SUSTAINABLE MANAGEMENT OF E-WASTE IN THE OFF-GRID RENEWABLE ENERGY SECTOR IN RWANDA

July 2017

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Contents

Acronyms and Abbreviations

BFR	Brominated Flame Retardant
CENELEC	European Committee for Electrotechnical Standardization
C&F	Cooling & Freezing Appliances
CFL	Compact Fluorescent Lamps
CRT	Cathode Ray Tube
COPED	Company for Environment Protection and Development
DFID	Department for International Development
EACO	East African Community Organisation
EEE	Electric and Electronic Equipment
EDCL	Energy Development Corporation Limited
EOL	End of Life
EnDev	Energising Development
EPR	Extended Producer Responsibility
EPIA	European Photovoltaic Industry Association
EU	European Union
FONERWA	National Fund for Environment and Climate Change
GOGLA	Global Off-Grid Lighting Association
GoR	Government of Rwanda
ICT	Information and Communication Technology
IT	Information Technology
ISO	International Organisation for Standardization
IRENA	International Renewable Energy Agency
LED	Light Emitting Diode
LHHA	Large Household Appliances
lm	Lumen
MINEACOM	Ministry of Trade, Industry and East African Community Affairs
MINECOFIN	Ministry of Finance and Economic Planning
MINIMFRA	Ministry of Infrastructure
MINYICT	Ministry of Youth and ICT
OAU	Organization of Africa Unity
OSHA	Occupational Health and Safety
OEM	Original Equipment Manufacturer
P1	Government of Rwanda Access to Energy Program
PAYG	Pay-As-You-Go
PC	Personal Computer
PCB	Printed Circuit Boards
POM	Put on Market
PPP	Public Private Partnership
PV (Modules)	Photovoltaic (Modules)
PWB	Printed Wiring Boards
RES	Rural Electrification Strategy
REMA	Rwanda Environment Management Authority
RURA	Rwanda Utilities Regulatory Authority
RoHS	Restriction of Hazardous Substances
RSB	Rwanda Standards Board
RDB	Rwanda Development Board
SHA	Small Household Appliances
SHS	Solar Household Systems
SLABs	Sealed Lead Acid Batteries
SPL	Solar Portable Lamps
SREP	Scaling-up Renewable Energy Program
t	tonnes
VAT	Value-added Tax
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

Rwanda (population 12 million in 2016) is one of the smallest countries on the African mainland, albeit with a high population density. The Rwandan Government has ambitious targets of bringing access to electricity to 70% of its largely young and rural citizens in 2017, with off-grid solar as a key enabler to achieve this target. Under its Rural Electrification Strategy (RES), between 35-39% of the access is expected to come from off-grid and mini-grid technologies.

With this determined push towards diffusion of off-grid solar products, the estimated volume of products put on the Rwandan market is projected to grow exponentially. Estimates made as part of this study show that nearly 400 tonnes (t) of off-grid products are expected to be put on the Rwandan market in 2017, and approximately 180 tonnes reaching the waste stream in 2017, representing a little under 5% of the total e-waste generated.

The Rwandan Government has developed a comprehensive enabling legal framework, with specific policy and legislations on e-waste, including solar products in the scope. The draft E-waste Bill and accompanying E-waste Regulations are based on the principle of producer responsibility, specifying the role and responsibilities of various stakeholders involved. The government led the way in setting up the collection and recycling infrastructure, financing the construction of a 10,000 tonnes/year capacity dismantling plant near Kigali and upcoming collection point network. Keen to attract investment and best-practice in the sector, the plant will be operated and managed by a private sector partner, while remaining in government ownership.

Analysis of the Rwandan situation and calculations presented in the report shows that the cost to collect, transport and properly treat approximately 8,500 tonnes of e-waste, including solar products expected to be generated in 2017 is approximately € 550,000, with an average economic impact of a cost of 65 €/t distributed across all products.

The largest share of costs arises from the disposal cost of CFL lamps containing hazardous mercury. Small off-grid solar products, typically powering one or two lamps, also have negative net treatment costs on account of Lithium Phosphate batteries which are hard to recycle. Larger solar home systems (SHS) on the other hand can potentially have a net positive or nearly zero net cost when using lead acid batteries as the intrinsic value of lead can often cover the cost of collection and treatment.

The report analyses extended producer responsibility (EPR) and assesses the framework conditions in Rwanda for establishing a sustainable e-waste take-back and recycling system and provides key policy recommendations on policy and legislation as well as stakeholder engagement, awareness and capacity building.

It concludes with next steps and areas for further research as well as the steps to establishing a financing mechanism and an EPR fund for e-waste management in Rwanda.

1. Introduction

Background

Off-grid solar solutions have recently become a key enabler for increasing access to energy for a growing number of persons living off the grid particularly in Africa (GOGLA, 2016). The Rwandan Government is targeting 70% access to electricity among its citizens in 2017. Off-grid solar plays a significant role: under the Rwanda Rural Electrification Strategy (RES), between 35-39% of the access is expected to come from off-grid and mini-grid technologies.

To meet this ambitious target, Rwanda is supported by the UK, among others. In 2017, the Rwandan and UK Governments signed the Energy Africa Compact aimed at accelerating the expansion of household solar throughout the African continent through mutual policy and programme commitments. This is a continuation of the international community support over the last decade to improve energy access, particularly through renewable technologies. Currently, the Rwanda off-grid market is seeing increasing investment (e.g. SREP, EnDev's RBF etc.) therefore it is the right moment to engage the sector for the end-of-life management of these technologies.

Data from the GOGLA annual report (2016)[1] show that solar product adoption in Rwanda has been seeing rapid growth. Conservative estimates show that already in 2017, over 250,000 solar products **will be sold in Rwanda, reaching half a million by 2021**. Recent data presented in a study by EnDev suggests similar overall numbers, although many more solar home systems are reported sold as compared to estimates. The total number of systems **sold in 2016 was around 135,000 solar lamps and 41,000 solar home systems** based on data from EnDev[2]. 97% of all systems sold or installed in 2016 were Lighting Global certified, with only a small fraction of products that are not. Given that solar products weigh between 0.150 kg/unit for the small solar portable lights, going up to more than 30 kg/unit for solar home systems, this translates into over 4,600 tonnes being put on market from 2017 -– 2022 based on our calculations.

The smaller solar lamps, which have by far the highest sale volume, come with a one-year warranty, while larger solar lamps and some SHS are offered with a two-year one. Companies offering larger products tend to also offer longer warranties, some extending up to 10 years, depending on the business model of the solar product provider, and the expected working lifetime of the product. At the end of 2016, there were over 20 companies in Rwanda engaged at some level in the solar off-grid market[3].

As the penetration of solar products increases in Rwanda, plans are needed at the end of their lives, when they turn into e-waste and need proper collection and treatment. The Government of Rwanda (GoR) is also in the process of developing and implementing national standards for off-grid solar products, recently publishing the Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems. Article 16 mentions disposal and is clearly aligned along the principle of extended producer responsibility, making it contingent on importers to finance the end-of-life disposal costs. As a result of conversations led by DFID and MINEACOM at the SHS Standards Workshop, the following text was inserted "companies are required to co-operate with the government as it develops a strategy for the disposal of relevant waste."

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[1] https://www.gogla.org/resources/gogla-annual-report-201617

[2] Energising Development (EnDev Rwanda), 2016. Rwanda: Off-grid Sector Status 2016, Achievements in 2016 and trends for 2017

[3] Energising Development (EnDev Rwanda), 2016. Rwanda: Off-grid Sector Status 2016, Achievements in 2016 and trends for 2017

E-waste in Rwanda

The total amount of Electric and Electronic Equipment (EEE) placed on Rwandan market, and corresponding estimates of Waste Electrical and Electronic Equipment[4] (WEEE) generated (UNU, 2015a), is shown in the figure below. Figure 1 below shows the estimates for 2009-2017[5], considering the wider scope (all EEE products included, excluding PV panels and Off-Grid solar products).

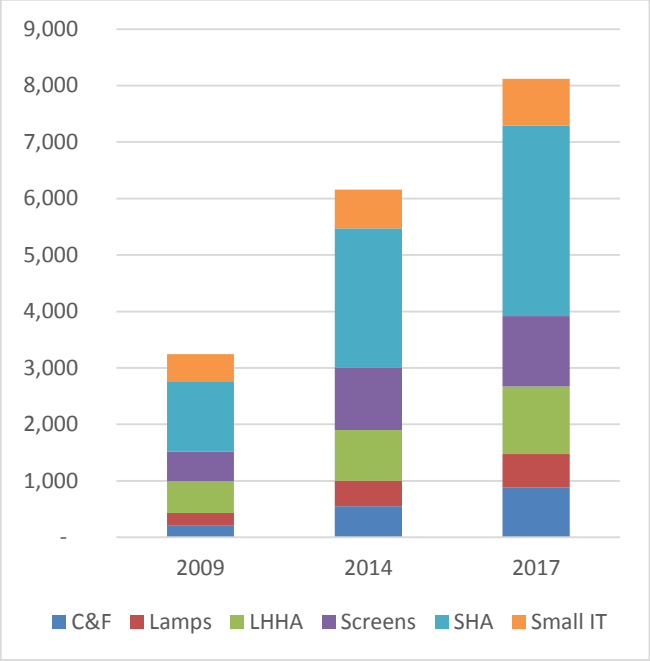

Figure 1: Evolution of e-waste generated in Rwanda (t) excluding PV and off-grid solar products

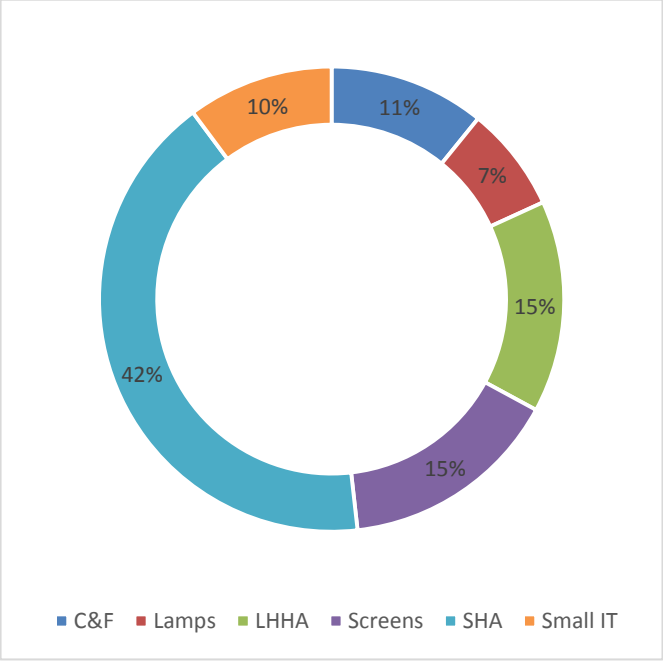

Figure 2: Estimated breakdown of e-waste generated in Rwanda in 2017 per category

More detailed data are also available from the 2015 inventory survey on EEE in Rwanda[6], EEE imports into Rwanda grew at the rate of 5.95% annually between 2010 and 2014. The report indicates that Rwanda has an annual generation potential of 9,741t of which 7,677t (82.9%) will be contributed by individuals, 597t (6.34%) by private institutions and 1,143t (12.14%) by public institutions. These amounts are estimated based on the most common EEE products i.e PCs, printers, Mobile phones, Copying machines, Refrigerators, Air conditioners, Televisions, Washing machines, Car batteries, Dry cell batteries, Stabilizers, Electric cooking stoves, Electric water heating systems, Fluorescent lamps and Radios.

End-of-Life of off-grid solar products: volume and impacts

Off-grid solar products have both a direct and indirect impact in the discussion on e-waste management – see table 1.

[4] Electrical and Electronic Equipment (EEE) reaching its end-of-life is called e-waste or WEEE, for Waste Electrical and Electronic Equipment.
[5] Results are obtained applying the 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 are obtained from COMTRADE database (UNU, 2015a).
[6] MINICOM, 2015. A detailed inventory of electrical and electronic waste in Rwanda

Aspect	Direct Impact	Indirect Impact
Volume of e-waste generated	Increased volume of e-waste from EoL SPLs, PV modules, cabling and control systems etc,	More electronic and electrical products e.g. mobile phones, TVs, fans etc. acquired by households resulting from greater access to energy. Several solar companies have launched own-branded electronics and appliances e.g. radios and TVs.
Environment	Immediate, and direct impact of inappropriate recycling or disposal of EOL products can mean local contamination e.g. through improper disposal of batteries and leaching of hazardous substances (e.g. lead and cadmium)	Indirectly, the impact of improper disposal is the loss of precious, often critical raw materials used in the production of solar products Losses of precious and scarce metals (e.g. silver, gallium, indium and germanium), conventional materials (e.g. aluminium and glass)
System Financing	Need for additional funding for collection and treatment	In case solar products have higher or lower recycling value, cross-financing of/ from other products may occur
Policy and legislation	Adaptations in existing legislation on e-waste as well as product standards (eg. inclusion of RoHS)	Can pave way for greater acceptability of EPR based legislation for other products and harmonisation across the region

Table 1: Direct and indirect impacts of solar products on e-waste management

Volume: As more off-grid systems are adopted, recycling will become an important challenge in the future. In 2016, DFID commissioned a study on e-waste from off-grid products in Africa. Updated estimates for off-gird solar products arising in Rwanda as waste are based on the same methodology as the previous DFID commissioned study[7], using sales forecasts, clustered in 3 groups - PC1+PC2; PC3 to PC6; PC7. The main change is an update in average weight of SHS (PC4 and above) based on further stakeholder interactions. The weights and expected lifespan of PC1, PC2 and PC3 products was also confirmed from the analysis of return stream at WEEE Centre Kenya. Lifespan estimates for PC4 and above are mostly based on inputs from solar companies as the large majority of products in this category have been deployed in the last three years, and therefore are still mostly operational, with only very few being disposed of. The estimation model is based on the following average weight and lifetime parameters.

Cluster	Average Weight	Average Lifetime		Remarks
		Certified Products	Uncertified Products	
PC1+PC2	0.2 kg	3.5 years	2 years	ratio of certified and uncertified products is kept at 50%-50% for simplification and in absence of better data. Some reports suggest between 80-95% certified products in Rwanda.
PC3 to PC6	10 kg	5.5	5	difference in age based on field inputs from users in 2016 study; avg. weight data from dismantling data from Kenyan recycler.
PC7	30 kg	10	9.5 years	50% are PC3 (avg. weight of 2.5 kg) while the remaining are PC4 to PC6, with an avg. weight of almost 20 kg; weight includes lead-acid batteries.
				weight includes lead-acid batteries.

Table 2: Estimation parameters for off-grid solar waste generation model

[7] Magalini, F.; Sinha-Khetriwal, D.; Rochat, D.; Huismann, J.; Munyambu, S.; Oliech, J.; Nnorom, I.C.; Mbera, O. Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector. Evidence on Demand, UK (2016)

Considering the total amount of e-waste generated in 2017, **off-grid solar products represent a little under 5% of the total volumes of total e-waste generated**. Figure 3 below shows the share of off-grid solar products in the e-waste stream, compared to other product categories. As saes of off-grid products increases, the e-waste share will also increase. Figure 4 shows the expected evolution of sales of off-grid products and waste generated, in tonnes looking at 2015-2022.

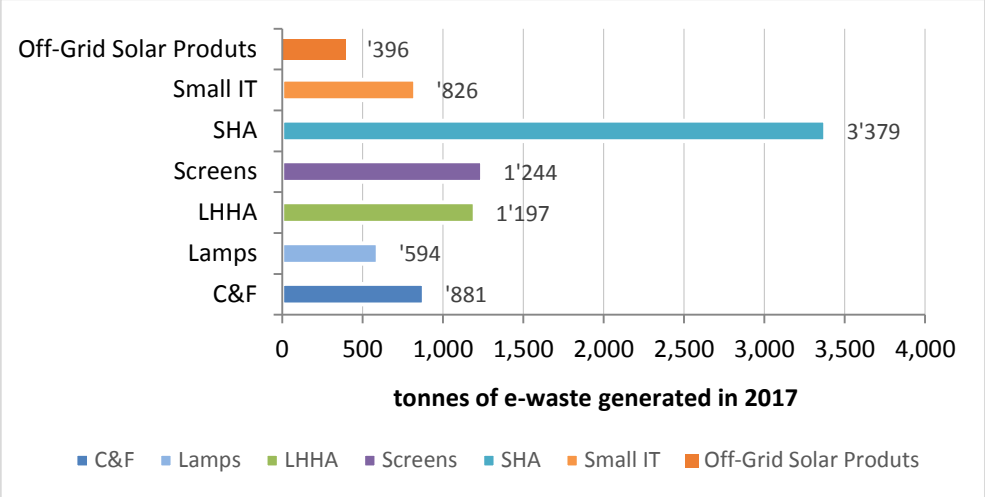

Figure 3: E-waste generated in other product categories in comparison to off-grid products

The estimated volume of off-grid products put on the Rwandan market is projected to grow exponentially, and based on average lifespan and average weight estimates, in 2017, nearly 400t of off-grid products expected to be put on the Rwandan market. In comparison, starting from a small base, the waste generated from EOL off-grid solar products is expected to be approximately half of the POM volume, at 183t, across all product categories. However, this is expected to grow to 625 tonnes of EOL off-grid solar products by 2022, with twice as much put on the market.

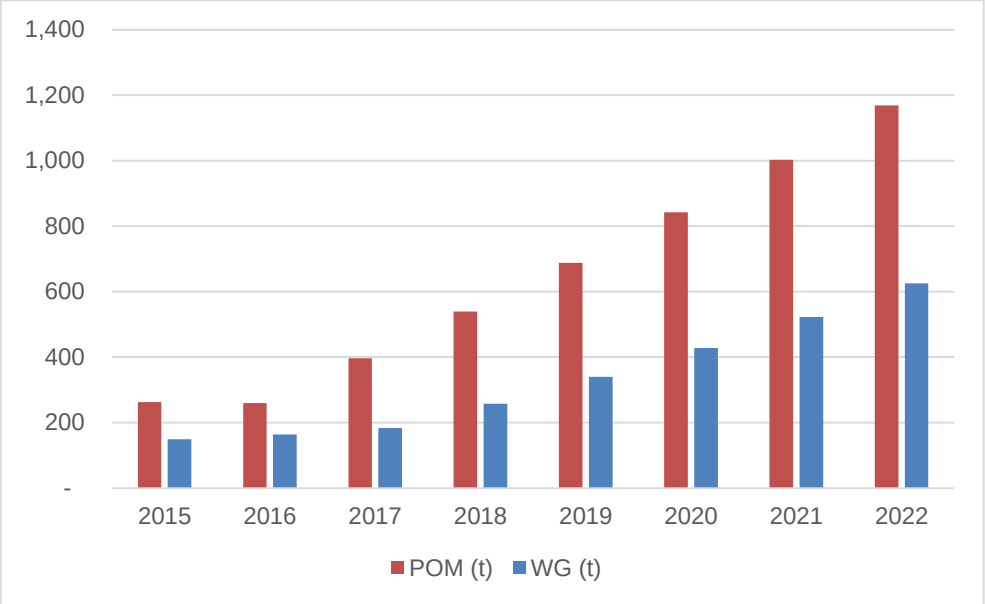

Figure 4: Amount of off-grid solar products placed on the market (t) and waste generated (t)

Impact of batteries on individual product weight, overall volume, and recycling cost: Figure 5 and Figure 6 show that most 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 battery weight, particularly where lead acid batteries are used. This has

consequences for the waste collection and treatment at end-of-life. This is because smaller products are normally more widely dispersed into remote areas and have lower intrinsic material value. Consequently they could have a higher "per unit" cost of recycling compared to larger products typically using Sealed Lead Acid Batteries (SLABs) that have a higher intrinsic material value [discussed more in detail in Section 4 under Technical costs.

Most PC4 and above systems use SLABs, and although the overall lifespan of the system, comprising the controller, and the panels, excluding accessories and consumables, is expected to be 5 years or more, the average battery life, depending on usage and battery management, is much shorter (1.5 – 3 years). So, the estimated volume from PC4 – PC7 products may potentially be underestimated. By some estimates, off-grid companies in Rwanda are already receiving over 50 batteries a week, on an installed base of approximately 5000 units[8].

As battery technology evolves, smaller and lighter batteries based on other chemistries, particularly Lithium are also being used in off-grid systems, and may mean lower average product weight in the PC4 and above categories. However, the overall lifecycle impacts of newer battery chemistries are unknown, especially at the end-of-life recycling and disposal.

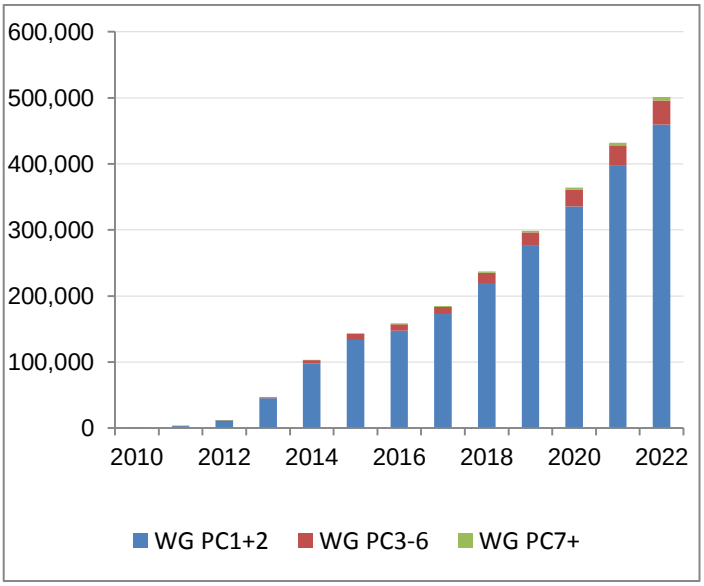

Figure 5: Breakdown of waste generated per product type (in units)

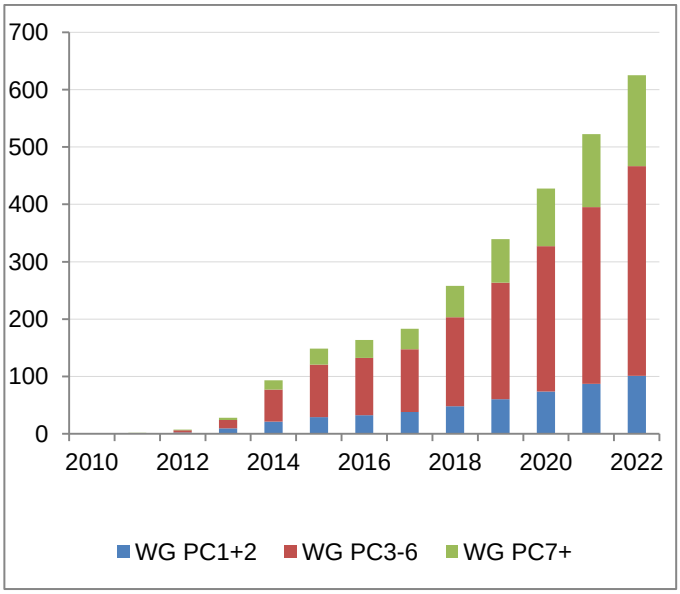

Figure 6: Breakdown of waste generated per product type (in weight)

2. Policy and legislation

Waste Policy

Extended Producer Responsibility (EPR) is an environmental policy approach in which a producer's responsibility for its product starts at product design and continues until the post-consumer end of product life cycle. An EPR policy is characterised by making producers responsible both upstream,

[8] Karla Cervantes Barrón (2016), Business Models for Recycling Waste from Solar Homes Systems in Rwanda

considering environmental considerations when designing their products, as well as downstream, for the physical, informational and financial aspects of EOL management. The main reasoning behind such an approach is to encourage industry to develop products that are easier to recycle and importantly, ensure producers internalise otherwise externalised costs, by factoring in the cost of the collection and end-of-life treatment into the sale price. Companies therefore have to provide a financial solution to cover the administrative and operational aspects of collecting and treating their waste products.

Since 2012, setting an important precedent worldwide, solar PV products fall under the EU WEEE Directive that provides the overarching framework for the collection, treatment and disposal of all e-waste. Until then, industry used a voluntary approach: founded in 2007, PV CYCLE[9] was the first pan-European Producer scheme for the treatment of photovoltaic waste . The WEEE Directive (2005), is founded on the principle of EPR, and squarely places the responsibility for the end-of-life management of all EEE products on the producer, including establishing targets for collection and recycling.

Current Legal Framework in Rwanda

Rwanda is a signatory and has ratified several multilateral environmental agreements, both regionally and globally. Relevant to e-waste, particularly waste shipment between countries are:

- The **Basel Convention** on the control of trans boundary movements of hazardous wastes and their disposal was ratified by Rwanda in August 2003; National implementation plan for the Basel Convention on the control of transboundary movements of hazardous wastes and their disposal 2014 – 2021 by REMA; and
- The **Bamako Convention,** adopted under the auspices of the Organization of Africa Unity (OAU), prohibits hazardous waste imports into Africa.

At the national level, the legal framework on e-waste has evolved significantly over the past years:

- **Environment Organic Law No. 04/2005** is an overarching law for the protection of the environment, which states that waste collection and treatment should be done in an environmentally friendly manner, however, does not specifically address e-waste.
- **National sanitation policy**: Approved by the cabinet and gazetted in December 2016, the national sanitation policy is an Umbrella Policy that provides guiding principles for all aspects of sanitation, including liquid and solid waste, industrial waste, e-waste, etc. The sanitation policy recommends specific e-waste management policy.
- **Draft National E-waste Policy** published in August 2016, and waiting to be approved by the cabinet, was developed to provide detailed guidance and policy direction on the appropriate legal and regulatory instruments for e-waste management[10].
- **Ministerial Order No: 1 of 25/10/2011** by the Ministry of Youth & ICT in collaboration with the Rwanda Standard Board restricted and controlled the import of used computers and electronics, often a channel to dump WEEE in developing countries.
- The **Rwandan E-waste Bill**, currently in a draft stage, provides the legal framework for the management of e-waste and the legal obligations to different institutions concerned with e-waste management. The Bill is based on the principle of producer responsibility and covers the entire range of electronic and electrical products and e-waste (Article 2, Scope of Application). As such, by definition, solar products are within its scope.
- **RURA Regulations:** The Rwanda Utilities Regulatory Authority (RURA) has been mandated to regulate and operationalize the provisions of the E-waste Bill. The Regulations lay out the roles of the various actors, in particular producers and recyclers, sets minimum requirements for licencing and sanctions and penalties for non-compliance. Annex 1

[9] See www.pvcycle.org
[10] http://www.fonerwa.org/sites/default/files/National%20E-Waste%20Management%20Policy%20for%20Rwanda.pdf

provides a non-exhaustive list of product categories covered under the regulations, divided into 13 categories, including solar products.

Energy Policy also has a significant impact in the adoption of off-grid solar products, and consequently the volume of solar waste generated.

- **Rural Electrification Strategy (RES):** The two key aspects of the RES include an access target of 35 to 39% through off-grid and mini-grid technologies and the fact that the private sector should be the main driver in the off-grid space. In fact, the GoR revised the off grid targets from 22% to 38% which will further increase the penetration of off grid solar products.
- **East African Customs Management Act and the Law on VAT Nº 02/2015 of 25/02/2015**: As part of this drive for energy access, certain solar products, such as solar phone chargers, solar powered fans etc. have been granted VAT exemptions[11].
- **Ministerial Guidelines on Minimum Standards for Solar Home Systems** setting product standards for off-grid solar products to avoid lock-in to poor quality technical solutions.

3. Existing e-waste management infrastructure

Collection infrastructure

Consumers in Rwanda are accustomed to paying for waste disposal, unlike in many other countries where waste holders expect a payment, or in other words 'sell' their e-waste. However, for some fractions, such as empty bottles, there is a collection incentive paid to consumers. In the case of lead-acid batteries, off-grid solar companies mentioned that consumers would expect some compensation, at least for batteries. The National E-waste Strategy document notes that e-waste was until recently collected by solid waste contractors, who disposed of it in landfills.

Consultations conducted in May-July 2017 have indicated that although e-waste is sometimes found in the trash sporadically, at least one waste collection contractor is currently storing it until a safe and approved route is available. So are many of the off-grid solar producers who are storing batteries as well as components and parts generated from repairs and replacements collected as part of their service/product warranty. The large off-grid solar companies operate their own logistics fleet and therefore are collecting faulty, broken, end-of-life products, especially batteries alongside their deliveries. According to EnDev, Rwanda Energy Group alone have about 2,500 faulty off-grid solar products in storage awaiting disposal, while others such as BBOXX and Dassy Enterprise also report large quantities[12]. Interviews with two of the largest companies within the market, BBOXX and Mobisol, indicated that there is a large quantity of batteries, mostly SLABs that have been collected by the companies and are awaiting disposal through the appropriate channels.

Itinerant scrap metal collectors mainly focus on construction and demolition wastes, and there is no active informal collection of e-waste in Rwanda. However, there are a large number of informal

[11] The full list of exempt products is given in the circular from the MINECOFIN dated 05 August 2015.
[12] Energising Development (EnDev Rwanda), 2016. Rwanda: Off-grid Sector Status 2016, Achievements in 2016 and trends for 2017

repair shops especially in commercial centres, called “kazinikazi”. These are usually repair technicians who store faulty products for component harvesting at their shops.

Dismantling and depollution infrastructure

With the financial support of Rwanda’s National Climate Fund (FONERWA), MINEACOM has constructed a dismantling facility located at Bugusera, approximately 40 km south of Kigali. The GoR is currently negotiating a PPP concession agreement with a private sector recycling operator to operate and manage the plant, with a defined revenue sharing model. In addition, the plant operator will be required to expand the facility with additional processing lines as well as establish a country-wide network of collection points, with at least one in each district.

The dismantling facility is operational and has the capacity to treat 10,000 tonnes per annum . The current infrastructure at the plant includes 18 dismantling stations, a complete plastic shredding and washing line, a CRT cutting and depollution line and a metal compactor/ baler. Adjacent to the main plant building, the administration block also houses a repair and refurbishment operation for PCs.

The on-going negotiation with the private operator responsible for the concession will request a step-by-step improvement, leading to adoption of international standards (like ISO or OSHA) but also progressive installation of equipment to process other waste streams (phase 1: mainly ICT; phase 2: large appliances, consumer electronics, and other products; phase 3: refrigerators, light bulbs and other equipment requiring dedicated technology and machine for the processing).

While the current and expected expansion of the plant is sufficient to process the volume of e-waste from off-grid products, typically the plastic and metallic fractions, battery disposal will remain a challenge for the off-grid sector with current infrastructure of the e-waste dismantling facility, especially as battery waste falls under the category of Special Hazardous Waste in the REMA classification and therefore has restrictions and strict requirements on its disposal.

Downstream options

It is crucial to have 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. Research on recycling of PV products indicates that the large majority of the product can be recycled. Research shows that almost 90% of the materials recovered from solar panels can be recycled into useful products[13].

In Rwanda local markets for final recovery can be found for base metals like steel, copper or aluminium while for more complex fractions local recyclers need to rely on international actors. By some estimates, with increasing volume, it would be viable to treat fractions in Rwanda, rather than exported as presently, both at a country and company level – for example, with an expected 6,000 batteries from solar home systems to be disposed of in Rwanda in 2016 alone, the scale of value will tip from outsourcing to in-house disposal in the next two years[14].

[13] Wambach, K., Schlenker, S., Müller, A., Klenk, M., Wallat, S., Kopecek, R., Wefringhaus, E., 2006. The second life of a 300 kW PV generator manufactured with Recycled wafer from the oldest German PV power plant. In: 21st European Photovoltaic Solar Energy Conference Germany, 2477–2480

[14] Karla Cervantes Barrón, 2016. Business Models for Recycling Waste from Solar Homes Systems in Rwanda

Based on inputs from government officials and waste management companies, informal recycling of e-waste, particularly burning cables or chemical recovery, typically considered the worst informal recycling practices, have not been observed as such in Rwanda.

The main fractions from e-waste and solar products, including their range in average composition of various products and the current downstream options are given below.

Material	**E-waste** (large, small household and mixed IT)	**Solar Products** (SPL & SHS)	**Market**
Ferrous/ steel/ stainless steel	6% - 70%	13% - 17%	Local
Copper	2% - 22%	0% - 17%	Local
Aluminium	1% - 4%	TBC (Mostly in large solar modules)	Local
Plastic	1% - 38%	*TBC (Mostly in SPLs)*	Local/International
Glass	7% - 30% (either in refrigerators or screens)	*TBC (Mostly silicon)*	International
Printed Circuit Boards (PCBs)	1% - 4%	*TBC (mostly in SHS)*	International
Batteries	Lithium ion, Lithium Phosphate, NiMH	Lead acid; Lithium ion, Lithium Phosphate	Regional/ International

Table 3: Material composition and downstream markets for main fractions

4. Assessment of framework conditions for EOL off-grid products

Policy and legislation

The policy framework provided in the Rwandan E-waste Regulation defines EEE and E-waste in Articles 2.3 and 2.5 respectively, while Annex I provides a non-exhaustive list of products covered by the regulations. Solar products have been added in the list as category XI. By definition, according to the Regulation, solar products are covered and in scope as shown in the table below.

Definition EEE	**SPL**	**SHS as whole**	**SHS (PV module)**	**SHS (Lamps, other elements)**	**SHS (Battery)**
Equipment which is dependent on electric currents or electromagnetic fields in order to work properly …	NO	NO	NO	✓	NO
…and equipment for the generation, transfer and measurement of such currents and fields…	✓	✓	✓	NO	NO

Table 4: Technical implications of legal definition of EEE and e-waste regulations

Assessment:

- *The Regulation is based on the EPR principle and is therefore following international best practice. Solar-product OEMs have responsibility for organising and financing the take-back and recycling of their products.*
- *Although solar photovoltaic products are specifically mentioned as a separate category, they may fall into one or more categories, with implications for reporting and financing. Categorisation with an e-waste category such as small electronics can help balance costs for solar products through potential cross-financing from richer fractions to poorer fractions. On the other hand, clustering solar lamps in the lamps category can mean significantly higher disposal costs for solar products.*
- *The E-waste regulations do not specify any specific levies or fees; nor is it decided who or how any fund, if established to collect recycling fees to pay for negative value fractions, is managed, and therefore both options of government as well as private sector led solutions are possible.*

Collection

Existing and potential collection channels may be:

1. A formal infrastructure of country-wide collection centres for e-waste is currently being established. As they are not yet operational, it is difficult to assess whether they sufficiently are able to collect e-waste and off-grid solar products. However, given that they are still being planned, there is an opportunity to site them
2. Through existing distribution chains and retail networks of solar products retailers, electronic and electrical product retailers as well as other frequently visited outlets such as petrol pumps. This may be especially beneficial for servicing more remote locations with low volumes that would not justify dedicated collection centres.
3. Utilise fleet and collection & storage infrastructure of existing waste management companies that already serve residential and commercial customers for door-to-door collection of solid waste as well as special waste.
4. Formalise and incorporate informal repair shops, the ‘kazinikazi’, in the collection network, through capacity building and developing a business model as a collection point to incentivise them and compensate appropriately for their effort and space.

Assessment:

- *The collection infrastructure being set-up for e-waste will be not only important as an intermediate storage but also generate awareness. However, these make sense only in urban areas with greater e-waste volumes.*
- *Well placed to service, collect and aggregate e-waste and off-grid solar products and components from even remote locations are the ‘travelling technicians’ and informal repair shops that are already active. So, there is a potential for the collection channels for EOL off-grid products to piggy-back on existing door-to-door distribution channels as well as service and other retail/ distribution networks.*
- *Also, given that a large number of off-grid solar systems are actually still owned by the companies under the Pay-Per-Use or Pay-As-You-Go models, companies can very accurately track their use of their SHS and manage its end-of-life.*

System Management

Financing is always one of the cornerstones of an e-waste management system, irrespective of whether the underlying principle is EPR or direct/ indirect taxation. The intrinsic economic value to be obtained from various fractions and component obtained after the treatment phase is not always, and not for all products or waste streams, enough to compensate the costs incurred for

collection, sound treatment and proper disposal of some fraction, which makes them 'negative value' fraction that need additional financing for disposal. This means that, without a proper financing mechanism in place:

- only products of fractions having positive value are collected and treated (so-called "cherry picking"), or
- fractions with negative value are improperly disposed or not recycled, and
- non-compliance treatment, mainly linked with cost-saving approaches, is performed.

In an EPR system **financial and organisational responsibilities** are two interconnected areas where the responsibility of producers plays a fundamental role which might characterise the solution adopted:

- Pure financial responsibility: producers are simply required to finance operations (collection & treatment) already carried out in national context without any further chance to influence or steer the system; and
- Financial and organisational responsibility: producers are requested to finance operations, but have also organisational responsibility, which might have different degrees of freedom. In the majority of cases, like in the EU, producers choose logistics and treatment partners to fulfil their take back obligations. Contracts might be signed directly between producers and transport and treatment service providers or via Compliance Schemes set up for this purpose by producers.

In addition to establishing the level of financial responsibility, several models exist regarding the **management of EPR funds collected from producers**, and the entity responsible for collection and disbursement of funds collected by way of eco-levies/ recycling fees or compliance fees. Pro and cons exist for the various options, as summarised in table below.

Options for Management of Funds	**Strengths**	**Weaknesses**
Fees managed by **dedicated entity set up by government** (e.g. Mauritius or California)	• Easier to control budget and ensure transparency. • Easier to have dedicated staff trained and focused one-waste management.	• Less control (and responsibility) by Industry. • More difficult to have pressure on cost-reduction.
Fees managed **directly by government** (e.g. Ghana)	• Maximum degree of central/ government control	• More difficult to ensure 100% of the fee collected are allocated to e-waste management if becoming part of overall budget. • More difficult to have dedicated staff focused on e-waste management. • More difficult to have pressure on cost-reduction. • Little involvement of industry in system management
Fees managed **by Industry, through dedicated private sector/ not-for-profit compliance organisation** (e.g. EU Compliance Schemes)	• Allow flexibility to responsible entities (producers) to organize how to comply. • Easier to have dedicated staff trained and focused one-waste management. • Easier to have cost-reduction in medium-term.	• In case of multiple schemes being set-up a coordination mechanism need to be established to avoid "cherry picking" or remote areas are not served. • Dedicated rules need to be established to ensure fair operations and competition (if multiple schemes exist).

Table 5: Strengths and weaknesses of various fund management options

For Rwanda, building on existing structures in place, in both government and private sector, the overall design of a system, and the actors involved at various stages in the recycling chain is given in Figure 7 below. While the ministries provide sectorial and thematic direction from the top in terms

of setting national policy and strategic objectives, other governmental organisations could be involved in the setting of standards, monitoring and compliance, private sector development etc.

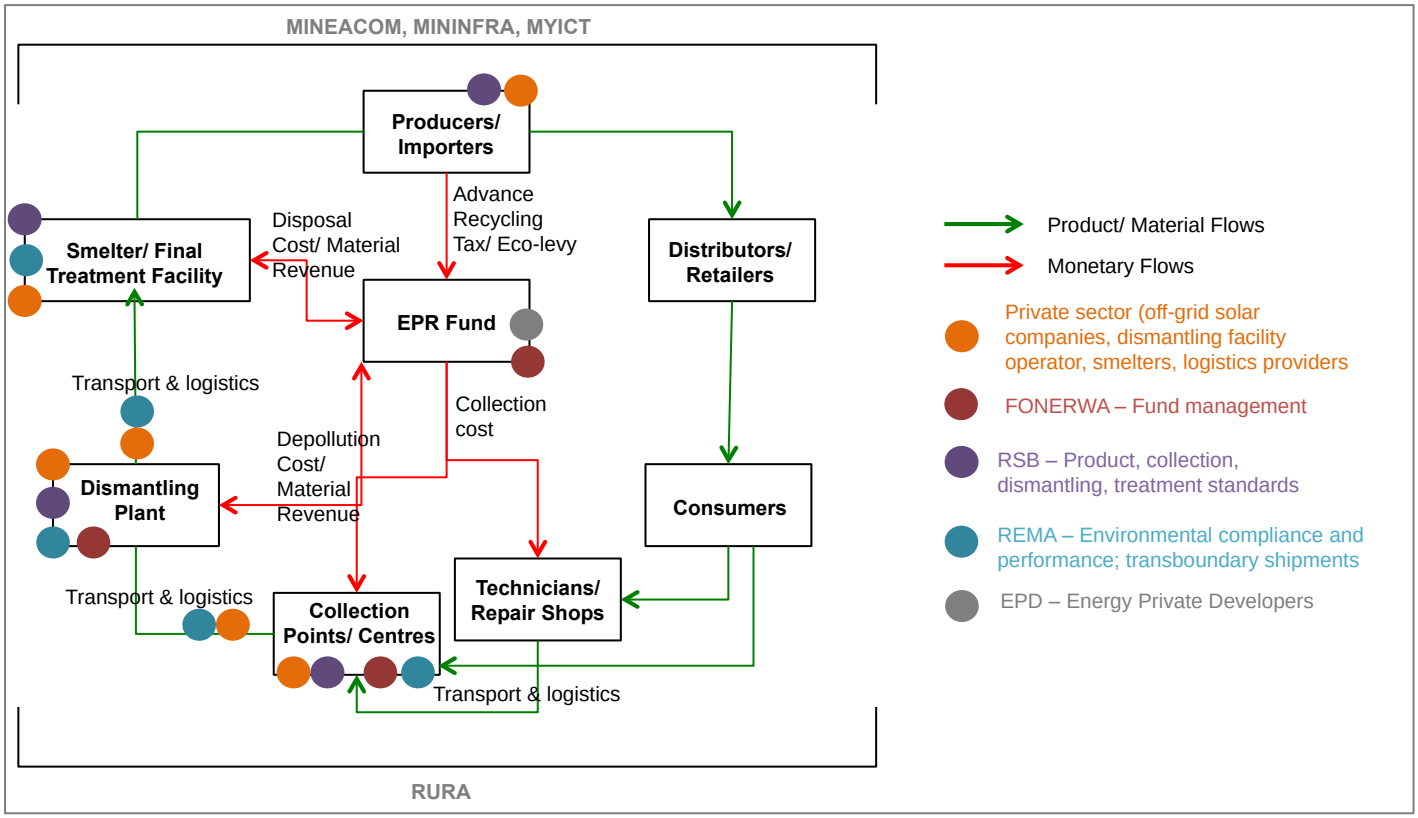

Figure 7: Key government and private sector actors in recycling system

Assessment:

- *In the context of Rwanda, the government plays a strong role in the economy, especially given the nascent private sector.*
- *Strong and established government institutions in particular FONERWA, have the experience of receiving and managing environmental funds, and could be a likely host of an EPR fund. Currently, the FONERWA already collects levies from the mining and forestry sectors as well as environmental fines and fees paid by companies.*
- *Recent revisions to FONERWA's mandate aim to broaden its funding base from domestic sources and act as the facilitator between government and private sector, particularly through PPPs. The e-waste recycling facility financed by FONERWA is part of its e-waste engagement, which included inventorisation, policy development and attracting private sector investment.*
- *FONERWA has the governance structures and mechanisms for collecting and disbursing funds, which can be adapted easily to suit the requirements of a dedicated EPR fund.*
- *Currently, the private partner operating the facility expects to be profitable without the need for any compensation from EPR funds. However, this is based on the assumption that the access to waste is free, heavily reliant on high value IT waste, and given fairly high metal prices. In the event that access to waste costs increase as well as cost of proper disposal of hazardous fractions, the economic viability will need rebalancing through additional financing, typically coming from EPR funds. However, FONERWA, as a partner in the recycling plant, may find itself in a conflict of interest in case payments from such a fund are to be made to the recycling plant.*
- *Industry-led private sector or not-for profit organisations, similar to Producer Responsibility Organisations in Europe, can also play the role of EPR fund manager. From the off-grid solar industry, EPD may potentially be able to play such a role, alongside other industry*

associations under the Private Sector Federation (PSF) which also includes the Rwanda ICT Chamber representing IT equipment resellers and telecom companies. However, their capacity and interest in accepting such a mandate needs to be assessed.

- *Other government organisations such as RURA, REMA and RSB would be well placed to provide licencing, monitoring and support on various issues such as transboundary shipments, monitor, set standards etc.*

Financing the E-waste Recycling Chain

Different e-waste categories have different environmental and economic weights. For products with high material value and low environmental impact, such as IT equipment, the costs of collection and recycling can be paid for from the intrinsic material value recovered. However, for products with high environmental impacts and low material value (e.g. lamps) are economically **unviable to recycle in the absence of a proper financing mechanism** that covers the cost of collection and recycling, as revenues from recovered materials are far from sufficient to cover the costs.

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 6: WEEE streams and priority settings

Product waste stream	Presence of toxic/hazardous components	Relevant disposal costs	Main sources of potential revenues
SPL	CFL (Hg), if present	Plastics, especially if containing BFR	
SHS	Batteries (see below)	Plastics, especially if containing BFR	Copper from cables PWB from control panels
Lamps	Mercury in CFL	CFLs containing mercury	
PV modules	Cadmium and Tellurium	Eventually the Glass	Aluminium for larger frames
Batteries	Lead, Cadmium	Li-Phosphate, Ni-Cd	Lead, Li-Ion, Ni-MH
Fridges & Air conditioners	Ozone Depleting Substances (circuit & PUR)	Ozone Depleting Substances, PUR	Steel, Copper, Aluminium, Plastics
Large Household Appliances	PCB-containing capacitors and mercury switchers (in older models)		Steel, Aluminium, Copper, Plastics
IT & Consumer electronics	Pb-containing Glass in CRT, Hg backlights in Flat Panels	Plastics containing BFR	Steel, Copper, Printed Circuit Boards

Table 7: Hazardous and valuable fractions from e-waste product categories

The e-waste recycling chain has been modelled according to previous studies[15] and comprises the following steps as illustrated in the figure below:

[15] Magalini, F.; Sinha-Khetriwal, D.; Rochat, D.; Huismann, J.; Munyambu, S.; Oliech, J.; Nnorom, I.C.; Mbera, O. Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector. Evidence on Demand, UK (2016)

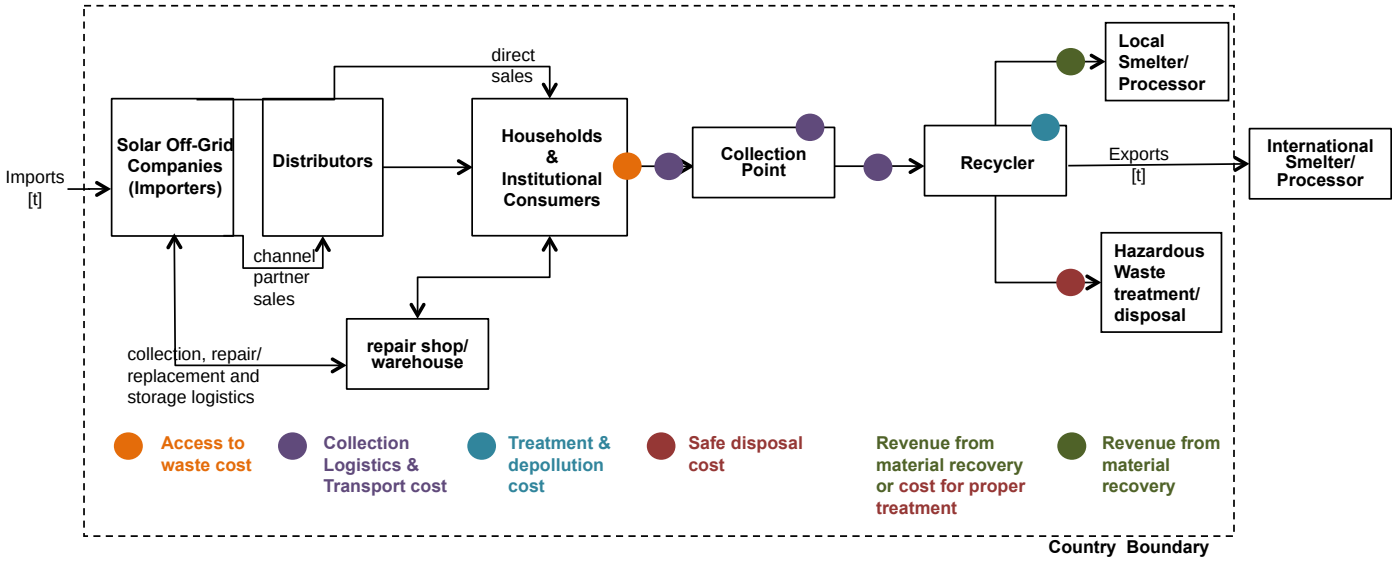

Figure 8: EEE & WEEE value chain

- **Access to waste**: includes the costs (or revenues) to get the waste from the original holder (the consumer). In the majority of developed countries consumers get rid of their waste for free (or in some cases they have to pay for that). In the context of developing countries in most of the cases it is the opposite: the holder of the product to be discarded expects an economic compensation when disposing off the waste.

  Assessment:
  - *In the case of Rwanda, consumers do not expect compensation for e-waste and are used to paying for waste collection and disposal services with few exceptions. However, as an incentive to consumers to dispose of their e-waste through the proper channels, free disposal is suggested. This would mean a nil access to waste cost, with neither the collector paying the consumer for the product, nor the consumer paying the collector for e-waste disposal.*
  - *Yet, as this might change in future, and consumers may expect a compensation for their e-waste, the access to waste costs should be reviewed regularly.*

- **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.

  Assessment:
  - *For Rwanda, the cost of collection through a dedicated infrastructure forms a large portion of the cost, and therefore it is recommended to use proposed EPR funds collected from producers instead to establish collection and take-back points as much as possible embedded into existing channels and logistics networks.*
  - *The funds can be more efficiently utilised to build capacity and provide incentives to retailers, repair shops etc. to store e-waste securely, and dispose of to the right channels.*
  - *The important thing is that **collection is a cost, and therefore a part of EPR funds should be allocated towards these costs**, whether the collection infrastructure is directly operated or outsourced.*

- **Transport**: includes all the transportation costs from the collection point or from the consumers' house/place to the treatment plant or plants, including shipments abroad.

Assessment:

- *Existing sales and distribution logistics networks, in particular for large off-grid solar companies have a milk-route approach, where the visit several locations across the country, both delivering new products as well as picking up any broken ones for repair.*
- *Distances in Rwanda are relatively limited, however, transportation takes time, so a truck may do one to two routes per week depending on the number of locations visited.*
- *The trucks are also often fitted with specialised crates/carriers to protect products from damage in transit. For end-of-life products, it would be possible to have similar trucks or even the same trucks to be deployed for collection.*
- *Transportation of end-of-life products overseas is considered a cumbersome, expensive and lacking a clear procedure in term of documentation requirements, categorisation of shipment and thereby taxes or duties applicable.*

- **Treatment**: Treatment cost is calculated as the net cost for proper treatment, including disposal of hazardous fractions. Each treatment plant processing e-waste incurs under operative costs: labour costs, energy costs, depreciation of capital investment, other overhead and administrative costs related to the functioning of the plant itself. This would also include the cost of final safe disposal of hazardous fractions, typically to a sanitised landfill or in an incinerator with the appropriate emission control technology.

  Assessment:

  - *Treatment costs are largely known for batteries currently as they are the most commonly replaced / disposed of part of solar products.*
  - *SPLs are not disposed of as much, but rather repaired, or simply stored at home. Therefore recycling costs are impacted by different battery technologies requiring different ways of recycling (e.g. lead versus lithium batteries). This is a fast developing area, and overall lifecycle costs of one battery technology may be different from the up-front cost or end-of-life disposal costs.*

Technical costs

Table 8 below shows, for different waste streams, the resulting average costs considering the assumptions and date of previous studies[16], along with current parameters as below:

- **Shared collection centres with EEE products**:
  - Collection centres with 30% FTE for employee responsible for collection, record keeping and monitoring, with 2t/load in the container.
  - A 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 taking into account the mass of products in the container;

- **Statistical distribution of waste generated** for various e-waste streams according to the shares described in Figure 2;
- **Average transport distance** to reach the plant from collection centre equal to 200 km and average transport cost of RWF 600/km;
- **Simplified material composition** for each waste streams as given in the table below; for all off-grid products, we assume only LED lamps being provided with off-grid solar products; for PC4 and PC7 only lead acid batteries;

[16] Same as Reference 16

- **Market value for main fractions** obtained on Rwandan market (Steel, Copper, Aluminium, Plastics plus local disposal) and shipment overseas for other fractions (considering average prices for various fractions); and
- **Local labour cost**, mainly linked to manual disassembly, and overheads varying for different waste streams including depreciation, other general costs (50% for the majority of waste streams to 200% for C&F and Screens to consider the depreciation of the machines used for the degassing and CRT cutting); For lamps, because of the mercury content, treatment overseas is assumed.

Category	Main materials	Access to waste cost	Collection cost	Transport cost	Intrinsic economic value	Net Treatment cost	Total cost/ revenue
Cooling & Freezing (CFCs)	Steel (50%), Plastic (28%) + PUR (10%), Glass (7%), Copper (2%), Aluminium (3%)	0 €/t	-10.60 €/t	-7.48 €/t	201 €/t	168.38 €/t	150 €/t
Screen (TV, CRT)	Glass (CRT)(30%), Plastics (25%), Steel (6%), Copper (5%), Other (34%)	0 €/t	-14.95 €/t	-10.55 €/t	55 €/t	-52.93 €/t	-78 €/t
Lamps (with mercury)	CFL (Hg) (80%), Aluminium (1%), Plastics (1%), Other (18%)	0 €/t	-7.14 €/t	-5.04 €/t	-916 €/t	-1,077 €/t	-1,090 €/t
Large household appliances	Steel (53%), Plastic (10%), Copper (4%), Aluminium (3%), Other (30%)	0 €/t	-14.39 €/t	-10.16 €/t	266 €/t	243.98 €/t	219 €/t
Small household appliances	Plastics (35%), Mixed plastic (incl. BFR) (25%), Steel (16%)Aluminium (3%), Copper (2%), PWB (1%), Other (18%)	0 €/t	-40.6 €/t	- 29 €/t	102 €/t	-19 €/t	-88.6 €/t
IT and Consumer Equipment	Steel (70%, Plastics (10%)Copper (6%), Aluminium (4%), PWB (4%), Other (6%)	0 €/t	-9.9 €/t	- 7 €/t	456 €/t	396 €/t	379 €/t
Off-Grid Solar (PC1)	LIP batteries (67%), LED (20%), Steel (13%)	0 €/t	-0.48 €/t	-0.34 €/t	-2'329 €/t	-3'675 €/t	-3'675 €/t
Off-Grid Solar (PC2)	PV modules (45%), Mixed plastics (inc. BFR) (23%), Steel (18%), LIP batteries (11%), LED (3%)	0 €/t	-1.13 €/t	-0.80 €/t	-593 €/t	-907.61 €/t	-910 €/t
Off-Grid Solar (PC4)	Steel (30%), PV Module (29%), Pb battery (30%), Copper (4%), Plastics (6%), PWB (2%)	0 €/t	-1.00 €/t	-0.71 €/t	145 €/t	112.93 €/t	111 €/t
Off-Grid Solar (PC7)	Steel (30%), PV Module (29%), Pb battery (30%), Copper (4%), Plastics (6%), PWB (2%)	0 €/t	-2.15 €/t	-1.52 €/t	92 €/t	51.96 €/t	48 €/t

Table 8: Collection, transport and recycling costs and potential revenues in E-waste and off-grid solar chain in Rwanda (average values), €/t

As the table above shows, the collection and recycling chain generates costs. For some products, the intrinsic economic value can mitigate the total treatment costs and partially also the others, for example screens and plastic-dominated small appliances have a negative net treatment cost while ICT products have a positive treatment cost.

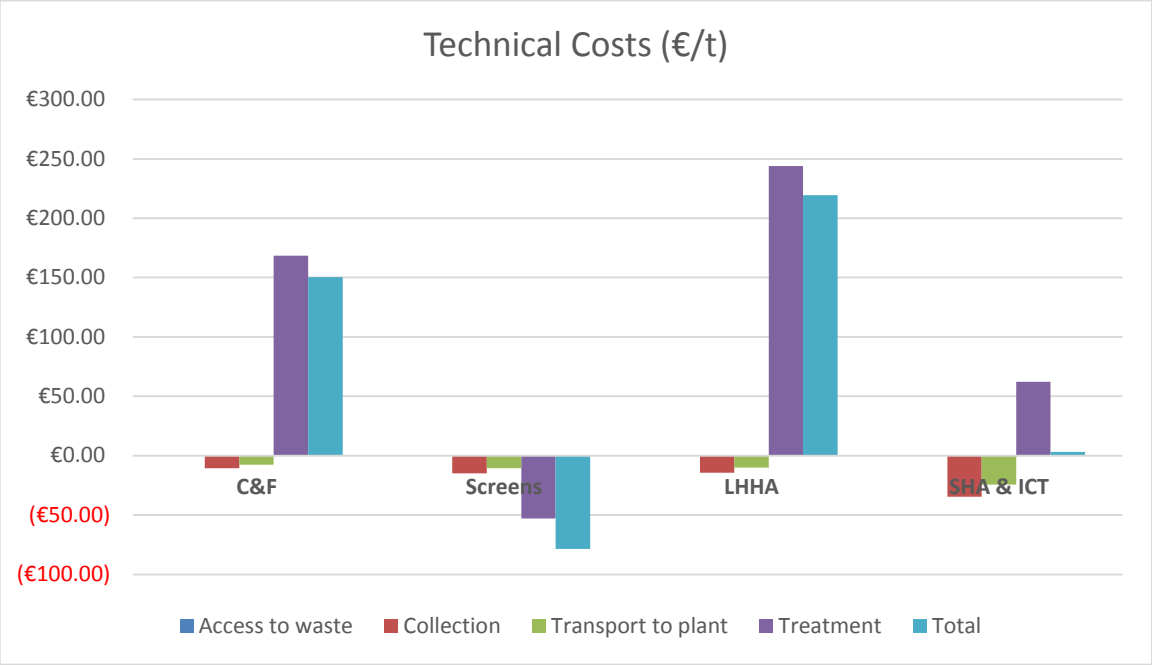

Figure 9: Technical costs for e-waste management chain (€/t)

In the case of off-grid products, the most common products – PC1 and 2 – have high cost of recycling, largely due to the Li-phosphate batteries, to the tune of over 3,500 €/t for PC1. On the other hand, PC4 and PC7 collection and recycling can be paid for by the intrinsic value of lead in the SLABs, given current market prices and estimates. Overall, the composition of the waste mix provides the weighted average cost per tonne, which for Rwanda is € 64.64/t. However, this average hides the wide range of net technical costs from a net positive € 219/t for large household appliances to a net negative € 78/t. Therefore, in the event of setting recycling fees, or eco-levies in Rwanda, average cost at a category level is suggested, rather than an overall average per tonne fee.

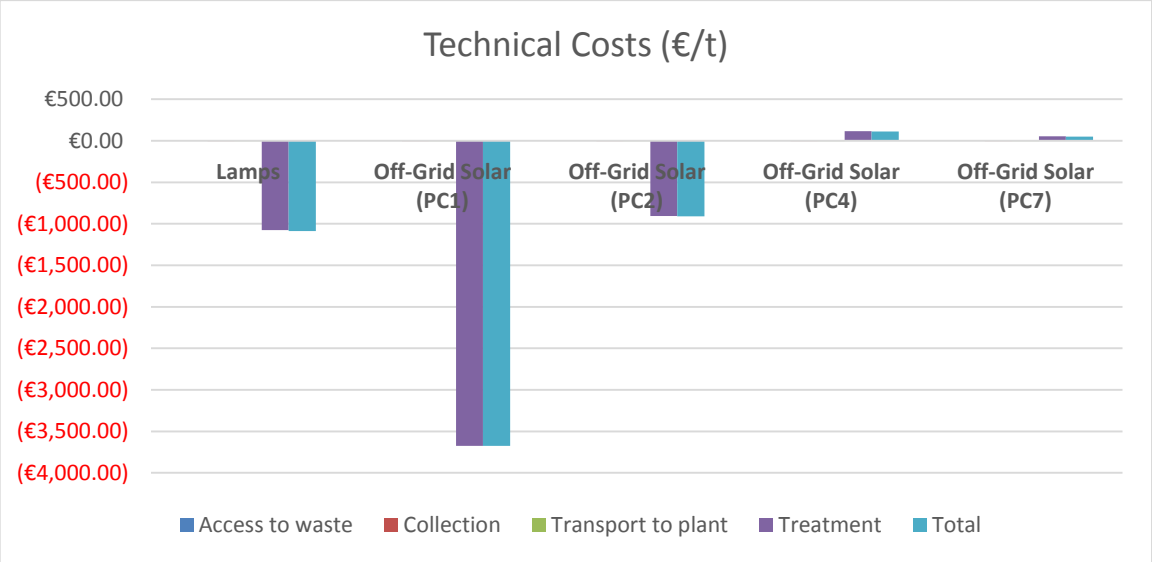

Figure 10: Technical costs for off-grid solar products recycling, (€/t)

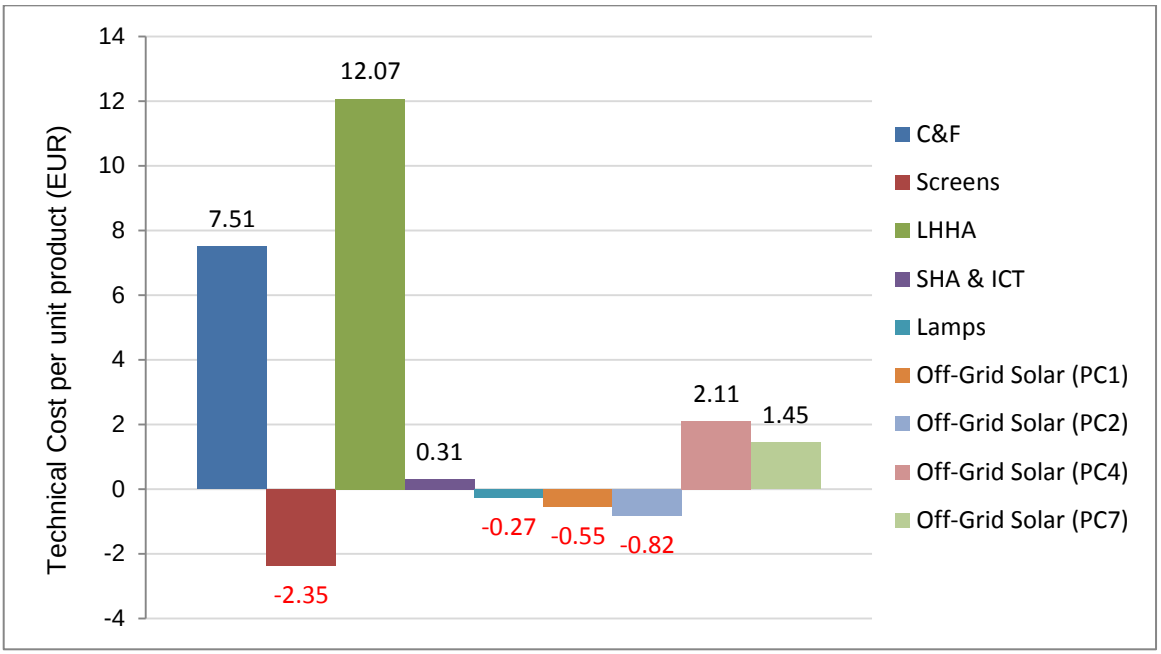

Figure 11: Technical cost per unit, (€)

However, while total costs for off-grid solar products may seem large, given the large number of units sold, the **per unit technical cost of collection and recycling a solar lantern or SPL under the PC1 or PC2 category is less than 1 €/ unit, while for the larger systems, per unit benefit is up to 2.11 €/ unit for PC4** as shown in Figure 11**.**

Total costs resulting from the simplified calculations and under the assumptions made suggest a cost of **approximately € 550,000 to collect, transport and treat properly the estiamted volume of e-waste and off-grid solar waste generated in 2017**. Averaged across all the product categories, the technical cost per tonne is € 64.64. However, as seen in Figure 12, the highest cost burden of end-of-life disposal is from the Lamps category, driven largely by the high quantities of mercury containing CFL lamps that would typically require expensive treatment and disposal at advanced facilities overseas. **Excluding lamps, the technical costs are nearly at break-even, returning a net positive revenue of approximately €100,000, albeit without any access to waste costs or incentives for better channelisation of fractions**.

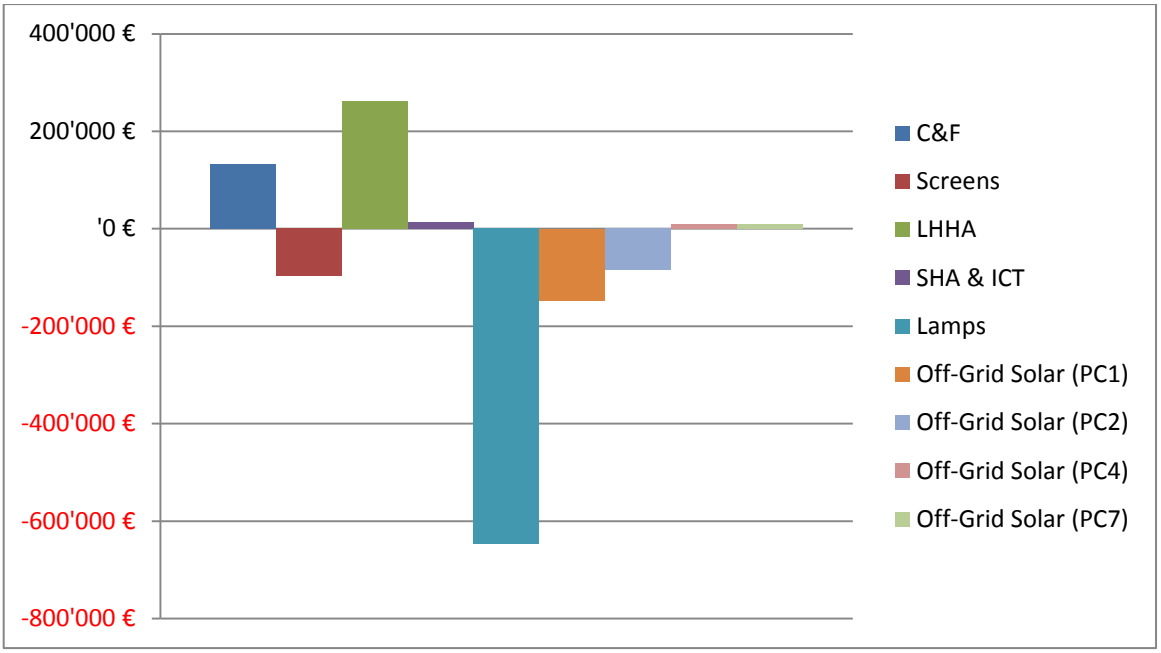

Figure 12:Total technical costs for all waste streams, €/year (for 2017)

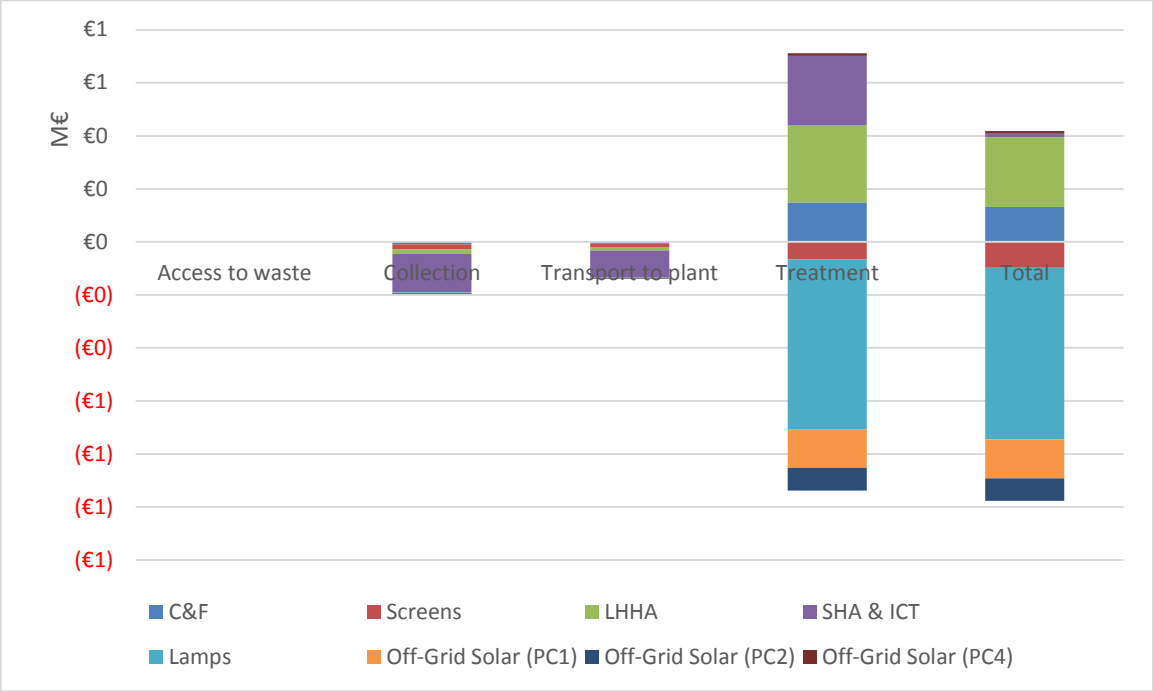

Figure 13: Total technical cost breakdown by cost category

From Figure 13, it is clear that the total cost over the whole value chain needs additional financing for proper recycling and disposal of low value and hazardous fractions.

The technical costs above **do not include system administration costs**, which typically can range from 10-25% depeding on the activities performed and structure of the system manager. These are not only managerial and administration costs, but also for awareness campaigns, audits and monitoring etc.

Assessment:

- *The technical costs of the system vary significantly by product category and therefore industry consultation and agreement has to be reached regarding the appropriate clustering and setting of any EPR fees or levies.*
- *Typically, these advance recycling taxes or eco-levies can be charged at the point of import or at the point of sale. Given that nearly all off-grid products, point of import may be more suitable than at point of sale (which is dispersed and sometimes via informal sellers).*
- *For solar companies, given the growing volumes, it is an appropriate time to start costing in end-of-life management costs. An IRENA report[17] also recommends the need for countries to enable a regulatory framework, along with the institutions needed to implement PV-specific waste regulations early on to ensure sustainable end-of-life management policies.*
- *The cost per unit required to collect and dispose of PC1 &2, especially leveraging on a larger waste stream of e-waste can additionally benefit from government and/ or donor incentives that factor in these costs within project budgets under the energy access programs.*
- *Other options could be to have targeted differentiated VAT concessions for producers who participate in the recycling system. Currently, private companies in the off-grid sector can avail both fiscal and non-fiscal incentives such as tax exemption including VAT on importation of equipment, investment allowance up to 50%, free repatriation of profits, 100% written-off development and research costs and preferential corporate income tax of 15%. Similar incentives can be considered for recycling.*

[17] http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=2734

- *Additionally, most off-grid solar companies place a high value on social and environmental aspects and therefore might not be driven only by financial incentives to participate in a take-back and recycling system.*

Assessment Summary

	Maturity Level	Strengths	Weaknesses
E-waste policy	++	• Well advanced draft regulations • Following international best-practice based on EPR • Backed by various government initiatives under overall National E-waste Strategy	• Lack of knowledge/ awareness regarding E-waste policy and compliance implications for off-grid solar companies • Limited engagement of off-grid sector in policy discussion as yet • More clarity on definition of producer/ importer/ service provider and categorisation of product types • Gaps in text on responsibility for managing system financing, targets and registry
Institutional set-up	++	• Coordination and collaboration between various government departments & agencies eg. RURA, REMA, FONERWA, MINEACOM, MININFRA, MYICT, RDB, RSB • Strong donor support and involvement	• Formalisation of governance and system management and monitoring needs to be developed
Collection infrastructure	+	• Zero/ low cost access to waste • Upcoming collection infrastructure • Already collect post-consumer products for repair and refurbishment/ repossessions	• Lack of trained staff on proper collection and storage
Transport / Logistics infrastructure	+	• Off-grid network companies have self-owned logistics fleet • Short distances; central location of Kigali	• Land-locked country makes any shipment by sea more expensive and time consuming
Treatment infrastructure	++	• GoR funded dismantling facility already established • Possibility for expansion to include waste streams from off-grid solar	• Current infrastructure lacks battery solution which is most pressing for the off-grid companies
System management	+	• Strong enforcement of laws by GoR • FONERWA as potential host of EPR funds	• Gap in regulations for data collection and reporting to a national register/ manager of EPR fund
Financing Mechanism	+	• Support from policy and national strategy as well as standards • Flexibility in regulation to collect advance recycling fees/ eco-levies	• Access to waste costs not provisioned therefore possibility of cost escalation • Limited e-waste volume nationally, therefore fixed cost shared
Private sector Incentives	++	• Solar companies are keen to be seen as clean, green and responsible • Leasing and pay-per-use models mean private companies are owners and have incentive to maximise life/ minimize waste	• Off-grid solar products targeted at price sensitive market therefore limited ability to pass on full cost e.g. on SPLs

Table 9: Assessment of framework conditions for EOL recycling of off-grid solar products in Rwanda. [Key: + low level of maturity – needs to be established, ++ medium level of maturity – existing setup but need significant adaptation, +++ high level of maturity – existing setup that can be rapidly adapted to manage EOL off-grid solar products]

5. Recommendations

In this section, based on the inputs from the workshop, interviews and desk research, we provide recommendations on current Rwanda policy, legislation and implementation framework that would lead to consumer and producers disposing of and recycling e-waste properly, including from the growing off-grid solar sector.

Policy and Legislation

1. **Clarification on scope and categorisation of off-grid products within legal framework**

With solar products included in the scope of products covered under the Rwandan E-waste Regulations, the implications, in particular financial, need to be clarified. For example, as lamps and batteries are classified separately, but both are components of solar products, it is important to have clarity in the policy on what category solar products fall under, what reporting and financing implications it will have and what would be the treatment and standards required for the same.

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

For all models based on the EPR principle it is crucial to implement and enforce a proper definition of "producer", as this is linked to all subsequent legal and financial obligations.. In the current draft regulations, there can be ambiguity regarding exactly who is considered the "producer. Given that batteries have a disproportionately large share of environmental impact and financial implications at end-of-life, it is recommended to clearly define whether the off-grid solar producer or the battery producer bears the responsibility. Also, for example, who pays for disposal in case of free distribution of solar products? Who would be considered a "producer" in this case?

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. **Provision of Eco-design incentives**

Eco-design incentives, rewarding firms with products that can be repaired and recycled easily, would help reduce e-waste generated in the first place. It would also correct market distortions. For example this would penalise low-quality non-certified products that have shorter lifespans and therefore have larger and more rapid flows into the waste stream. Eco-design provisions may be included in the Minimum Standard for Solar Home Systems being developed by the RSB, and / or be operationalised through differentiated recycling fees – with lower fees for Eco-designed products as done by some producer responsibility organisations in Europe. A cross- government approach to this area is recommended as well as cooperation with the Rwandan Development Board is recommended.

4. **Development of treatment standards for PV solar products**

The Global PV industry is already working on requirements within the framework of the European Committee for Electrotechnical Standardisation (CENELEC), an organisation mandated by the European Commission to develop a European standard for the treatment of WEEE, including PV modules. Under the current efforts to develop standards for off-grid solar products by RSB, it is

recommended to also consider standards for the end-of-life treatment for these products, harmonised as much as possible with international standards and best-practice.

5. **Align with and shape regional strategy**

A regional e-waste strategy is currently being developed by the EACO regional e-waste management steering committee, which presents a 5-year plan to establish and mainstream e-waste management in all the member countries. For the off-grid solar industry in the EACO countries it would be important to be engaged and active contributors and participants to the development of this strategy. This provides the opportunity to harmonise policy and regulatory frameworks across the region as well as ensure optimisation of infrastructure given smaller volumes in some countries and larger volumes in others. Also, it would help reduce any redundancies in reporting and can help to ease onerous transboundary shipment procedures.

Stakeholder Engagement, Capacity Building and Awareness

1. **Promote collective engagement and industry association**

Potentially, through existing platforms such as the Energy Private Developers (EPD), activate a channel for off-grid solar companies to engage through and represent the sector at policy level discussions and forums. As solar PV products are already included in the draft regulations, it is important that the industry understands their role, responsibilities and compliance requirements. As yet, the industry is not familiar or aware of the regulations and the concept of Extended Producer Responsibility itself. Therefore, industry consultation is needed on what EPR is, and what that means for off-grid solar companies. Through such a platform, the industry should **develop a position paper** on the EOL management aspect of their products on the basis of which they can engage with government as well as other stakeholders. Additionally, it can also be the vehicle to provide industry support on the topic, for example, through **development of a toolkit** for EOL management of off-grid solar products.

2. **Facilitate alignment and coordination between energy access programmes and waste management aspects**

The strong push by the GoR towards its energy access targets is driving significant investment in the off-grid energy access sector, with programmes supported by various development partners as well as multi-lateral donors. There is a need for greater alignment between energy access programmes and e-waste collection and recycling efforts. Integrating take-back and disposal requirements are essential provisions in the programme roll-out with required budgetary provisions, for example by embedding voluntary or mandatory take-back requirements in the implementation of the Energy Africa Compact in Rwanda.

3. **Widen EPR remit**

EPR is a policy instrument being increasingly applied to a wide range of waste streams across the world. As e-waste is likely the first instance of EPR being applied in Rwanda, it will certainly not be the last. Within this context, it is recommended that the government can take the initiative in bringing together stakeholders and producers from other potential sectors such as packaging and vehicles (batteries, tyres and end-of-life vehicles), among others, to establish EPR as a strategic basis for a boarder waste management policy. This could potentially be in the form of a cross-sector working group or similar that is mandated to work on coordinated policy and EPR-based legislation.

Establishing a recycling scheme or EPR Fund

The draft E-waste Bill, under Article 10.2 and corresponding Article 23.2 in the E-waste Regulations clearly place the financial and organisational responsibility of environmentally sound disposal of e-waste on producers. However, the financing mechanism itself is not defined providing industry the opportunity to define and shape the recycling fund.
At the workshop, of the three options discussed – to (i) continue with business as usual (i.e. without recycling), (ii) implement a voluntary take-back system or (iii) implement a mandatory EPR-based system – the third option, for the industry to have a mandatory system had more support, although some companies were in favour of starting with a mandatory system too.

The essential components in establishing such a fund are given below, and activities under each component may take place concurrently with activities from other components, or in other words, the follows steps are not suggested only as serially, but can also be done in parallel to some extent.

- **Initiate multi-stakeholder dialogue**
    - Facilitate industry-wide consensus and feedback on RURA E-waste regulations and agreement on EPR system. As part of this process, in addition to industry wide capacity building and consultation on EPR, joint consultation between off-grid stakeholders and EEE producers would be important to shape a coherent and synergistic solution.
    - Establish a process to provide policy inputs, specifically on critical aspects of the Regulations such as scope, clustering of product categories, governance structure, budgets/ fees, targets, logistics and collection/ treatment infrastructure, legal requirements etc.

- **Pilot a collection and recycling trial**
    - To understand drivers, challenges and opportunities in the set-up of the collection and take-back system, conduct a collection trial (preferably multi-location mix of urban and rural) accompanied by awareness campaign, collection logistics and monitoring metrics.
    - Analyse the data from the trial to establish the total cost of the system and allocation of various costs and potential revenues, to eventually determine the level of recycling fees required, if any on various products/ categories.

- **Appoint system manager / EPR Fund host**
    - Establish requirements and terms of reference for the fund manager/ producer responsibility organisation that is responsible for receiving and disbursing EPR funds and day to day management of operations of various activities related organising the collection, transport, administration etc.
    - Evaluate mechanisms and alternatives to collect recycling fees or eco-levies and examine legal establishment status e.g. private for-profit firm, not-for-profit membership association, public department or autonomous government entity etc.
    - Establish governance mechanisms and rules and procedures for setting advance recycling taxes/eco-levies, disbursement of funds, monitoring and audit and awareness.
    - Raise the seed funding necessary to launch the system, either through government funds, donor funds, or advance payment from producers to the EPR fund.

- **Conduct capacity building and awareness**
    - Organise capacity building and training on EPR, e-waste management and legislative compliance requirements for off-grid companies.
    - Create awareness on sound e-waste management and recycling and appropriate channels for disposal by bulk consumers as well as domestic households.
    - Build capacity in governance and regulatory bodies for proper monitoring and auditing of system.

Next steps and further research

- Strengthening current legislative provisions on e-waste
    - Map exiting/upcoming policies, legislation and regulations to identify gaps, overlaps and inconsistencies.
    - Identify opportunities and incentives for private sector participation.
    - Strengthen legal backing for establishing and collecting EPR funds.

- Assessing current e-waste management volumes and routes for material and monetary flows
    - Understanding how much e-waste, of which kind, is generated how often, at which locations and by whom, specially with regards to off-grid solar products
    - Identifying drivers and barriers for collection and recycling.
    - Understanding consumer disposal habits, level of awareness and willingness to pay

- EPR fund set-up and management
    - Assess options for hosting and management of EPR funds at industry level for off-grid solar only or jointly with other sectors.
    - Assess pros and cons for various financing options and fund management models.
    - Build capacity in fund management organisation(s) regarding operational aspects, governance issues and technical requirements.

- Technical audit and standards for recycling
    - Assess current recycling capacity and gaps for proper treatment and processing end-of-life solar products specially for problematic fractions.
    - Development of technical audit requirements and standards for recycling of off-grid products, their components and fractions.

6. Annex

Main institutions and stakeholders to engage with

Ministry of Trade, Industry and EAC affairs (MINEACOM) www.mineacom.gov.rw	MINEACOM has taken the lead in shepherding the e-waste topic in Rwanda Leads the project funded under FONERWA to develop policy and dismantling plant Currently chairs EACO E-waste Technical Committee
Rwanda Utility Regulatory Agency (RURA) www.rura.rw	RURA is mandated to develop and regulate e-waste
Ministry of Youth and ICT (MINYICT) www.myict.gov.rw	MINYICT has developed the e-waste policy.
Rwanda Standards Board (RSB) www.rsb.gov.rw	RSB developed e-waste management standards to be used by operators
National Fund for Environment and Climate Change (FONERWA) www.fonerwa.org	FONERWA has an independent board and is charged with mobilizing and harmonizing funds across various areas to support Rwanda's green growth and sustainable development.
Ministry of Infrastructure (MININFRA) www.mininfra.gov.rw	MININFRA is the lead Ministry responsible for developing energy policy and strategy, monitoring and evaluation of projects and programs implementation. The Ministry is in charge of setting an enabling policy and legal framework for the energy sector, including a suggested general approach to the optimal use of state subsidies in the sector, budget preparation, resource mobilization (together with MINECOFIN), and political oversight over government programs designed to expand energy access and service provision including off-grid. A key coordination mechanism for the sector in Rwanda is the energy Sector Wide Approach (eSWAP) which has a secretariat within MININFRA. Energy Sector Working Group (SWG) Energy SWG is a forum in which government meets its development partners to discuss matters influencing the sector.
Ministry of Natural Resources (MINIRENA) www.minirena.gov.rw	MINIRENA is responsible for ensuring the sustainability of natural resources exploitation including water, and also has the mandate for developing and managing compliance to the environment policy and law. As such it is the custodian of environmental welfare in Rwanda.
Rwanda Environment Management Authority (REMA) www.rema.gov.rw	REMA has the mandate to coordinate, oversee and implement environmental policy. Is the focal point for the Basel Convention and authorizing transboundary shipments of e-waste;
Rwanda Development Board (RDB) www.rdb.rw	RDB plays the lead role in investment mobilization and promotion for the energy sector, acting as a gateway and facilitator. It actively promotes private investor participation in the energy sector, including local financial institutions. RDB also issues Environmental Impact Assessments for all energy projects for which one is required. Host a centralized authority or advisory agency for PPPs across government.
Rwanda Energy Group Ltd. (REG) www.reg.rw	REG and its subsidiaries help execute and implement the energy policy and strategies and support day-to-day monitoring of project implementation. Operating under company law, it will have a more corporate orientation and greater autonomy from political interference whilst still being accountable to MININFRA and the Rwanda Utilities Regulatory Authority (RURA) in charge in terms of project development activities, utility services and performance standards.
Energy Private Developers Association (EPD)	EPD is a grouping and advocating for the needs of energy private companies

Interviews and Face-to-Face meetings

- Iwona, PhD researcher, 19th June 2017
- Justus Mucyo, Bboxx, 23rd June 2017
- Athina, Phenix, 26th June 2017
- Godfrey Idhambo, Off-Grid Electric, 23rd June 2017
- Brekke Berg, OneAcreFund, 27th June 2017
- Alex Mulisa, FONERWA, 30th June 2017
- Patrick Mugabo, Mobisol Rwanda, 30th June 2017
- Tom Rwahama, E-SWAP/ MINIFRA, 30th June 2017