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INNOVATIONS AND LESSONS IN SOLAR E-WASTE MANAGEMENT

Global LEAP Solar E-Waste Challenge

MARCH 2021

EFFICIENCY FOR ACCESS COALITION

SunnyMoney e-waste sculpture built with materials collected through their Solar E-Waste Challenge project.

Photo Credit: Paisley/SunnyMoney.

OVERVIEW

The rapid expansion of the off-grid solar sector over the past decade has been one of the most exciting trends in clean energy generation, reducing CO2 emissions and granting energy access to hundreds of millions of people living in off- or weak-grid environments. But this success has come at a cost. The proliferation of solar e-waste in communities around the world poses a threat to the environment and to the health of the very people benefiting from off-grid energy services. The imperative to act on this problem is growing increasingly urgent, both for the off-grid sector and for other stakeholders, including donors and governments.

In 2019, the Efficiency for Access Coalition launched the inaugural Global LEAP Awards Solar E-Waste Challenge to identify innovations in off-grid solar e-waste management. Eight companies– off-grid solar companies, recyclers and waste management companies from five African countries – were chosen to test different aspects of e-waste collection and disposal, including recycling, repair and refurbishment, take-back and collection, and awareness raising and incentives. Through the Challenge, the projects built waste processing facilities, purchased crucial equipment, explored repair and refurbishment possibilities, conducted consumer-awareness campaigns across a variety of platforms, and implemented a number of different e-waste take-back schemes. Over the 12-month project period they collectively amassed more than 250,000kg of off-grid solar waste, a small fraction of the total levels, but enough to identify key lessons about the design and implementation of e-waste management programmes.

The aim of this report is to share the good practice that emerged from these projects, to inform future efforts to address growing amounts of e-waste and advance the state of practice in the sector. In examining and analysing the experiences of these eight companies, we gleaned data and insights for others to replicate their successes and avoid some of their pitfalls.

The report was written for off-grid solar company staff involved in developing and implementing e-waste strategy and operations. However, it is also relevant for e-waste service providers (such as recyclers), investors, sector support programmes and governments, each of whom has a role to play in ensuring that solar e-waste is more responsibly managed in the future.

High costs remain one of the most significant barriers to improving e-waste management practices, including the costs involved in accessing waste, transporting it, treating it, and, when necessary, shipping it overseas. The lack of e-waste infrastructure and service providers in Africa is another, including the absence of recycling facilities that meet minimum standards and the difficulty of finding the spare parts necessary to repair or refurbish non-functioning products.

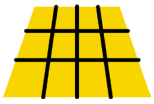
Still, the imperatives for business action on e-waste are compelling. Apart from the very real risks it poses to consumers and the environment, unmanaged e-waste also has the potential to damage the brand reputation of individual solar companies and the industry as a whole. On the other hand, addressing the problem through consumer outreach and e-waste collection schemes can actually boost brand recognition and improve consumer retention. It is in the interests of both investors and governments to encourage the development of e-waste management practices and support related innovations where possible.

E-waste management also presents a number of opportunities for improvements in the sector, including the adoption of new technologies and business models. It also creates opportunities to collaborate with the informal sector, thereby building trust within communities and providing a boost to local value chains and jobs.

One of the most important conclusions that can be drawn from the Challenge is that for now, the cost and complexity of significantly reducing e-waste remain too heavy a burden for the industry. Using data from the Challenge projects, we can estimate that an entry level solar lantern has a negative value (therefore, a cost) of US$-1.36/unit at EoL, while an SHS with a lead acid battery has a positive value of US$1.01/unit. There is a growing need to collaborate to reduce barriers to e-waste management and improve the cost-effectiveness of business models attempting it.

RECOMMENDATIONS

Implementing lessons from the eight Challenge projects across the continent can proactively address this growing challenge.



Off-Grid Solar Companies

Off-grid solar companies can leverage existing consumer touchpoints in order to raise awareness of the risks of e-waste, and of how to dispose of products once they reach end-of-life. The industry itself can also use joint collection schemes and consumer-awareness campaigns to help companies access e-waste. Supporting the reliable repair of out-of-warranty products is an important step as well, since it extends the lives of these products and results in less waste produced. This can be achieved by improving access to technical guidance and good quality spare parts.

Donors

Donors should be offering more funding for e-waste management innovation and project design. They are encouraged to explore novel ways (such as results-based financing) to support early adopters of e-waste management practices, and to help finance the development of innovative models to tackle the problem of e-waste without passing the cost on to consumers.

Governments

Governments can reduce the cost of removing e-waste from their communities by investing more in waste management infrastructure. More robust legislative and regulatory frameworks around responsible recycling would also help raise awareness of the issue and encourage compliance, while lowering import taxes on spare parts would make repairing off-grid solar products a more financially viable option.

Recycling Companies

Recycling companies can leverage existing connections with relevant government agencies in the development and implementation of legislative and policy frameworks for proper e-waste management and installation of extensive national collection networks that reach both far flung areas and known porous border points. They can also carry out awareness campaigns on the importance of proper e-waste disposal and create partnerships with companies for collection, recycling and disposal.Collaborating with informal sector actors such as collectors and recyclers is vital, it could increase volumes available for recycling and reduce cherry picking activities. This can be achieved through training, provision of proper PPE, tools and welfare packages.

These Challenge projects are only the beginning of what must ultimately be a sustained effort to bring solar e-waste under control.

CONTEXT

This report was co-authored by CLASP and GOGLA, as part of the Global LEAP Awards Solar E-Waste Challenge, a programme under the Efficiency for Access Coalition (EforA). EforA is a global coalition working to promote high performing appliances that enable access to clean energy for the world's poorest people. It is a catalyst for change, accelerating the growth of off-grid appliance markets to boost incomes, reduce carbon emissions, improve quality of life and support sustainable development.

The Global LEAP Solar E-Waste Challenge launched in 2019, and is implemented by CLASP. The Global LEAP Solar E-Waste Challenge: Lessons on Take-Back, Collection, Repair & Recycling of Off-Grid Solar Products report was developed by CLASP and GOGLA. The Challenge was funded with UK aid from the UK government and by the United States Agency for International Development (USAID), through the Transforming Energy Access (TEA) and Scaling Off-Grid Energy (SOGE) programmes respectively. One Challenge project was funded by Shell Foundation. The views expressed in this report do not necessarily reflect the UK or U.S. Government's official policies.

ACKNOWLEDGEMENTS

We are grateful to all the awardees for their commitment to improving e-waste management in the off-grid solar sector, and for their valuable contributions to the learnings shared in this report. The report was made possible through their thorough and thoughtful qualitative and quantitative feedback and data.

The report was authored by Hannah Blair and Monica Wambui (CLASP), Rebecca Rhodes (GOGLA) and Declan Murray (Independent). The authors are thankful to CLASP's Sam Grant and James Wakaba, as well as Drew Corbyn from GOGLA, for their invaluable guidance throughout the Challenge, and for taking the time to review the report and provide feedback.

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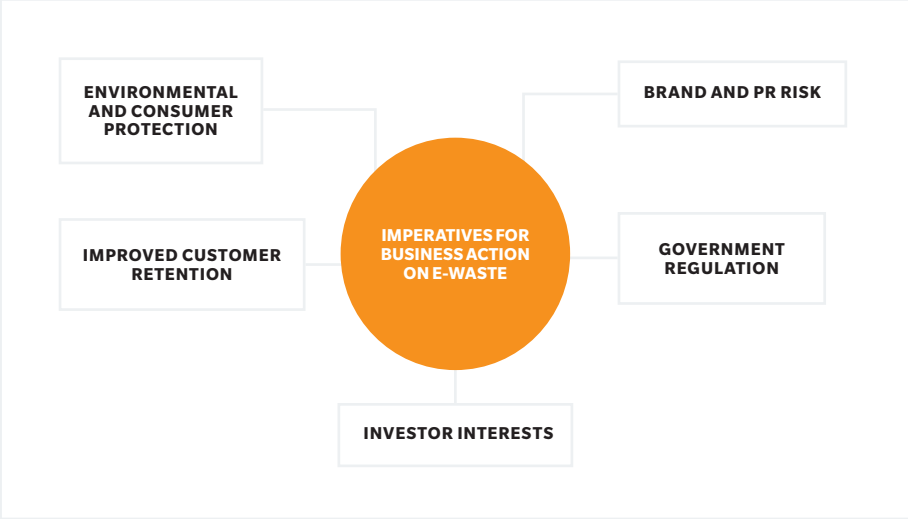
A repair technician in Choma District, Zambia. Credit: SunnyMoney/Courtney Paisley.
Photo Credit: SunnyMoney/Courtney Paisley

Introduction

Since 2010, an estimated 180 million off-grid solar products have been sold globally,[1] benefitting more than 420 million people today. During their useful lifespan, pico-solar products (PSPs), solar home systems (SHS) and solar-powered appliances reduce CO2 emissions and increase the quality of life for consumers and their households. Improvements in design and materials, as well as the widespread adoption of VeraSol quality standards, mean that the average lifespan of products is increasing; but every product, no matter how good, will eventually stop working.[2] If not properly managed, end-of-life (EoL) solar products can be damaging to both human health and the environment, and the growing volumes of improperly managed solar e-waste pose a reputational risk to off-grid solar companies and sector as a whole.[3]

Since GOGLA published its Industry Opinion on product lifecycle and recycling in 2014,[4] various studies by industry and academia[5] have provided insights into the nature of off-grid solar e-waste and explored strategies to effectively reduce and manage EoL products. There's no question that the imperatives for businesses to act on off-grid solar e-waste are growing. (see figure 1)

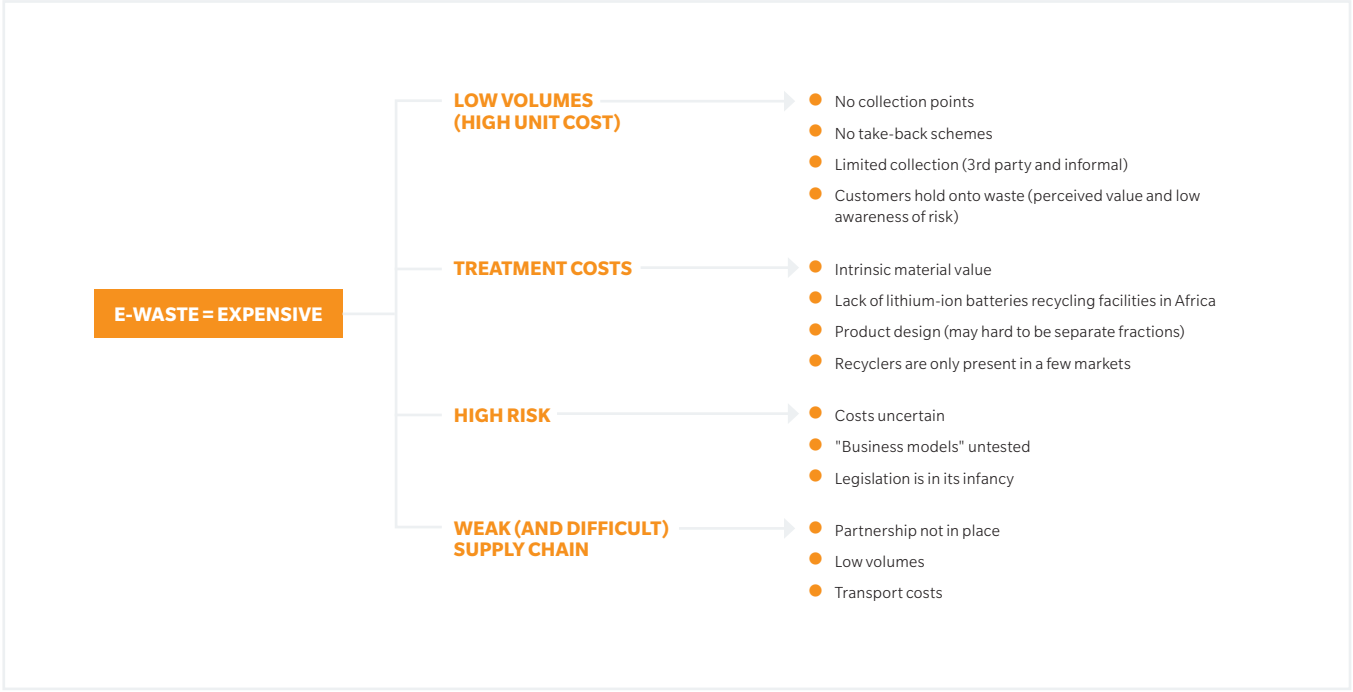
Figure 1: The imperatives for business action on e-waste. Adapted from GOGLA's E-waste Toolkit



However, there are considerable challenges when it comes to e-waste management. The off-grid solar industry is still relatively young. It serves markets with nascent or immature waste management infrastructure, where related legislation is in its infancy. Low volumes of collected e-waste and high treatment costs also make it difficult to implement effective e-waste management strategies. (see figure 2)

The Enviroserve Rwanda facility in Bugesera, Rwanda.

Figure 2: Challenges to E-Waste Management Initiatives



The Efficiency for Access Coalition launched the Global LEAP Solar E-Waste Challenge[6] in 2019 to catalyse the development of sustainable approaches to off-grid solar e-waste management. By addressing the barriers to effective management of off-grid solar e-waste,[7] the Challenge seeks to promote sustainable industry growth and enhance the sector's reputation as a leader in environmental responsibility.

"We understand that in order to operate sustainably, we must proactively take responsibility for all our e-waste and not just warranty returns. It is possible that e-waste collection is an opportunity to gain new customers and also provide high quality lighting that positively impacts lives." - Charlotte Heffer, Senior Partnerships Manager, d.light.

THE CHALLENGE

The first round of the Challenge[8] (supported by USAID, UK Aid and Shell Foundation) made US $1 million available in grants of up to US$200,000.

The grants were intended to support:

- Distributors of off-grid solar products seeking to pilot and implement end-of-life programmes; fill critical information and data gaps regarding end-of-life product management; and address key logistical challenges related to take-back and collection of off-grid solar e-waste.
- Recycling and e-waste management companies looking to expand business activities in the off-grid sector, and strengthen operational processes at e-waste processing facilities in order to increase solar e-waste recycling capacity across Sub-Saharan Africa.

The Challenge received 159 applications to implement projects in 49 countries across Sub-Saharan Africa.[9]

An expert panel of judges selected the winners based on criteria that included viability, potential impact and the capacity of the applicant. The winning projects – announced in May 2019 at the GOGLA Solar E-Waste Festival in Nairobi, Kenya – presented innovative ideas that not only met the Challenge objectives, but also harnessed partnerships with academia, local government and the informal sector to better understand regulatory environments and formulate clear plans for de-risking the wider sector.

The eight awardees included five off-grid solar distributors (d.light, ENGIE Energy Access, Solibrium, SunnyMoney and WeTu) and three recycling companies (Enviroserve, Hinckley Recycling and WEEE Centre) with projects in Kenya, Uganda, Rwanda, Zambia and Nigeria.

Figure 3: Solar E-Waste Challenge Cumulative Reach & Impact

TAKE-BACK & COLLECTION

251.6
TONNES OF OGS E-WASTE COLLECTED

415
NEW COLLECTION POINTS FOR OGS E-WASTE ESTABLISHED

$1.17
AVERAGE COST OF TAKE–BACK INCENTIVES

TREATMENT

72.5
TONNES OF OGS E-WASTE TREATED

$0.75/KG
AVERAGE COST OF TREATMENT

RECYCLING

30,000
TONNES OF ANNUAL RECYCLING CAPACITY

10
NEW RECYCLING MACHINES PROCURED AND INSTALLED

39
NEW E-WASTE MANAGEMENT TOOLS

$0.24/KG
AVERAGE RECYCLING REVENUE FROM OGS PRODUCT

SECOND-LIFE BATTERIES

30,000
LITHIUM BATTERY CELLS TESTED

UP TO 64%
LI BATTERIES TESTED FOUND TO BE USEABLE

01
DIAGNOSTIC AND REPAIR APP FOR ANDROID

245,981
LITHIUM BATTERIES COLLECTED

AWARENESS RAISING

6216
AWARENESS RAISING ACTIVITIES

6.7
MILLION PEOPLE REACHED THROUGH AWARENESS-RAISING CAMPAIGNS

JOBS & TRAINING

129
JOBS CREATED (INCLUDING 27 WOMEN)

328
TRAINED ON E–WASTE (INCLUDING 100 WOMEN)

GOOD PRACTICE IN E-WASTE MANAGEMENT FOR THE OFF-GRID SOLAR SECTOR

Over the course of the 12-month implementation period, the Challenge collected learnings from the eight projects as they addressed key constraints to off-grid solar e-waste management. However, due to the limited time frame and funding of the Challenge, there are many areas these projects didn't cover (such as company led repair and refurbishment), which require more in-depth investigation. By sharing the case studies, we hope to improve overall e-waste management in the sector. This report was intended for off-grid solar company staff with a role in developing and implementing e-waste strategies and operations, but the insights it contains are also relevant for e-waste service providers (such as recyclers), investors, sector support programmes and governments.

After sharing the highlights from each project, the report takes a closer look at four key themes: Awareness Raising and Incentivisation (page 25), Take-back and collection (page 35), Repair and refurbishment (page 44) and Recycling Infrastructure (page 51). Opportunities for engagement with informal sector stakeholders are highlighted in blue boxes after themes one, three and four.

COORDINATION ACROSS PROJECTS

Representatives from the Solar E-Waste Challenge winning projects at the GOGLA E-Waste Festival in Nairobi, July 2019

Effective collaboration and coordination on e-waste management across the sector will be instrumental in developing best practice, as well as replicating and scaling successful operations. To ensure that the Challenge would collect learnings for the benefit of the off-grid solar sector, the Challenge team developed a Learning and Coordination (L&C) framework. The L&C framework included extensive data collection,[10] product sampling, qualitative case studies and coordination meetings. Evaluating the data captured through the L&C framework helped to identify the key insights, lessons and good practice shared in this report.

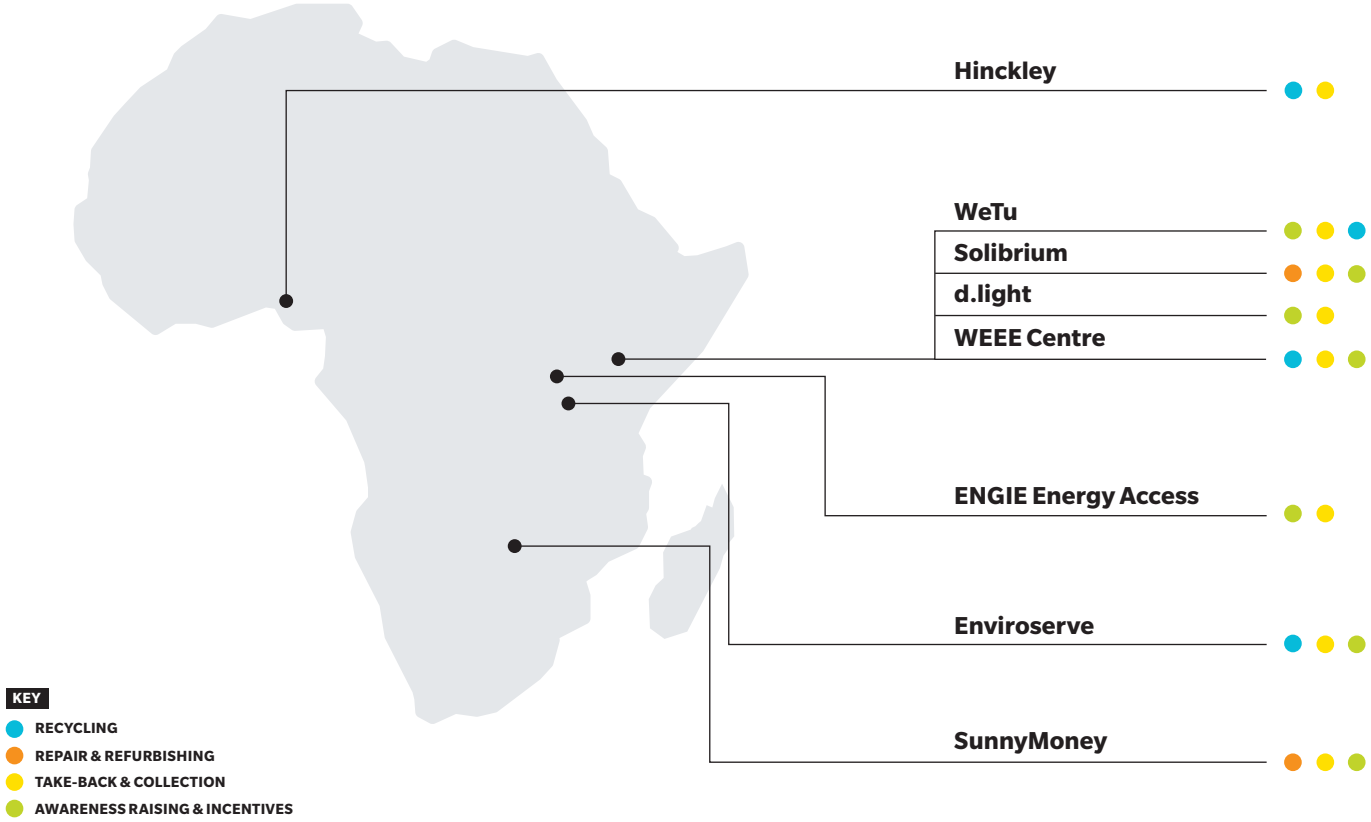
To support collaboration and identify areas in which coordination between projects could enhance outputs, the Awardees attended two in-person workshops (in November 2019 in Dakar, Senegal, and in February 2020 in Nairobi, Kenya), and joined virtual coordination calls in July and November 2020. The coordination calls allowed awardees to provide updates on their projects and, crucially, share any challenges they were facing or best practices they had adopted. Project leaders found that these calls helped them tackle unforeseen challenges and explore different approaches to topics such as consumer awareness raising, incentivisation and agent motivation. We hope that in the long term, other opportunities for sharing and collaboration within the industry, such as the GOGLA Circularity Working Group, can foster even greater innovations to help reduce and manage off-grid solar e-waste.

COVID-19

The novel Coronavirus caused both delays (in equipment purchases) and disruption (bans on travel and in-person interactions) to the Challenge projects. The Awardees adapted their project plans, adopted the necessary safety precautions and remained flexible throughout. Thanks to these efforts, the Challenge was able to conclude on schedule. More details on the effects of the pandemic on individual projects can be found throughout the report.

An informal sector worker disassembling a battery in Jinja, Uganda.

Figure 4: Solar E-Waste Challenge Awardee Locations



The Challenge Projects

In 2020, d.light achieved their longstanding goal of impacting 100,000,000 lives through off-grid solar lights.

They are now transitioning towards providing a wider array of sustainable products that will positively impact customers' quality of life, but they are also focusing on sustainable solar e-waste management.

During the Challenge, d.light piloted a take-back scheme in Kenya's Nyanza and Western Provinces. It included a marketing campaign offering discounts on new solar-lanterns in exchange for trade-ins of EoL solar products via d.light field agents and retail shops. By providing a significant discount on a quality-verified product, the company was also hoping to overcome negative perceptions some consumers might have following bad experiences with non-quality-verified products, thus enhancing the impact of off-grid solar.

d.light's project aimed to:

- **EDUCATE** companies and individuals on the benefits of proper disposal of e-waste
- **INCREASE** e-waste collection rates by developing a collection network covering the whole of Rwanda and providing access to neighbouring countries
- **DESIGN** a second life battery pack programme and collect data and insights on the reusability of battery packs, as well as exploring applications and business models for the new packs
- **INCREASE** the facility's institutional capacity by developing a software dashboard for logistical optimization and communication, and by procuring essential equipment to treat solar e-waste fractions

By the end of the project, d.light had established more than 200 collection points by leveraging their existing network of customer experience centres. They also found that reducing the incentive – offering a 100KES (US$1) discount on their entry-level A2 lantern rather than 50% off the more expensive S3 – did not deter consumers from using the take-back scheme, leading d.light to conclude that the primary motivating factor was how cheaply consumers could access a replacement solar product. Marketing-style radio advertisements were found to be the most effective way to raise awareness among consumers.

On the other hand, motivating staff and agents was a challenge since they were not initially incentivised for e-waste collection, either monetarily or via KPIs. They therefore tended to prioritise other duties, such as sales, over the take-back scheme. Ensuring that e-waste management responsibilities are adequately supported throughout the organisation was found to be key to success.

AT A GLANCE

PROJECT LOCATION

Kenya

ORGANISATION TYPE

OGS company

FOCUS

Take-back, awareness raising and incentivisation

388kg

OGS e-waste collected

222

collection points

5

jobs created

166

people trained

Enviroserve Rwanda is a waste management company dedicated to electronic and electrical waste recycling, green growth, and circular economy.

Apart from being one of the first in Africa to develop and adopt e-waste regulation, the Rwandan government has set a goal of reaching 48% of its population with off-grid energy solutions by 2024. Enviroserve works closely with both the government and the off-grid sector to achieve overall sustainable e-waste management.

During the Challenge, Enviroserve Rwanda developed a robust network of collection points in 18 districts and at strategic border points in order to access rural and hard-to-reach customers. The company also ran a nationwide awareness campaign to encourage businesses and consumers to dispose of EoL products at the collection points. As one of the few recyclers in the region, Enviroserve invested in new machinery to enhance the reuse, refurbishment and recycling capacity of off-grid solar products, as well as creating a digital tracking system.

Enviroserve Rwanda's project aimed to:

- **EDUCATE** companies and individuals on the benefits of proper disposal of e-waste
- **INCREASE** e-waste collection rates by developing a collection network covering the whole of Rwanda and providing access to neighbouring countries
- **DESIGN** a second life battery pack programme and collect data and insights on the reusability of battery packs, as well as exploring applications and business models for the new packs
- **INCREASE** the facility's institutional capacity by developing a software dashboard for logistical optimization and communication, and by procuring essential equipment to treat solar e-waste fractions

By the end of the project, Enviroserve Rwanda had collected approximately 86 tonnes of solar e-waste and treated about 80% of it. They reached over 66,000 people through awareness-raising activities including roadshows and held free e-waste disposal days for companies. Although the outbreak of the COVID-19 pandemic delayed procurement by nearly three months, the acquired equipment added a bulb eater, a cable stripping machine, battery testing equipment and a plastics recycler to their facility. Through their second life battery programme, the company tested over 3,000 battery cells (almost 50% were reusable), and produced 149 second life battery packs. Continued engagement with relevant government agencies was vital to the success of these activities.

AT A GLANCE

PROJECT LOCATION

Rwanda

ORGANISATION TYPE

Waste-management company

FOCUS

Collection, recycling and awareness raising

RESULTS

86,354kg

OGS e-waste collected

18

collection points

8

jobs created

120

people trained

As a pioneer of the PAYGo solar model in Sub-Saharan Africa, ENGIE Energy Access used the expertise they gained while operating as Fenix International in Uganda – as well as the country's dispersed rural customer base – to pilot an ambitious end-of-life lead acid battery collection pilot.

ENGIE Energy Access was created when French energy leader ENGIE integrated Fenix International, ENGIE Mobisol and ENGIE PowerCorner under one entity.

ENGIE Energy Access developed a comprehensive buy-back scheme to retrieve broken off-grid solar components (of any brand), along with off-grid solar lead acid batteries from the informal sector. They then worked to map out the informal sector landscape for EoL solar products.

ENGIE Energy Access' project aimed to:

- **INCREASE** awareness of the importance of proper e-waste management, not only for key industry stakeholders but also for end consumers through community-based education and outreach
- **IMPROVE** the solar industry overall by collecting 15 tonnes of generic solar e-waste and forwarding it on for safe recycling and disposal
- **DEVELOP** learnings to help the off-grid solar sector understand the generic solar industry, the potential scale of environmental harm if it is left unchecked, and possible solutions to the problem

By the end of the project, ENGIE Energy Access had surpassed their initial target and collected over 77 tonnes of generic solar e-waste, the largest category of which was batteries. But this represents just the tip of the e-waste heap, since the company learned that consumers store as much as 20kgs of e-waste in their houses. They piloted two buy-back prices, and found that a 16% price drop (3,000 UGX (US$0.86) to 2,500UGX (US$0.73)) resulted in a 79% (8,739kgs to 1,820kg) drop in the quantity of e-waste collected between the first two quarters. They also mapped out the hierarchical structure of scrap collectors within Uganda, and now believe sustainable e-waste management can be achieved through collaboration with industrial disposal companies handling large quantities of e-waste.

AT A GLANCE

PROJECT LOCATION
Uganda

ORGANISATION TYPE
OGS company

FOCUS
Collection and informal sector

RESULTS

77,982kg
OGS e-waste collected

8
collection points

2
jobs created

74
people trained

Hinckley Recycling is the first formally registered e-waste recycling facility in Nigeria.

The country suffers from acute electricity shortages, and the federal government would like to ensure that at least 20% of its energy is generated from renewable energy sources. As a part of this effort, Hinckley works closely with government agencies such as NESREA (National Environmental Standards and Regulations Enforcement Agency) and LASEPA (Lagos State Environmental Protection Agency), as well as informal scrap collector coalitions such as ECAN (E-waste Collectors Association of Nigeria) to create sustainable e-waste management pathways.

Hinckley Recycling obtained over 60 tonnes of lithium-ion batteries through partnerships with Lumos, an off-grid solar company in Nigeria. They developed a sorting, conditioning and reassembly process for battery cells from solar e-waste, and designed battery prototypes to evaluate the potential for diverting used cells into second life applications. They also invested in Africa's first lithium-ion battery recycling facility.

Hinckley's project aimed to:

- **SET UP** a complete battery testing and recycling facility
- **DEVELOP** a detailed sorting, conditioning and reassembly process for solar e-waste battery cells to allow for second life applications, and a manual for others to follow
- **DEVELOP** a second life battery prototype, begin manufacturing battery packs and establish a sales channel for reconstituted battery packs
- **RECYCLE** their first batch of lithium-ion batteries
- **ESTABLISH** partnerships with organizations that have advanced technology for treatment of problematic fractions

By the end of the project, Hinckley had tested over 6,000 battery cells and found that approximately 65% were reusable; in 2021 they aim to test nearly 25,000 more battery cells and perform field testing. Through their partnership with Carnegie Mellon University (CMU), they developed several applications for their battery packs, including Uninterruptible Power Supplies (UPS). Hinckley also purchased the first lithium-ion battery recycling equipment in Africa; this represents a profitable and sustainable solution for treating solar lithium-ion batteries, which, until now, have had to be shipped to Europe at considerable expense (figure 58).

Hinckley RECYCLING

AT A GLANCE

PROJECT LOCATION
Nigeria

ORGANISATION TYPE
Recycling company

FOCUS
Recycling, collection and second-life batteries

RESULTS

85,000kg
OGS e-waste collected

5
collection points

16
jobs created

18
people trained

Solibrium Solar, a registered B-Corp, brings affordable clean energy to underserved communities in Kakamega County, Western Kenya.

Because they are still a young PAYGo SHS distributor, most of their products have not yet reached EoL. But Solibrium is confident that forward planning and early investment in infrastructure can mitigate against future solar e-waste problems.

Solibrium aimed to address the lack of information on e-waste by developing a solar e-waste tracking tool to identify types, quantities and locations of EoL products, and mapping out the actors in the e-waste ecosystem in Kakamega County. Building partnerships with local stakeholders was key to Solibrium's project, which involved engaging local government and informal-sector players.

Solibrium's project aimed to:

- **RESEARCH** the use and prevalence of solar products, as well as the e-waste problem in Kakamega County
- **DEVELOP** a virtual and physical infrastructure to track solar e-waste
- **DEVELOP** and pilot a take-back/buy-back business model

By the end of the project, Solibrium had developed an e-waste tracking tool and used it to carry out data collection across the county. The results informed the design of a targeted SHS take-back and repair model that seeks to extend the lifespan of SHS and PSPs. Solibrium repaired and refurbished more than 300 SHS during the project, and sold repaired or refurbished components to the informal repair sector.

While gathering data on the informal collection and repair sector, the company relied heavily on the knowledge of local guides. This highlights the importance of building relationships and investing in stakeholder engagement in order to improve the management of solar e-waste.

They found very little awareness among consumers about expected SHS lifespans, product lifecycles and responsible disposal methods. Addressing these issues through customer education at point of sale could be one easy point of sector-wide action on e-waste.

SOLIBRIUM-SOLAR
Nuru Maishani

AT A GLANCE

PROJECT LOCATION
Kenya

ORGANISATION TYPE
OGS distributor

FOCUS
Take-back, repair and refurbishment

RESULTS

185kg
OGS e-waste collected

88
collection points

55
jobs created

55
people trained

After operating for more than a decade in Zambia, SolarAid's social enterprise SunnyMoney remains committed to providing solar lights to the most vulnerable communities.

Through the Challenge, SunnyMoney is building a solar product repair ecosystem in-country to support bottom-of-the-pyramid customers.

The company aimed to reduce e-waste by extending the lives of solar lights. They developed an innovative incentive scheme to encourage customers in rural Zambia to take back their EoL products, and conducted an awareness-raising campaign to inform people of these incentives and of the dangers of e-waste. The lights obtained through this take back informed the development of solar light repair guidance through a freely-available repair manual and mobile app.

SunnyMoney's project aimed to:

- **DEVELOP** an incentivized voucher scheme
- **DEVELOP** a customized app providing diagnostic procedures and repair guidance for six key SunnyMoney products
- **SET UP** and equip the repair centres, and train technicians on solar product repair

After twelve months, SunnyMoney had successfully launched the SunnyMoney Picosolar Repair Guide app (available on Android) for six common PSPs, along with a training manual to accompany the app. The company also trained their own staff and two accredited repair shops to enhance the availability of repair services for consumers with out-of-warranty products. In one survey, SunnyMoney learned that 100% of customers were willing to pay for a repair, and that they would pay up to 60% of the cost of a new product for a repaired or refurbished product.

SunnyMoney's take-back scheme consisted of an incentive (~20% discount voucher) and extensive awareness-raising activities to encourage customers to return faulty and EoL products to collection points. As this awareness raising was carried out by word-of-mouth, initial messaging was muddled and many customers arriving at take-back locations were confused by the collection scheme. But once there, SunnyMoney agents were able to explain both the programme and the risks of e-waste, indicating that getting customers to a collection point to talk in-person is best practice.

AT A GLANCE

PROJECT LOCATION
Zambia

ORGANISATION TYPE
OGS distributor

FOCUS
Take-back, repair and refurbishment, awareness raising and incentivisation

RESULTS

75kg
OGS e-waste collected

51
collection points

10
jobs created

28
people trained

1
new product diagnostics and guidance app

As one of the first formal recycling centres in East Africa, WEEE Centre in Nairobi is deeply committed to protecting consumers from the harmful effects of electronic waste.

They employ 600 people across Kenya and provide a growing range of recycling services.

For the Solar E-Waste Challenge, WEEE Centre focused on collection, refurbishment and recycling of off-grid solar products. They carried out a nationwide awareness campaign designed to increase public knowledge of the importance of solar e-waste recycling and existing e-waste collection points. The Challenge project created strong linkages with other companies in the region, strengthened their institutional capacity and supported youth agents across Kenya to collect end of life off-grid solar products.

WEEE Centre's project objectives included:

- **INCREASE** public awareness and stakeholder engagement on e-waste disposal and recycling.
- **EXPAND** the facility's processing capacity.
- **SUSTAIN** direct employment of 40 WEEE Centre employees and indirectly employ over 1,000 youth involved in collection, refurbishment and pre-processing of solar e-waste.
- **COLLECT** and sort batteries for upcycling .
- **DEVELOP** a partnership with a recycler for the safe disposal of collected items

By the end of the project WEEE Centre's consumer awareness-raising activities, broadcast on TV and radio, had reached more than 800,000 Kenyans with messaging on the dangers of e-waste and opportunities for collection. The company also established 13 new collection points across Kenya, operated by fully trained youth workers and supporting widespread e-waste collection across the country.

WEEE centre also procured equipment to improve their facilities for e-waste treatment, including a waste baler and plastic recycling machinery which will help deal with plastic casing of solar lanterns and SHS.

AT A GLANCE

PROJECT LOCATION

Kenya

ORGANISATION TYPE

Recycling company

FOCUS

Collection, recycling, awareness raising

RESULTS

1,990kg

OGS e-waste collected

13

collection points

10

new collection and recycling agreements

WeTu is a social enterprise founded by Siemens Stiftung to provide innovative solutions for energy and drinking water in communities around Lake Victoria.

They specialise in leasing solar lanterns to fishermen in lakeside areas. Through the Solar E-Waste Challenge, they conducted a consumer awareness-raising campaign and established six e-waste collection points, as well as a pre-processing plant in Western Kenya. The intent was to boost proper e-waste management practices by educating the community on the impacts of e-waste and encouraging customers to dispose of products at designated safe locations rather than discarding them in the lake or elsewhere in the community.

WeTu's project aimed to:

- **SENSITIZE** community members and stakeholders on the importance of returning e-waste, and incentivize them to do so.
- **ESTABLISH** collection points at each of their seven sales and distribution hubs.
- **DEVELOP** an e-waste pre-processing and dismantling plant at their biggest hub.

By the end of the project WeTu had established six collection points and a pre-processing plant. Their dedicated e-waste management team had also participated in in-depth trainings on e-waste management, and launched a digital e-waste management system. They found that in-depth employee training motivated the team to care about e-waste and prioritise the project.

One of the main components of WeTu's project was community sensitization. Through leaflets, plays, social media and radio, the team reached more than one million people in Western Kenya with education on the risks associated with e-waste. Targeted education was provided to community health workers and informal sector agents on responsible and safe e-waste management strategies. WeTu also piloted several incentive schemes including non-cash incentives, such as vouchers redeemable against drinking water or fishing lantern leasing to incentivize community members and a cash-based program for the informal sector. Consumers were found to collect vouchers to increase their value before redeeming.

AT A GLANCE

PROJECT LOCATION

Kenya

ORGANISATION TYPE

OGS company

FOCUS

Take-back and collection, recycling

RESULTS

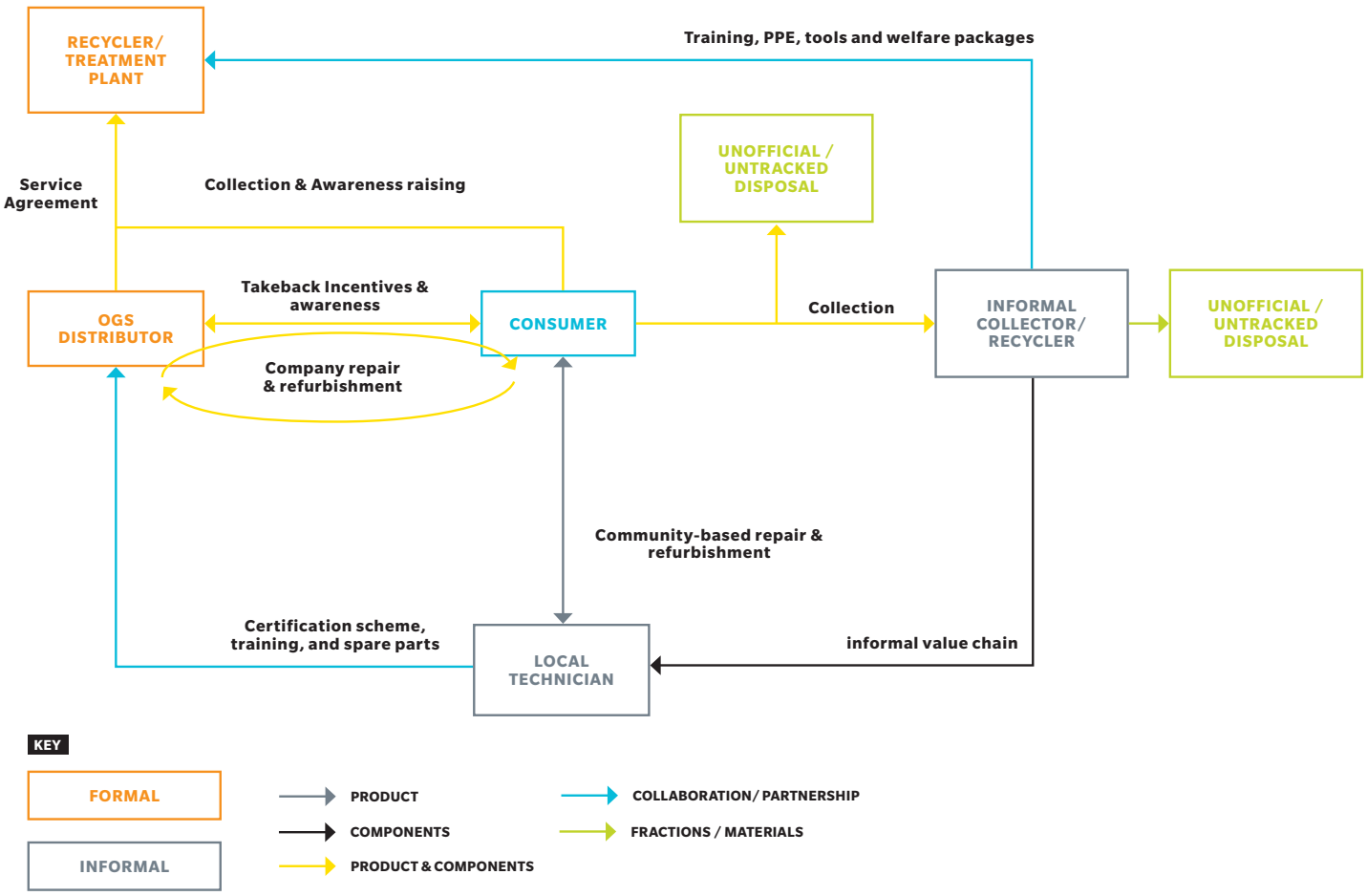
185kg
OGS e-waste collected

6
collection points

7
jobs created

48
people trained

Figure 5: The off-grid solar e-waste ecosystem, as experienced by the Global LEAP projects



Insights & Learnings

Good Practice for Off-Grid Solar E-Waste Management

SunnyMoney solar light user in Southern Zambia.

Photo Credit: SunnyMoney/Patrick Bentley

1

Improving Access to Waste: Awareness Raising & Incentivisation

Procuring end-of-life e-waste products from consumers is one of the primary challenges for e-waste management in the sector. For off-grid solar products – as with all consumer electronics – the journey from consumption to disposal is complex. It can include periods of repair, reuse and repurposing, as well as "hibernation" during which a broken product is stored at home.[11] Consumers are often unaware of the value of and risks posed by e-waste products at end-of-life, or the recommended means of disposal. They also tend to develop an emotional attachment to objects that enter their homes and enrich their lives.

The success of any take-back scheme depends on building consumer awareness of the initiative, as well as incentivising consumers to relinquish these waste products. The key to a sustainable business model is doing this in a cost-effective way that adds value for the company.

1.1 CONSUMER AWARENESS RAISING

HIGHLIGHTS

- Activities undertaken by Challenge projects are estimated to have **reached more than six million people.**
- Methods of communication included **word of mouth, SMS and social media, radio and TV campaigns, leaflets and roadshows.**

RECOMMMENDATIONS

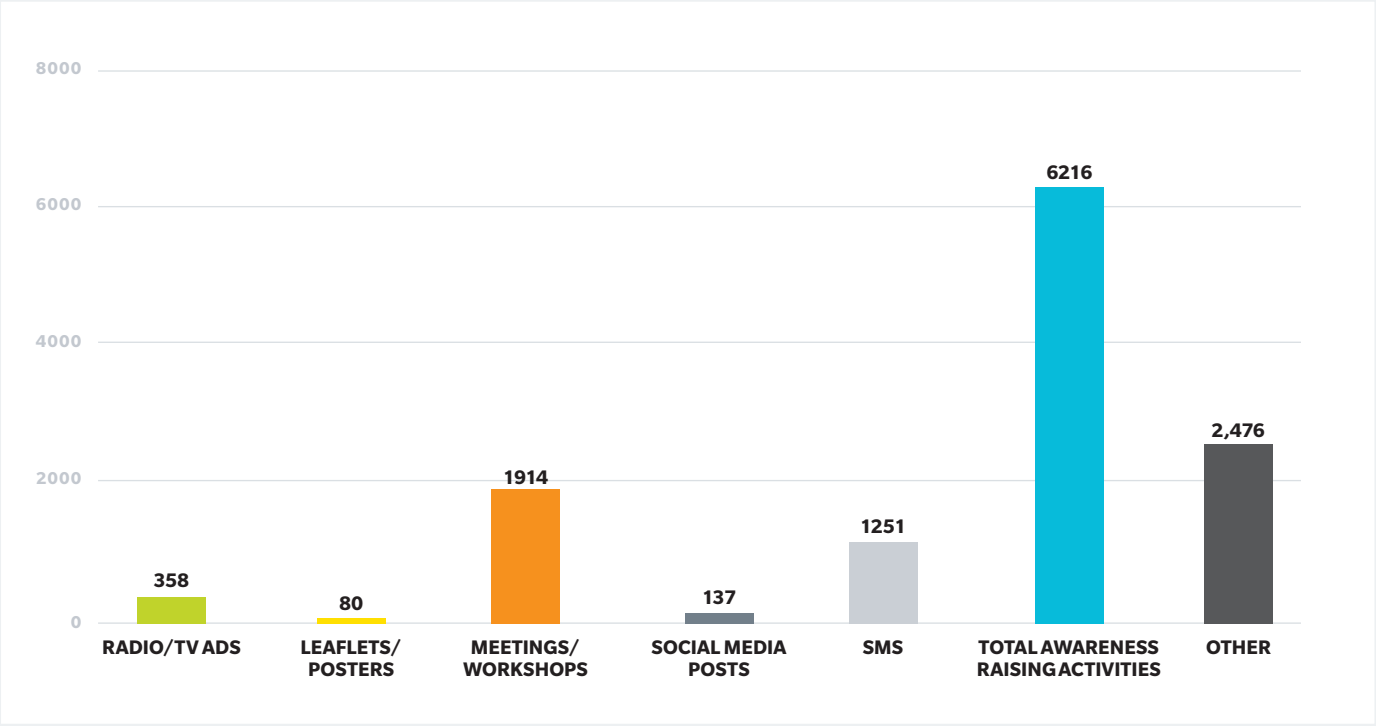
- **Integrate e-waste consumer awareness raising activities into existing communications channels.** Companies should consider which existing networks and channels could support messaging on e-waste take-back and collection schemes. For example, companies using a community-based sales model could train sales agents on e-waste messaging, while companies promoting sales through radio advertisements could use this channel for e-waste related content.
- **E-waste communications campaigns are as nuanced and varied as their target markets.** Each of the eight projects were implemented in vastly different markets, cultures and locations. The success of a campaign in one location does not guarantee that the same campaign would work in another county, region or country.

- **Take-back schemes provide an additional customer touchpoint** that can support customer retention, help acquire new customers and strengthen brand recognition in the target market. Integrating e-waste messaging into wider communications strategy can therefore add value for a company, as well as mitigating against the cost of e-waste.
- **If seeking new communications channels or promoting e-waste management in new markets, conduct a market assessment prior to launching a campaign.** This allows companies to target resources towards channels that will yield the greatest benefits. A market assessment should also establish the level of stakeholder understanding and awareness of e-waste. Do not make assumptions about what consumers do and do not know.
- **Ask customers returning products how they heard about the take-back or incentive scheme.** This feedback allows companies to better target their communications efforts.

Lack of awareness of the hazards of e-waste and proper disposal mechanisms presents a huge barrier to solar e-waste management across the continent. Data from the eight Challenge projects suggest that knowledge levels regarding optimal product use and disposal, as well as concerns around e-waste, are highly varied among consumers, local authorities and repair technicians. Awardees piloted awareness campaigns aimed at educating different solar stakeholders on the risks of improper disposal, and used communications to encourage people to return faulty or end-of-life products to designated collection centres. The companies tested outreach through radio and television advertisements, mobile messaging, roadshows, field agents and even community theatre.

Over the course of the Solar E-Waste Challenge, awardees undertook a total of 6,216 awareness-raising activities that reached 6,787,460 solar e-waste stakeholders and consumers.

Figure 6: Solar E-Waste Challenge Awardee Awareness Raising Activities



Education begins at the point of sale

Poor user education on proper solar product maintenance can contribute to the premature failure of products and an associated increase in e-waste volumes. To inform the design of their take-back scheme in Western Kenya, Solibrium tracked data on daily household use and charging patterns in order to estimate battery life expectancy. They found that most households were reducing the battery life of their products much faster than designated warranty durations. This suggests that greater efforts are required at point of sale and during installation to educate customers on recommended usage and maintenance that will improve a product's performance and extend its lifespan. This includes how to clean the panel, best charging practices, and troubleshooting with the help of user manuals and call centres.

Solibrium recommends education programmes that stress moderate use and proper charging.

Methods of communication can be varied and context-specific

Awardees piloted a range of awareness campaigns across the five Solar E-Waste Challenge implementation countries. Because the continent hosts such demographically diverse populations, communications campaigns are not one-size-fits-all. Even within the same country, methods that worked well in one region may not be as successful in a neighbouring region.

For example, many companies marketed their e-waste collection schemes and incentives via radio advertisements. At collection points, agents would ask consumers how they heard about the project. **Enviroserve Rwanda, d.light** and **WeTu** found that many consumers had heard about it over the radio. But in Zambia, **SunnyMoney** found that none of their customers had learned about the take-back scheme through radio adverts; instead, they had learned about it through talking to teachers and other community members. Piloting various forms of advertising and asking consumers how they heard about the scheme can help solar e-waste stakeholders identify the most high-impact, context-specific communications methods.

THE AWARENESS-RAISING ACTIVITIES CARRIED OUT BY THE AWARDEES ARE OUTLINED BELOW:

Kisii FM radio presenter mentioning d.light's e-waste take-back scheme.

RADIO

WeTu piloted messaging on Radio Lake Victoria, a popular station in Western Kenya that mainly broadcasts news in Luo (the local language). WeTu organized an e-waste theme day on the station, mentioning WeTu's e-waste services three times per day. Also in Kenya, **d.light** conducted regional radio campaigns with widespread success. In one survey, the company found that more than 76% of customers returning products from Kisii and Nyamira countries had heard about the promotion through Kisii FM radio. This suggests that in Kenya, radio is highly influential in reaching customers and creating awareness. **Enviroserve** also conducted advertisements across radio platforms, including Rwanda Broadcasting Agency (RBA) Radio, on e-waste management best practices and collection centre locations.

PRINT MEDIA

Enviroserve established a relationship with the Rwanda Environmental Journalists Association (RNEJ) to publish over ten articles in print and online media. Several of the companies that signed up to work with Enviroserve learned about their solar e-waste collection services through print and digital media placements.

COMMUNITY HEALTH WORKERS

WeTu trained Community Health Volunteers and Public Health Officers to conduct household visits and integrate information on e-waste into general education on community health and wellbeing.

SMS

Existing **WeTu** clients were sensitized on existing e-waste management services through bulk text messages (at 2 KES/ $0.02 USD per message). The team found that bulk SMS was the most effective followed by radio, sensitization by the Community Health Volunteers and personal referrals. While WeTu could not concretely link the volumes collected to the method, customers coming to the hub quoted they heard about the general hazards of e-waste through radio. From a mini-survey done in September 2020, about 18% of respondents brought in e-waste because of SMS. **SunnyMoney** also sent bulk SMSs to customers and used telephone calls with teachers and community leaders to discuss take-back.

SOCIAL MEDIA

Because of COVID-19, many companies pivoted their awareness campaigns to digital platforms. **WeTu** and **Enviroserve** shared regular posts on Facebook and Twitter informing the general public about e-waste management best practices.

Enviroserve Rwanda advertising radio appearances on their Twitter account

Enviroserve Rwanda @EnviroserveRw · Oct 26, 2020
Tubararikiye gukurikira ikiganiro #Imboni kuri @RwandaTV kuva saa 9-10pm kigamije kw'ibutsa abanyarwanda imicungire myiza y'ibisigazwa bikomoka kw'ikoranabuhanga (e-waste) mu Rwanda.
@peterkagabo
1 3 9

Enviroserve Rwanda @EnviroserveRw · Oct 26, 2020
Ikiganiro kiritabirwa na Enviroserve Rwanda ihagarariwe n'umuyobozi wayo @MberaOliver ndetse nabafatanyabikorwa bayo aribo @RURA_RWANDA ihagarariwe na Charles Gahungu ushinzwe ikoranabuhanga na @REMA_Rwanda ihagarariwe na Twiringire Samson. Turengere ibidukikije n'ubuzima bwacu.
1 4

IN-PERSON MEETINGS

Awardees targeted specific demographic groups through in-person meetings. **WeTu** conducted meetings with county governments, local Beach Management Units and boda boda (moto-transport) associations. **Enviroserve** targeted local authorities and repair technicians, citing their involvement as key to a smooth and successful campaign.

TRAININGS

Enviroserve trained 60 technicians in Rwanda's Southern and Eastern Province on e-waste awareness. Educating frontline workers is a critical component of awareness raising, since they are often the first contact for consumers dealing with faulty products. **WeTu** reported that some of their staff was initially reluctant to support the Solar E-Waste Challenge project as there was widespread belief that e-waste was trash, and therefore dirty. However, after two trainings in Western Kenya for all WeTu staff, most better understood the project, were excited by it and asked to join the project.

E-WASTE DAYS

Enviroserve organized large-scale free e-waste collection days to encourage consumers to visit their new collection centres and head office in Kigali. These events were organized in collaboration with different organizations, including solar distributors and the relevant regulatory agencies. Partnership is key to a successful event.

TELEVISION

Media involvement is critical to public awareness. **Enviroserve** appeared on six talk shows across different broadcast media platforms, and observed considerable interest in e-waste management during the shows. **ENGIE Energy Access** considered options to appear on TV talk shows but this did not come to fruition.

Messaging strategies

Succinct and deliberate messaging is critical to successful awareness raising. OGS companies and recyclers should first determine what will motivate consumers to return EoL products, and establish a concrete understanding of consumers' perspectives and knowledge of e-waste. This can be done through a baseline survey or market assessment.

The Challenge projects let their project objectives and market contexts determine their messaging strategies. **d.light** considered the following questions while designing their awareness-raising campaign:

- What will motivate customers to return a broken product?
- Will customers recognise the term e-waste? How and when should it be used?
- How to convey the message – verbally, pictorially or through text?

d.light's campaign ultimately focused its message on promoting the discount incentive. It used the campaign as a marketing tool, combining posters, radio campaigns and word-of-mouth through sales agents.

Evaluating consumer barriers to relinquishing solar e-waste (figure 7) is a useful place to start when designing a consumer awareness campaign. Messaging should address these barriers.

Figure 7: Barriers to relinquish solar products at end-of-life

SOURCE, GOGLA E-WASTE TOOLKIT

Message content

The Challenge projects largely focused their messaging on

1. The promotion of incentives and take-back schemes, and
2. The risks to environmental and human health of improperly disposing of e-waste.

Companies looking to implement similar consumer awareness campaigns should align their messaging to their own motivations and broader take-back scheme design. For example, if utilising marketing budget and activities, then a focus on the return of an old product in exchange for money off a new one would be well suited. If messaging focuses on the risks to the environment or human health, companies and recyclers should ensure that information provided is accurate, does not overstate the hazards and will not deter consumers from using OGS products in the first place.

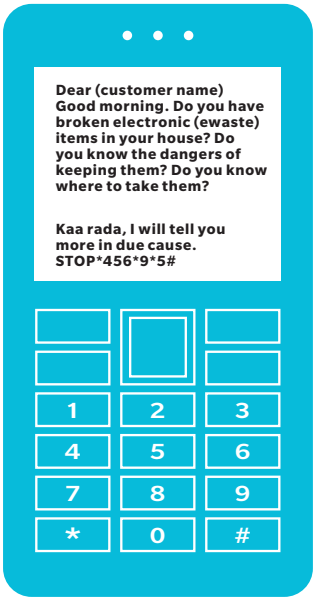
A d.light advertisement for their take-back and incentive scheme. 'Has your solar product gotten old and stopped working? Don't worry. Bring it to d.light and get a 50% discount on a new S3 light.

Clarity of message

It is important that messaging is simple, clear and available in local dialects wherever possible. Written messaging, in posters and leaflets, works well when supported with clear visuals, and verbal messaging should be simple and concise.

In Zambia, **SunnyMoney** offered vouchers to customers who returned their end-of-life products. They used verbal messaging via field agents, headmasters, teachers and students to promote the take-back scheme to their primary customer - parents. But by the time news of the incentive scheme reached the parents, the message had lost its clarity and there were some misunderstandings. Many customers indicated that they first wanted the programme explained face-to-face before surrendering their lights, since the concept was new and they needed to fully understand the process. Even many of those who correctly understood the take-back scheme came to the drop-off points without their products.

Consumer responsiveness was lower than anticipated. To address this challenge, SunnyMoney launched radio advertisements that provided clear messaging around the take-back process. However, in questionnaires at drop-off points, not a single customer said they had heard about the scheme on the radio; instead, they learned about it through SunnyMoney, the school or students. In Zambia, best practice was to encourage consumers to come in-person to collection sites where they can receive more information from agents.



SMS sent to WeTu customers

Consumer awareness raising is not always enough

Despite significant consumer awareness raising efforts, volumes of returned e-waste from consumers remained lower than expected. Awareness of disposal options and of the risks of e-waste were often not enough for consumers and other stakeholders to return faulty or EoL products to collection centres. **Incentives** were the real driving factor.

Nevertheless, getting the messaging right is key to a successful take-back campaign. In providing an additional customer touchpoint, these schemes can support customer retention and the acquisition of new customers, as well as strengthening brand recognition in the target market. Integrating messaging and communication about e-waste and take-back schemes into a company's wider communication strategy (using the existing marketing budget) can build value for the company and mitigate against the cost of e-waste management.

Solar companies disposing solar e-waste products like batteries, panels and solar lamps at Enviroserve Gikondo HQ Facility in Rwanda

Photo Credit: Enviroserve Rwanda

Steven Agola, WeTu Operations Manager, holding a solar lamp in Mbita, Kenya

1.2 INCENTIVISING CONSUMERS TO GIVE UP SOLAR E-WASTE

HIGHLIGHTS

- **Average cost of incentive for returned EoL products was US$1.17.** This excludes Solibirum, whose average incentive was US$34 due to their focus on higher value SHS.
- **Vouchers offering discounts against new products were the most common incentive,** followed by cash and merchandise. Vouchers have the benefit of encouraging consumers to buy a quality verified replacement and avoid returning to traditional, polluting energy types.

RECOMMMENDATIONS

- **Pilot different types and values of incentives to identify the most sustainable and effective option in terms of number/amount of products returned.** Many of the projects piloted different types of incentives (cash, discounts and vouchers) to identify which yielded the best response from consumers.
- **Give vouchers long redemption periods to account for seasonal incomes** and ensure consumers can use the vouchers when it suits them best.
- **Wait until the customer is willing to give up a product for free rather than try to buy it when there is still a perceived value.** Customers are hesitant to relinquish products with perceived value. Build this "hibernation period" into waste forecasts, expectations and messaging.
- **Incentivize staff.** Staff members, particularly field agents, were often unwilling to participate in e-waste collection activities without incentives.

Consumers often expect to receive financial incentives to give up or return broken products – this is especially true for products of high sentimental or monetary value. Awardees piloted cash, voucher and merchandise incentives, and found that successful incentives must meet three basic criteria:

- **They must be effective.** An effective incentive is one that motivates customers to bring their faulty or EoL products to a collection point.
- **They must be useful.** A useful incentive offers a tangible benefit to customers (such as a replacement product or discount voucher).
- **They must be sustainable.** A sustainable incentive can be implemented beyond the life of the pilot, and will not affect the affordability of new products offered by the company.

Consumer incentives: discounts, vouchers and merchandise

Several of the awardees piloted vouchers or discounts on replacement products when customers returned faulty or EoL solar systems or lights.

In Western Kenya, **WeTu** piloted a scheme offering one of three incentives that could be redeemed with a range of points correlating with returned e-waste (3 points per kg e-waste handed in). WeTu tested the following incentives:

Table 1: WeTu's point-based incentive scheme

WATER		
	20 litres (one jerrycan) of water	3 points
	Water token (pre-loaded with 100 KES)	60 points
	Water credit loaded to token (3kshs)	1 point
	WeTu branded new disinfected jerry can	60 points
AIRTIME		
	Bamba 10	3 points
	Bamba 20	6 points
MERCHANDISE		
	Branded pen	3 points
	T-Shirt	80 points
FISHING LANTERN		
	One day lamp charging lease	22 points
	Deposit for fishing lantern lease	300 points

Merchandise was geared around the needs of the fishing community and available WeTu products, clean drinking water from water ATMs and fishing lantern lease. Of the various incentives, it was difficult to evaluate which was most successful as most clients decided to save their waste points to redeem at a later stage, which might indicate that the higher quality incentives are more attractive.

WeTu water ATM. Credit: Tilmann Straub.

The incentives piloted by WeTu were mostly oriented towards fishermen. Although they and members of Beach Management Units showed an interest in the e-waste take-back program, few lead acid batteries were handed in. For this reason, WeTu will continue to trial different types of incentives in 2021, expanding their focus to include women and families.

Also in Kenya, **d.light** rolled out a "100 bob" promotion, offering the A2 light at a discounted rate of 100 KES (or US$1.00) in exchange for broken or non-functioning solar products. To market the promotion, d.light used radio campaigns and word of mouth. The company received positive feedback on the new product incentive, and saw an increase in the number of collections following the A2 light promotion.

d.light customer turning in e-waste in exchange for the 100 bob promotion.

Similarly, **Solibrium** offered a discount of 5,000 KES ($45 USD) on a new solar home system or component in exchange for a larger EoL solar home system, such as a TV kit, that retailed between 65,000- 99,500 KES ($600-900 USD). They also offered cash for returned components, basing the amount on the technical team's determination of its value. Both incentives worked well, though the majority of users opted for the discount. Consumers still needed an energy source, so they used the discount to select a newer version of their old system or to upgrade their system entirely.

In Zambia, **SunnyMoney** ran a pilot where they offered a test group a financial incentive for a returned e-waste product and a control group that received no incentive. The test group was offered vouchers worth 15 Kwacha (US $0.75) for smaller products that retailed between 60-110 Kwacha (US$3.30 - $6.00). They also offered a 30 Kwacha (US$1.50) for larger items that retailed between 350-450 Kwacha (US$19 - $25). Taking into consideration the fact that many consumers rely on seasonal income, vouchers could be redeemed any time within a six-month period. With the discount applied, the price of the products was reduced to the point at which SunnyMoney could not make a profit, but did not incur a loss.

Hinckley operated a buy-back scheme at collection points available to consumers, businesses and informal sector collectors. The financial incentives offered were based on component type and dependent on volume. In order of the volumes collected of each, the incentives were:

1. Solar panels (US$0.50 to US$1.00)
2. Small complete solar systems (solar lamps) (US$1.00 to US$3.50)
3. Solar system batteries (lead acid and lithium-ion) (US$0.10 to US$5.00)
4. Larger complete solar systems (US$10.00 to US$30.00)

The next steps for Hinckley are to determine an incentive level that increases the number of transactions with the informal sector, and to implement a marketing programme to raise awareness of collection centres.

Overcoming reluctance to part with e-waste

SunnyMoney found that some customers were unwilling to surrender their lights, claiming the value of the voucher was lower than that of their non-functioning product. In surveys, many people felt that their non-functioning light was worth an average of 50 kwacha (anywhere between 20-60% of the cost of a new product). But the voucher only provides a 15-30 Kwacha discount (5-22%). Further research into the resale value of old electronics in Zambia's Southern Province found that an informal market exists for the purchase and sale of old/non-functioning electronic products such as mobile phones and televisions, where resale values are high. Given this, the vouchers may not be sufficient for people to give up their products.

In the district where SunnyMoney offered no voucher, only five products were collected during the first visit, compared to 25-35 products collected in other areas. **People were much less willing to participate when no voucher was provided and were highly suspicious that they were giving away something that someone else would profit from.** Those who did relinquish their lights only did so when the coordinator opened the product and showed them where it was broken. When several customers returned home without giving away their non-functioning lights, the company decided to offer vouchers in all districts.

SunnyMoney found that the condition of the lighting product matters. Those returning very old, well-used products tended to be happy with the performance of their products and accepted to exchange them for a voucher. Those who had tried to repair them also accepted that their lights had exhausted their value. But customers with newer lights in fairly good visual condition were more reluctant. They believed more strongly in repair, and felt that their lights had greater value.

Incentives for staff and agents

WeTu and d.light received fewer returns than expected; both companies attribute this to the fact that they needed to incentivize field staff with commissions on returned materials. **d.light** found that sales commissions were insufficient motivation for staff to participate in e-waste take-back and collection. Providing financial incentives and incorporating targets into KPIs for management staff is also a good means to ensure that the team is participating in e-waste processes and increasing the number of take-backs.

Additionally, d.light found it was important to actively involve local management in e-waste efforts, including monitoring collections, filling forms and supporting reverse logistics. Hiring a local team member to focus solely on e-waste in each region proved effective in making e-waste a priority in dispersed sales/collection centres.

Solibrium used their field agents for collection, which resulted in a successful take-back scheme. The team noted that because sales agents are members of the community who understand the rural market terrain and landscape, the relationships and trust they have established allowed them to collect materials during home visits. This model also turned out to be more efficient than the others; since clients did not need to travel to Solibrium offices to return obsolete components, they incurred no transportation costs.

E-waste collected through SunnyMoney's take-back pilot.
Photo Credit: SunnyMoney/Courtney Paisley

Olivier Mbera, General Manager of Enviroserve Rwanda and Monica Wambui of CLASP at the Enviroserve facility in Bugesera, Rwanda.

2

Designing Effective Take-Back & Collection Operations

HIGHLIGHTS

- The amount of off-grid solar e-waste collected was **251.6 tonnes** - 78.8 tonnes from OGS companies and 172.8 tonnes through recycler collection.
- The set up cost of a collection point ranged from **US$20 to US$2,000** depending on the design. Operating expenses varied depending on whether a collection point utilised existing staffing and facilities or required dedicated resources.
- Solibrium developed an e-waste mapping tool to support planning and forecasting for collection points and reverse logistics.

RECOMMMENDATIONS

- **Collection points should leverage existing infrastructure for maximum impact at low cost.** OGS companies often have extensive distribution networks that can be utilised in any take-back scheme. Collection points can easily be added to shops or service centres, and for those willing to invest the time to establish effective relationships, using local repair shops and community centres such as schools can also increase the volume of waste collected. However, recyclers targeting much bigger quantities of solar e-waste (along with other household electronics) benefit from building dedicated collection points in targeted locations.
- **Where possible, take-back schemes should be brand agnostic to recover as much OGS e-waste as possible from consumers.** Although this increases disposal and treatment costs for companies, there are still advantages to this. They include strengthening a company or brand's reputation, and attracting new customers through incentives to purchase new, quality-verified products.

Each of the eight Challenge projects involved the take-back or collection of off-grid solar waste. Table 2[12] provides an overview of three different models available to OGS companies and recyclers.

Table 2: Take-Back and Collection Models from GOGLA's E-Waste Toolkit

TAKE-BACK SCHEME
An initiative organized by a manufacturer or distributer to collect used, end of life products or components from consumers to either a) reintroduce them to the market through repair and refurbishment or b) ensure that they are safely and appropriately recycled or disposed of.
THIRD PARTY COLLECTION
An activity to collect and process e-waste carried out by a third party such as national WEEE recycling facility, or a Producer Responsibility Organisation (PRO) acting on behalf of the original equipment manufacturer. Retail outlets, filling stations or government agencies' buildings are also possible options for collection.
INFORMAL SECTOR
Covers many different type of actors including informal repair shops (often known as a 'fundi'), recyclers, or collectors to cover an entire informal waste-management process. E-waste in this stream often ends up either in informal land-fill, or being burnt so that components can be extracted—posing risks to both the environment and health of those involved.

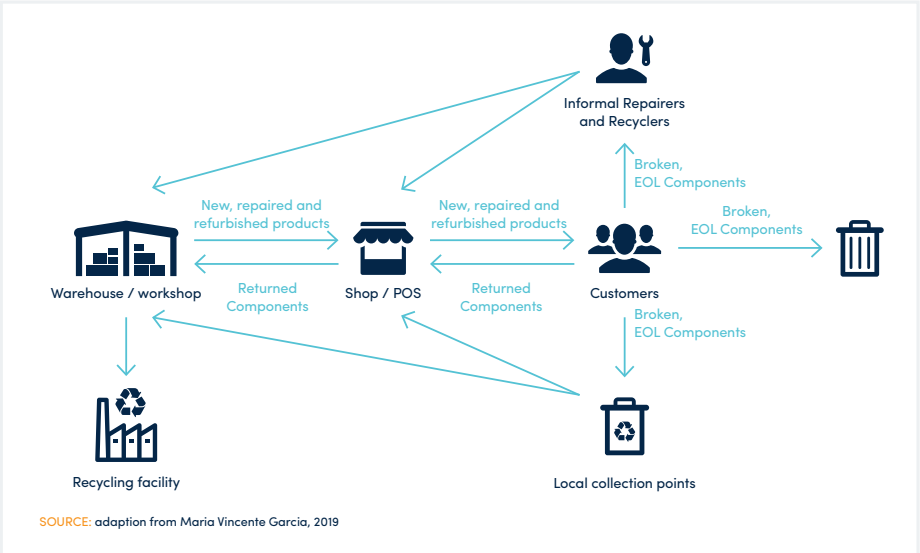
Many off-grid solar companies have well-established operations and reverse logistics for dealing with in-warranty breakdowns, repairs and replacements. However, few have expanded these to manage end-of-life, out-of-warranty products. For recyclers, building infrastructure for the widespread collection of e-waste is essential to enabling better management of e-waste in the off-grid solar sector.

The operational design and logistics of any take-back and collection scheme is highly dependent on context, and each of the Challenge awardees took a different approach. Cumulatively, the eight projects collected **251,629kg** of solar-e-waste, though on an individual level this ranged from 75kg to 86,000kg. These projects bring to light a number of operational considerations for OGS companies and recyclers planning take-back and collection schemes, including geographical mapping to inform collection point locations, reverse logistics, training staff and utilising existing informal collection networks.

Table 3: Factors to Consider When Developing a Take-Back Scheme from GOGLA's E-Waste Toolkit

WHY RECEIVING?	WHY RETURNING?	WHAT?	HOW?	WHO?
• Warranty process • Customer retention / as sales tool • Environmental and social risk management • Compliance with EPR legislation • Investor incentivisation	• In-Warranty • Upgrading product • Incentivisation • Education or Awareness campaign	• Faulty Product • End-of-life Product • Complete or incomplete system • Own brand or any brand	• Agent pick-up • Point of Sale Drop-off • Third Party collection point • Via informal collectors • Swap, repair or dispose	• Customer (old or new) • Agents and technicians • Third party recycling facilities • Community organisations • Informal collectors, repairers and 'recyclers'

Figure 8. SHS Distribution Cycle With Reverse Logistics



SOURCE: adaption from Maria Vincente Garcia, 2019

MAPPING THE E-WASTE ECOSYSTEM

Companies and recyclers seeking to enhance take-back and collection may benefit from first evaluating the local e-waste ecosystem. This can help in planning reverse logistics and forecasting the capacity needs of collection points.

Having identified that take-back schemes in the off-grid solar sector suffer from an information gap, **Solibrium** undertook a county-wide mapping exercise to inform the design of their take-back scheme in Kakamega County, Kenya. They carried out a survey to understand the **prevalence and distribution of obsolete solar kits** across the region, as well as identifying sales agents and distribution centres that could form part of their reverse logistics network. This mapping also helped identify areas where the informal sector was most active, and **where collection points could be established to leverage the existing network of informal e-waste collectors** (figure 9). Due to the prevalence and wide distribution of repair shops, this is a realistic opportunity that OGS companies could consider.

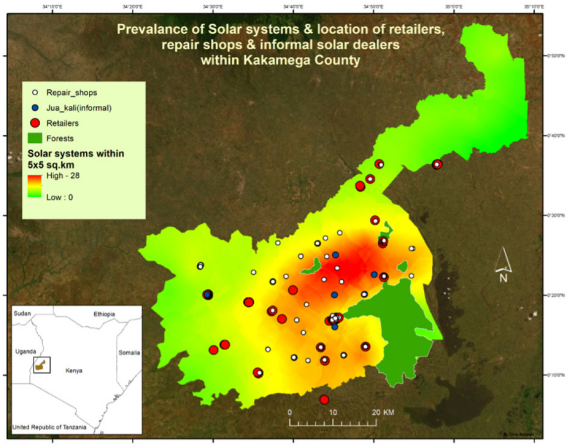
Many OGS companies lose touch with their customers after the sale (for cash purchases) or completion of the payment period (for PAYGo purchases). As a result, Solibrium found that it was difficult to locate EoL solar products in the region. The survey results enabled them to fill the information gap and plan effective customer education campaigns, collection points and reverse logistics.

Off-grid solar companies can fill their own information gaps by ensuring that basic customer data is collected during every sale (for example, each customer's village/district), and using service offerings like extended warranties to foster long-term customer engagement.

Operating as they do outside of formal distribution networks, informal repairers and refuse collectors may prove to be a **valuable source of knowledge about local e-waste ecosystems.** But because they are often poorly branded and located far from main thoroughfares, they may also be difficult to locate; **Solibrium** had to rely on local guides to help with their survey. In Zambia, **SunnyMoney** also found that unless they spent considerable time building relationships on the ground, local repairers were often unwilling to engage with them or share information. The same was true in Uganda, where **ENGIE Energy Access** relied on the information gathered by local sales agents to better understand the informal markets for end-of-life batteries and other types of solar e-waste. This information was useful in evaluating the EoL ecosystem, and enabled the project to identify where in the value chain their activities would be most effective.

However, this type of research comes at a cost. For some companies this is a barrier to exploring and de-risking possible commercial opportunities in collaboration with local actors.

Figure 9: Mapping the prevalence of OGS consumers, dealers and repair shops in Kakamega County, Kenya.



SOURCE, SOLIBRIUM

An informal repair shop SunnyMoney partnered with for more formal repair services of branded products.

FORECASTING FUTURE E-WASTE

In addition to mapping the distribution and prevalence of solar products, **Solibrium** also modelled the projected solar e-waste burden over time in order to plan for the capacity needs of collection points for their operations in Kakamega County. To do this, they used three possible sales growth rates for the period 2020-2029 and combined with expected product lifespan and repair cycle.

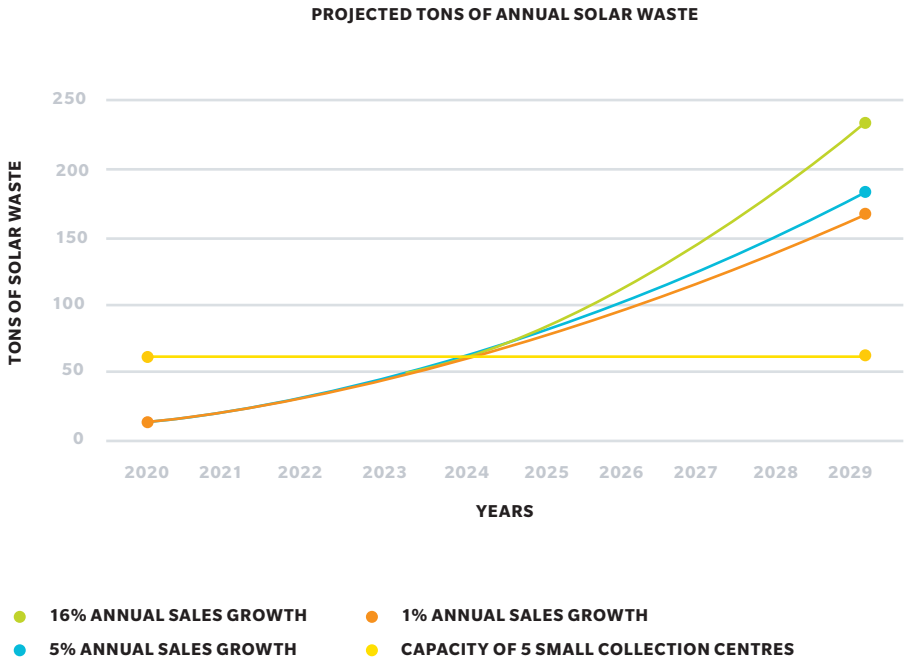
"Within five years it is expected that solar e-waste [in Kakamega County, Kenya] will exceed 50 tonnes annually and at various levels of market growth the waste is projected to accumulate at 165 to 230 tonnes per year by 2029, assuming current repair infrastructure and use behaviours." –Solibrium Halfway Report, Kakamega County, Kenya

ENGIE Energy Access's project in Uganda demonstrated the importance of forecasting in capacity planning, as scrap dealers inundated the company with solar lead acid batteries - waste that had been accumulated by the dealers over time. This caused problems in storage and transportation capacity. Despite moving rapidly to "provide adequate storage, training and facilities to house the inflow", they found that demand still outstripped their collection capacity, although they expect the demand to reduce once the backlog is dealt with.

"I collect this scrap in huge tonnes because I have several stores."

– Ivan, scrap collector in Uganda

Figure 10: Projected yearly tonnes of solar waste in Kakamega County, Kenya, with three annual growth scenarios from Solibrium.



GROWTH RATH	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
1% Annual Sales Growth	12	20	30	42	58	77	98	120	142	165
5% Annual Sales Growth	12	20	30	43	59	79	102	126	152	179
16% Annual Sales Growth	12	20	30	44	62	85	113	146	184	231

–SOLIBRIUM

COLLECTION POINTS - DESIGN AND OPERATIONS

Between the eight projects, a total of 415 collection points for solar e-waste were established, of various types. The set-up cost per collection point ranged from US$20 for a simple "bin" at an existing location to US$2,550 for larger-scale infrastructure such as a converted shipping container in a new location. Companies whose main focus is distribution mostly used their existing networks of service centres or points of sale (e.g. shops and kiosks). Others set up special locations for e-waste collection. **Enviroserve**, for example, established 18 new collection points across the country, including at the borders with Burundi, the DRC, Tanzania and Uganda. This will allow for collection from neighbouring countries as well as in Rwanda.

For **SunnyMoney**, community engagement was a key aspect of their take-back model; collection points were established at schools and other community centres, and the team organised visits on specified dates when collection would take place. Meanwhile **d.light** utilised their existing network of customer-facing experience centres. Operating expenses for collection points depend on the design. Where collection points are operated by existing employees (i.e. shop or sales managers), **it is recommended that the responsibility is embedded into staff KPIs to ensure adequate motivation and prioritisation against other tasks.**

The following considerations are useful when establishing collection points as part of a take-back scheme:

Who is the target user of the collection point(s) or service?

Identifying the target users for take-back and collection schemes can help companies find suitable locations, understand capacity needs and design effective awareness-raising campaigns.

Hinckley's five collection points in Lagos, Nigeria are open to businesses, individuals and informal-sector collectors. They are designed to meet a broad range of requirements and are available for walk-in drop-offs during business hours. In Uganda, **ENGIE Energy Access** initially targeted consumers, but found themselves competing with informal collectors who had long-established relationships and networks within the target communities. Consumers also expected a higher price for their e-waste from ENGIE Energy Access (perhaps due to perceptions of large companies) than they would from a locally-based scrap dealer. **By working directly with the scrap dealers rather than with consumers, ENGIE Energy Access were able to increase their collection rates and reduce the cost of collected e-waste.** (See 'The Collector' on page 43.)

Enviroserve Rwanda launching their Kayonza District e-waste collection centre.

Where should the collection point(s) be located?

Carefully-located collection points are instrumental to a successful take-back scheme. Their location should balance accessibility to users with the cost of reverse logistics.

Consumers who returned solar e-waste to the Challenge projects travelled on average between 9km and 19km to reach the collection point – many by foot, bicycle or public bus. Where the distance is greater, customers will likely need a bigger incentive to return the waste, which adds to the overall cost of a long-term take-back scheme. On the other hand, collection points with larger capacity will also require easy access to main roads and transport hubs.

Enviroserve needed to create a new logistics route to serve the 18 collection points in each of Rwanda's districts. They carried out a cost-benefit analysis of different options to ensure that transportation between locations was as efficient and environmentally friendly as possible, taking into account kilometres and travel time between each stop, cost-per-stop, and total cost. Meanwhile **d.light's** 222 collection points – all located at existing d.light experience centres – have been using the reverse logistics already in place for in-warranty returns. **WeTu** was also able to leverage existing infrastructure, adding WeCollect facilities to their hubs in Western Kenya. This is the recommended option for OGS companies who already have extensive distribution networks.

An initial information-gathering exercise around the distribution of solar e-waste, existing infrastructure (sales agents, shops, repair centres, scrap dealers, etc.) and forecasts of future volumes can help companies identify the most suitable locations for collection points.

What e-waste will be accepted by the collection point(s)?

The eight winning projects each included take-back schemes with different parameters on what type of solar e-waste would be collected (with the exception of **WeTu**, who accepted all e-waste at their WeCollect Hubs). The best practice that emerged is that **collection of e-waste should be brand agnostic;**[13] in other words, take-back schemes should be designed to accept solar e-waste of any brand, including non-branded waste.

The increased processing costs associated with this approach can be offset in a number of ways. Companies can increase their impact by removing poor quality, broken products from the community and creating an opportunity to educate consumers on product quality and care. This was also found to increase the effectiveness of take-back schemes in which customers had suspicions about the intended use of collected products, assuming companies were using them as a cheap source of spare parts.

Through incentives, customers can be encouraged to replace broken non-branded products with quality-verified alternatives. Collective industry-wide action against both generic and branded solar e-waste may also help to build positive perceptions of the off-grid solar sector and safeguard the brand image of responsible companies producing quality-assured products.

Beyond brand, companies should agree **what components of solar e-waste they will include** in a take-back scheme. **SunnyMoney** initially told customers that a complete product was necessary to receive a take-back voucher. They later decided that even incomplete products would be accepted, in the interest of removing as much e-waste from rural areas as possible. They received solar products in varying states of disrepair, some missing switches and panels, others with nothing left but a shell of the casing. More than half the products with a separate (not integrated) panel were missing this panel when collected. When questioned, many customers said it had been stolen. Some indicated that they kept the panel to charge their cell phones, cutting the cable and linking the wires to the cell phone charger.

In one take-back location, many of the batteries had been removed from the solar products. This was problematic; when expired batteries are stored within the plastic casing of the product and protected from the elements, they pose minimal risk. But once separated, a battery becomes more hazardous both to the environment and to human health. SunnyMoney revised their messaging to state that batteries must be included for collection.

As a recycling centre, **Hinckley's** take-back scheme accepts any type of solar e-waste, and in doing so they have been able to measure which components or products are most prevalent. Ranked in order of volume, collected components include: 1) solar panels, 2) small complete solar systems (solar lamps), 3) solar system batteries (lead acid and lithium-ion), and 4) larger solar home systems.

ENGIE Energy Access designed their take-back scheme specifically to collect and dispose of OGS solar components (any brand) and lead acid solar batteries. Their aim was to clean up the waste created by component-based solar home systems, up to 300,000 of which, they estimate, are sold in Uganda per year (of all brands). They decided to focus on the components that are most harmful to communities and the environment and, in doing so, to build a sustainable model to deal with the growing number of discarded, poor quality batteries in the market – the value of lead acid batteries can offset collection of other components.

One risk of selective collection is that the components that take-back schemes do not accept (components from an incomplete system, for example, or those with low or negligible end-of-life value) will be improperly discarded or burned either by consumers or informal scrap collectors.[14]

A range of products collected by WeTu.

Local regulations and licencing requirements

In off-grid markets local regulations governing the handling and transportation of e-waste may be immature and complex, and often require engagement with both regional and national administrations.[15] It is recommended that companies with collection points and take-back schemes study the national waste management legislation.

In Kenya, for example, permits are typically required for the storage, transport and processing of e-waste; these can be obtained through the regional branch of NEMA. Partly due to restrictions put in place during the COVID-19 pandemic, WeTu experienced project delays as they waited for their permits to be issued. They were, however, able to begin certain operations, such as the transportation of e-waste, by leveraging partnerships with local recycling companies who already had permits.

Engaging the government at an early stage can help not only in understanding the legal requirements but also in lending official legitimacy to the collection scheme within local communities. Enviroserve found that including government officials in the launch of their e-waste collection added a "seal of approval" to the programme.

TRAINING STAFF INVOLVED IN E-WASTE COLLECTION

Extensive training was deemed to be a success factor for most of the collection projects: "The more training we do with our own sales agents, the better off we will be in the longer term", states ENGIE Energy Access' Q1 report. "These hard working women and men move around the field every day, and will be a reliable conduit to gather this potentially harmful waste to us."

All the take-back and collection schemes implemented through Challenge projects included the design and delivery of training for the new and existing staff and agents who would interact with e-waste collection. Over the course of 12 months, 91 people[16] were hired and trained on collection activities across the projects. The companies developed project-specific curricula covering the following topics, which form the recommended foundation for any such training:

- Issues surrounding e-waste in the community, such as risks[17] to human health and the environment, as well as motivations for responsible waste disposal and management.
- Health and safety, specifically pertaining to the safe handling and storage of e-waste and its potential risks, including PPE and requirements for storage facilities.
- Individual project processes, including data collection from consumers, reverse logistics and methods of community engagement.

Selected training materials from the Challenge Projects are available in the Transforming Energy Access data repository.

DATA COLLECTION AND KPIS

The Challenge projects collected a substantial amount of data during the 12 month project period. Data captured at the point of collection can help companies and recyclers refine take back schemes and collection operations, better understand consumer behaviour and improve product design. As a sector, there is an opportunity to standardise KPIs to track and measure industry-wide progress in end-of-life management, support partnerships with recyclers and enable adoption across sector support programmes.

Table 4: Recommended data to be captured at collection points

DATA	DESCRIPTION	INSIGHTS
Details of solar product returned	Categorisation of OGS product or component (Panel, Pico-lantern, Li battery, SHS etc.), including model, brand, condition.	Understand the nature of EoL products in the target market
Weight of returned product	In Kg, using accurate scales	In order to aggregate total collected waste
Date of purchase and date of breakdown	Original purchase date of the product when new, and date that it stopped working	Calculate the age of the product and understand the realised lifespan and hibernation time
Repair attempt	Yes/No, and by whom	Gain insights into repair behaviours
Reason for return	Categorisation of listed motivations (e.g. Incentive, replacement product, risk perception)	Gather insights into consumer behaviour and incentives
Source of information about take-back scheme	List of communication methods/campaigns employed	Understand the effectiveness of awareness raising campaigns

Table 5: Recommended KPIs to measure organisational level performance

MEASURE	DESCRIPTION	INSIGHTS
Weight (Kg) of waste collected	Per period, per collection point and aggregated total	Understand the performance of take-back scheme/ collection points
Weight (Kg) of waste recycled	Per period and aggregated total	Understand e-waste flows
Cost of incentive (US$)	Per incentive type and average per kg collected	Refine unit economics
Cost of transport (US$)	Per kg, per km travelled	Refine unit economics
Cost of treatment (US$)	Per kg recycled	Refine unit economics
FTEs employed in e-waste management	Number of hours spent on designated e-waste management activities per period. Disaggregated by gender, location, and role.	Refine unit economics and understand operational capacity of take-back scheme/collection points. Monitor gender inclusion in EoL value chain.

Plastic casings from SHS kits at the Enviroserve facility.

INFORMAL SECTOR: THE COLLECTOR AGGREGATOR

CHARACTERISTICS

In touch with community, business savvy and knowledgeable, male dominated

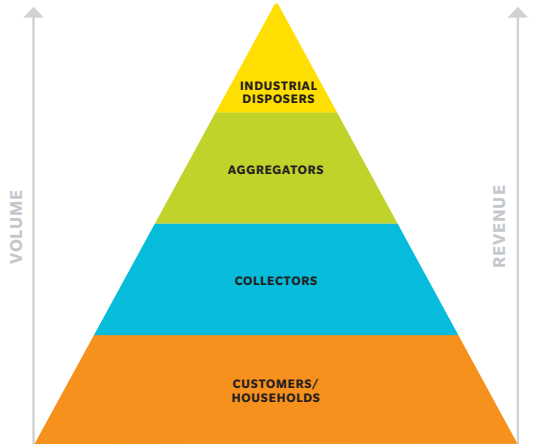
STRENGTHS

Strong local networks, access to both e-waste generators and disposers/recyclers

WEAKNESSES

Price sensitive, risky business, suffers from social stigma

Figure 11: Informal Sector Hierarchy in Uganda



An informal collector aggregates e-waste from disparate sources, including individuals and businesses. E-waste and scrap collection in most OGS markets is a complex hierarchical system with the biggest differentiator being the volumes collected at each stage and by extension revenue. The scrap collector network in Uganda is depicted in Figure 11.

For collectors, **weight is the most important determinant of e-waste value and eventual price paid, rather than brand or type of component.** From the moment these products enter the supply chain, they have a cost attached to them. This figure varies widely and in the case of batteries and metal, it is determined by global market prices. Closer to the source, financial engagements with collectors and local agents should be **prompt** and **stable:**

- Prompt exchange of products for cash. In Uganda, other forms of payment such as bank deposits and cheques are welcome but mobile payments are discouraged, as the associated transactional charges are quite high.
- Stable: Scrap agents are extremely sensitive to price changes. In the first quarter of their pilot, Fenix purchased batteries at 3,000 UGX per kilogram (82 US cents) and collected over nine tonnes. In the second quarter they offered 2,500 UGX per kilogram (68 US Cents) and collected less than two tonnes.

Opportunities for engagement with informal collectors

Increased engagement with collectors has the potential to close both the repair and collection loop in the e-waste value chain. ENGIE Energy Access found that consumers were willing to accept up to ten times less compensation for their e-waste (such as lead-acid batteries) from collectors than from OGS companies. This is because collectors have strong local connections and consumers often know them already.

Collectors can also provide links to repair technicians and act as "champions" for proper disposal by conveying information to consumers on the hazards of poor e-waste management.

Recommendation for collaboration with collectors include:

- Pay a competitive purchase price for e-waste
- Provide stable payment in either cash, bank deposit cheque
- Ensure trustworthy weighing scales are used for transactions
- Optimize transportation costs through provision of shared trucks and scheduled collection days

Challenges in collection

Scrap agents suffer from a lack of verifiable ownership data. Because they have no way to know the source of the products they buy – some of which are stolen – they are prone to harassment by police, who accuse them of theft and contribute to the social stigma surrounding the scrap business.

WEEE Centre Repair Agent in Nairobi, Kenya

3

Encouraging Repair & Refurbishment of Off-Grid Solar Products

HIGHLIGHTS

- **100% of OGS customers are willing to pay to repair a broken product.** This is a viable option for EoL SHS but not for PSPs, where the cost of repair is still too high compared to the price of a new product.
- **Consumers will pay between 50-60% of the cost of a new product for a repaired or refurbished product.** A commercial repair service would therefore be more viable for SHS than for PSPs.
- **The SunnyMoney Pico Solar Repair Guide,** covering diagnostics and repair instructions for common product faults, is freely available for Android via Google Play.

RECOMMMENDATIONS

- Import costs are still too high to enable affordable access to good quality spare parts, and minimum order quantities are prohibitive for small actors in the e-waste repair ecosystem. **Governments can help by supporting favourable import tax regimes for solar components, while OEMs can support the spare part supply by sharing information and building regional supply networks.**
- Local repair technicians often lack the tools and knowledge necessary to repair and refurbish OGS products. **To leverage the existing repair ecosystem in off-grid markets, more investment is required to further de-risk training and certification schemes for third-party repair.**

An effective circular economy includes extending a product's lifespan and optimising its reuse,[18] thus maximising the yield from raw materials and resources used in production. Extending the useful lifespan of off-grid solar products is key to reducing e-waste, and the business imperatives for taking action in both areas are broadly similar. The concept for repairability[19] is gaining traction within the sector, and is widely understood as the cornerstone of a circular off-grid economy.[20] During the Challenge, innovative ways to encourage the repair and refurbishment of broken out-of-warranty solar products were piloted by **SunnyMoney** in Zambia and **Solibrium** in Kenya.

"Everyone deserves the opportunity to have their lights repaired. Repairs help extend the life of products, reduce e-waste and ensure that people continue to benefit from access to safe, clean and renewable light." –Courtney Paisley, E-Waste Project Manager for SunnyMoney

In off-grid markets, extensive networks and ecosystems for the repair and reuse of electronics are already an integral part of everyday life and economic activity.[21] Alongside their take-back schemes, **Solibrium** and **SunnyMoney** sought to leverage and build the capacity of local repair technicians to make consumer-initiated local repair and refurbishment a viable option for out-of-warranty products.

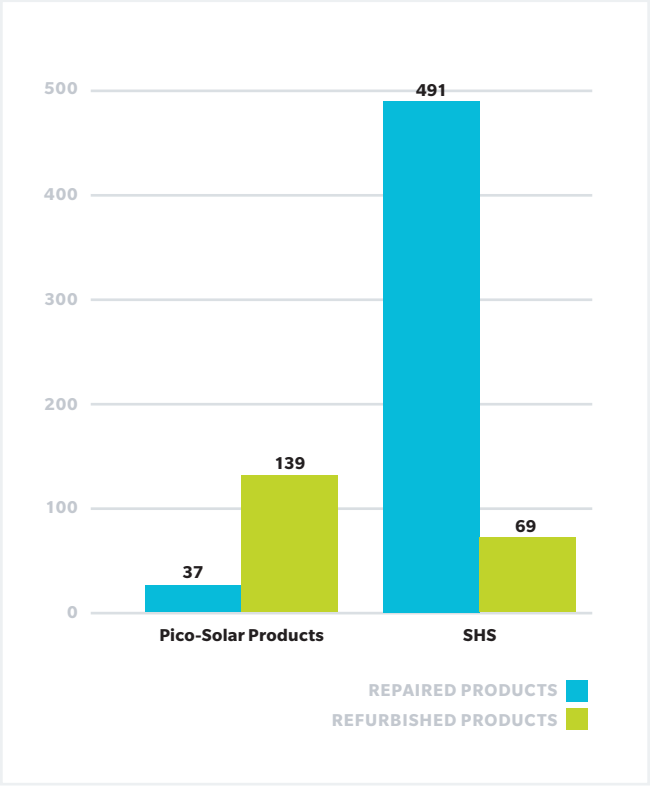
During the course of twelve months, 528 products were repaired and 208 were refurbished.

Once warranties have expired and distributor/manufacturer-led repairs[22] or OEM commercial repair services are not an option, engagement with local repair networks provides an opportunity to boost repairs and refurbishment of off-grid solar products. Repair technicians in local networks often have good penetration in rural areas far from official service centres, and are able to access large volumes of e-waste.

Solibirum's survey of the solar e-waste ecosystem in Kakamega County, Kenya found that "most users with SHS that are out-of-warranty seek repairs from local technicians." During the COVID-19 restrictions in Kenya, demand grew even more for home-based repair services from locally trusted technicians.

Working within these networks can prevent companies from inadvertently competing against them. This was an important consideration for Solibrium, who did not want to duplicate existing channels but instead partner, train and equip informal technicians.

Figure 12: Number of repaired and refurbished products attributed to Project activities



The off-grid solar sector "works to ensure that people purchase high quality products that meet global standards. Repair should be held to the same standards." Courtney Paisley, E-Waste Project Manager for SunnyMoney

BARRIERS TO REPAIR

There are numerous reasons why repair might not be considered (or even possible), and the barriers to repair are different for each player in the value chain.[23] Here, we summarise the most serious hurdles encountered by the Challenge projects in Zambia and Kenya.

Products are not designed for repair and technical information is not widely available

Many products are designed to be especially robust to withstand harsh external environments (like dust and rainwater), and in the case of PAYGo products, they are also made to be tamper-proof. This makes repairs difficult for third-party distributors and external repair shops, who cannot easily access internal components, diagnostics or repair instructions. During a survey of the OGS repair ecosystem in Kakamega County, Kenya, **Solibrium** found that designs requiring special tools for access and those based on a single printed circuit board (PCB) were especially difficult for poorly-equipped technicians to effectively repair.

Inadequate tools and equipment

Due to the nature of informal repair operations, many technicians do not have access to high quality tools. They may be limited by capital, and don't always have an electricity supply to power a tool like a soldering iron. Since solar products are not always designed for easy repair, special tools or equipment may also be required to open the external casing. The Challenge projects found that when they didn't have these specialized tools, technicians tended to break the casing in order to carry out repairs and use adhesive to glue it back together.

Inaccessible or poor quality spare parts

Both **Solibrium** and **SunnyMoney** found that high quality spare parts were not readily available. The source of this problem is threefold:

- For some parts such as batteries, there is an abundance of poor quality and fake branded merchandise available in the market
- It is difficult to source and procure high quality, genuine component parts
- Importing small volumes of spare parts is complex and costly, which makes doing so prohibitive for both OGS distributors and informal repairers alike

During the project, SunnyMoney subsidised the cost of replacement batteries supplied to local technicians; however, this

is not a sustainable solution, and an alternative will need to be identified in order to maintain a supply of replacement batteries and create a viable repair model.

"Some of the users have products whose spare parts are not available locally. In some cases, technicians in the informal sector do not know where to source the spare parts from" and therefore, the client is forced to give up the product.

–Solibrium findings in Kakamega County, Kenya

"Some repair shops in Southern Province are using very poor quality batteries in the repair of solar lanterns and no better products are locally available either in Zambia or neighbouring countries. Sourcing of good quality components remains a bottleneck for repair."

–SunnyMoney findings in Zambia

Lack of knowledge

Not all local technicians in off-grid communities have received formal training in their field. Instead, many learn their trade from family or friends, developing skills over time through trial and error. Even for those with formal training, specialised education on OGS products was not normally included in curricula. As a result, both **Solibirum** and **SunnyMoney** found that local repair technicians are not always skilled enough to provide high quality repair services for off-grid solar products.

Many consumers seem to be aware of this problem; a consumer survey carried out by SunnyMoney in Zambia found that they tended not to trust the abilities of local technicians to fix solar lights.

IMPROVING ACCESS TO REPAIR IN THE OFF-GRID SOLAR SECTOR

Product design, information and guidance

A circular economy must utilise the entire value chain, and design decisions have the power to enable or facilitate repair efforts that can extend a product's life. As Lighting Global notes, "in many cases these decisions can be cost neutral to the product, relying on the manufacturer's commitment to the underlying concept of repairability as a positive product attribute that enhances the product brand."[24]

Where the repair of off-grid solar products is made possible through design, increasing the availability of product information and technical specifications can help enhance the quality of repairs and make it easier to source good-quality, compatible spare parts. Although 732 OGS products were successfully repaired or refurbished during the course of the Challenge, Solibrium and SunnyMoney found that much of the project time was spent sourcing technical guidance and the correct spare parts.

By providing guidance on best repair practices and helping to source high quality components, manufacturers can increase the prevalence and quality of community-based repairs and refurbished products. In doing so, they may be able to mitigate against perceived brand risk resulting from poor quality community-level repairs while also enhancing their socio-environmental impact.

Pico Solar Repair Guide

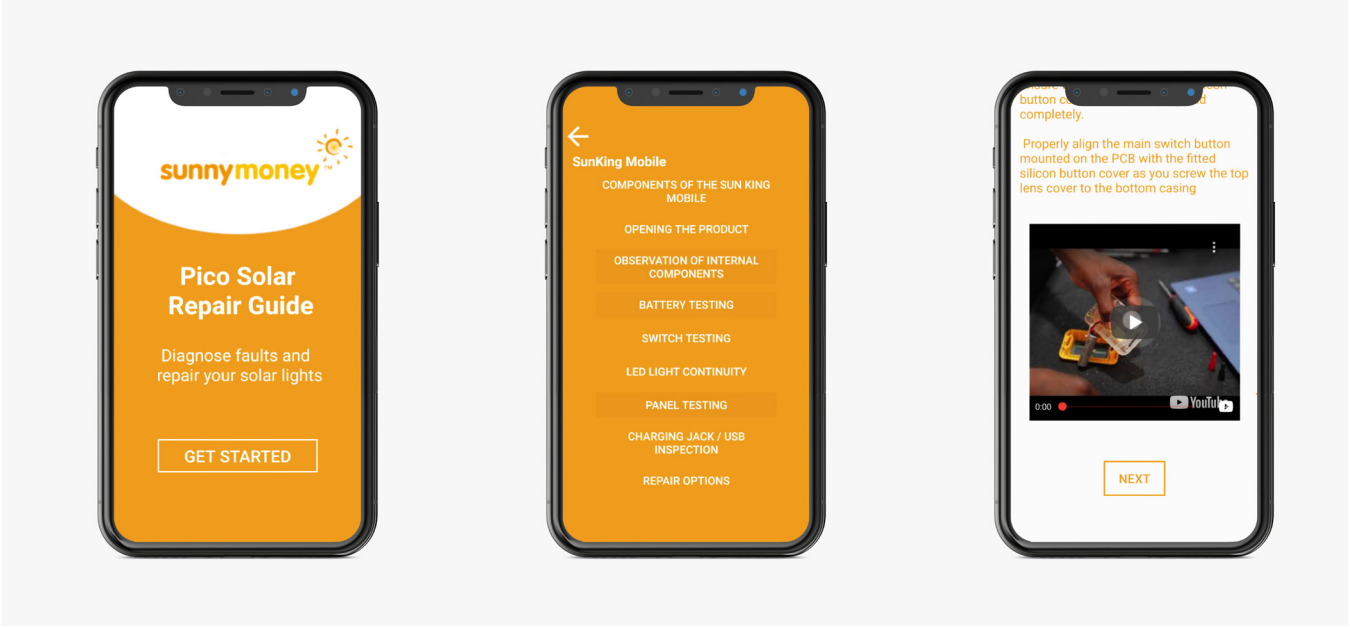
In order to make information more readily available, **SunnyMoney** developed a guide to diagnostics and repair in the form of a smartphone app. Covering products from d.light, SunKing and OV Solar, this easy-to-use interactive tool provides guidance accessible to both distributors and repair technicians.

In order to develop this app, SunnyMoney assessed in-warranty PSPs that had been returned for repair in order to determine their most common faults and the best repair techniques. Because publicly available information about products is limited, SunnyMoney also reached out to a number of other manufacturers to request technical information they could include in the app. Some companies were reluctant to share such information due to concerns about intellectual property and brand risk from poor-quality repairs.

The resulting app includes diagnostics and repair instructions for the most common problems encountered for six pico-solar products from three manufacturers, all supplemented by diagrams, photos and videos. SunnyMoney was also careful to include warnings about the damage that may be incurred by inexperienced repair technicians.

For the benefit of the entire sector and in support of the "right to repair"[25] SunnyMoney has made the beta app freely available for Android phones on the Google Play store.[26] With more investment, the app could be expanded to include a larger catalogue of products and become an invaluable tool for circularity in the OGS sector.

Figure 13: Screengrabs from the SunnyMoney Pico Solar Repair Guide



Training and capacity building

Training local technicians is instrumental in improving the repair and refurbishment of out-of-warranty solar products, and avoiding "trial and error" methods that may do irreparable damage to products and pose a risk to brand reputation. Companies could also look into building certification schemes for repair technicians in order to gain consumer trust and protect their brand image in the community.[27] The StEP initiative provides guidance on formalising relationships between companies and the informal sector, and outlines potential benefits such as increased quality and brand recognition.[28]

SunnyMoney worked on a certification partnership with two repair shops and a technical training college to increase knowledge of OGS products in general. The training provided included basic information on how solar lights work and how to properly maintain them, as well as essential technical skills to address common faults and soft skills for running a repair business. These included:

- Using the correct replacements parts and not cutting corners: many technicians use poor quality or incorrect replacement parts when repairing products
- Proper battery maintenance: proper battery management and maintenance are important topics for education and awareness. Many products were found to have been consistently over discharged, and "supercharging" batteries using mains electrical supply appears to be a widespread practice at repair shops. Due to the risk of damage to the battery, this is not a recommended procedure for SunnyMoney's approved repair services.
- Improved record keeping: existing systems were found to include simply writing telephone numbers on products to inform the client when their product is ready. With improved information on fault types and the costs of repair, a better-targeted repair response can be created.

Increasing access to high quality spare parts

Increasing the availability of spare parts has been identified as manufacturer best practice by Lighting Global[29] and confirmed by the Challenge projects. Making replacement parts available to distributors and well-trained repair shops could have a hugely positive impact on the quality and prevalence of repair in the off-grid solar industry. This could include appliance-level spares such as lights and solar modules, or components such as replacement batteries, electronic parts and circuit boards.

"These have been sitting here for three months. I told the customer that I cannot find the batteries to repair them. So they ask me to keep it, in case I can find some." Mr Nsolo, repair technician in Choma, Zambia, talking about two solar lights in his shop that are waiting to be repaired (SunnyMoney)

Solibrium learned that due to the lack of available spare parts, local technicians collect obsolete products from end users to harvest parts for other repairs; this practice often results in the unused components being stored indefinitely in workshops.

For SunnyMoney, the lack of good quality spare parts created a bottleneck in repairs during the project. They had little success

in sourcing replacement batteries in the region, although they looked in Zambia, Malawi and Kenya. "Discussions with local technicians in Southern Province revealed that they sometimes used one battery that is available locally, but they know it is poor quality (with an unreasonable 6800mAh listed on the battery), informing us that the battery only lasts two days", the company said in their report.

Advice for shipping spare parts

Anyone sourcing parts from outside regional markets is likely to encounter challenges with shipping lithium-ion batteries, as well as import charges applied to individual components that can't be attributed for use solely in solar products. SunnyMoney tried two approaches to these obstacles:

1. **Ordering batteries along with existing solar shipments.** Ideally this reduces shipping costs and may protect the batteries from import duty under exemptions for solar products; however, this exemption is not guaranteed, and including the batteries may cause delays and increase the cost of the entire shipment. But SunnyMoney's first shipment in February 2020 was a success, with batteries arriving duty free along with new solar lanterns.
2. **Ordering batteries on their own.** Finding a reliable source proved difficult; manufacturers were approached for assistance, but either minimum order quantities were found to be prohibitive or information on component suppliers was unavailable. After considerable effort, SunnyMoney located one potential supplier in Shenzhen and ordered a small quantity of batteries.

When ordering stand-alone lithium-ion batteries for repair, asking the supplier to clearly indicate on the label that the product is to be used with solar products (for example: "3.2v 1500mAh LiFePO4 solar battery") may help the shipment benefit from any tax exemptions in place.

SunnyMoney customers.
Photo Credit: SunnyMoney/Patrick Bentley

WILLINGNESS TO PAY FOR REPAIR

100% of respondents to **SunnyMoney's** survey said that they would pay to have their solar products repaired, and that 50-60% of the cost of a new product was a reasonable fee. From speaking to consumers who participated in take-back schemes, we have also found that they are typically willing to have their products repaired, and to pay for the service.

When asked why they returned a product to the collection point, the most popular response (30%) amongst Solibirum customers was because they wanted it to be repaired.

Asked whether or not they had previously sought to repair the returned product, 46% of SunnyMoney customers (bringing products to take-back locations) said yes.[30]

In SunnyMoney's take-back scheme, many customers returning broken products wanted to add their names and telephone numbers to the products in case they were subsequently repaired and could be returned to them. Perhaps as a reflection of the emotional attachment they felt to a valuable asset, customers were less interested in receiving vouchers in exchange for their products than they were in finding suitable repair facilities, for which they were willing to pay.

Although hurdles to repair and refurbishment persist, the willingness to repair is strong, and facilitating it is essential to increasing circularity and reducing e-waste within the off-grid solar sector. The **ability** to pay, on the other hand, requires more investigation, and the cost of repair versus replacement must ultimately make good economic sense.

BUSINESS VIABILITY OF REPAIR & REFURBISHMENT

Although there is undeniably a need and a demand for high-quality repair and refurbishment services for out-of-warranty off-grid solar products, the service does need to be financially viable for both the repair provider and the consumer.

The cost of repair and refurbishment

Customers are willing to pay up to 60% of the price of a new product for a repaired or refurbished product.

For PSPs priced at around US$10, the cost of repair is therefore unlikely to be viable. The landed price of high-quality spare parts alone may exceed the market value of the repaired product. For higher-value SHS, on the other hand, there may be market viability for repaired and refurbished products.

Through the Challenge, SunnyMoney has been able to subsidise high-quality batteries for their certified repair shops. One such establishment has seen solar lantern repairs grow to account for 15% of its business since becoming a "certified" SunnyMoney repair shop, receiving around 3 solar lanterns to repair each week. Another now attributes up to 40% of their repair work to solar lanterns.

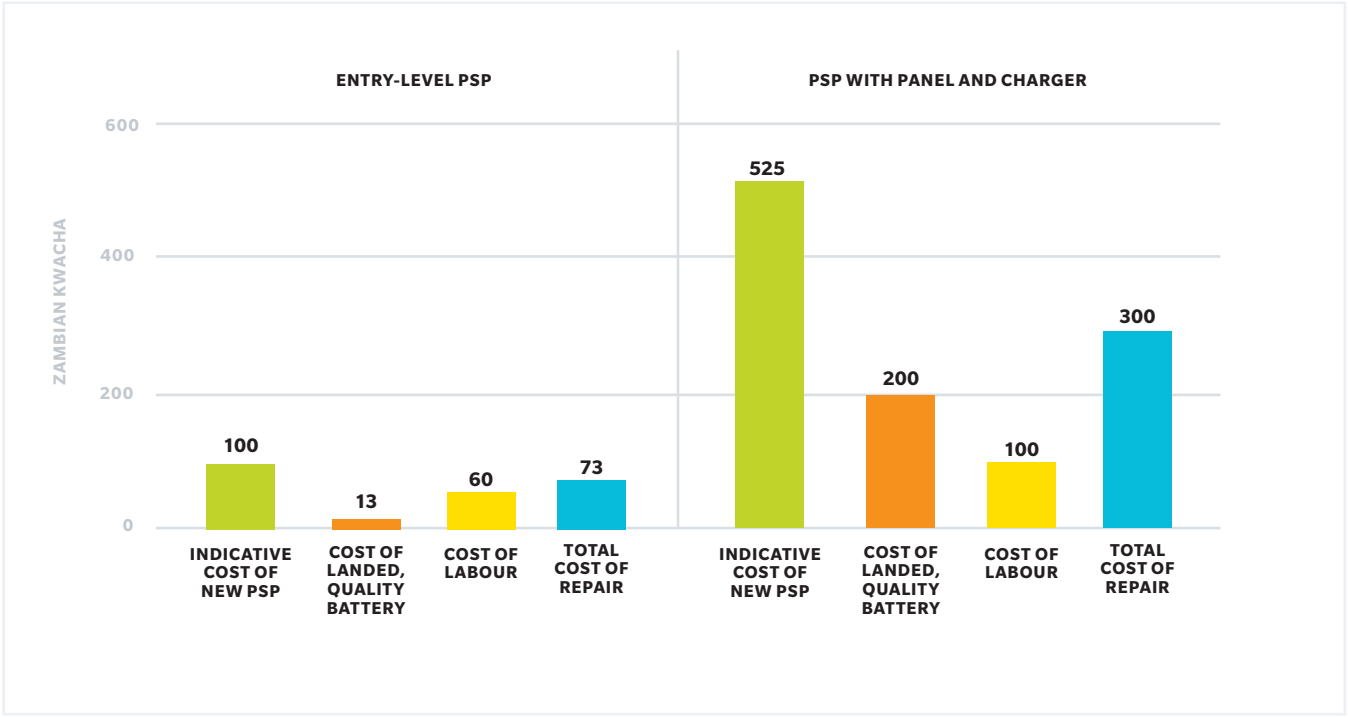
But without action to reduce the cost of high-quality spare parts (through duty-waivers or manufacturer supply networks, for example), the long-term viability of the repair and refurbishment business model is uncertain.

Consumer protection

To maintain consumer protection standards where resale markets can be established, the sector must work to ensure that customers are fully aware that they are purchasing a second-hand, refurbished product which conforms to expected performance standards.

For company-led repairs and refurbishment this may include a warranty on the product according to a quality rating. Where partnerships are made with informal technicians to carry out "certified" repairs, it is recommended that the terms of partnership include a clause that stipulates products must be clearly labelled as "repaired/refurbished."

Figure 14: Cost of repair vs cost of new products. Without improved access to affordable spare parts, the cost of repair is not viable



INFORMAL SECTOR: THE LOCAL REPAIR TECHNICIAN

CHARACTERISTICS

Accessible to consumers, familiar with the local community, knowledgeable on basic electronics repair

WEAKNESSES

Likely to operate informally, limited business and operational skills

STRENGTHS

Willing to learn, trusted by local consumers

Opportunities to collaborate with local repair technicians:

OGS companies may be able to leverage existing repair facilities, especially in hardtoreach areas. Opportunities for engagement with local repair technicians exist across the EoL value chain, from consumer education, collection, repair and proper disposal.

Awareness creation: local technicians are trusted by their communities and can therefore be considered a reliable source of information. Companies can harness this to raise awareness of proper disposal of broken OGS products. In Kakamega County, Kenya, local technicians helped increase the volume of collected EoL products after Solibrium engaged them in their awareness-raising campaign.

Collection-points: accessible to consumers, local repair shops can be used as e-waste collection points, though companies should ensure safe facilities exist for storage and conduct adequate training around handling EoL products.

Repair clinics: building capacity for the repair of SHS and OGS appliances can extend the reach of repair facilities and ensure consumers have access to repair when products ultimately stop working.

When engaging with informal sector technicians, it is important to assess the viability of the engagement. Criteria to consider include their technical knowledge, their interest in expanding, their business model and revenue, standards of record keeping, how they access information, and the characteristics of their customer base.

Affiliate technician schemes

After the SunnyMoney training, one of the repair technicians in Zambia said that he began receiving 2-3 solar lights per week (out of a total of 16 items), accounting for about 15% of his business.

An affiliate technician scheme can enable OGS companies to take advantage of the existing repair ecosystem. Such a scheme might include certification of a technician or shop following a period of training, capacity building, and co-branding. In choosing an affiliate technician to repair an out-of-warranty product, a consumer is assured that:

- The technician has undergone the necessary technical, health and safety training
- The technician has access to the necessary product repair manuals and schematics, as well as the right tools and spare parts
- The technician follows Standard Operating Procedures (SOPs) governing routine operations, such as:
  - Suitable storage spaces
  - Clear finances and accounting
  - Proper recording systems to keep track of products

The Enviroserve Rwanda facility in Bugesera, Rwanda.

4

Improving the Recycling Infrastructure for Off-Grid Solar Markets in Africa

HIGHLIGHTS

- The Challenge projects **treated 72.5 tonnes of off-grid solar e-waste, and recovered 29.9 tonnes of lead acid batteries.**
- The **cost of treatment for off-grid solar e-waste** is US$0.75/kg.
- The **recycling capacity of Enviroserve, Hinckley and WEEE Centre is now ~10,000 tonnes each per year,** yet they are currently utilizing only 30% of this.
- **53% of lithium-ion battery cells tested from EoL OGS products were reusable.** Second life batteries are a viable and innovative way to reduce the amount of e-waste created by OGS products.
- **Hinckley procured the first lithium-ion battery treatment equipment in Africa,** which will be installed in 2021.

RECOMMMENDATIONS

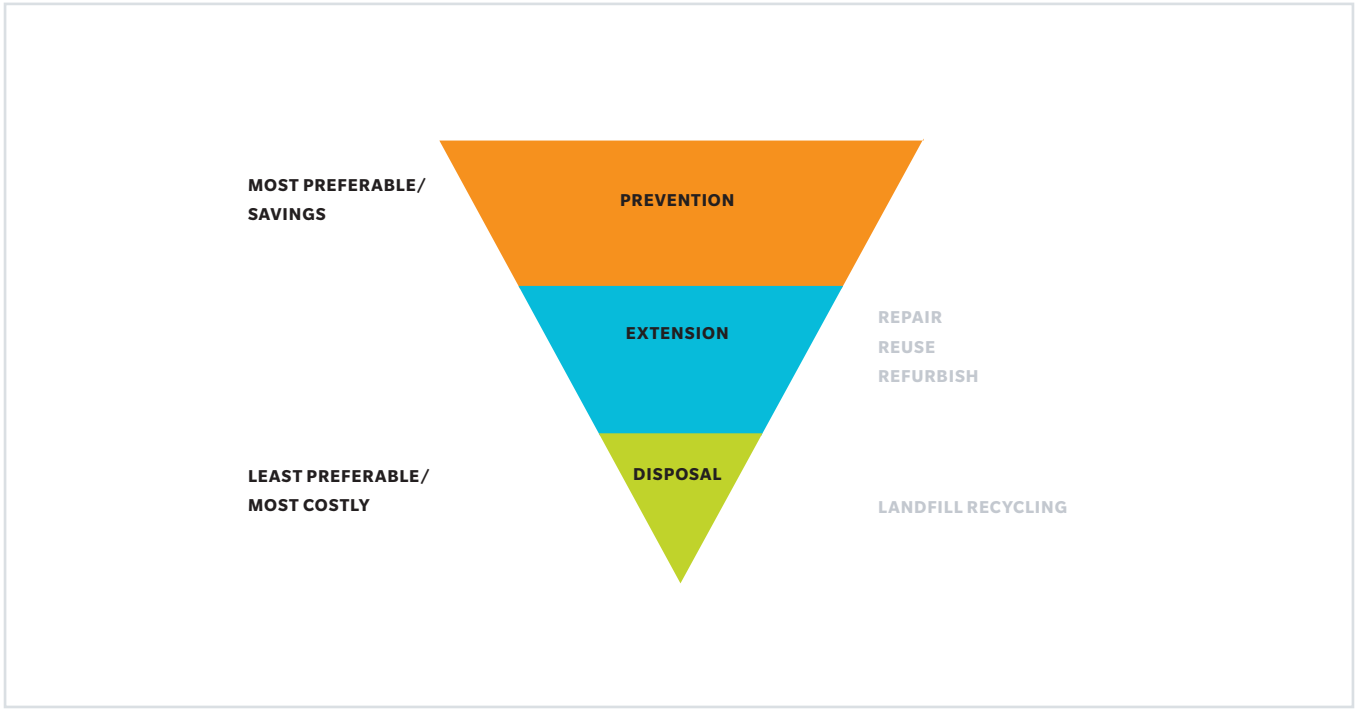
- High treatment costs and low utilization rates are some of the challenges that recyclers continue to face. In order to avoid passing these costs to consumers and companies, **supportive legislative and policy frameworks, investment in robust collection infrastructure and new business models are required to ensure sufficient volumes and eventual profitability.**
- Recycling of OGS products requires specific equipment and processes. The Challenge projects reduced the recycling infrastructure gap by procuring and installing machinery in Kenya, Rwanda and Nigeria that allows for cables, bulbs and lithium-ion batteries to be processed and recycled on-site.**Further investment is required to close the remaining gap for many other offgrid markets across Sub-Saharan Africa.**
- Trans-boundary movement of e-waste is banned under the Basel Convention. However, porous borders mean that e-waste continues to move between countries. **Regional collaboration between governments to develop supportive regulatory frameworks and other innovative solutions can reduce illegal movement of e-waste and harness existing recycling infrastructure in different countries.**

RECYCLING & THE CIRCULAR ECONOMY

Globally, only 17.4% of all e-waste (four million tonnes) is formally collected and recycled, with a raw material value of US$10 billion out of a possible US$57 billion.[31] According to the waste hierarchy (figure 15) – which presents the options for managing waste in terms of what is best for the environment in a circular economy – recycling is the least preferable and most costly approach to maximizing the benefits of a product and minimizing waste generation. It involves organizing, dismantling and separating waste fractions, before subsequently recovering raw materials.

However, recyclers have the opportunity to contribute to higher levels of the hierarchy through the reuse of materials and resource recovery. With access to both up- and downstream markets, recyclers can pilot unique businesses models and test their financial viability.

Figure 15 : Waste Hierarchy, GOGLA E-Waste Toolkit



Recovering metals and other valuable materials in e-waste can reduce the environmental degradation caused by mining, as well as cutting down on the pollution of improper e-waste disposal. During the Solar E-Waste Challenge, **WEEE Centre** recycled plastic from OGS products to create plastic poles for fence posts. **Enviroserve Rwanda** used ABS plastic from control units and solar lanterns to develop custom parts for prototype second-life battery packs. Both recyclers are also testing the possibility of using recycled materials as construction material, including the glass from solar panels and lamps.

One objective of the Challenge was to improve and strengthen operational capacity of solar e-waste processing facilities by:

- Increasing the number of partnerships with off-grid solar companies
- Increasing the volumes of solar e-waste to recycle
- Increasing access to key infrastructure to enhance recycling capacity

Business-to-business (B2B) partnerships are the most common model adopted by recyclers, and during the Solar E-Waste Challenge **Enviroserve Rwanda, Hinckley** and **WEEE Centre** signed **26 partnership agreements** to handle off-grid solar e-waste (including collection, refurbishment and recycling). They collected 173 tonnes of off grid solar equipment through these B2B partnerships.

Recycling in Africa

In many off-grid solar markets, formal recycling infrastructure is underdeveloped or not-existent. There are e-waste recyclers in Ghana, Kenya, Nigeria, Rwanda and South Africa,[32] but due to the complexity of e-waste, components such as lithium-ion batteries, solar panels and PCBs have to be shipped to other continents for treatment. Outside of formal channels, e-waste is often stored indefinitely (which has cost and hazard implications), dumped in landfills, or informally dismantled and burned.

The e-waste regulatory landscape is similarly underdeveloped. Ghana, Rwanda, Nigeria and Uganda are among few countries that have adopted e-waste legislation, while Kenya and Sierra Leone have similar regulations in various stages of development.

BARRIERS TO RECYCLING IN OFF-GRID MARKETS

The recycling sector in Africa faces a number of challenges, the most serious of which are outlined below.

Lack of facilities that meet required standards

Where e-waste recycling services are available, operational standards may be inadequate or even harmful. For example, lead acid battery recycling processes in some facilities are sub-standard, which can lead to substantial harm to human and environmental health. It is important for recycling facilities managing off-grid solar e-waste to meet basic health, safety and quality management standards.

Recyclers and solar companies participating in the Solar E-Waste Challenge identified the following minimum requirements for recycling facilities:

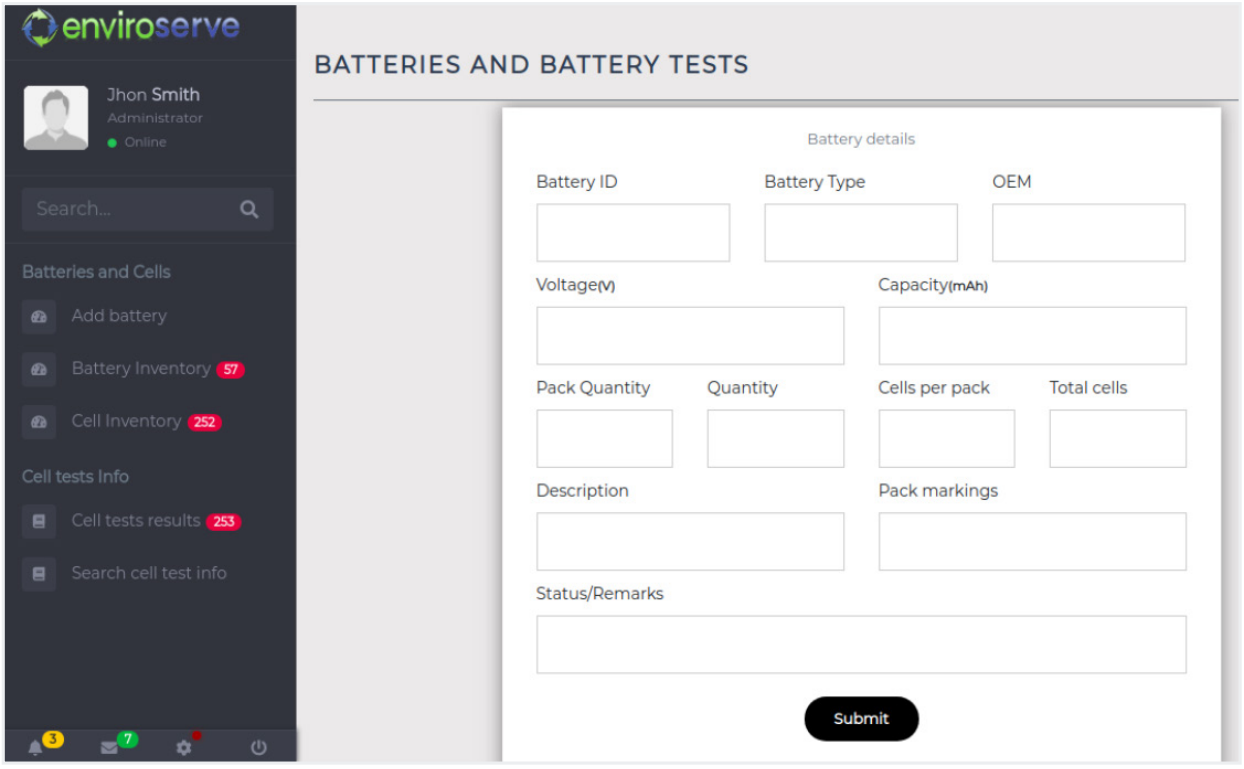
- Compliance with health, safety and operational standards as defined by ISO 45001, ISO 14001 and ISO 9001.
- Compliance with local licensing requirements. Companies that partnered with Enviroserve indicated that the recycler's open engagement with regulatory agencies increased their confidence in the services offered.
- Data protection: disposers need to know that intellectual property is safe and will not be leaked or sold to outsiders.
- Comprehensive inventories that capture various types of product data (serial numbers, makes, models, weight of items, etc.

Table 6: Examples of ISO health, safety and operation standards

ISO 9001	An international standard that specifies requirements for a quality management system (QMS). Organizations use the standard to demonstrate their ability to consistently provide products and services that meet customer and regulatory expectations.
ISO 14001	Specifies requirements for an effective environmental management system (EMS). It
ISO 45001	An international standard that specifies requirements for an occupational health and safety (OH&S) management system, and gives guidance for its use, to enable organizations to provide safe and healthy workplaces by preventing work-related injury and ill health, as well as by proactively improving its OH&S performance.

For companies looking for recycling services, the GOGLA E-Waste Toolkit can be used to assess recyclers for solar products.[33]

Enviroserve Inventory System, Reference this inventory system screen grab



Insufficient volumes for efficient recycling

At present, volumes of off-grid solar e-waste are still low, so the demand for recycling services is insufficient to drive economies of scale. Figures emerging from the Challenge projects indicate that the treatment of off-grid solar e-waste costs about US$0.75 per kg. Increasing the volumes of waste collected can help drive down this cost.

The recycling capacity of Enviroserve, Hinckley and WEEE Centre is now each ~10,000 tonnes per year, yet they are currently utilizing only 30% of this.

Barriers to achieving higher volumes of solar e-waste for recycling include:

- The prevalence of unstructured collection by informal refuse collectors, which leads to unsafe disposal of e-waste or landfill. Two groups in Kenya and Nigeria – E-Waste Initiative Kenya (EWIK) and E-Waste Collectors Association Nigeria (ECAN) – are trying to tackle this problem through cooperation between the informal sector and multiple private sector companies.
- A lack of awareness of responsible recycling practices among both individuals and companies, and a lack of availability of such services.
- The high cost of disposal. Solar companies in Rwanda reported that theUS$0.2 per kg cost of disposal was inhibitive, and as a result they had large quantities of EoL products in storage.
- Insufficient legislative frameworks and government agencies' lack of capacity to enforce regulations. Even where it is adopted by governments, EPR legislation is often not implemented properly. In Nigeria, NESREA (the agency tasked with environmental protection) operates with very limited power and resources.

IMPROVING THE INFRASTRUCTURE & CAPACITY FOR OFF-GRID SOLAR E-WASTE RECYCLING IN AFRICA

The treatment of e-waste is a complex business, and some fractions – such as batteries, bulbs, solar panels and plastic – require specialized tools and machinery. As part of the Challenge, **Enviroserve, Hinckley and WEEE Centre** purchased the following additional equipment:

- **Lithium-ion battery treatment equipment (Hinckley, Nigeria)**: In partnership with Chinese company Taisen, Hinckley have developed a method of mechanically processing solar lithium-ion batteries without hydro- or pyro- technology; this is a clean, low energy solution ideal for the African environment. Once installed, Hinckley's will be the first lithium-ion treatment facility in Africa, and will provide pre-shipment treatment that significantly reduces the cost of export. Installation of the facility was delayed due to the impact of COVID-19 restrictions and will be carried out in 2021.
- **Battery capacity detection and recovery system (Enviroserve, Rwanda):** This system will enable the testing of battery cells (both lithium-ion and lead acid), including discharging, recharging and impedance measurement. Such testing will support battery repurposing.
- **Cable stripping and wire recycling machine (Enviroserve, Rwanda):** This machine enables the recovery of aluminium and copper in the small (<1mm) cables used in OGS products, which is very difficult and expensive to do manually. The machine also peels off the insulators, which in turn aids conductivity of the end-product. When the metal core is recovered, it is refined to produce brand-new cable and can serve as raw material for the cable manufacturing industry. The machines have stripped and recycled over 9 tonnes of waste cable so far stripped nearly
- **Bulb eaters (Enviroserve, Rwanda & WEEE Center, Kenya):** Bulb eaters allow for different types of lamps to be crushed, recycled and used as raw material for the construction industry. The crusher also absorbs mercury and other hazardous substances that may be released during the process. Insert photo of bulb eater This piece of equipment can reduce labour by 20 hours per 1,000 lamps, saving up to 50% on recycling costs and minimizing storage space by 80%.[34]
- **Baler (WEEEE Center, Kenya):** Plastic baler machine is an essential piece of kit when it comes to any recycling strategy. It is fitted with a press – a vertical hydraulic arm that operates on a vertical or horizontal plane and works by crushing together plastic producing a bale, which can then be tied together. Baling reduces the space required for storage, simplifies transportation and reduces overall costs.

- **HDD Destroyer (WEEE Center, Kenya):** Also known as a degausser, it disrupts and eliminates magnetic fields stored on tapes and disk media and as a result makes data unreadable and impossible to recover. Degaussers provide

an extra layer of security against illegal access to private information before shredding. Insert photo of destroyer

- **Plastic recycling equipment (Enviroserve, Rwanda / WEEE Centre, Kenya):** Plastics constitute 40-60% of the total material composition in solar products; most is ABS, HIPS, PP, PC and PVC. ABS plastic is typically used in solar systems because it is strong and hard, with a shiny impervious surface. Plastic recycling requires several pieces of equipment, including extruders, welders, 3D printers and prototyping equipment. It is generally impossible to recycle different types of plastic together due to their different melting points.[35]

Enviroserve Rwanda conducted Environmental Impact Assessment (EIA) tests to understand the impact of plastic recycling equipment. They also evaluated toxicity issues associated with melting the flame retardants in the materials, which would require the use of other waste plastics or of virgin materials.

For Hinckley, recycling ABS plastic was challenging because it is a petroleum-based, non-biodegradable material. ABS plastic is toxic when burnt, unlike PLA (polylactic acid), the most commonly used plastic filament in 3D printing. For this reason they sell it to plastic recyclers if they have the proper equipment to recycle it, or hand it over to local plastic manufacturers. Overall, the demand for e-waste plastic is lower than the supply.

Other equipment purchased by WEEE Centre include a forklift, Personal Protective Equipment (PPE) and power tools.

Cable crushing equipment at the Enviroserve facility

MODELS TO SUPPORT RECYCLING IN THE OFF-GRID SOLAR SECTOR

Decrease disposal costs

To counter prohibitive disposal costs and provide much needed recycling services, Enviroserve Rwanda organized three free collection days for off-grid solar organizations with more than a tonne of e-waste to dispose of; they intend to continue these collections regularly. This, however, has cost implications for Enviroserve, who will seek to offset the cost through other revenue sources in order to treat the e-waste.

For companies with less than a tonne, Enviroserve has signed an agreement for them to deposit their e-waste at the closest collection point in the recycler's extensive network.

Support and enhance regulatory frameworks

Several licenses are needed to operate a recycling facility and, by extension, transport e-waste. The three recyclers – WEEE Centre, Enviroserve and Hinckley – work closely with the relevant government agencies as responsible partners in e-waste management. Through these relationships, they also have the chance to participate in the development of relevant legislative bills. WEEE Centre, for example, is among the stakeholders working closely with the Kenyan government to develop Extended Producer Responsibility (EPR) legislation, which is expected in 2021.

In Nigeria, the environmental protection agency NESREA is working closely with Hinckley in their efforts to structure the informal sector. Meanwhile in Rwanda, the government has introduced an e-waste management requirement into an ongoing subsidy programme for solar companies; Enviroserve attributes this in part to their close collaboration with the relevant agencies and robust awareness raising strategy.

Increase subsidies

Some recycling activities, such as lithium-ion battery treatment, usually result in negative returns. Enviroserve, for example, treated 70.5 tonnes of off-grid solar products at a cost of about US$51,000, but realized only US$ 33,731 in revenue. However, treatment is essential for environmental protection and to reclaim valuable elements. Recyclers could benefit from incentives and subsidies to cover these costs

Table 7: Recycling Cost, Enviroserve

WEIGHTS OF E-WASTE COLLECTED	86,354kg
WEIGHT OF E-WASTE RECYCLED	70,570kg
COST OF RECYCLING	$51,578
GROSS REVENUE	$33,731.5
GROSS REVENUE PER KG	USD$ 0.25 per kg

A variety of components were treated including solar lanterns, plastic and metallic covers, lead acid batteries, LCD displays and radios.

INFORMAL SECTOR: THE INFORMAL RECYCLER

CHARACTERISTICS

Vulnerable, bottom of the pyramid (BoP)

STRENGTHS

May be locally organised (though informally), partnerships can provide access to steady income

WEAKNESSES

Lacks a safe working environment, poor safeguarding

E-waste materials have significant monetary value; the raw materials in the e-waste generated in 2019 is worth approximately US $57 billion. Yet many of these raw materials are lost due to inefficient and unsafe recovery methods employed by the informal sector. These actors are most interested in elements that can be extracted from the waste that have a high resale value: copper from cables, lead ingots from batteries, and other metals.

Informal recyclers typically work in extremely unsafe conditions, and they rely on crude methods such as burning cable for copper and cutting lead-acid batteries to extract lead. They are vulnerable to the risks of e-waste, have little power to negotiate their working conditions and only recover a fraction of the recyclable materials in the waste. At the same time they risk their own health and contaminate the vulnerable communities where informal e-waste recycling takes place. In Uganda, for example, informal recycling accidents include acid burns and cuts from glass batteries.

Company engagement with informal recyclers: a case study

Through partnership with stakeholders like recyclers, informal recyclers can gain recognition as relevant players in the EoL value chain. Partnerships can enable them to acquire essential protective gear and tools, and gain access to both upstream and downstream markets. This increases their income and improves the safety of their work spaces.

In Nigeria, Hinckley helped set-up an association of informal e-waste collectors and recyclers, the E-waste Collectors Association Nigeria (ECAN), which consisted of 121 collectors by the end of 2019. As members, collectors are invited to trainings on safe e-waste collection and dismantling, receive support in opening bank accounts, get access to medical assistance, and receive a fair price for the e-waste they collect.

For Hinckley, this partnership has two key advantages: they receive larger quantities of e-waste, and it reduces the cherry picking of valuable waste. Informal workers usually possess in-depth knowledge of the economic value of different e-waste components, and will ordinarily make sure that the most valuable elements in a product go to repair and component harvesting before the rest is recycled. Providing a fair purchase price encourages the collectors to hand in the full product.

Battery Recycling

LEAD ACID BATTERIES

Recycling of lead acid batteries is widespread due to ease of processing and the profitability of high quantities of recovered lead (lead acid batteries are about 70% lead). However, recycling practices in off-grid markets are often poor. The result can be damage to human health and the environment, including lead poisoning and leaching. For SHS that use lead acid batteries, responsible recycling of EoL products is essential to mitigate these risks. It is also less costly than lithium-ion battery recycling, and easier for OGS companies to implement. Enviroserve treated 29.9 tonnes of lead acid batteries in their regeneration equipment.

Based on their experiences in Uganda collecting EoL solar batteries via scrap dealers, ENGIE Energy Access identified several stages in the post-consumer value chain for solar batteries. Each one goes through between two and four stages (see call out The After-Life of a Solar Battery) before it reaches EoL. Some batteries move through each stage of the chain, while others will skip certain stages; the most commonly skipped are stages one and three.

LITHIUM-ION BATTERIES

Lithium-ion (Li-ion) batteries, on the other hand, are rarely recycled, even though Hinckley's analysis shows they often maintain over 80% of total usable capacity. Currently there is no Li-ion battery recycling facility in Sub-Saharan Africa, meaning that they must first be shipped to facilities such as Li-Cycle in Canada and Umicore in Belgium[36] for treatment and recycling.

Shipping used Li-ion batteries is a tedious and expensive process, and involves the following steps:[37]

- **Rigorously packing the batteries due to fire risks.** Li-ion batteries are prone to thermal runaway which can cause fires.
- **Finding a shipping company willing to transport batteries.** Because transporting Li-ion batteries is high risk due to possible explosions, transporters are often reluctant to carry them or charge significantly more.
- **Securing the permits to ship hazardous material in line with the Basel Convention.** It took Hinckley almost 12 months to acquire the requisite permits for their first shipment.
- **Paying high gate fee charges**[38] imposed by international Lithium-ion battery recyclers for lithium-ion phosphate batteries, which further discourage formal recycling practices for companies operating in developing countries. According to Hinckley, Li-Cycle charges US $0.7/kg for LiFePO batteries.

The shipment of five tonnes of unprocessed batteries costs approximately US$3,500.

THE AFTER-LIFE OF A SOLAR BATTERY

STAGE 0
Customer owns the defective product.

STAGE 1
Collector/sub-agent collects the product, usually paying a small fee to the customer. They pay less than 1,000UGX/kg(27 US cents) in Uganda.

STAGE 2
Local agent aggregates products from sub-agents, but can also purchase directly from customers. They pay 1,000-1,500UGX/kg(27-41 US cents).

STAGE 3
Regional agent buys the product. These agents are often located in larger rural towns with lots of commerce. They pay 1,200-1,800UGX/kg(33-49 US cents).

STAGE 4
Big city agents – typically savvy businessmen in larger industrial hubs like Jinja – purchase products from several regional agents, with the goal of selling them at a profit to industrial disposers. They pay 1,500-2,000 UGX/kg(41-55 US cents).

STAGE 5
Industrial disposers deal with the export of metals and other valuable fractions. They offer wildly varying purchase prices for batteries depending on the season, need and pricing of heavy metals. They pay in cash, and have considerable funds available.

THE LITHIUM-ION BATTERY RECYCLER

To address the lack of processing facilities in Africa, Hinckley have partnered with Taisen in China to develop an innovative technology for affordable and safe processing of EoL lithium-ion batteries. Once installed in early 2021, this will become the first such facility in Africa.

Hinckley will offer treatment of EoL Li-ion batteries as a commercial service, and have developed a profitable business model based on recovering 99% of component materials (copper, aluminium and black mass (a composite of cobalt, lithium and manganese).

Recovered materials are cheaper and safer to ship: Five tonnes of unprocessed Li-ion batteries costs around US $3,500 to ship to Europe for recycling. However, a shipment of five tonnes of black mass (equivalent to 50 tonnes of unprocessed batteries) costs just US $3,000.

Recovered materials have a positive value: Once shipped to off-takers in Europe, materials recovered from EoL solar Li-ion batteries can be sold at London Metal Exchange (LME) rates, creating a profitable business model. The value of the black mass recovered from some Li-ion batteries is approximately US $2,000-2,500/tonne.

The final value depends on battery chemistry: Different types of lithium-based batteries contain different volumes of precious metals. Hinckley found that Cobalt in solar lithium-ion battery black mass is 5% whereas Cobalt in mobile phone black mass is 35%, worth US $1,000-1,500/tonne. The cobalt in the lithium-ion phosphate (LiFePO4) batteries that some OGS companies are now using has an even lower economic recovery value, estimated at around US $500/tonne. This makes it challenging to develop sustainable business models for solar battery recycling. Hinckley suggests that OGS products will require subsidies from EPR models or companies to offset processing costs.

Lithium-ion blackmass cost and revenue comparison between solar and laptop batteries

	COST OF SHIPMENT	PURCHASE PRICE	REVENUE
BLACK MASS FROM LAPTOPS/TONNE	$600	$2000-2500	$1400-1900 (Excluding overhead costs of operation)
BLACK MASS FROM OFF-GRID SOLAR/TONNE	$600	$1000-1500	$400-900 (Excluding overhead costs of operation)

SECOND LIFE BATTERIES

Innovations to give batteries a second life have multiple benefits. Aside from reducing environmental damage by extending a battery's usable lifespan and mitigating the high cost of recycling, they can also create jobs and support the local value chain.

Table 8 :Batteries collected & tested through the Challenge

COLLECTED BATTERIES	245,007
TESTED CELLS	10,360
REUSABLE CELLS	53%
REUSABLE CAPACITY OF CELLS	20-90% of first-life capacity

Hinckley has developed four second life battery prototypes which are currently undergoing testing ahead of further battery production. Each is an uninterruptible power supply system with a rated power output of 400W and 180Wh capacity, and they can be used to power small electrical appliances such as laptops, phones, fans and lamps. Two companies have already expressed an interest in using these second life battery packs for their operations.

Enviroserve intends to deploy second life battery packs in less demanding applications such as replacement battery cartridges for UPS, home storage systems, and mobile power banks for phone charging in rural settings. Meanwhile **Solibrium** will use them for customized solar installations.

These innovations are proof that batteries can be repurposed for new applications, extracting more value from the raw materials and avoiding premature disposal. However, there are a number of challenges to deriving and adapting second life applications:[39]

- **Inflexible battery assembly:** Traditional battery assembly uses spot welding or other permanent methods that make it difficult to modify battery packs without using destructive techniques that can prevent reuse. The compression technique developed by Aceleron (Round 2 Global LEAP E-Waste Challenge Winner)[40] makes it easier to repurpose Li-ion batteries and reduce battery waste.

- **Lack of robust state-of-health estimation and battery management systems (BMS):** The BMS is like the brain of an off-grid solar product. It enables the optimal performance of a battery by protecting it from deep discharge and over charging, and by performing cell balancing. This improves the available capacity of a battery pack and increases each cell's longevity. MKOPA (Round 2 Global LEAP E-Waste Challenge Winner) plans to collect and analyse battery performance parameters in order to improve battery design and develop predictive tools to reduce battery failure and degradation.
- **Liability concerns:** The lack of data about battery performance in second life applications raises quality assurance concerns. Further funding to de-risk the operational applications of second life batteries in off-grid solar products could enable wider adoption.

GIVING BATTERIES A SECOND LIFE: REQUIREMENTS FOR IMPLEMENTATION

The Challenge projects that explored using second life batteries found that the following conditions are required to ensure that battery reuse becomes part of the circular value chain for OGS products:

Access to sufficient quantities of used batteries

To create cost-effective second life batteries recyclers need access to a significant number of used solar batteries, which can be achieved through B2B partnerships. **Hinckley,** for example, gained access to over 240,000 (approximately 60 tonnes) Li-ion batteries through their partnership with two OGS distributors. In theory, there should be plenty of used batteries available, since the OEMs' current business model is to replace failed units for their customers. Their lack of repair capacity means that most of these non-working units, along with their batteries, are eventually recycled.

For the Challenge innovations, having access to a large number of batteries allowed them to test various performance parameters, including usable capacity, in order to refine second life applications. But **Enviroserve** found that currently, there is little data on the availability of used solar batteries, which could be used to forecast supply. More data is needed before recyclers can carry out business planning to offer second life batteries as a commercial service.

It should be noted that shipping delays of large capacity battery testing equipment greatly reduced the total number of cells that had been tested by the end of the project period. Hinckley and Enviroserve will continue their testing over the course of 2021.

Access to equipment for production of second life batteries

Enviroserve and **Hinckley** procured the following equipment to enable them to test and produce second life batteries:

- **Meters (Garsent Multimeter, Proster Digital Clamp Meter):** to measure the impedance of Li-ion batteries without charging or discharging them.
- **Probes, connectors and switches:** for stable measurement less affected by environmental noise.
- **Capacity grading and matching test equipment (Hioki BT4560 Battery HiTester, Neware BTS9000 8-channel battery tester, Ningbo DT50W 128-channel battery charging cabinet):** to carry out multiple tests including capacity tests, charge and discharge tests, and internal resistance tests. It can also charge and discharge the unbalanced battery pack to balance the battery. The number of batteries that can be tested concurrently depends on the number of channels, typically 64 or 128 channels.
- **Creality 3D Printer-** to print battery casings.

Enviroserve and Carnegie Melon University staff examining second-life batteries.

Building operational capacity

As a novel innovation, the development of second life battery packs requires specialized skills and knowledge. In partnership with Carnegie Melon University (CMU), Hinckley developed procedures for sorting, conditioning, reassembly and testing of reusable battery packs. The company was also able to design and implement the necessary safety and quality standards to guide their operations. Prior to the Challenge, Hinkley's team had no skills in second life battery production; they are now at the forefront of implementing this new technology in Nigeria.

Cell testing online training at Hinckley

THE POTENTIAL OF SECOND LIFE BATTERIES IN THE OFF-GRID SOLAR SECTOR

Most discarded lithium-ion batteries are reusable

Tests conducted by several of the Challenge projects indicate that most lithium-ion batteries harvested from EoL solar products are healthy enough to be reused. **Hinckley** tested 10,348 cells of cell type 18650,[41] and found that the majority were in good health: 62% were reusable, with 85-89% of their original capacity. This is likely due to the fact that the majority of these batteries were previously owned by middle-income households, and were used as a backup to a weak-grid power supply.

Enviroserve also obtained 467 battery packs and tested 3,354 cells. They found that 44% of the cells were reusable, and subsequently developed 149 new battery packs.

Solibrium partnered with Aceleron to check the health status of their battery cells and the possibility of repurposing them. By the end of the fourth quarter, they had obtained 21 battery packs of cell type 26650.[42] They are still building a sufficient stockpile for adequate testing, but preliminary tests suggest that the majority are still reusable.

Cell testing at Enviroserve

Battery casing is irregular and difficult to reuse

Although the batteries may be reusable, the casing is often a different matter. Solibrium noted that battery casings from different manufacturers usually have different designs. Once the original battery has been dismantled for repurposing, it is not easy to get the repurposed cells back into a similar casing. To solve this problem, **Aceleron** is designing a reusable casing that can be repurposed, while **Hinckley** has designed a 3D-printed casing stored in recycled UPS inverter units for their second life battery packs. They will use ABS plastic commonly found in solar products to produce new battery cases once they acquire the necessary equipment.

Testing speed is key to productivity

Obtaining rapid test results is essential to increasing productivity. However, because of the limitations of battery cells and the need to replicate the OEM testing environment for given ratings, this process takes an average of six to eight hours. To reduce this time and increase their testing capacity, Enviroserve and Hinckley acquired 128-channel grading and matching testing equipment.

Drawing on the learnings of Aceleron and Lagazel, the second round of the Global LEAP Solar E-Waste Challenge should be able to provide deeper insights into the sustainability of second life battery packs.

Informal scrap workers in Jinja, Uganda.

Photo Credit: SunnyMoney

5

Market Insights from the Challenge

INFORMAL SECTOR & E-WASTE MANAGEMENT

The importance of the informal sector[43] in the e-waste management landscape cannot be ignored, and proper engagement with these players is vital to achieving sustainability. The sector is not only closely integrated with the community but also has a good understanding of the value of different e-waste fractions. Through market assessments of the informal sector landscape, partnerships with existing initiatives and coalitions, and provision of training, the off-grid solar sector has an opportunity to improve the logistics and disposal rates of solar e-waste.

From the Challenge projects, we learnt that the informal sector actors fall into three categories:

1. Local technicians (repairers or fundis)
2. Collectors or waste aggregators
3. Informal recyclers

Each group plays a unique role in the e-waste value chain, yet are highly interconnected. This presents ample opportunities for collaboration. Formalized engagement can benefit the informal sector workers and other off-grid solar e-waste stakeholders in several ways:

- **Formalizing operations:** this includes regular training to improve technical skills and responsible recycling methods, as well as support to business operations such as better record keeping and administration.

  SunnyMoney is creating a network of "SunnyMoney Repair Technicians"

- **Environmental protection:** removing and properly treating hazardous waste which would have otherwise been stored in customer homes, unsafely disposed of or forwarded to industrial disposers.

  ENGIE Energy Access discovered that customers had nearly 20kgs of battery stockpiles in their homes. They also removed 85,630kgs of solar battery waste from Uganda's informal ecosystem and directed it to their recycler, Enviroserve Rwanda. These batteries would have otherwise been sent to larger scrap aggregators and industrial disposers in Kampala, whose primary interest is in extracting heavy metals for resale and export, and may not meet operational standards.

- **Health and safety:** poor management of e-waste has negative health impacts. Scrap collectors in Uganda confirmed that some of their staff have suffered cuts and burns while manually dismantling lead acid batteries.

  Hinckley, in collaboration with E-Waste Collectors Association of Nigeria (ECAN), holds training workshops to raise awareness on the impacts of the hazardous practices used to extract material. They also equip trainees with suitable PPE and essential tools.

- **Increased social and economic well-being:** apart from securing their income sources, formalized processes can reduce the chances of informal sector workers being harassed by law enforcement. Scrap dealers in Uganda noted that a lack of ownership documents made them regular targets of harassment from police for alleged theft.

  As a result of their initial engagement with the informal sector, Hinckley has helped set up an association of over 100 collectors. It provides the collectors with:

  - Training on how to safely collect and dismantle e-waste
  - Support in opening bank accounts and accessing medical assistance
  - A fair price for collected e-waste

INFORMAL SECTOR: WOMEN & E-WASTE MANAGEMENT

Female agent weighs collected batteries for ENGIE Energy Access, Uganda

SunnyMoney solar customers.
Photo Credit: SunnyMoney

The Challenge projects have allowed us to explore a little into the demographics of solar e-waste management, particularly the gender division. 20% of people hired and 30% of people trained by the Challenge projects were women. Among users, however, no discernible trends were detected in terms of gender or age; men and women visited collection points in roughly equal numbers, and their ages ranged from late teens to over-50s.

More distinct patterns were observed in the informal sector, among those working as partners to the awardees rather than as employees. In Uganda, for instance, women served as sales agents in the ENGIE Energy Access project, but the third-party collectors they worked with were overwhelmingly male. Waste collection in Uganda, we were told, is "seen as a job meant for men." This was also true for repair work in Zambia, where the technicians SunnyMoney worked with were all male.

These observations suggest that awareness raising targeting end users should remain universal, while particular efforts could be made to further engage women throughout the end-of-life value chain. Gender disaggregated data will be important to monitor and improve the inclusivity of EoL management in the off-grid solar sector.

"Our early efforts to recruit agents led to a superabundance of male agents and much fewer females: in the second expansion we were able to achieve a little under 30% female representation for our collection agents, which we hope to improve in the future. The perception among some of these communities is that e-waste (or, more generally, scrap industries) are very male-based, so we are looking to encourage more participation from females through awareness raising and active participation of more females in our work." - Silver Tulyamureba, Home Service Specialist at ENGIE Energy Access Uganda.

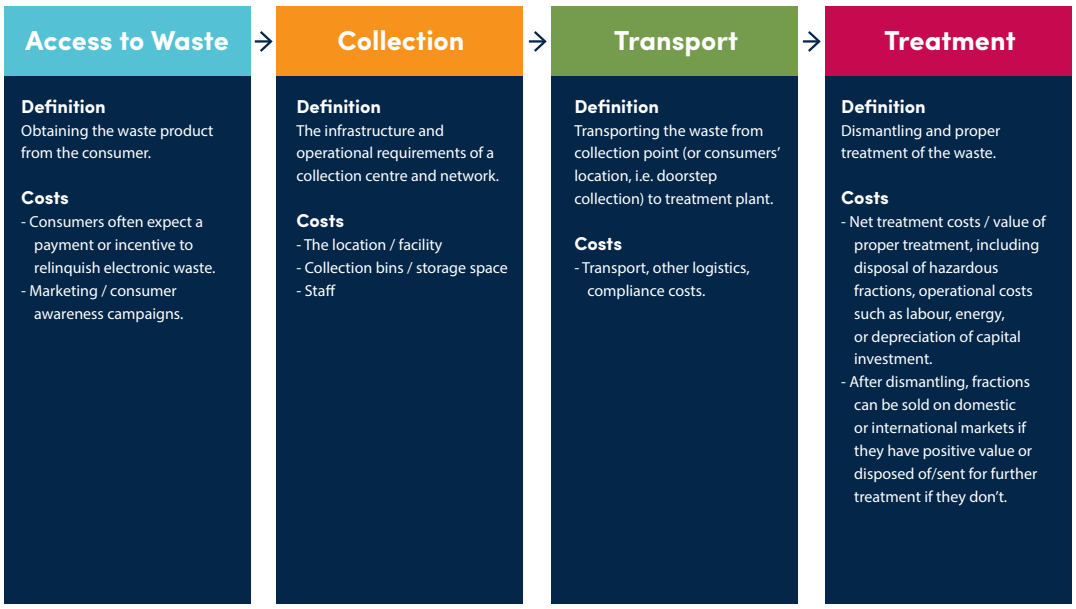
The Cost of Managing Off-Grid Solar E-Waste

The cost of e-waste management remains a significant barrier to OGS companies, many of whom lack the resources to build operations to manage end-of-life products while simultaneously focusing on the profitability of their core business and maintaining affordability for low-income consumers.

However, if cost assumptions for EoL management can be built into unit economics upfront, companies can better understand the cost gap and make the case for additional support from external partners. Doing so will also help companies embed a culture of responsibility for e-waste.

For the purpose of cost analysis, the e-waste chain is broken into four stages: access to waste, collection, transport and treatment.

Figure 16: From GOGLA E-Waste Toolkit, the Financials of E-Waste Management



SOURCE: DfID 2017

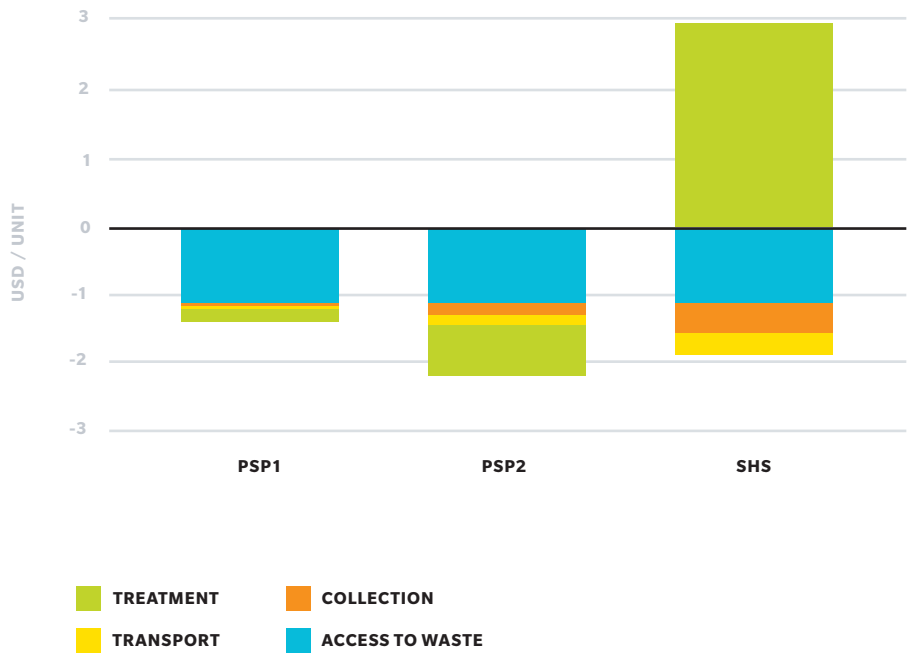
The following estimates build on cost analyses originally carried out by DfID in July 2016,[44] and by GOGLA in 2019.[45] They use data gleaned from the Challenge projects to refine the cost of access, transport and treatment of e-waste. We kept the original assumption regarding the cost of collection, as we were unable to collect substantial operating expense data for the management of collection points within the Challenge timescale.

We can estimate[46] that an entry level solar lantern (PSP1) has a negative value (therefore, a cost) of US$-1.36/unit at EoL, a solar lantern with external PV panel (PSP2) has a negative value of US$-2.17/unit, while an SHS with a lead acid battery has a positive value of US$1.01/unit.

From the original estimates, these values have decreased from US$-0.85, US$-1.35 and US$2.2, respectively.

d.light take-back scheme

Figure 17: Projected yearly tons of solar waste under three annual sales growth scenarios



	SOLAR LIGHT	SOLAR LIGHT + CHARGER	SHS WITH LEAD ACID BATTERY
Weight/unit	0.2kg	1.0kg	20kg
Value/unit	$-1.34	$-2.16	$1.02
Value/tonne	$-6825	$-2173	$50.5

Against the previous cost estimate, the increase is driven by the cost of access. It is perhaps not viable for OGS companies to financially incentivise consumers to return end of life products, unless subsumed into marketing budgets to support sales of new, replacement products. If significant efforts can be made within the sector to raise consumer awareness at existing touchpoints in the customer journey alongside greater availability and visibility of take-back schemes and collection facilities, then the cost of access could be reduced.

CLASP's Monica Wambui at an informal e-waste collection site in Jinja, Uganda.

6

Conclusion

The first round of the Global LEAP Solar E-Waste Challenge successfully piloted several innovations that could help address the barriers to effective solar e-waste management in the off-grid sector. These projects have increased the volume of OGS e-waste collected in Sub-Saharan Africa by over 251 tonnes, reached approximately six million people through consumer awareness campaigns, tested take-back and incentive models, and increased the capacity for OGS recycling on the continent to 30,000 tonnes per year though Enviroserve, Hinckley and WEEE Centre.

We have seen that effective models for take-back, collection, repair and recycling can enhance the circular value chain of the OGS sector. Some learnings have been universal: collection schemes cost money and take time (and training) to set up and run; end users expect a lot in exchange for their products; lots of consumers said they would opt for repair over a replacement; and used batteries can be put back into "new" products. But in some respects the projects' findings were very different: in Kenya radio was seen as useful tool for raising awareness, while in Zambia it was found to be less important than face-to-face contact; in Uganda using agents to collect waste products was a hindrance (it led to higher prices being demanded by end users), but in Kenya the agent network was an asset.

Access to OGS e-waste through take-back schemes has proven particularly expensive. Consumer incentives typically cost around US$1.17/unit, which is particularly burdensome if offset against the price of an entry-level PSP. Sector-wide efforts to address e-waste should be mindful of the need to maintain affordability for BoP consumers. Opportunities to reduce the cost of access can be found in collaboration with the informal sector, whose workers can obtain OGS e-waste at lower costs (or even for free) through personal and community-based networks.

To offset the cost of managing OGS e-waste, companies can leverage the opportunity it provides to engage with consumers – boosting customer retention and customer acquisition – and build brand recognition. The high perceived value of waste by consumers is, however, a stubborn nut to crack.

Further downstream, repair, refurbishment and recycling each enhance the circular value chain, conserve raw materials and create opportunities for jobs and local manufacturing. Investment in skills, information-sharing, supply chains and infrastructure, combined with supportive regulation, are all key to unlocking these opportunities. Continued collaboration between manufacturers, distributors and recyclers is also important.

In the spirit of continued innovation, round two of the Challenge is currently underway, with projects running in Burkina Faso, Kenya, Rwanda and Tanzania. The four

awardees – Aceleron, Lagazel, M-KOPA Labs and Solaris Off-Grid – are each investigating the heart (and the Achilles heel) of a PSP or SHS: the battery. By improving battery management systems, further developing the case for second life batteries and examining modularity, these projects seek to extend the battery's usable product lifespan, delaying and reducing the waste produced by the OGS sector.

Ultimately, the cost of accessing and treating off-grid solar e-waste remains high. For some of the round one projects long-term sustainability would require further financial support, especially to ensure affordability for consumers.

But thanks to the Challenge, we now know more about how to raise consumer awareness, how end-user incentives work, the viability of third-party repair partnerships and the opportunity in bringing "waste" batteries back to life. Crucially, we have learned that all such interventions cost time and money. We call on the sector to contribute the funding necessary to de-risk, scale up and replicate these pioneering projects.

THERE IS MORE ACTION TO BE TAKEN

- **Companies** can leverage existing consumer touchpoints as a "quick-win" way to raise awareness of proper management of OGS products once they reach EoL.
- **Industry-wide collaboration** can catalyse efforts to increase access to waste (through joint collection schemes and consumer-awareness campaigns), and support reliable repair for out-of-warranty products by enabling access to good quality spare parts and basic technical guidance for partners.
- **Funders and investors** are encouraged to explore novel ways (such as RBF) to support early adopters, as well as innovative models to implement e-waste management while avoiding passing on the cost to consumers.
- **Governments** can support the sector's efforts by supporting lower import costs for OGS spare parts and components, and by developing regulation that supports responsible recycling.

AND THERE IS STILL MORE TO LEARN

- Is there a role for Pay-As-You-Go (PAYGo) technology in solar e-waste management?
- What is to be done to combat e-waste from non-affiliate products? And by whom?
- Can a viable market for refurbished products be established and would it be sustainable for both companies and/or local repair technicians? What is the residual value of repaired and refurbished products?
- What is the best model for collaboration between the industry and the informal sector for sustainable e-waste management, and how can this be achieved?

Learning and Coordination Framework - Metrics

Quarterly Metrics

At the end of each quarter the awardees completed an online form detailing their activities for that three-month period. The 43 metrics they reported on included figures such as how many kilogrammes of waste they had collected and how many staff they had hired.

Qualitative Research

While the form captured important information such as how many awareness raising activities were carried out, it offered no insight into the effectiveness of those activities. To account for this the L&C Framework also included tailored qualitative research (through interviews and surveys) to find out more about the experiences of beneficiaries of each of the eight projects.

Resources & Outputs from the Global LEAP Award Projects

All materials are available at **globalleapawards.org/e-waste** under **First Competition Resources**.

- Hinckley Battery Pack Disassembly Guideline
- Hinckley Battery Design & Build Guideline
- Hinckley Battery Cell Testing Guideline
- SunnyMoney Repair Assesssment
- SunnyMoney Repair App
- WeTu Best Practice PPE Module
- WeTu E-Waste Management Module
- WeTu Kobo Collect Brochures
- Enviroserve Inventory Dashboard & Tracking Dashboard

Product Sampling

An additional metric included in Challenge data collection was the composition of the collected waste, which was categorized by type (i.e. panel, battery, casing), by brand/model, and by condition (rated from "good" to "very poor"). Rather than recording detailed descriptions of all waste collected throughout the year-long project period (which would have been time-consuming and costly), the awardees were asked to sample 20% of the products collected in the third quarter and, as a one-off, conduct this more detailed reporting on their waste.

ENDNOTES

[1] Lighting Global et al, Off-Grid Solar Market Trends Report 2020 (March 2020).

[2] Advertised lifespans can be up to five years, but the experience of users is often closer to two years.

[3] The Challenge activities included all types of off-grid solar products and associated appliances, including both quality-verified and non-quality-verified products. Non-quality-verified products represent a majority market share, and therefore a greater volume of solar e-waste generated.

[4] GOGLA, GOGLA Industry Opinion on Lifecycle and Recycling (2014). More recently GOGLA compiled an advisory toolkit for the industry that covered the key aspects of this topic, from product design to materials recycling.

[5] Examples include: Magalini et al, Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector, Evidence on Demand, UK (2016); and Declan Murray, Fixing development: breakdown, repair and disposal in Kenya's off-grid solar market, Edinburgh Research Archive (2020).

[6] The Global LEAP Awards is a series of international competitions designed to accelerate market development and innovation in order to meet the growing demand for energy services in underserved markets

[7] Global LEAP Awards, The Global LEAP Solar E-Waste Challenge Market Scoping Report (October 2019).

[8] The second round of the Challenge (ongoing) has awarded a further US$900,000 in funding to four more winning projects.

[9] Although the Challenge was open to all markets in SSA, the majority of applicants came from companies in Kenya and East Africa. This reflects the maturity of off-grid solar markets in the region.

[10] A list of metrics used to track and evaluate the projects can be found in Annex 1.

[11] GOGLA, E-Waste Toolkit Module 5&6 Briefing Note (May 2020); see also: Jamie Cross and Declan Murray, "The Afterlives of Solar Power," Energy Research & Social Science Volume 44 (October 2018): pages 100-109.

[12] GOGLA, E-Waste Toolkit Module 5&6 Briefing Note (May 2020).

[13] Where brand-agnostic collections are carried out, it is recommended that the implementing company engages other companies whose products they may collect in order to avoid undue concerns over IP and to explore potential collaborative approaches.

[14] Interview with scrap dealer conducted by ENGIE Energy Access, Uganda.

[15] See the GSMA e-waste legislative framework map for country-level information.

[16] This is out of 129 hired and 328 trained overall.

[17] See Operational guidelines for handling used batteries in the off-grid solar sector

[18] Ellen MacArthur Foundation, Growth Within: A Circular Economy Vision for a Competitive Europe (2015).

[19] Repairability is described as the "manageable and realistic mechanism for product lifetime extension." Repair and refurbishment both involve restoring broken products to a working, usable state; however, they sit within different stages of a product or customer journey. For the purpose of monitoring and evaluation, the Challenge defined **repair** as products that are restored to a working state either in-house or through partners and returned to the same customer, potentially in exchange for a repair service fee. **Refurbishment** is defined as products that are restored to a working state either in-house or through partners and placed back on the market (with a different customer) either as a swap for a faulty system OR for a fee as a reduced price/second-hand system.

[20] Efficiency for Access Coalition and the University of Edinburgh, Pathways to Repair in the Global Off-Grid Solar Sector (October 2020).

[21] Ibid.

[22] Distributor- or manufacturer-led repair and refurbishment was not addressed by the Solar E-Waste Challenge awardees. However, it should be noted that it is an area of opportunity in which companies can leverage their existing warranty repair services. More needs to be done to understand to what extent this is already happening in the off-grid solar sector, and to capture further lessons and best practice for repair and refurbishment of broken products as a commercial service for OGS companies.

[23] For a detailed review of the barriers to repairability, see: Efficiency for Access Coalition and the University of Edinburgh, Pathways to Repair in the Global Off-Grid Solar Sector (October 2020; chapter 4, p.20).

[24] Lighting Global, "Product Repair Part II: Manufacturer best practices," Technical Notes Issue 7 (March 2017).

[25] See ifixit.com

[26] Available at: SunnyMoney PicoSolar Repair Guide.

[27] A similar strategy is used by the Apple Independent Repair Provider Program.

[28] Step, Partnerships between the informal and the formal sector for sustainable e-waste management (April 2020).

[29] Lighting Global, "Product Repair Part II: Manufacturer best practices," Technical Notes Issue 7 (March 2017).

[30] From a sample of 50 Solibrium customers and 39 SunnyMoney customers.

[31] Vanessa Forti, Cornelis Peter Balde (Kees) and Ruediger Kuehr, The Global E-Waste Monitor (2020).

[32] GOGLA maintains a catalogue of e-waste service providers for the off-grid solar industry.

[33] GOGLA, E-Waste Toolkit Module 1 Briefing Note (March 2019).

[34] "The Bulb Eater," Environmental Protection.

[35] GOGLA, E-Waste Toolkit Module 1 Briefing Note (March 2019).

[36] Umicore in Belgium is not currently accepting solar batteries.

[37] As identified by Hinkley.

[38] The gate fee is charged to cover low-grade fractions in electronic scrap, for which the net intrinsic metals value after treatment costs is negative. (see: Hageluken, Recycling of Electronic Scrap at Umicore: Precious Metals Refining (June 2006)).

[39] Noshin Omar, "Second life batteries – opportunities or challenges," Mobility, Logistics and Automotive Technology Research Centre (June 2018, Brussels).

[40] Global LEAP Awards, Solar E-Waste Challenge Project Spotlights (February 2020).

[41] "What is an 18650 Battery?" 18650 Store.

[42] "26650 Batteries," BatteryJunction.com

[43] The informal sector can be defined as enterprises owned by individuals or households that are not constituted as separate legal entities independently of their owners, are not registered under specific forms of national legislations, and are not engaged in agricultural activities. (see: Hussmanns, Statistical definition of informal employment: Guidelines endorsed by the Seventeenth International Conference of Labour Statisticians (ILO, 2003).

[44] F Magalini, D Sinha Khetriwal and C Mugabo, Sustainable Management of E-Waste in the Off-Grid Renewable Energy Sector in Rwanda: Evidence on Demand, Department for International Development (2016).

[45] GOGLA, E-Waste Toolkit Module 3 Briefing Note (September 2019)

[46] The calculation uses the same methodology as previous calculations with the following updated figures: cost of access (US$1.17/unit), cost of collection (no change), cost of transport (US$0.66/km), cost of treatment (US$0.73/kg, except for SHS where original data is used to account for the value of lead acid batteries). Original data was converted from Euros to US$ for comparison.

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