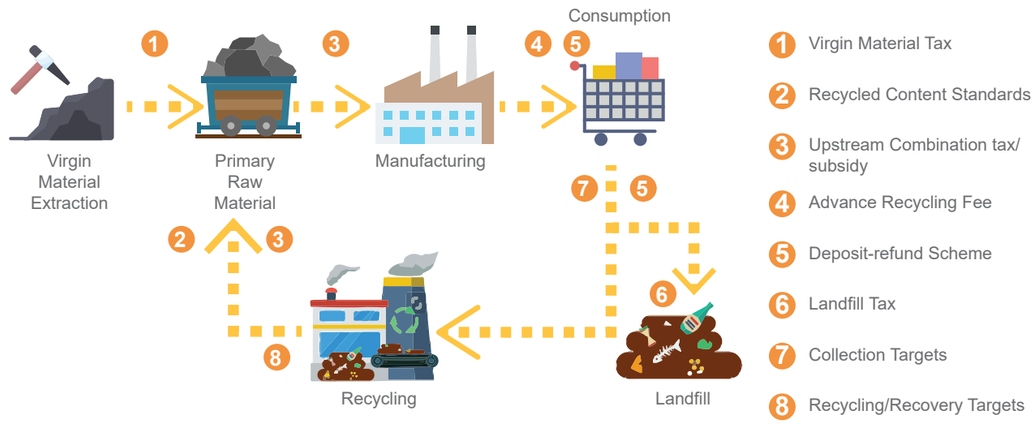
## Producer Responsibility Organisation (PRO)/ Compliance Scheme


*Figure 1: Responsibilities of a PRO/Compliance Scheme*

Producers can implement EPR policy either individually or collectively, that is, either through a PRO or a compliance scheme. A PRO can be for profit, e.g. European Recycling Platform (ERP) in Europe, or not-for-profit, e.g. the Waste Electrical and Electronic Equipment (WEEE) Forum. The PRO takes responsibility for operational aspects such as collection, transportation, and environmentally sound recycling and disposal of end-of-life products on behalf of the producers to meet EPR obligations. While a PRO is founded by producers collectively, a compliance scheme is similar, except that it is normally a for-profit company that provides services to producers.

### Economic instruments

To enable the financing of a system, there is often a fee that may be designated 'environmental fee', 'eco-fee', 'eco-levy', 'advance recycling fee', etc., depending on the regulation. Figure 2 shows various economic instruments at different points in the product life cycle. The OECD provides a useful criterion for evaluating economic instruments, including environmental effectiveness, economic efficiency, administration and compliance costs, revenues, wider economic benefits, soft effects, and dynamic effects.[2] Figure 3 illustrates the EPR financing mechanism of advance recycling fees as used in Switzerland.




*Adapted from Extended Producer Responsibility Updated Guidance for Efficient Waste Management*
DOI: https://dx.doi.org/10.1787/9789264256385-en

*Figure 2: Economic instruments along the product life cycle*

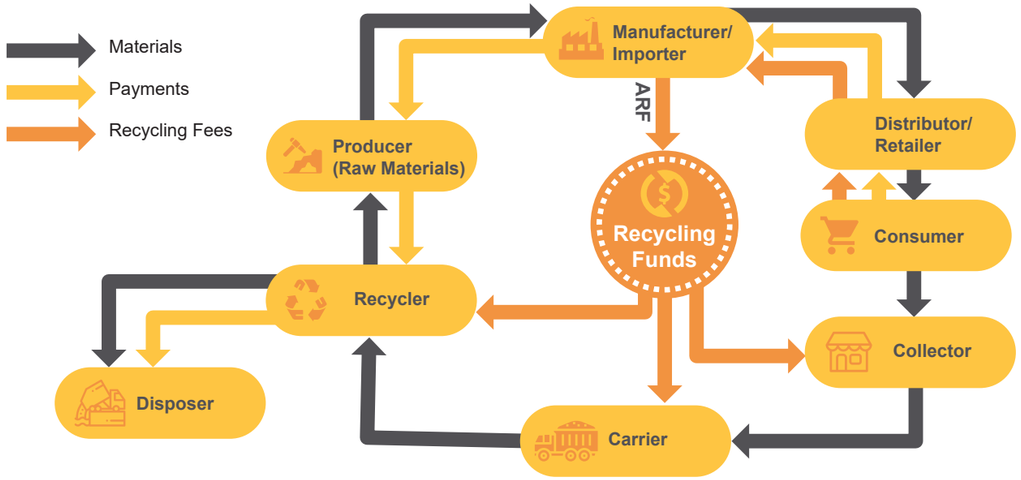



*Figure 3: System financing through advance recycling fees (ARF)*

### Informal sector

The Guidance Principles for the Sustainable Management of Secondary Metals (ISO IWA:19, 2017) categorises informal actors as those in economic subsistence activities, or unofficial economic activities. The former category includes recyclers who subsist on their recycling activities, while the latter category includes those who have profitable or even lucrative businesses that deliberately evade compliance with relevant regulations.

### Downstream value chain

The post-consumer value chain handling e-waste consists of stakeholders such as dealers/retailers, collectors, dismantlers, refurbishers and recycler/ material recovery operations mainly for metal and plastics.

### Product scope and characterisation

The types of products included under an EPR-based regulation may be very specific, including only certain products (e.g. in India, Taiwan, California) or broadly defined based on their characterisations (e.g. EU six product categories as shown in Table 1). Solar PV panels are also included in EU WEEE legislation.

*Table 1: EU e-waste categories*

| | Category | Weight/Size | Env/Health Impact | Material Value |
|---|---|---|---|---|
| | 1. Cooling and Freezing (CFCs) | HIGH | HIGH | MEDIUM |
| | 2. Screen | HIGH | HIGH | MEDIUM |
| | 3. Lamps with Mercury | LOW | HIGH | LOW |
| | 4. Large Houshold Appliances | HIGH | LOW | MEDIUM |
| | 5. Small Household Appliances | MEDIUM | LOW | MEDIUM |
| | 6. IT and Consumer Equipment | MEDIUM | HIGH | HIGH |

*It is important to also clearly identify and define waste and non-waste[3].*

[3]Technical Guidelines on Transboundary Movements of Electrical and Electronic Waste and Used Electrical and Electronic Equipment, in Particular Regarding the Distinction Between Waste and Non-Waste Under the Basel Convention, 2015



## 1.2 Overview of common challenges and trade-offs

Effective management of e-waste demands a comprehensive and structured approach This includes legal and institutional frameworks as well as physical infrastructure, which are often lacking in most developing economies, including ACE countries. The experience in many countries across the world of implementing e-waste policies and establishing e-waste management systems provides rich insights into the common challenges faced and potential trade-offs to consider. While some common challenges are given below, each country should consider its unique challenges based on factors such as geographic, demographic and socio-economic conditions, coupled with market maturity and industrial development.

### 1.2.1 Common challenges

#### Insufficient data on e-waste stocks, flows and routes

Many developing countries, including ACE countries, do not have robust data on the quantity of e-waste or solar waste generated annually, where the hotspots are, what routes the waste takes and where the flows end up. A baseline inventory on amount, type, composition, etc., of e-waste generated is necessary so as to build policies and strategies tailored to meet the needs of the country. There are various methods that can be used to make an estimate of the e-waste generated in a country[4,5]. The Global E-waste Monitor[6] provides statistically calculated average per capita e-waste generated per country, which provides a ballpark figure that should be supplemented with a local inventory.

#### Entrenched informal sector

The informal sector is often seen as a challenge, but also as an opportunity. Informal sector actors are common in most developing countries in waste collection, treatment and recycling. Informal recyclers who practice material recovery externalise environmental costs, in the process risking health, and air, water and soil pollution. Informal sector actors distort the market for formal recyclers and are often difficult to access and communicate with. For a sustainable solution, the informal sector should be integrated with the formal sector rather than displaced entirely[7,8].

#### Lack of awareness

Limited awareness on e-waste hazards is common in most countries. Awareness creation is required at all levels, from policymakers and other government operators to household consumers and all actors across the value chain. Studies[9,10] have shown there's need for communication and awareness programmes to encourage responsible consumer behaviour and efficient management of e-waste. Chapter 6 discusses this in more detail.

#### Lack of stakeholder engagement

Shared responsibility is an integral part of an e-waste policy. Failure to engage key stakeholders inhibits the development of a strong and efficient system. Draft legislations in several countries have been languishing for many years because of insufficient stakeholder engagement. On the flip side, strong stakeholder engagement ensures that workable solutions are found, such as in Colombia's experience[9].

#### Limited capacity (personal and technical)

There is limited capacity in terms of physical collection and treatment infrastructure in many developing countries. Compounding the challenge is the limited availability of human resources with the necessary skills and technical know-how on e-waste management at each level, whether government officials or dismantlers and recyclers. International cooperation and technical assistance have been instrumental in capacity building e.g. ewasteacademy.org, as well as in creating enabling conditions, providing support to demonstration projects and creating physical infrastructure e.g. the Global Environment Facility (GEF) projects.

#### Lack of enforcement

The main hurdle lies in the enforcement of regulations and ensuring that each stakeholder fulfils their duties and obligations. E-waste management involves various government departments, which largely work on distinct objectives and priorities. These departments will now have to coordinate their efforts. Since e-waste is a lucrative business, there is also the problem of corruption, which needs to be taken care of. Ultimately, the principle of shared responsibility should be upheld so that each player is aware and willing to contribute by performing their duties as outlined in the legislation.

[4]E-waste Assessment Methodology Training & Reference Manual, 2012
[5] E-Waste Statistics: Guidelines on Classification Reporting and Indicators, 2nd Edition, V. Forti et al, 2018
[6]The Global E-waste Monitor, 2017
[7]Bridging the Gap Between Informal and Formal E-Waste Producers, R. M. Panwal, 2018
[8]From Worst to Good Practices in Secondary Metals Recovery, SRI, 2017
[9]A Practical Guide for the Systemic Design of WEEE Management Policies in Developing Countries, SRI, 2017
[10]A Research on Electronic Waste Awareness and Environmental Attitudes of Primary School Students, O. Ercan et al. Anthropologist, 17(1): 13–23, 2014

## 1.2.2 Trade-offs

### System ownership and operation

Various models of e-waste management systems exist, ranging from a single state run system, to a hyper competitive market system in which there are multiple private sector actors providing operational services as part of the system [Chapter 3].

### Import and export bans

Import bans on e-waste are active in many countries, including ACE TAF[11a] countries, often under the Basel Ban Amendment, however, there are no restrictions on import of used electronics. Whether a country also bans the import of second-hand electronics along with e-waste is treated differently in various ACE countries depending on their market development. Similarly, some countries have export bans or barriers in place, restricting shipment of valuable fractions and metal scrap in order to develop their own industry, while others prefer to allow exports to the appropriate treatment facilities globally given the lack of such facilities in the country.

## 1.3 Key steps in policy development and implementation

Experience from international cooperation projects supporting the development of e-waste systems in developing countries is available in several reports[11].

The five key issues are:

1. Getting the system started: how to overcome inertia and bring stakeholders to act
2. Securing financing: how to ensure that the system is financially sustainable
3. Getting the collection logistics right: what the scope and logistics arrangements of the system should be
4. Ensuring compliance: how to ensure obligated actors fulfil their responsibilities
5. Correcting market failures: how to prevent anti-competition and unfair practices.

In many cases, a three-step approach has been used in policy development:

### Step 1: Country assessment of framework conditions

Reviewing existing legislation, stakeholder mapping, mass flow assessment (inventory) and an environmental and socioeconomic impact assessment [4,5,6,12,13,14]

### Step 2: Multi-stakeholder approach to developing a structured strategy

- Policy and legislation: reviewing existing legislations; establishing elaborate requirements for permits or licences; amending existing waste management legislation to allow for specific regulations on e-waste; harmonising with international regulations. The document[9] provides a detailed description and guidance for the development of e-waste policy, particularly for developing countries. The building blocks for developing a framework for e-waste management and implementing an e-waste policy can be found in guidance manuals by OECD[1,15]. The two reports from StEP[9,16] provide a useful framework for both system development and legislation.
- Business and finance: identifying and/or creating appropriate institutions to allocate the responsibilities (e.g. Producer Responsibility Organizations); developing appropriate systems to ensure long-term financial sustainability of an e-waste management system; and ensuring fair market conditions[17].
- Technology and skills: identifying, quantifying, and evaluating existing downstream material markets; developing and improving skills and capacities through training; developing business models;[11,18,19,20,21,22]
- Monitoring and control: establishing technical standards and auditing procedures for recycling processes; creating processes for data acquisition and continuous update for monitoring and control of an e-waste management system;[23,24,25]
- Marketing and awareness: creating awareness at all levels of governance and in the general public through multiple means, sustained over time [Refer to Chapter 6].

[11a] Ghana, Ethiopia, Kenya, Malawi, Mozambique, Nigeria, Rwanda, Senegal. Sierra Leone, Somalia, Tanzania, Uganda, Zambia, Zimbabwe.
[11] Recycling: From E-Waste to Resources, UNEP, 2009
[12] Sustainable Management of E-waste in the Off-grid Renewable Energy Sector in Rwanda, DFID, 2017
[13] Electronic Waste (e-waste) Impacts and Mitigation Options in the Off-grid Renewable Energy Sector, DFID, 2016
[14] Cost Benefit Analysis and Capacity Assessment for the Management of Electronic Waste (e-waste) in the Off-grid Renewable Energy Sector in Kenya, DFID, 2017



### Step 3: Implementing the strategy through a roadmap with assigned responsibilities and a timeframe

The implementation phase can be divided into immediate actions, mid-term solutions or long-term solutions. The following matrix can be used to establish a road-map for the implementation of an e-waste management strategy[26].

**Table 1: EU e-waste categories**

| | Type of Action/ Solution | Policy & Legislation | Business & Financing | Technology & Skills | Monitoring & Control | Marketing & Awareness |
|---|---|---|---|---|---|---|
| Pilot phase | | e.g. existing legislative framework | e.g. baseline financing gap; mapping stakeholders | e.g. baseline technical capacity | | e.g. engagement with stakeholders |
| Implementation phase | Immediate action | e.g. import ban on used/ waste refrigerators | | e.g. engagement and training of informal sector dismantlers/ recyclers | e.g. stopping illegal worst practices under existing legislation | |
| | Mid-term solution | e.g. strict purchasing and disposal policies led by government/green public procurement | | e.g. dismantling facility | e.g. develop independent auditing body | e.g. awareness campaign at school level |
| | Long-term solution | e.g. new legislation on e-waste | e.g. sustainable financing scheme | e.g. recycling technology transfer | e.g. establish online systems for monitoring and control | |

## 1.4 Country experiences in developing e-waste policy and legislation

### Europe

The EU WEEE Directive is based on the concept of EPR and has become one of the global standards for e-waste management. It is often used as an example as it represents a coherent and comprehensive set of requirements, especially when combined with the provisions of the Waste Framework Directive[27], the overarching environmental legislation of the European Union. The objective of the WEEE Directive encompasses all the stakeholders in the life cycle and encourages them to improve their environmental performance. The Directive, originally published in 2003,[28] went through a complete revision and the current version was published in 2014[29]. A more detailed analysis can also be found in[17].

[15] Development of Guidance on Extended Producer Responsibility (EPR), European Commission, 2014
[16] Developing Legislative Principles for E-waste Policy in Developing and Emerging Countries, StEP, 2018
[17] Financing Models for Sound E-waste Management in Ethiopia, UNIDO, 2015
[18] WEEE Recycling Economics: The Shortcomings of the Current Business Model, EERA, 2018
[19] National and International Downstream Markets for DMF E-waste Dismantling Fractions: Metals, Printed Wiring Boards and Plastics, StEP, 2015
[20] The Best-of-2-Worlds Philosophy: Developing Local Dismantling and Global Infrastructure Network for Sustainable E-waste Treatment in Emerging Economies, F. Wang et al, Waste Management, 2012
[21] End-of-Life Management of Batteries in the Off-Grid Solar Sector, GIZ, 2018
[22] E-waste Dismantling: An Entrepreneur's Guide, IFC, 2018
[23] WEEELABEX Normative Document on Collection V9.0
[24] WEEELABEX Normative Document on Treatment V10.0
[25] Introduction of a Management System of WEEE: WEEE Information System
[26] Case Study E-waste Management, M. Schluep, 2014
[27] Waste Framework Directive 2008/98/EC
[28] WEEE Directive 2002/96/EC (Original)
[29] WEEE Directive 2012/19/EU (Recast)

**Table 2: Development of e-waste management system – European Union**

| Year | Main Developments |
|---|---|
| 2000 | Proposal for WEEE Directive introduced; Already active PROs in Netherlands, Belgium etc. |
| 2003 | WEEE Directive is signed and comes into force. |
| 2004 | Deadline for Member States to transpose WEEE Directive into national legislation. Many Member States do not meet deadline. Anticipating legislation, wave of new PROs and compliance service providers start-up. |
| 2005 | Separate collection and treatment of WEEE financed through EPR mechanisms. Each Member State can design collection and financing mechanism as long as it meets WEEE Directive criteria (i.e. free for consumers at point of disposal). Producers to mark products with crossed out wheelie bin logo. |
| 2006 | Deadline to achieve collection targets (4 kg/inhabitant) and recycling targets (between 50–80% for reuse, recycling and recovery). |
| 2006 – 2012 | Review of the original WEEE Directive. Main changes include:<br>○ wider scope, including PV panels (previously excluded)<br>○ new collection targets (higher) and recycling targets (inclusion of preparation for reuse). |
| 2012 | New version adopted. |
| 2016 | Revised targets (45% put on market) enter into force. |
| 2018 | Entry into force of the 'open scope' (more appliances covered by legal obligations). |
| 2019 | Revised targets (65% put on market or 85% waste generated) enter into force. |

## Switzerland

Switzerland has been the pioneer in e-waste management legislation. The Swiss Federal Office for the Environment (FOEN) issued the Ordinance on the Return, the Taking Back and the Disposal of Electrical and Electronic Equipment (ORDEE) in 1998. Voluntary initiatives by producers, precursors to PROs, were started before the legislation and had put in place the formal collection and management of e-waste. Hence, while the legislation details the roles and responsibilities of stakeholders, the PROs have also stipulated a few of them. The flow of material and finance in the Swiss e-waste management system is shown in Figure 3.

**Table 3: Development of e-waste management system in Japan**

| Year | Main Developments |
|---|---|
| 1991 | Law for Promotion of Utilization of Recyclable Resources issued.<br>Aimed at promoting recycling to industries including design for recycling and use of secondary materials in production |
| 2000 | Above law was amended to include the following five concepts:<br>○ prevention of waste management by eco-design<br>○ extended life of electronics<br>○ design for recycling<br>○ reduction of recycling cost<br>○ creation of an information-sharing mechanism. |
| 2001 | Law for the Recycling of Specified Kinds of Home Appliances (often referred to as the 'Home Appliance Recycling Law') enacted.<br>○ Includes television sets, air conditioners, washing machines, dryers, freezers and refrigerators.<br>○ The system is financed by the consumers through purchase of recycling tickets.<br>  <br> |
| 2013 | Law for Recycling of Small Electronic Appliances (Small WEEE Law) enacted.<br>○ Voluntary schemes to collect mobile phones and personal computers resulted in low collection rates and other small items went to the municipal landfill.<br>○ The Small WEEE Law was developed to address these issues. |

**The transboundary movement of hazardous waste is controlled by the Basel Law and the Waste Management and Public Cleansing Law. The government also conducts awareness programmes and offers consultation services to companies, besides working closely with customs to inspect cargo and ensure compliance.**



## Japan

Japan is home to a highly advanced EEE manufacturing sector. Being an island nation, the limitation of natural resources and land for disposal sites acted as one of the driving factors to have an e-waste policy. Japanese consumers are considered to have strong recycling traditions. The road to e-waste regulation in the country is summarised in Table 3.

## Colombia

It was one of the first countries in Latin America to implement post-consumer programmes and a national e-waste policy in line with the principle of EPR. Colombia is an example of the benefits of early stage regulations and programmes, and fruitful collaboration for knowledge transfer. Table 4 gives an overview of the timeline and efforts that took place, resulting in the enactment of the national policy. For more information on the process of design and development of national policy for the integrated management of WEEE in Colombia, refer to Chapter 3 and the report by SRI[9].

**Table 4: Development of e-waste management system in Colombia**

| Year | Regulation/Programme |
|---|---|
| 2005 | National Environmental Policy for the Management of Waste or Hazardous Materials |
| 2007–08 | E-Waste Recycling Latin America, Phase 1 Assessment, bilateral cooperation between Colombia and Switzerland |
| 2009–12 | Enactment of resolutions (computers, lighting equipment, and batteries), 2010 |
| | National Policy on Sustainable Production and Consumption, 2010 |
| | E-Waste Recycling Latin America, Phase 2 implementation |
| | Post- consumption programmes for computers, lighting and batteries |
| 2013 | Enactment of Law 1672 for the integrated management of WEEE |
| 2014 | Support of the policy design with a systemic design |
| 2016 | Regulatory framework for the management of WEEE |
| 2017 | Enactment of National Policy for the Integrated Management of WEEE in Colombia |

## Costa Rica

Costa Rica was one of the first countries in Latin America to develop an e-waste management system, supported by Netherlands[30]. The process to start developing a WEEE management system started with three organisations:

- a non-governmental organisation (NGO) called Central American Association for the Economy, Health and the Environment (ACEPESA) supported by state university
- the Chambers of Industries of Costa Rica (CICR)
- an international NGO called WASTE, advisors on urban environment and development from the Netherlands.

The approach was based on the Integrated Sustainable Waste Management Model (ISWM) of understanding existing and necessary who, how and what elements of waste management. The country took a notable inclusive approach, making great effort to bring together all possible stakeholders with the goal of obtaining consensus on agreements.

The Decree for WEEE Management was approved in May 2010 after public consultations; Costa Rica was the first one to do so in Latin America. The entire process is summarised in Table 5.

[30]WEEE Resource Management System in Costa Rica, Abarca-Guerrero et al, Resources, 2018

**Table 5: Development of e-waste management system – Costa Rica**

| Phase | Objectives and Steps Followed | |
|---|---|---|
| Phase 1 (2003–04) Strategy Design for implementation of WEEE Management | 1. Baseline analysis<br>○ Literature review<br>○ Survey<br>○ Structured interviews<br>○ Field visits | 2. Strategy design<br>○ Analysis of WEEE management in Netherlands<br>○ Field trip to the Netherlands<br>○ National technical committee (CTN) formation |
| Phase 2 (2004–07) | 1. Decree approval<br>○ CTN Decree approval support | 2. Understanding the process<br>○ Learning exercises (with pilot project) |
| | 3. Community information<br>○ Collection campaigns<br>○ Mass media messages<br>○ Workshops<br>○ Conferences | 4. Experience systemisation<br>○ Project team |

## India

The e-waste discussion in India was started in 2004 and took until 2011 to have a specific regulation following a detailed stakeholder process involving industry, government and civil society. Table 6 provides a timeline of the main developments and overview of the drivers and outcomes. The most important lesson from the experience is perhaps that for industry to act and implement EPR, the government needs to take the lead in enforcing collection targets to create a level playing field for all[31].

**Table 6: Evolution of e-waste regulation – India**

| Year | Main Developments |
|---|---|
| 2004–2008 | A draft, based on hazardous waste and batteries legislations, was discussed at the first national level e-waste workshop in May 2006 under the Indo-German-Swiss E-waste Initiative. Based on EPR, extensive scope, same as the EU with 10 categories, but limited industry participation.<br>In 2008, first Guidelines for Environmentally Sound Management of E-waste issued. |
| 2010–2013 | EU supported SWITCH Asia project, facilitated stakeholder discussions and gave policy support. |
| 2011–2012 | E-waste Management and Handling Rules notified in 2011 and came into force in 2012, giving industry one year to prepare. |
| 2012–2014 | Regulation in force, but limited producer compliance. Public interest litigation at the National Green Tribunal (NGT) forces government to revise Rules with stricter compliance and enforcement. |
| 2014–2016 | Ministry conducts a year-long open consultation process on E-waste Rules, as part of wide-ranging review of all waste legislation. Revised Rules issued, with strengthened EPR framework; introduces collection targets for producers; introduces possibility of compliance through PROs; introduces e-waste exchanges and deposit refund schemes. Notified in April 2016, with enforcement to start in October 2016. |
| 2016–2018 | Teething troubles and industry lobbying forces amendments to 2016 Rules. Following closed consultations, Rules are amended to dilute collection targets, with incremental annual increases of 5% to eventually reach a maximum of 70%. Targets are also applicable on new producers in the market. |

[31]Framework of India's E-Waste, India Urban Development Gateway, UK India Business Council



# 2 E-waste Regulations Landscape in Africa and Internationally

**This chapter briefly looks at the existing landscape of e-waste policy in Africa, specifically in the ACE target countries. It also looks at policy interactions external to ACE target countries such as the Basel/ Bamako Convention, and examples of effective policies. It includes case studies from the solar sector, approaches to voluntary collection and recycling, and how solar companies have worked with waste management companies to improve e-waste adoption rates.**

## Chapter objectives

- Present an overview of international multilateral environmental agreements relevant for e-waste and solar waste
- Provide examples of existing policy, legislation and standards for e-waste and solar waste globally
- Map the current status of national e-waste and solar waste legislation in ACE countries.

## 2.1 International multilateral environmental agreements relevant to e-waste and solar waste

International conventions, treaties and agreements are considered one of the driving factors for promoting development of national frameworks, and providing a common point of reference relevant to e-waste and end-of-life solar products. These agreements provide a common platform for countries to begin the process of examining their situation, determining their needs, understanding the socio-economic and environmental impacts, and developing a regulatory framework to meet the objectives.

### Basel Convention (Global)

The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of hazardous waste. Its scope covers a wide range of wastes defined as "hazardous waste" based on their origin and/ or composition and their characteristics. It also covers two types of wastes defined as "other wastes" – household waste and incinerator ash. The provisions of the Convention centre around the following principal aims[32]:

- The reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes, wherever the place of disposal
- The restriction of transboundary movement of hazardous wastes except where it is perceived to be in accordance with the principles of environmentally sound management
- A regulatory system applying to cases where transboundary movements are permissible.

### Stockholm Convention (Global)

This treaty aims to eliminate or restrict the production and use of persistent organic pollutants (POPs). POPs are organic compounds that are resistant to environmental degradation, and their longevity has adverse impacts on human health and the environment.

The present 'alarmingly high levels' of certain POPs in e-waste entering the food chain around the areas where e-waste is burned or harmful processes are carried out have been widely discussed and governments called to act upon this pressing issue.[32]

### Bamako Convention (Regional)

This treaty, ratified by the Member States of the Organisation of African Unity, came into force in 1998 and focused on prohibiting imports and controlling movement of hazardous wastes within Africa. It was born out of the need to overcome certain issues that the Basel Convention was not able to address completely. The treaty prohibited imports of all waste without any exceptions and provided a much stronger tool to prevent trade of hazardous waste to less developed countries.

[32]Basel Convention Website

## Minamata Convention (Global)

A United Nations Treaty with 128 signatories and 105 parties, it is designed to protect human health and the environment from emissions and releases of mercury and mercury compounds arising from human activities. The unique properties of mercury make it attractive for use in the extraction of materials, manufacturing of goods such as electrical and electronic products, among others. There are also unintentional emissions of mercury as a result of power generation, cement production and mining. The Minamata Convention outlines measures related to the entire life cycle of mercury, along with controls and reductions across a range of products, industries and processes that use, release or emit mercury.

## 2.2 Examples of existing policy, legislation and standards for e-waste and solar waste globally

The EU has some of the most stringent environmental legislations and standards in the world, developed over decades. Waste management covers a wide range of activities and has legislations directed at different waste streams, from consumer goods such as end-of-life vehicles, packaging waste, batteries etc., to waste from specific activities such as extractive industries and industrial emissions. The WEEE Directive aims to promote re-use, recycling and other forms of recovery in order to improve the environmental performance of economic operators involved in the treatment of WEEE. The Directive sets criteria for the collection, treatment and recovery of WEEE. A 2012 amendment to the directive enlarged its scope to include photovoltaic (PV) panels. The associated directive, Restriction on Hazardous Substances (RoHS) restricts or bans the use of certain hazardous substances in the manufacture of electrical and electronic equipment[33].

The East African Communications Organisation (EACO) is an autonomous organisation that brings together stakeholders across the telecommunications, broadcasting and postal sub-sectors among six East African countries. The working group on e-waste and counterfeit gadgets management offers cooperation to:

- analyse the quantity of e-waste and its impact
- recommend best practices and environmentally sound e-waste management systems
- develop strategies for public awareness and education
- coordinate collaboration between different regional, national and international players.

The knowledge of solar waste is more recent compared with that of e-waste and hence has not found a separate space in the legislative framework. Developing end-of-life management schemes for solar PV panels, for instance, requires evaluation of the collection, recovery and recycling targets that mainly drive any waste management policy. There is also need to account for the different collection systems and the nature and design of products. This might become one of the drivers to simplify the design of the products to favour easier treatment of waste. A snapshot of the regulatory and non-regulatory frameworks in various countries specific to solar waste is presented in Table 7.

### Standards

The main internationally recognised standards for e-waste are the European Electrotechnical Committee for Standardisation (CENELEC) and WEEE Label for Excellence (WEEELABEX) standards from Europe, and the R2 and the Electronic Product Environmental Assessment Tool (EPEAT) Standards from the USA. Additionally, there are national standards such as the Swiss SENS/SWICO Technical Standard, as well as developments in Ghana, India, and Egypt, among others. A comparison of the European, American and Swiss standards can be found in SRI report comparing WEEE standards from Europe, Switzerland and the US[35].

CENELEC is responsible for standardisation in the electrotechnical engineering field in Europe. The EN 50625 Series of standards is meant to become the reference standard for WEEE treatment for Europe. It ensures that e-waste is collected, transported and treated in accordance with the WEEE Directive. The WEEELABEX organisation has been able to fully implement these in their accredited certification schemes, including PV panels.

The WEEELABEX organisation is a non-profit entity set up to train auditors in the WEEELABEX standards and to promote adoption of these standards in the Member States for better management of e-waste. Originally, WEEELABEX was a project (2009-12) with the objective of designing a set of standards with respect to the collection, sorting, storage, transportation, preparation for re-use, treatment, processing and disposal of all kinds of WEEE, and to put in place a process of monitoring companies through audits conducted by auditors trained by its office. Successful audits will result in operators and processes being listed on a publicly accessible WEEELABEX website. This procedure, whereby processes are audited and listed, is referred to as conformity verification (CV). Presently, there are WEEELABEX standards on treatment, collection and logistics covering all operators, regardless of size, focus of activities, geographic location, structure of the WEEE business, or legal status of the operator's business. The following are the standards:

- WEEELABEX Standard V9.0 on Collection[23] addresses all operations before the treatment (first physical modifications) i.e., all collection operations including the take-back of WEEE, handling, sorting, and storage, and preparation for transport of WEEE at the collection facilities.

**Table 7: Example of various regulatory and non-regulatory frameworks**

| Country | Regulatory and Non-regulatory Framework | Remarks |
|---|---|---|
| **Germany – Mature market with EU-directed, PV-specific waste regulations** | The Electrical and Electronic Equipment Act was revised in 2015 to reflect the amendment in the EU directive on WEEE to include solar PV panels. | |
| **UK – Young market with EU-directed, PV-specific waste regulations** | The UK WEEE legislation (transposing EU WEEE into national law) has specific rules to define PV producer and the EPR principle. The creation of a separate PV category will give the PV sector more control over financing PV panels collection and recycling. | Before the WEEE Directive, PV industry set up an own take back scheme (PV Cycle) that was establishing take back systems in each EU country, responsible for operations |
| **Japan – Advanced market without PV-specific waste regulations** | The end-of-life PV panels are treated under the general framework of the Waste Management and Public Cleansing Act[34]. The act defines wastes, industrial waste generator and handler responsibilities, industrial waste management including landfill disposal, etc. | In addition, the Construction Waste Recycling Law[34] prescribes how to manage construction and decommissioning waste. |
| **USA – Established, growing market without PV-specific waste regulations** | PV panels disposed in line with the Resource Conservation and Recovery Act, which is the legal framework for managing hazardous and non-hazardous solid waste. As the act does not include specific requirements for PV panels, they have to be treated under its general regulatory framework for waste management. | California is in the forefront of developing a regulation for the management of end-of-life PV panels within its borders, by moving PV panels from hazardous waste to universal waste.<br>Washington became the first state to pass the Solar Stewardship Bill (ESSB 5939) requiring manufacturers selling solar products into the state to have end-of-life recycling programmes for their products. |
| **China – Leading market without PV-specific waste regulations** | Waste Electrical and Electronic Product Recycling Management Regulation came into effect in January 2011. At present, however, PV panels are not included in the WEE products processing directory of the regulation. | The National High-tech R&D Programme PV Recycling and Safety Disposal Research provides policy and technology signposts for the future. |

[33]End-o-Life Management: Solar Photovoltaic Panels, IRENA & IEA-PVPS, 2016
[34]Waste Management and Public Cleansing Law, Japan: https://www.env.go.jp/en/recycle/basel_conv/files/Waste_Management_and_Public_Cleansing.pdf
[35]Comparison of WEEE-Standards from Switzerland, Europe and the US, SRI, 2015

- WEEELABEX Standard V10.0[24] on Treatment addresses all treatment operations, including preparing for re-use, handling, sorting, storage and treatment of WEEE (including the full treatment of hazardous fractions). The first part is the general requirements, addressing all operators involved in the treatment of e-waste. The second part includes specific requirements concerning CRT display appliances, flat panel displays, cooling and freezing equipment (temperature exchange equipment) and lamps, which demand special requirements.

- WEEELABEX Standard V9.0 on Logistics[36] addresses all logistics operations, including handling, sorting, storage and transport until the first treatment step.

EPEAT is the leading global ecolabel for the information technology (IT) sector. The EPEAT programme provides independent verification of manufacturers' claims, and the EPEAT online Registry lists sustainable products from a broader range of manufacturers than any comparable ecolabel. National governments, including the USA and thousands of private and public institutional purchasers around the world, use EPEAT as part of their sustainable procurement decisions. EPEAT's registry contains products belonging to these categories: servers, computer and display, imaging equipment, mobile phones and television. The Green Electronics Council (GEC) supports both IT manufacturers and purchasers to understand, commit and act upon the challenges of designing, manufacturing and procuring sustainable IT products (2.5).

R2 was designed by the Environmental Protection Agency (EPA) of the United States. It is a voluntary standard that is characterised by its global applicability and the fact that since its first publication in 2008, 511 operators in 17 countries have already been certified – more than by any other standard (as of March 2014).

The e-Stewards standard was created by an NGO known as Basel Action Network (BAN). Its creation was initiated by NGOs that had been involved in the design process of the R2 standard, but had not been happy with some directives (in particular, those about exports). As no satisfactory compromise could be made, these parties abandoned the R2 standard and initiated the e-Stewards project. Therefore, e-Stewards is more restrictive in general, especially in the areas of exports and the protection of human health. As of March 2014, there were 68 operators certified in three countries (United States, Canada and England).

Technical guidelines on environmentally sound e-waste management in Ghana[37] have been developed by the Environmental Protection Agency (EPA) with the support of the Sustainable Recycling Industries (SRI) project. ISO/IWA 19, Guidance Principles for the Sustainable Management of Secondary Metals, and the European Standards on Collection, Logistics and Treatment Requirements for WEEE–Part 1 General Treatment Requirements (EN 50625-1), were used as reference in developing the technical guidelines. The first draft, presented in 2016, was tailored to specific needs and challenges of stakeholders in the public and private sectors in Ghana based on the analysis of existing voluntary guidelines and standards in other jurisdictions. The later versions incorporated feedback that led to the extension of the guidelines with an approach that addressed the various target groups of the reverse supply chain of electronic and electric equipment becoming e-waste. The guidelines at hand specifically address the following five target groups: collectors, collection centres, transporters, treatment facilities, and final disposal.

The pilot version of the GreenCo rating system for e-waste recyclers[38] in India was developed by the Confederation of Indian Industry (CII) in collaboration with other national and international players. The objectives of this rating system are to have a performance monitoring system that caters to both local and international requirements, to strengthen the recycling chains by supporting upstream and downstream partners, to stay ahead of the compliance, and be prepared for future market. Focus areas are formed to help achieve the above objectives as shown below.

- General aspects address mandatory requirements that an e-waste recycler has to adhere to, requirements aligned to the operations of the facility, occupational ethics, occupational health and safety, and risk cover.

- Supply chain management aspects address requirements that need to be followed with vendors, partners and service providers, and during transportation of materials and products. The aspects also give credits to recyclers for implementing innovative projects and exhibiting exemplary performance over and above the requirements of the system.



- Material flow management aspects cover requirements with respect to basic accounting systems, material balance and frequency, material flow monitoring systems, dismantling and recycling efficiencies.

- Environmental management aspects cover the minimum and essential requirements that a recycler should meet with respect to safe and environment-friendly operating conditions namely, energy efficiency, water conservation and waste management.

## 2.3 Status of national e-waste and solar waste legislation in ACE countries

The status of e-waste regulation in the ACE target countries is outlined in Table 8.

Several international and regional partnerships and cooperation efforts have led the way in the development of regulatory frameworks and infrastructure required for the environmentally sound management of e-waste. Table 9 offers some examples.

**Table 8: National e-waste and solar waste legislation in ACE countries**

| Country | Comments |
|---|---|
| Kenya | E-waste Rules (Draft – January 2019)<br>National E-Waste Management Strategy |
| Rwanda | (In force, April 2018)<br>National E-Waste Management Policy |
| Uganda | (In force, March 2016)<br>Guidelines for E-Waste Management in Uganda |
| Tanzania | No specific policy or regulation related to e-waste management, but the National Information and Communication Technology Policy (2016) recognises the challenge of e-waste and the need for environmental laws and regulations to address it. |
| Ethiopia | No specific policy. The UN University (UNU), the UN Industrial Development Organization (UNIDO) and the US Environmental Protection Agency (EPA), in partnership with the Ethiopian Environmental Protection Authority and Ministry of Communication and Information Technology to implement an Ethiopian E-waste Management Project. |
| Somalia | No specific regulation for waste management. |
| Sierra Leone | The scope of the National Policy Roadmap for Integrated Waste Management includes e-waste along with four other waste streams (Draft). |
| Nigeria | National Environmental (Electrical/Electronic Sector) Regulations S.I. No 23 of 2011 to address the E-waste problem. |
| Senegal | No specific regulation on e-waste. |
| Malawi | No specific regulation on e-waste. The National Waste Management Strategy recognises e-waste as a significant, emerging waste stream in Malawi. |
| Zambia | No specific regulation on e-waste. |
| Zimbabwe | No specific regulation on e-waste. ZOL (Zimbabwe's leading Internet service provider) has partnered with EnviroServe (a UAE based recycling firm) and Econet to make the environment better through the responsible disposal of e-scrap by providing recycling services for electronic devices in this programme endorsed by the Environmental Management Agency. |
| Mozambique | No specific regulation on e-waste. |

[36]WEEELABEX Normative Document on Logistics V9.0
[37]Technical Guidelines on Environmentally Sound E-Waste Management for Collectors, Collection Centres, Transporters, Treatment Facilities and Final Disposal, Ghana, EPA, 2018
[38]GreenCo Rating for E-Waste Recyclers, India, GreenCo, 2018

**Table 9: Organisations involved in the development of regulatory framework and infrastructure required for the environmentally sound management e-waste**

| Organisation | Role |
|---|---|
| Department for International Development (DFID) | Commissioned studies on 'Sustainable management of e-waste in the off-grid renewable energy sector in Rwanda' and 'Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector'. |
| Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) | ○ Commissioned a study on 'Leveraging Formal-Informal Partnerships in the Indian E-Waste Sector' in 2017.<br>○ Involved in the Environmentally Sound Disposal and Recycling of E-waste project in Ghana, which is assisting the Ghanaian Ministry of Environment, Science, Technology and Innovation (MESTI) in improving the framework for sustainable e-waste management. |
| International Finance Corporation (IFC) | Its India e-waste programme is focused on developing a responsible and sustainable e-waste management ecosystem in India with the end goal of mobilising private sector investment. |
| United Nations University (UNU) | Its StEP Initiative is a collaborative, global effort to dramatically reduce e-waste through policy change, product re-design, re-use, recycling and capacity building. |
| United Nations Industrial Development Organization (UNIDO) | ○ The UNIDO-GEF project, Strengthening of National Initiatives and Enhancement of Regional Cooperation for the Environmentally Sound Management of POPs in Waste of Electronic or Electrical Equipment (WEEE), assists 13 Latin American countries both technically and financially, advising on e-waste policies and regulations, suitable management technologies, business models, capacity-building and awareness-raising.<br><br>Their e-waste initiative aims at addressing the full lifecycle of ICT equipment by properly dismantling and recycling it once the equipment has become obsolete. An e-waste dismantling facility will be piloted in Uganda and Tanzania. |
| United Nations Development Programme (UNDP) | ○ A safe health and electronic waste management programme in order to reduce emissions of harmful solid organic pollutants is implemented by the Ministry of Environment in collaboration with the Ministries of Health and Communications and Information Technology in Egypt.<br>○ UNDP China worked with Internet company Baidu and developed a mobile application called Baidu Recycle, which links end-users to legally certified e-waste disposal companies for safe disposal and recycling. |
| UN Environment | ○ Through its Switch Africa Green project in Ghana, jointly with the EPA and Ghana National Cleaner Production Centre, implemented a project on e-waste, and developed the Ghana e-waste model that formed the basis for the Hazardous and Electronic Waste Control and Management Act (2016). This led the government of Ghana to prepare for the setup of an e-waste recycling plant at Agbogbloshie. |
| Swiss Federal Laboratories for Materials Science and Technology(EMPA) | ○ Since 2009, commissioned by the State Secretariat for Economic Affairs (SECO), EMPA has supported the development of sustainable take-back and recycling systems for electronic waste in Colombia. |
| State Secretariat for Economic Affairs Switzerland (SECO) | ○ SECO launched a global e-waste initiative the 'Knowledge Partnerships in e-Waste Recycling' in 2003. The programme aimed to assess current e-waste management practices in India, China and South Africa, to design improvement recommendations and strategies, and to support the implementation of the most promising and urgent activities in pilot projects. |
| East African Communications Organisation (EACO) | ○ EACO is developing a five-year Regional E-Waste Management Strategy for its Member States. The strategy will help to sustainably and productively address the e-waste problem in the Member States. |
| Southern African Development Community (SADC) | ○ The Southern Africa Telecommunications Association (SATA) Secretariat has embarked on the drafting of the 'Guidelines for e-Waste Disposal'. The objective of these guidelines is to provide guidance for identification of various sources of waste electrical and electronic equipment (e-waste) and prescribed procedures for handling e-waste. |
| International Telecommunication Union (ITU) | ○ ITU develops reports, toolkits and educational material to raise awareness on e-waste among its Member States, sector members and academia on e-waste. It also provides direct assistance in planning and implementation of e-waste management techniques. |
| International Renewable Energy Agency (IRENA) | ○ Prepared the 'End-of-life Management: Solar Photovoltaic Panels' report, jointly with the International Energy Agency Photovoltaic Power Systems Programme (IEA-PVPS). It is the first-ever projection of PV panel waste volumes up to 2050. |



# 3 Typology of E-Waste Compliance Schemes

Proper collection and recycling of e-waste can hardly happen without either a legal obligation, or a voluntary initiative from industry (producers and importers or waste holders). This is because the exploitation of the economic value embedded in products might create environmental and human health impacts if not done properly[39]. The situation is particularly aggravated in developing countries where recycling and separation of e-waste has become a major source of income.

Even where some formal recycling infrastructure exist, the risks created by unfair competition from informal recyclers might create an economic barrier to accessing waste for legitimate recyclers. In developed countries as well, where formal recycling infrastructure with state-of-the-art technologies exist, evidence of competition distortion caused by substandard treatment is available.[18]
In many cases, the costs of proper collection and recycling of e-waste[13,14] exceed the revenues generated from recovered materials, and this is why control over operations and eventually a proper financing mechanism are needed.[17]

### Chapter objectives

- Present an overview of alternatives available in collection and recycling for off-grid solar sector
- Compare voluntary approaches with legally binding ones
- Identify main pros and cons when setting up collection and recycling operations using alternative mechanisms

[39]E-Waste and Harm to Vulnerable Populations: A Growing Global Problem, EHP, 2015
[40]An efficient & effective E-waste Collection System for Ethiopia, Oeko-Institut, 2015
[41]GOGLA Industry Opinion on Life Cycle and Recycling, 2014

## 3.1 Alternatives for collection and recycling

### Business as usual scenario

If e-waste management is left to market dynamics, two main options exist:

- For the few formal recyclers active in various countries in Africa, the costs for proper collection and treatment of the products have to be paid by the person or company disposing of the product unless the intrinsic economic value is high enough to cover them (unfortunately, this is only possible for very few products that are metal dominated).
- A large number of informal collectors and recyclers extract, using rudimentary and often hazardous and polluting technologies, the economic value of some components, and re-sell functioning components on the refurbishment market, neglecting the proper and environmentally sound disposal or treatment of all the other fractions[40].

### Voluntary take back and recycling

Even in the absence of legal obligations, industry might do collection and recycling on a voluntary basis. This is the case for the PV industry in Europe. Before the inclusion of panels in the scope of the WEEE Directive, PV CYCLE, founded in 2007 in the context of the European Photovoltaic Industry Association (EPIA), was the first pan-European producer scheme for the treatment of photovoltaic waste. PV CYCLE expanded its operations to Japan. Voluntary approaches are also encouraged in countries such as Australia where in 2016, the government announced that PV systems might be included in the scope of the Product Stewardship Act, either in some form of accreditation or regulation.

In some cases, companies that have e-waste to discard are willing to pay for proper collection and recycling. This is mainly linked to corporate social responsibility or internal waste management policy, and is the case for institutions such as banks, telecom providers, international organisations and

other representatives of the private sector.

Across Africa, most off-grid solar companies proactively organise take back and recycling of their products[14]. This is done to support internal repair and refurbishment operations, sometimes creating low-cost entry-level products for other customers, or ensuring management of the faulty products during the warranty period.

Industry players, from back in 2014, have shown strong interest in ensuring sustainability of business models and access to energy.[41]

## Mandatory take back and recycling

Under mandatory take back and recycling, a few key elements are necessary to help distinguish various approaches. These elements include the following:

Roles and responsibilities of the stakeholders involved in the end-of-life chain should be addressed, particularly in respect of daily operations and financing implications.

If producers are requested to finance operations (under EPR principle), or waste holders (e.g. Japan), or consumers (e.g. California[42,43]).

If producers have organisational and operational responsibilities (e.g. Europe[29]) or not (e.g. China, Taiwan or Ghana).

Definition of the scope of the legislation, and particularly if off-grid solar products are inside or outside the scope. This is especially so in regard to PV panels and batteries, and how they are classified.

## Approaches to running operations

Whether take back operations are done on a voluntary basis or under mandatory legal obligation with organisational responsibility, there are various alternatives a company or the industry as a whole can pursue:

- Sign a contract with a recycler active in the country – This is the easiest and quickest option. The process might include a visit to check operations, control of licensing and other aspects, and definition of contractual agreements[44]. A single recycler can offer nationwide coverage working with a network of partners.
- Sign a contract with an intermediary (e.g. waste broker, waste management company, service integrator), who is responsible for identifying other partners to ensure operations and offer full compliance service with national or regional coverage, against the payment of a fee.
- Set-up and/or join a compliance scheme (or PRO) which takes over obligations on behalf of the members. Members contribute financially through payment of a fee.

There are pros and cons for each of the options, depending whether it is a single company or the industry as a whole. Sometimes, the general interest might not necessarily be optimum for the individual company. For instance, a single company might negotiate better take back and recycling conditions with one or more recyclers, depending on the specific product portfolio or material composition (e.g. if Pb-batteries are used instead of Li-batteries), but the effort of searching for a partner, ensuring operations are compliant and maintaining the relationship might be daunting. Table 10 summarises the options, taking the industry perspective; in some cases, the pros of one alternative might be seen as cons in another one.

## 3.2 Comparison of approaches

There are advantages and disadvantages from an industry perspective of the various approaches to collection and recycling. These are summarised in Table 11.

[42]California Senate Bill No. 50, September 2004
[43]California Senate Bill No. 20, December 2002
[44]E-waste Toolkit Module 1 Briefing Note: Technical Introduction to Recycling of Off-grid Solar Products, GOGLA



**Table 10: Overview of pros and cons in setting up operations or purchasing a compliance service for take back and recycling**

| | Purchase Compliance Service Directly via a Single Recycler | Purchase a Compliance Service via Waste Management Company | Set Up and Control a PRO |
|---|---|---|---|
| **Ease of implementation** | Medium | Medium | Easy |
| **Set-up effort** | Low | Low | High |
| **Advantages** | ○ **Some control over quality and technical standards –** Contractual power to push/enforce desired standards might be limited and depends on size of the individual client.<br>○ **Easy to implement and control –** No need to compromise with other industry members; full decisional power.<br>○ **Easier and quicker in reacting to needs –** As any other supplier might be keener to react timely to requests of new services and changes. | ○ **Cost optimisation working with different recyclers –** Service integrator usually works with a network of recyclers, choosing the best configuration possible.<br>○ **Easy to implement and control**<br>○ **Easier and quicker in reacting to needs** | ○ **Not for profit –** Costs for operations are shared as they are. No mark-ups.<br>○ **Each OEM has same contractual conditions (level playing field) –** All members have same conditions and pay the same fees (per unit or kg of product placed on the market or recycled).<br>○ **Minimise compliance cost for OEMs –** PRO exclusively pursues the interests of its members, including continuous reduction of compliance costs through tenders involving various recyclers and/or service integrators. The negotiation power of the PRO is bigger than that of individual companies.<br>○ **Full control over quality and technical standards –** Negotiation power is high since the entire industry (or part of it) is represented.<br>○ **Full transparency on costs and revenues –** Balance sheet and how compliance fees are related to operational costs are known (budgeted) for members.<br>○ **Full transparency on contracts –** Contracts with recyclers are known.<br>○ **Can contract multiple service providers, including integrators and recyclers –** PRO can set up a network of partners to ensure operations or contract service providers to simplify the start-up phase (same cons listed in the service provider option).<br>○ **PRO becomes a recognised stakeholder in the system –** This brings more lobbying and advocacy power as industry is represented by a single player with more knowledge and power. |
| **Disadvantages** | ○ **For profit –** Clients are charged a mark-up.<br>○ **OEMs will have different confidential individual contracts –** Since each client has confidential conditions unique to them, some may be disadvantaged and not know that they can get a better deal.<br>○ **Capacity cap –** A single recycler might have a capacity cap. In case other recyclers are involved, usually a mark-up is added by the recycler holding the contract with the company.<br>○ **Best chance to reduce the fee is by changing recycler –** This is due to limited contractual negotiation power. | ○ **For profit –** In addition to the mark-up of recyclers and logistics providers, the integrator has his own margin.<br>○ **OEMs will have different confidential individual contracts.**<br>○ **Best chance to reduce the fee is by changing compliance provider.**<br>○ **Service fee includes a margin sufficient to hedge against market prices –** While contracts with recyclers might be "indexed" on the main commodities to ensure big fluctuations are somehow compensated, contracts with service providers are usually not considered.<br>○ **No/limited visibility on costs and revenues.**<br>○ **No/limited visibility and control on contracts –** These are not known to the client of the service provider; usually, liability and other re-assurance against potential illegal activities carried out by recycler, with potential reputational risk for the company, need to be defined in the contract with the service provider (in case the company has enough negotiation power). | ○ **End-of-life management no longer a competitive advantage of a single company –** All the members of the PRO can claim the same environmental benefits for end-of-life management.<br>○ **Effort in start-up phase and need to accept compromises with other members –** All the companies might not have the same strategy; discussion on potential cross-financing between various products type might happen (e.g. Pb vs Li batteries). |

**Table 11: Comparison of collection and recycling approaches**

| | Business as Usual | Voluntary Approach | Legal Obligation |
|---|---|---|---|
| **Advantages** | Lower (if any) financial implications. | ○ Industry can fine-tune the level of financial commitment.<br>○ Free to organise operations.<br>○ Opportunity to develop alternative business models, services, customer retention programmes. | ○ When properly enforced, there is a level playing field and end-of-life management is no longer a competitive advantage or a burden only a few companies share.<br>○ Clarity on roles and obligations. |
| **Disadvantages** | ○ Reputational risk related to potential drawback for improper local treatment of waste.<br>○ No chances to develop strategic projects or engage consumers in offering repair/recycling services. | Might be a financial disadvantage compared to those companies not doing it (unless take back operations generate more business opportunities). For majority of products (except Pb batteries alone) the full net cost is negative. | ○ Freedom to organise operations might be limited by law or organisational setup (e.g. Ghana, China, Taiwan).<br>○ Financial implication to be considered in advance.<br>○ When not properly enforced might penalise more responsible companies. |

## 3.3 Enabling factors for take back and recycling

Irrespective of the willingness of the private sector to ensure proper collection and recycling on a voluntary basis, or their legal obligation to do it, there are fundamental enabling factors that need to be considered outside the responsibilities of producers in any EPR-based legislation; actual opportunities for producers; and financial capabilities. These include:

The availability of national players adopting suitable technologies for pre-processing (de-pollution or removal of hazardous components) and segregation of various fractions and components for further processing and recovery/disposal. This can be done manually, which has been demonstrated to lead to very good results from an environmental and economic perspective,20 or eventual adoption of mechanical processes where suitable.

- The availability of collection infrastructure, particularly in remote and rural areas, where waste could be consolidated and stored prior to transportation.
- The availability of local or international accessible markets for the proper disposal of hazardous fractions/components, or the final recovery and economic valorisation of valuable fractions resulting from the pre-processing stage. In many African countries, local markets for final recovery can be found for base metals like steel, copper, aluminium, and sometimes plastics. For more complex fractions, local recyclers need to rely on international players,[19] despite some countries banning export of certain waste fractions.
- Creation of favourable conditions for transboundary shipment of troublesome fractions to developed countries is important. This is because, in the short term, it is not possible to establish processing capacity for all fractions, and the volumes are also not sufficient. For valuable fractions, it is also important to allow export to enable local recyclers to profit from the materials they have in stock (for printed circuit boards the value can be more than USD 1,000 per metric ton of material, and a full load constitutes a huge financial capital).
- Consumer awareness is paramount since consumers are the interface between the waste and a formal take back and recovery system. It's crucial to explain to consumers the importance of proper end-of-life management for off-grid products. This could also help tackle the unfair competition of informal recyclers and prevent consumers from asking for financial compensation[40] for disposal of the products – which sometimes creates a big financial barrier to proper recycling and increases the costs of the system – at least when they are collected for recycling and material recovery.
- Enforcement of legislative provisions, particularly in respect of financing and proper recycling is vital to ensuring a level playing field in the industry and avoiding market distortion. Companies bearing financial obligations for e-waste management or recyclers investing in suitable treatment processes may be economically disadvantaged compared to informal ones[18] if enforcement is not done.



# 4 Basics of Solar E-waste Recycling

This chapter explains what an off-grid solar system is in terms of waste fractions, the hazards it has and how they can be handled responsibly by waste management companies.

## Chapter objectives

- Discuss the volume and mass of e-waste and solar waste
- Enable understanding of the material composition of e-waste and solar waste
- Present an overview of technical treatment and recycling requirements

## 4.1 Quantification of e-waste and solar waste generation

The Global E-waste Monitor provides a ballpark figure of per capita e-waste generated in a country based on statistical estimates.[6] The main components of an off-grid solar product include:[44]

- Solar panels
- Batteries – lithium-based or lead acid
- Lamps (mainly LED)
- Control units with circuit-board-mounted electronic controls
- Cables
- Metal frames and fixtures
- Connected devices/appliances (TVs, radios, fans, etc.).

Estimates can be made on the waste arising from solar products in a country by considering the quantities of off-grid solar products put on the market, the typical weight for each component as reported in Table 12 and the typical lifetime of components as indicated in Table 13. This is the 'sales-lifespan' model, in line with the common methodology adopted by the European Commission. In some cases, the life cycle of the entire system (e.g. SHS or street lighting) might be longer than the lifetime of the batteries, and thus different substitution cycles might happen in between. Estimates of e-waste and solar waste in some countries are presented in the DFID reports,[12,13] the Oeko-Institut report[45], as well as the IRENA report.[33]

Estimations can also be carried out by adopting the same model, and considering:

- sales data (in weight), provided by the industry or retrieved via custom statistics[5]
- lifespan profiles, to be generated through local consumer surveys.[46]

Detailed inventory and assessment of e-waste generated can also be done by analysing the stock of products in households and the disposal habits of consumers using existing methodology and tools, as detailed in the UNEP manual.[4]

[45]Report on the Fact-Finding Mission on the Management and Recycling of End-of-life Batteries used in Solar Home Systems in Myanmar, Oeko-Institut, 2018
[46]Household WEEE Generated in Italy: Analysis on Volumes and Consumer Disposal Behaviour for WEEE, F. Magalini et al, 2012

### Table 12: Overview of off-grid solar products components

| Products | Lanterns | Solar Home Systems | Street Lighting |
|---|---|---|---|
| Description | Single or multi-light systems, which may or may not enable mobile charging | Typically powering several lights as well as other appliances (e.g. fan, TV, etc.) | Streetlight with solar panel |
| Main components | Solar panels (400 g)<br>Battery (100 g)<br>LED (30 g)<br>Plastic casing (200 g)<br>Steel (160 g) | Solar panels (3–10 kg)<br>Battery (10–25 kg)[4]<br>Charge controller and/or an inverter (150–900 g)<br>Cables (1–2.5 kg)<br>LED (100–150 g)<br>Not including connected devices | Solar panel (5–13 kg)<br>Battery (30–100 kg)<br>Controller (150–900 g)<br>Lighting fixture (4–15 kg)<br>Pole (130–250 kg)<br>Cables (2–3 kg) |
| Common type of batteries | Lithium iron phosphate (LFP), Lithium manganese oxide (LMO) | LFP, LMO<br>Lead-acid | LFP, LMO<br>Lead-acid |

### Table 13: Indicative lifetimes and material compositions of off-grid solar product components[47]

| Solar Product Components | Expected Lifetime | Typical Material Compositions |
|---|---|---|
| PV panels | >10 years | Crystalline silicon, glass, aluminium, copper, trace elements (indium, tin, gallium, etc.) |
| Control devices | 5–15 years | Printed circuit boards, solder paste, various electrical and electronic components, plastics, etc |
| Batteries | 2–6 years | Lead-acid batteries: lead, lead oxide, plastic, electrolyte (sulphuric acid)<br>Li-ion batteries: graphite, various organic substances, copper, aluminium, lithium, plastics, etc |
| Cables | >10 years | Copper, plastic insulation |
| Connected EEE (lamps, radios, fans, TVs) | 2–10 years | Various plastic types, aluminium, copper, various electrical and electronic components |
| Solar lanterns | 3–5 years | PV panel, Li-ion battery, LEDs, printed circuit board, plastics |

## 4.2 Material composition of e-waste and solar waste

A range of materials are used in EEE (devices connected to SHS) and in off-grid solar products themselves (PV modules, batteries and control panels). Some of these materials are metals, including precious ones (such as gold, platinum and palladium mainly contained in printed circuit boards), and others such as copper, aluminium (non-ferrous) and iron (ferrous). Metals (both ferrous and non-ferrous) comprise about 60 per cent and plastics a little over 25 per cent of the total mass of mixed e-waste, although the composition differs from product to product. The other fractions make up the balance, with the high value fraction of printed circuit boards (PCBs) constituting approximately only three per cent of the total mass. In terms of value, the share of revenue from the various fractions is quite different.

E-waste and solar waste consist of hazardous and valuable fractions, described in various sources.[12] The hazardous fraction makes up only about one per cent or less of the total mass of solar and e-waste. This fraction consists of batteries, lamps, cooling agents from refrigerators and air conditioners, CRT screens, etc., and must be separated from other fractions, and treated further or disposed through special treatment (e.g. incineration or hazardous waste landfill). However, due to the relatively small volumes, and the high costs associated with disposal of these hazardous fractions, proper management methods are often overlooked, especially in informal systems.



### Table 14: Average composition of SHS, SPL and connected devices

| Material | SPL | MLS | SHS | PV Module | Washing Machines | Fridges | Air Conditioners | Desktop | Laptop |
|---|---|---|---|---|---|---|---|---|---|
| Steel | 13% | 30% | 30% | | 50% | 46% | 45% | 70% | 16% |
| Copper | | 4% | 4% | 1% | 2% | 2% | 22% | 4% | 2% |
| Aluminium | | | | 10% | 3% | 2% | 2% | 6% | 34% |
| Pb batteries | | 30% | 30% | | | | | | |
| Li batteries | 67% | | | | | | | | |
| PV modules | | 29% | 29% | | | | | | |
| CFL (Hg) | | | | | | | | | |
| LED | 20% | | | | | | | | |
| Plastics (incl. BFR) | | 6% | 6% | 11% | 13% | 35% | 20% | 16% | 7% |
| Glass (CRT) | | | | | | | | | |
| Glass | | | 3% | 74% | 2% | 10% | | | 5% |
| PWB/ electronics | | 3% | 30% | | 2% | 1% | 2% | 1% | 10% |
| Concrete | | | | | 23% | | | | |
| Silicon | | | | 3% | | | | | |
| Other | | | | 1% | 5% | 3% | 9% | 4% | 26% |

## 4.3 Technical treatment and recycling requirements

Despite the wide range of electronic products (upwards of 700), they are usually collected and treated in waste streams depending on the treatment process needed. For many of them, a manual disassembly can ensure proper removal of hazardous components and the recovery of valuable fractions. It is crucial to have access to local or international markets for proper management of the hazardous fractions and for economic valorisation of the valuable fractions. In western countries, heavily mechanical and automated processes are widely used, mainly due to high labour costs and the necessity of processing high volumes in order to achieve economies of scale. Specific technical processes are required only for:

- Treatment of energy saving lamps (containing mercury) and mercury containing backlights of LCD screens
- Removal of cooling agents from refrigerators and air conditioners
- Shredding of refrigerators containing ozone depleting substances like chlorofluorocarbons (CFC) and hydrofluorocarbons (HCFC), which are used as blowing agents in insulating foam
- Treatment of CRT screens, in case the facility is aiming at treating the tube itself (cutting, removal of coating on the panel and separation of Pb-containing glass – the funnel).

Detailed descriptions of specific technical processes for dismantling and proper management of these fractions may be found under the UNEP and GIZ reports[48,49], and in the technical datasheets of individual vendors.

Research on recycling of PV products indicates that a large majority of the products' components can be recycled – almost 90 per cent of the materials recovered from solar panels can be recycled into useful products. For off-grid solar products, simple mechanical disassembly results in separation of clean fractions of aluminium, copper (in the form of cables), steel, plastics, etc., from hazardous components such as batteries, lamps, plastics containing brominated flame retardants (BFR), and PV panels. The clean fractions can be sent for direct valorisation to existing downstream vendors. Aside from the dedicated technologies required for connected devices, as mentioned above, specific and dedicated technologies are also required for the following resulting fractions of solar products:

- Pb batteries[47]
- Li-based batteries
- PV panels[50].

[47]E-Waste Treatment Facility in Uganda Business Plan, UNIDO, 2014

**Lead-acid batteries,** by weight, consist of about 65 per cent lead and lead oxide, and 10–15 per cent sulphuric acid. Lead is a highly poisonous heavy metal with numerous adverse effects on human heath when swallowed or inhaled, and can lead to death. Sulphuric acid can cause skin burns and eye damage through direct contact, and its improper disposal contributes to acidification of the environment. Therefore, proper management of Pb batteries is of utmost importance. Fortunately, due to the high lead content, stable market and attractive prices, a large percentage of waste lead-acid batteries are collected and recycled across the world. However, best practices are yet to be adopted in many parts of the world to ensure that health and environmental considerations are made.

While the toxic potential of **Li-based batteries** is significantly lower compared to those of lead-acid batteries, Li-ion batteries are associated with safety risks. Overcharging, high temperatures and physical stress to battery cells may cause thermal runaway, which can lead to the destruction of the battery, fire and or explosions.[21] Therefore storage and transport of these batteries must be done in an appropriate manner. Since Li-based batteries have limited recycling value and require specialised technology based on their specific chemistries, they are more likely to be disposed of in an uncontrolled manner. Recycling of Li-ion batteries is a rather new field and currently only done by a few plants such as Umicore (Belgium), Retriev Texchnology (USA), American Manganese (Canada), Accurec (Germany) and Redux Recycling (Germany).

Additional information on Pb batteries and Li-ion batteries waste management, and the environmental and health risks associated with them may be found in various referenced reports and documents.[13,44,45,47]

Due to insufficient PV waste quantities currently on the global waste market, and not enough economic incentives, dedicated PV panel recycling plants have not been created. End-of-life PV panels are thus typically processed in existing general recycling plants. Here, mechanical separation of the major components and materials of PV panels is the focus. This still achieves high material recovery (up to 85 per cent) by panel mass even though some higher value materials (that are small in mass) may not fully be recovered.[33] The most difficult fractions to recover from PV panels are the crystalline silicon wafers. Most PV panel recycling is currently carried out in a rudimentary manner by regional waste management companies that often treat PV panels like glass. The recycling process starts with the removal of the aluminium frame. When done manually, this often shatters the glass and renders any further separation of components impossible thus leaving glass with small traces of silver and other materials, which are often passed to local cement industries. If the aluminium frame is dismantled properly, then further mechanical separation of the glass from silicon wafers and back foils can be done.
A high-value recycling approach is now the foundation for the WEEE Directive and ensures the following:[33]

- Potentially harmful substances (e.g. lead, cadmium, selenium) will be removed and contained during treatment
- Rare materials (e.g. silver, tellurium, indium) will be recovered and made available for future use
- Materials with high embedded energy value (e.g. silicon, glass) will be recycled
- Recycling processes will consider the quality of recovered material (e.g. glass).

For full and complete recycling of PV panels, advanced recycling technologies exist in some facilities in Europe.[44] In the process of identifying suitable technology to be adopted in the country, the following parameters should be considered:

- Type of technology – detailed process description, type of waste handled, products (if any), emissions, job potential and available capacities
- Operational and technical details including parameters and specifications for procurement, operation and maintenance requirements
- Environmental and social considerations, particularly those linked to job creation, and health and safety
- Investment and operating costs
- Institutional and regulatory requirements.

The Global Off-Grid Lighting Association (GOGLA) briefing note[44] provides an overview of off-grid solar products, their components and fractions, the environmental and safety hazards of each fraction, safe storage, handling and transportation of components, details of how and where the fractions are recycled, and how to choose an e-waste management provider. The document also lists additional resources that give more comprehensive insights into each of the stages.



While the recycling of waste PV modules has already begun to be commercialised, various technologies for PV module recycling are under development in order to improve process efficiency, economics, recovery and recycling rates, and environmental performance. The IEA-PVPS report[50] provides an overview of trends in the development of PV module recycling technologies from the perspective of patents and national R&D projects, and addresses expected upcoming issues related to these technologies. In addition, the IRENA report[33] details the main actors involved and some recycling technologies for PV panels researched over the past 15 years.

The SRI fact sheets[8] are a set of useful documents that give a comprehensive insight into poor recycling practices often observed in developing countries, and their negative health and environmental impacts. The document also provides suggestions and a step-by-step guide to transitioning to good waste management practices.

IFC's e-waste dismantler toolkit[51] focuses on the operational aspects of dismantling: tools required, environmental and health aspects; training requirements and general guidelines for dismantling activities; and areas of caution while carrying out such activities. The guide also provides references to multiple international resources that give detailed and comprehensive dismantling instructions for the various types of e-waste.

UNEP's report on recycling e-waste[11] provides a comprehensive analysis of pre- and post-processing technologies available for the e-waste recycling sector, and the market potential of relevant technologies in selected developing countries. It also examines the application of transfer of relevant technologies in emerging economies. In addition, their compendium of technologies used in the recovery of materials from WEEE[48] gives in-depth information on commercially available technologies and techniques for resource recovery from e-waste, and subsequent treatment of residual wastes. It provides criteria to facilitate the assessment of various technology options, guidelines to shortlist the most relevant and suitable technologies, and relevant case studies.

[48]Compendium of Technologies for the Recovery of Materials from WEEE/E-waste, UNEP, 2017
[49]Management and Destruction of Existing Ozone Depleting Substances Banks: Guideline on the Manual Dismantling of Refrigerators and Air Conditioners, GIZ, 2017
[50]End-of-Life Management of Photovoltaic Panels: Trends in PV Module Recycling Technologies, IEA, 2018
[51] E-waste Dismantler Toolkit, Vol. 3

# 6 E-Waste Management Value Chain and Financing

This chapter looks at the costs of solar e-waste, how it differs financially from other e-waste fractions, and why this is important in policy. It also looks at what part of the waste value chain is self-financing, what needs additional financing, and the general mechanics of cost and profit for e-waste management players.

## Chapter objectives

- Give an overview of the value chain in e-waste management
- Present the basic economics of e-waste collection and recycling
- Outline financing mechanisms for e-waste management.

## 5.1 E-waste management value chain and key stakeholders

One of the differences between e-waste and waste from the off-grid solar sector and other waste streams is the variety of players involved in the entire value chain, particularly when the downstream players that are active after the very first dismantling phase are considered. The stakeholders involved in the e-waste collection and recycling chain are:[51]

- Waste generation: consumers, including individuals at the household level and institutional consumers such as businesses, industries and government organisations. The mode of waste disposal depends heavily on the disposal behaviour and awareness of the consumers [Chapter 6].
- Waste collection and aggregation: retailers, waste collectors and aggregators. In many African countries, collection of e-waste is done mainly by small and medium collectors (door-to-door, municipal dumpsite), with small informal collectors dominating.
- Dismantling and treatment of waste: second-hand markets, scrap dealers, dismantlers, processors and recyclers. End-processors (downstream partners) responsible for proper disposal or material recovery of the multitude of fractions generated during the dismantling phase play an important role in good waste management.

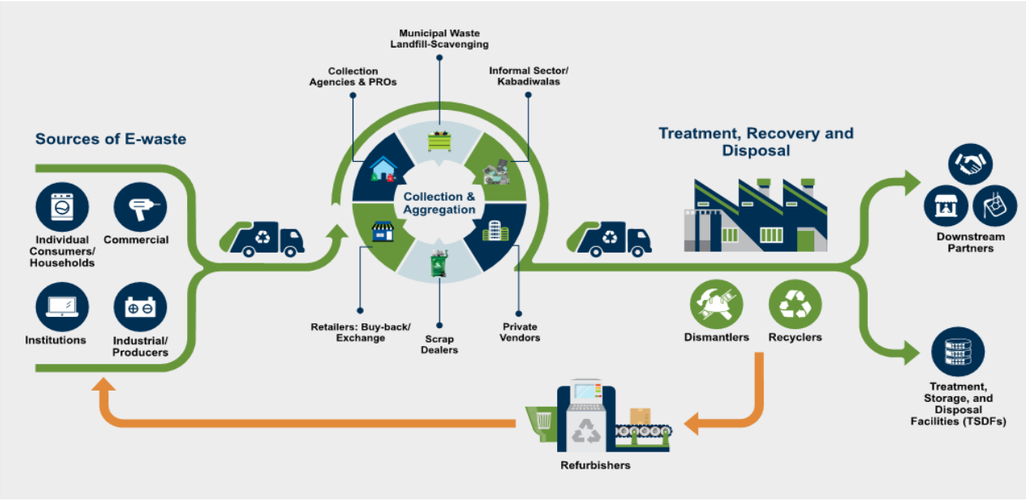



*Figure 4: E-waste management value chain[22]*



Waste electronic products are collected and treated in waste streams depending on the treatment process required. For many of them, a manual disassembly can ensure proper removal of hazardous components and the recovery of valuable fractions. Others (e.g. lamps and refrigerators) need dedicated and specialised mechanical processes. In the case of off-grid solar products, specific processes are necessary for batteries (Pb- or Li-based) and for PV panels. After dismantling, the valuable fractions are sold on national or international commodities markets (e.g. copper, iron) or channelled through downstream partners for further treatment and extraction of further valuable resource (e.g. printed circuit boards, hard drives, processors). Hazardous fractions are sent for proper disposal or incineration.

## 5.2 Economics of e-waste collection and recycling

The fundamental business aspect of the e-waste management value chain is to account for the net cost of all the activities carried out by the different players along the value chain (collection, transport, treatment and disposal), including disposal of hazardous fractions.[17,51] Technical costs can be divided into four groups:

- Access to waste: costs (or revenues) to get the waste from the original holder (the consumer).

In many developed countries, consumers dispose of their waste for free, sometimes they even have to pay. In developing countries, the holder of the product to be discarded expects an economic compensation in most cases. Access to waste is considered a cost when the waste holder receives economic compensation, and revenue if the consumer pays to dispose of his/her waste.

- Collection: includes the cost of hiring, purchasing (or the corresponding depreciation of) items like containers, cages and bins used to collect and store waste. It also includes the salaries of staff.
- Transport: costs to transport the waste from the collection point or from the consumers' houses/places to the treatment plant.
- Treatment: each treatment plant incurs operation costs including labour, energy, and costs related to capital investment depreciation and the functioning of the plant itself. After dismantling, the resulting fractions are sold on the national or international commodities markets; some fractions have positive value (representing a revenue) while others have a negative value (representing a cost).
The evaluation of the net treatment cost is based on a straightforward economic balance of all costs and revenues as indicated in Figure 5.

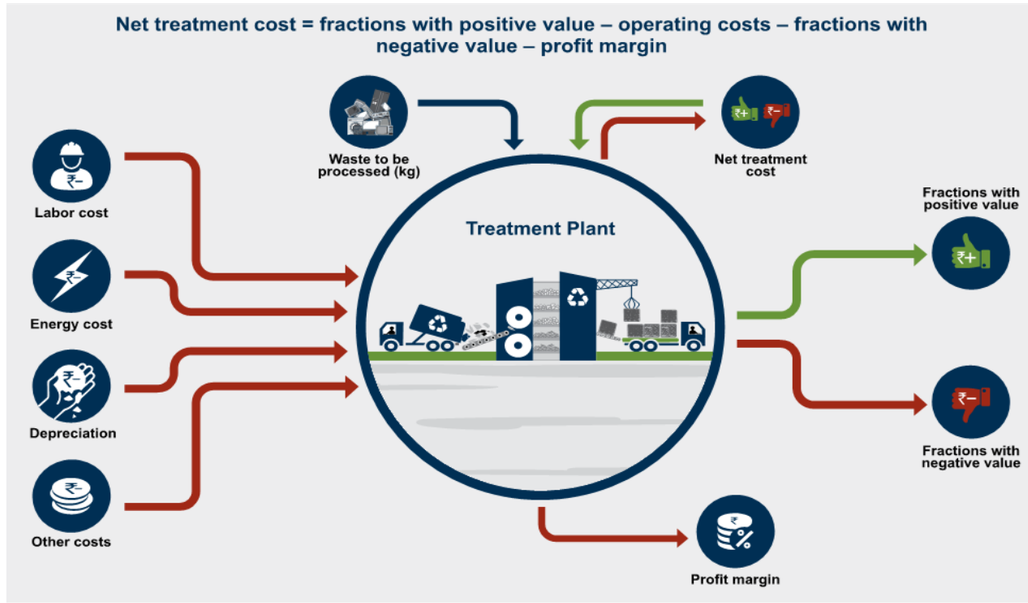



*Figure 5: Net treatment cost[22]*

When the costs for proper disposal of fractions having a negative value are lower than the revenues, the net treatment cost is positive and there is no need for external financial support. Extra revenues generated by treatment of products can then be used (depending on the decisions of plant management) to purchase waste from holders, and thus generate a higher margin for the plant.
In many cases, the revenues generated from downstream markets are not sufficient to offset the costs of proper disposal of fractions that have a negative value, or the operating costs are particularly high and the net treatment cost is negative. Therefore, a proper financing mechanism, tailored on the societal context of the country, need to be defined and then enforced.
In the case of off-grid solar products, the intrinsic value of the products is often negative, and although local markets exist for iron, copper and aluminium, many of the resulting fractions need to be exported, particularly the hazardous components. In almost all African countries, local solutions for Pb batteries[47] exist even if the standards, processes, and technologies adopted are not always able to ensure the desired level of environmental and human health protection. Where informal recycling of Pb batteries is done, severe impacts on human health and the environment are observed.

**Table 15: Main fractions resulting from treatment of off-grid solar products**

| Product or Component | Toxic/Hazardous Components | Fractions that Carry Disposal Costs | Main Sources of Potential Revenues |
|---|---|---|---|
| Solar portable lanterns | Mercury in CFL (if present) | Plastics, especially if containing BFR | |
| Solar Home Systems | None | Plastics, especially if containing BFR | Copper from cables<br>Circuit boards from control panels |
| Lamps | Mercury in CFL (if present) | CFLs containing mercury | None |
| PV modules | Cadmium and tellurium | Glass (potentially) | Aluminium for larger frames |
| Batteries | Lead, cadmium | Li-Phosphate, Ni-Cd | Lead, Li-Ion, Ni-MH |

Assessing end-of-life costs for off-grid products (or other e-waste streams) can be done with an activity-based costing, considering operations for the main cost items described (access to waste, collection, transport to recycling plant and treatment). The main variables and steps to perform the costing are described in existing reports.[13,14,17,21]

## 5.3 Financing mechanisms

The definition of financing models is critical to understanding the design and operation of e-waste take-back systems. To ensure cost-effectiveness of the system in the long term, it is necessary to:

- clearly assess which activities are financed under the e-waste legislation
- define and allocate financial responsibilities.

The fundamental idea behind EPR is to provide an economic incentive to producers in order to encourage them to make environmental considerations when designing and manufacturing their products so that waste management can be improved. EPR aims to shift some of the waste management responsibilities (administrative, financial and/or physical) from governments or municipalities (and thus taxpayers) to the entities that produce and sell the products that are destined to become waste. Although in EPR-based financing systems producers ensure the financing of the systems, consumers might eventually pay the end-of-life costs via an increase in product price.

In an EPR-based financing system, producers are liable for financing end-of-life operations but they could also have organisational responsibilities. One of the key aspects of organisational responsibility is the opportunity to enable fair competition among service providers (logistics providers or treatment plants), which might lead to long-term cost effectiveness in the system when properly coordinated.

In an effective financing system, the roles and responsibilities of various stakeholders along the e-waste management value chain can be as shown in Table 16.



**Table 16: Example of allocation of responsibilities and costs according to EU WEEE Directive[17]**

| Stage in the End-of-Life | Operational Responsibility | Financial Responsibility | Notes and Examples |
|---|---|---|---|
| Access to waste | Consumers | ○ Free of charge<br>○ Producers might reimburse | ○ Consumers dispose of their waste for free in existing collection infrastructures (municipalities, retailers, etc). Infrastructure costs (set-up & running) are borne by municipalities or retailers.<br>○ In some cases, Producers or their Compliance Schemes reimburse them for a quota of operational costs (e.g. Netherlands, Belgium), or reward effective collection performance (e.g. Italy) |
| Costs for containers and logistics infrastructures | Collectors<br>Recyclers | Usually producers | ○ Service providers (logistics companies contracted by Producers/ Compliance Schemes) own containers. Renting price is usually included in the contractual agreement with Producers/Compliance Schemes.<br>○ In some cases, Compliance Schemes purchase containers (e.g. Italy, for lamp collection) |
| Transport | Collectors<br>Recyclers | Producers | ○ Service providers (logistics companies contracted by Producers/ Compliance Schemes) contractually agree on the price for services provided. |
| Treatment | Recyclers | Producers | ○ Treatment plants (contracted by Producers/Compliance Schemes) contractually agree on the price for services provided (net treatment cost, per waste stream usually, positive or negative) in a competitive environment. |
| Enforcement | Government | Government | ○ Enforcement is the responsibility of central government and dedicated agencies (which are authorised to issue fines). |
| Audit on treatment standards | Government<br>Producers | ○ Government<br>○ Producers (Compliance Schemes) running own audits | ○ Audits, particularly linked with issuing and monitoring of waste permit provisions, are the responsibility of central government and dedicated agencies (also authorised to issue fines).<br>○ In many cases, Producers/Compliance Schemes voluntarily audit their contracted suppliers (on an annual basis at minimum) to enforce contractual provisions and monitor environmental performance according to applicable standards (e.g. WEEE Forum, WEEELABEX) |
| Awareness raising | Government<br>Producers<br>NGOs | ○ Governments<br>○ Producers (Compliance Schemes) voluntarily | ○ Awareness raising is usually the responsibility of Member States.<br>○ In Austria, the clearinghouse is responsible for setting a fee for the costs incurred by municipalities, or associations of municipalities, to ensure harmonised information of final consumers as a function of the number of residents; costs are borne by Compliance Schemes according to market share. For 2013, it amounted to €0.055/inhabitant (approx. €460,000).<br>○ In many cases, Compliance Schemes across EU organise dedicated awareness raising campaigns. |

The cost effectiveness of the system helps minimise financial impacts on producers, which positively impacts the society at large by minimising product price increases due to internalisation of end-of-life costs. Past research shows that implementation of the WEEE Directive across EU has led to a sensible increase of product prices. Minimising financial impacts on producers might also reduce the negative impacts on the financial wellness of SMEs.

Transparency on the management of financials can further contribute to cost-effectiveness, particularly in ensuring that financial contributions from obliged parties under the e-waste legislation (producers or others) are used for the sole purpose of financing e-waste management activities.

# 6 Engaging the Public in Responsible E-Waste Management

This chapter explains the basics of raising public awareness as well as different strategies available to policymakers to engage with the public. It also provides an overview of channels and strategies for awareness campaigns and illustrative examples from around the world.

Chapter objectives

- Give an overview of main channels available for consumer awareness campaigns
- Provide examples of campaigns used in the past in various regions.

## 6.1 Channels and strategies for awareness campaigns

Even when legislation is in place, there exist gaps in knowledge and awareness of e-waste handling and management issues among communities. It is important to understand the knowledge and awareness levels of the consumers of electronic products, who ultimately become the generators of e-waste, in order to develop an effective campaign. The first step in designing an awareness campaign is to set objectives, including clearly defined short-term and long-term objectives that are specific, measurable, achievable, realistic and time-bound (SMART). This will help to ensure realistic targets and the development of each awareness activity in a well-paced manner that will work towards the achievement of the objectives.

The needs of the various target groups are then identified and the most relevant approach to reach and influence their behaviour selected. The research to understand public knowledge and awareness on e-waste can be done through surveys.

Coming up with the message, selecting an appropriate tone for the message and developing a visual identity is the next step. The message has to:

- be simple (jargon will put people off)
- have a clear ask – spell out what you want people to do and what could happen as a result of their actions
- be compelling by explaining why action is needed now
- be consistent – in both overall campaign concept and in the wider organisational style
- be repeated.

It is at this point that the most appropriate distribution methods to achieve the aim and objectives of the campaign are selected. A campaign strategy should use a number of communication methods (See Table 16) because no single method will be effective in isolation, and each one has advantages and disadvantages in different situations.

Aside from the main target group, other groups might need to be involved in an awareness campaign. Generally, these groups may not necessarily be the recipients or end users of the campaign (households) but they can lend their support in delivering the campaign or its messages.

## 6.2 Illustrative examples from around the world

### "Don't bin it, bring it" – UK[52]

Recycle Now has developed a specific communications campaign to raise awareness amongst households of the need to dispose of small household WEEE items correctly, and where they can do so. Research has shown that most households have at least three items of old, unwanted or broken electronic or electrical equipment at any one time, and that they are often unsure of how to dispose of it. The relatively small size of some WEEE increases the temptation to simply throw them in the household bin. Types of small WEEE that this campaign focuses on are:



**Table 17: Examples of communication methods**

| Communication Methods | Examples | Broad brush/Targeted |
|---|---|---|
| Advertising | Radio, TV, print press, outdoor, mobile, online etc. | Mainly broad brush though can be targeted if used carefully |
| PR | Media relations via radio, print press, TV and online. | Mainly broad brush though can be targeted if used carefully |
| Direct marketing | Door-to-door canvassing, leaflet/ information distribution, exhibitions and events | Targeted |
| Community engagement | Building on-going permanent relationships with local communities | Targeted |
| Online | Website, social media (Facebook, Twitter, Instagram, etc.) | Broad brush |
| Internal communications | Newsletter, memo, e-mail | Targeted |

- high-tech electronic devices
- electrical personal care devices
- electrical appliances
- do-it-yourself (DIY) and garden electricals.

The campaign asks households to take small WEEE items to the local recycling centre, rather than disposing of them in their residual waste. Households are encouraged to visit the Recycle Now website to find out more about recycling electrical goods and for information about other options available, including:

- bring banks
- retailers offering in-store take-back
- community reuse projects.

This campaign was developed for local authorities but can be adapted to include large WEEE for use by producer compliance schemes and waste management companies.

### EU

In 2015, the EU ran a pilot project on awareness raising for e-waste in Greece.[53] They created a series of YouTube videos, social media posters, radio and TV adverts, and also ran a roadshow. This coordinated effort resulted in an increased collection rate of 16.5 per cent in the target area, compared to an increase of only 7.8 per cent in the rest of Greece. Examples of the materials created in this awareness campaign are freely available, including on their YouTube channel.

Many European compliance schemes have developed awareness campaigns. Most of them have involved schools, aiming at (i) carrying out collection pilots and competitions between classes; (ii) stimulating the awareness of younger generations; and (iii) creating a positive effect on the parents.

[52] Raising Public Awareness of Recycling and Reuse, WRAP: http://www.wrap.org.uk/sites/files/wrap/2.0%20Raising%20public%20awareness%20of%20recycling%20and%20reuse%20-%20Online.pdf
[53] LIFE-INFOCYCLE: Development of a Communication and Training Campaign for the Recycling of Waste Electrical & Electronic Equipment (WEEE), 2016
[54] ERP UK launches new e-waste awareness raising campaign, G. Faulkner, Recycling Waste World, 2015: http://www.recyclingwasteworld.co.uk/news/erp-uk-launches-new-e-waste-awareness-raising-campaign/82542/

### European Recycling Platform (ERP) – UK[54]

Their campaign, which ran in 2015, asked people to submit a #SelfiEEE – a photograph of themselves with a broken or unwanted electrical item – and make a pledge to reuse or recycle it. The idea was to spread the environmental conservation message and encourage the use of local reuse or recycling facilities. As an added incentive, ERP UK donated £250 each month to one of four charities: the British Heart Foundation, the Furniture Reuse Network, the National Foundation for Youth Music, and the Young People's Trust for the Environment.

### Café Recupel – Belgium

Café Recupel is a pop-up café that targets students in Belgian universities and university colleges. In 2017, several Belgian universities were visited. Students who handed in an old electronic or electric appliance were rewarded with a free refreshment.

### Recupel Horror – Belgium

This campaign focused on luminaires. It used a video clip to mobilise the average Belgian to hand in old lamps and fixtures at a collection point instead of simply throwing them in the waste bin. This way they could be recycled properly.

### WEEE Forum International E-waste Day[55]

International E-Waste Day was created by the WEEE Forum, an international association of e-waste collection schemes with 26 members. It involves around 40 different organisations in 20 different countries worldwide. The day is used to raise the public profile of e-waste and encourage consumers to correctly dispose of their e-waste with the aim of increasing re-use and recycling rates on the day itself and in the future.

Initiatives undertaken by participant organisations on the day were diverse and include conferences, events, school and city collections, in-store promotions and an online guide for proper e-waste disposal. All these initiatives were promoted locally on and around the International E-waste Day.

### Environmental Education Centre, Red Hill Waste Management Facility – Australia

Interested groups, including school and community groups, are encouraged to take a free tour of Eastern Metropolitan Regional Council's (EMRC) Red Hill Waste Management Facility and find out how their waste is being managed safely and responsibly. They can also visit the Environmental Education Centre (EEC) and learn more about how waste is managed and what to do at home to reduce, reuse and recycle.

The aim of both the tour and the EEC is to provide an engaging, visually memorable experience of waste, and the work required to manage it. This, in turn, encourages people to think more carefully about what they put in their bins and the impact that this has.

### London Borough of Barnet – UK

London Borough of Barnet undertook a campaign to boost participation in recycling by people living in flats. The main campaign activity was door-to-door canvassing, with the Council commissioning teams of recycling promoters to visit all 15,000 flats with communal recycling bins. Return visits were carried out to achieve a 50 per cent face-to-face contact rate. The promoters offered residents free, reusable bags to store recyclable items and handed out an information leaflet on recycling.

Other communication activities included:

- Media releases to achieve instant and sustained awareness, and to launch the 'Flats Recycling' publicity campaign
- Newsletters, including features in local newsletters and community magazines
- Website – the pages dealing with recycling on the council 's website (barnet.gov.uk) were updated with a separate section for flats
- Service leaflets were produced for distribution as part of the door-stepping campaign
- Direct mail – a letter to provide information about the service was posted to residents who were not in when the door-steppers called
- Posters featuring details of the campaign were produced for communal areas of flats
- Reusable bags for storing and transporting recycling materials printed with service information were distributed to all residents visited
- Signage on recycling containers – new, clear, easy-to-follow information stickers conforming to national 'Recycle Now' branded signage were introduced
- Showcards were produced illustrating the materials collected for recycling for use by residents who do not speak English as a first language.



Residents were surveyed before a decision was made. They indicated a high level of support (95 per cent) for the introduction, partly because the cost of collection would not increase. Most agreed that it was not only a better service but also a sustainable one.

The roll-out was supported by a mix of communication methods including local newspaper advertisements, brochures, etching on the bins, and a pamphlet distributed with every bin. This groundwork ensured that residents were aware of the changes when green bins were presented from the very first collection.

### WEEE Pledge – Ireland

The WEEE Pledge programme rewards schools that pledge to do their part to recycle batteries. For every battery box collected, a donation of €5 is made to Laura Lynn, Ireland's Children's Hospice.

Boxes were provided along with flyers/posters with instructions for students as well as parents. Information about battery safety was also included.

### China

Through a GEF funded project, the Ministry of Environment and project partners have implemented various activities to engage consumers, particularly younger generations. These activities include use of modern mass media (e.g. WeChat, which is particularly used by the younger generation), involvement of famous testimonials (e.g. Ms Zhao Wei), or leveraging of crowded places (e.g. the subway).

### Tetra Pak campaign among school children – Egypt[56]

Tetra Pak Egypt runs an awareness programme for schools in partnership with the Spirit of Youth Association. The initiative involves a range of interactive sessions for children on the importance and benefits of separating their waste at source, and recycling their used beverage cartons. It has now expanded beyond schools to engage NGOs and libraries to reach more people. In total, they have conducted 71 awareness raising sessions in 28 different venues, and reached 5,880 students, 215 teachers and supervisors and 37 mothers. In addition, 46 waste bins have been distributed to encourage source separation at schools.

### 'Educating the next generation' by Tetra Pak – Malaysia

Tetra Pak Malaysia works with the City Council of Shah Alam, west of the capital Kuala Lumpur, and local business Fraser and Neave Holdings Bhd to run a successful annual recycling competition for school children from kindergarten to secondary school. The competition is now in its tenth year and in this time, the children have collected an estimated 900 tonnes of recyclable waste and earned prize money for their schools. The project combines educating children about the environment with promoting family-wide recycling. As a result, all schools in Shah Alam now have collection facilities on site, thus improving local recycling rates and ensuring that environmental awareness comes naturally for the next generation of consumers.

### Cleaning up waste in Gurgaon – India

With the aim of educating people and spreading awareness about e-waste, Deshwal Waste Management company organised an e-waste collection initiative. The event witnessed active participation from more than 5,000 residents and students. As part of this initiative, the firm also created 100 collection points by placing e-waste collection bins across the city to facilitate responsible disposal.

### "Eu jogo limpo com São Paulo" – Brazil

In this campaign, the meaning of the word "jogo" (play, throw), and the meanings of the word "limpo" (fair, clean), lead to two interpretations of the slogan: "I act fairly" (when) "I throw things in the dustbin" (because) "it helps keep the city clean". The campaign was promoted by municipal authorities and the Union of Municipal Cleaning Companies of the State of São Paulo in 2014. It aimed at strengthening the concept that the population has an essential role in cleaning the city, especially by not littering in public places.

### "SPKindCity" – Brazil

An initiative from the concessionaries Ecourbis and Loga, with the support of the City of São Paulo, presented in 2016, combined art, a web series, news and services. The campaign aimed to create dialogue with the public on recycling issues and selective collection, and generate positive experiences in the daily relationship with waste.

[55] International E-waste Day, WEEE Forum, 2018: http://www.weee-forum.org/news/first-international-e-waste-day-aims-to-raise-public-awareness-of-e-waste

[56] Raising Consumer Awareness of Recycling, TETRA PAK, 2016: https://www.tetrapak.com/sustainability/cases-and-articles/raising-consumer-awareness-of-recycling

# References

| Footnote | Title | Comments |
|---|---|---|
| 1 | Extended Producer Responsibility: A Guidance Manual for Governments (online) | Written by the OECD, this manual provides information on EPR issues and benefits, and actions required to establish effective EPR policies and programmes. It is intended to help governments ensure that in implementing EPR, the benefits outweigh the costs, and that the programmes meet their goals and priorities. |
| 2 | Analytical Framework for Evaluating the Costs and Benefits of Extended Producer Responsibility Programmes, 2005 | Report sets out a suggested methodology that can be used by individual countries as a starting point for evaluation of EPR programmes. It looks at good practice in evaluation as well as experience from other countries. The report provides a system approach in assessing how well individual EPR programmes succeed in achieving their objectives. |
| 3 | Technical Guidelines on Transboundary Movements of Electrical and Electronic Waste and Used Electrical and Electronic Equipment, in Particular Regarding the Distinction Between Waste and Non-Waste Under the Basel Convention, 2015 | Document provides guidance on the transboundary movement of e-waste pursuant to the Basel Convention. This includes information on the relevant provisions, guidance on the classification of waste vs. non-waste when equipment is transferred, and distinction between hazardous and non-hazardous waste. Document is intended for government agencies. |
| 4 | E-waste Assessment Methodology Training & Reference Manual, 2012 | Document presents methodology for performing a country assessment in order to understand the current framework conditions, define a strategy and implement the most suitable e-waste management system. The document provides all the methodology required to provide comparable results from e-waste assessments in other countries. |
| 5 | E-Waste Statistics: Guidelines on Classification Reporting and Indicators, 2nd Edition, V. Forti et al, 2018 | Report describing a measurement framework followed by the EU as a common methodology to track collection and recycling target for Article 7 of the EU WEEE Directive. Also includes the classification of e-waste, methods, and country examples to help countries make their own estimates. |
| 6 | The Global E-waste Monitor, 2017 | Overview of volumes of waste generated worldwide. Calculations are made on the basis of the sales-lifespan methodology, taking into account import/export of EEE from international statistics. |
| 7 | Bridging the Gap Between Informal and Formal E-Waste Producers, R. M. Panwal, 2018 | Research paper on the informal sector in Delhi and Bangalore with a proposal for a model that bridges the economic gap between informal and formal processes to promote responsible e-waste recycling. |
| 8 | From Worst to Good Practices in Secondary Metals Recovery, SRI, 2017 | Report uses extensive stakeholder consultation to provide a collection of factsheets on worst practices that can be used to accelerate the learning curve of stakeholders in implementing improved practices for secondary metal recovery. |



| Footnote | Title | Comments |
|---|---|---|
| 9 | A Practical Guide for the Systemic Design of WEEE Management Policies in Developing Countries, SRI, 2017 | Guide uses the process of implementing WEEE legislation in the Andean region to highlight and provide guidance on how to facilitate the process in other regions. The methodology proposed includes participatory tools that can be used to design a fit-for-purpose process in other regions. |
| 10 | A Research on Electronic Waste Awareness and Environmental Attitudes of Primary School Students, O. Ercan et al. Anthropologist, 17(1): 13–23, 2014 | Study examining the level of awareness of electronic waste in primary school students in Turkey. It presents findings on what factors affect student's environmental attitude, such as the type of school attended and income level of the parents. |
| 11 | Recycling: From E-Waste to Resources, UNEP, 2009 | Study analyses market potential of relevant technologies from e-waste recycling sectors, the application of the framework for UNEP technology transfer activities, and the identification of innovation hubs in emerging economies as relevant for e-waste recycling technologies. |
| 12 | Sustainable Management of E-waste in the Off-grid Renewable Energy Sector in Rwanda, DFID, 2017 | Report analysing the current Rwandan situation including legislative framework on e-waste management, the current collection and recycling infrastructure and calculations on the costs and volumes of off-grid renewable energy in Rwanda in 2017. The report provides recommendations on policy and legislation as well as stakeholder engagement, awareness and capacity building. |
| 13 | Electronic Waste (e-waste) Impacts and Mitigation Options in the Off-grid Renewable Energy Sector, DFID, 2016 | Report provides an overview of the main challenges for the off-grid solar sector when implementing end-of-life operations in Africa. Three case studies (Nigeria, Kenya and Rwanda) are presented. |
| 14 | Cost Benefit Analysis and Capacity Assessment for the Management of Electronic Waste (e-waste) in the Off-grid Renewable Energy Sector in Kenya, DFID, 2017 | Report provides detailed assessment of the end-of-life implications for e-waste management in Kenya. Focus is on off-grid solar sector but also details potential areas of improvement for legal and organisational aspects. |
| 15 | Development of Guidance on Extended Producer Responsibility (EPR), European Commission, 2014 | Study providing an overview of EPR schemes in Europe, identification of good practices, and based upon benchmarking the guiding principles on how to design efficient and effective EPR schemes using a six-component approach. |
| 16 | Developing Legislative Principles for E-waste Policy in Developing and Emerging Countries, StEP, 2018 | Paper presents core legal principles based upon EPR as guidance for policymakers in countries currently developing legislation. Guidance is presented in a way that legislators can implement EPR programmes in a local context without copy-pasting from post-industrialised countries. |
| 17 | Financing Models for Sound E-waste Management in Ethiopia, UNIDO, 2015 | Report analyses different examples of e-waste legislations and related financing mechanisms in different regions, highlighting their pros and cons, particularly on financing. Different models are analysed considering the Ethiopian context, and four different policy options are presented for Ethiopia. |

| Footnote | Title | Comments |
|---|---|---|
| 18 | WEEE Recycling Economics: The Shortcomings of the Current Business Model, EERA, 2018 | Report provides an overview of the main technical costs for proper recycling of electronic products in Europe. It also provides an overview of the scavenging of products collected and the environmental and economic implications of such activities using the material collected by members of European Electronics Recyclers Association (EERA) in 2017 as the basis. |
| 19 | National and International Downstream Markets for DMF E-waste Dismantling Fractions: Metals, Printed Wiring Boards and Plastics, StEP, 2015 | Market study as part of the Ethiopian E-Waste Management Project to identify downstream markets for fractions from the demanufacturing facility, investigate the administrative procedures, analyse the costs and business models, and give recommendations concerning the legal status of the demanufacturing facility. |
| 20 | The Best-of-2-Worlds Philosophy: Developing Local Dismantling and Global Infrastructure Network for Sustainable E-waste Treatment in Emerging Economies, F. Wang et al, Waste Management, 2012 | This paper introduces the 'Best-of-2-Worlds' philosophy (Bo2W), which provides a network and pragmatic solution for e-waste treatment in emerging economies. It seeks technical and logistic integration of 'best' pre-processing in developing countries to manually dismantle e-waste, and 'best' end-processing to treat hazardous and complex fractions in international state-of-the-art end-processing facilities. |
| 21 | End-of-Life Management of Batteries in the Off-Grid Solar Sector, GIZ, 2018 | A comprehensive paper introducing the realities of managing e-waste and battery waste in the context of developing countries, specifically off-grid solar. Includes an overview of management pathways of off-grid solar waste as well as the management of their waste batteries. |
| 22 | E-waste Dismantling: An Entrepreneur's Guide, IFC, 2018 | Brochure outlining the high-level information needed for entrepreneurs to consider e-waste dismantling, including the economics of a dismantling business, applicable laws and how international markets work. |
| 23 | WEEELABEX Normative Document on Collection V9.0 | WEEELABEX was a four-year EU-funded (Life+) multi-stakeholder project aimed at laying down a set of European standards with respect to collection, handling, storage, recycling, preparation for re-use, disposal of waste electrical and electronic equipment (WEEE), and monitoring the processing companies through audits conducted by auditors trained by the WEEELABEX office (www.weeelabex.org). |
| 24 | WEEELABEX Normative Document on Treatment V10.0 | WEEELABEX was a four-year EU-funded (Life+) multi-stakeholder project aimed at laying down a set of European standards with respect to collection, handling, storage, recycling, preparation for re-use, disposal of waste electrical and electronic equipment (WEEE), and monitoring the processing companies through audits conducted by auditors trained by the WEEELABEX office (www.weeelabex.org). |
| 25 | Introduction of a Management System of WEEE: WEEE Information System | Presentation from head of national register of France (ADEME). |
| 26 | Case Study E-waste Management, M. Schluep, 2014 | Paper looking at the management of WEEE in developing and emerging economies – current status, proposed approaches and implementation methods – using specific examples from various countries. |



| Footnote | Title | Comments |
|---|---|---|
| 27 | Waste Framework Directive 2008/98/EC | Gives general principles of waste management across EU, consolidating principles since 1975. It sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling and recovery. It also 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. |
| 28 | WEEE Directive 2002/96/EC (Original) | Original text of the WEEE Directive |
| 29 | WEEE Directive 2012/19/EU (Recast) | Actual text of WEEE Directive (revised version) |
| 30 | WEEE Resource Management System in Costa Rica, Abarca-Guerrero et al, Resources, 2018 | Article analysing the different steps taken in Costa Rica to develop an e-waste management system. The paper looks at the effect of consistency of national waste legislation and the importance of stakeholder participation. |
| 31 | Framework of India's E-Waste, India Urban Development Gateway, UK India Business Council | Brochure giving a high-level introduction to India's e-waste sector by the UK India Business Council. |
| 32 | Basel Convention Website (online) | Website with resources and all official information related to the Basel Convention and its signatories. |
| 33 | End-of-Life Management: Solar Photovoltaic Panels, IRENA & IEA-PVPS, 2016 | Report that presents global projections for future PV panel waste volumes up to 2050. |
| 35 | Comparison of WEEE Standards from Switzerland, Europe and the US, SRI, 2015 | Document provides a comparison of five technical and environmental standards for the treatment of WEEE. The comparison is from three European and two North-American countries, and covers all types of WEEE and its components as well as all steps from collection, transportation to final disposal. This comparison is intended to provide a framework for the development and implementation of corresponding standards. |
| 36 | WEEELABEX Normative Document on Logistics V9.0 | WEEELABEX was a four-year EU-funded (Life+) multi-stakeholder project aimed at laying down a set of European standards with respect to collection, handling, storage, recycling, preparation for re-use, disposal of waste electrical and electronic equipment (WEEE), and monitoring the processing companies through audits conducted by auditors trained by the WEEELABEX office (www.weeelabex.org). |
| 37 | Technical Guidelines on Environmentally Sound E-Waste Management for Collectors, Collection Centres, Transporters, Treatment Facilities and Final Disposal, Ghana, EPA, 2018 | Guidelines for environmentally sounds e-waste recycling tailored to the specific needs of public and private stakeholders in Ghana. The guidelines target collectors, collection centres, transporters, treatment facilities, and final disposal. They were developed with reference to the ISO/IWA 19 Guidance Principles for the Sustainable Management of Secondary Metals. |
| 38 | GreenCo Rating for E-Waste Recyclers, India, GreenCo, 2018 | A rating system to provide guidance to recyclers on implementing important requirements within four areas: general aspects, material flow management, supply chain management and environmental management. This rating system can be used by stakeholders to assess current recyclers and enable compliance. |

| Footnote | Title | Comments |
|---|---|---|
| 39 | E-Waste and Harm to Vulnerable Populations: A Growing Global Problem, EHP, 2015 | The article, written by the main members of the WHO e-waste network, provides an overview of the scale and health risks arising from e-waste. It presents a review of international efforts on environmental hazards, especially those affecting children, as a preface to presenting the next steps in addressing health issues stemming from the global e-waste problem. |
| 40 | An efficient & effective E-waste Collection System for Ethiopia, Oeko-Institut, 2015 | The report aims at working out a proposal for an efficient and effective e-waste collection system in Ethiopia. Based on the assessment of four Ethiopian cities (Addis Ababa, Dire Dawa, Hawassa and Jigjiga), the study lays the ground for a future national e-waste collection system in urban areas of the country. |
| 41 | GOGLA Industry Opinion on Life Cycle and Recycling, 2014 | A statement by GOGLA outlining its members' commitment to environmental conservation and minimising hazardous waste contamination. |
| 42 | California Senate Bill No. 50, September 2004 | Text of California e-waste bill |
| 43 | California Senate Bill No. 20, December 2002 | Text of California e-waste bill |
| 44 | E-waste Toolkit Module 1 Briefing Note: Technical Introduction to Recycling of Off-grid Solar Products, GOGLA | Introduction to the technical side of recycling aimed at solar product manufacturers giving a brief overview of how solar systems are recycled and their impacts. |
| 45 | Report on the Fact-Finding Mission on the Management and Recycling of End-of-life Batteries used in Solar Home Systems in Myanmar, Oeko-Institut, 2018 | Study looking at the end-of-life management of batteries, general practices and the shortcomings that cause adverse impacts. It also discusses the regulatory and business context of battery recycling and lists suggestions for improvement. |
| 46 | Household WEEE Generated in Italy: Analysis on Volumes and Consumer Disposal Behaviour for WEEE, F. Magalini et al, 2012 | Country study in Italy through a consumer survey to define lifespan profiles. |
| 47 | E-Waste Treatment Facility in Uganda Business Plan, UNIDO, 2014 | Document provides a strategic analysis of the framework in which an e-waste treatment facility could be set up in Uganda along with detailed potential profit and loss forecast and break-even scenarios. Very informative document on the business models of recyclers. |
| 48 | Compendium of Technologies for the Recovery of Materials from WEEE/E-waste, UNEP, 2017 | Presents information on commercially available technologies for resource recovery from the treatment of e-waste. It includes operation details, environmental impacts and criteria that can be used to select the technologies. Also includes discussion of various e-waste regulations in developed countries and the economic, technical and environmental implications of the technologies. |
| 49 | Management and Destruction of Existing Ozone Depleting Substances Banks: Guideline on the Manual Dismantling of Refrigerators and Air Conditioners, GIZ, 2017 | Guide providing basic technical knowledge on the disposal of refrigeration and air conditioning appliances. It should help improve proper waste management practices for domestic appliances by addressing key issues such as cost, environmental impacts and safety. |



| Footnote | Title | Comments |
|---|---|---|
| 50 | End-of-Life Management of Photovoltaic Panels: Trends in PV Module Recycling Technologies, IEA, 2018 | Report that provides an international survey of trends related to PV module recycling from both the public and private sectors. It reviews patents since 2011 as well as R&D plans and investments made by public sectors. Expected upcoming issues related to PV module recycling technologies are also addressed. |
| 51 | E-waste Dismantler Toolkit, Vol. 3 | Toolkit for small and micro entrepreneurs looking to start their e-waste dismantling plant, including essential requirements and best practice. Vol. 3 is an operational guide for small and micro-dismantlers giving such details as tools required, environmental and health aspects, training requirements and general guidelines. Also includes references to international resources that provide detailed dismantling instructions for various types of e-waste. |
| 52 | Raising Public Awareness of Recycling and Reuse, WRAP | A chapter in the WEEE Collection Good Practice Guidance document outlining various communication activities undertaken in the UK around recycling. |
| 53 | LIFE-INFOCYCLE: Development of a Communication and Training Campaign for the Recycling of Waste Electrical & Electronic Equipment (WEEE), 2016 | Project report on a consumer awareness campaign run in Greece and the results of each method, including various awareness campaign types with a list of materials produced (most of which are available to the public). |
| 54 | ERP UK launches new e-waste awareness raising campaign, G. Faulkner, Recycling Waste World, 2015 | An article describing the #SelfiEEE campaign by EPR UK encouraging people to recycle their broken electrical items. |
| 55 | International E-waste Day, WEEE Forum, 2018 | An article on the celebration of the International E-Waste Day. |
| 56 | Raising Consumer Awareness of Recycling, TETRA PAK, 2016 | A summary of the various recycling efforts that Tetra Pak has been engaged in around the world. |

# Further Reading

| Title | Comments |
|---|---|
| Catalyzing a Sustainable E-waste Ecosystem in India Through Private Sector Engagement: A Brief Window of Opportunity, IFC, 2017 | Slides providing on overview of IFC's India e-waste programme and the results of the first pilot project, including lessons learned and next steps. |
| Developing an E-waste National Policy and Regulatory Framework for Malawi, ITU, 2018 | Report is a detailed analysis of national e-waste policy framework in Malawi, including an overview of existing legal framework, international benchmarking from 11 other countries, a mass flow estimation and forecast, and recommendations for an e-waste regulatory framework in Malawi. |
| Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on Waste Electrical and Electronic Equipment (WEEE) | European WEEE Directive on the handling of e-waste. |
| European Standards for Waste Electrical and Electronic Equipment (WEEE) | Brochure giving a high-level introduction to EPR and European WEEE Legislation including many diagrams and easy to use tables with relevant WEEE Directive articles. |
| E-waste Dismantler Toolkit, Vol. 1 | Toolkit for small and micro entrepreneurs looking to start their e-waste dismantling plant, including essential requirements and best practice. Vol. 1 is specific to a dismantling facility in India, regional e-waste legislation, legal requirements and guidance on appropriate regulatory bodies. |
| E-waste Dismantler Toolkit, Vol. 2 | Toolkit for small and micro entrepreneurs looking to start their e-waste dismantling plant, including essential requirements and best practice. Vol. 2 looks at international best practice, standards and other relevant operational aspects for e-waste dismantlers, including plant layout, logistics and equipment. Also includes chapters on international standards and certifications. |
| E-Waste Inspection and Enforcement Manual, SBC E-Waste Africa Project | Developed by the Secretariat of the Basel Convention, this document offers practical guidance and information to regulatory and enforcement officers who deal with transboundary movements of used EEE on how to manage their movements through the Basel Convention. |
| E-waste Management in Kenya, KICTANET, 2008 | Report presenting the findings of a baseline study of e-waste in Kenya. Includes a literature review, methodology and outlines the assumptions used to estimate e-waste flows in Nairobi, and thus the rest of Kenya. Also includes analysis of policy context. E-waste in this study focuses mostly on IT equipment. |
| Ghana's Hazardous and Electronic Waste Control and Management Act, 2016 | Text of Ghana e-waste law. |



| Title | Comments |
|---|---|
| Guiding Principles to Develop E-waste Management Systems and Legislation, StEP, 2016 | Guidance document for stakeholders developing solutions for e-waste management. Includes recommendations that can be tailored to local conditions. Document developed through a combination of SWOT analysis of existing e-waste management systems around the world. |
| Handbook for the Development of a Policy Framework on ICT/E-waste, ITU, 2018 | Handbook on key aspects to consider when designing, implementing and improving a legal, regulatory and policy framework on ICT/e-waste. Discusses planning, implementation, monitoring and review. |
| How are WEEE Doing? A global Review of the Management of Electrical and Electronic Wastes, Ongondo et al, Waste Management, 2010 | Paper presenting current WEEE management practices and looking at global trends in quantities and compositions of WEEE, and the various strategies adopted. Also discusses priority areas for WEEE across the globe. |
| Material Flows of the Home Appliance Industry, CECED, 2017 | A detailed report by the European Committee of Domestic Equipment Manufacturers on the circularity of material flows in the European domestic appliances sector. It provides statistical data on the flows and stocks of materials as well as background information on the sector. It also discusses the methodology of this measurement and the estimated recovery volumes. |
| Multiple Elemental Exposures Amongst Workers at the Agbogbloshie Electronic Waste (e-waste) Site in Ghana, R.K. Srigboh et al., Chemosphere 164: 68–74, 2016 | Study that looked at the effects of exposure to essential and toxic elements such as copper, iron, cadmium and lead in the urine and blood of workers in Agbogbloshie. It helps to document the effects of working within e-waste with some potentially concerning levels noted. |
| National E-Waste Management Policy for Rwanda, 2016 | Text of Rwanda e-waste policy. |
| Pilot Study on the Internal Exposure of Heavy Metals of Informal-Level Electronic Waste Workers in Agbogbloshie, Accra, Ghana, J. Wittsiepe et al., Environmental Science and Pollution Research, 2016 | Study examining informal level e-waste workers in India, China and Ghana and the levels of heavy metals and toxic exposure to general population. Samples from e-waste workers are compared to the general population not exposed to e-waste recycling activities to assess the effects of working in the sector. |
| Recycling Used Lead-acid Batteries: Health Considerations, WHO, 2017 | Document outlining how lead exposure can occur in the process of recycling used lead acid batteries, including three case studies to illustrate the effects uncontrolled recycling can have on communities. It provides an overview on methods for assessing lead exposure through measurement and environmental sampling, and provides references for more technical information on the issue. |
| Regional E-waste Monitor for East and Southeast Asia, 2016 | Overview of volumes of waste generated in East and Southeast Asia. Calculations made on the basis of country assessments under the Asia E-Waste Project and through national e-waste inventories. |
| Role and Size of Informal Sector in Waste Management – A review, R. Ramush et al. Waste and Resource Management 166(2):69–83, 2013 | Paper is a review of the informal sector in waste management. Data is compiled on informal waste management activities and its contribution to the overall system in low-income countries in Africa, Asia, Latin America and Europe. Includes research findings on salaries, number of jobs, collection methods and contribution to total national waste management sectors. |

| Title | Comments |
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| Toward a Just and Sustainable Solar Energy Industry, SVTC, 2009 | Paper providing an overview of health, safety and environmental issues faced by the solar PV industry, and potential end-of-life hazards of the products. It also includes recommendations to address these challenges and to grow a sustainable solar industry. |
| Zero Waste Scotland Communications Guidance: Improving Recycling Through Effective Communications, 2012 | Guide gives a broad introduction to issues around developing a national recycling and waste prevention communications strategy using examples from local authorities throughout the UK. The guide signposts other sources for further information and provides a methodological approach to implementing a communications campaign. |

# Africa Clean Energy Technical Assistance Facility (ACE TAF)

Coffey International Development leads the implementation of the Africa Clean Energy Technical Assistance Facility together with several key partners. Coffey is responsible for the programme set-up, leadership and overall management taking an inclusive and collaborative approach ensuring that we engage partners throughout the implementation of the programme.

# E-Waste Policy Handbook

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