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OFF-GRID E-WASTE MANAGEMENT TOOLKIT

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ESMAP
Energy Sector Management Assistance Program

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The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and over 20 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank Group (WBG), ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WBG strategies and programs to achieve the WBG Climate Change Action Plan targets. Learn more at: https://esmap.org

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Abbreviations

€	Euro (currency)
E&S	environmental and social (used in the context of risks)
ECOP	Environmental Code of Practice
EIA	Environmental Impact Assessment
EPC	engineering, procurement, and construction
EPR	extended producer responsibility
ESA	Environmental and Social Assessment
ESCP	Environmental and Social Commitment Plan
ESF	Environmental and Social Framework
ESIA	environmental and social impact assessment
ESMF	Environmental and Social Management Framework
ESMP	environmental and social management plant
ESMS	environmental and social management system
ESRC	Environmental and Social Risk Classification
ESRS	Environmental and Social Review Summary
ESS	Environmental and Social Standards
ESSF	Environmental and Social Screening Form
e-waste/WEEE	electronic waste/waste from electrical and electronic equipment
GIIP	Good International Industry Practice
GOGLA	Global Off-Grid Lighting Association
HCFC	hydrochlorofluorocarbon
HR	human resources
IEC	International Electrotechnical Commission
ILA	International Lead Association
LED	light-emitting diode
LIB	lithium-ion battery
NGO	non-governmental organization
O&M	operations and maintenance
OGS	off-grid solar
PAYG	pay-as-you-go
PCB	printed circuit board
PFI	partner financial institution
PRO	producer responsibility organization
PURE	productive uses of renewable energy
PV	photovoltaic
R&D	research and development
RBF	results-based financing
REF	Renewable Energy Fund

SHS	solar home system
SME	small and medium-sized enterprise
TA	technical assistance
TT	task team (World Bank staff)
WB	World Bank
WEEE	waste electrical and electronic equipment
Wp	watt peak

All currency is in United States dollars (US$, USD), unless otherwise indicated.

Key Definitions

Affiliate (company)	Affiliate companies are connected to any of the partner organizations involved in the semi-annual Global Off-Grid Lighting Association (GOGLA) sales data reporting process. This matrix of companies includes GOGLA members, companies selling products that meet Lighting Global Quality Standards, and appliance companies that participated in the Global LEAP Awards or are engaging with the Low Energy Inclusive Appliances (LEIA) program.
Circular Economy	A circular economy is an economic system in which the value of products, materials, and other resources in the economy is maintained for as long as possible, enhancing their efficient use in production and consumption. This reduces the environmental impact of their use and minimizes waste and the release of hazardous substances at all stages of their life cycle.
Component Based Systems	In component-based systems, individual components, such as the solar photovoltaic module, battery, lights, inverter, wiring, and appliances, are sourced and assembled independently by either a product aggregator or an individual for their own household, sometimes even piecemeal over a long period of time. Component-based solar home systems (SHS) typically have power ratings above 11-Watt Peak (Wp), which classifies them as SHS products.
Eco-Design	The integration of environmental aspects into the product development process, by balancing ecological and economic requirements. Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle. Eco-design would include considerations like increased durability, modular design, use of recycled materials, and recyclability of components and materials.
Electronic Waste (e-waste)	Electrical or electronic equipment which the holder discards or intends or is required to discard, including all components, sub-assemblies and consumables which are part of the product at the time of discarding. Also referred to as 'waste electrical and electronic equipment' or 'WEEE.'

End-of-Life	In the context of this Toolkit, end-of-life denotes the end of the service life of a product, after which it cannot be used and is disposed of. This differs from the technical definition, whereby "equipment reaches its end-of-life once it becomes dysfunctional for the end-user, becoming what some classify as waste for the particular need the user has" (International Telecommunication Union 2012). According to this technical definition, the original equipment manufacturers stop selling the product and providing maintenance support for the product, although it can still be repaired and reused.
Extended Producer Responsibility (EPR)	This represents a "policy principle" that aims to promote life cycle environmental improvements of product systems. This is achieved by extending the product manufacturers' responsibility to include additional parts of the life cycle of the product, and especially to the take-back, recycling, and disposal.
Informal Sector	The International Labour Organization (ILO) defines informal sector waste workers as individuals or small and micro-enterprises that intervene in waste management without being registered and without being formally charged with providing waste management services. This sector is often not officially recognized and acknowledged, yet its members contribute significantly to waste management by collecting, sorting, processing, storing, and trading waste materials in the recycling value chain.
Non-Affiliate (companies)	Companies that are not within the matrix of affiliate companies are considered non-affiliate companies. Products distributed by non-affiliate companies are considered non-affiliate products. These companies do not report their sales to GOGLA, and much less is known about the quality and level of Tier of access their products provide.
Off-Grid Solar (OGS) sector	The off-grid solar sector is designed to supply power through standalone solar products, systems, and services, to people living without access to the grid power supply. This is predominantly in the developing world, where 675 million people currently live without access to clean, reliable, and affordable energy. Off-grid solar is also sometimes referred to as distributed renewable energy sources (IEA, IRENA, UNSD, World Bank, WHO 2023).
Pay-As-You-Go (PAYG)	PAYG business models allow end-users to use products by paying in increments, for the service used (energy-as-a-service) or for the ownership of the products (lease-to-own). A PAYG company will typically offer solar products such as solar home systems and multi-light pico devices for which an end-user makes a down payment, followed by regular payments. Payments are usually made via mobile money, although alternative payment methods include scratch cards, mobile airtime, and cash.

Solar Lanterns	Pico-PV products include small, portable solar lanterns, flashlights, or torches designed to meet basic lighting needs as a direct replacement for kerosene lamps in households. These products are typically packaged either as a simple, one-light system with one light-emitting diode (LED) light, an embedded 0.5–3.0 Wp solar panel, and an internal rechargeable lithium-ion battery (LIB), or as multi-light systems of up to three or four LED lights with a standalone solar panel rated up to 10 Wp and a rechargeable LIB. Many models include USB charging for mobile phones.
Producer Responsibility Organization (PRO)	Under a voluntary or legally mandated extended producer responsibility (EPR), companies take either individual or collective responsibility for their waste. Since it is more challenging to monitor and enforce systems based on individual responsibility, collective responsibility models are more common. A collective responsibility system requires a central organization within the EPR to coordinate activity within the system. This organization is known as the PRO or the system operator and takes over the responsibilities of the obliged companies in the collective system.
Productive Use of Renewable Energy (PURE)	Productive uses of renewable energy (PURE) involve the utilization of energy—both electric, and non-electric energy in the form of heat, or mechanical energy—for activities that enhance income and welfare. These are typically in the sectors of agriculture, rural enterprise, health, and education. Examples include pumping water for agriculture, geoprocessing, lighting, information and communications, and vaccine refrigeration. PURE specifically utilizing solar energy can sometimes be referred to by stakeholders as Productive Use Leveraging Solar Energy (PULSE). Productive use of energy can support livelihoods through increasing economic productivity in multiple ways (i.e., commercial phone charging, fridge for a shop, solar water pump for agriculture).
Solar Home System (SHS)	SHS have a solar panel rated 11 Wp and higher and include both home lighting systems and large systems which can power appliances. SHS refer to both plug-and-play and component-based systems, unless specified.

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Executive Summary

Off-grid solar systems represent the least-cost solution to electrify more than 363 million people on the way to achieving SDG7 by 2030. As the World Bank provides financing to companies selling off-grid solar systems to close the access gap, it is critical to address the Environmental and Social (E&S) risks associated with these systems, particularly the generation of electronic waste (e-waste) at the system end-of-life.

The e-waste from off-grid solar components can be toxic and not biodegradable. Exposure to e-waste can lead to irreversible health effects, including cancer, miscarriages, neurological damage, and diminished IQs. This means that some off-grid solar components at end-of-life bring about significant risks when not properly handled, dismantled, or treated. Batteries pose the highest risks due to the presence of toxic substances that pose direct harm to both health and the environment, but challenges are also posed by the accumulation of less hazardous system components such as solar panels. It is thus imperative to address the E&S risks associated with off-grid solar systems, particularly by components like batteries.

The OGS e-waste management sector faces multiple challenges. Some are unique to OGS e-waste, like a complicated reverse supply chain and the abundance of poor-quality products, while others belong to the broader e-waste realm, such as missing treatment infrastructures and lack of consumer awareness on the health and safety risks. In many countries, most e-waste is handled by the unregulated, informal sector which faces high E&S risks. It is thus critical that off-grid solar projects and the stakeholders involved provide effective risk management measures for e-waste.

Promoting a Circular Approach

A circular economy approach can minimize the generation of e-waste by intervening at each step of the off-grid solar system lifecycle. The principle of the 5Rs—reduce, reuse, repair, refurbish, and recycle—highlights how multiple measures can be incorporated at different moments of the off-grid solar product lifecycle, such as design, production, and usage.

The off-grid solar sector already shows examples of good practices based on the 5Rs as implemented by the private sector, donors, and governments. The off-grid solar private sector shows numerous voluntary efforts. At the design and manufacturing levels, quality assurance standards like VeraSol, and other eco-design standards encourage enhanced durability, usability and repairability. Larger off-grid solar products can implement tracking and monitoring, improving functionality and extending product lifecycles. Finally, companies voluntarily partner with recycling firms individually or via producer responsibility organizations to manage their e-waste.

Donor and development partner interventions on e-waste focus on providing capacity building to local communities, businesses, and governments. Secondly, they provide financial incentives such as grants and coordinate global challenges to promote sustainability and innovation. Finally, they tend to set eligibility criteria to instill sustainable practices across the product lifecycle.

Governments tend to intervene on the regulatory and policy environment by promoting quality assurance criteria, tax exemptions, and forward-looking measures such as legal frameworks to adopt extended producer responsibility.

Managing Environmental & Social Risks in Off-Grid Solar Projects

The World Bank energy teams, E&S specialists, and Government counterparts can follow a step-by-step process to identify and implement E&S risk management measures related to off-grid solar e-waste. In the context of off-grid solar, critical E&S risks relate to the environmental sphere. First, World Bank project teams and government counterparts can conduct an E&S situation analysis to comprehend the e-waste challenge, employing stakeholder capacity assessments and infrastructure analysis to develop suitable mitigation strategies. Such an analysis involves estimating e-waste quantities, assessing stakeholder capacities, evaluating infrastructure strength, and surveying policy environments. Five types of risks related to products, end-users, business models, infrastructure, and policy are considered, guiding the identification of mitigation strategies.

After identifying E&S risks, World Bank project teams and government counterparts must determine suitable and proportionate management strategies to prevent, minimize, alleviate, or offset those risks. Key risk management strategies available to World Bank OGS projects range from 'Core' interventions, which are implementable at relatively low cost, to 'Best to Have' and 'Ambitious' interventions, which may require more substantial investment and management oversight. The 'core' interventions primarily focus on bolstering OGS company capacity in handling e-waste, while 'best to have' and 'ambitious' interventions encompass additional actions that Borrowers can undertake, such as conducting consumer behavior studies or auditing recyclers, investing in e-waste infrastructure, and advocating for policy reforms. The most ambitious interventions aim to foster cross-sectoral and regional collaboration in e-waste infrastructure development and policy advancement.

As a following step, the World Bank teams and government counterparts must design and implement E&S risk management strategies. World Bank projects utilize three primary mechanisms, or 'levers'. Firstly, technical assistance is employed to conduct studies, run campaigns, and offer practical aid to stakeholders. Secondly, various funding mechanisms, including upfront grants, results-based financing, credit lines, or tax exemptions, are utilized to incentivize OGS companies and recyclers to enhance e-waste management and alleviate private sector costs, thus avoiding passing them fully on to end-users. Thirdly,

eligibility criteria are established, which companies must meet to qualify for support, serving as an incentive for OGS companies and recyclers. However, such criteria should focus on low-hanging fruits to avoid penalizing small companies, and should be used in conjunction with the other two levers, particularly technical assistance.

Finally, progress on E&S risk management strategies should be monitored to identify advancements and resolve issues. OGS e-waste risks ought to be integrated into the project's E&S performance monitoring procedures. This entails regular reporting, site visits, and gathering information from third-party sources, including grievance redress mechanisms and stakeholder engagement. Additionally, companies should establish internal tracking mechanisms and report on progress regarding key indicators. Projects may also incorporate site visits and spot checks as necessary.

The Way Forward

Fully implementing E&S risk management strategies that follow the 5R principles in the off-grid solar value chain will bring about multiple benefits to off-grid solar end-users, companies, the sector, and the climate. End-users will have increased product satisfaction, customer protection, and trust in the products; off-grid solar companies can lower company-level costs, improve client management, and diversify business; the off-grid solar sector would benefit from greater industry resilience by shortening supply chains and lowering dependance on imports of material; and the climate would benefit from lowering the sector's greenhouse gas footprint and material impact.

To achieve circularity in the off-grid solar sector, stakeholders must pursue a diversified, complementary agenda. Off-grid solar program managers should design activities that support circular economy, promote intra-industry collaboration, develop knowledge, and raise public awareness. Policy makers should promote regulations that enable a circular economy, such as mandating quality standards and enabling e-waste transboundary movement and investing in infrastructure. Investors and donors should support circular initiatives, deploy innovative financing and grants that foster private sector participation, and invest in infrastructure and private partnerships. Finally, off-grid solar companies should be incentivized to adopt circular business models throughout their entire supply chain.

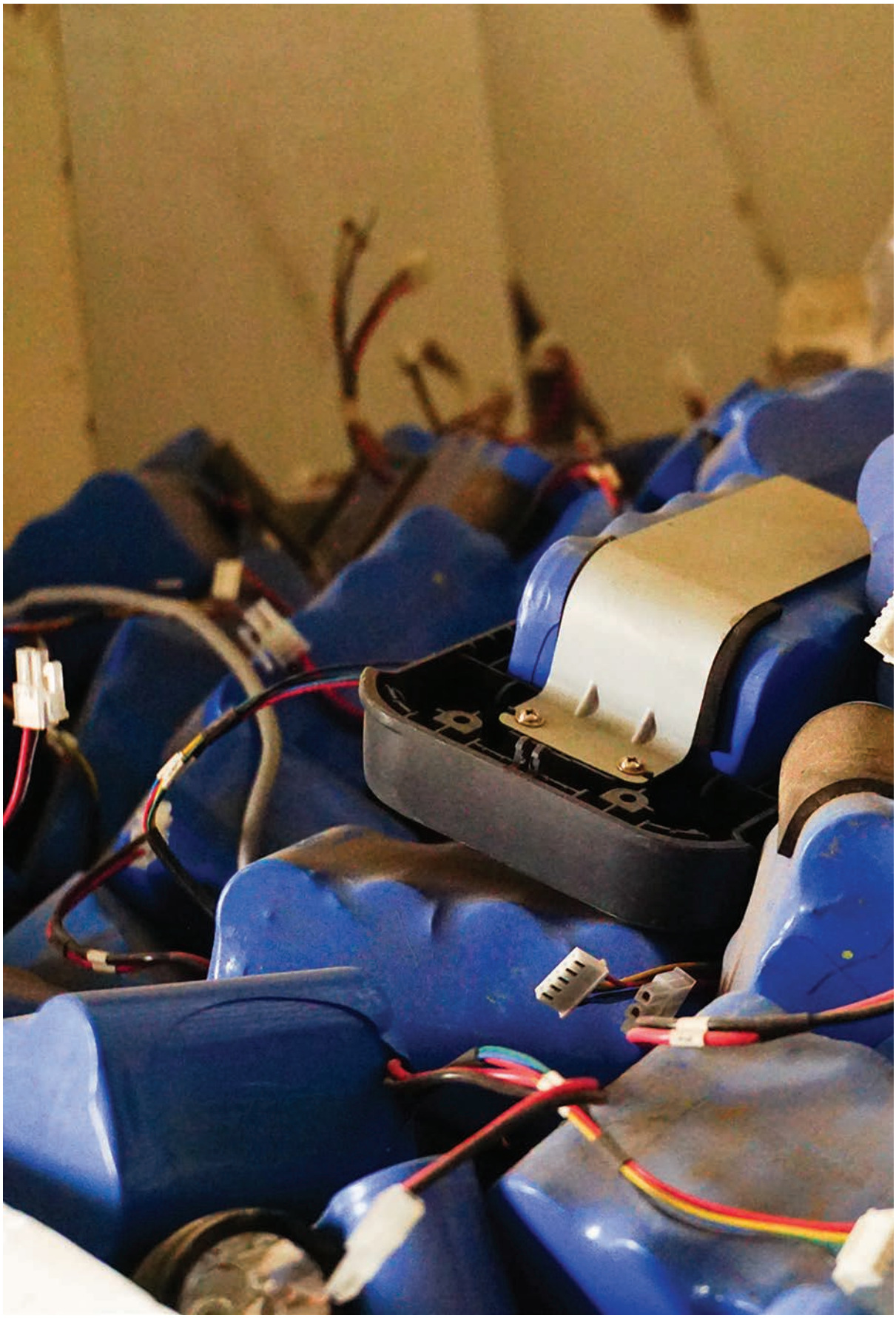
This Toolkit

This Toolkit is intended to assist World Bank Energy and Safeguards teams with analyzing E&S risks in the off-grid solar sector and adopting appropriate safeguards. This Toolkit will help project teams and counterpart governments align with the World Bank Environmental and Social Framework (ESF) and meet the mandatory Environmental and Social Standards (ESS),

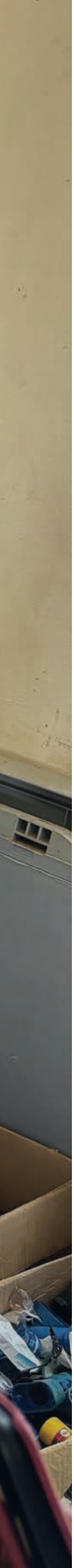
especially ESS3 (Resource Efficiency and Pollution Prevention and Management). The Toolkit is divided into four chapters followed by Annexes:

- **Chapter 1** introduces off-grid solar products, describes how World Bank projects typically promote energy access through off-grid solar (OGS), and outlines the main E&S risks associated with each market segment.
- **Chapter 2** provides an overview of the OGS e-waste challenge before sharing examples of good practice in e-waste management from the private sector, donors, agencies, and governments.
- **Chapter 3** outlines a step-by-step process project teams and government counterparts can use to assess risk, before developing and implementing appropriate safeguards.
- **Chapter 4** sketches out an inspiring long-term vision for how the OGS sector can achieve circularity and outlines the roles of key stakeholders in achieving this vision.
- **Annexes** include a set of practical tools that can assist World Bank teams in their work, allowing them to directly implement some of the Toolkit's key concepts and to align with the Environmental and Social Framework.

The draft Toolkit was tested through four energy projects promoting off-grid solar, in Malawi, Uganda, Ethiopia, and the West Africa region. Lessons learned from the testing process were incorporated into the content of this Toolkit.



ONE
THE OFF-GRID SOLAR SECTOR: PRODUCTS, PROJECTS, ENVIRONMENTAL AND SOCIAL RISKS AND SAFEGUARDS



This chapter introduces Off-Grid Solar (OGS) products and business models, describes how World Bank projects typically promote energy access through OGS, and outlines the main environmental and social (E&S) risks associated with each market segment, with a focus on the risks posed on the environmental side. It will particularly benefit energy and environmental and social safeguard specialists are less experienced with the off-grid solar sector.

About the Off-Grid Solar Sector

685 million people globally still lack access to modern and reliable electricity, and OGS represents the least-cost solution for 44 percent of households totaling to about 363 million people that need to be connected between 2022 and 2030 to achieve SDG 7—access to affordable, reliable, sustainable, and modern energy for all. The sector was already serving 490 million people in 2021, up from 420 million people in 2019, with an increasing proportion gaining access to larger systems through pay-as-you-go, a consumer financing solution that enables customers to pay overtime. In addition to providing first-time energy access, the sector also provides backup power solutions to customers with weak grid connections. The market was worth an estimated $2.8 billion a year in 2022 and having bounced back from disruptions caused by COVID-19 and other global crises, is continuing to grow. It consists of four main market segments:

- **Solar Lanterns and Multi-Light Systems**: This segment consists of basic solar lights and multi-light systems for households with a power range from 0.1 to 11Wp, capable of providing lighting and phone charging. Over 80 percent of OGS products are in this category, but the share of larger solar home systems is steadily growing, with an increasing proportion gaining access to larger systems through pay-as-you-go (PAYG).
- **Solar Home Systems (SHS)**: These larger household systems with a power range between 11 and 350 Wp are capable of powering a range of highly efficient DC-powered appliances including radios, fans, and televisions, in addition to several LED lights. The largest systems, above 50Wp, can power refrigerators and conventional AC-powered appliances. Most SHS are 'plug & play'—with the solar system and related appliances sold together in one box with no need for professional installation. Some are 'component-based', with individual components and appliances sold separately, and requiring professional installation.
- **Productive Uses of Renewable Energy (PURE)**: This segment consists of OGS powered appliances and machinery used for income-generating activities, such as solar water pumps, refrigerators, milling machines and walk-in cold rooms—sold to households, enterprises, and smallholder farmers.
- **Public Facility Electrification**: The larger OGS systems used to electrify health and education facilities, as well as other public buildings, are typically component-based requiring professional installation, and in some cases bespoke design and system sizing.

OGS products consist of solar panels, batteries, charge controllers, printed circuit boards (PCBs) wiring and appliances. Larger component-based systems, PURE systems or solutions for public facility might also include ground or roof mounting for the panels, and other components such as inverters. An OGS product starts its life as a complete unit, but individual components usually enter the waste stream at different times. For example, a battery may fail first without hindering the functioning of the solar panel or LED light.[1]

How World Bank Projects Support the Off-Grid Solar Sector

Through projects, the World Bank provides financing to Government counterparts, and assists them in designing and implementing financing solutions for companies retailing OGS products. This is achieved through a range of public funding mechanisms including upfront grants, results-based financing (RBF), tax exemptions, credit lines, and risk management instruments such as guarantees, as well as end-user subsidies and public procurement. These funding mechanisms can be implemented by government agencies or development banks, or by independent fund managers. Sometimes World Bank projects also undertake consumer awareness campaigns, market intelligence studies, and provide technical assistance to OGS companies, financial institutions, or government agencies.[2]

In the past, public facility electrification has been undertaken through engineering, procurement, and construction (EPC) contracts, which often include provisions for operation & maintenance (O&M) over a limited number of years. While this model enables facilities to be electrified at speed, it has faced sustainability challenges with government agencies lacking the capacity or funding to maintain systems over the long term. The World Bank has therefore been exploring service models through long-term contracts (10–15 years), through which private sector providers install, operate, and maintain the OGS systems. Service provision must comply with key performance indicators on the quality, reliability, and amount of electricity supply, which is remotely monitored. The systems remain property of the private sector providers, who offer energy-as-a-service, and may or may not be transferred to the Borrower at the end of the service agreement.[3] An example of this approach can be found in Box 1.1.

Off-Grid Solar Environmental and Social Risks & Safeguards

The E&S risks associated with off-grid solar systems are multifaceted, and mostly relate to the generation of electronic waste (e-waste). E-waste is one of the fastest growing waste streams in the world. The volume of e-waste generated globally increased

BOX 1.1

PUBLIC FACILITY ELECTRIFICATION IN THE UGANDA ELECTRICITY ACCESS SCALE-UP PROJECT

The Uganda Electricity Access Scale-up Project (EASP) targets the electrification of public facility like schools, health centers, and the public water supply system located far from the grid. It implements a service delivery model whereby the Ministries of Health and Education coordinate with the Ministry of Energy and Mineral Development to select contractors following a competitive bidding process. Once contractors are selected, they are responsible for the design, installation, operation, and maintenance of the system against a set of predefined Key Performance Indicators. The Uganda Energy Credit Capitalization Company provides a grant to the energy service providers to cover a portion of the capital cost of the systems, while the Ministries of Health and Education put in place Service Contracts to cover the costs related to the operations and maintenance (O&M) of the systems over 10 years. The World Bank provides performance-based grants to the Ministries of Health and Education for 5 years on the condition that timely payments are made to contractors.

The responsibility for e-waste lies with the energy service providers, as the public sector does not have ownership of the systems. To this end, the energy service providers will be required to have an Environmental and Social Management System (ESMS) that will encompass e-waste measures and reporting requirements to ensure the implementation of the measures mentioned.

by about 4 million metric tons between 2019 and 2021, with projections for it to rise to nearly 75 million tons by 2030 (World Economic Forum 2021). In Africa, total e-waste generated rose by 30 percent from 2016 to 2019 (Baldé, et al. 2017). Up to 95 percent of e-waste ends up in the informal e-waste sector, which is unregulated, where E&S risks are high.

The e-waste from off-grid solar components can be toxic, is not biodegradable, and accumulates in the environment, in the soil, air, water and living things. Exposure to some e-waste fractions, such as by workers working informally and without protection and training, can lead to irreversible health effects, including cancer, miscarriages, neurological damage, and diminished IQs. This means that some off-grid solar components at end-of-life bring about significant environmental and social risks when not properly handled,

dismantled, or treated. In most OGS markets formal disassembly and recycling facilities and infrastructures which follow environmentally-sound practices, are often not available. Those that are available are often informal and follow sub-standard health and safety practices: no personal protective equipment and ventilation, open fire burning and acid bath stripping, environmentally unsound disposal of residues, and discarding unsalvageable parts directly in the environment.

Batteries pose the highest E&S risks due to toxic substances that can directly harm health and the environment. Lead-acid batteries, commonly used in legacy off-grid solar systems, contain hazardous materials such as lead dust and sulfuric acid, posing risks of environmental contamination and major health issues if mishandled. Lead-acid batteries have a well-established and efficient infrastructure, which allows for the recycling of the vast majority of components, and the reduction of their environmental impact. Despite this, lead-acid batteries have a shorter lifespan (3 to 5 years) and lower energy density compared to alternatives such as lithium-ion, leading to more frequent replacements and greater overall material use. While simpler to recycle, the shorter lifecycle and lower efficiency of lead-acid batteries can result in a higher long-term environmental footprint compared to lithium-ion batteries.

In contrast, lithium-ion batteries offer superior performance and longevity (up to 8 to 9 years), but also pose E&S risks. Their improper handling by end-users or informal workers can result in the release of hazardous substances into water and soil, explosions, and fire hazards. Despite their higher initial cost, lithium-ion batteries have become increasingly popular due to their higher energy density and longer lifespan. However, the complex chemistry of lithium-ion batteries presents multiple technical and cost challenges in recycling and disposal, as proper management of end-of-life batteries is crucial to mitigate these risks and ensure responsible stewardship of resources.

Printed Circuit Boards (PCBs) also pose environmental risks. PCBs are often burned after they are discarded, to remove and salvage their precious metals; a process that can release dioxins and furans, which persistently pollute the environment for many years. The informal sector also often uses dangerous chemicals like cyanide and mercury to strip the gold from used-up PCBs, which contaminate water and soil, enter the food chain, and harm the health of living beings.

Solar panels present a significant E&S risk, particularly in the form of e-waste accumulation. While solar panels contain potentially toxic materials such as cadmium, lead, and silicon tetrachloride in silicon-based panels, and cadmium and selenium in thin-film panels, the environmental impact is low as compared to batteries, and can be mitigated through improved manufacturing processes, safe handling, and effective recycling programs. The sheer volume of panels installed, however, raises concerns about proper disposal and recycling, as improper handling may result in environmental degradation and negative public perception due to the visual presence of discarded panels. Photovoltaic (PV) cells have an average life of 15 to 20 years.

Other components such as electrical cables, though generally safe during use, present E&S risks at the end of their lifespan, particularly if not disposed of properly. Improper treatment of cables, such as burning to recover valuable metals, releases harmful pollutants like dioxins and furans into the environment, posing risks to human health and exacerbating environmental degradation. Cables tend to have an average lifetime of more than a decade.

Annex 1 provides a detailed breakdown of the key E&S risks associated with specific OGS product components.

Given the above, it is critical to recognize the differences between E&S risks in on-grid and off-grid electrification projects. The risks presented above for off-grid solar systems are radically different from those faced in the extension of electricity grids or the promotion of mini grids. For instance, the latter can involve acquisition of land or resettlement of people, impacting human habitats and existing public, religious, and historical infrastructure. They might also have an adverse impact on indigenous peoples or biodiversity. Such risks are not faced in off-grid solar projects, due to the small scale of the systems involved. Larger-scale off-grid solar technologies may pose further challenges as identified in Box 1.2.

BOX 1.2

COMPARISON OF E&S RISKS IN ON-GRID, MINI-GRID AND OFF-GRID PROJECTS WITH LARGER SIZED SYSTEMS

Larger-scale off-gird solar (OGS) technologies, such as productive uses of renewable energy (PURE) or public facility electrification, might pose temporary environmental risks during civil works—with possible impact on soil or water. There is also the possibility of discrimination within off-grid solar companies or contractors, as well as occupational health and safety hazards for engineers working, particularly those installing systems using AC power. Such risks can be mitigated by requiring companies and contractors to develop and implement environmental and social management systems (ESMS), taking steps to ensure technicians are appropriately qualified and trained, and ensuring accidents are monitored, documented, and prevented in line with Environmental Social Safety Standard 2 on Labor and Working Conditions. All companies should also be required to ensure there is no child or forced labor in their supply chain.

The off-grid solar sector experiences specific challenges related to e-waste management, which include the following:

- **Proliferation of poor-quality OGS products:** Products that have not been quality-verified are abundant in the market and more likely to have short lifespans, which can significantly contribute to e-waste accumulation. They are less likely to be sold with a warranty, or to be sold by companies offering after-sales services such as repair. Spare parts are also less likely to be available. A foundational e-waste management strategy is to ensure products meet quality standards, such as IEC TS 62257-9-8,[4] which covers off-grid solar products up to 350Wp. If appropriate national or international quality standards are not available, perhaps because a product category is still relatively nascent, it is still recommended to work with products that have at least been independently tested, by organizations such as Verasol (see Box 1.3).[5]
- **Low end-user awareness and lack of incentives to manage e-waste responsibly:** End-users may not know about the risks of unsafe OGS disposal, and may not have any incentive to give their OGS product back to the supplier at end-of-life, even if such an option is available to them. It may not always be possible for OGS companies—especially smaller ones—to develop take-back schemes which involve conducting consumer awareness campaigns, reaching customers in remote areas, and providing financial incentives. Consumers might not be willing to pay for repair, or for repaired, reused, and/or refurbished products, for financial and also social and aesthetic reasons. In such cases, joint awareness campaigns and collection efforts are needed.
- **OGS companies need financial and technical support to manage e-waste responsibly without passing costs on to end-users, which could exacerbate**

BOX 1.3

VERASOL: THE OFF-GRID SOLAR SECTOR'S QUALITY ASSURANCE PROGRAM

Launched in 2020, VeraSol is an evolution of the World Bank's Lighting Global Quality Assurance program. It builds upon the strong foundation for quality assurance laid by the World Bank Group and merges it with comparable product data for off-grid appliances and productive use equipment. Verasol's services include the development of test methods and quality standards, appliance testing and certification, test lab capacity building, product data sharing, technical assistance, stakeholder engagement and market surveillance.

affordability challenges and put achievement of energy access goals at risk: OGS companies operate on tight margins in price sensitive markets, where economies of scale are hard to achieve. If companies are required to implement e-waste management safeguards that incur significant costs without financial support, they will be forced to pass those costs on to end-users in the form of higher prices, making them less affordable. This risks slowing down or undermining efforts to accelerate OGS market growth to reach ambitious energy access goals. E-waste management safeguards should be carefully designed so that they do not exacerbate affordability challenges or slow down market growth rates, through the provision of financial and technical support to individual companies, and sector wide, as well as national and regional e-waste initiatives that unlock economies of scale.

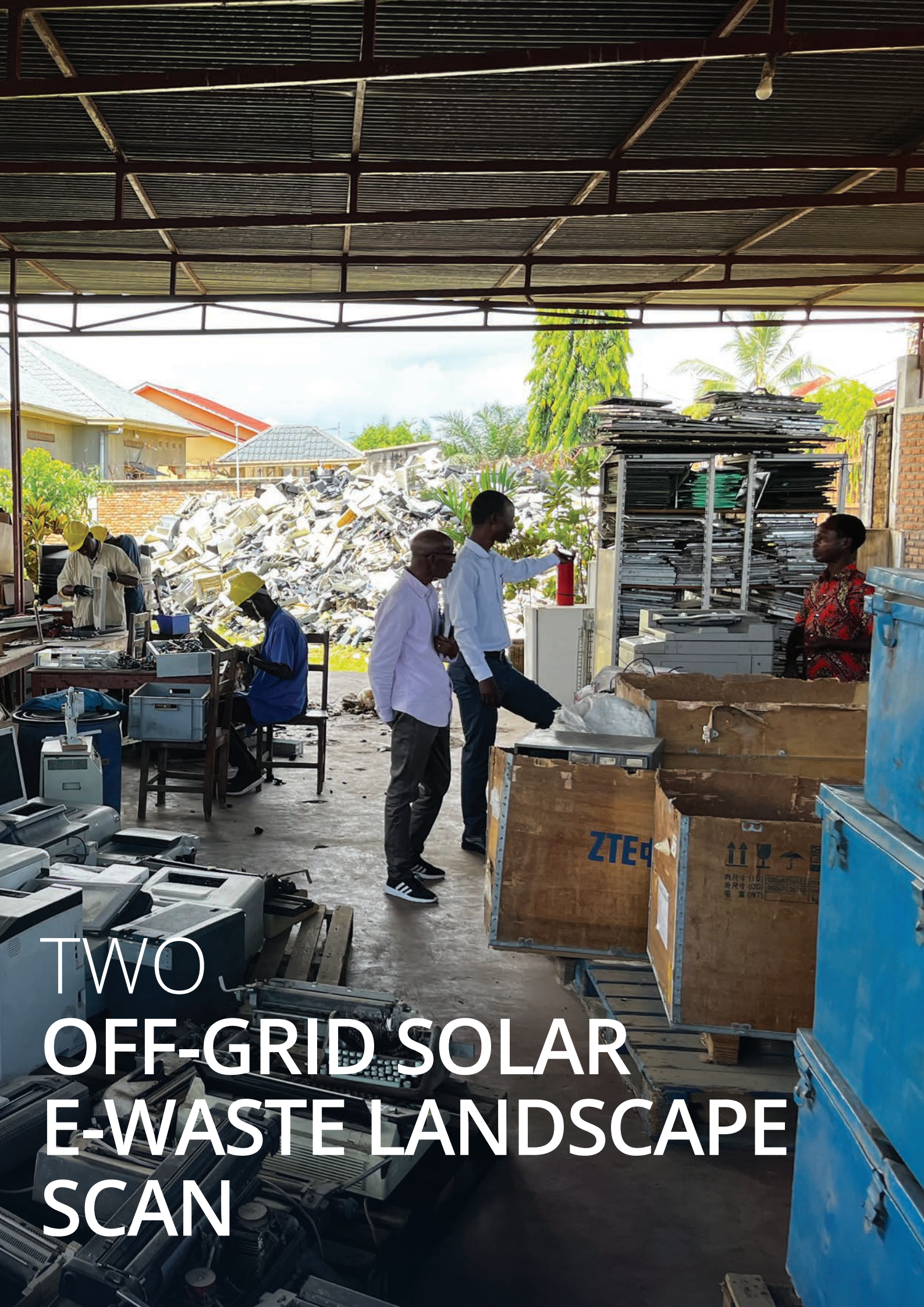
- **Insufficient e-waste treatment infrastructure:** In OGS markets, most local formal dismantlers and recyclers are small and lack the capacity to carry out specialized end-treatment to recover materials from OGS systems, and to safely dispose of the systems. Complex e-waste is therefore shipped overseas or stored indefinitely. There is little economic incentive to establish extensive OGS recycling infrastructures due to cost considerations. Recyclers also need funding and technical assistance if they are to more effectively manage e-waste. Efforts to build e-waste management infrastructure need to be carefully coordinated at national and regional levels.
- **A pervasive informal sector:** The informal sector is crucial for many livelihoods as it has low resource and skill requirements. However, it often prioritizes material recovery at the expense of health and safety. Solutions include systematically empowering informal repairers and collectors by building their skills to achieve a more comprehensive recovery of useful materials and safe disposal of system components, while also discouraging and preventing dangerous practices.
- **Little/no e-waste data:** Paper-dependent systems, high data collection costs, lack of effective reporting frameworks, and low priority for e-waste data are common issues contributing to the lack of data on e-waste management. Investments in digitizing and integrating reporting systems are required to enable efficient planning and management.
- **Lack of donor coordination:** Donor funding for e-waste management is often fragmented and sometimes deployed with limited or no coordination. Improving donor coordination can help use limited funds more efficiently, unlock economies of scale and address challenges more systematically over time.
- **Missing, ineffective and not enforced e-waste regulation:** When regulations are lacking or poorly implemented, local markets are not incentivized to implement environmentally sound e-waste management strategies. They also don't develop environmentally-sound processing industries, thereby precluding cost-effective compliance options for OGS companies. Filling-in the gaps at the national and regional regulatory level is key to ensure a sustainable enabling environment for e-waste management.

The exact challenges that need to be overcome depend on which market segment(s) a project is focused on, on the maturity of the markets the project is seeking to support, and on the size and capacity of companies participating in the project.

- **Market segment:** For solar lanterns, home systems and PURE, households and businesses decide what to do with products at end-of-life. For public facilities, the decision might lie with a firm responsible for providing O&M under an Engineering, Procuring and Constructing (EPC) contract or an Energy-as-a-Service contract, or with the beneficiary ministry. In each case the challenges around end-user awareness, product design, and capability—and the corresponding funding and support needs - are different.
- **Market maturity:** Less mature markets with smaller companies typically face a wide range of e-waste challenges including limited consumer awareness; companies with limited product take-back, reverse logistics or repair/refurbishment/recycling capability; inadequate e-waste infrastructure and little/no e-waste regulation. More mature markets might benefit from greater consumer awareness and company capacity, but most still have limited e-waste infrastructure or e-waste regulation.
- **Company size and capacity:** Larger companies, active in multiple markets, or those focused on selling larger SHS on PAYG, are more likely to have developed in-house capacities for repair, reuse, refurbishment, and e-waste management. Smaller OGS companies or those focused on selling more basic solar lanterns, may lack any product take-back, reverse logistics, repair, or refurbishment capability. Acknowledging these differences is crucial in crafting effective strategies to address e-waste challenges within the diverse landscape of the off-grid solar industry.

Endnotes

1. For more information on off-grid solar products and business models, see the Off-Grid Solar Market Trends Report 2022: State of the Sector (Lighting Global/ESMAP 2022).
2. For more information, see Designing Public Funding Mechanisms in the Off-Grid Solar Sector (Rysankova and Miller 2022).
3. For more information, see Livewire: Increasing Human Capital by Electrifying Health Centers and Schools through Off-Grid Solar Solutions (Elahi, Srinivasan and Mukurazhizha 2020). Further resources on the World Bank and ESMAP's public facility electrification agenda can be found at: https://www.lightingglobal.org/activities/electrifying-schools-health-facilities/.
4. IEC TS 62257-9-8 is a technical specification published by the International Electrotechnical Commission (IEC). It provides guidelines and requirements for the testing and verification of standalone renewable energy products, particularly focusing on small photovoltaic (PV) systems and components intended for use in rural and off-grid areas.
5. For more information on VeraSol: https://verasol.org/.



TWO
OFF-GRID SOLAR E-WASTE LANDSCAPE SCAN

This section aims to provide a basic understanding of good practices in the off-grid solar e-waste landscape undertaken by private sector, development partners, and governments.

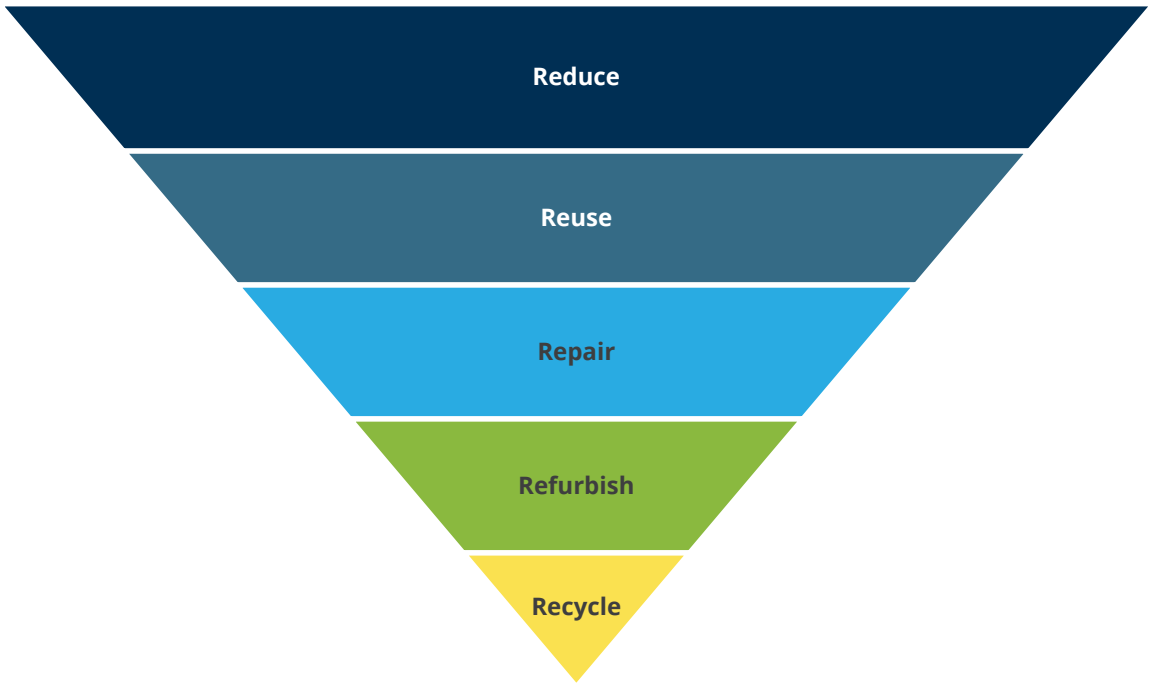
Improving OGS E-Waste Management | Learning from Good Practices

Off-grid solar e-waste is an output that can be minimized by intervening at the previous product lifecycle steps—such as product design, production, and usage—as promoted by the concept of the circular economy.

The 5Rs (reduce, reuse, repair, refurbish, recycle) highlight how multiple measures can be incorporated at different stages of the off-grid solar product lifecycle. The waste hierarchy presented below ranks e-waste management options according to what is best for the environment (Figure 2.1). Interventions at the top of the 5R hierarchy are better for the environment and more cost-effective in the long run; as such, actors should focus on providing efforts in the reduce, reuse, and repair areas in order to minimize e-waste streams.

FIGURE 2.1

The 5Rs and the E-Waste Hierarchy



The off-grid solar sector shows already examples of good practices based on the 5Rs as implemented by the private sector, donors, and Governments. These practices build on the understanding that only intervening at the end-of-life of systems represents a costly and ineffective practice.

As an overview, at the *reduce* level, stakeholders aim to intensify the use of products, increase efficiency, functionality, use time, and durability. This translates into implementing eco-design strategies, modular products and business models, and promoting energy-as-a-service models. At the *reuse* level, rental models, and resale of repossessed SHS are common strategies to promote direct utilization of products by different users. As for *repair,* stakeholders promote repair and regular maintenance of solar products, as well as harvesting spare parts from non-functional systems. *Refurbishment* consists in the restoration or remanufacturing of a product to a quasi-original state; this practice is mostly used for lead-acid batteries and increasingly for lithium-ion batteries. Finally, *recycling* practices count on processing components and materials for other use.

Further examples of good practices are shared below, arranged by key stakeholder group.

Good Practices from the Private Sector

Off-grid solar products can be designated as affiliate and non-affiliate.[1] Non-affiliate solar lanterns are sold through distribution channels that include street vendors, hardware stores, and other informal sellers. In general, these products do not come with any warranty or after-sale support. On the other hand, affiliate solar lanterns are required to come with a warranty and after-sale support, although the capability for replacement and repair by the company tends to be varied. The quality of non-affiliate solar lanterns varies widely; however, even quality assured products tend to have only a 1 to 2-year warranty, with life spans of only a few years (Munro, et al. 2023). Larger systems, such as SHS, offer a more complex spectrum. Some companies selling SHS tend to have in-house repair capability, although these systems can also be repaired by third parties.

The off-grid solar private sector shows numerous voluntary efforts along the 5Rs (Table 2.1). Many of the larger and most vertically integrated companies have been successful in implementing e-waste mitigation measures along the entire value chain. This includes reverse logistics for disposal: informing end-users on risks and how to dispose of their OGS products, take-back schemes, working with recyclers to transport and recycle the collected e-waste, jointly trying to prove concepts and overcome challenges such as the cumbersome transportation across markets. Some efforts have even broader circular economy and consumer protection implications, such as providing extended warranty, or repair through in-house or affiliated technicians. Coordinated efforts such as industry-led Producer Responsibility Organizations (PROs) have also gained traction, aiming through e-waste aggregation to get better e-waste recycling prices for members.

TABLE 2.1

Examples of Good Practice Efforts Undertaken by the OGS and E-Waste Management Private Sector

INTERVENTION	RE-DUCE	REUSE	REPAIR	REFURBISH	RECYCLE	WHAT DOES THIS ENTAIL?	EXAMPLE OF IMPLEMENTING COMPANY
Take-back of non-functioning products			X	X	X	Offering cost-effective takeback schemes and recycling programs to their consumers for end-of-life products	• Fenix • d.light • Engie
Extension of product life through repair	X		X			Offering repair services for products along with Internet-of-Things solutions for remote support and troubleshooting	• SunnyMoney • Apex Solar • Innovex
Upcycling used product components				X	X	Reintroducing secondary materials into the process, through upcycling and refurbishment of product components, which includes reusing functioning Lithium-ion tubes to create refurbished batteries	• SunKing • Suncrafter • Rinovasol • FINCA
Resale of used solar products	X	X				Selling repaired and refurbished products and upcycled product components	• EnergyBin • SunKing • Qotto
Building second-hand markets for used products	X	X	X			Building web platforms to connect with PV professionals for integrated solutions on repair, resale, and recycling	• pvXchange • SecondSol
Improvement of recycling technologies		X			X	Developing recycling technologies which enable better sorting of reusable secondary materials, ensuring maximum efficiency in the value chain	• Suez • Reclaim PV recycling • EnviroServe
Enabling the informal sector to manage E&S risks and contribute to waste collection	X	X	X	X	X	Providing training to informal sector workers to better integrate them into the formal reverse supply chain in developing countries, to serve different electronic markets, such as OGS	• Hinckley
Producer Responsibility Organisations (PROs)		X	X	X	X	Creating Producer Responsibility Organizations that handle e-waste management in exchange for a fee	• Karo Sambhav • Recupel • EPROK
Consumer education on E&S risk management and product management					X	Informing end-users on proper disposal, and on E&S risks related to improper e-waste handling	• We Tu • Solibrium Solar Ltd.

Several 5R measures are adopted before products reach their end-of-life, notably at the design and manufacturing; software development; distribution; and installation, operation and maintenance stages.

At the design and manufacturing level, some companies adopt eco-design standards and VeraSol quality assurance to enhance durability. Furthermore, product design can enhance repairability although, as of now, many affiliate products are designed to be repairable only by the brand itself, and many solar lanterns are not repairable at all. At the software development level, larger off-grid solar products have tracking and monitoring capabilities, which can flag when repair and replacement may be needed. Software can be built in-house to support repair technicians. At the distribution level, some off-grid solar companies offer direct product replacement or repair under warranty under PAYG via the energy-as-a-service model. However, companies that only engage in distribution or that are limited in size might be reluctant to offer extended repair and take-back schemes due to complex logistics and high-internal costs. At the installation and O&M level, off-grid solar companies can offer direct component replacement, and repair of small systems under warranty, or repair of larger systems under O&M contracts. third-party repairers can also be involved in the maintenance of component-based and unaffiliated products.

Once products reach their end-of-life, some off-grid solar companies hire the services of e-waste management firms individually or via PROs to manage their e-waste, the latter still being a scarce practice. Without applying steps all along the whole 5R chain, relying only on recycling of off-grid solar products can be very difficult for off-grid companies, due to lack of sufficient infrastructure, high costs and logistical constraints. third-party informal collection and recycling is abundant, and often beyond the control of off-grid solar companies. Large recycling firms can sell spare parts and salvage components, like for battery refurbishment, to improve their profitability.

Good Practices from Donors and Development Partners

In the off-grid solar sector, donor interventions on e-waste are limited and typically utilize technical assistance, financial mechanisms, and program eligibility criteria & voluntary standards (Table 2.2).

Firstly, donors can provide knowledge, capacity building and training for local communities, businesses, and policy makers. Several studies and toolkits have been created with donor efforts and funds on topics like policy making, proper dismantling techniques, hazardous material handling, and recycling processes. By providing knowledge and training on e-waste management, donors and partners can empower different stakeholders to handle e-waste in a safe and environmentally friendly manner.

Secondly, financial mechanisms are also critical to implement e-waste measures in the off-grid solar market. Grants are instrumental in funding projects aimed at improving e-waste management practices, but their implementation has been limited. Donors and development partners can allocate grants to support research and development, pilots,

TABLE 2.2

Examples of OGS E-Waste Good Practice Efforts, by Donors and Development Partners

TYPE OF ASSISTANCE	RE-DUCE	REUSE	REPAIR	REFURBISH	RECYCLE	WHAT DOES IT ENTAIL?	EXAMPLES
Technical	X				X	Developing capacity building resources like toolkits and handbooks for the private sector and for governments	• GOGLA E-Waste Toolkits (1 & 2) • CDC E-waste Toolkit • World Bank E-Waste Toolkit • Beyond the Grid for Africa, E-waste Policy Handbook (2019) • Oeko Institute toolkit for GIZ • GOGLA Guidance for Governments • IOM Guidance for Humanitarian Organizations and Displacement settings
	X				X	Facilitating the formation of industry associations in the private sector	• EU, Global Environment Fund facilitating industry associations like the Solar Industry Association of Zambia
	X				X	Formalizing informal sector entities through capacity building	• E-MAGIN GHANA funded by EU (SWITCH Africa Green Program)
Financial	X	X	X	X	X	Incentivizing the sectoral linkages between the recycling and OGS private sectors by funding small-scale pilot programs	• CDC (now BII) funding to Enviroserve for capacity upscaling • Grant initiatives like the Global Leap awards to e-waste recyclers
	X	X	X	X	X	Providing upfront grants to initiate collective action by the private sector	• EnDev's funding to Kenya Solar Waste Collective enabled establishment of a voluntary OGS e-waste PRO
	X	X	X	X	X	Providing upfront grants to fund Research & Development and eco-design pilots	• Global LEAP awards, implemented by Efficiency for Access Coalition
	X	X	X	X	X	Providing funding to governments for sectoral studies to create baseline information for e-waste in the sector	• GEF funding for a report on e-waste legislations and financing mechanisms in Ethiopia • DFID funded report on landscape assessment of e-waste management in Rwanda (2017)
	X	X	X	X	X	Funding sectoral infrastructure to assist governments in closing the infrastructure gap in e-waste management	• WEEECAM project funded by French institutions to scale up e-waste collection and recycling in Yaoundé and Douala, Cameroon • GEF-funded and UNIDO-implemented project in Abidjan for infrastructure development

(*continues*)

TABLE 2.2

Examples of OGS E-Waste Good Practice Efforts, by Donors and Development Partners (*Continued*)

TYPE OF ASSISTANCE	RE-DUCE	REUSE	REPAIR	REFURBISH	RECYCLE	WHAT DOES IT ENTAIL?	EXAMPLES
Program Eligibility	X				X	Incorporating e-waste management requirements in program eligibility (for Governments and private sector) to mandate the incorporation of OGS e-waste management practices.	• EnDev Mali has a comprehensive e-waste management strategy to screen projects • BGFA eligibility criteria (requiring e-waste policy and plan) • Triple Jump eligibility criteria (requiring e-waste champion appointment)

infrastructure development and community-based initiatives, such as setting up collection centers, implementing awareness campaigns, and conducting training programs on e-waste management. Pilot projects provide valuable insights into the effectiveness and cost of e-waste management strategies and technologies in real-world settings. Financial support for pilot programs allows stakeholders to test new approaches, refine processes, and identify best practices that can be scaled up for broader implementation. Pilots also facilitate collaboration between different actors, including government agencies, NGOs, and private sector entities, fostering a holistic approach to e-waste management. Financial support for research and development (R&D) is essential for driving innovation in e-waste recycling technologies specific to off-grid solar products. By supporting research initiatives, donors and development partners enable scientists and engineers to explore novel methods for recovering valuable materials from solar panels, batteries, and other components.

Thirdly, eligibility criteria and voluntary standards for off-grid solar projects serve as pivotal mechanisms in managing e-waste streams by instilling sustainable practices across the lifecycle of solar products. These criteria and standards drive innovation in product design and business models by incentivizing manufacturers to create durable, repairable, and recyclable solar solutions. Quality assurance benchmarks, such as VeraSol's, increase durability, reduce premature failures, and minimize e-waste generation. Additionally, these initiatives promote responsible end-of-life management practices by requiring provisions for take-back programs, recycling schemes, and refurbishment initiatives, ensuring of or repurposed to minimize their environmental impact. Furthermore, monitoring and reporting requirements embedded within these standards promote transparency and accountability, enabling donors and stakeholders to track progress in e-waste management efforts and identify areas for improvement.

In addition to the above, fostering collaboration and coordination among stakeholders is essential for effective off-grid solar e-waste management. Donors, development partners, governments, NGOs, and the private sector all play crucial roles in addressing this issue. By forming partnerships and pooling resources, investment, expertise, and best practices, stakeholders can maximize the impact of their efforts and create synergies that lead to more sustainable e-waste management systems. Coordination also helps avoid duplication

of efforts and ensures that interventions are aligned with local needs and priorities. Through collaborative approaches, donors and development partners can leverage their collective strengths to create lasting solutions for off-grid solar e-waste management. Successful examples of impactful coordination can be found in Box 2.1.

Good Practices from Governments

Governments have targeted the incorporation of e-waste management in the OGS value chain in multiple ways (Table 2.3). Tax exemptions on certain off-grid solar products can promote products with certain qualities such as eco-design. Studies on national-level e-waste capacities and capabilities, harmonized product taxonomies and e-waste categorization, and incentive schemes for recyclers, eco-design, and repair have also been sporadically implemented.

BOX 2.1

GLOBAL LEAP SOLAR E-WASTE CHALLENGE

The Global LEAP Solar E-Waste Challenge, implemented by the Efficiency for Access Coalition, provides OGS companies and recyclers with the capital to pilot their winning ideas and innovations.

d.light piloted a take-back scheme in Kenya, with the funds they won, in which they offered discounts for new off-grid solar products to those willing to return their non-functioning systems to retail shops and field agents. By the end of the program, 200 collection points were created. After the pilot, d.light slightly reduced the discount, which did not dissuade consumers from returning their non-functioning products. The project aimed at achieving multiple objectives: to educate companies and individuals on proper e-waste disposal; to increase e-waste collection rates; to facilitate design of second life battery packs and explore their applications and business models; and increase capacity to treat solar e-waste fractions. d.light is currently scaling up the lessons learned and practices from the pilot.

Hinckley, another winner from the challenge, utilized the funds to increase and improve their logistics for solar e-waste collection in remote areas of Nigeria, to ensure that products are recycled safely. The funds also contributed to innovation through procurement of better equipment and upscaling of local capacity building for their solar e-waste recycling facility.

TABLE 2.3

OGS E-Waste Initiatives Taken by Governments

INTERVENTION	REDUCE	REUSE	REPAIR	REFURBISH	RECYCLE	WHAT DOES THIS ENTAIL?	EXAMPLES
Implementation of laws/policies based on EPR Framework	X				X	Introducing policies and regulations on EPR for e-waste (and specifically OGS e-waste)	Nationwide draft e-waste policies including: • Kenya: EPR regulation (2020) mandates registration with National Environment Management Authority and joining a PRO • Ghana: E-waste/eco levy charged from manufacturers and importers of Electrical & Electronic Equipment for financing e-waste management • South Africa: EPR Regulations (WEEE Notice 2020) mandates all Producers to register and implement an EPR Scheme • Rwanda: EPR regulations (2018 and 2024) establish the polluter pays principle for all electronic sectors in the country.
Data generation and capacity building	X				X	Financing studies, to generate data on specific products, their components, recycling requirements, and current practices to help develop informed policies and training programs	At the national level: • Blueprint on management of antimony containing glass from end-of-life Solar PV panels, Central Pollution Control Board (2017), India • Ministry of Information, Communication and Technology and Namibia Statistics Agency study on national capacity building on e-waste data and statistics, Namibia
Incentivizing sales of high-quality products through tax exemptions			X	X		Providing tax exemptions to facilitate competitive pricing in the market and incentivize the consumers to avail durable, superior quality products at lower prices	At the national level: • Rwanda (2014) introduced VAT exemptions for solar lighting • In Kenya and Tanzania, solar products are VAT and tariff exempted
Incentivizing recovery of critical secondary resources from e-waste			X	X	X	Incentivizing formal recycling facilities to encourage their formalization and recovery of precious metals	Nationwide Scheme for Promotion of Manufacturing of Electronic Components and Semiconductors (SPECS), India

(*continues*)

TABLE 2.3

OGS E-Waste Initiatives Taken by Governments (*Continued*)

INTERVENTION	REDUCE	REUSE	REPAIR	REFURBISH	RECYCLE	WHAT DOES THIS ENTAIL?	EXAMPLES
Eco-design policies for easing downstream recycling processes			X		X	Integrating a holistic and circular perspective right at the design stage for PV products (excluding building integrated PV panels) by mandating manufacturers to plan for eco-design principles like recyclability, extended life, repairability, etc.	At the regional level in EU: • Eco-design Directive (2009) • Proposal for Eco-design for Sustainable Products Regulation (March 2022) • Eco-design and Energy Labelling Working Plan 2022–2024
Facilitating Electrical & Electronic Equipment repair through legislation			X			Incorporating the right to repair into Electrical & Electronic Equipment Linked policies to improve consumers' access to repair services beyond the guarantee period and motivating manufacturers to design repairable products with readily available parts	• State-level Bill for Fair Repair Act, New York (2021–22) • Region-wide Right-to-Repair Policy, EU*
Proper categorization of OGS e-waste	X					Mandating proper categorization of e-waste to ensure effective and safe collection, dismantling, processing, and disposal	At the state-level in the US: • California classifies solar waste as universal waste, as opposed to hazardous waste
Proper collection and recycling of e-waste including solar waste	X				X	Introducing legislative frameworks or creating institutions that require manufacturers to abide by collection and recycling standards to help create a uniform practice and channel financing for proper collection and recycling of generated solar e-waste	At the state-level in the US: • Solar Panel Collection Bill – New York (2018) • PV Module Stewardship and Takeback Program – Washington (2017) • Bill on establishing solar waste recycling committee – New Jersey Nation-wide, SENS Foundation by the Swiss Government

(*continues*)

TABLE 2.3

OGS E-Waste Initiatives Taken by Governments (*Continued*)

INTERVENTION	REDUCE	REUSE	REPAIR	REFURBISH	RECYCLE	WHAT DOES THIS ENTAIL?	EXAMPLES
Safe disposal of PV modules					X	Restricting disposal of Electrical & Electronic Equipment (including OGS) products in landfills through bans, waste categorization and collection programs	• At the regional-level – EU Landfill Directive (1999) • At the state-level – Solar Panel Collection Bill – New York (2018)
Exim policies for solar modules	X				X	Regulating export and import of PV modules, particularly end-of-life products and providing necessary checks to inhibit their misappropriation	At the regional level, several arrests and seizures made in Umbria, Italy for dumping PV modules as 'recycled waste' in other countries

*Still in development

Off-grid solar e-waste is one of multiple e-waste streams in a country which must be addressed within a national e-waste regulatory framework. To date, however, most countries which host OGS markets still do not have an overarching framework for e-waste management,[2] and where one exists, it is usually not effectively enforced or designed for administrative and impact efficiency. Off-grid solar e-waste is now often regulated as hazardous waste and is often subject to relevant national regulations, standards, and guidelines. This ensures stricter regulations and safer handling practices, minimizing the risk of environmental contamination and health hazards, and also raises awareness about the potential dangers of e-waste, prompting more responsible consumption and disposal behaviors. Global conventions and standards also play a role. On a single market level, while they are not legally binding, they can drive the national frameworks forward, providing a common point of reference.

Most national policy instruments targeting e-waste globally follow the concept of extended producer responsibility (EPR) (Sofies 2021). EPR creates incentives for all the 5Rs to be implemented and shifts the responsibility for e-waste collection, management, and safe disposal through recycling to producers and importers in line with the polluter-pays principle.

E-waste management is a cross-sectoral issue for a country, calling for extensive inter-institutional coordination. Often, however, mandates and coordination areas between ministries (Environment, Finance, and other ministries), regulators, and implementing agencies are either unclear or fragmented. Having a clear institutional lead, mandates, responsibilities, and coordination mechanisms is critical when it comes to

policy making, regulation, and enforcement in e-waste management. While the overall mandate holder might best be the Ministry of Environment (or as it often happens—the Ministry of Telecommunications), it is recommended that the Ministry of Energy and/or other national agencies promoting and regulating electrification through solar are also involved. The high risk of developing e-waste regulation unfit to capture e-waste from the OGS sector, and of the negative perception created by OGS e-waste (including injuries or health issues) can slow down electrification and energy access, making e-waste management a core issue of interest for these agencies. They can formally engage in the overall national e-waste management dialogue, for example, by participating in an inter-ministerial working group on e-waste.

Legislative interventions and reforms can take considerable time, be costly and hard to quantify. However, small interventions (e.g., EPR-related studies or technical assistance (TA) contract on the set-up of transboundary shipment procedures) can be performed with a maximum budget of €1 million. Annex 6 provides a list of global and regional conventions and standards governing e-waste and Box 2.2. provides an example of EPR policy development and implementation.

BOX 2.2

E-WASTE EXTENDED PRODUCER RESPONSIBILITY POLICY DEVELOPMENT AND IMPLEMENTATION IN INDIA

Extended producer responsibility (EPR) legislation for e-waste was first introduced in India in 2012 and saw limited impact until 2014. In 2016, due to litigation at the National Green Tribunal and following an industry consultation, rules were revised for better enforcement. India (and many developing markets) faced two foundational challenges: (1) the current lack of disaggregated e-waste data at the national and sub-national level, and (2) the difficulty to gather traction to approve e-waste EPR laws.

The EPR framework has been significantly strengthened since 2016, and a series of new measures were introduced, including collection targets, producer responsibility organizations (PROs), e-waste exchanges, and deposit re-fund schemes. A centralized EPR portal was established to streamline and track e-waste flows across the value chain (Sofies 2021).

Endnotes

1. Affiliate companies are connected to any of the partner organizations involved in the semiannual GOGLA sales data reporting process. This matrix of companies includes GOGLA members, companies selling products that meet VeraSol quality standards, and appliance companies that participated in the Global LEAP Awards or are engaging with the Low Energy Inclusive Appliances (LEIA) program. GOGLA, ESMAP. Off-Grid Solar Market Trend Report. 2022.
2. The GSMA Platform provides a comprehensive overview of the e-waste legislative landscape in Africa and South Asia, in 2020. For more information, please consult: https://www.gsma.com/mobilefordevelopment/e-waste-legislative-framework-map/

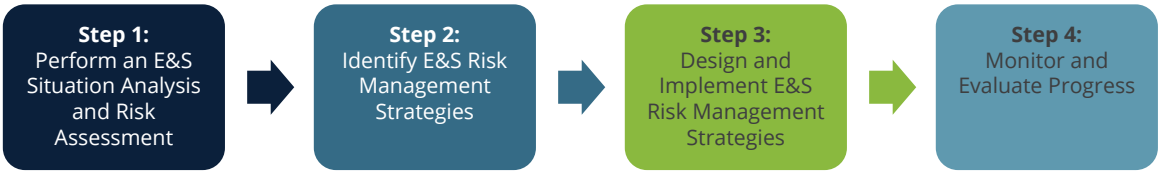
THREE ENVIRONMENTAL & SOCIAL RISK MANAGEMENT GUIDELINES

The chapter outlines a step-by-step process which World Bank energy teams, Environmental and Social (E&S) specialists, and government counterparts can use to: (1) conduct an E&S situation analysis and risk assessment; (2) select mitigation strategies; (3) design and implement mitigation strategies; and (4) monitor and evaluate e-waste management. It is intended for teams that have completed risk assessment and now need to select and design appropriate risk management strategies (Figure 3.1).

At the request of counterpart governments, the World Bank can provide Hands-on Expanded Implementation Support (HEIS) during the preparation and implementation of a project's environmental and social safeguards. However, this does not substitute the Borrower's responsibility to meet the requirements of the World Bank's Environmental and Social Framework. This support is provided in addition to the World Bank's own E&S due diligence process.

FIGURE 3.1

Off-Grid Solar E-Waste Management Process



Step 1 | Perform an E&S Situation Analysis and Risk Assessment

As a first step, World Bank project teams and government counterparts are encouraged to undertake an E&S situation analysis, ideally at the project identification stage or as early in the project cycle as possible. This helps to understand the size and characteristics of the e-waste challenge, to identify the most appropriate mitigation strategies based on a stakeholder capacity assessment, as well as analysis of available e-waste infrastructure and the status of any relevant policy/regulatory frameworks. This market intelligence and insight can then be used to develop an E&S risk assessment and appropriate mitigation strategies. A situation analysis can:

1. **Estimate the Size and Characteristics of the OGS E-Waste Challenge:**
    - Estimate the quantity of OGS products in each market segment already in the market, based on recent OGS market assessments or stakeholder consultations
    - Estimate the quantity of OGS products in each market segment that will be added over the course of the project, with reference to project targets
    - Estimate the volume of OGS e-waste likely to be generated during the project lifespan, ideally in tons and split out by fraction

2. **Assess Stakeholder Capacity to Handle OGS E-Waste, with a particular focus on the OGS Private Sector:**
    - Understand any activities and good practices OGS companies are already doing in areas, such as product take-back, reverse logistics, repair, refurbishment, or recycling
    - Get feedback from OGS companies regarding end-user awareness of e-waste issues, as well as financial and technical barriers preventing them from doing more to ensure sound e-waste management
    - Learn about the Borrower's previous experience with off-grid solar projects and their e-waste, capture lessons learned from any previous e-waste initiatives undertaken, and assess the capacity to implement e-waste E&S risk management measures
    - Find out more about current, previous, or planned OGS e-waste management activities undertaken by donors, other government agencies and institutions, recyclers, consumer protection associations, or NGOs
    - Map stakeholders and assess the capacity of institutions to play a role in e-waste management policy making and enforcement
3. **Assess the Strength of E-Waste Infrastructure**
    - Map and assess the strength of e-waste management infrastructure in the market, such as:
        - Informal or formal e-waste collection networks
        - How e-waste is transported and stored
        - Whether there is any formal or informal disassembling and recycling infrastructure in the market or regionally
        - What working conditions are like in e-waste value chains
        - How e-waste management costs are currently covered
    - Identify key e-waste routes and regional linkages, if used by companies or recyclers
4. **Analyze the E-Waste Policy Environment**
    - Identify any policy, legislative and regulatory requirements, processes, and procedures that exist for the assessment and management of e-waste and hazardous waste
    - Assess the extent to which existing policy and regulatory frameworks are meaningfully enforced
    - Review OGS product, component, and fraction import and export legislation, to determine whether e-waste can be sent across borders for treatment

This kind of analysis, based on literature review and stakeholder consultation, can either be undertaken in-house by World Bank teams or government counterparts, or through developing a Terms of Reference and hiring a firm. It can be undertaken as a standalone exercise or undertaken in conjunction with other assessments, such as off-grid solar market assessments, assessment of the Borrower's E&S Framework, or regional Environmental and Social Assessments.[1] In general, if a situation analysis needs to be completed quickly or at low-cost, it is best to undertake it in-house. If there is time and budget—or E&S risks are likely to be particularly high - then it is recommended to hire a firm or consultant to explore the issue in more depth, and perhaps undertake additional primary data collection. Firms undertaking e-waste situation analysis can also support with developing E&S risk assessments, with design and costing of mitigation strategies, and with capacity including, in needed. Examples of how a situation analysis was performed in WB project can be found in Box 3.1.

BOX 3.1

EXAMPLES OF CHANNELS USED TO PERFORM A SITUATION ANALYSIS

In 2023, four World Bank projects tested this Toolkit and decided to undertake an e-waste situation analysis using different channels. In Malawi, the analysis was performed by the E&S specialists of the Borrower. In Uganda, the World Bank team took over the process, providing insights to the Borrower project team. In West Africa, the World Bank and Borrower teams decided to wait for the Borrower's environmental specialist to be hired and involved in the process. Finally, in Ethiopia, the team decided to hire an external consultant to perform this work.

Building on a situation analysis, World Bank project teams and government counterparts can then complete a Risk assessment. This involves categorizing the main potential E&S risks in terms of the projected scale and severity of their *impact* if they do occur. The *impact* of an E&S risk can be defined with reference to Good International Industry Practice (GIIP) in E&S management.[2] The *scale* on which a risk is likely to occur, in the absence of risk management strategies, can be determined based on the project design and the e-waste situation analysis. If scale and impact are both considered to be high, the overall level of risk can be considered high—correspondingly, if scale and impact are low, the risk can be considered low.

Considering five categories of E&S risk sources—those related to: (1) products; (2) end-users; (3) OGS business models; (4) e-waste infrastructure; and (5) policy—can help to identify appropriate risk management strategies. A summary E&S Risk Assessment table using this approach is provided in Table 3.1.

Some project types present challenges to effective early screening and risk identification due to their characteristics and design. These include but are not limited to: TA projects; framework/programmatic projects which finance programs or a series of projects which are not defined in advance with respect to the timing, location, and/or type of investments; financial intermediation projects; projects in post emergency or in fragility, conflict, or violence settings; and regional projects with activities and implementing partners across several countries.

TABLE 3.1

Example Environmental & Social Risk Assessment Table

RISK CATEGORY	ENVIRONMENTAL OR SOCIAL	RISK	SCALE	IMPACT
Products	Environmental	Low product quality means products and components have short lifespans and are more frequently disposed of	**Low:** Most products in the market are quality-verified **Medium**: Some products are quality-verified **High:** Few products are quality-verified	Medium
End-Users	Environmental and Social	Improper disposal of OGS products into municipal solid waste streams/in fields/rivers, etc. because of lack of awareness	**Low:** High awareness of proper disposal **Medium:** Some awareness **High:** No consumer awareness	Medium
OGS Business Models	Environmental	OGS companies unable to take-back and handle products at end-of-life	**Low:** Most companies have product take-back, reverse logistics, and repair/refurbishment/recycling capability **Medium:** Some companies have some e-waste management capability **High:** No companies have any e-waste management capability	Medium
E-Waste Infrastructure	Social	Pollution from improper disposal of lead acid or lithium-ion batteries	**Low:** Most batteries are collected and recycled in facilities operating to high health & safety standards **Medium:** Some batteries are collected and recycled at facilities with medium health & safety standards **High:** All or most batteries likely to be disposed at facilities with low health & safety standards	High
Policy	Environmental	Lack of meaningfully enforced e-waste regulation in mature market means companies are not required to manage e-waste from their products	**Low:** E-waste regulation meaningfully enforced **Medium:** E-waste regulation with some enforcement **High:** No e-waste regulation in place	Medium

Step 2 | Identify E&S Risk Management Strategies

E&S Risk Management Strategies

Once risks have been identified, appropriate and proportionate risk management strategies must be identified to avoid, minimize, mitigate, or compensate for the identified risks. Table 3.2 provides an overview of the main risk management strategies available to World Bank OGS projects, categorized by risk type and placed on a spectrum from 'Core' interventions which can be implemented directly by the project at relatively low cost, to

TABLE 3.2

Core, Best to Have, Ambitious Framework for Risk Management Strategies in World Bank OGS Projects

	CORE	BEST TO HAVE	AMBITIOUS
Products	Where quality standards exist, project only supports quality-verified products. If quality standards are not available, project only works with products that have been independently tested by accredited labs. Products are sold with warranties lasting at least one year for solar lanterns and appliances, or two years for SHS.[a] Lithium-ion batteries are used, rather than lead-acid, whenever possible. Battery life is monitored.	Product warranties are extended to two years for lanterns and appliances, and three years for SHS.	Product design for repair, recycling, and less use of hazardous materials (eco-design).
End-users	Companies provide customers with guidance on risks, maintenance & disposal in-person and in writing at point of sale and/or throughout the relationship with the customer.	Nationwide consumer awareness campaigns provide information on E&S risks and disposal options.	Well-designed incentives for end-users to return out-of-warranty products.
OGS Business Models	Companies replace or repair OGS products or components that fail under warranty. Companies have basic e-waste management policies, procedures, and action plans in place, in line with GOGLA's E-Waste Toolkit (GOGLA 2024). Depending on the size and sophistication of the company, these could cover areas such as: • Safe storage • Product take-back schemes • Reverse logistics, collection points • Repair • Partnerships with recyclers, if possible • Forecasts and monitoring of quantities of end-of-life products and components	Industry-level take-back schemes. Extended company-level e-waste management plans (e.g., following ISO 9001). • National OGS sector coordination and joint work on e-waste management (e.g., producer responsibility organisations). • Repair, refurbishment, and re-deployment of products.	third-party auditing of recyclers. Operational commitment to work towards circularity in the OGS supply chain.
E-Waste Infrastructure		Financial and technical support for third-party repairers offering repair and refurbishment services. Building and upgrading national collection, storage, and pre-processing facilities. Lead-acid batteries recycled using smelters compliant with International Lead Association standards.	Coordinated national and regional planning and implementation to strengthen e-waste collection, storage, pre-processing, and end-processing infrastructure. Cross-sectoral and regional collaboration on e-waste management.

(*continues*)

TABLE 3.2

Core, Best to Have, Ambitious Framework for Risk Management Strategies in World Bank OGS Projects (*Continued*)

	CORE	BEST TO HAVE	AMBITIOUS
Policy	Government data tracking systems for OGS e-waste through baseline surveys, regular forecasting, and ongoing monitoring.	National OGS quality standards, including e-waste requirements. National e-waste policies, strategies, regulations, and standards. Political commitment to work towards circularity in the OGS supply chain.	National policies on right to repair and green procurement. Regional policies allowing for cross-border movement of e-waste and fractions.

[a] VeraSol is the quality standard that all OGS products that are supported through WB projects must follow. The standard stipulates minimum different warranty periods for different segments, such as at least 1 year for a Solar Lantern, at least 2 years for an SHS, and at least 1 year for appliances. The extended warranty period listed here is therefore tagged as good to have.

'Best to Have,' and 'Ambitious' interventions, which are likely to require greater investment, coordination, and management oversight otherwise known as the CBA Framework. The 'core' interventions are focused on enhancing OGS company capacity to handle e-waste, whilst the best practice and ambitious interventions include other activities Borrowers can undertake, such as consumer behavior studies or recycler auditing, investing in e-waste infrastructure and advancing policy reform. The most ambitious interventions seek to advance cross-sectoral and regional collaboration on e-waste policy and infrastructure development.

The most appropriate risk management strategies to focus on depend on factors outlined in Chapter 1. The market segment(s) the OGS project is focused on, the maturity of the OGS market, and the size and capacity of OGS companies participating in the project.

- **Market segment:** For solar lanterns and SHS, end-user awareness and incentives are key to ensure products are disposed of appropriately. Solar lanterns, when repairable, are more likely to be repaired by third-party repairers, whereas SHS are more likely to be repaired in-house by the company selling the SHS (Munro, et al. 2023). For PURE and electrification of public facilities, the major e-waste risk is associated with batteries, so it makes sense to focus on those. Contracts for companies to provide O&M for public facilities should have clear requirements regarding e-waste management, including incentives or penalties to encourage companies to take their commitments seriously, and lasting monitoring mechanisms.
- **Company size and capacity:** If projects impose requirements on companies that need to be met in order to benefit from financial or technical support, those requirements need to take account of the size, capacity, and starting point of participating companies. Smaller companies are likely to need more and different financial and technical support to enhance e-waste management compared to larger companies.
- **Market maturity:** In less mature OGS markets, or when promoting more nascent product categories such as PURE, it makes sense to focus on products, end-users,

and OGS business models. As markets mature and volumes of e-waste are more visible, the case for investing time and money in building e-waste infrastructure and advancing policy reform, as well as promoting cross-sectoral and regional collaboration, gets stronger.

The nature of a World Bank project also has an impact on the most appropriate e-waste E&S risk management strategies to pursue. For example, projects that are already in implementation might need to focus on measures that can be put in place quickly—such as new requirements for companies participating in a financing facility, or the provision of funding or TA to companies to help them build e-waste management capability individually or jointly. In contrast, projects at design stage might be able to take a longer-term view and focus on interventions that are likely to have a greater impact but take more time to implement, such as investing in the updating of an off-grid solar pre-treatment facility. National OGS projects operating over longer timeframes[3] are well-placed to focus on risk management strategies that are likely to take longer, such as supporting development and implementation of e-waste policies, standards, and strategies, or strengthening e-waste management infrastructure—over multiple project phases.

Regional projects are particularly well-placed to promote regional e-waste infrastructure development or policy reform initiatives, for example to allow for the cross-border movement of e-waste so it can be processed at regional hubs. Some countries or regions have adopted existing international conventions and standards on e-waste management. Examples of international conventions and standards on e-waste management are provided in Annex 6. However, operationalization is still lacking, thereby impairing results in this area.

Strengthening e-waste infrastructure should be prioritized in both nascent and mature OGS markets, but OGS projects cannot tackle this challenge alone. World Bank project teams and government counterparts are encouraged to make every effort to join forces with stakeholders working in related electronic sectors such as information and communication technology, to strengthen pre-processing and end-processing (recycling) facilities, or cross-border trade agreements that enable e-waste to be exported to countries where such facilities are available. These ambitious endeavors could have a strong multiplier effect, enhancing e-waste management across a wide range of product categories and countries.

The Cost of E&S Risk Management Measures

Estimating the cost of OGS e-waste management options is challenging. Relatively low volumes of OGS products have reached end-of-life, meaning supply chains, costs and financing models are still evolving. Costs also vary from country to country depending on the presence of e-waste service providers, infrastructure, and regulation. The OGS sector also has unique costs to consider, and challenges that have few parallels in other regions with mature e-waste management frameworks (GOGLA 2024). E-waste costs are broken down across five steps in Table 3.3, with treatment being the most significant driver of cost, and batteries being by far the most expensive fraction to treat.

TABLE 3.3

Key Cost Drivers in E-Waste Management

	ACCESS TO WASTE	COLLECTION	TRANSPORT	REUSE, REPAIR, AND REFURBISH	PRE-TREATMENT AND TREATMENT
Definition	Obtaining the product from the consumer	The infrastructure and operational requirements of a collection center and network	Transporting the waste from collection point (or consumers' location, i.e., doorstep collection) to treatment plant	Disassembly, repair and/or refurbishment so that a product can be resold and reused	Dismantling and proper treatment of the e-waste
Costs	End-user incentives (e.g., payback, discounts) Consumer awareness campaigns	Storage infrastructure Collection bins Personnel to undertake collection Travel costs	Logistical costs Insurance costs	Spare parts Repair tools & equipment Repair technician personnel Quality assurance	Disassembly, sorting, treatment infrastructure Labor costs Energy costs Depreciation of capital investments
	All steps incur additional overhead costs—such as coordination, monitoring, and capacity building				

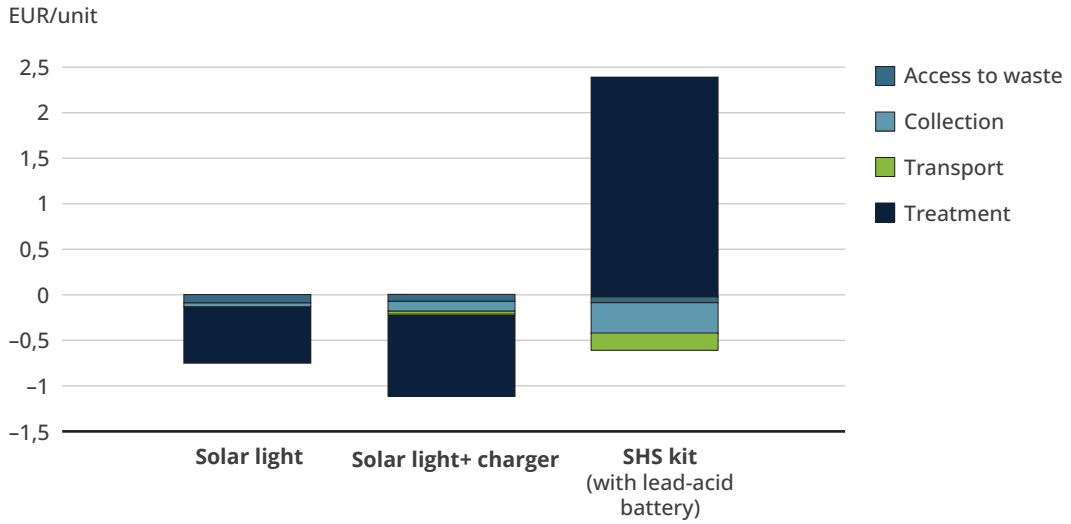
In most countries, OGS companies play a leading role in handling OGS e-waste, including accessing, collecting, transporting, and repairing OGS products. In countries with relatively mature OGS markets and stronger e-waste management infrastructure, e-waste might largely be handled by collectors and recyclers in the formal and especially informal sectors. In a few countries, such as Rwanda, OGS companies also hire recyclers to undertake treatment.

Larger OGS companies are more likely to have e-waste management systems and processes in place than smaller ones. Specific activities larger companies might already be doing include product takeback schemes, reverse logistics, repair/refurbishment, or hiring formal recyclers for some e-waste fractions. Conversely, smaller OGS companies don't usually have e-waste management systems in place, and their efforts would mostly be limited to storing e-waste when products are returned under warranty. When donor funding is available, small OGS companies can form agreements with recyclers; however, even when those are in place, small OGS companies might require funding and technical assistance to put in place takeback schemes and reverse logistics, and might struggle to collect enough e-waste to meet minimum volumes required by recyclers.

Repair, refurbishment, and treatment can generate revenue which can help to off-set some of the cost of sound e-waste management. Third-party repairs of solar lanterns overseen by SolarAid in Zambia suggest the cost of repairing a solar lantern ranges between $0.45 and $13.15, with a median cost of $2.80—around a third of the price of buying a new solar lantern (Munro, et al. 2023). Most OGS products contain valuable fractions which can be sold after final treatment, potentially offsetting some of the cost of e-waste management, assuming recycling infrastructure is available. Currently, smaller OGS products such as solar lanterns have less valuable materials than larger systems and are expensive to collect, disassemble, and treat. Therefore, the extraction and the sale of their valuable materials may not be as cost-effective as for larger systems (see Figure 3.2). Additionally, lithium-ion

FIGURE 3.2

Monetary Gain or Loss per Unit for E-Waste Management for Solar Lights and Solar Home Systems in East Africa, Assuming Recycling Infrastructure is Available



Source: GOGLA 2019.

Note: The content was elaborated in 2019, although background data refers to 2016–2017.

batteries, especially those without cobalt, tend to be a net cost when treated; conversely, lead-acid batteries allow for larger cost recovery due to valuable lead and acid components recovered from the batteries.

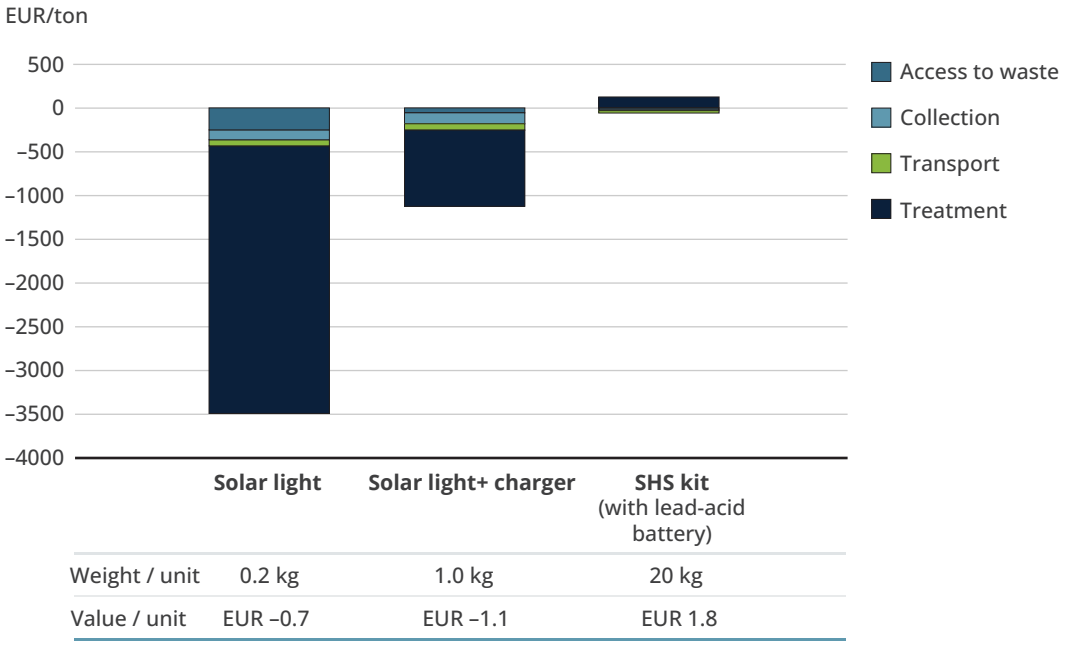
No comparable data could be found for public facility electrification—more research is needed in this area to be able to make a cost analysis.

In most countries, the cost of OGS e-waste management cannot be covered by selling the raw materials reclaimed in the process. This is chiefly because of limited recycling infrastructure, the technical costs involved in the process, the limited value that can be retrieved by some materials, and the prohibitively high cost and complexity of exporting e-waste for treatment. This is especially true for smaller systems which contain limited valuable materials compared to the cost necessary to disassemble and recover such materials (Figures 3.2 and 3.3). Larger systems, especially those using lead-acid batteries, could allow for greater cost recovery from the sale of recovered materials, such as copper, and the lead and acid components in the batteries.

World Bank OGS projects are also typically unable to cover the full cost of upgrading e-waste infrastructure on their own. However, OGS projects might be able to co-fund these costs with other WB projects or donors. The cost of upgrading existing facilities to handle lead batteries to International Lead Association (ILA) standards is estimated to be around $200k–$500k, whilst the cost of setting up a new hydrometallurgy plant for recycling lithium batteries for up to 500t of batteries per year is estimated to be at least $5 million.

FIGURE 3.3

Cost (per ton) Estimate of Off-Grid Solar Waste Management in East Africa



Source: GOGLA 2019.

Note: The content was elaborated in 2019, although background data refers to 2016–2017.

Given the high cost of treating OGS e-waste and limited availability of recycling infrastructure, risk management strategies focused on the prevention and minimization of e-waste are typically more cost-efficient. Such measures include:

- Using quality standards to ensure products have long lifespans
- Promoting design for repair and 'eco-design' - the phaseout or substitution of materials or components which are non-recyclable, non-repairable, and/or have negative environmental impacts[4]
- Battery life monitoring and refurbishment, to prolong lifespans and reduce the need and cost for final battery treatment

Economies of scale can help to unlock cost efficiencies. For example, delivery models that boost customer density make it more affordable for OGS companies to offer repair services and collect end-of-life products. Aggregating access to e-waste, collection and transport through national take-back schemes, producer responsibility organizations, and regional collaboration can also help to unlock economies of scale and cost efficiencies.

Covering the Cost of E&S Risk Management

The cost of E&S risk management can either be borne by companies, World Bank projects, or government ministries. Each of these approaches has advantages and disadvantages.

World Bank projects or government ministries can subsidize a portion of the e-waste management costs. They can do this through running awareness campaigns, providing financial and technical support to OGS companies to strengthen their e-waste management capability, through investing in e-waste infrastructure and policy dialogue, or by covering the cost of treatment for all OGS products recovered by a given group of companies. This last approach is typically preferable in more nascent markets, when working with smaller companies, when e-waste infrastructure is weak, or when sound policies are not in place. Supporting sound e-waste management in this way is unlikely to affect end-user pricing or OGS company business performance. However, a key challenge with this approach is ensuring sustainable funding of ongoing e-waste management costs over time, or once World Bank projects come to an end. A key challenge is ensuring sustainable funding of ongoing e-waste management costs over time, or once World Bank projects end.

Companies can be required to cover some of the cost of e-waste management through project-level eligibility criteria, which must be met in order to qualify for financial support, or to adhere to national regulations. Extended producer responsibility (EPR) policies establish the principle that the "polluter must pay" and make producers/importers responsible for e-waste management at a project, sector, or national level, with fines for non-compliance. Producer Responsibility Organizations can implement e-waste management activities on behalf of groups of companies, and be funded by them through membership fees. These kinds of approaches are likely to be more feasible in more mature markets or when e-waste infrastructure is fairly developed. Producer responsibility organizations in particular can support small companies to enhance their e-waste management by leveraging economies of scale**,** and by granting more negotiating power with recycling and transporting contractors.

In the OGS sector it would be important to consider the implications of these approaches for company commercial performance, considering that most OGS companies are not yet profitable, and the implications for end-user pricing. It is vital that efforts to improve the management of e-waste do not exacerbate existing affordability challenges in the OGS sector, given the need to rapidly scale up OGS markets and the fact that affordability is a significant barrier to market growth.

Step 3 | Design and Implement E&S Risk Management Strategies

World Bank projects have three main 'levers' they can use to implement E&S risk management strategies. Technical assistance can be used to undertake studies, conduct consumer campaigns, and provide practical support to stakeholders. Funding mechanisms - such as upfront grants, results-based financing, credit lines, or tax exemptions - can be

used to support OGS companies and recyclers to improve e-waste management, and help cover private sector costs so that OGS companies and recyclers are not forced to pass them on to end-users. Eligibility criteria, which companies need to meet before benefiting from support, can also be used to incentivize OGS companies and recyclers. In this case, some or all of the costs are borne by the company, potentially impacting business performance and pricing. The kinds of activities that can be supported using each lever are outlined in Table 3.4, mapped to the same 'Core, Best to Have, Ambitious' (CBA) Framework used to present risk management strategies.

Priority should be given to risk management strategies that rely on supportive rather than control mechanisms. This translates into a preference for TA and targeted financing over simply prescribing eligibility criteria. When eligibility criteria are implemented, they should focus on basic requirements to avoid excluding companies from projects because of their currently limited e-waste management capacity; furthermore, they should be

TABLE 3.4

CBA Framework for Risk Management Risk Management Strategies and Activities that can be Supported through Technical Assistance, Funding Mechanisms, and Eligibility Criteria

	CORE	BEST TO HAVE	AMBITIOUS
Technical Assistance	E-waste situation analysis and risk assessment Capacity building support to individual OGS companies to build e-waste management capability Training for governments, development banks, or other stakeholders involved in policy and project development implementation	Consumer awareness campaigns Capacity building support to joint private sector activities such as the establishment of producer responsibility organizations Capacity building support to e-waste management firms, repairers	Consumer behavior studies, tests, and incentives Advancing policy and administrative dialogue on e-waste and other circularity-related topics Cross-sectoral/regional collaboration
Financial Mechanisms	Grants to OGS companies to research, pilot, or scale up new e-waste management systems and processes Grants to support new joint e-waste management efforts in the sector, such as the establishment of producer responsibility organizations or repair hubs RBF to incentivize basic e-waste management and take-back from bigger companies Financing of commercially viable e-waste management firms and activities through credit lines E-waste specifications in tender documents for public procurement, along with lasting monitoring mechanisms and financial incentives/penalties for non-compliance	Companies could be allowed to claim RBF on repaired, refurbished, and resold products Public Private Partnerships and project finance could be set up with recyclers to support broader e-waste management Pilot projects of national-level take-back schemes can be promoted Import tax exemptions on core recycling and repair equipment and product spare parts	RBF structures that incentivize the provision of maintenance and repair services over the lifetime of an OGS product could be piloted OGS projects might provide risk financing directly to collectors, transporters, third-party repair providers, end-users or recyclers, or contribute to specialized funds set up to do so
Eligibility Criteria	Eligibility criteria should focus on low-hanging fruits to avoid penalizing small companies, such as having basic consumer awareness activities, and the adoption (or willingness to adopt over specific timeframe) of basic company e-waste policies and procedures When set, these eligibility criteria should be coupled with technical assistance, and potentially financing mechanisms, to implement the required screening criteria in case of lack of capacity		

supported by adequate technical assistance (TA) and/or financing mechanism(s) to support the implementation of the required measures. Finally, eligibility criteria should always follow comprehensive analyses that determines their feasibility in the local context. This is particularly true for nascent markets and markets in conflict areas, including those with insufficient local recycling infrastructure, small size of historic OGS sales, and/or generally challenging operating environment for OGS companies. In addition, this applies to markets where most of the local OGS private sector might have difficulty accessing the market.

The following guidance should also be considered:

- **Appropriateness:** Risk management options should be designed in view of the current state and trends of the e-waste and OGS systems in different markets. No one size fits all.
- **Flexibility:** Risk management options should be flexible so that they can adapt to changes in the market, respond to emerging challenges and opportunities in a timely fashion, and rapidly apply lessons learned from the implementation experience. In this regard, close monitoring of developments in the market and the project itself is essential.
- **Proportionality:** The management options and implementation mechanisms selected, budget allocated, and complexity created should be proportionate to the risks and the opportunities within the OGS and recycling sectors.
- **Timeliness:** Risk management options should provide timely support. Financing for OGS companies should be disbursed time-efficiently as it otherwise can pose challenges or de-prioritization of e-waste efforts for capital-constrained OGS companies, especially smaller ones.
- **Sustainability:** Carefully designed risk management strategies will incorporate phase-out to ensure the sustainability of the interventions during and after the project.

Finally, e-waste management strategies can be applied via a decentralized or centralized approach. The decentralized approach relies on the private sector's capacity to lead e-waste management measurement. Centralized approaches, on the other hand, rely on the Borrower's capacity to collect and manage OGS e-waste. Projects already designed with a centralized approach in mind could easily add-on e-waste. Projects that follow a decentralized approach can have positive spillovers on local job creation and economic development. An example of multiple strategies deployed simultaneously can be found in Box 3.2

The following sections will explore E&S risk management strategies for each lever available in World Bank projects.

Technical Assistance to OGS Companies and Borrowers

Capacity building should be the core implementation mechanism for OGS e-waste risk management. OGS markets are not yet mature, and the sector's response to the e-waste challenge is still in an early stage of development. Improved understanding of

BOX 3.2

HOW A WORLD BANK OFF-GRID PROJECT IN UGANDA UTILIZED MULTIPLE STRATEGIES TO MANAGE E-WASTE

In 2023–2024, a World Bank project in Uganda evaluated and implemented different options to manage its resulting OGS e-waste, using this an early version of this Toolkit as guidance. For example, the project screening of OGS applicants included e-waste management considerations. By doing so, the project learned about applicant companies' need for support with e-waste management, and offered technical assistance to fill such gaps. It is also considered incentivizing companies to work jointly, ideally in a formal e-waste collective or as a producer responsibility organization. Finally, the project engaged with the Ugandan inter-ministerial commission on e-waste management, promoting regulatory improvements.

the challenges and solutions, as well as support to implement solutions, is typically needed at the company and government level, as well as across sectors and regions.

'Core' technical assistance interventions include e-waste situation analysis and risk assessment, as well as training for OGS companies and governments. OGS companies need to be trained in e-waste management, and supported to develop e-waste management plans and procedures (GOGLA 2021). Government stakeholders typically need to be trained in the topics covered by this toolkit, including e-waste risk assessment, mitigation strategy selection and design, as well as monitoring & evaluation. Technical assistance for OGS companies or government stakeholders can take the form of toolkits or guidelines, one-to-one advisory support, or group training workshops or classes. If basic information about e-waste management is needed by a large number of organizations and personnel, the most cost-efficient way to share this information is in a group setting. More advanced or bespoke capacity-building requires a more targeted approach, targeting individual OGS companies, government agencies, or recyclers. For example, one-to-one technical assistance for OGS companies could be used to help a small company put basic e-waste management strategies and volume forecasting in place for the first time, whilst a larger company could be supported to fine-tune a pre-existing e-waste management system or process.

'Best to have' technical assistance interventions include consumer awareness campaigns, the provision of support to third-party repair providers or recyclers, or national

coordination of joint OGS e-waste management activities. Consumer awareness campaigns, typically used to create trust and demand for off-grid solar products, can also be used to inform end-users about end-of-life options and encourage take-back. Third-party repair providers can be provided with technical and business support, and supported to establish partnerships with OGS companies, especially those selling more basic solar lights (Munro et al. 2023). Recyclers can also be trained to further develop their technical and business capabilities and to work better with OGS companies. Joint OGS e-waste management activities might include piloting joint collection so that significant e-waste volumes can be sent to a recycler, unlocking economies of scale, and helping to reduce costs.

'Ambitious' technical assistance interventions include consumer behavior studies and incentives design, and efforts to advance policy dialogue, or cross-sectoral and regional collaboration. Consumer behavior studies can help to inform the design of awareness campaigns and take-back incentives, as well as individual or collective OGS e-waste management activities undertaken by OGS companies. Policy dialogue and cross-sectoral or regional collaboration can be advanced through off-grid solar taskforces, intra-ministerial committees, or similar forums. New forums can be set up for this purpose. Technical assistance providers can build stakeholder knowledge and understanding in advance of discussions, share best practice and case studies, and facilitate dialogue and decision making. Lighting Global's Off-Grid Solar Policy Toolkit (ESMAP, PPIAF and DDP 2024) is a useful resource in this area (Box 3.3).

BOX 3.3

LIGHTING GLOBAL'S OFF-GRID SOLAR POLICY TOOLKIT

The Off-Grid Solar Policy toolkit (ESMAP, PPIAF and DDP 2024) is designed to assist governments in creating an enabling environment for OGS and pay-as-you-go (PAYG) sector growth by establishing policy reforms determined through a structured process of inter-ministerial policy dialogue. It identifies 12 key policy issues—including e-waste management—and considers the advantages and disadvantages of different policy approaches to each issue. The toolkit then outlines a step-by-step process that governments can use to facilitate policy dialogue, providing guidance and tools at each step. This process envisions a scenario where government ministries and agencies work together to advance policy reforms.

Funding Mechanisms

World Bank projects provide financial support to OGS companies through a range of public funding mechanisms including upfront grants, results-based financing, tax exemptions, credit lines, and risk management instruments such as guarantees, as well as end-user subsidies and public procurement.

'Core' solutions include the provision of upfront grants to improve e-waste management. Grants can be used to research, pilot, or scale up new e-waste management systems and processes. Grants can be used to fund individual company efforts, or joint efforts in the sector, such as the establishment of producer responsibility organizations. If OGS or e-waste management companies can develop commercially viable e-waste management models, these could potentially be financed through credit lines providing loans, to be repaid using revenues from repaired, refurbished, and resold products, as well as through the sale of valuable fractions from SHS, PURE or Public Facility systems.

E-Waste management should be an important consideration in public procurement, especially for electrification of public facilities. E-waste management requirements should be clearly stated in tender documents, with mechanisms in place to monitor contractor performance in this area during the contract, and financial incentives or penalties to ensure compliance. Tender documents can also ask bidders to present a calculation of e-waste management costs (especially for recycling), as part of their offers. This cost can then be accounted for in the overall project budget and contractual design.

'Best to have' solutions include enabling companies to claim RBF on refurbished, repaired, and resold OGS products, or using tax exemptions to reduce the cost of spare parts and e-waste management equipment. Typically, companies are not allowed to claim results-based financing on products that have been refurbished, repaired, and resold, because of concerns around double-counting (i.e., governments are reluctant to provide RBF on the sale of the same system twice). Allowing companies to do so would greatly incentivize companies to enhance their repair and resale capability. Governments also have the option of offering tax exemptions on spare parts and on equipment needed for repair and recycling.

World Bank projects and government counterparts can also explore the possibility of establishing Public Private Partnerships for e-waste management. Such partnerships must be carefully designed to equitably share costs, risks, and revenues, whilst providing financial incentives for companies to hit targets whilst meeting environmental and social standards. For example, in Rwanda, the government covered 100 percent of the capital cost to establish a recycling facility, in parallel with developing key e-waste policies, standards and guidelines. The facility was then leased to a private operator with expertise in e-waste management, under a revenue-sharing agreement and following a solid business model. The facility treats waste from across the country, and increasingly the African continent (Box 3.4).

BOX 3.4

PUBLIC PRIVATE PARTNERSHIP FOR E-WASTE MANAGEMENT IN RWANDA

In 2014–2017, the Rwandan government's Ministry of Trade and Industry utilized the Rwanda Green Fund—Fonerwa—for a full capital investment in a state-of-the-art national e-waste dismantling and recycling facility. In parallel, Fonerwa developed key strategic documents that would enable the sustainability of the facility, including a national e-waste management policy, a 5-year strategic plan, an e-waste law and relevant regulations, e-waste technical guidelines, and two standards on e-waste developed with the Rwanda Standards Board. The facility is installed in a special economic zone, providing logistical and commercial benefits to operators and itself a public-private partnership (PPP)—between the Rwandan government and a pan-African developer and operator of industrial ecosystems.

In 2017–2018 the Government leased the facility to Enviroserve, an e-waste management company, to ensure the facility was efficiently and expertly developed, operated, and maintained. The facility generates profit from selling refurbished products, extracting and reselling critical raw materials, and collecting service charges. Under the terms of the revenue sharing agreement, the government is set to make a profit on its initial investment, which will be reinvested in further environmental and green growth initiatives through Fonerwa. Enviroserve is responsible for following E&S standards as well as establishing collection points, running awareness campaigns, transferring skills to local staff to manage and operate the facility, and upgrading facility equipment as needed. The government is a key client of the facility, using it for all e-waste resulting from its offices and operations.

'Ambitious' solutions include piloting RBF structures that incentivize companies to provide maintenance and repair services over the whole life of the OGS product. Results-based financing is already used to incentivize companies to honor warranty and after-sales commitments. In some programs, a small proportion (about 10%) of the RBF is retained until a year after a sale has taken place, and only paid upon verification of adequate after-sales service. This approach could potentially be built upon to incentivize and finance companies to provide service—including maintenance and repair as needed—over longer time periods, or the full lifespan of the product.

Another ambitious solution might involve an OGS project providing funding to e-waste collectors, transporters, third-party repair providers, or recyclers directly, or joining forces with other projects and sectors to do so. Credit lines could potentially enable e-waste companies to establish, expand, or enhance their businesses. Project finance, although more complex to design and implement, could also be considered for larger-scale, regional recycling infrastructure. Such models offer optimal risk sharing, as well as the potential for raising larger amounts of blended financing (e.g., a mix of grants, private capital, loans) for larger projects.

Eligibility Criteria for OGS Companies

Eligibility criteria can serve as core tools to promote effective e-waste management strategies within World Bank off-grid solar electrification projects. These criteria represent screening standards to ensure that project beneficiaries and participants adhere to responsible E&S practices related to e-waste, thereby mitigating environmental and health risks associated with improper waste management. By incorporating eligibility criteria into project frameworks, the World Bank can incentivize and enforce sustainable practices throughout the lifecycle of off-grid solar systems, from procurement to end-of-life disposal.

As noted, supportive measures such as TA and grants should be preferred to eligibility criteria and other prescriptive measures. When utilized, eligibility criteria should not be the only lever, but rather be coupled with robust technical assistance and capacity building. While setting criteria can be useful, their effectiveness hinges on stakeholders' ability to understand, implement, and adhere to them. Strict eligibility criteria may exclude smaller companies, which do not have the economies of scale or business maturity to pursue comprehensive e-waste management strategies. Furthermore, eligibility criteria must be reflective of the local infrastructure available, the regulatory environment, and the development of the e-waste sector. To this end, it is critical that World Bank projects leverage technical assistance and financial mechanisms to support the implementation of the required e-waste eligibility criteria.

There are several low-hanging fruits that can be used as eligibility criteria. These include the presence, or availability to create a basic company-level e-waste management policy and Standard Operating Procedure, requiring that the topic is officially acknowledged internally in companies. Further requirements can include the free swap of faulty products within warranty, the identification of an initial reverse supply chain (such as safe storage, identification of potential e-waste management service providers like repairers or recyclers, etc.), and prioritization of lithium-ion batteries over lead-acid. Additionally, companies can be required to properly inform customers on E&S risks, educate on appropriate product use to increase product life, and provide information on returns and disposal options. An Environmental and Social Screening Template for screening OGS companies can be found in Annex 6.

More advanced company practices can be encouraged via eligibility criteria accompanied by capacity building and/or financing mechanisms. These include adopting company-level take-back schemes, promoting extended e-waste management plans (such as following ISO 9001), and the adoption of the 5Rs in the supply chain, including through product refurbishment or repair. In contexts where voluntary-based EPR organizations are available, companies could be required to participate.

Step 4 | Monitor and Evaluate Progress

It is critical that E&S risk management strategies related to e-waste be tracked during, at the end, and ideally after the project. To this end, OGS e-waste risks should be part of the project's E&S performance monitoring process. Tracking should happen through regular reporting, supervision site visits, and information sharing from third parties, such as through grievance redress mechanisms and stakeholder engagement, and as per the legal agreement with the Borrower. Furthermore, companies should have internal tracking mechanisms and report progress on key indicators. Projects can also envision site visits and spot checks as needed.

OGS risks should be reassessed over time, and performance monitoring should also capture new risks that may have emerged. The Borrower reporting should identify any material issues that require adaptive management, including changes in regulations, unexpected increased impacts, and further unforeseen variables. The e-waste situation analysis, the environmental and social impact assessments (ESIAs), and environmental and social management plants (ESMPs) should be treated as dynamic and adaptive instruments. In case the Borrower has limited capacity, third-party monitoring is warranted.[5] An example of e-waste monitoring can be found in Box 3.5.

BOX 3.5

E-WASTE MONITORING IN THE WORLD BANK RENEWABLE ENERGY FUND RWANDA PROJECT

In the Renewable Energy Fund (REF) Project Rwanda, E&S monitoring of solar companies is carried out to track e-waste management in the program and gather insights for its improvement.

Project monitoring verifies compliance with the approved REF Environmental Code of Practice, to which all OGS companies participating in the project are parties. The Code of Practice requires an active contract with the local processing facility. The Q3 2023 monitoring discovered that, while all 11 monitored companies have a valid contract with the local processing facility, the majority (8:11) take their e-waste to the local representative of their manufacturer. This might be connected to the 3-year warranty conditions within the program. Since the manufacturer is not a registered recipient of e-waste within the project and its Code of Practice, project documents will have to be adjusted; however, the involvement of the manufacturer is viewed positively by the local implementing agency as it is likely to enable further circularity, such as eco-design, refurbishing, and recycling.

Endnotes

1. Multiphase Programmatic Approach projects allow countries to structure a long, large, or complex engagement as a set of smaller linked operations (or phases), under one program. Subsequent phases of these programs should be prepared as separate operations with rigorous adherence to all applicable WB policies and requirements.
2. See ESS1 and the WB Technical note on Screening and Risk Classification under the ESF (2020) and Annex 1 of ESS1.
3. Multiphase Programmatic Approach projects allow countries to structure a long, large, or complex engagement as a set of smaller linked operations (or phases), under one program. Subsequent phases of these programs should be prepared as separate operations with rigorous adherence to all applicable WB policies and requirements.
4. In some cases, trade-offs between product functionalities during and in the end-of-life might persist, like in batteries (e.g., weight, duration, production costs).
5. See further guidance at ESF Good Practice Note on 3rd Party Monitoring.

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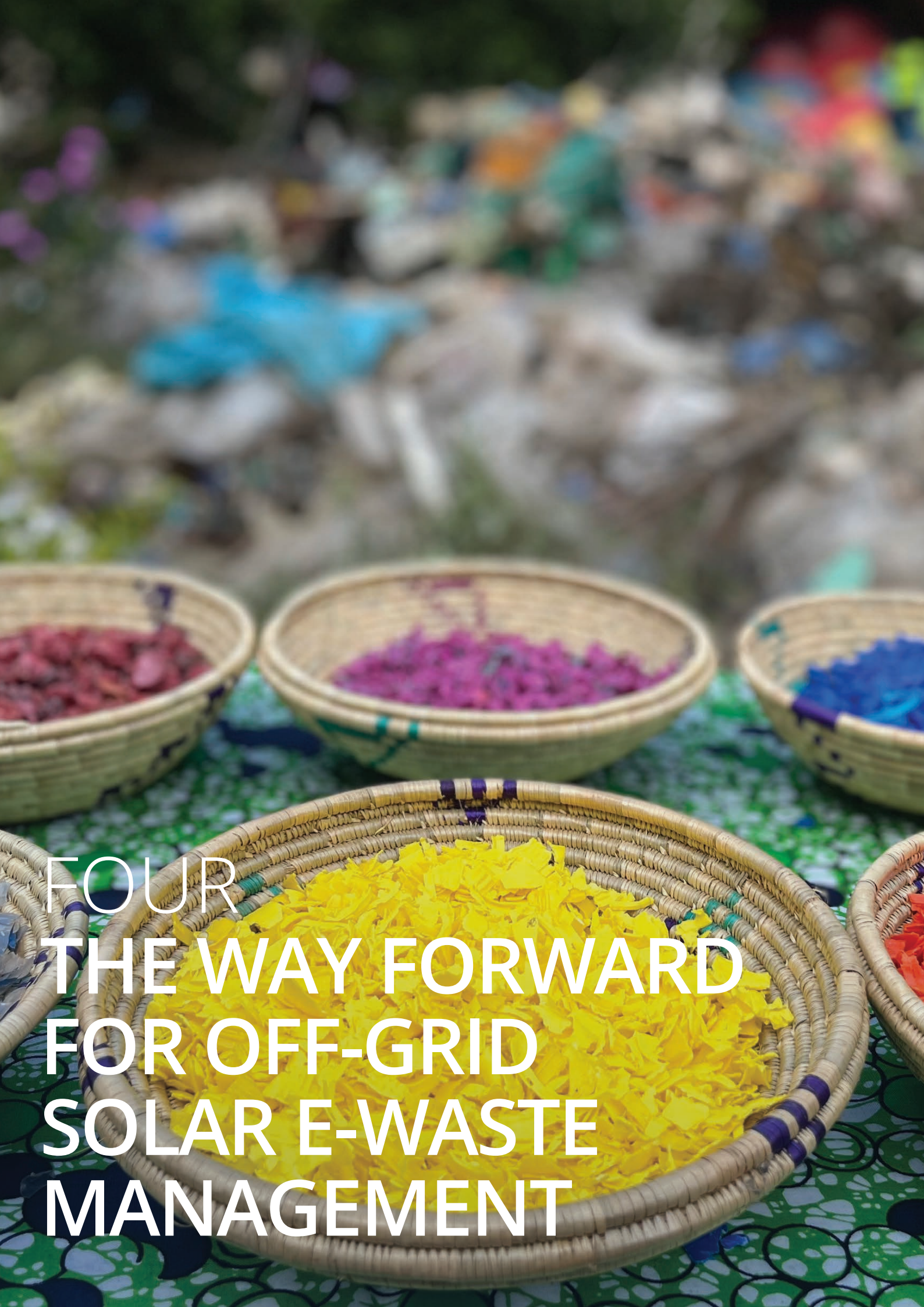


FOUR
THE WAY FORWARD FOR OFF-GRID SOLAR E-WASTE MANAGEMENT

The objectives of this chapter include how to build a fully circular off-grid solar sector, understand the enabling factors, and identify immediate next steps to address the priority issues highlighted by this Toolkit.

Creating a Circular Economy in the Off-Grid Solar Sector

An ideal, fully circular off-grid solar sector can design e-waste out of its systems following the 5R principles of circularity. This includes reducing the need for and impact of raw materials through eco-design of off-grid solar products and other service-oriented strategies; reusing off-grid solar products, components and materials; repairing off-grid solar products to extend their useful lifetime; encouraging remanufacturing and refurbishing, and the sale of refurbished off-grid solar products; and finally recycling all off-grid solar products, components and materials.

Adopting circular economy principles would benefit the off-grid solar sector stakeholders at all levels. **End-users** would have increased product satisfaction, customer protection, and trust in the products; **off-grid solar companies** can lower company-level costs, improve client management, and diversify business; the **off-grid solar sector** would benefit from greater industry resilience by shortening supply chains, boosting industry image, and lowering dependance on imports of materials; and the **climate** would benefit from lowering the sector's greenhouse gas footprint and material impact.

An Action Plan for the Off-Grid Solar Sector

To achieve circularity, stakeholders must pursue a diversified, complementary agenda. Off-grid solar program managers (including development institutions, NGOs, and other stakeholders) should design programs that support circular approaches, including by fostering research, development, and innovation to enable full repair, refurbishment, and recycling-led off-grid solar businesses. They should promote intra-industry collaboration forums to identify common challenges, share lessons learned, and foster coordination among actors. In parallel, they should also support knowledge development and pilot implementation, public awareness campaigns on e-waste risks, and technical assistance to build knowledge and skills.

Policy makers and governments should promote institutional coordination, policy, and support systems to build the overall country system for the 5Rs of the circular economy, such as regulations that encourage the safe transboundary movement of off-grid solar

e-waste—which is often prohibited mandate the eco-design in off-grid solar product quality standards, create take-back and recycling targets, and harmonize metrics and data related to e-waste. Policy makers and public actors should also invest in local e-waste recycling infrastructure, encourage the development of secondary marketplace for repair and refurbishing, and collect accurate data on e-waste including its transport, import, export, collection, and recycling.

Investors and donors should support circular initiatives brought about by program managers and policy makers, including projects, infrastructure, and technical assistance, and should deploy innovative financing mechanisms that support circular interventions. Actively fostering donor and investor coordination and supporting the institutional coordination on the national level and building the overall country systems for the 5Rs should also be a core aim. In particular, investors and donors should encourage public-private partnerships to attract private sector services in the field of circular economy, such as in infrastructure, empowering the informal sector, and enabling economies of scale. Demand-side subsidies should also be considered for the integration of all practices along the 5R principles.

Finally, **off-grid solar companies** should adopt circular business models throughout their entire supply chain. In order to enable that, they should engage in technical assistance activities offered by off-grid solar projects, that would allow them to upskill workers, enable R&D, and build capacity. Additionally, off-grid solar companies should engage actively in intra-industry collaborations such as through Producer Responsibility Organizations, which can create economies of scale and limit costs.

Stakeholders such as the World Bank can intervene in several of the areas above. They can support governments and public actors with the development and enforcement of e-waste policies and promote the integration of circular economy principles along the off-grid solar supply chain. They can pilot innovative solutions like take-back and recycling schemes, to validate ideas, understand cost implications, and to collect lessons learned. Finally, they can support the construction, upgrade, or maintenance of recycling infrastructure, particularly collection hubs, manual disassembly, or mechanical processing facilities.

Bibliography and Resources

IEA, IRENA, UNSD, World Bank, WHO. 2023. *Tracking SDG 7: The Energy Progress Report.* Washington DC: World Bank.

Elahi, R., R. Srinivasan, and T. Mukurazhizha. 2020. *Increasing Human Capital by Electrifying Health Centers.* Washington DC: World Bank.

ESMAP, Lighting Global, PPIAF, and DDP. 2024. *Off-Grid Solar Policy Toolkit.* Washington DC: World Bank.

GOGLA. 2021. *Circularity Toolkit: E-waste Blueprints*.

———. 2024. *E-waste Toolkit.*

International Telecommunication Union. 2012. *End-of-life management for ICT equipment*.

Lighting Global/ESMAP, GOGLA, Efficiency For Access, Open Capital Advisors. 2022. *Off-Grid Solar Market Trends Report.* Washington DC: World Bank.

Magalini, Federico., Deepali Sinha Khetriwal, Jaco Huisman, David Rochat, Seth Munyambu, Joseph Oliech, Innocent C Nnorom, and Olivier Mbera. 2016. *Electronic waste (e-waste) impacts and mitigation options in the off-grid renewable energy sector.* DFID.

Munro, P., S. Samarakoon, T. N. Ngwenya, K. Kanyanga, J. Keane, J. McCloskey, and F. Mwale. 2023. *Off-Grid Solar Repair in Africa: From Burder to Opportunity.* London: SolarAid.

Rysankova, Dana, and Charlie. Miller. 2022. *Designing Public Funding Mechanisms in the Off-Grid Solar Sector (English).* Washington DC: World Bank.

Sofies. 2021. *Independent Research*.

World Economic Forum. 2021, October 18. "This year's e-waste to outweigh Great Wall of China." Accessed May 27, 2024: https://www.weforum.org/agenda/2021/10/2021-years-e-waste-outweigh-great-wall-of-china/#:~:text=In%202021%2C%20human%20beings%20will,the%20world's%20heaviest%20human%20construction.

Resources for Further Reading

OGS Company-Level Operations

- GOGLA E-Waste Policy Blueprints

E-Waste Policy Development

- Step's "Developing Legislative Principles for E-Waste Policy in Developing and Emerging Countries" (2018)
- Prevent and STeP's "Practical Experiences with the Basel Convention: Challenges, Good Practice Ways to Improve Transboundary Movements of E-Waste in Low- and Middle-Income Countries" (2022)

- A practical guide for the systemic design of WEEE management policies in developing countries (2017)
- SRI's International E-Waste Management Practice: Country Factsheets from 12 Jurisdictions (2019)
- OECD's "EPR: Basic Facts and Key Principles" (2024)

Repair

- SolarAid's Whitepaper on Off-Grid Repair in Africa (2023)
- CLASP's Pathways to Repair in the Global Off-Grid Solar Sector (2020)
- UKaid's "Landscaping the Repair and Reuse Economy in Kenya" (2022)

Toolkits with Relevance to OGS E-Waste

- ACE TAF's E-waste Policy Handbook (2019)
- IOM's Toolkit for Creating a Circular Economy for E-waste in Displacement Settings (2023)
- WB's Off-grid Solar Policy Toolkit (2024)
- GIZ's E-Waste Training Manual (2019)

Batteries

- SESA's Factsheet on Second-life Lithium-ion batteries (2023)
- IDB's Review of Global and Regional Practices for Recycling and Reuse of Lithium Batteries in Latin America and the Caribbean (2024)
- GIZ's 'End-of-Life Management of Batteries in the Off-Grid Solar Sector' (2018)

Other Core Reading

- BGFA's E-Waste Management Recommendations (2020)
- SRI's "Bridging the Gap Between the Formal and Informal E-Waste Sectors in Egypt" (2024)
- DFID's "Sustainable Management of E-Waste in the Off-Grid Renewable Energy Sector in Rwanda" (2017)
- ECOSWEEE's "Best Practice Collection Initiatives Booklet" (2023)
- Grid Arendal's "Circular Economy on the African Continent: Perspectives and Potential" (2021)
- CEP's "Circular Electronics Roadmap and Purchaser Guide for Circularity" (2024)

Resources for a Situational Analysis

OGS E-Waste Quantity Estimations

- E-waste Statistics—Guidelines on Classification, Reporting and Indicators (2019): Provides source of statistics, average weights per product, average lifespan.
- The Global E-waste Monitor (2020): Overview of volumes of waste generated worldwide. Calculations made based on sales-lifespan methodology, considering import/export from international statistics.
- OGS Market Trend Reports, LG, GOGLA, ESMAP (2018,2020, 2022): This series of reports measures trends of the OGS market, includes comprehensive sales and impact data as well as an in-depth analysis on current market dynamics, and an outlook on the future of the industry.
- Historical information on the market or sales of OGS can also be found in import export statistics, government reports, industry/ trade associations, e.g., GOGLA. Ideally, sales data going back at least as long as the project lifespan (i.e., 5 years) should be used.

Stakeholder Mapping

- The Global E-Waste Monitor (2020).

Legislative Review

- E-waste Legislative Framework Map, GSMA (2019). The e-waste legislative framework map explores 76 countries from the study and provides access to e-waste related policy summaries, plus gives an overview of the country population and the amount of e-waste and mobile phone waste generated in 2019.
- Policy Practices for e-waste management, ITU (2021). Policymakers are invited to use this toolkit as a pragmatic guide to formulate and strengthen e-waste management systems. The toolkit can be referred to for the entire system or for the individual pillars of business and finance, policy and regulation, technology and skills, monitoring and control, and marketing and awareness. The toolkit is designed to support members of the African Circular Economy Alliance.
- The Africa Clean Energy Technical Assistance Facility (2019). This handbook provides guidance and policy options for policymakers and the industry to analyze ways to manage e-waste produced by OGS products. It draws on country examples and also discusses the elements of designing and implementing sustainable solutions for e-waste management.

- Extended Producer Responsibility, A Guidance Manual for Governments. Written by the Organisation for Economic Co-operation and Development, this Guidance Manual provides information on EPR issues, benefits and actions required to establish effective EPR policies and programs. It is intended to help governments ensure that in implementing EPR, the benefits outweigh the costs and that the program meets their goals and priorities.
- WEEE Directive (2012/19/EU). Actual text of EU WEEE Directive (revised version), which is seen as the state-of-the-art in EPR regulation.

ANNEX 1

Environmental & Social Risks Associated with Off-Grid Solar Product Components

The categorization of OGS project components' Environmental and Social (E&S) risks is based on qualitative assessment of two factors: the potential negative social and environmental impact, and the probability of exposure. In general, if the probability of exposure is high and so is the impact, the risk is defined as high. If the impact is low and so is the probability of exposure, the risk is deemed to be low. If either one of the two factors is high, the risk is "medium."

Probability of exposure is considered high if direct exposure to these fractions is likely to have a severe negative impact, if fractions are likely to be handled without adequate safety gear, or if it is likely fractions will be handled in a way that is not safe (especially in the informal sector). It is considered low if direct exposure does not have a detrimental impact, or the likelihood of safe handling practices is high. Environmental and social impacts are considered high or low based on the criteria outlined in Table A1.1.

Using the above framework, Table A1.2 categorizes E&S risks from OGS product components.

TABLE A1.1

Criteria for Determining Social & Environmental Risk of OGS Product Components

IMPACT	SOCIAL	ENVIRONMENTAL
High	• There is documented evidence of severe impacts on human health from exposure to these fractions • Potential health impacts include chronic illness, hormone disruption, DNA changes, fetal development issues, death	• These fractions can persist in the environment for long periods of time without degradation or becoming inert • These fractions are highly mobile through soil, water, or air, leading to large-scale impacts
Low	• There is either documented evidence of low impacts on human health from exposure to these fractions or not enough evidence to suggest a connection between exposure to the fraction and ill-effects on human health • Documented health impacts show short-to-medium term illnesses and/or impacts that can be managed	• These fractions either degrade or become inert in the environment, and are unlikely to spread through soil water or air

TABLE A1.2

E&S Risks Associated with OGS Product Components

PRODUCT COMPONENT	CRITICAL FRACTIONS; USE LIFETIME[a]	RISK LEVEL, MAIN REASON FOR RISK	PROBABILITY OF EXPOSURE	IMPACTS	STEPS TO AVOID POTENTIAL NEGATIVE EFFECTS THROUGH IMPLEMENTING E-WASTE MANAGEMENT PRACTICES
Battery	**Lead Acid** 3–5[b] years	**HIGH** • Exposure to lead • Exposure to sulfuric acid	**HIGH** • If the external battery case is opened, lead dust is dispersed and may be inhaled by end-users or informal workers • Fumes can be caused by the melting of lead plates	**HIGH** **Environmental:** • Lead can persist in all matrices (soil, air, water), often as dust • Sulfuric Acid (the main component of battery acid) is highly toxic to ecosystems, can pollute ground water when dumped **Social:** • Lead causes miscarriages and fetal defects, brain damage and cancer in adults, and blocks normal neurological development in children • Sulfuric acid can cause irreparable injuries to humans	• Avoid using lead acid batteries • Avoid Lead Acid Battery damage from over/ under-charging, by training end-users • If undamaged externally, arrange for lead-acid batteries to reach formal recycling: lead components to be smelted and refined, sulfuric acid electrolytes to be purified and treated in settings which follow formal operating procedures[c] • Try to avoid informal lead-acid batteries recycling due to unsafe worker practices and severe health impacts • Carry audits on recyclers, permits' check is not enough[d] • Ensure that only smelters operating in compliance with ILA standards are used • Establish community outreach programs to raise awareness on lead risks and operations
	Lithium-Ion 2–6 years	**HIGH** • Fires and explosions. • Exposure to hazardous substances (e.g., copper, nickel, lead, and organic chemicals)	**HIGH** • Improper discharging, storage, and transportation is highly likely to cause thermal runaway fires and explosions • Contamination due to contact with other toxic chemical components also likely	**HIGH** **Environmental:** • Potentially toxic metals (less than other batteries) can lead to water and soil contamination **Social:** • The potential fire and explosions make lithium-ion dangerous to any person mishandling them, notably end-users and informal waste management workers	• Use safe storage and transportation: solid containers between layers of sand, individual sachets to place batteries into to prevent leakages spreading, tape fixed over the contacts to avoid accidental short-circuits • Recycle in existing specialized treatment facilities (currently located only in Europe or USA). • Build new specialized recycling facilities close to the projects • Avoid dismantling, opening, or disruption by end-users and informal waste workers • Take steps to aggregate battery amounts to ensure they are sent for recycling faster (rather than stored indefinitely)

(*continues*)

TABLE A1.2

E&S Risks Associated with OGS Product Components (*Continued*)

PRODUCT COMPONENT	CRITICAL FRACTIONS; USE LIFETIME[a]	RISK LEVEL, MAIN REASON FOR RISK	PROBABILITY OF EXPOSURE	IMPACTS	STEPS TO AVOID POTENTIAL NEGATIVE EFFECTS THROUGH IMPLEMENTING E-WASTE MANAGEMENT PRACTICES
	Plastic casing *2–8 years*	**LOW** • Exposure to chemical contaminants (e.g., halogenated flame retardants), if any • Pollution due to Improper handling and disposal e.g., landfill and burning instead of appropriate recycling	**LOW** • Lack of proper recycling exacerbates improper disposal, including burning • Open burning in informal waste management settings may lead to toxic emissions if chemical additives are present	**LOW** **Environmental:** • Plastic pollution leading to release of micro-plastics over time in soil and water **Social:** • Open burning fumes would be a health hazard for informal workers working without protection as well as for communities in the vicinity	• Send plastic casings to recyclers, who would decide how to handle. Non-hazardous recyclable plastics will be sorted by color and type, chipped, and sold to local plastic manufacturers. The plastic chips may be shipped internationally for recycling. Also, non-hazardous, non-recyclable plastics are landfilled locally or sometimes upcycled. • Avoid burning of plastics or uncontrolled/informal recycling practices that involve melting, by working with formal recyclers and informing informal recyclers
PV Panels	**Aluminum frame**	**LOW** • Injuries from improper handling.	**LOW** • Aluminum from PV frames is often stripped and handled separately, increasing risks of mishandling	**LOW** See Base Metals.	• Send whole PV panels to advanced recyclers (still limited in number and geographies, i.e., only in Europe), that can separate its components • Rudimentary recycling that treats the PV panels like glass can often be found locally
	Glass	**LOW** • Injuries and pollution from improper handling.	**LOW** • Improper handling of glass by workers without proper safety kits occurs often and poses safety risks and reduced material recovery potential	**LOW** **Environmental:** • Uncontrolled dumping in landfills increases pollution and decreases recovery potential **Social:** • Glass can cause serious injury through dermal contact) or inhalation (without protection)	
	PV cells (Silicon, crystalline, or thin film) *15–20 years*	**MEDIUM** • Exposure to heavy metals like lead & cadmium (in crystalline or thin film cells)	**LOW** • Unlikely to leach in soil or water, unless processed mechanically—they are usually closely bonded with other materials	**HIGH** • Heavy metals pose serious E&S risks. *See: Lead Acid Batteries*	

(*continues*)

TABLE A1.2

E&S Risks Associated with OGS Product Components (*Continued*)

PRODUCT COMPONENT	CRITICAL FRACTIONS; USE LIFETIME[a]	RISK LEVEL, MAIN REASON FOR RISK	PROBABILITY OF EXPOSURE	IMPACTS	STEPS TO AVOID POTENTIAL NEGATIVE EFFECTS THROUGH IMPLEMENTING E-WASTE MANAGEMENT PRACTICES
	Plastics (potentially containing PVF)	**LOW** • Pollution due to Improper handling and disposal e.g., landfill and burning instead of appropriate recycling	**LOW** • Lack of proper recycling exacerbates improper disposal, including burning	**LOW** **Environmental:** • Plastic pollution leads to release of micro-plastics over time in soils and water • PVF (sometimes included for durability) is not harmful **Social:** • See Plastic Casing	
Printed circuit boards (PCBs)	Central Processing Units	**HIGH** • Exposure to mercury or cyanide used for gold leaching • Exposure to dioxins & furans	**HIGH** • Burning, often used to remove metals, can cause dioxins and furans to form • Gold stripping from PCBs in the informal sector often uses dangerous chemicals like mercury and cyanide	**HIGH** **Environmental:** • Dioxins and furans are persistent organic pollutants (POPs), polluting the environment for many years when released • Cyanide has extremely negative environmental impacts, contaminating aquifers for long periods, including for mercury *See TV Flat Panel Displays* **Social:** • See *Cables*	• Handle appropriately: segregate PCBs from other components, manually remove capacitors, transport intact to recyclers (most in Europe or Middle East since high costs and complexity of recycling) • Avoid informal recycling
Solar Lamps	**Solar Lamps** *25,000 hours (LED lamps) 8,000 hours (CFL)*	**HIGH** • Exposure to heavy metals, like gallium, arsenic, nickel (LED lamps) • Exposure to mercury (CFLs)	**HIGH** • Single lamps have small quantities of toxic materials, high volumes increase probability of exposure • Improper handling and disposal of lamps is often the case	**HIGH** **Environmental:** • Mercury leakage from CFLs has multiple negative impacts (see *TV Flat Panel Displays*) • LED lamps are less negatively impactful, but if heavy metals are released groundwater and soils get contaminated **Social:** • Mercury poses serious adverse health risks to humans, through ingestion via water and soil (*see TV Flat Panel Displays*) • LED lamps release toxic heavy metal fumes when broken, expose unprotected workers and end-users to health risks	• Proper sorting and dismantling of lamps, through formal recyclers

(*continues*)

TABLE A1.2

E&S Risks Associated with OGS Product Components (*Continued*)

PRODUCT COMPONENT	CRITICAL FRACTIONS; USE LIFETIME[a]	RISK LEVEL, MAIN REASON FOR RISK	PROBABILITY OF EXPOSURE	IMPACTS	STEPS TO AVOID POTENTIAL NEGATIVE EFFECTS THROUGH IMPLEMENTING E-WASTE MANAGEMENT PRACTICES
Other parts/ components	**Cables** *>10 years*	**MEDIUM** • Exposure to dioxins, furans, and copper oxide due to burning or manual dismantling	**LOW** • Open burning, incineration, and manual stripping are common ways to recover materials from cables, especially in the informal sector	**HIGH** **Environmental:** • Dioxins and furans are POPs, remaining in the environment for many years • Copper oxide fumes released through open air burning or manual dismantling for copper are toxic in different degrees to a variety of organisms **Social:** • Dioxins and furans can remain in living organisms for a long time, causing severe reproduction, development, immune system, and hormone problems, as well as cancer • Copper oxide fumes may cause irritation of the upper respiratory tract, resulting in flu-like symptoms; direct skin contact may result in irritation	• Avoid cable burning • Prefer mechanical recycling of cables by peeling or shredding as it can allow the separation of the conductor from the plastic sheathing and insulation in a safe manner
	Screws, pumps etc. made of base metals (Iron, Copper, Aluminum[e])	**LOW** • Exposure to metal participles due to improper handling	**LOW** • Improper handling and open burning are common in the informal sector	**LOW** **Environmental:** • Metal particles accumulating in air, soil and water systems have adverse impacts in high concentration **Social:** • Ingestion of base metals causes gastrointestinal irritation. High levels of aluminum contamination in drinking water leads to bone pain, deformities, seizures, slow growth in children, and muscle weakness • Copper oxide fumes may cause irritation of the upper respiratory tract, resulting in flu-like symptoms; direct skin contact may result in irritation	• Avoid informal recycling and open burning to recover valuable metals • Separate ferrous metals using magnets. Crush them into steel and separate aluminum bales for reprocessing • Separate non-ferrous metals (such as copper or zinc) using Foucault currents and industrial machinery. In developing countries, manual sorting will be preferred when possible • Copper is one of the few materials that can be recycled repeatedly without any loss of performance. It can be sent to a local recycler as it is valuable and easy to recycle

(*continues*)

TABLE A1.2

E&S Risks Associated with OGS Product Components (*Continued*)

PRODUCT COMPONENT	CRITICAL FRACTIONS; USE LIFETIME[a]	RISK LEVEL, MAIN REASON FOR RISK	PROBABILITY OF EXPOSURE	IMPACTS	STEPS TO AVOID POTENTIAL NEGATIVE EFFECTS THROUGH IMPLEMENTING E-WASTE MANAGEMENT PRACTICES
	Plastics with brominated flame retardants (BFR)[f]	**MEDIUM** • Pollution due to improper disposal into landfills or open burning	**LOW** • Lack of technical capability to recycle plastics often causes it to be disposed improperly in landfills or burned • Open burning can lead to the release of BFRs • However, the likelihood of BFR-plastic being used in OGS products is low	**HIGH** **Environmental:** • Items with BFR, whether in use or disposed of, can cause BFR to leach and persist in air, soil & water and enter the food chain **Social:** • BFRs and heavy metals such as lead and cadmium are hazardous, if ingested • BFRs build up in tissue, cause cancer, disrupt hormones, harm the reproductive system, cause neurodevelopmental problems	• Do not recycle but dispose in a lined and managed landfill or incinerate in a suitable facility
	Plastics without BFR	**LOW** *See Plastic Casing*	**LOW** *See Plastic Casing*	**LOW** *See Plastic Casing*	*See Plastic Casing*
Connected appliances	**TV flat panel** displays *8–9 years*	**HIGH** • Mercury leakage due to breakage during handling, dismantling, or storage	**HIGH** • Mercury is contained within the backlight display tubes and can relatively easily leak if broken during handling, dismantling or storage.	**HIGH** **Environmental:** • If released into the environment, mercury accumulates in water laid sediments where it converts into toxic methylmercury and enters the food chain. **Social:** • Mercury (as methylmercury) can bioaccumulate through the food chain and easily enter the human bloodstream and affect the brain & nervous system.	• Ensure dismantlement and recycling through formal facilities - most parts of flat panel display can be dismantled and recycled • Ensure backlight tubes are carefully treated—remove from the TVs to avoid breakage, store in closed containers to prevent emissions, handle dismantling emissions with care

(*continues*)

TABLE A1.2

E&S Risks Associated with OGS Product Components (*Continued*)

PRODUCT COMPONENT	CRITICAL FRACTIONS; USE LIFETIME[a]	RISK LEVEL, MAIN REASON FOR RISK	PROBABILITY OF EXPOSURE	IMPACTS	STEPS TO AVOID POTENTIAL NEGATIVE EFFECTS THROUGH IMPLEMENTING E-WASTE MANAGEMENT PRACTICES
	Appliances with coolants (refrigerator, cold storage) *10–20 years*	**HIGH** • Ammonia and/or hydrochlorofluorocarbons (HCFC) leakage[g] in closed spaces due to damage and improper recycling • Fires due to high flammability of ammonia	**HIGH** • Ammonia requires high pressure, through carbon dioxide, which if not maintained can lead to leaks, often the case in end-of-life systems where damage and improper recycling are abundant • Improper dismantling can lead to HCFC leakage	**HIGH** **Environmental:** • Release of HCFCs causes ozone depletion and leads to an increase in global warming • Ammonia negatively affects biodiversity **Social:** • Ammonia is toxic even at low quantities in the air and can lead to asphyxiation and severe burns to workers in enclosed spaces without protection • Ammonia can lead to severe burns without safety precautions	• Ensure sorting, dismantling, and treatment is done properly/with safety and protection in mind, especially protective gear, etc. • Ensure fire safety guidelines are adhered to at the recycling facility, to minimize the aftermath of accidental fires
	Other appliances (radios, fans, etc.) *varies*	**MEDIUM** • Improper handling & recycling	**HIGH** • Electronics are often handled in the informal sector through dangerous practices (e.g., acid leaching, open burning, manual dismantling, all without adequate safety gear)	**LOW/ VARIES** **Environmental:** **Social:** • Base metals and plastic in appliances can lead to various issues (*See Base metals & Plastic casing)*	• See Base Metals & Plastic Casing

[a] All life-time information is indicative only. It is highly dependent on how components are maintained, external conditions (heat, humidity, physical stress) and usage patterns.
[b] Most lead-acid batteries last 3–5 years but could live 12+ years if well maintained. Battery lifetimes depend on several factors, including battery quality, charge management and exposure to externalities.
[c] More here: https://www.sustainable-recycling.org/wp-content/uploads/2023/03/ULAB_recycling_SOPs.pdf
[d] Due to insufficient environmental regulations and control, many developing economies host lead-acid battery recycling companies whose treatment practices are not environmentally sound despite being compliant or certified by authorities. Much caution is advised when addressing a local battery recycler.
[e] Aluminum is expensive, so local markets for recycled aluminum are common. E-waste distributors will sell their aluminum to metal scrapers who bale it and ship it internationally.
[f] BFRs are rarely found in OGS products.
[g] Ammonia is the most used coolant in solar refrigerators. While 53% refrigerators use ammonia as a coolant, around 39% still use HCFCs.

ANNEX 2

Implementation Steps and Specific Activities that Task Teams Can Take to Integrate Off-Grid Solar E-Waste Management Across the Project Cycle

TABLE A2.1

Implementations Steps and Activities to Integrate E-Waste Management

PROJECT CYCLE STAGE	IMPLEMENTATION STEP	ACTIVITIES	RESPONSIBLE PARTY	ENVIRONMENTAL AND SOCIAL STANDARD (ESS) RELEVANCE
Project Identification: Screening, awareness raising and engagement of key stakeholders to identify main risks	As part of initial screening for main E&S risks and impacts, include first e-waste management risk analysis	• Assess basic Borrower capacities and frameworks in terms of e-waste risk management • Decide if Borrower E&S framework on e-waste management will be used in the project • Identify preliminary major e-waste E&S risks, based on previous projects of similar type, location, and size; sectoral reference materials, such as this Toolkit, expert inputs • Identify initial opportunities to integrate E&S e-waste issues with project objectives and design • Identify key stakeholders in relation to the e-waste topic, hinting to the type and breadth of stakeholder engagement processes needed within the project • Use screening results as a basis for scoping the Environmental and Social Assessment, by determining its extent and approach (i.e., strategic vs. project-level, also in view of e-waste) • Draft concept-stage Environmental and Social Review Summary (ESRS) and initial Environmental and Social Risk Classification (ESRC)	Task Team (including Accredited Environmental and/or Social Specialist)	ESS1
	Awareness raising to IA and other government departments/ministries on e-waste E&S risks and initial management options within the project	• (Re)discuss current country experience, plans, capacities in relation to e-waste management • Identify on a high-level the need for improvements, additional studies and support already received	Task Team	ESS10
	Engagement of key actors in the OGS and e-waste sectors	• Identify improvements for the overall sector and the project • Identify need for additional studies (e.g., ESIA)	Implementing Agency	ESS1, ESS10
	Ensure WB HR covers the required skills to support the Borrower during the project preparation	• Involve specialists with e-waste and OGS experience as part of the WB project team- either in-house or third-party	Task Team	ESS1

(*continues*)

TABLE A2.1

Implementations Steps and Activities to Integrate E-Waste Management (*Continued*)

PROJECT CYCLE STAGE	IMPLEMENTATION STEP	ACTIVITIES	RESPONSIBLE PARTY	ENVIRONMENTAL AND SOCIAL STANDARD (ESS) RELEVANCE
Project Preparation: Assessment and preparation for handling risks	Ensure Borrower HR comprises the required skills to support the Borrower during the project preparation	• Based on initial Environmental and Social Risk Classification (ESRC), allocate first responsibilities, resources, and implementation support on e-waste management to the Project. Involve specialists with e-waste and OGS experience as part of the Implementing Agency team—either in-house or contracting third-party consultants	Implementing Agency (with support from Task Team)	ESS1
	Incorporate e-waste risk assessment in the project's E&S assessment for the project	• Identify hazards, impacts, probability, and categorize risks, confirm risk prioritization (e.g., through ESIA and/or full self-standing e-waste situation analysis) • Include risks and mitigation options in overall Environmental and Social Management Plan (ESMP), prepared for the project	Implementing Agency (project preparation team) for ESMP or third-party consultants, Task Team (to review)	ESS1, ESS3, ESS4
	(Re)assessment of Borrower capacity to effectively handle OGS e-waste-related risks, including potential to implement different mitigation options to mitigate risks	• Identify TA needs and budget to support the TA for the Borrower in relation to the management of e-waste risks	Implementing Agency, Task Team, third-party consultants	ESS1
	Confirm mitigation options to address OGS e-waste-related risks	• Conduct risk assessment considering the project's specific location and components • Identify fitting mitigation options • Discuss mitigation options within WB team but also with local stakeholders (e.g., workshop) • Confirm implementation mechanisms (TA, financial mechanisms, eligibility criteria) • Confirm budget ranges for implementing the mitigation options through specific mechanisms • Where appropriate, coordinate with other projects in implementation and design in the country of intervention	Implementing Agency, Task Team, third-party consultants	ESS1, ESS3, ESS4, ESS10
	Prepare ESCP, submit with financing agreement	• Identify specific commitments (including dates/targets) and include in formal Environmental and Social Commitment Plan (ESCP)	Implementing Agency, with support from third-party consultants Task Team (review)	ESS1

(*continues*)

TABLE A2.1

Implementations Steps and Activities to Integrate E-Waste Management (*Continued*)

PROJECT CYCLE STAGE	IMPLEMENTATION STEP	ACTIVITIES	RESPONSIBLE PARTY	ENVIRONMENTAL AND SOCIAL STANDARD (ESS) RELEVANCE
Project Appraisal: Integration of mitigation measures in project design and Borrower support	Integrate OGS e-waste mitigation measures in project design, including budget, M&E framework	• Confirm mitigation options that will be implemented as well as specific mechanisms (TA, financial mechanisms, eligibility criteria, equipment) • Confirm budget for implementing, monitoring, and evaluating the mitigation options • Define key processes and staff for M&E, develop KPIs around e-waste and include in M&E manual	Implementing Agency with support from Task Team and third-party consultants Task Team (review)	ESS1
	Integrate OGS e-waste mitigation measures in project operational documentation (implementation manuals/guidelines)	• Identify key processes and steps for operationalization • Develop manuals/guidelines for implementing the options • Include e-waste considerations in standard project documentation, such as concept and appraisal Environmental and Social Review Summary (ESRS), Environmental and Social Commitment Plan (ESCP), Stakeholder Engagement Plan (SEP) and any draft documents prepared by the Borrower relating to the E&S assessment of the project • Develop capacity building plan for different stakeholders involved in the implementation chain, to ensure they have the capacities needed	Implementing Agency, with support from third-party consultants Task Team (review)	ESS1
Project Implementation: Implementation of risk management actions; M&E and corrective actions	Implement mitigation measures	• Implement in a timely manner and up to the standards and commitments set in the project • As needed, train stakeholders on key E&S aspects of the project	Implementing Agency, following Environmental and Social Management Plan (ESMP), Environmental and Social Commitment Plan (ESCP) and project design Task Team (M&E through supervision, implementation support)	ESS1
	Monitor and evaluate the mitigation measures implemented as well as existing and emerging E&S e-waste risks	• Conduct regular M&E, including on stakeholder engagement activities and management of grievance mechanisms • Report on KPIs (especially cases for non-respect of mitigation actions and against ESS) • Gather, discuss, and address identified issues, including new risks. • Review mitigation measures, based on M&E and implementation insights, as well as change in best practices	Implementing Agency, following Environmental and Social Management Plan (ESMP) Task Team (M&E through supervision)	ESS1, ESS3, ESS10

(*continues*)

TABLE A2.1

Implementations Steps and Activities to Integrate E-Waste Management (*Continued*)

PROJECT CYCLE STAGE	IMPLEMENTATION STEP	ACTIVITIES	RESPONSIBLE PARTY	ENVIRONMENTAL AND SOCIAL STANDARD (ESS) RELEVANCE
	Update OGS e-waste mitigation measures and safeguard documentation, based on implementation insights and need	• If needed, identify significant additional risks and impacts, documenting these in the Implementation Status and Results Report • If needed, re-design or update mitigation measures or implementation mechanisms used • Review/clear out E&S documentation, including Environmental and Social Commitment Plan (ESCP), Environmental and Social Risk Classification (ESRC) • Confirm Project Operations Manual (POM) and procurement documentation include e-waste management, implementation arrangements, requirements, and measures, as per the E&S documentation	Implementing Agency, Task Team (support)	ESS1
	Proactively prepare for rapid crisis management and corrective action implementation	• Define railways to define "crisis" • Confirm adequacy of incident reporting and response procedures in place • Raise awareness and increase capacity of stakeholders implementing WB projects with OGS components (e.g., contractors) on crisis identification and prevention • End-user awareness campaigns		
	Reactively assess crisis, prepare, and execute action plan to enable the grievances redress mechanism		Implementing Agency, with Task Team support	ESS1,
Project Closing and Evaluation: Lessons learned and good practices capturing	Collect insights for future operations and/or scaling up of the WB project/intervention within the Borrower's system	• Conduct evaluation on mitigation options • Collect good practices (including from successful mitigation options). • Conduct evaluation of Environmental and Social Standard (ESS) implementation performance • If needed, suggest further mitigation actions to continue after WB's supervision ends)	Implementing Agency	

ANNEX 3

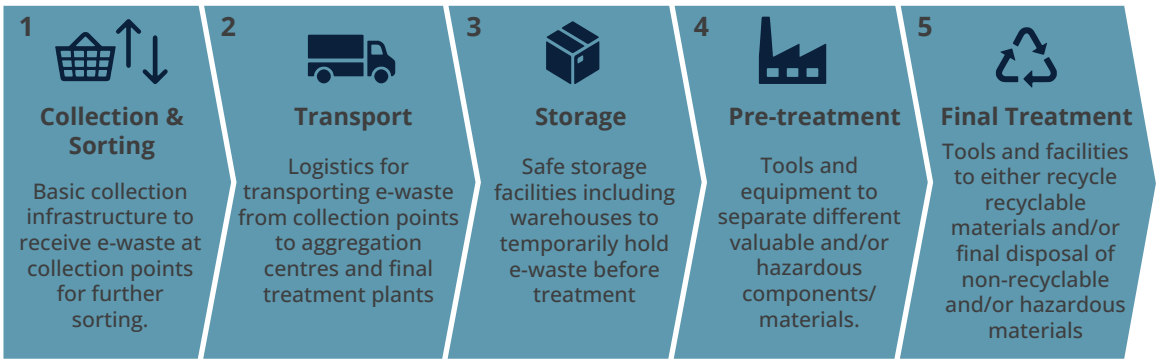
Infrastructure and Process Needed for Off-Grid Solar E-Waste Handling

The OGS e-waste management infrastructure needed to adequately manage different e-waste streams covers different stages, including: (1) **collection**, (2) **pre-processing** (including disassembly, pre-treatment) and (3) **end-processing** (including recycling) (Figure A3.1). After the collection phase, end-of-life Electrical & Electronic Equipment is treated to obtain product components (to be reused or refurbished) or material fractions (to be recycled and reused as raw materials). Components or material fractions that are not being re-used or recycled (due to their intrinsic hazardous content or lack of secondary markets or uses) are sent to suitable disposal sites. This reverse supply chain may vary in complexity based on country and location and some stages may overlap. **Moreover, the local context influences what is practically feasible based on available but also needed capacity.**

- **Collection and sorting** of end-of-life solar products begins the reverse supply chain, and is key in getting efficient solar WEEE management right. Typically, collection points are set up with suitable containers for drop off, i.e., users returning their products at end-of-life. Alternatively, (for pico-solar) WEEE can be collected through collection drives (specific days when collection close to the end-user happens, for which end-users are pre-informed and incentivized to participate), as well as from institutions where large volumes of e-waste accumulate or where equipment is installed (for public facilities and SHS). Depending on the type of waste collected, basic sorting (usually manual) of different equipment/components can be performed.
- Local **transportation** of solar WEEE, either from collection points or institutions with large on-site waste volumes, will either bring it to temporary **storage** facility or directly to a waste treatment facility. In locations far from a treatment facility, temporary storage is the intermediate stage to allow for aggregation of e-waste. In the case of

FIGURE A3.1

Steps and Infrastructure Needed to Handle Solar Waste Electrical and Electronic Equipment



some hazardous e-waste streams like batteries, specific safety precautions and handling guidelines must be adhered to, to prevent environmental and health hazards.

- **Pre-treatment** precedes safe disassembly and/or recycling of solar WEEE. Pre-treatment includes manual or mechanical processes to separate different valuable and/or hazardous components and materials. This involves the removal of gases and other hazardous substances from the e-waste, ensuring again E&S risk management. A treatment line for solar PV panels, for example, may be necessary to separate the different components/ materials. However, not all waste streams may require this process. Automated shredding and sorting lines are commonly used for WEEE pre-treatment, once equipment has been depolluted (i.e., hazardous components have been manually removed). Relying on various sorting technologies (magnetic, eddy-current, density, screening, etc.), these technologies allow for separation of different materials (e.g., steel, non-ferrous, plastics). For most solar energy products and components, manual disassembly is a viable pre-treatment option. Specific (and more complex) processing technologies are generally only needed for a few fractions:
  - Treatment of energy saving lamps (containing mercury) and mercury containing backlights of LCD screens, to ensure mercury is not emitted into the workplace and the environment.
  - Removal of cooling agents from refrigerators and air conditioners, to ensure cooling fluids (with potent ozone-depleting and/or global warming effect) are not emitted into the environment.
  - Discharging of lead-acid or lithium batteries, to reduce the risks of fires.
- **Final treatment** refers to either the recycling of recyclable materials (metals, plastics, glass, etc.) or the disposal of non-recyclable and/or hazardous materials (usually through incineration or landfilling) that were separated at the pre-treament stage. Recycling processes are usually tailored to specific materials, such as steel, copper, plastics, lead-acid batteries, and lithium batteries. They necessitate large quantities of material to be economically feasible, given the significant investments required for infrastructure and pollution control measures. Such processes may therefore not exist at the local or national level, due to insufficient waste volumes. Disposal processes such as incineration plants and sanitary landfills also require significant initial and operational investments and are not widely found, especially in low-income countries.

Pre-treatment and final treatment technologies aim to recover valuable materials while removing and, ideally, destroying hazardous substances. While **pre-treatment technologies are rather simple and can be financially, technologically, and operationally viable even at small scale, final treatment technologies typically require large volumes and large investments, if done in an environmentally sound manner**. Of course, incineration can be done in the open, metals can be remelted at small scale in unsafe conditions, and precious metals can be recovered using acids in backyards, however all these processes entail disastrous environmental and health impacts. In low- and medium-income countries, environmentally sound final treatment technologies are often lacking, due to lack of volumes, lack of financing, and high involvement of the informal sector. In such cases, export for final treatment abroad may be the preferred option, at least in the short- and medium-term.

In any case, it is crucial to understand how OGS e-wastes are currently managed locally and regionally, in the formal and informal sectors, and identify stakeholders that can play a role in collection, pre-treatment and final treatment, as well as those having access to international markets for fractions that cannot be properly treated locally (Magalini, et al. 2016). For example, at the local level, capacity may exist to recycle steel, aluminum, glass, and plastics, which represent more than 90 percent of the weight of solar panels. For other fractions, solutions would need to be found at the regional or international level. Practical challenges involved in transboundary shipments of (hazardous) waste would need to be clearly identified.

ANNEX 4

Integrating Off-Grid Solar E-Waste Considerations when Applying the Environmental and Social Framework

The information below provides insights on how OGS e-waste risk at the level of the OGS project or OGS project component can be managed through the Environmental and Social Framework (ESF), by interpreting the different Environmental and Social Standards (ESS) relevant to OGS e-waste and linking them with the WB project cycle. For further guidance, please refer to the Directive and Guidance Notes (GN).

TABLE A4.1

Environmental & Social Standards and E-Waste Considerations

ESS[a]	INCLUDE OGS E-WASTE CONSIDERATIONS IN . . .[b]
ESS1	• the overall E&S risk assessment, management, and monitoring cycle of the project, to facilitate reaching ESS1's overall objectives (GN14.1–14.4). • the review of the Borrower's E&S framework, should the Borrower and the Bank propose to use the whole or part of it (GN20.1–20.2). • the risk assessment and in the needed management tools associated with the ESA (GN 23) (e.g., ESIA, EIA, ESMP, ESMF, ESCP, manuals etc.) that the Borrower needs to prepare, with assistance from the Bank (GN36–41). • selecting specialists for the ESA, i.e., specialists that have the right technical skills, experience, and competency in e-waste, who would assist the Borrower in carrying the ESA (GN25). • selecting specialists/experts in the case that projects have been labelled high-risk or contagious when it comes to e-waste, who would assist the Borrower in the project cycle (GN33). • the Monitoring & Evaluation (M&E) on E&S performance of the project against the ESS (GN15.1, GN45). • the review of the Borrower's ESF, that the Bank would carry (GN 20.1–20.4). • the mitigation hierarchy for overall E&S risks, for those e-waste risks considered significant in ESA (GN27).
ESS2	• the social assessment part of the ESA, to assist with deciding on the overall importance of ESS2 for the project (2[c]). • Occupational Health and Safety measures set out in the legal agreement and ESCP, for those e-waste risks considered significant in ESA (GN24.2). • deciding on an approach for utilizing or not utilizing community workers (especially informal collectors, recyclers) (GN 34) as well as applying ESS2 to them in manner proportionate to the project's e-waste risks and impacts, if ESS2 is applicable and ESA shows significant negative impacts (GN 35.1).
ESS3	• the environmental assessment part of the ESA, to assist with deciding on the overall importance of ESS3 to the project (3). • raw material use, by adopting guidance from this Toolkit, other Good International Industry Practice (GIIP), coupled with the he WB Environment, Safety and Health Guidelines and Industry Sector Guidelines when seen applicable (GN10.1). • pollution prevention and management, in the assessment cumulative historical pollution caused by e-waste as part of historical pollution (GN12.1). • the management of hazardous and non-hazardous wastes: – including e-waste in the ESA and considering the waste mitigation hierarchy when proposing mitigation actions to manage e-waste risks (GN17.1–2). – following this Toolkit, other GIIP, international conventions (including those regulating transboundary movement of e-waste) for environmentally sound disposal (GN18.1–3). – considering developing own e-waste treatment and disposal facilities or long-term storage in case other disposal options are not available, all in line with this Toolkit and other GIIP (GN18.4).
ESS4	• community health assessments, as part of ESA (GN18.2), especially for informal collectors and recyclers of e-waste. • the measures to avoid or control community exposure to hazardous components (GN18.1), when seen necessary through the ESA, especially for informal collectors and recyclers of e-waste. • developing management plans for those e-waste risks with significant community exposure (GN 18.4).

(*continues*)

TABLE A4.1

Environmental & Social Standards and E-Waste Considerations (*Continued*)

ESS[a]	INCLUDE OGS E-WASTE CONSIDERATIONS IN . . .[b]
ESS9	• the list of E&S risks the Financial Intermediaries would evaluate and potentially monitor and manage for their portfolio through an ESMS and its procedures and application, to avoid a range of financial, legal, and reputational consequences. (GN7.1–2, GN11.3) • the Financial Intermediary E&S policy as part of the ESMS, to the extent seen relevant (GN14.1–2). • the Financial Intermediary E&S procedures of the ESMS that will implement the E&S policy, such as in: – Financial Intermediary subprojects' screening, acknowledging applicable e-waste risks and mitigation options (16b). – including the necessary measures in the Financial Intermediary subprojects agreements, requiring they are assessed, prepared, and implemented to comply with the national e-waste laws (16c, d). – assessing and addressing e-waste incidents (e.g., explosion of stored e-waste batteries) in accordance with relevant aspects of the ESSs, modifying the Financial Intermediaries procedures should they not be adequate to address this increased risk (GN16.1) and notifying the WB (GN22.1–2). – monitoring, keeping, and regularly updating e-waste-related information on Financial Intermediary subprojects, in a manner proportionate to the e-waste risks identified (GN 21.2, GN23.1.). – the risk categorization system for Financial Intermediary subprojects, if seen relevant, to enable significant e-waste risks to enter the systematic aggregation and analysis of portfolio E&S risk (GN 17.1). • developing and maintaining organizational capacity to handle e-waste risks, whereas the Financial Intermediary may identify and use in-house staff with appropriate qualifications or retain the services of external experts, by ensuring training and/or budget are made available (GN 19.1). • including e-waste topics (e.g., risks, disposal methods, and management options and plans on different levels) in the stakeholder engagement and external communications, in a manner that is proportionate to the risks and impacts (GN 24.1, GN25.1, GN27.1) and accessible and culturally appropriate (GN27.2).
ESS10	• considering e-waste collection, repair, and recycling sector, including an informal one, as key stakeholders that need to be appropriately engaged (GN5.2, GN10.1, GN11.1–2) in a meaningful manner (GN 22.1–2). • including the same sector in engagements prior (GN6.3) and after (GN6.4) the project approval, and in general in the Stakeholder Engagement Plan (GN6.2, GN13.1–5). • asking OGS companies to share core information with OGS end-customers, i.e., on environmental hazards associated with poor disposal of used batteries and e-waste, and on disposal options.

Note: EIA = Environmental Impact Assessment; ESMF = Environmental and Social Management Framework; ESCP = Environmental and Social Commitment Plan; ESIA = Environmental and Social Impact Assessment; ESMP = Environmental and Social Management Plant; ESS = Environmental and Social Standards.

[a] Should the ESS apply to the project, please consider including e-waste through the following approaches.
[b] References made are from the Guidance Notes (GN) to the particular ESS, i.e., ESS1, ESS2, ESS3, ESS4, ESS9, ESS10.
[c] Numerical references (i.e., without GN) refer to the paragraph of the ESS referred to in the Table.

ANNEX 5

Terms of Reference (TOR) for Hiring Consultant to Carry Out Off-Grid Solar E-Waste Situation Analysis

Support to the Government of [ ] on the Management of Electronic Waste from Off-Grid Solar Technologies

ASSIGNMENT BACKGROUND AND OBJECTIVES

As part of the project "[ ]" (the Project), the World Bank is financing support to the Government of [ ] (the Government) to implement concrete actions for the effective management of electronic waste (e-waste) from off-grid solar (OGS) technologies powering [public facilities, Micro-SMEs, SMEs, and/or households].

The Project's environmental risk classification is [ ] as activities may present adverse environmental impacts to the environment, including those related to the mismanagement of end-of-life batteries. To fulfil its environmental and social obligations under the Project, risks and impacts are expected to be managed by the Government in accordance with the World Bank Group's Environmental and Social Framework (ESF), including the Environment, Health, and Safety Guidelines and the relevant requirements of the different ESSs (especially ESS3).

Different risk management approaches are to be envisioned. An e-waste-related support to ultimately enable [the reverse supply chain[a] for the Project, e-waste policy development process, repair modalities, etc.]. As outlined in these ToR, support will therefore be given to the [ ] to ensure e-waste resulting from the Project can be handled safely and proactively to manage environmental risks.

SCOPE OF WORK

To contextualize the OGS e-waste management approach of the Project and assess OGS e-waste risks, an e-waste situation analysis needs to be carried out, zooming in on risks that arise from factors internal and external to the OGS project. To be comprehensive and useful to the purposes of managing OGS e-waste risks, the e-waste situation analysis in a market is be structured as follows:

A. **Internal project review.** This analysis will focus on studying: the Project (components, stakeholders, financial and contractual mechanisms, adjoint programs) and how it can enable effective e-waste management, given its existing design and planned actions; calculations of the e-waste (batteries, components) to be generated over time by the Project (and how they contribute to the overall OGS e-waste and other e-waste quantities in the local and regional market over time); capacities of the implementing agency to handle e-waste risks, especially through implementing specific interventions.
B. **Stakeholder mapping.** Map and study the stakeholders relating to OGS e-waste, including local OGS private sector, as well as the local and regional collection and recycling sector actors, trying to pinpoint gaps but also quick opportunities.
C. **Legislative and policy review.** Study the local legislative framework (policy, legal framework, enforcement mechanisms, administrative framework) regulating OGS e-waste, trying to pinpoint gaps and quick opportunities for reforms within the Project. National, regional, or local frameworks may be relevant and applicable.
D. **Infrastructure assessment.** Develop an overview of the current collection, pre-processing/disassembly (including informal sector), repair, and end-processing/recycling infrastructures and routes within the specific market but also regional linkages, especially with a view to study the possible reverse supply chain/infrastructures and costs for appropriate e-waste management.
E. **Institutions.** Map and assess the influence, interest, and capacities in e-waste management of entities responsible for implementing and enforcing the legislative framework. Analyze mandates to spot conflicts in responsibilities and lack of clarity. Evaluate technical and institutional capacity of the different institutions to carry out their responsibilities.
F. **Summary and recommendations.** Overall, help pinpoint the e-waste challenges and opportunities in the market and inform how to leverage on the opportunities and manage the challenges through the Project's design. This will ultimately aim, therefore, to generate actionable recommendations/pointers to inform the Project in what it can do within its existing remit and design to manage the e-waste risks resulting from the Project. It will also aim to gain an overview of improvement efforts underway to align with/build on them and fill in any gaps. Where possible, it should also contain implementation suggestions/details.

Desk studies, interviews, expert observations, workshops and validation sessions, and field visits are envisioned, as needed. Central to this work is the development of a robust baseline of knowledge with an emphasis on (i) operationalization/implementation steps already during the Project, with a view for a sustainable intervention lasting after its end, (ii) effective capacity building of the Government, WB, the private sector, and other partners for the purposes of enabling the effective operationalization of the suggestions included in the study. In particular, the approach should aim to ensure that e-waste management is well-understood with the Project and that the topic has clear and capacitated owners that can work on the topic immediately and continuously.

(*continues*)

DELIVERABLES

- Draft and final situation analysis
- [XX] workshops with Project stakeholders to [validate the results, build their capacity on the topic, etc.]

BUDGET

The estimated budget for the advisory services for delivering this study is a maximum of [ ].
Reimbursables for the field visits are also envisioned.

CONSULTANT PROFILE

- Experience, knowledge and expertise in the following topics: Circular Economy; E-waste management; Energy and Environmental Policy Development; Business and Operational Models for Renewable Energy; Capacity Building, Training, and Coaching

[a] In this context, a reverse supply chain usually refers to the logistics, roles and responsibilities, and contractual arrangements (e.g., extension of O&M responsibilities, new contractual and financial etc.) associated with the collection, transport, storage, treatment, and recycling of e-waste.

ANNEX 6

International Conventions and Standards on E-Waste Management (2022)

TABLE A6.1

International conventions and standards on e-waste management

NAME	REACH	DESCRIPTION
The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	Global	International treaty designed to reduce hazardous waste generation and its movements between nations; prevent transfer of hazardous waste from developed to developing countries; minimize the amount and toxicity of wastes generated; ensure their environmentally sound management as closely as possible to the source of generation; and assist least developed countries (LDCs) in environmentally sound management of the wastes they generate. Entered into force for a few signatory countries the Ban Amendment to the Basel Convention, which prohibits the export of hazardous waste from developed countries to developing countries. This entered into force in December 2019 for the concerned countries.
The Stockholm Convention on Persistent Organic Pollutants (POPS)	Global	The Stockholm convention focuses on the proper management of some components of e-waste: the imports of plastic products, electrical and electronic goods, computers, mobile phones, foams, and flame retardants that form the bulk of the newly listed POPs occur. The main challenge that comes with chemical use is the proper management of chemicals across the lifecycle. Poor management of chemicals comes with a price due to poor health and degraded ecosystems.
Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	Global	The Rotterdam Convention is an international treaty designed to facilitate informed decision-making by countries on trade in hazardous chemicals. It establishes a list of covered chemicals and requires parties seeking to export a chemical on that list to first establish that the intended importing country has consented to the import. This also applies to chemicals included in battery chemistries and overall hazardous chemicals used in e-waste issues. This treaty is especially important in Latin America, where most of the countries have ratified it to comply with e-waste standards.
R2	Global	R2 was developed by a multi-stakeholder group conveyed by the United States Environmental Protection Agency (US-EPA), including electronic recyclers, refurbishers, trade associations, manufacturers, and NGOs. Currently, 947 certified players around the world are adopting the R2 standard, including China, India, and Thailand. Only two are in Africa (both in South Africa).
WEELABEX	Global	WEEELABEX, now included in the CENELEC EN-50625 series, is probably the most comprehensive and complete set of standards, defining normative requirements and technical specification for collection, transportation, re-use, and treatment of e-waste, developed by industries in Europe. Currently, 183 plants are WEEELABEX certified across the EU; one operator has been certified in South Africa. In quarter 3 (Q3) of 2020, a trial audit on the plant of Enviroserve in Rwanda was successfully conducted in the context of the EU funded project CEWASTE6.
The E-Stewards Standard	**Global**	Developed by the Basel Action Network (BAN), this standard is adopted currently by 57 players in Canada, Mexico, United States, Singapore, and United Kingdom.
Bamako Convention	Regional: Africa	This treaty, ratified by the Member States of the Organization of African Unity, came into force in 1998 and focused on prohibiting imports and controlling movement of hazardous wastes within Africa. It was born out of the need to overcome certain issues that the Basel Convention was not able to address completely, including the failure to prohibit trade of hazardous waste to LDCs. The treaty prohibits imports of all waste without any exceptions and provides a much stronger tool to prevent trade of hazardous waste to less developed countries. One of the main aims of the Bamako Convention is to facilitate the transport of waste across Africa.

(*continues*)

TABLE A6.1

International conventions and standards on e-waste management (*Continued*)

NAME	REACH	DESCRIPTION
EACO Regional E-Waste Strategy (2017)	Regional (East Africa)	The EACO regional e-waste management strategy is a five-year plan, from 2017/18 to 2021/22 that aims at strengthening the policy and regulatory framework for sustainable e-waste management, at putting in place the necessary infrastructure, at establishing mechanisms for the mobilization of e-waste management resources, at increasing coordination of relevant structures at the regional and national level, and at promoting research and innovation in e-waste management. It was signed by Tanzania, Rwanda, Uganda, Burundi, Kenya and South Sudan, and its vision spans about 20 years.
ASEAN Harmonized Electrical and Electronic Equipment Regulatory Regime	Regional (South East Asia)	The objectives of the Agreement on the ASEAN Harmonized Electrical and Electronic Equipment Regulatory Regime are: a. to enhance cooperation amongst Member Countries in ensuring the protection of human health and safety and property and the preservation of the environment insofar as they are affected by trade of electrical and electronic equipment in ASEAN; b. to eliminate restrictions to trade of electrical and electronic equipment through harmonization of technical requirements and registration; and c. to facilitate the negotiations for Mutual Recognition Agreements on Conformity Assessment between ASEAN and other countries or group of countries.
ASEAN Sectoral Mutual Recognition Arrangement for Electrical and Electronic Equipment	Regional (South East Asia)	This Sectoral MRA applies to all instances, where test reports and/or certifications are used as the basis for regulatory action in respect to electrical and electronic equipment. The scope of equipment covers all new* electrical and electronic equipment that is intended to be either directly connected or plugged-in to the low voltage power supply or is battery powered, but does not include any equipment covered by the ASEAN Sectoral MRA on Conformity Assessment Telecommunications Equipment.

ANNEX 7

Environmental and Social Screening Form (ESSF) Template for Screening OGS Companies

Introduction

This Environmental and Social Screening Form (ESSF) module has been designed to assist in the evaluation of the status of e-waste activities planned and/or implemented by [Company name], to assist the company in assessing funding from [Organization/WB project/Fund name/PFI]. The content presented here, in full, or parts of it, should be added to the full ESSF used to screen for E&S issues. The ESSF will mainly be used by the [Organization/WB project/Fund name] and guides the evaluator teams (part of the [Department name]) in:

- Gathering information on e-waste management practices by OGS companies.
- Identifying any E&S impacts associated with e-waste and their planned or already implemented mitigation measures.
- Determining the requirements for further E&S work, as needed.

The form is to be completed by the evaluator teams (part of the [Department name/Organization]) at the E&S due diligence stage.

Guidance for Users

The evaluator should undertake the assignment after:

- Gaining adequate knowledge of the geographical area where [Company name/project] will operate/operates.
- Gaining knowledge of [Company name/project] and how it will operate/operates.
- Having been briefed/trained in environmental and social (ES) screening, including the OGS e-waste management topic.

Section A: Company Details Info Points with Relevance to E-Waste Management		
Contact person for E&S issues: (Name and title / Phone /E-mail)	Contact person for e-waste issues:	
Section B: Products and Business Activities (OGS sector):	Number of products POTM in the last [3–5 years]:	Projected number of products to be POTM during financial support from [the Fund/WB project/PFI]:
Pico-solar products		
Solar Home Systems		
Productive use of renewable energy systems (such as solar pumps)		
Other *(specify)*		
Section C: Environmental and Social Management System - does the company have policies, procedures, and processes related to:	**Yes** (capture details)	**No** (capture details)
Regulatory Compliance		
Does the company have an Environmental/Social Policy? Does it include e-waste management as a topic?		
Does the company conduct any E&S monitoring visits with its business customers? Does it include e-waste management as a topic?		
Does the company ensure compliance with all relevant environmental laws, regulations, and standards specific to OGS e-waste management in country?		
Does the company have the necessary permits and approvals from local authorities for e-waste handling, storage, transportation, pre-processing, and processing (recycling activities)?		
Collection & Transport		
Does the company have any policy or process for collecting used batteries (both lead acid and lithium ion), as well as used units and equipment from customers?		
Does the company have a systematic approach for the collection and transportation of OGS e-waste from rural/remote areas and end-users through to designated end-treatment facilities?		
Does the company have partnerships with local communities, NGOs, other OGS and EEE producers, and governmental organizations to facilitate e-waste collection campaigns and awareness programs?		
Handling & Storage		
Does the company implement safe handling procedures to spot and prevent damage to OGS e-waste components during storage and transportation and therefore limit H&S risks?		
Does the company store e-waste in safe storage facilities equipped with appropriate containment measures to minimize the risk of contamination and unauthorized access?		
Processing		
Does the company have any policy/process for collecting, sorting, recycling and disposal of used LAB and LIBs or any other used material resulting from solar systems' installation process and subsequent use?		
Does the company have protocols for identifying and segregating different components of OGS systems, including solar panels, batteries, inverters, and electronic control units?		

(*continues*)

Does the company partner with certified pre- and end-processing (recycling) facilities equipped to handle OGS e-waste, ensuring dismantling, recycling, and disposal of parts is done environmentally appropriately?		
Does the company support the use of environmentally sound recycling technologies that minimize energy consumption and emissions?		
Circular Economy & Resource Recovery		
Does the company have any buy-back agreements with equipment manufacturers as part of its waste management approach?		
Does the company maximize resource recovery from OGS e-waste by recovering valuable materials such as metals, silicon, and lithium for reuse in new products?		
Does the company prioritize the repair, reuse, repurposing, and refurbishment of intact components and products to extend their lifespan and minimize waste generation?		
Community Engagement and Empowerment		
Does the company inform end users on the e-waste issue and provide them with information on proper e-waste management (disposal, etc.)? What materials does it use?		
Does the company have a plan for engaging with stakeholders, communities, customers (including a mechanism to receive and address complaints)? *If yes, please attach a copy of the procedure, website link etc*.		
Did the company identify key external stakeholders in relation to e-waste management that are important for its business?		
Does the company empower communities by awareness raising, capacity-building, job creation, entrepreneurship programs on e-waste collection, take-back, recycling, upcycling, and incentives?		

COMPONENTS	APPRAISAL			MITIGATION AND CORRECTIVE ACTIONS
	LOW	MEDIUM	HIGH	
Regulatory Compliance				
Collection and Transport				
Handling and Storage				
Processing				
Circular Economy and Resource Recovery				
Community Engagement and Empowerment				

Overall evaluation of Environmental and E-waste Screening Exercises
The results of the screening process would trigger one of the following options:

REVIEW OF ENVIRONMENTAL SCREENING	TICK FOR YES
1. The company is cleared. No serious corrective measures needed (When all scores are "Yes")	
2. There is need for additions to the company's processes, procedures, and policies (When some scores are "No")	
3. Need to prepare dedicated Environmental and Social Management Plan (ESMP) (When most scores are "No")	

ANNEX 8

Environmental Code of Practice (ECOP) Template

Introduction

- This Environmental Code of Practice (ECOP) is designed to guide the environmentally responsible management of off-grid solar e-waste at [Company/Organization Name]. It provides practical guidelines to minimize environmental impact and ensure continuous compliance with local regulations and standards.
- The document is to be signed by [Company/Organization Name] as part of the funding/loan agreement with [Fund/PFI name]. The prescriptions below are to be complied with and can be checked on and even incentivized by including them in milestone loan/funding disbursements. The requirements mentioned in the template therefore would be shown by [Company/Organization Name] at the time of the relevant milestone, verified by the [Fund/PFI name] team to enable disbursements.
- The content presented here, in full or parts of it, is added to the full ECOP and aligned with any additional insights from the national e-waste situation assessment insights, when relevant. For further details, ideas, and templates that can assist companies in fulfilling these requirements, please see the GOGLA Blueprints.

COMPONENT	RESPONSIBILITY	REQUIREMENTS/EVIDENCE
Regulatory Compliance	• Ensure compliance with all relevant environmental laws, regulations, and standards specific to OGS e-waste management or for general e-waste management in [Country]. • Obtain necessary permits and approvals from local authorities for e-waste handling, storage, transportation, pre-processing, and processing (recycling activities) in [Country], whenever applicable.	Permits and approval documentation Company-level e-waste policy compliance with local regulations Compliance task officially added to HR job description(s)
E-Waste Collection and Transport	• Develop a systematic approach (reverse supply chain) for the collection and transportation of off-grid solar e-waste from rural and remote areas and end-users through to designated end-treatment facilities, wherever needed, working with service providers. • Establish partnerships with others such as local communities, NGOs, other OGS and EEE producers, and governmental organizations to facilitate e-waste collection campaigns and awareness programs.	Partnership MoUs and/or service provision contracts
E-Waste Handling and Storage	• Implement safe handling procedures to spot and prevent damage to OGS e-waste components during storage and transportation and therefore limit H&S risks. • Store e-waste in safe storage facilities equipped with appropriate containment measures to minimize the risk of contamination and unauthorized access.	Company-level e-waste policy and SOP

(*continues*)

COMPONENT	RESPONSIBILITY	REQUIREMENTS/EVIDENCE
Pre-processing Component Identification and Segregation	• Develop protocols for identifying and segregating different components of OGS systems, including solar panels, batteries, inverters, and electronic control units. • Prioritize the repair, reuse, repurposing, and refurbishment of intact components and products to extend their lifespan and minimize waste generation.	Company-level e-waste policy and SOP
End-Processing: Recycling and Disposal	• Partner with certified pre- and end-processing (recycling) facilities equipped to handle OGS e-waste, ensuring dismantling, recycling, and disposal of components is done in an environmentally appropriate way. • Support the use of environmentally sound recycling technologies that minimize energy consumption and emissions.	Partnership MoUs and/or service provision contracts Proof of due diligence approach for selecting and managing relationships with treatment/processing partners
Resource Recovery and Circular Economy	• Maximize resource recovery from OGS e-waste by recovering valuable materials such as metals, silicon, and lithium for reuse in new products. • Implement buy-back agreements with equipment manufacturers as part of the waste management approach.	Company-level e-waste policy; ESMS
Worker Health and Safety	• Provide comprehensive training and personal protective equipment (PPE) to workers involved in OGS solar e-waste handling and recycling activities. • Conduct regular health and safety assessments to identify and address occupational hazards associated with OGS e-waste management.	Proof of training plans and content Proof of approach to H&S assessments/ audits
Community Engagement and Empowerment	• Ensure end-users are continuously and appropriately informed about appropriate disposal, e-waste risks, and repair opportunities at key points of the end-user journey, ideally starting at the point of sale (i.e., through manuals, flyers, posters, technicians/sales personnel, hotline). • Establish a mechanism to receive and address complaints in relation to e-waste. • When possible, empower communities through awareness raising, capacity-building initiatives, job creation, and entrepreneurship programs focused on e-waste collection, take-back, recycling, upcycling, and incentive programs.	Engagement action plan Examples of communication materials
Continual Improvement and Innovation	• Establish tools for monitoring and evaluating environmental performance metrics and KPIs related to OGS e-waste management. • Foster innovation and collaboration with local partners to develop sustainable solutions for OGS e-waste recycling and resource recovery as well as the other circular economy.	Action plan and self-assessment tools

By adhering to this Environmental Code of Practice, we commit to promoting sustainable OGS e-waste management practices in [Country(ies) of Operation] that safeguard the environment, protect human health, and support community development.

[Company/Organization Name] Management
Date: [Insert Date]
Signed: [Insert Signatures]

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