GOGLA
The Voice of the Off-Grid Solar Energy Industry

E-waste Toolkit Module 3 Briefing Note

The financials of e-waste management

Executive summary

In most cases, off-grid solar waste has a negative value. This means that the cost of return logistics and recycling exceeds the revenue generated from the recovered materials. In order to accelerate the transition to a financially efficient recycling chain, the off-grid solar industry is evaluating cost-effective solutions that can meet social and environmental obligations without making products unaffordable or slowing market growth.

An entry-level solar light is estimated to have a negative end-of-life value (i.e. a cost) of EUR 0.7 per unit, or EUR 3500 per ton. Larger SHS kits that use lead-acid batteries are estimated to have a positive end-of-life value of EUR 1.8 after the costs, or about EUR 100 per ton. The existing financial model and cost data can help companies calculate their financial liability and serve as a baseline to measure and improve their practices. Yet there is need to continually refine and reexamine the data as models evolve and waste volumes increase in line with the growth of the sector.

Costs are generated along the four steps in the chain - access to waste, collection, transport and treatment – with the final step being the most expensive, though take-back and collection are also potentially costly. The value of treatment la rgely depends on the battery type – lithium-based batteries are expensive whereas lead-acid batteries are generally valuable – and the copper content in the product. With this in mind, there is the opportunity to reduce the overall lifecycle costs through innovative practices, models and partnerships that can achieve high volumes and recover value from products at the treatment stage.

A solid understanding ofthe financials is key for individual companies and the sector to develop and implement e-waste strategies, in particular to help:

- Inform pricing and unit economics
- Forecast possible financial liability
- Identify business services and product features that reduce the overall lifecycle costs.
- Provide guidance for agreements with e-waste service providers
- Identify areas where coordination action and collaboration will be cost-effective

An estimated 3 million off-grid solar products, with a combined weight of about 2,500 tons, will reach their end-of-life in Kenya in 2019. The full end-of-life costs of this is estimated to be EUR 1.4m, though in practice will be much lower given the actual volumes being collected and treated. Nonetheless, this still represents a significant liability for a young sector struggling with profitability.

As a sector, it is important to consider our consumers in the off-grid sector when evaluating models for dealing with e-waste. Any price increase resulting from action on e-waste will hurt low-income consumers and essentially stall, rather than accelerate access to energy in rural areas. There is also a risk that it will further increase the price gap between non-quality-verified products and quality-assured products which may cause consumers to opt for cheaper, environmentally harmful products. These are crucial elements to consider when evaluating the lifecycle of off-grid solar products.

To combat these concerns, public sector investment in collection and recycling infrastructure is necessary, alongside a solid regulatory framework that ensures the transparent and fair allocation of financial obligations. Methods for cross-subsidising off-grid solar e-waste should be explored to avoid low-income consumers paying the poverty premium.
As a sector we have a duty of care to ensure our products are handled safely and do no harm throughout their lifespan from production to end-of-life. We believe with vision, collaboration and support, we can find a cost-effective way to provide access to waste, collection, transport and treatment for off-grid solar products for the entirety of their lifespan.

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Disclaimer

The information in this Briefing Note is designed to provide helpful information on the topic. GOGLA and the authors are not responsible or liable in any manner for any damages resulting from use of information in this Briefing Note.

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Introduction

This briefing note details the costs incurred at each step of the product's end-of-life journey - access to waste, collection, transport and treatment. The aim is to help companies plan their e-waste management strategy. E-waste cost data is required to help companies forecast their financial liability and serves as useful guidance when establishing partnerships with e-waste service providers. Mapping the costs at all stages of the product's lifetime can inform the unit economics and the pricing for consumers. It can also influence decisions about product and business model design – for example, it may show that it is cost effective to invest in product design changes that enhance disassembly and reduce the cost of recycling, or to push repair and refurbishment services that reduce waste[1].

Companies are bound within regulatory frameworks to develop e-waste operational strategies with different financial models. The models vary and in some, the costs are passed on directly to consumers through an increased product price. In others costs are covered by e-waste producers or by taxpayers. Companies also have different ways to achieve compliance with regulation that influences the cost and finance mechanism. This Briefing Note will unpack this complex chain of costs, to help companies adapt to an evolving e-waste landscape.

This Briefing Note is largely informed by the data from two studies commissioned by DfID and delivered by Sofies, including an E-waste Forecast Model Tool, and insights gained from GOGLA policy engagements in Kenya and Ghana.

1 Briefing Note 2: Design for Reduction of Waste explored strategies and practices to reduce waste.

The costs of e-waste management

Putting a price tag on e-waste is tricky business. There are still relatively low volumes of off-grid solar products that have reached end-of-life, so the supply chains, costs and financing models are still very much in flux. Furthermore, the costs can vary from country to country depending on the presence of e-waste service providers, infrastructure and regulation. The sector has unique costs to consider and challenges that have few parallels in other regions with mature e-waste management frameworks.

The data presented herein is from two studies that conducted research in East Africa to generate a cost model. Costs are presented per product category and disaggregated according to four discrete steps (see schematic below). It is important to note that the cost data would benefit from further validation and refinement using more recent operational experience (this is the objective of upcoming studies). The estimate of the treatment step is considered the most accurate since this is based on costs charged for services. The other steps entail a lot more variation in their method (and associated costs), and hidden costs (how waste products are collected and transported).

The smaller off-grid solar waste largely has a negative value; the intrinsic cost of the recovered materials is much lower than the costs of access, transport and treatment. The low weight and distributed nature of products also entails a high price per unit. It is estimated that an entry-level solar lantern has a negative end-of-life value (i.e. a cost) of EUR 0.7 per unit, or EUR 3500 per ton (with 5,000 units per ton). Clearly, a price increase of EUR 0.7 on an individual product in the EUR 5-20 price range constitutes a significant increase that would impact the affordability for low-income consumers.

Larger SHS kits are likely to have a positive value given the components and materials have worth, and the costs per unit weight of collection and transport are less with heavier items. It is estimated that an SHS kit (with lead-acid battery) has a positive end-of-life value of EUR 1.8 after the costs, or about EUR 100 per ton (with 50 units per ton).

Figure 1: The e-waste chain is broken into four steps for the purpose of cost analysis

Access to Waste →

Definition
Obtaining the waste product from the consumer.

Costs
- Consumers often expect a payment or incentive to relinquish electronic waste.
- Marketing / consumer awareness campaigns.

Collection →

Definition
The infrastructure and operational requirements of a collection centre and network.

Costs
- The location / facility
- Collection bins / storage space
- Staff

Transport →

Definition
Transporting the waste from collection point (or consumers' location, i.e. doorstep collection) to treatment plant.

Costs
- Transport, other logistics, compliance costs.

Treatment

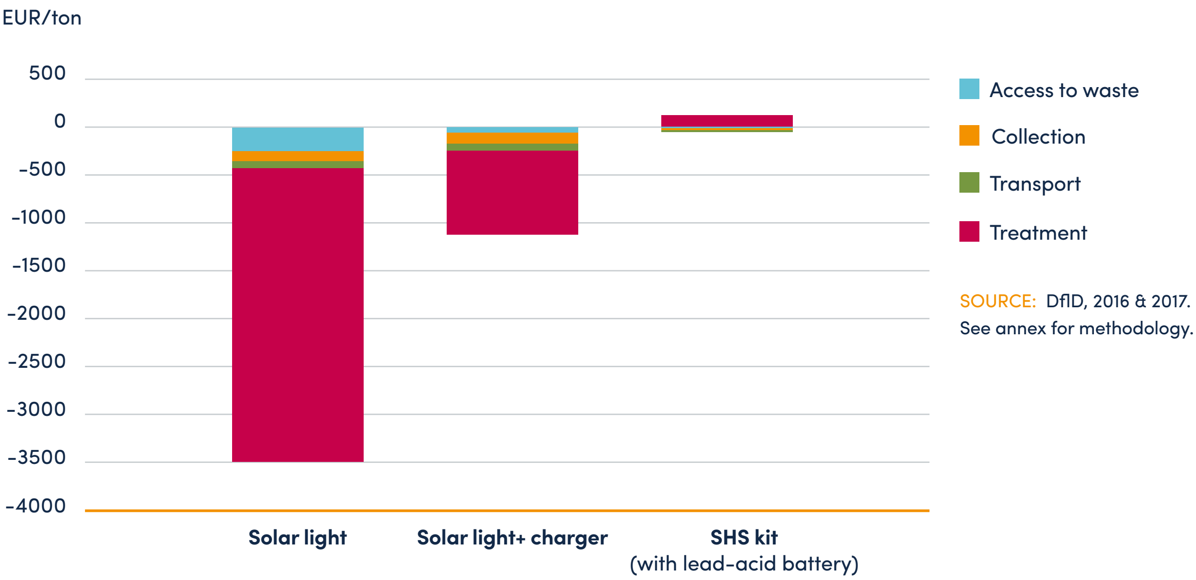
Definition
Dismantling and proper treatment of the waste.

Costs
- Net treatment costs / value of proper treatment, including disposal of hazardous fractions, operational costs such as labour, energy, or depreciation of capital investment.
- After dismantling, fractions can be sold on domestic or international markets if they have positive value or disposed of/sent for further treatment if they don't.

SOURCE: DfID 2017

The costs of e-waste management

Figure 2: Cost (per ton) estimate of off-grid solar waste management



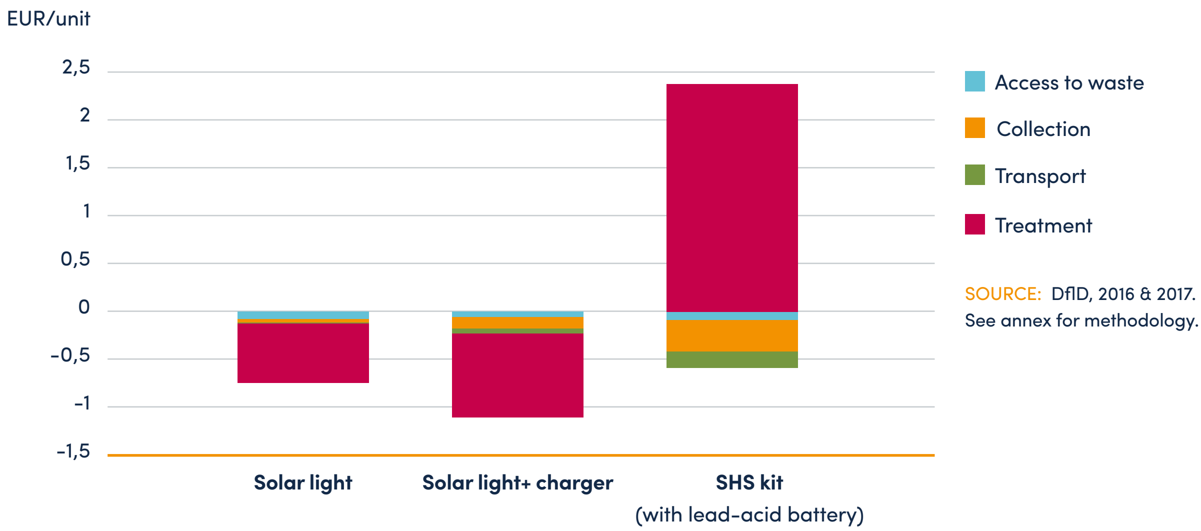
	Solar light	Solar light+ charger	SHS kit (with lead-acid battery)
Weight / unit	0.2 kg	1.0 kg	20 kg
Value / unit	EUR -0.7	EUR -1.1	EUR 1.8

SOURCE: DfID, 2016 & 2017.
See annex for methodology.

The main cost drivers for off-grid solar e-waste are:

- Battery type. Lead-acid batteries have a positive value. Lithium-based batteries generally have a negative value (particularly LFP).
- Copper content in cables.
- The method of access to waste and collection. If existing operations and infrastructure can be leveraged the costs can be absorbed relatively easily, however if new investment in infrastructure, staff, etc is required the costs could be significantly higher.

Figure 3: Cost (per unit) estimate of off-grid solar waste management



SOURCE: DfID, 2016 & 2017.
See annex for methodology.

The costs along the e-waste chain

The following section explores each step in the chain to help understand each area of cost and how it can fluctuate.

Access to waste

Access to waste is the first and arguably most difficult step in the e-waste chain. This simply means obtaining the product from the consumer. Yet there are a number of barriers to access to waste.

Many consumers in developing countries perceive that all forms of electronic waste have a value, and they expect to be paid to hand over products or components at end-of-life. They may feel that they can get it repaired informally or sell the components to repair shops or informal collectors. Who declares when a product is waste and should be recycled, and on what basis, is a topic for rich debate. It may well be that an off-grid solar company (or informal recycler) is able to repair or salvage parts from a product that is considered waste by the consumer.

To achieve high rates of take-back from consumers will require some form of incentive, both to overcome the issue of perceived value and to offset any travel costs or time spent in returning the product. **GOGLA strongly recommends that cash incentives are not practiced (by off-grid solar companies, collectors or other actors). This is likely to set a precedent in the mindset that is difficult to shift.** Given the negative value for small off-grid solar products, it is not a viable long-term option[2]. Alternative incentives include discounts on new product purchases, merchandise or entry into a raffle. Other incentives have also been explored to reduce barriers to access waste. Other institutions that partake in collection may also offer incentives, for examples schools could offer a free school meal or awards for students. Module 5 will look at take-back schemes and incentives in detail.

To influence consumers' perception of the value of waste, off-grid solar companies can educate consumers about end-of-life issues and options at each of the touch points they have with consumers – during sale (sales agents and packaging), after-sales service (technicians, call-centres, USSD platforms) and at product end-of-life itself (if the consumer returns products to the point of sale or call customer support for example).

Awareness raising campaigns are used to inform consumers about the issues of holding on to waste and where they may be able to return them. Off-grid solar companies or e-waste collectors may run these, either through targeted channels (such as SMS to existing consumer lists) or broadcast on radio, etc. These campaigns have to balance the need to inform about the problems of waste and encourage consumers to relinquish products at end-of-life, while not raising undue alarm about the prospect of buying and using products.

2 For example, an effective cash incentive to return a waste product would likely need to be in the order of $0.5-1, which would double the total end-of-life cost of a small off-grid solar product.

The costs along the e-waste chain

Collection

Collection is the next step in the chain and refers to the infrastructure and operational requirements of a collection network. Access to waste and collection can be easily confused as they go hand in hand. Access to waste can be thought of as the consumer interaction (informing and incentivising the consumer), whereas collection entails the physical return points (and in some cases the network to connect collection centres) and personnel required for this to function.

Collection may be done through three main channels:

- Off-grid solar companies (roaming agents or points of sale)
- Third-party collection centres (in such as another electronics retail outlet, filling station, a supermarket, school, e-waste management facility, etc.)
- Informal sector (local repair shops, door-to-door collectors or dumpsite scavenging)

In practice, maximizing the collection rate will entail all three channels operating in parallel. Clearly, collection efforts are more likely to be effective if the collection points are closer to the waste holder and minimise the cost and effort for the consumer to return the waste product.
In terms of actual collection infrastructure, this could be a container, bin or designated area (a locked room or corner of a warehouse) to collect and store waste at designated collection points. Safety considerations of storage and handling are paramount (see Module 1 of the Toolkit), particularly for lead-acid batteries that are hazardous. Security is another consideration to avoid the waste stockpile being pilfered of any valuable elements.

Collection also encompasses the personnel costs of employing staff to oversee collection points, who may require training to assess whether the product can be repaired or is indeed waste and be aware of necessary health and safety measures. There are technological solutions to assist end-of-life management, connecting the informal sector with formal collectors via apps, capturing waste stock volumes and movements, etc.

To a large extent, if existing operations and infrastructure can be leveraged, the costs can be absorbed relatively easily. However, if new investment in infrastructure, staff, etc is required, costs could be significantly higher. Partnerships and cooperation with other product companies (such as in the mobile industry) and e-waste collectors and/or recyclers will be key to achieve scale in a cost effective manner.

The off-grid solar industry produces a small percentage of the overall e-waste generated; the significant investment requirements of collection infrastructure should not be borne by the sector and underserved rural consumers. The Global LEAP Solar E-waste Innovation Prize is funding Enviroserve Rwanda to establish a nationwide collection network that connects to the e-waste facility they operate. Further investments by governments and development partners are encouraged.

Transport

Transport costs encompass everything from the point of collection (or sometimes even the consumer's house) to the treatment plant. The model estimates the transport cost to be between €10 – 60 per ton, a relatively small amount compared to those incurred in other steps. Many companies use the reverse trips of outbound logistics to get waste products or components back to a central point to limit additional expenses. Of course, a large country with weak transport infrastructure will negatively affect transport costs. Transboundary movement of waste products is necessary in many countries that do not have an e-waste management facility and need to send to a licensed recycler (e.g. the facilities in Kenya or Rwanda). Of course, this is more costly, likely requiring a dedicated delivery and compliance with applicable regulations (such as border controls and working with licensed e-waste transporters).

Many fractions can be recycled or safely disposed regionally, but lithium batteries need to be sent to Europe for environmentally sound recycling. Achieving volumes will help minimise this cost.

The costs along the e-waste chain

Treatment

Net costs for proper treatment include disposal of hazardous fractions, operational costs such as labour, energy, and depreciation of capital investment. Then there are other costs related to the functioning and maintenance of the treatment plant itself.

The table below illustrates the positive and negative costs of treatment for individual fractions found in off-grid solar products (sourced from the London Metal Exchange). Lithium-iron-phosphate batteries have a high negative value – reflecting the high costs of transport and low intrinsic value of the materials that are recovered (though it is important to note that they have strong performance and good durability)[3]. Lead-acid batteries have a positive value which creates an opportunity for end-of-life management, though their toxicity requires robust health and safety practiced.

Figure 4: Material composition, treatment destination and average cost of treatment for off-grid solar fractions

	Solar light	Solar light with charger	SHS kit	Market destination	Average price (incl. transport) €/t
Average weight (g)	**150**	**906**	**2,450**		
Steel	20	160		Local	140
Copper			418.6	Local	2.649
Aluminium				Local	615
Plastics				Local	129
Pb Batteries				Overseas	363
LIP Batteries	100	100	100	Overseas	-3.250
PV modules		411	1,180	Overseas	-185
CFL (Hg)	30	30	107	Overseas	-675
LED			551,4	Overseas	80
Mixed Plastics (incl. BFR)		205	93	Overseas	23
Printed Wiring Boards (PWB)				Overseas	500

SOURCE: Electronic Waste Impacts and Mitigation Operations in the Off-Grid Renewable Energy Sector (DfID, 2016)

3 Responsible landfill is one possible low-cost option for lithium-iron-phosphate batteries given they are non-toxic. There are no suitable facilities in Africa, though it may be considered an intermediate solution that does not require a high investment or technological capability, unlike environmentally-sound lithium recycling plants.

The costs along the e-waste chain

The impact of disassembly time for off-grid products is substantial, especially considering that thefew fractions of positive value are not of sufficient weight to represent much financial value. In other words, the cost of disassembly may outweigh the recovered value of the materials. In this case, it would be cost-effective to focus on the removal of hazardous components and fractions rather than on the recovery of valuable fractions (such as printed wiring board, copper or aluminium).. As individual case studies show, disassembly costs could significantly change the overall economic balance for specific products Product design considerations (e.g. avoiding encapsulating certain components in glue) can enhance the ease of disassembly and thus reduce the cost of treatment .

A recycler or e-waste management company typically prices its services according to volumes (weight in kg). Volumes will affect operational costs of running an e-waste management facility as well as transportation costs. However, there are some considerations that they factor into the prices they charge: it is common that they provide a case-by-case quote after evaluating the waste. The presence and type of batteries, PV panels and PCBs is normally taken into account due to the scarcity of recyclers that can deal with some of them in a sound manner. The presence of plastics and metal, on the other hand, does not represent an additional cost for recyclers since they can typically be recycled or disposed of locally. E-waste treatment costs can be reduced with higher volumes that achieve economies of scale. Industry collaboration on collection and treatment could facilitate higher volumes. This could include shared collection infrastructure and transport, or collaboration to identify a recycler and aggregate waste stocks for treatment. A Producer's Responsibility Organisation (PRO), such as Karo Sambhav in India, is another model whereby a new entity is established to fulfil the e-waste management obligations of its governing members.

4 Briefing Note 2: Design for Reduction of Waste has more on this topic.

Total annual cost of treatment in Kenya

The two DfID studies cited in this Briefing Note include an e-waste model that forecasts the volume of off-grid solar generated in individual countries and their region, and a forecast of the end-of-life costs. While the model provides a useful overview, further validation and refinement is necessary for a precise picture.

An estimated 3 million off-grid solar products, with a combined weight of about 2,500 tons, will reach their end-of-life in Kenya in 2019. This represents about 3% of the total e-waste generated in Kenya, considering all electrical and electronic equipment (in Rwanda and Nigeria off-grid solar represents only 0.4% and 0.02% respectively)[5]. SHS kits constitute the largest proportion of the weight of off-grid solar waste, though the small (and lighter) products are much more numerous. More than 50% of the waste generated is from non-quality-verified products.

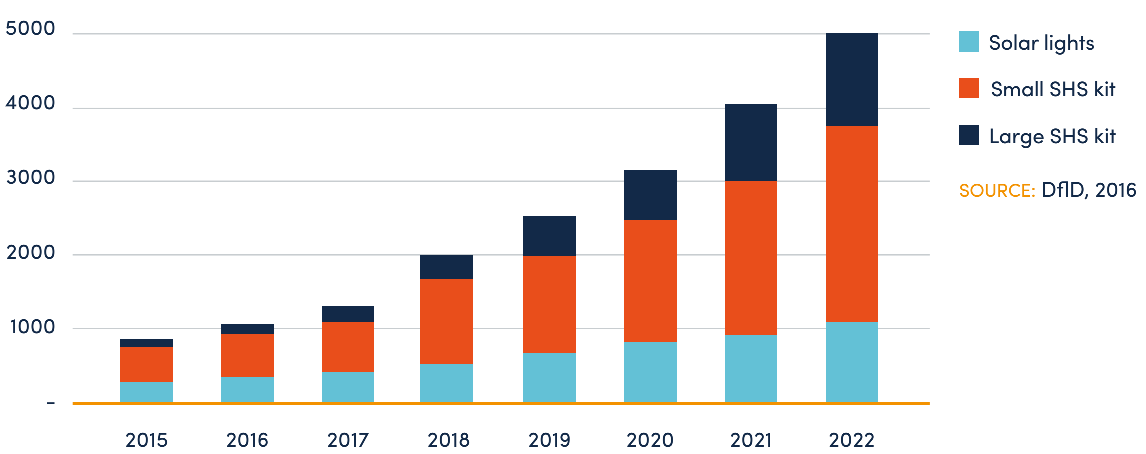
The full end-of-life costs for this volume of off-grid solar waste is estimated to be EUR 1.4m. This assumes that 100% of products are being collected and treated; given that the actual amounts being collected are significantly lower, the costs incurred by the sector are in practice less. Nonetheless, this still represents a significant liability for a young sector struggling with profitability. Companies should take steps to minimize and prepare for the costs. Development partners and governments have a role to play with investment in collection and treatment infrastructure.

Off-grid solar waste is 3% of the total e-waste generated in Kenya.

As the e-waste regulation and implementation framework in Kenya is defined, care should be taken to leverage the strengths of off-grid solar companies without adding undue obligations that would increase costs to companies and consumers. The financial obligation and mechanism may enable cross-subsidy from other product lines to avoid low-income rural consumers from paying a poverty premium.

The high proportion of non-quality-verified products in the waste stream – and the associated end-of-life costs – are also of critical consideration for regulators when designing the financial mechanism. The costs of treating non-quality-verified products should not be borne by consumers of good quality products and responsible companies.

Figure 5: Estimate of off-grid solar waste generated in Kenya (weight in tons)



5 Cost Benefit Analysis and Capacity Assessment for the Management of Electronic Waste in the Off-Grid Renewable Energy Sector in Kenya (DfID, 2017).

Forecasting waste volumes

Forecasting waste volumes is key to developing efficient e-waste management streams. For an individual company to calculate the end of life financial liability of their product fleet is a function of cost and volume. Estimating the volume of products that will reach the end of life, and that will enter the formal e-waste channel, is a challenging exercise.

The **sales-lifespan model** is a common methodology for forecasting the number of products that will reach end of life in a given period:

Waste volume (kg) =
Product sales x weight x lifespan

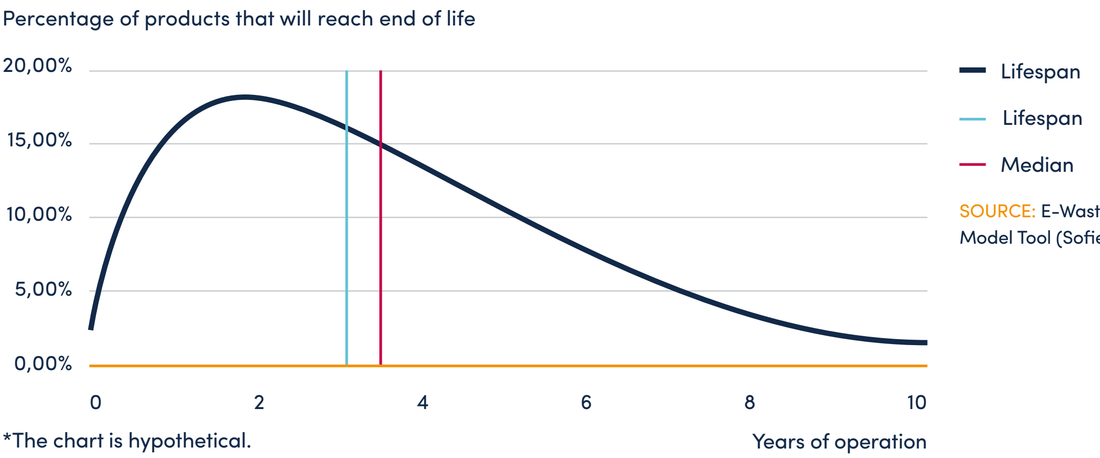
The most uncertain parameter in this calculation is of course the lifespan of products. While individual companies may have good data and research on their product and core component lifespan, for many it is not known to a high degree of accuracy. PAYGo companies with remote monitoring functionality have the capability to track performance that links to a CRM tool, stock inventory, service actions etc. However, after the consumer has completed payments, monitoring may be reduced or stop altogether to avoid costs or because consumers may wish to stop system monitoring. For entry-level cash sale products, it is very hard to track the usage, performance and location after the customer has bought the product.

Lighting Global certified products come with a warranty (one year for picoPV <10W and two years for SHS kits of 10-350W) though the design life is often much longer (up to five to seven years with modern lithium batteries). The GOGLA **standardized impact metrics** estimate product lifespan using the warranty period multiplied by 1.5, though this is considered a conservative estimate. A Weibull distribution is commonly used as a reasonable approximation for the lifespan of a product fleet, this maps the range of lifespans that are realized in practice.

Another confounding factor when forecasting waste volumes is that components in a product have different lifespans. From a waste perspective, one product is not one product. Batteries, charging cables, LED lights may be replaced multiple times throughout the life of a product (particularly true for SHS kits and larger systems). It is therefore not as simple as 'product sales x weight'.

To calculate the financial liability for treatment also requires a discount factor for take back and collection rates. At present, a small proportion of products at end of life are brought back through formal channels. There are various initiatives being led by off-grid solar companies and recyclers to increase access to waste – results should guide the sector to better forecast waste volumes and liabilities.

Figure 6: A Weibull distribution to forecast the lifespan of a product fleet*



SOURCE: E-Waste Forecast Model Tool (Sofies)

*The chart is hypothetical.

Financing models and calculating financial obligations

The prevalent situation in most off-grid solar markets is that of industry self-regulation, whereby off-grid solar companies pay the end of life costs on a voluntary basis. Particularly where the e-waste has a negative value, it may be argued that government regulation is necessary to increase the rate of treatment, fairly allocate the cost burden among producers and enable profitable recycling businesses. Indeed, government e-waste regulation has recently come into force in some off-grid solar markets and is in the pipeline in more. There are four main types of regulation, each with a different financing model and mechanism:

- Waste-holder financing: the individual disposing of the waste pays.
- Consumer Financing: The consumer pays (direct to the e-waste fund) upon purchase of the new product.
- Producer Financing: The "producer", i.e. the original equipment manufacturer or importer, pays. The payment may be upon placing the product on the market (e.g. an Eco-levy as in Ghana), or upon the waste being treated (Extended Producer Responsibility).
- Hybrid Model: Taxpayers finance access to waste and producers finance remaining steps.

Producer financing using the EPR model is the most common form of regulation, both in industrialised and developing economies. In Africa, Ghana is a notable exception having recently implemented an Eco-levy. This obliges importers of any electrical and electronic equipment to pay a fixed levy prior to importation, though absolves them of any operational responsibility (on take-back, collection and treatment)[6]. The Eco-levy amount is $1.5 for solar lanterns and $8 plus for SHS kits (depending on components and appliances).

The EPR model entails both operational and financial obligations for producers, with both direct and indirect costs associated[7]. The principal direct cost is for the collection and treatment of "problematic fractions" (i.e. e-waste with a negative value). Other direct costs include the license and registration with the regulator, though this is a nominal annual sum. Indirect costs include administrative efforts on sales data and recycling reporting, selection and audits of licensed transporters and recyclers, etc.

The draft e-waste bill in Kenya sets out the following method for defining the financial obligation of the producer:

Draft Kenya e-waste bill – Calculating the producer's financial obligation

A producer shall, within their relevant product type and on the basis of their market share, finance the treatment of problematic fractions by the licensed treatment facility.

Whereby, "**problematic fraction**" means a component or part of electrical and electronic equipment waste where the **collection and treatment** cost outweighs the material recovery value.

Market share calculation[8] for a producer is the weight of products put on the market by an individual producer in his product type divided by the total weight of products put on the market by all producers in this **product type**.

6 Read more here, and the legislation – with a full list of Eco-levy amounts per component - is available on the GOGLA website member space.

7 Briefing Note 4 will explore E-waste Regulation and Compliance.

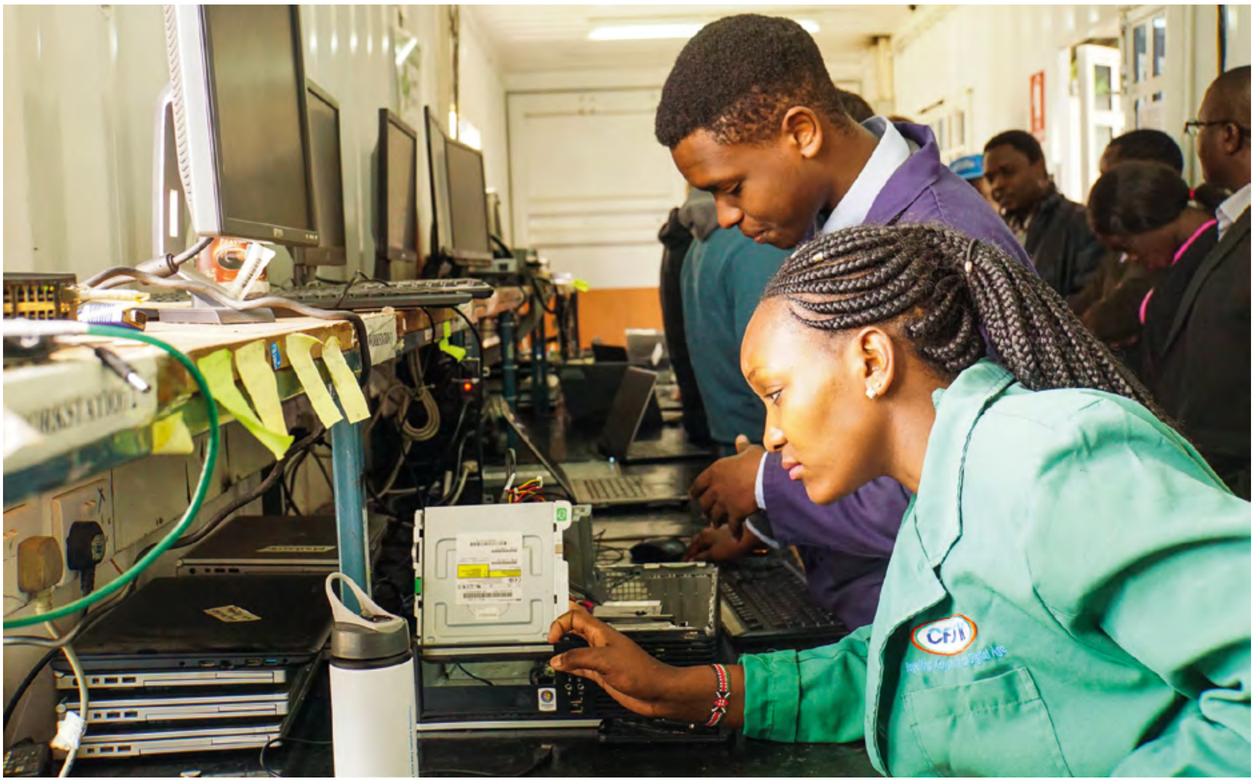
8 The regulation requires that all producers submit sales data to the National Register periodically, this is used as the basis for calculating the market share.

Financing models and calculating financial obligations

"Off-grid solar product" is not explicitly itemized in the product listing, so it is likely the individual components would be the basis for the calculation. Significantly, the "product type" to be used in the calculation has not yet been defined; it may be at the level of "Batteries" or the more granular categorization "Portable batteries – rechargeable". This is significant as the range and volume of products entering the category will determine the level of cross-subsidy; for example, if the lithium batteries for the off-grid solar sector (with a negative value) were aggregated with lead-acid batteries from vehicles (with a positive value) this would offer a cross-subsidy that would reduce the financial obligation of off-grid solar companies.

The uncertainty as to how off-grid solar products and components will be categorized, and the yet undefined details of the calculation, makes it difficult to forecast the financial obligation. There is an argument for advocating off-grid solar products should be explicitly itemized in the bill to give greater transparency, certainty and control over the obligation, though this can risk making responsible off-grid solar companies a target for regulators and miss out on potential cross-subsidisation.

It is also noteworthy that the definition of "problematic fraction" includes the costs of both collection and treatment. A high-cost scenario could be envisaged whereby a recycler invests heavily in collection infrastructure and operations and passes this on to producers through the financial obligation. It is GOGLA's view that the high costs of servicing underserved people in rural areas (both in distribution and take-back) should not be passed on to the consumers; this would make products less affordable and dampen efforts to achieve electrification targets. Public investment in infrastructure, combined with smart public-private partnerships for take-back and collection are needed to achieve a cost-effective scheme. Even then, a form of cross-subsidy through such as other e-waste streams should be considered to avoid low-income consumers paying the poverty premium.



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Annex 1 - E-waste financial model

This model was developed by Sofies for a DfID study (2016). A summary of the outputs and methodology is presented here. Costs are presented per product category and disaggregated according to four discrete steps. It is important to note that the cost data would benefit from further validation and refinement using more recent operational experience.

Worst case	Access to waste		Collection		Transport		Treatment		Total	
	EUR/unit	EUR/ton	EUR/unit	EUR/ton	EUR/unit	EUR/ton	EUR/unit	EUR/ton	EUR/unit	EUR/ton
PC1	-0.05	-250	-0.02	-100	-0.01	-50	-0.62	-3100	-0.7	-3500
PC2	-0.05	-50	-0.12	-120	-0.06	-60	-0.88	-880	-1.11	-1110
PC4	-0.08	-4	-0.32	-16	-0.17	-8.5	2.38*	119*	1.81	90.5

Best case	Access to waste		Collection		Transport		Treatment		Total	
	EUR/unit	EUR/ton	EUR/unit	EUR/ton	EUR/unit	EUR/ton	EUR/unit	EUR/ton	EUR/unit	EUR/ton
PC1	-0.05	-250	0	0	0	0	-0.54	-2700	-0.59	-2950
PC2	-0.05	-50	0	0	0	0	-0.75	-750	-0.8	-800
PC4	-0.08	-4	0	0	0	0	2.38*	119*	2.30	115

*This value is taken from DfID 2017.

Annex 1 - E-waste financial model

Parameters and assumptions:

The "Worst case scenario" is the one leading to highest economic impact: dedicated collection infrastructures, lowest values of commodities, products with CFL.

The "Best case scenario" is the one leading to lower economic impact: shared collection infrastructures, highest values of commodities, products with LED.

Product categories, material composition and weight:

Category	Main materials	Weight (kg)
Solar light PC1 - Single light source without external power outlet/ mobile phone charging < 100 lumens	LFP batteries (67%) LED (20%) Steel (13%)	0.2
Solar light + charger PC2 - Single light source with external power outlet/ mobile phone charging < 100 lm OR Single light source without external power outlet/ mobile phone charging > 100 lumens	PV modules (45%) Mixed plastics (inc. BFR) (23%) Steel (18%) LFP batteries (11%) LED (3%)	1
Solar Home System Kit PC4 - Multi light source application with external power outlet/ mobile phone charging	Steel (30%) PV Module (29%) Pb battery (30%) Copper (4%) Plastics (6%) PWB (2%	20

Access to waste

It is assumed, considering the low intrinsic economic value, that off-grid products are disposed of by end-users without, or with very little, financial compensation (Nigeria shown approx. 0.13-0.25 €/product).

It is assumed that products are collected in their entirety, and that the valuable elements (e.g. copper cables, lead-acid batteries, etc) are not "harvested" by someone else along the chain.

Cost for collection:

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.

Transport

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.

Treatment

Based on market rates of main recyclers operating in East Africa at the time of study.

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);

References

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