COST BENEFIT ANALYSIS AND CAPACITY ASSESSMENT FOR THE MANAGEMENT OF ELECTRONIC WASTE (E-WASTE) IN THE OFF-GRID RENEWABLE ENERGY SECTOR IN KENYA

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This report and compact has been written by Federico Magalini, Deepali Sinha Khetriwal, Seth Munyambu and produced by Evidence on Demand with the assistance of the UK Department for International Development (DFID) contracted through the Climate, Environment, Infrastructure and Livelihoods Professional Evidence and Applied Knowledge Services (CEIL PEAKS) programme, jointly managed by HTSPE Limited and IMC Worldwide Limited.

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Contents

Acronyms and Abbreviations

BFR	Brominated Flame Retardant
C&F	Cooling & Freezing Appliances
CFL	Compact Fluorescent Lamps
DC	Direct Current
EEE	Electric and Electronic Equipment
EOL	End of Life
EPR	Extended Producer Responsibility
GOGLA	Global Off-Grid Lighting Association
GSM	Global System for Mobile Communications
ICT	Information and Communication Technology
IT	Information Technology
LED	Light Emitting Diode
LHHA	Large Household Appliances
lm	Lumen
NEMA	National Environment Management Authority
PAYG	Pay-As-You-Go
PCB	Polychlorinated Biphenyls
POM	Put on Market
POP	Persistent Organic Pollutants
PV (Modules)	Photovoltaic (Modules)
PWB	Printed Wiring Boards
TEQ	Toxic Equivalent
SHA	Small Household Appliances
SHS	Solar Household Systems
SPL	Solar Portable Lamps
t	tonne
WEEE	Waste Electric and Electronic Equipment
WG	Waste (WEEE) Generated

GOGLA Product categories

Product Category	Definition
PC 1	Single light source without external power outlet/ mobile phone charging < 100 lm
PC 2	Single light source with external power outlet/ mobile phone charging < 100 lm OR Single light source without external power outlet/ mobile phone charging > 100 lm
PC 3	Single light source with external power outlet/ mobile phone charging > 100 lm
PC 4	Multi light source application with external power outlet/ mobile phone charging
PC 5	Outdoor lighting, street lighting/ public lighting
PC 6	Lighting products of any other type not mentioned under category 1-5 of any size
PC 7	Providing multi-lighting, mobile charging, TV and/or fan above 69W

Executive Summary

Kenya is one of the most populous countries in Africa with more than 46 million people. Approximately 75% of the population live in rural areas.

The Government of Kenya has set out plans to achieve universal energy access by 2020, but with the current electricity generation and grid capacity, only 20% of Kenyans currently have access to electricity. For those reasons, Kenya is one of the most vibrant markets for the solar industry in Africa, with off-grid solar products reaching 15%-20% of households.

The rapid diffusion of off-grid solar products on Kenyan market is also leading also to growing discarded volumes in the coming years. Despite representing approximately 3% of the total volume of e-waste generated in the country they are already present in the waste streams handled by local e-waste recyclers.

The Kenyan government has already developed specific legislation on e-waste, addressing the role and responsibilities of various stakeholders involved and setting the legal framework for operations. Unfortunately, the bill is still not officially adopted and enforced.

This leaves room for informal collectors and recyclers to still operate, adopting practices not always in line with the desired level of environmental and human health protection. It also means that formal recyclers concentrate their efforts only on waste streams or products that have a positive net treatment cost or leverage on companies willing to pay to properly dispose such waste. Absence of legislation and proper financing mechanism in place hamper the possibilities to develop a nation-wide formal e-waste management system.

Analysis in the report shows how the financial impact of proper e-waste management system in Kenya is more than 6 M€, with an average impact of 110 €/t. This takes as a baseline the total amount of e-waste estimated to arise in 2017 (approximately 57kt, including nearly 1.5kt of off-grid solar products).

Off-grid solar products, particularly Solar Portable Lamps (SPL) are, together with lamps, among the products with highest cost mainly because of the impact of battery treatment cost (overseas). In addition, the collection costs in remote areas, might further increase the total costs, calling for the development of alternative strategies and sources of funding to create user incentives.

The report discusses and provides some key policy recommendations for the final adoption of the bill and the establishment of an e-waste management system. This includes clarification of the role of National Register, its funding, options to establish industry-led Compliance Scheme(s) and a recycling fund to support the initial start-up of the system and/or create incentives for users of off-grid solar products living in remote areas.

Finally, a compendium of incentives for private sectors is included. Suggestions are clustered around three main themes: increase of collected amount of e-waste, minimisation of collection costs and minimisation of treatment costs. This highlights the need for financial contributions into the system, whilst striving for increased of cost-effectiveness of the entire system.

1. Overview of solar products and e-waste in waste stream

Kenya is one of the most populous countries in Africa with a population of more than 46 million, with approximately 25% living in urban areas, with the rest 75% in rural Kenya. Urban areas have better access to grid electricity, albeit only 60% of the urban population is connected to the grid, while in rural areas, only 7% of the population has grid access. The Government of Kenya has set out plans to achieve universal energy access by 2020. However, Kenya currently has 2,150 MW of generation capacity, resulting in only 20% of Kenyans with access to electricity.

Kenya is one of the most vibrant markets for the solar industry in Africa, with off-grid solar products reaching 15%-20% of households. Kenya holds the second position in terms of volume of product sales in 2015 in the sub-Saharan Africa region and more than 80% of these are quality verified products. Currently with 15 GOGLA members with sales presence, Kenya accounted for 30% of branded products sold in Africa in 2014-2015.

Baseline and Projected E-waste Burden

The total amount of Electric and Electronic Equipment (EEE) placed on Kenyan market, and corresponding estimates of Waste EEE (WEEE), also called e-waste, generated (UNU, 2015a), is shown in the figure below. Results are obtained applying the so-called sales-lifespan model, in line with the common methodology recently adopted by the European Commission (UNU, 2015b), thus considering the past sales of products and the corresponding average lifespan prior the disposal. Sales figures are obtained from COMTRADE database (UNU, 2015a). Figure 1 below shows the estimates for 2009-2017, considering the wider scope (all EEE products included, excluding PV panels and Off-Grid solar products).

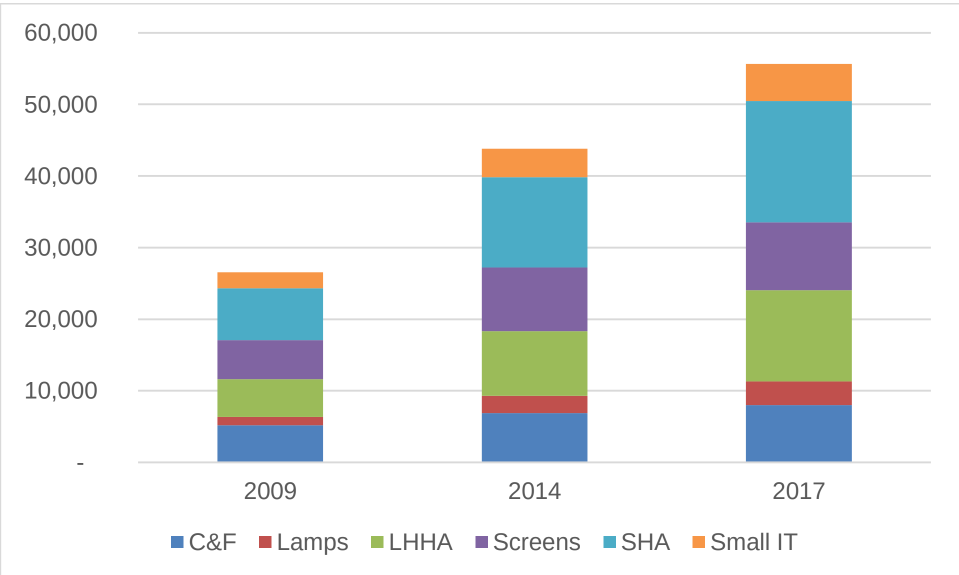

Figure 1. Evolution of e-waste generated in Kenya (t), excluding PV and Off-Grid solar products.

Figure below shows the breakdown of waste arising, according to different waste streams.

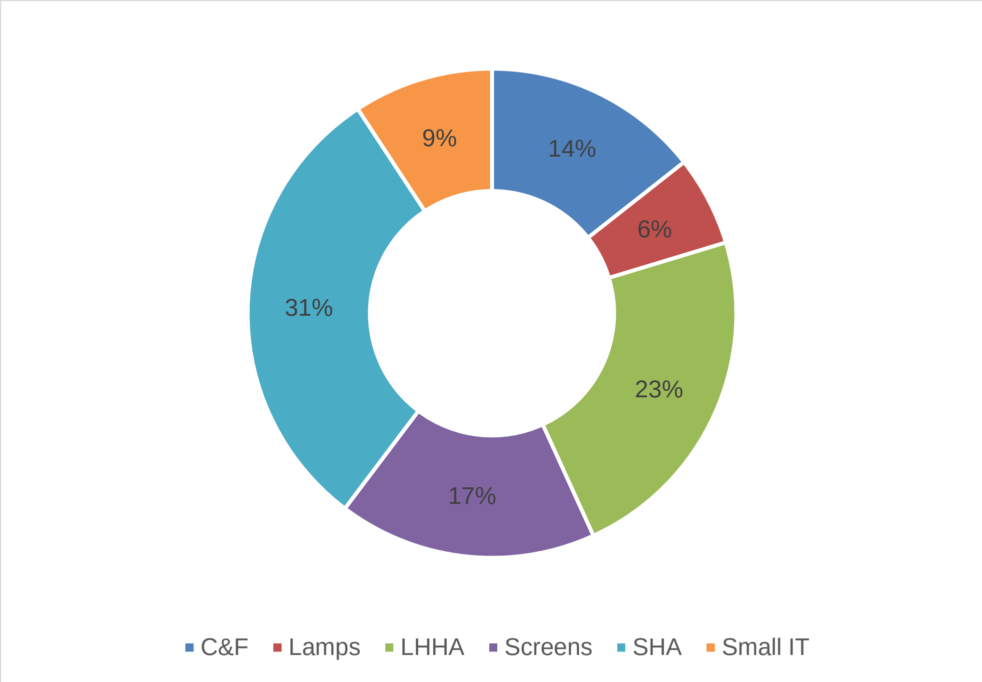

Figure 2: Estimated breakdown of e-waste generated in 2017 in Kenya.

Impact of Off-Grid Solar products

Estimates for off-gird solar products arising in Kenya as waste has been done adopting the same methodology of previous study (Magalini et. al, 2016) as regards Kenyan sales; one important change is related to the average weight of SHS (PC4 and above). The following setting has been used in the model:

- Off-grid products clustered in 3 groups: PC1+PC2; PC3 to PC6; PC7;
- Average weight of the 3 groups of 0.2 kg, 10 and 30 kg; For the last 2 groups, the weight includes lead-acid batteries; for the cluster PC3 to PC6 in particular, it is estimated that 50% of the products are PC3 (average weight of 2.5 kg) while the remaining are PC4 to PC6, with an average weight of almost 20 kg.
- Share of Non-Certified products placed on the market equal to 50% (of the certified ones);
- Average lifetime of certified products equal to 3.6 years and for non-certified products 1.8 years for PC1+ PC2; 5.3 (certified) and 5 years (non-certified) for PC3 to PC6 and 9.8 (certified) and 9.5 years (non-certified) for PC7.

Figure 3 below shows the expected evolution of sales and waste generated, in tonnes looking at 2015-2022. Considering the total amount of e-waste generated in 2017, off-grid solar products represent nearly 3% of the total volumes of waste generated.

As can be seen in Figure 4 and Figure 5, majority of the products are portable solar lighting (PC1 and PC2) in terms of number of products discarded, but the impact of heavier PC4 to PC7 is substantial, especially when considering the weight of batteries, particularly where lead acid ones are used.

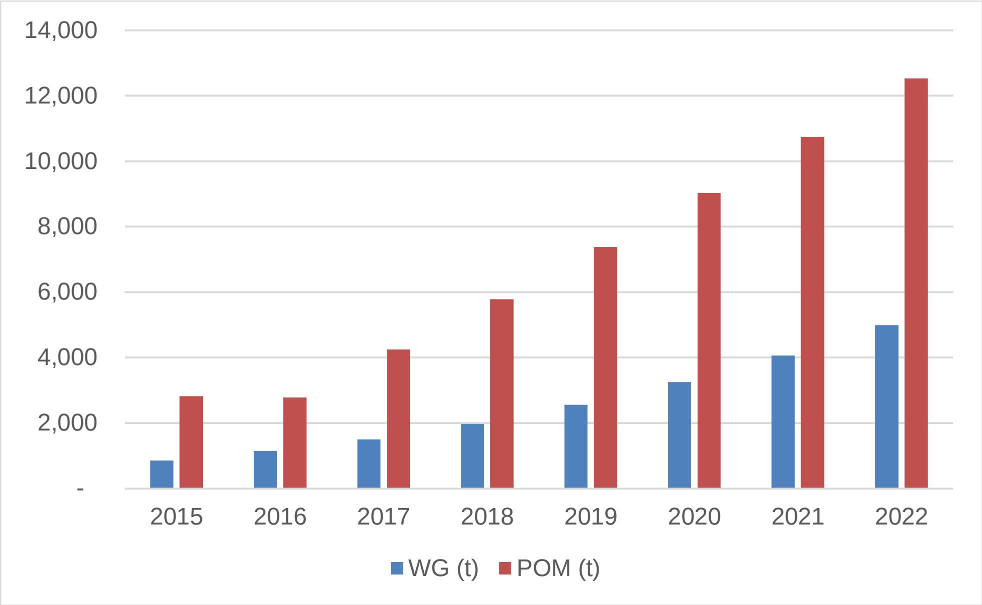

Figure 3: Amount of Off-Grid solar products placed on the market (t) and waste generated (t).

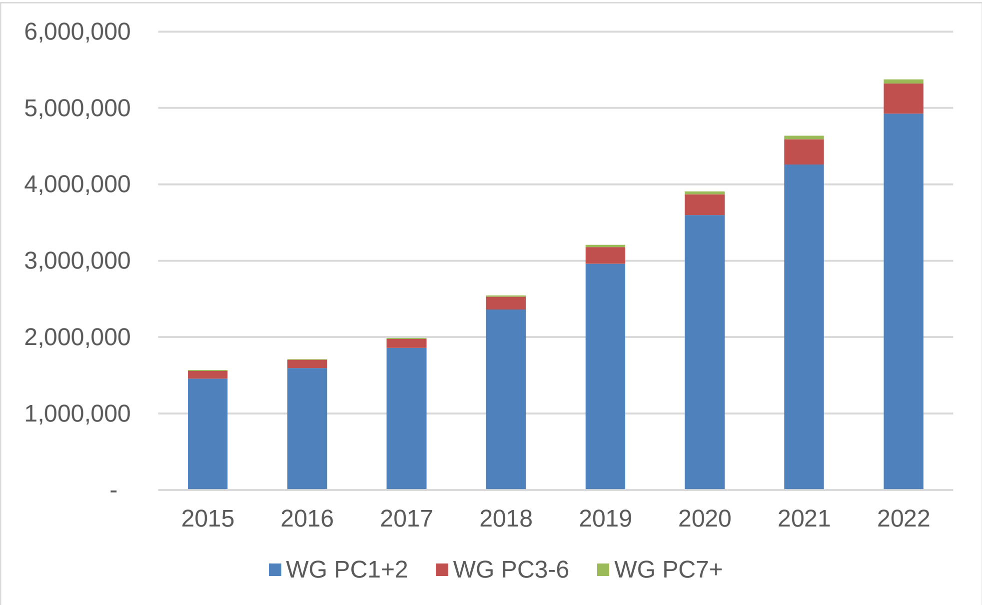

Figure 4: Breakdown of waste generated per product type (in units).

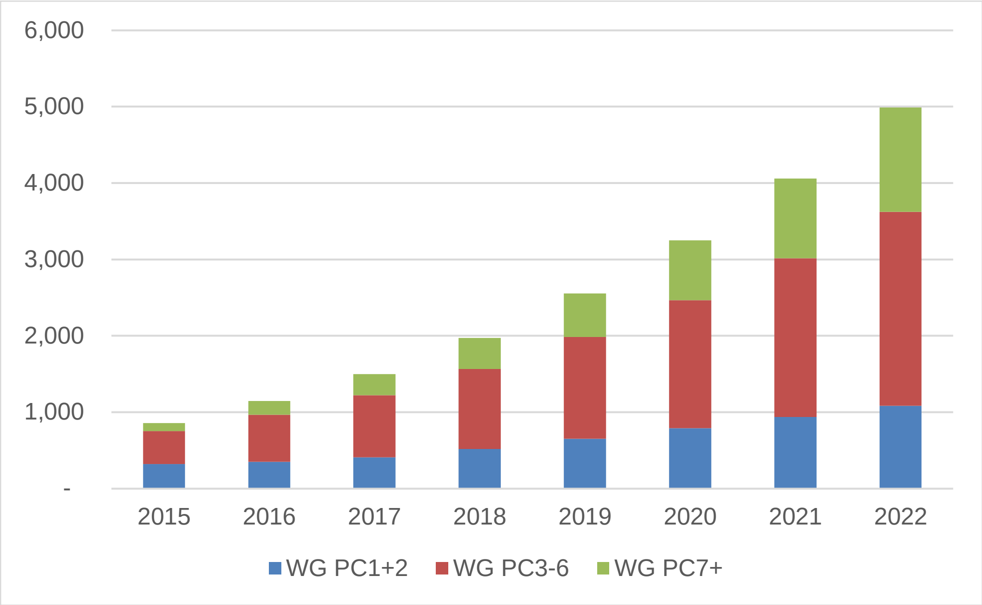

Figure 5: Breakdown of waste generated per product type (in weight).

When considering the impact of certified versus non-certified products, the breakdown is shown in Figure 6.

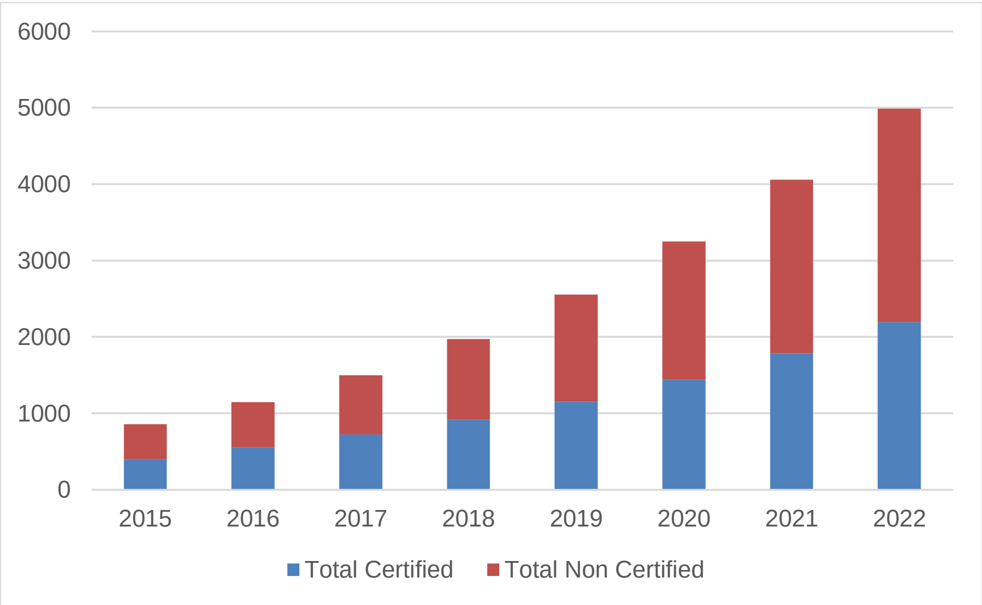

Figure 6: Breakdown certified versus non-certified products.

Simulation has been carried out, using the model, to assess how the shorter lifespan of not-certified products, might have an impact on the total volume of waste generated. Four scenarios have been considered, assuming the total number of products placed on the market as fixed:

- 100% of certified products
- 50% certified products and 50% non-certified products
- 100% non-certified products
- 100% non-certified products with even shorter lifespan.

Impact is shown in the Figure 7 below. It can be observed that compared to the best-case scenario (100% certified products), the 2 scenarios with non-certified products, because of shorter life-span and quicker replacement generate between 10% and 30% more waste.

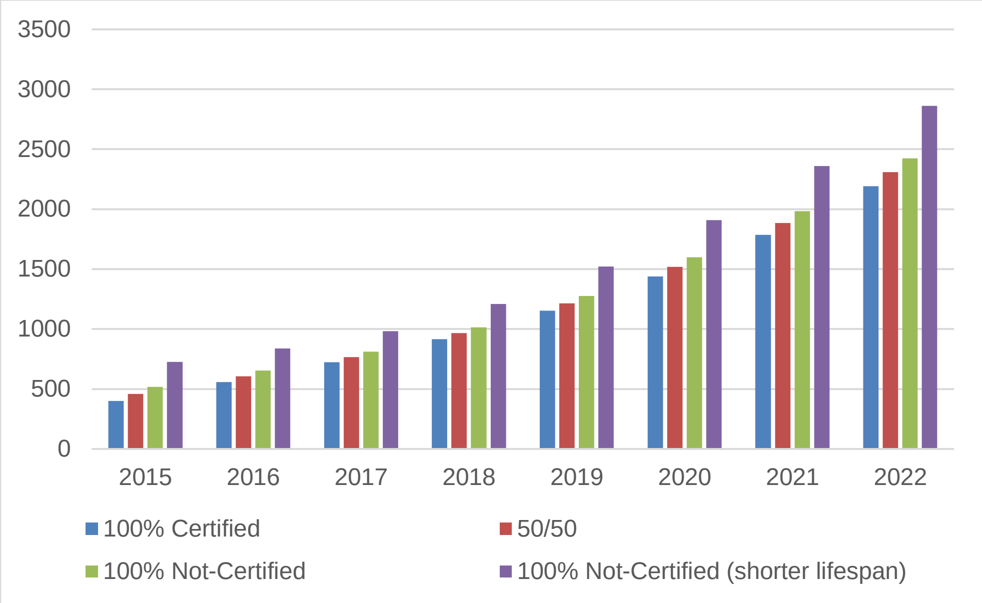

Figure 7: impact of non-certified products on total amount of waste generated.

Interviews with four of the main players active on Kenya market revealed that companies have placed on national market over the last years (starting from 2014, in some cases earlier) more than 8 million products. During this period companies also collected defective products returned during the warranty period: returned products over the last years sum up to more than 530,000 items. In some cases, those products have been recycled, in other cases they are still in warehouses. Overall, the percentage of products returned during the warranty period is around 7%, on average.

The bulk of solar products that are not covered in the warranty period might end up in the hands of informal recyclers where components of interest are extracted and parts that are not of value thrown into the general waste. Repairers have a nationwide presence and end users with defective solar lamps are likely to try to have them repaired by them. This is mainly linked to the fact that most distributors are located in urban or peri-urban centres while most users of solar products live in the remotest parts of Kenya.

Most informal recyclers do not have formal training on how to repair solar lamps (and e-waste in general) and handle e-waste simply focusing on high-value fractions. This contributes to the growth of e-waste as well as most of their repair shops cherry-pick components and discard the remaining fractions, as observed in other East Africa countries (Oeko Institute 2014, Magalini et al. 2016).

Analysis of return stream handled by the WEEE Centre, one of the main e-waste recycler in Kenya, reveals how nearly 50t of the 750t of e-waste treated in the last 3.5 years was made up of off-grid solar products.

Table 1 below shows data from 7 different companies; Can be observed how:

- Majority of the products are small ones (average weight is 0.22 kg);
- Off-grid solar products represent approximately 7% of the e-waste streams handled by the WEEE Center.

Importantly, despite off-grid solar representing 2% of the total e-waste generated, as highlighted in previous paragraphs, given the lack of legislation in Kenya, not all the e-waste generated is handled by national recyclers. When not accounting for Cooling and Freezing and Large Household Appliances, the share represented by off-grid solar products increases to nearly 5%, which is roughly in line with the empirical data from the WEEE Center.

Company	Total weight off-grid solar products (kg)	Number of products	Average weight (kg/product)
Company A	1,078.11	6252	0.17
Company B	43.7	44	0.99
Company C	43,974.57	208,037	0.21
Company D	337.42	772	0.44
Company E	2,123.9	165	12.87
Company F	133.35	502	0.27
Company G	1,128.2	2347	0.48
Total	48,819.25	218,119	0.22

Table 1: Off-grid solar products collected and treated by WEEE Centre in last 3.5 years.

2. Assessment of existing capacity in Kenya

As in many African countries, collection of e-waste is done largely by small and medium collectors, with small informal collectors dominating the collection. There is no public infrastructure for collection of e-waste. Some small-scale collectors move from door to door of commercial buildings and houses in the residential areas to collect recyclable materials. There is also a large network of small scale collectors who collect e-waste from dumpsites where e-waste generated by individual users and small companies also ends up, particularly through the municipal solid waste management services in commercial and residential areas.

The small-scale collectors would then separate e-waste from general solid waste and dismantle to extract components of interest such as copper wires, steel, aluminium, plastic and printed circuit boards. They separate e-waste from the recyclable materials and sell to different agents of the mid-scale collectors. The rest of the components that cannot be sold are left in the dumpsites or collection areas.

Even though the role of informal players might remain relevant, changes are expected with the adoption and enforcement of the new e-waste bill which is also regulating the process to obtain license for collection points and treatment plants adopting the procedures detailed in the following paragraphs.

Collection infrastructures

Anyone intending to establish a collection centre shall notify and obtain authorisation from NEMA; as collection centres are the interface between waste generators (consumers or non-household users) it is foreseen a pivotal role for collection centres, meant to facilitate the receiving, sorting and transfer of e-waste to recycling facilities or refurbishers.

The process to obtain a license as collection centre will have to be defined as is a newly introduced option in the e-waste bill. To date collection centres are licensed in the wider framework of treatment waste permit. To date there are not yet licensed collection centres for e-waste, but 7 centres licensed for hazardous waste collection.

A licence is also foreseen for companies aiming at transporting e-waste. The main elements to obtain the license include:

a) Payment of application fee;
b) Details on company registration, vehicle(s) (including photographs), insurance certificate and inspection reports, as well as diver license(s) of drivers.
c) estimation of waste and type of waste to be transported;
d) information on the destination of the waste to be transported, matching one of the sites licensed by NEMA;
e) tracking documents with company log, as prescribed by NEMA.
f) appointment of a contact person.

Currently formal collection of e-waste at national level is ensured trough collection points set up by recyclers; when considering the example of the WEEE Center, the company has 6 collection points across the various counties (Kisumu, Kakamega, Nakuru, Nairobi, Mombasa, and Machakos), collect e-waste in 120 Safaricom outlets and directly from companies. For Off-Grid solar products is currently testing the option to use TOTAL petrol stations. Currently it is estimated that:

- 60% of e-waste at the WEEE Centre comes from private companies and government institutions,
- e-waste collection from learning institutions represents 20% of the total,
- collections from individual users stands at 10% and
- the remaining 10% of e-waste collection come from repairers.

Treatment Infrastructures

A licence is also foreseen for companies aiming at processing e-waste. The main elements to obtain the license include:

a) Payment of application fee;
b) Details on company registration, precise address of the plant and approval of local planning authority;
c) Details on the type of waste to be handled, including the annual amount;
d) Estimation on the operative lifetime of the plant;
e) An Environmental Impact Assessment with the NEMA acknowledgment letter;
f) Plans for controlling emissions, noise, risk of fire, emergency plan including training and first aid;
g) List of equipment, maintenance plan and environmental management system in place;
h) Proof of technical competence of operators, health and safety procedures and protective equipment;
i) Company budget and business plan, including operating temperature range and ways to dispose ash.

To date the number of licensed recyclers for e-waste is 3. Those recyclers are mainly concentrated in Nairobi region. Other e-waste recyclers currently waiting to obtain permit are present.

International cooperation

Like other African countries, Kenya currently has no downstream options (i.e. facilities) for some of the components/fractions obtained from e-waste processing, including off-grid solar products. National outlet can be found for common materials like scrap iron, copper, aluminium and plastics, but many other fractions need to be exported for proper treatment or disposal. This is the case for valuable and non-valuable fractions, hazardous and non-hazardous ones like: batteries, plastics containing Brominated Flame Retardants, Mercury containing lamps and printed-circuit-boards when looking at off-grid solar products, but also lead-containing glass from CRT monitors and TV, mercury containing backlights from Flat Panels, PCB capacitors or polyurethane foam when considering other e-waste products.

Environmental and economic performances of the national e-waste management system will rely at least in the medium term, for the great majority of those fractions, on international markets; for some fractions a national or even better a regional approach might make sense, while for some others, the high investments needed as well the amount of material needed to ensure cost-effectiveness in the processing might not justify the development of local processing infrastructures.

3. Cost/benefit analysis for e-waste management

E-waste is usually regarded as a waste problem, which can cause environmental damage and human health severe consequences if not safely managed. On the other hand, e-waste is more often seen as a potential source of income for individuals and entrepreneurs aiming at recovering the valuable materials (metals in particular) contained in discarded equipment. Treatment processes of e-waste aim thus to either remove the hazardous components and recover as much of the main materials (e.g. metals, glass and plastics) as possible; achieving both objectives is most desired. Unfortunately, e-waste handling poses unique and complex challenges (Table 2), including:

- The heterogeneity of appliances, in terms of size, weight, function and material composition (most of these properties change over time), and subsequently, in environmental impact at end-of-life;
- The continuous introduction of new products and features, such as the shift from heavy Cathode Ray Tube (CRT) to Liquid Crystal Display (LCD) televisions, introduction of tablets, along with a progressive reduction in average lifespans of products calling for continuous development of appropriate treatment technologies;
- The presence or phasing out of certain constituent elements or potentially hazardous substances in appliances, such as ozone-depleting substances, mercury and other heavy metals, that require proper treatment;
- The relatively high use of certain precious metals and critical resources (e.g., gold, silver, ruthenium, indium, platinum group metals, rare earth elements) and the challenges in their recovery due to the "dissipated" nature of the low-concentration elements and the technological complexity involved in recovering them in recycling processes;
- The large and diverse group of actors involved in various end-of-life activities, such as collection, recycling and treatment, reuse, refurbishment, waste disposal and export of products and fractions.

Category	**Weight / size**	**Environmental /health**	**Material value**
Cooling & Freezing (CFCs)	High	High	Medium
Screen	High	High	Medium
Lamps (with mercury)	Low	High	Low
Large household appliances	High	Low	Medium / High
Small household appliances	Medium	Low	Medium

IT and Consumer Equipment	Medium	High	High
Off-Grid Solar	Low	Medium	Low

Table 2: WEEE streams and priority settings

In many cases the costs of proper collection and recycling e-waste exceeds the revenues generated from the recovered materials. So, a proper financing mechanism, tailored on the societal context of the country need to be defined first and enforced afterwards.

The e-waste recycling chain has been modelled according to previous studies and work (Magalini et al. 2016) and comprises the following steps:

- **Access to waste**: includes the costs (or revenues) to get the waste from the original holder (the consumer). In most developed countries consumers get rid of their waste for free (or in some cases they must pay). In the context of most developing countries it is the opposite: the holder of the product to be discarded expects an economic compensation when disposing off the waste. Access to waste is considered a cost when the waste holder is receiving economic compensation. It will be considered revenue when the consumer will pay for disposing it.
- **Collection**: includes the cost for hiring, purchasing (or the corresponding depreciation) the collection infrastructures like containers, cages, bins used to collect and store waste at the collection points. This also includes salary of staff at collection points.
- **Transport**: includes all the transportation costs from the collection point or from the consumers' house/place to the treatment plant.
- **Treatment**: represents the net costs for proper treatment, including disposal of hazardous fractions. Each treatment plant processing e-waste incurs in operative costs: labour costs, energy costs, depreciation of capital investment, other costs related to the functioning of the plant itself; e-waste being processed into the plant is dismantled and results in different fractions that are sold on national or international commodities markets.

Table below shows, for the various waste stream the resulting average costs considering the assumptions and date of previous studies (Magalini et al. 2016) plus the following:

- Access to waste estimated for the various waste streams, excluding the potential financial compensation for off-grid solar products in remote areas (can have incidence up to 4,500 €/t assuming 1 €/product[1]);
- Collection centres with 30% FTE for employee responsible for collection, record keeping and monitoring, with 2t/load in the container. Container is assumed to be "shared" for the collection of all waste streams (best case scenario). Having dedicated collection infrastructures for streams having lower generation (e.g. off-grid solar only) leads to cost increase, as already detailed in previous studies; costs are now allocated considering the mass of products in the container.
- Disposal rate for collection centre equal to current performances of the collection network of the WEEE Center (best case scenario);
- Breakdown of waste generated for various e-waste streams according to the shares described in chapter 1 of the report, assuming thus that the system collects and treat all type of e-waste;
- Average transport distance to reach the plant from collection centre equal to 300 km and impact of 50 Kenyan Shillings per km for the transport;

[1] In some cases, has been reported customers to pay up to 100 KHS, equivalent to 2-3% of the small portable solar product price to reach the closest point to purchase a product.

- Simplified material composition of the waste streams as reported in Table below; for all off-grid products LED lamps has been assumed to be present and for PC4 and PC7 lead acid batteries (treated oversea);
- Market value for main fractions obtained on Kenyan market (Steel, Copper, Aluminium, Plastics plus local disposal) and shipment overseas for other fractions (considering average prices for various fractions);
- Local labour cost, mainly linked to manual disassembly, and Overhead varying for different waste streams to consider depreciation, other general costs (50% for most waste streams to 200% for C&F and Screens to take into account the depreciation of the machines used for the degassing and CRT cutting); For lamps, due to mercury content, it is assumed treatment takes place overseas.

As table below reveals, most activities along the collection and recycling chain generate costs. For a few products, the intrinsic economic value can mitigate the total treatment costs and partially also the others, but clearly a financing mechanism need to be in place to ensure proper recycling. Total costs resulting from the simplified calculations and under the assumptions made are anyway showing convergence on few elements:

- Screens and plastic-dominated small appliances are having a negative net treatment cost while ICT products have a positive one (similarity to what we have experienced in Europe in the start-up phases);
- Lamps containing mercury are representing a high cost for proper treatment (overseas);
- Cheap labour cost and manual disassembly play a crucial role in having lower treatment costs for some fractions, fridges in particular, compared to EU or other markets. But such calculations do not take into account the impact of properly treating the polyurethane foam containing Ozone Depleting Substances but only the de-gassing phase; this means that treating foams in state of the art mechanical process might substantially increase the costs for fridge recycling. Such effect has been also seen in other African countries (Cyrcle, 2015);
- For off-grid solar products the chemistry of the batteries used (Li-phosphate versus lead acid is playing a major role in the cost figures, as well as the presence of the copper cables in the SHS).

The way products or waste streams are clustered can eventually bring cross-financing opportunities that might eventually further mitigate the financial impacts of certain products or product groups. Historically, however, industry has not been in favour of such an approach.

Category	**Main materials**	**Access to waste cost**	**Collection cost**	**Transport cost**	**Intrinsic economic value**	**Net Treatment cost**	**Total cost**
Cooling & Freezing (CFCs)	Steel (50%), Plastic (28%) + PUR (10%), Glass (7%), Copper (2%), Aluminium (3%)	-50 €/t	-13 €/t	-10 €/t	122 €/t	91 €/t	18 €/t
Screen (TV, CRT)	Glass (CRT)(30%), Plastics (25%), Steel (6%), Copper (5%), Other (34%)	-50 €/t	-16 €/t	-12 €/t	35 €/t	-67 €/t	-144 €/t
Lamps (with mercury)	CFL (Hg) (80%), Aluminium (1%), Plastics (1%), Other (18%)	0 €/t	-5 €/t	-4 €/t	-825 €/t	-978 €/t	-988 €/t

Large household appliances	Steel (53%), Plastic (10%), Copper (4%), Aluminium (3%), Other (30%)	-50 €/t	-21 €/t	-16 €/t	186 €/t	165 €/t	78 €/t
Small household appliances	Plastics (35%), Mixed plastic (incl. BFR) (25%), Steel (16%)Aluminium (3%), Copper (2%), PWB (1%), Other (18%)	-50 €/t	-22 €/t	-17 €/t	63 €/t	-52 €/t	- 141 €/t
IT and Consumer Equipment	Steel (70%, Plastics (10%)Copper (6%), Aluminium (4%), PWB (4%), Other (6%)	-100 €/t	-8 €/t	-6 €/t	351 €/t	294 €/t	180 €/t
Off-Grid Solar (PC1)	LIP batteries (67%), LED (20%), Steel (13%)	0 €/t	-1 €/t	-1 €/t	-2,259 €/t	-3,537 €/t	-3,539 €/t
Off-Grid Solar (PC2)	PV modules (45%), Mixed plastics (inc. BFR) (23%), Steel (18%), LIP batteries (11%), LED (3%)	0 €/t	-1 €/t	-1 €/t	-529 €/t	-828 €/t	-830 €/t
Off-Grid Solar (PC4)	Steel (30%), PV Module (29%), Pb battery (30%), Copper (4%), Plastics (6%), PWB (2%)	0 €/t	-3 €/t	-2.3 €/t	149 €/t	119t	114 €/t
Off-Grid Solar (PC7)	Steel (30%), PV Module (29%), Pb battery (30%), Copper (4%), Plastics (6%), PWB (2%)	0 €/t	-1 €/t	-1 €/t	149 €/t	130 €/t	129 €/t

Table 3: Total collection & recycling chain cost (average values), €/t.

Figures below show the contribution of the various steps in the total, final cost. SHA and ICT has been aggregated considering their relative weight.

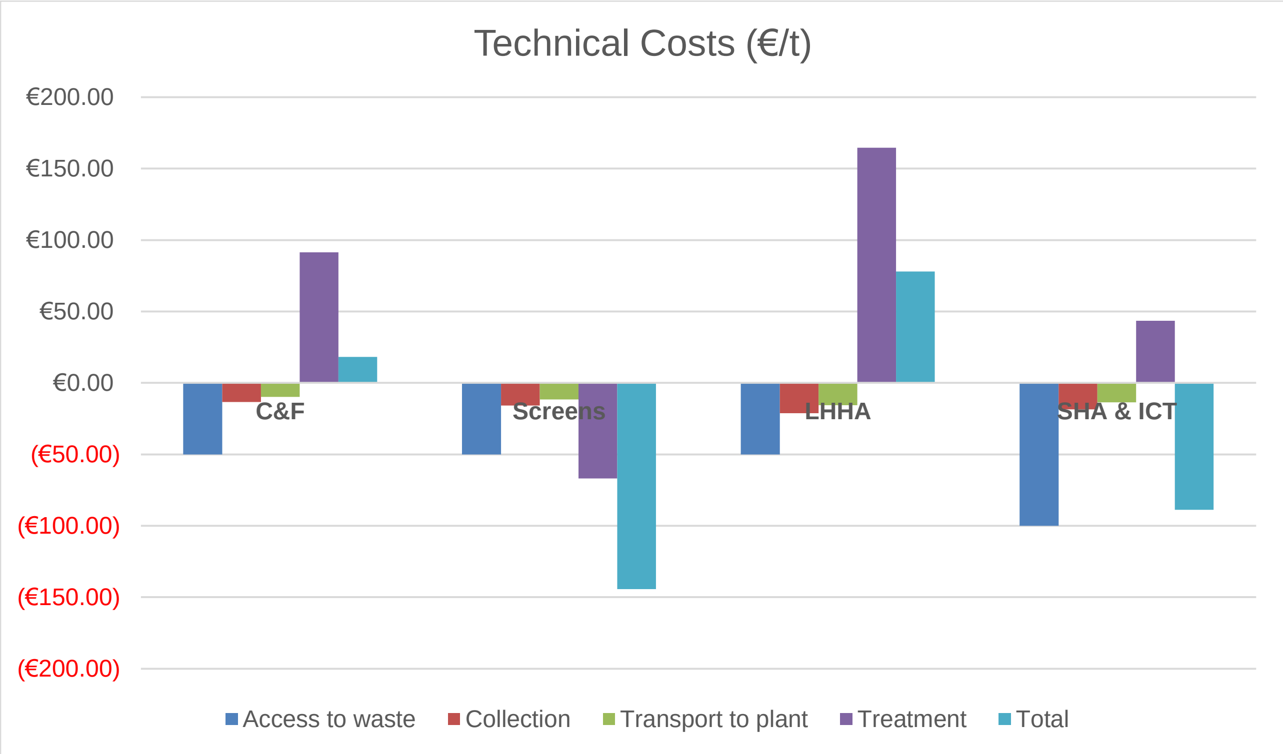

Figure 8: Costs for e-waste management along the chain (€/t).

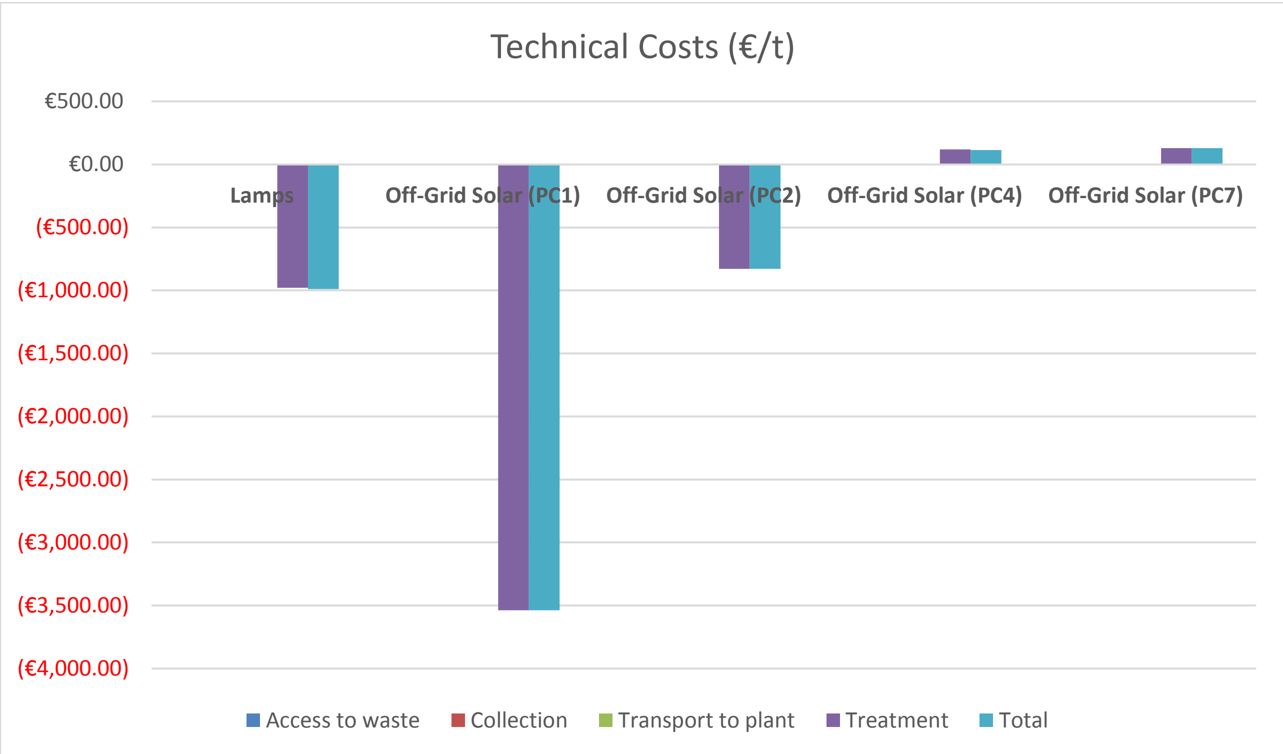

Figure 9: Costs for e-waste management along the chain (€/t).

When considering the projection of e-waste generated in Kenya for 2017 the following results are derived: approximately 6.3 M€ the total costs, with approximately 0.8 M€ for off-grid solar Industry alone (representing nearly 14% of the total). This is mainly linked to the high treatment costs of Lithium phosphate batteries and the low intrinsic economic value of solar portable lighting (and potentially the impact of collection in remote areas); for SHS the current calculations assume lead acid batteries, but in case of Lithium-phosphate ones the costs are higher, and the total economic impact for off-grid industry would be close to 2 M€. Such an economic impact is also high for mercury-containing energy saving lamps.

Those numbers are anyway based on the assumptions that all e-waste generated is being collected and treated; experiences in Europe shows anyway that this is hardly happening, especially for small products and lamps in particular. So the actual financial impact in Kenya might be lower.

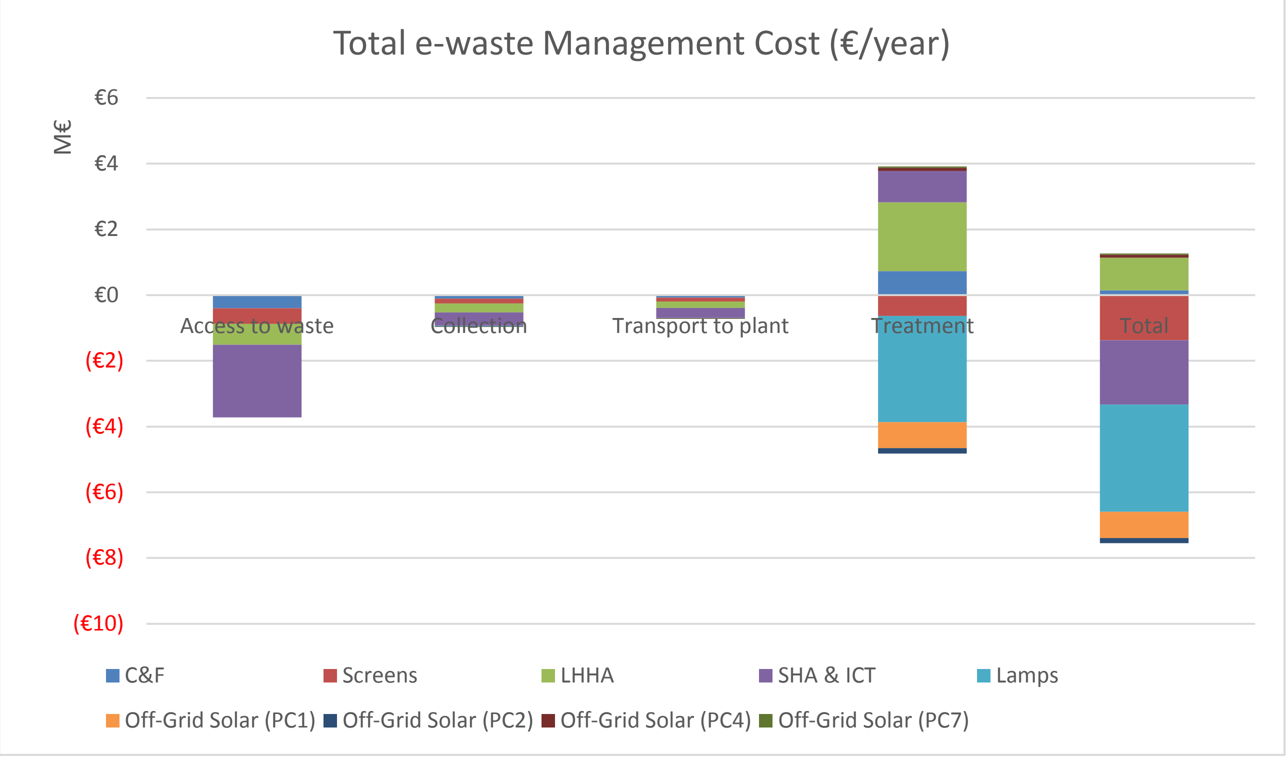

Figure 10: Total costs for e-waste management in Kenya (assuming 2017 e-waste generated volumes).

Enabling proper e-waste management through adequate financing mechanisms is of paramount importance as e-waste contains a multitude of hazardous substances that may be released into the environment when the waste is handled and processed. In addition, in some processes used, new hazardous compounds, such as dioxins, may be formed as the original e-waste components are degraded.

The compounds of most concern during these activities vary depending on the material being recycled and the methods used. However, on the whole, dioxins (chlorinated and brominated) and polybrominated diphenyl ethers (PBDEs) seem to be particularly problematic among the organic compounds. These compounds are all very toxic and may potentially be emitted in large amounts during rudimentary e-waste recycling activities, particularly open-burning processes.

In Kenya, these practices are particularly widespread and the amount of persistent organic pollutants (POPs), including PCDD, PCDF and PBDE, released to the environment is one of the highest emission rate per capita in the world[2]. In 2012, open burning processes were estimated to be responsible of the emissions of 241.1 Toxic Equivalent grams (TEQg), out a total of 2,872 g TEQ of unintentionally produced POPs[3].

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[2] Toolkit for Identification and Quantification of Releases of Dioxins, Furans and Other Unintentional POPs January 2013. Figure III.7.3 Total annual release per country (g TEQ/a)

[3] Kenya national implementation plan for the Stockholm convention on persistent organic pollutants.

Based on estimated waste generated in 2017 used in this study, average material composition per waste stream as well as the emissions factors found in UNEP Toolkit on POPs, the amounts of dioxins and furans released during the open burning of the cables and printed circuit boards of E-waste generated in 2017 has been calculated assuming that 100% of WEEE generated is treated using open-burning, this is a worst-case estimate:

Product type	**POPs due to open-burning (g)**
C&F	3.4
Lamps	0.0
LHHA	3.0
Screens	4.5
SHA	32.1
Small IT	6.5
Solar products	
PC1	0.0
PC2	0.0
PC4	0.1
Total	**49.57**

Table 4: Estimations of POPs emissions in 2017 due to open burning of e-waste

Proper handling of e-waste streams would prevent the emissions of nearly 50 g TEQ of POPs per year, which represents nearly 20% of all POPs emissions from open burning in 2012 in Kenya.

Other substances of concern are emitted during open burning but lack of suitable data did not allow to quantify those emissions. In any case, it is anticipated that the amounts of toxic substances (e.g. PM) released in addition to POPs during open-burning would be prevented/reduced via sound e-waste management.

4. Legal framework and policy recommendations

The waste management sector in Kenya is overseen by the National Environment Management Authority (NEMA) and the existing legal framework for general waste management includes the Environmental Management and Coordination Act (1999) and the Waste Management Regulations (2006). The only legal document that specifically addresses the issue of e-waste is the 2013 draft bill, which it has not yet been approved by the National Assembly.

The proposed legal framework

The proposed bill is based on the principles of Extended Producer Responsibility. It seeks to address a cross-section of the product value chain from producers/ manufacturers, importers and assemblers to large institutional and household consumers to refurbishers and recyclers. However, whether off-grid products are included or excluded from the scope of the draft regulations is unclear, as is the definition of “producer”.

In the proposed e-waste bill the scope is quite wide, closer to the one of the EU WEEE Directive, with the same 10 product categories of the original WEEE Directive. In addition, batteries are also included in the scope of the legislation (portable, automotive and industrial ones). The table below summarises the main requirements.

Step in the recycling chain/activity	**Main provisions**
Collection	• Set-up of collection points is demanded to private sector, despite the financing of the set-up is not addressed in the bill. • Is responsibility of the waste generator – defined as “any person whose activity produces e-waste or the person who is in possession or control of that e-waste” – to properly dispose the waste through refurbishers (if the product is still working), collection centres or licensed recyclers. • Specific provisions on open burning, uncontrolled disposal or abandoning are included. • Refurbishers are responsible to transfer e-waste or components which are no longer useful to licensed recyclers. • Producers might also directly and individually channel to contracted recyclers. • Recyclers might set up collection infrastructures or stipulate agreements with logistics providers to ensure the waste is arriving at the facility. • The establishment of collection centres needs to be notified to NEMA; notification includes the name of the recycling facility to which the collected e-waste is transported.
Treatment	• Recycling facilities need to be licensed by NEMA in accordance to general waste management regulations. • Recyclers, where possible, should give priority to refurbishment of appliances rather than recycling. • Recyclers shall collect and treat e-waste in accordance with specific guidelines from NEMA, • Specific provisions on quarterly reporting are also included and detailed.
Financing	• EPR is the cornerstone of the Kenyan regulation; • "Problematic fractions” are defined as “those components or parts of e-waste where the collection and treatment costs outweigh the material recovery value”. This means that collection and treatment costs are born by recyclers and, where needed, producers financially support their operations.
Information & reporting	• Key element of the financing model is the establishment of a national register, responsible for the monitoring and fulfilment of obligations by different stakeholders. • The National Register is responsible to check and allocate to Producers potential excess of total costs incurred by the licensed facilities to process the problematic fractions. *Producers* • Are requested to register and declare the amount of products placed on Kenyan market on annual basis, dived into product categories. • When applying for registration each producer should proof the contractual agreements with one of more licensed recyclers to fulfil his share of obligations. • Annually, producers should report and prove the payment for their “share” of financial obligations for the treatment of problematic fractions. • The National Register calculates the individual shares of responsibilities on the basis of total weight of products placed on the market in each product category. *Recyclers* • Must report quarterly on the amount of e-waste collected and received, the products/components reused or refurbished, the amount recovered and recycled within the facility and the total amount of precious metals recovered.

Table 5: Main provisions of Kenya draft bill.

Policy recommendations on the implementation of the bill

To address these open points in the current text, the following recommendations are made:

1. **Inclusion/exclusion from the scope of e-waste legislation**

The definition of Electric Equipment part I, Article 2 refers to:

> *'electrical equipment' means equipment for the generation, transfer and measurement of electric currents and fields falling under the categories set out in schedule 1 of these regulation;*
>
> *'electronic equipment' means equipment which is dependent on electric currents or electromagnetic fields in order to work properly under the categories set out in schedule 1 of these regulation;*

Off-grid products and PV panels are not clearly mentioned while batteries are clearly included in the scope, as a specific element in schedule 1.

It is paramount to obtain clarity on this, even in the view of industry position papers (GOGLA 2014) to ensure a level playing field across industry (IRENA, 2016). This is particularly linked to the impact of financing EOL management of products which should not create asymmetries, market distortions and barriers for off-grid products as, for instance, the case of kerosene subsidies and VAT exemptions (ODI, 2016a).

2. **Identification of the "producer" in the context of EPR legislation**

For all models based on the EPR principle it is of crucial to implement and enforce a proper definition of "producer", as this is linked to all subsequent legal obligations. In an EPR context this cannot only refer to the manufacturer or the brand of the individual product, as the EPR is used as a principle to shift part of the financial contribution for proper e-waste management from society or consumers to entities making profits out of the introduction of EEE on the national market. In (Step, 2016) the following definition is proposed:

> *The local manufacturer or importer of new and used EEE to be placed on a national market at first invoice by sale or donation. The producer can be a legal or natural person and must be established in the country of import*.

3. **Identification of the role of National Register and details on the financing of problematic fractions**

Collection and treatment costs are born by recyclers and, where needed, producers financially support their operations. So recyclers have an intrinsic interest in collecting and processing e-waste. For those products with positive net treatment cost, there is already the incentive in collection and treatment as they are directly contributing to the profits of the plant. For products having a negative net treatment cost due to the presence of "problematic fractions", the financial support from producers will fill the gap so that the proper treatment and the profitability of entrepreneurial activities are ensured.

Allocation, by National Register, of excess volumes treated by recyclers to producers on pro-rata basis will have to be further detailed in its functioning.

Broader policy recommendations

In addition to specific recommendations on the bill itself, other elements can be considered:

4. **Clarification of the role of the different actors of the Government (central versus local)**

During a dedicated workshop organised in Nairobi and involving key stakeholders from governmental organisations and private sector, examples were provided where County Governments and the National Government means of collecting revenues overlap.

To ensure a uniform approach to dealing with e-waste or hazardous wastes in general, the responsibilities of the different actors in the law enforcement process needs to be defined clearly. In particular, the definition level at which the law is enforced (national versus regional or local) is critical to avoid any gap or any overlap when enforcing the law.

5. **Allow the establishment of producer Compliance Schemes**

From an overall cost-effectiveness perspective, the absence of any intermediate body between the recyclers (the entity carrying out operations and affording the technical costs) and producers (the entity responsible to finance those costs) can increase the cost-effectiveness of the entire system and ensure a lean structure in the system.

On the other hand, for small and medium sized producers it could be simpler and less burdensome to delegate to an external entity (like a compliance scheme) all the administrative aspects related to compliance (like reporting, scouting and signing contracts with licensed recyclers, etc), as happens in Europe or other regions.

How the collection and recycling chain costs will be charged and paid is still not clearly defined:

- will each individual producer have bilateral contract(s) with recyclers?
- will the financing be done through an independent, Industry-managed body (e.g. Compliance Scheme)?
- will the financing be done through a government controlled body (e.g. National Register or dedicated entity)?

6. **Clarify the role of private sector & consider the option of establishing a recycling fund.**

The current bill leaves room for the private sector to establish collection points, operate transport and recycling facilities, but does not clearly define the boundaries for the financing by producers. While it appears clear that the set-up of collection and recycling infrastructure is not meant to be funded under EPR scheme (only treatment of problematic fractions is), it might be possible to mobilise additional financial resources, in line with the draft Regional E-Waste Strategy developed by the Working Group of East African Communications Organizations (EACO) on e-waste through development cooperation agencies or other donors (e.g. GEF).

Such a fund could eventually serve the purpose of supporting local governments in the start-up of e-waste systems, including investments in collection and recycling infrastructures or awareness raising campaigns.

Such a fund could eventually mitigate the financial impact related to the collection of off-grid solar products in remote areas. The likelihood of users traveling to dispose of their old products free of charge, is very low. In such cases, financial incentives might be needed to ensure the collection of products from such remote areas is possible.

5. Incentives for private sector

For the successful implementation of an e-waste management system in Kenya it's important to facilitate the development of a suitable "ecosystem" where the stakeholders can play their role according to the responsibilities allocated and defined by the legislation. Three main areas and aims has been identified during a dedicated workshop organised in Nairobi on the 31st of May 2017 with relevant stakeholders, and detailed in the paragraphs below.

Make it easy for the waste holder & increase volumes

The main focus of this area is the increase of the awareness of consumers to stimulate the proper collection of e-waste and off-grid solar products in particular. It is particularly crucial to create a nation-wide network of collection point, easy to use by consumers and reach the more remote areas where off-grid solar products are. Activities include:

- Coordination of nation-wide awareness raising campaign under the leadership of NEMA, which might include development of dedicated leaflets or announcement on radio;
- Broadcast messages, like those provided by Safaricom to subscribers are also a viable alternative;
- Development of toll-free information number for consumers and companies;
- Encouraging OEMs and distributors to adopt or promote takeback initiatives in their marketing plans, also trough the roadshows;

Make it cheap for the collectors

The focus for this area is the decrease of the economic incentive that waste holders are requesting when getting rid of their waste (so-called access to waste cost); and secondly the implementation of an effective collection and transportation system to licensed recycling facilities. Activities include:

- Awareness creation focusing on the dangers of e-waste and advantages of proper disposal, eventually supported by specific research and studies;
- Transparency on the cost of processing chain to increase the acceptance of the system; this would also help Industry to show the impact of proper end-of-life management and avoid disruption caused by players by free-riders;
- Enforcement by competent authorities of applicable legislation, particularly tackling the improper disposal;
- Leveraging on roadshows organised by Off-Grid solar companies, particularly in more remote areas;
- Distribution and placement of secure collection bins close to generators, eventually leveraging on alternative locations (e.g. petrol station, like in the pilot run by TOTAL). Simplification of waste permit requirement for collection of small products should be introduced, similarity to what the EU Battery Directive introduced (e.g. exemption from waste permit for collection of batteries in shops);
- Streamlining licensing procedures within relevant government agencies to increase the number of registered and approved collection points nation-wide.

Make it cheap for recyclers (& producers paying)

The focus of this area is to facilitate the creation of a network of licensed recycling facilities in the country and the development of local markets for commodities and solutions for problematic fractions. This is to make it easier and cheaper for recyclers to ensure a proper treatment and consequently minimise the need of financial support by producers and, generally speaking, by society. Activities include:

- Develop a publicly accessible database containing all required information for registration of business to comply with government and international standards;
- Set-up of take-back schemes to allow producers, especially small one, not being able to develop own systems, to join and comply with the regulations;
- Streamlining of licensing process, particularly clarifying the role of central government versus counties;
- Develop bilateral (regional agreement, within EACO community or at COMESA level) agreements to handle transboundary movement issues for recycling of problematic fractions that can't be treated in Kenya and would need to be exported to countries were adequate facilities exist. Facilitating such transboundary movements through the enforcement of bilateral agreements would remove a burden from recycling companies and increase the efficiency of the process.
- Adopt, similarity to what happens in France, where products complying with specific eco-design requirements have lower recycling fee, a modular structure for the recycling fees; in particular, as simulation in section 1 demonstrated, higher fees could be introduced (up to 20-30%) for Producers selling non-certified products given the shorter lifespan and the higher impact in terms of waste generation.

6. Overall challenges and opportunities for e-waste management in Kenya

The table below summarises the main challenges and opportunities for Kenya considering previous studies (Magalini et al., 2016) and the input received from stakeholders during the dedicated workshop organised in Nairobi.

Main challenges related to e-waste management	Specific challenges for disposing EOL solar products	Opportunities in EOL solar product management
Low consumer awareness and **unwillingness to change attitude** of consumers. • Awareness about e-waste disposal. • Harmful effects of improper disposal or recycling. • Information on better ways of disposing e-waste.	**Ministerial jurisdiction & policy** • Alignment between access to energy programmes, and e-waste bill.	**Awareness amongst OEMs/ Producer & Institutional Consumers** • Government agencies and companies in Kenya positively are responding to the contractual arrangement for e-waste disposal • Voluntary pilots from off-grid

Main challenges related to e-waste management	Specific challenges for disposing EOL solar products	Opportunities in EOL solar product management
• Request of financial compensation when disposing. • Reluctance to pay for products that cost money to recycle properly.		Industry on collection & recycling • Willingness to try new models (e.g. leveraging on petrol stations, combine take back with road-shows,...)
Lack of legislative framework • Bill still to be adopted; adoption and implementation could foster the establishment of a formal system	**Unbranded/Non-certified products**: • Large market of generic or unbranded solar products, with lower quality shorter product life, • Potentially unknown producers, local assemblers, potentially acting as freerides on the market.	**Possibilities of geo-location** • Many SHS systems connected. • Information on operational efficiency, geo-location.
Lack of government support for collection and recycling infrastructure: • Lack of nation-wide infrastructure and resources for environmentally sound management of e-waste. • Need to enforce separate collection of various waste streams	**Low volumes and low value** • Low volumes and weight compared to other EEE • Very low intrinsic material value.	**Leveraging on PAYG, leasing** • Where ownership remains with the producer or distributor, easier to engage consumers (with various incentives too).
Inadequate technical expertise • Lack of trained staff on proper e-waste management • Most small scale and medium scale operators work without any formal training, unaware of best practices and available technologies • Need to foster adoption of or measures that not only are environmentally sound but also more economically profitable.	**Deeper rural penetration** • Widespread dispersion especially in remote rural areas which is a challenge for collection and take-back.	**Establishing a recycling fund** • Leveraging on EACO E-waste strategy and establishing a fund to potentially compensate costs for collection in rural areas.

Table 6: Summary of challenges and opportunities for e-waste and off-grid solar products collection & recycling.

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