Market research on the circular economy of the renewable energy sector in Nigeria

January 2022

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Executive summary

Executive summary | Research background

The high energy deficit in Nigeria has driven a rise in demand for renewable energy, which will lead to the generation of large volumes of electronic waste

Background of the study

The Nigeria power generation sub-sector includes 25 thermal and hydropower generating plants with a combined installed capacity of over 13,000MW, of which c.46% is available. The limited capacity is expected to serve an estimated demand of 180,000MW.

Research shows that Nigeria has the largest energy deficit in the world, with up to 43% of the population without access to grid electricity. The electrification deficit has driven the rise in demand for renewable energy, including solar energy.

Meeting the demand for clean energy in Nigeria has spin-off effects on the environment including the creation of a new generation of electronic waste (e-waste).

Potential solar e-waste arises from components which have reached their end-of-life (EOL) such as expired solar panels, lead-acid and lithium-ion batteries as well as battery inverters. Improper disposal of these components could present severe health and environmental risks in the near future.

Objective of the research

The overarching objective of the research is to fill the information gap about the solar e-waste industry in Nigeria as well as identify how solar e-waste can be properly managed through self-regulation, government regulation and commercially driven initiatives, to address the potential environmental and health risks associated with the improper disposal of solar e-waste.

Executive summary | Research background

E-waste disposal and recycling in Nigeria is stifled by inadequate regulation and absence of formal collection systems

Solar e-waste in Nigeria

There is a direct relationship between increased usage of solar components and the likelihood of increased solar e-waste in the near term.

a Solar waste management

Our research shows that solar e-waste is predominantly handled by informal players, who collect household solar waste through scavengers and either sell to formal players or dismantle and dispose.

b Regulatory framework

The current regulations targeted at encouraging proper solar waste disposal are inadequate in addressing the projected solar waste volume in the near term. There are regulatory gaps in Nigeria's solar waste management vis-à-vis the regulatory models that exist in matured economies including the European Union, USA amongst other economies. Challenges associated with the effective regulation of the sector include poor implementation and inadequate technical know-how. Lessons from other economies provide a road map for Nigeria in achieving an effective regulatory framework.

c Challenges and opportunities in the solar waste sector

There are existing inefficiencies in the current disposal and collection techniques of solar waste in Nigeria. challenges identified during our research includes:

- *Absence of formal collection centers*
- *Dearth of infrastructural facilities for transporting solar waste to recycling facilities*
- *Poor enforcement of existing policies such as the Extended Producer Responsibility*
- *Limited regulation about the operations of informal collectors*

The challenges in solar e-waste management in Nigeria present the following opportunities for investors, entrepreneurs and regulators;

- *Entry of formal players*
- *Re-use of recycled components*
- *Creation of new industries*
- *Improved financing for the solar waste value chain*
- *Improved regulation for management of e-waste*

Executive summary | Research background

The collaboration of major stakeholder groups will play a major role in managing solar e-waste in Nigeria in terms of raising awareness for consumers and providing equipment to enable appropriate disposal and recycling

Summary of recommendations

Achieving a sustainable approach to managing solar e-waste in Nigeria requires the collaboration of various stakeholder groups including regulators, industry associations, donor agencies and investors.

Our recommended action points for key stakeholder groups are highlighted below:

- *Consumer awareness and promotion of research and development activities*
- *Capacity building for collectors and recyclers*
- *Standardisation of solar products sold to end-users*

- *Provision of grants to encourage efficient operations within the sector*
- *Embed requirements for collections/ take back of components as a condition for grants awarded to industry players*

- *Capital expenditure (CAPEX) support to facilitate the procurement of necessary facilities*
- *Technical assistance to investees*
- *Education of informal players on waste collection best practices*

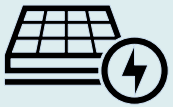
02

Solar energy e-waste in Nigeria

Solar energy e-waste in Nigeria | Overview

Overview

For the purpose of this research, we have defined e-waste as refuse generated by electronic devices including mobile phones, computers etc. at the end of their useful life.



Our specific focus is on solar waste i.e., waste from solar components including solar panels, lead acid batteries, lithium-ion batteries, inverters and other ancillary components.

Select players in the solar energy industry in Nigeria- SHS

ENGIE

LUMOS

d.light

sunking

OOLU

SALPHA

Select players in the solar energy industry in Nigeria- Mini-grid

AYO

HAVENHILL SYNERGY LIMITED

RUBITEC POWER
RUBITEC SOLAR

GVE
"...Creating a Reliable Renewable Energy Future!!!"

Solar energy e-waste in Nigeria | Sources and components

Total import value of solar components in the last three years is estimated at USD 518 million. Solar panels accounted for the highest portion of c.48.6% of the total import value

Cumulative import value of components between 1 January 2018 and 31 August 2021

Components	Value (USD)
Panels	251,579,019
Lead acid batteries	153,286,227
Inverters	76,541,883
Lithium-ion batteries	36,232,004
Total	517,639,134

Source: Proprietary data from Nigeria Customs Service (NCS) and Deloitte Analysis

Import of solar components

In the last three years, there has been an influx of solar power components into the domestic market. The increase in import of solar components has been largely driven by the shift towards renewable energy generation, which is enhanced by the efforts of the government and impact investors towards upscaling the reach of off-grid renewable energy.

The table on the top left corner shows the values of components imported into Nigeria between 1 January 2018 and 31 August 2021. Lead acid and lithium-ion batteries include imports, which were not intended solely for utilisation in renewable energy generation. Over USD350 million of components imported between 1 January 2018 and 31 August 2021 are expected to be utilised in the generation of solar power.

While solar component imports were largely by wholesale dealers, a proportion of imports during the period were made directly by mini-grid developers and corporate entities, for the delivery of specific commercial and private projects respectively.

Solar energy e-waste in Nigeria | Sources and components

Indicative analysis shows that approximately 47 – 52 million kilograms of solar panels were imported between 1 January 2018 and 31 August 2021

Indicative estimation of import volumes – solar panels

Components	Lower	Upper
Value of imports (USD)	251,579,019	251,579,019
Average price per 300w panel (USD)	96	87
Number of panels	2,618,569	2,894,208
Weight per panel (kg)	18.1	18.1
Estimated volume (kg)	47,396,099	52,385,162

Source: Proprietary data from Nigeria Customs Service and Deloitte Analysis

Indicative analysis of import volumes

Based on the cumulative import value between 1 January 2018 and 31 August 2021, we estimate that about 2,894,208 – 2,618,569 units of solar panels, weighing c.47 – 52 million kilograms were imported. This estimate is based on an average price range per 300-watt panel of USD87 – USD96 and an average weight of c.18.1kg per panel.

Basis of analysis

- *We have performed an indicative analysis of imports to estimate the volume of components imported, based on the reported values between 1 January 2018 and 31 August 2021. Due to diversity in the specification and measure of solar components, we have limited our analysis to solar panels, which have a less diverse unit of measurement compared to lead acid and lithium-ion batteries.*

Solar energy e-waste in Nigeria | Sources and components

Lead acid batteries currently account for the largest portion of solar waste. By 2040, waste from solar panels will grow to account for c.14.6% of total waste volumes

Projected solar waste volume(kg)

Components	2021	2025	2030	2035	2040
Lead acid batteries	3,313,918	5,012,260	6,824,101	13,000,511	20,937,454
Lithium-ion batteries	-	620,325	951,525	838,762	712,019
Inverters	-	11,040	61,034	67,386	74,400
Panels	-	1,056,345	1,603,262	1,552,094	3,706,865
Total	3,313,918	6,699,970	9,439,921	15,458,754	25,430,737

Source: Deloitte Analysis

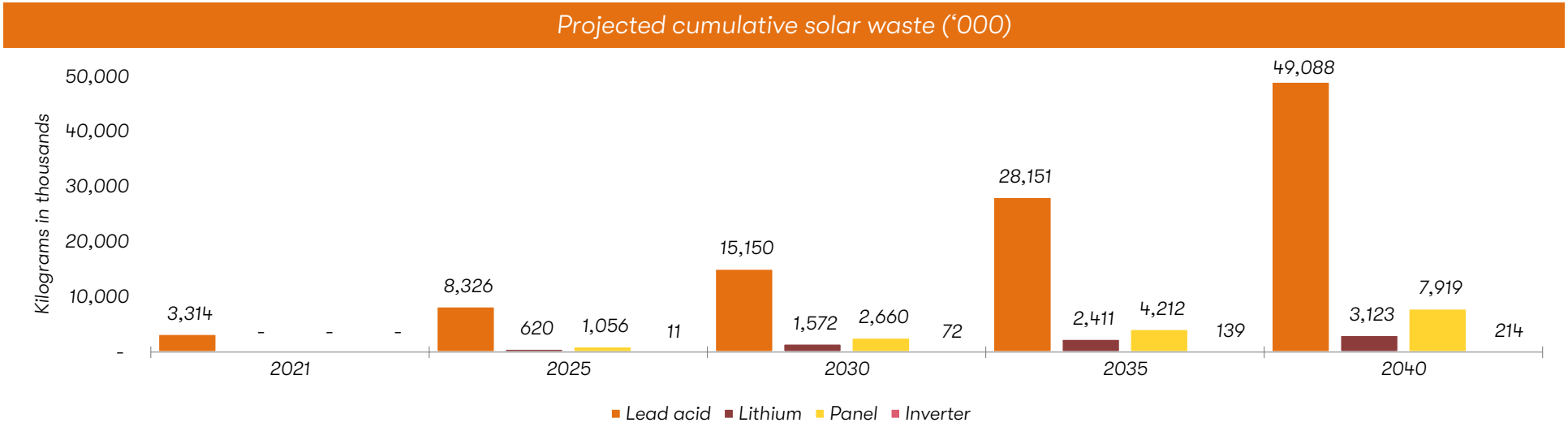
Lead acid batteries: *Estimated solar waste as at 2021 is largely composed of lead acid batteries, with average life span of three to five years. The waste is expected from lead acid battery powered projects deployed in the year 2018 and earlier. The expected waste from lead acid batteries are subsequently expected to account for a lower proportion of total waste volume, as more projects are deployed using either lithium-ion batteries or a hybrid model, which is not powered by batteries. Regardless of the expected increase in the rate of adoption of other models, lead acid battery usage is still expected to grow, due to its affordability. Based on our estimations, we expect the proportion of lead acid battery waste to total solar e-waste to decline from 100% in 2021 to 82.3% in 2040.*

Lithium-ion batteries and inverters: *Relative to lead acid batteries, lithium-ion batteries and inverters have a longer life span, with an average life of 7 – 10 years. We project wastes from lithium-ion batteries and inverters to start building up around 2025, for projects deployed by 2018 and earlier. From our projections, waste from lithium-ion batteries and inverters are expected to jointly account for c.3.1% of total waste generated by 2040.*

Panels: *Solar panels have an average life span of 20 – 25 years, as such substantial waste volumes from panels are expected to build up around 2040. Panels are projected to account for c.14.6% of total waste volumes by 2040.*

Solar energy e-waste in Nigeria | Sources and components

Total solar waste is projected to grow from 3.3 million kilograms in 2021 to a cummulative of 60.3 million kilograms by 2040



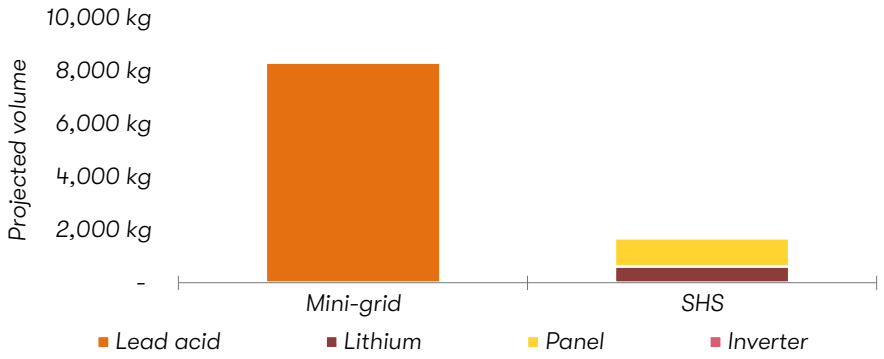
Source: Deloitte analysis

- *The above chart shows our estimate of solar e-waste as at 31 August 2021, as well as our projections based on projects deployed by government agencies and private sector players.*
- *Our volume projection is based on a combination of commercial and private solar power projects and initiatives, including mini-grids and solar home systems, which had been deployed as at 31 August 2021.*
- *We estimate the total volume of solar waste to grow from 3.3 million kilograms in 2021 to c.60.3 million kilograms in 2040, representing a CAGR of 15.6%.*

Solar energy e-waste in Nigeria | Sources and components

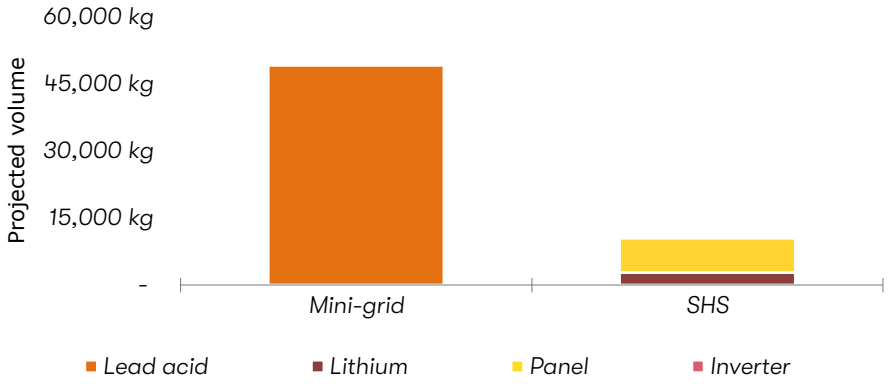
Mini grids are expected to account for a larger portion of solar waste over the forecast period compared to Solar Home System (SHS)

Projected solar waste by solar system ('000) as at 2025



Source: Deloitte analysis

Projected solar waste by solar system ('000) as at 2040



Mini-Grid

Mini-grid refers to a set of generators, which provide electricity to a small group of corporate and residential users, relative to a standard grid. For the purpose of our estimations, we have defined mini-grids to also include micro-utility grids, which are smaller in terms of scale and capacity. w The components that make up a mini-grid system includes solar panels, inverters and batteries, amongst others.

We expect mini-grid systems to generate a greater proportion of solar e-waste over the forecast period, contributing an average of 82.7% of solar waste over the forecast period.

As at 31 August 2021, wastes from mini-grid systems were mainly from the lead acid components. Given the large scale of mini-grid systems and their longer life span relate to SHS, we expect infrequent but large volume disposal of e-wastes over the forecast period. This is also expected to increase with the development of more mini-grids, in line with initiatives of the government.

Solar Home System (SHS)

Solar Home Systems are single customer systems as opposed to mini-grids, which provides electricity to a group of customers. The components that make up a SHS system includes PV panels, control devices, batteries and other associated components.

SHS are less durable that mini-grids and have shorter useful lives, therefore, we expect frequent but small volume disposals over the forecast period.

Solar energy e-waste in Nigeria | Sources and components

Solar components are becoming lighter due to improving technology. Over the last decade, the conversion rate for solar panels and lithium-ion batteries are up by 6% and 150% respectively

Impact of technological improvements on weight of solar components

Technological improvements on solar components is likely to affect the volumes of solar waste in the future. As solar components overtime are able to generate higher capacities of electricity, smaller components in terms of weight are likely to be adopted in the future.

We leveraged on historical information to discount the projections made to reflect further technological improvements on the solar components. We were able to find information on the difference in capacity generation for solar panels and lithium-ion batteries in the last ten years.

Our research shows that the average commercial solar panel converts 17-19% of the light energy hitting it to electricity. This is up from the conversion rate of 12% a decade ago. In a similar manner, lithium-ion batteries generate about 1.5 times more electricity than they did 10 years ago.

We used this information to discount our projected volumes as detailed in Appendix A5.

03

E-waste management

E-waste management | Overview

Overview

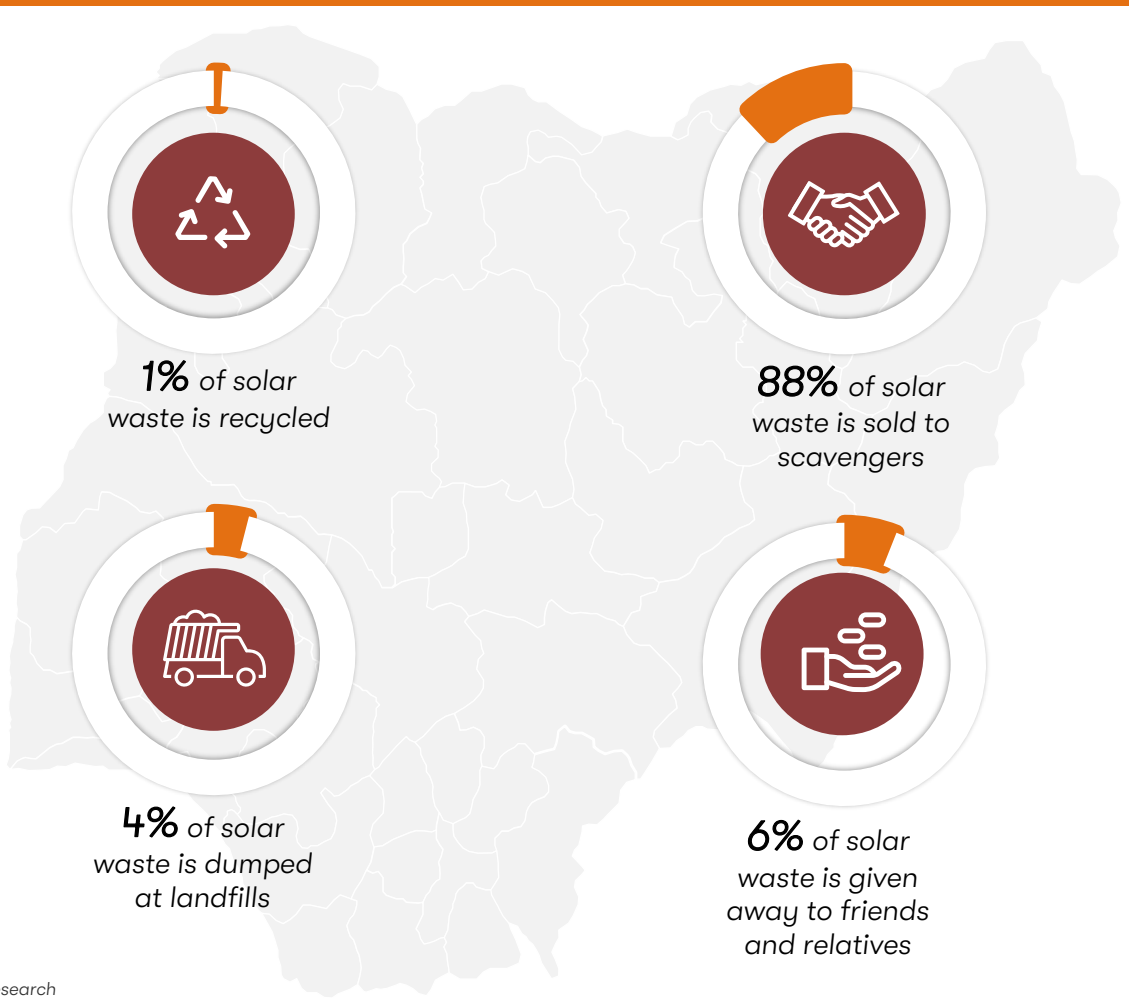
- *Disposal of solar energy components in Nigeria is mostly informal and carried out through scavengers and other informal and largely unregulated collectors.*
- *Notwithstanding, these collectors serve as intermediaries between end-users and recyclers. They collect solar components from industrial and non-industrial users before handing them over to formal recyclers for a fee.*
- *This research profiles both formal and informal collectors and recyclers. Our choice of respondents was based on the scale and structure of the businesses.*

Adverse health and environmental impact of improper disposal

Solar components	*Health risks associated with improper disposal*	*Environmental impact of improper disposal*
Lead acid batteries	• *Lead poisoning. According to Human Rights Watch, over exposure to lead from gold mining in Zamfara state resulted in the death of over 400 children in 2010.* • *Sulphuric acid electrolyte from lead acid batteries is corrosive to the skin*	• *Air pollution from lead fumes and dust* • *Water contamination*
Lithium-ion batteries	• *Lung irritation*	• *Fire hazard* • *Air pollution*

E-waste management | Overview

Disposal techniques

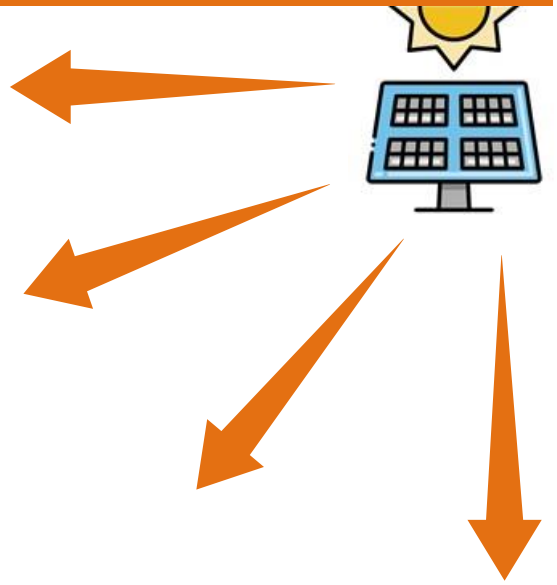


1% of solar waste is recycled

88% of solar waste is sold to scavengers

4% of solar waste is dumped at landfills

6% of solar waste is given away to friends and relatives



The remaining portion of solar waste is either collected by suppliers or disposed in an unconventional manner

Source: Primary research

E-waste management | Current disposal techniques

Nigeria currently lacks a well-established system for collection, separation, storage, transportation and disposal of e-waste as well as adequate enforcement and monitoring of regulations to hazardous E-waste

Solar waste in Nigeria

Solar waste management in Nigeria, like every other e-waste, is yet to be fully established due to the conventional methods of waste management practiced in Nigeria

In most cities across the country, there are visible piles of refuse that have built up on the roads, riverbanks and swampy land. Electronic waste is likely to cause environmental and health related problems in parts of the country due to hazardous and toxic chemicals contained in components of electronic products include solar panels and used lead acid batteries.

Common disposal methods by households

- *Sold as scrap to informal dealers*
- *Donated to family and friends*
- *Sold as secondhand product*
- *Disposed with other waste*
- *Stored in the house in hope to repair later*
- *Abandoned at repair shops*

Common disposal methods by corporates

01 *Recycling*

02 *Sold to collectors or waste management agencies*

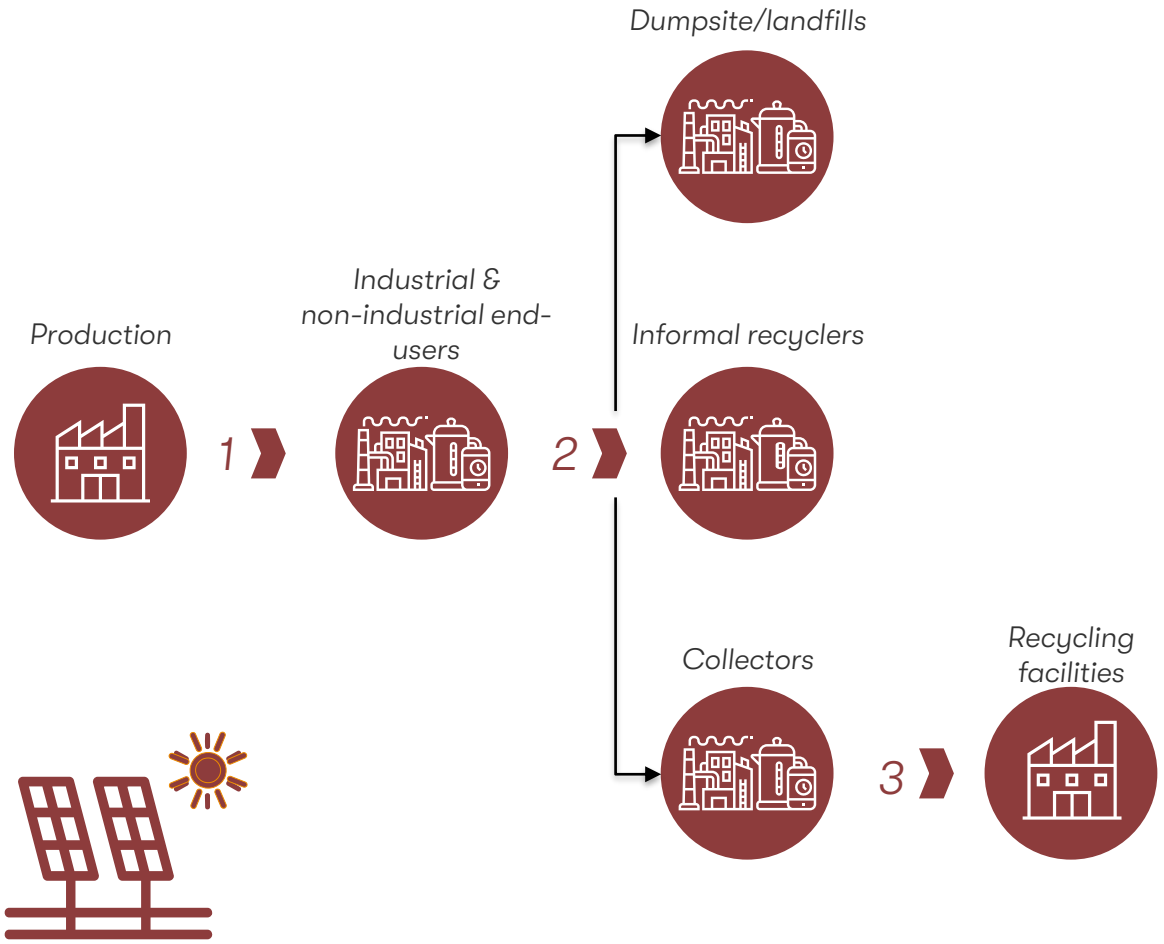
03 *Exchange for non-financial benefits*

04 *Melting*

E-waste management | Current disposal techniques

Nigeria currently lacks a well-established system for collection, separation, storage, transportation and disposal of e-waste as well as adequate enforcement and monitoring of regulations to hazardous E-waste

Solar waste in Nigeria



Key points

01 *Solar users in Nigeria are classified into industrial and non-industrial end-users.*

02 *End users either dump their solar waste at dumpsites/landfills, sell them to informal recyclers for a scrap fee or in rare cases, give them to formal waste collectors. Scavengers typically pick solar waste from landfills and proceed to remove valuable components while the remnants are discarded.*

03 *There are only a few formal recycling companies in Nigeria, and they are generally more experienced in battery recycling compared to other solar components.*

E-waste management | Collection activities

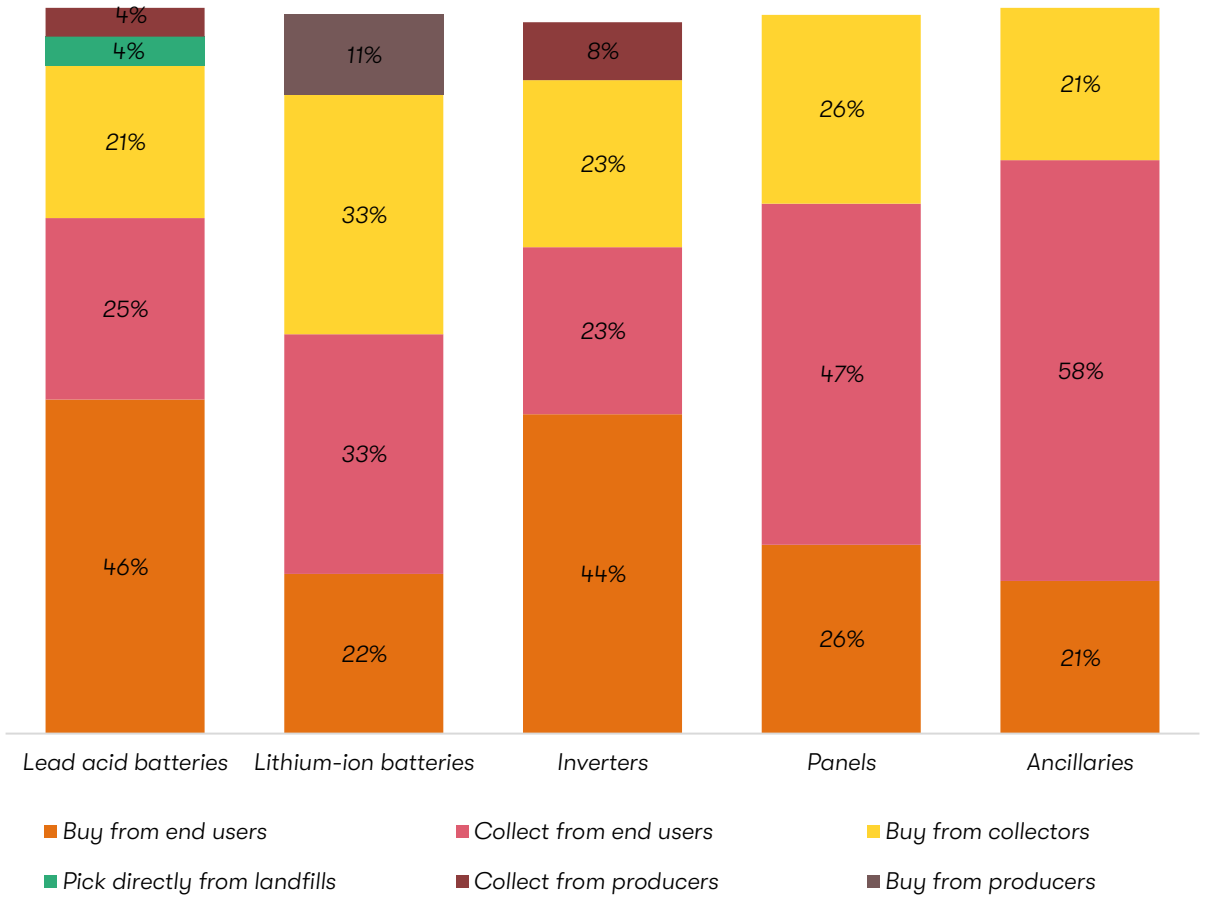
Informal collectors are the dominant players in the sub-sector. These collectors are largely unregulated and tend to prioritise profit making over environmental sustainability

	Formal collection	Informal collection
Market activities	• These collectors are defined as corporate bodies that deal with the collection, packaging and supply of e-waste.	• These are individuals or group of collectors who lack structure in terms of operations, administration, outlets or record keeping.
Challenges	• The most common challenge highlighted by formal collectors is the absence of infrastructure to transport the waste collected. • Other challenges highlighted include lack of regulations from relevant authorities, scarcity of waste from end-users and lack of Personal Protective Equipment (PPE) to protect collectors.	• Absence of regulation and records of the informal collection network makes it difficult to adequately capture the market size. • Informal collectors highlighted other challenges including: – Scarcity of waste from end-users – Increased price for waste as more end-users become aware of the economic value – Inadequate capital needed to scale operations
Suggested regulatory remedies	• Respondents classified as formal collectors highlighted the need for government agencies to introduce e-waste channels e.g., designated areas for disposing solar waste. This would ensure a seamless drop off by end-users.	• The most common regulatory remedy suggested by informal respondents is the introduction of an incentive-based model that encourages proper solar waste management • Other suggested regulatory actions for government agencies include: – Price regulations on solar waste collected – Proper implementation of policies

E-waste management | Collection activities

Collectors have various sources for collecting solar waste from end-users. Once the waste is collected, the most common practice is to sell the solar waste to formal or informal recyclers

Sources of solar waste by component



Source: Primary research

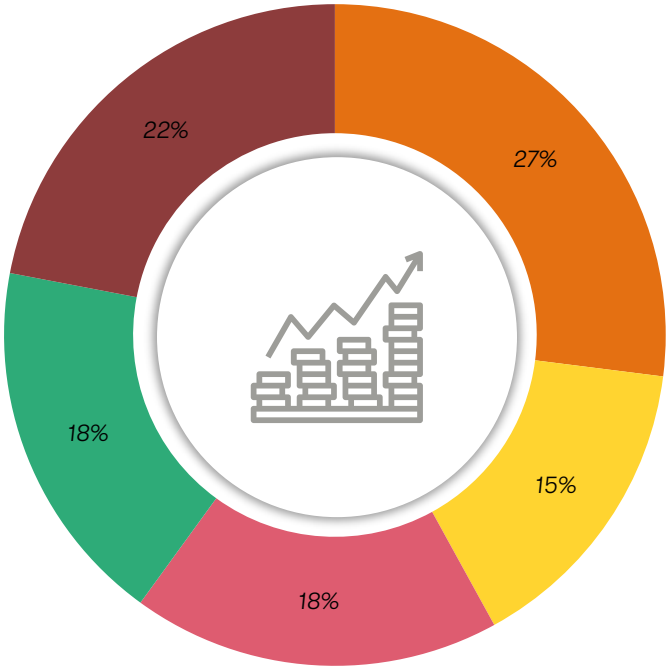
Key insights

- The most common source of solar waste by collectors is to buy or collect the waste from end-users.
- The choice by end-users to either sell their waste or give to collectors for free often depends on their level of awareness about the value of solar waste and their disposable income.
- Affordability and availability are key factors behind the source of solar waste by collectors.

E-waste management | Collection activities

Collectors have various sources for collecting solar waste from end-users. Once the waste is collected, the most common practice is to sell the solar waste to formal or informal recyclers

Most valuable components by revenue generation



Lead acid batteries | Lithium-ion batteries | Inverters | Panels | Ancillary components

Source: Primary research

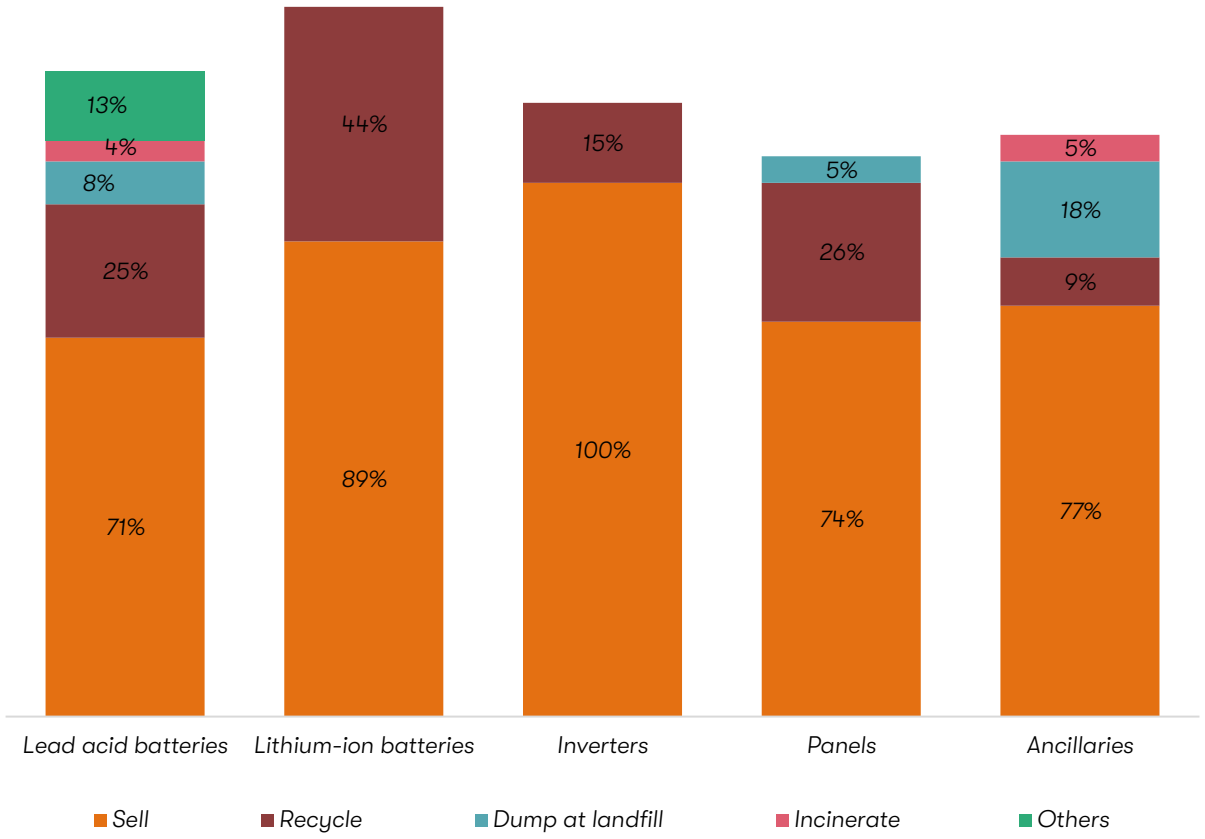
Key insights

- Lead acid batteries are the most valuable solar component for collectors. This may be due to a number of reasons:
  - They are easy to source from end-users
  - Recycling facilities specialising in lead acid batteries serve as off takers and ensure profitability for collectors
- Other components such as solar panels and inverters have a longer lifespan compared to lead acid batteries. This is likely the reason why these components are not as valuable to collectors as lead acid batteries.

E-waste management | Collection activities

Collectors have various sources for collecting solar waste from end-users. Once the waste is collected, the most common practice is to sell the solar waste to formal or informal recyclers

Waste management by component



Source: Primary research

Key insights

- The most common waste management practice by collectors is to sell the components collected. Buyers include international and domestic recyclers.
- Although informal collectors are essential players in the waste value chain, these collectors often engage in harmful waste practices such as dumping solar components at landfills and incinerating indiscreetly which pose a threat to public health.

E-waste management | Solar waste recycling

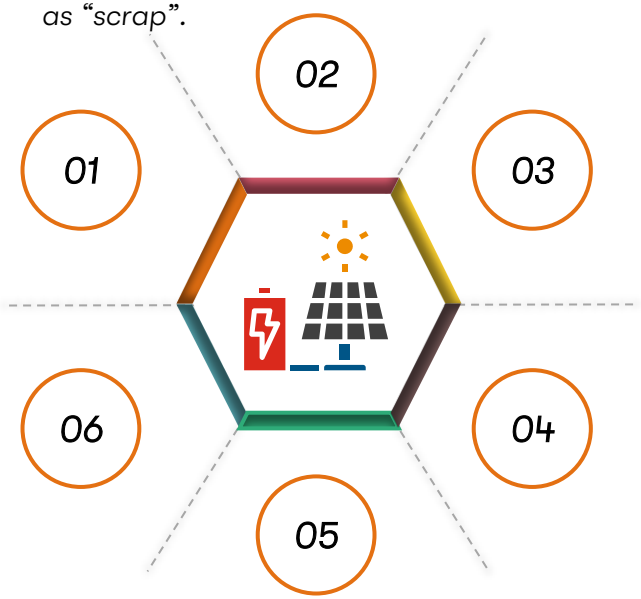
Nigeria's solar waste recycling system is largely informal. There are only a few formal recyclers, who mainly specialise in battery recycling

Solar waste recycling in Nigeria

Currently, there are very few formal recycling companies in Nigeria. Generally, informal recyclers are the biggest players in the recycling of e-waste in Nigeria. Scavengers move around communities to collect, buy, and sell e-waste also known as "scrap".

Solar waste recycling sector in Nigeria is largely underdeveloped. Lack of finance, awareness, advanced recycling technology and limited government support, are some of the factors considered to be militating against the adoption of formal recycling in Nigeria.

Notwithstanding, formal recycling of solar e-waste is slowly emerging in Nigeria. However, the sector requires government support and adequate investment before it is fully established in the long term.



The usual practice is to go around picking up waste or buying from households and then proceed to dismantling in order to retrieve materials like lead acid and copper. Recovered materials are sold to medium or large-scale informal recyclers and industries.

For lead acid batteries, the scavengers typically break open the used batteries before draining the lead acid. This practice although harmful/hazardous to the environment and human health, is very popular among informal recyclers.

There are currently little to no regulations restricting informal recycling in Nigeria which has resulted in the poor state of the solar waste recycling sector.

E-waste management | Solar waste recycling

Nigeria's solar waste recycling system is largely informal. There are only a few formal recyclers, who mainly specialise in battery recycling

Top recycling players in Nigeria

Scrap metal and iron recyclers

- *Metalworld Recycling LTD*
- *Takman Recycling Services*
- *Babs and Celia Trading and Contracting International*
- *African Foundry*

Uncategorized

- *Gain Fountain Recycling LTD*
- *Kws Global Investment LTD*
- *Winfordtech Nigeria LTD*
- *Everest Metal*
- *Charzom Group*
- *MetricTon Recycle*

Lead recycling to ingot

- *BPL Nigeria Limited*
- *Techcast Nigeria LTD*
- *Polymechanos LTD*
- *MathsMetals*
- *Eastern Metals Limited*
- *Green Recycling Industries*
- *Technmonitos Foundries and Industries LTD*
- *Great Height Metal Works Nigeria LTD*
- *Jimola Metals*
- *Eastcoast LTD*

Lead-acid battery recycling

- *Ibeto Group – Union Autoparts Manufacturing Company LTD*

Other e-waste recyclers

- *Hinckley Recycling*
- *E-Terra Technologies LTD*

Collectors

- *LAWMA*
- *Abuja Environmental Protection Board (AEPB)*

E-waste management | Recycling companies in Nigeria

Hinckley Recycling is the first registered e-waste recycler in Nigeria and operates a recycling facility in Lagos with drop off points located in Kaduna and Delta states

About Hinckley Recycling

- *Hinckley is a registered e-waste recycler in Nigeria with the primary objective to provide solutions for e-waste recycling in Nigeria.*
- *Hinckley Recycling was amongst the awardees of the 2020 Global Leap Awards Solar E-Waste Challenge. With the grant fund provided, the recycling company aims to set up a complete battery testing and recycling equipment, develop a detailed sorting, conditioning and reassembly process for battery cells, develop second life battery prototype and establish a sales channel for reconstituted battery packs.*

Role in solar waste value chain

- *Hinckley Recycling offers diverse e-waste recycling services including collection, data destruction, re-use and redeployment amongst others.*
- *In 2020, Hinckley Recycling in partnership with a Dutch sustainable technology innovator, Closing the Loop, facilitated the export of thousands of Li-on batteries to Belgium for safe recycling.*

Annual recycling capacity of Hinckley's facility in Ojota, Lagos

20,000 tons

Solar component recycled

Batteries

Waste management services offered

Collection, recycling and reuse of batteries

E-waste management | Recycling companies in Nigeria

Hinckley Recycling is the first registered e-waste recycler in Nigeria and operates a recycling facility in Lagos with drop off points located in Kaduna and Delta states

Challenges

- *Absence of financial support for procuring modern recycling equipment*
- *Absence of government support regarding the disposal and recycling of solar waste*
- *Poor awareness about the health and environmental benefits of recycling by end-users*
- *Unwillingness by end-users to pay for recycling services*

Key takeaways

- *Focus on Commercial & Industrial (C&I) end-users as they tend to generate the most volume of e-waste and are more willing to pay for recycling services.*
- *Collaborations with regulatory agencies to raise awareness and sensitise end-users about the need for proper disposal of their solar components*

Proposed solar waste initiatives

- *Using Lagos state as a pilot, Hinckley plans to establish 15-18 small collection points in rural areas to facilitate easy disposal of e-waste by end-users.*
- *Provision of trucks to pick up and transport e-waste from each collection point to recycling facilities.*
- *Hinckley has also signed a deal with Lumos Global BV to recycle thousands of Li-ion batteries. In March 2021, Hinckley received the delivery of 10,000 Li-ion batteries for recycling.*

E-waste management | Recycling companies in Nigeria

BPL Nigeria Limited is a lead acid battery recycling company located in Ogun State. BPL's business model involves the recycling of used lead acid batteries to produce pure lead ingots which are exported

About BPL Nigeria Limited

- *BPL Nigeria Limited commenced operations in 2010 as a commodity trading company before specialising in lead acid batteries in 2011.*
- *BPL was previously conducting a manual process of extracting lead plates from scrap batteries and exporting extracted substances to global clients. The Company has since established a recycling facility where 99.97% pure lead ingots are extracted and exported to clients across the world including Spain, Greece, Belgium amongst others.*

Role in solar waste value chain

- *BPL specialises in lead acid battery recycling in an environmentally friendly and sustainable manner. The recycling plant located in Ogun state, improved the Company's annual capacity from 4,000MT when the recycling process was mostly manual to a current capacity of 7,000MT.*
- *The Company has signed off-take agreements with battery manufacturing companies in other countries to supply pure lead ingots. The absence of domestic manufacturers is the primary reason behind the export model adopted by BPL.*

Annual recycling capacity

7,000MT

Solar component recycled

Lead acid batteries

Waste management services offered

Recycling

E-waste management | Recycling companies in Nigeria

BPL Nigeria Limited is a lead acid battery recycling company located in Ogun State. BPL's business model involves the recycling of used lead acid batteries to produce pure lead ingots which are exported

Challenges

- *Limited access to finance for the procurement of equipment and for capacity building*
- *Absence of a centralised collection system*
- *Uncoordinated government policies regarding proper solar waste management*

Key takeaways

- *Establishment of an environmentally friendly recycling plant this year to replace the manual recycling process*
- *Incentivising designated collectors by paying them in advance for waste collected*

Proposed solar waste initiatives

- *Establishment of a battery manufacturing unit within the next 2-3 years. The manufacturing plant would source its inputs from the recycling facility.*

E-waste management | Recycling companies in Nigeria

BPL Nigeria seeks to formalise informal collectors by educating, empowering and incentivising them in order to avoid supply shortage of used batteries

Business model of the Company

01 Receive used batteries	There are designated collectors working with the Company to provide used lead acid batteries for recycling
02 Battery separation and processing	Batteries bought from collectors are first separated before they are sent to the recycling facility for further processing
03 Recycle used batteries	Lead acid batteries are recycled to produce lead ingots (between 99.7% to 99.85%) and related materials such as Lead Oxides
04 Export secondary lead to foreign battery manufacturers	Upon recycling of the spent batteries, the extracted lead ingots are used by the battery manufacturing unit of the Company

Recommended policy actions

Introduction of parks for each local government area

Small scale parks can be introduced across local governments to repair solar components or to hand them to formal recyclers. These parks can either be managed by local government authorities or franchised to private sector players to manage on behalf of the government.

Provision of transport infrastructure

To address the current challenge of a weak transport network for solar waste, local governments in collaboration with state governments can license vehicles and drivers for the sole purpose of transporting solar waste.

Raising awareness

Regulatory authorities should prioritise educating end-users about the risks associated with improper waste management. These awareness programmes can be creatively implemented using social media platforms and through collaborations with influential youths.

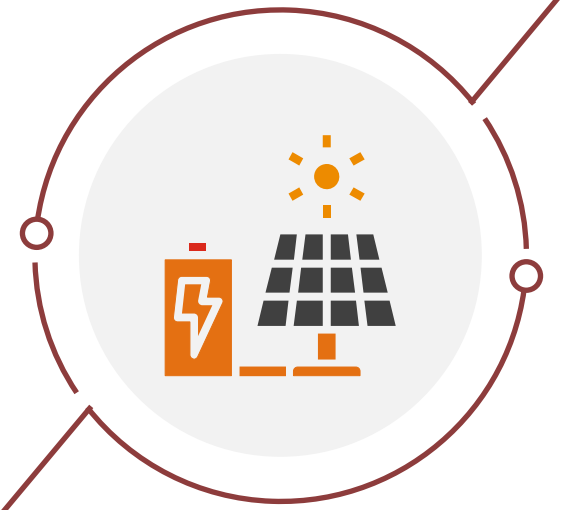
E-waste management | Recycling companies in Nigeria

BPL Nigeria seeks to formalise informal collectors by educating, empowering and incentivising them in order to avoid supply shortage of used batteries

Value addition of BPL

Formalising informal players

BPL is seeking to set up a not-for-profit framework to support and incentivize informal players.
The Company seeks to educate and empower these players in order to ensure regular supply of used batteries.



Export model

BPL specialises in lead acid battery recycling despite the absence of domestic manufacturing plants to serve as off takers. The Company's export model is used to ensure that lead acid batteries are managed in an environmentally friendly manner before they are exported to other countries with battery manufacturing facilities.

E-waste management | Recycling companies in Nigeria

Union Autoparts Manufacturing Company is a subsidiary of the Ibeto Group. The company specialises in lead acid battery manufacturing with a recycling facility to support its backward integration strategy

About Union Autoparts Manufacturing Company

- *Union Autoparts is a lead acid battery manufacturing company. The unique feature of the Company is the presence of a recycling unit to provide the necessary raw materials for the manufacturing process. The recycling unit, which receives spent lead acid batteries from collectors, produces pure lead acid ingots which is subsequently used as an input in the battery manufacturing unit.*
- *Excess secondary lead not used in the manufacturing unit is exported to countries such as India and the USA as a source of revenue for the Company.*

Role in solar waste value chain

- *Union Autoparts actively collaborates with both international and domestic agencies such as GIZ, Federal Ministry of Environment, NESREA to offer technical know-how and expertise regarding policy formulation targeted at proper waste management.*
- *The Company is also at the forefront of setting the standards for proper recycling evident in its transition from using blast furnaces to modern rotary furnaces in order to ensure safe operations.*

Recycling capacity

160,000kg per day

Solar component recycled

Lead acid batteries

Waste management services offered

Recycling and reuse of batteries

E-waste management | Recycling companies in Nigeria

Union Autoparts Manufacturing Company is a subsidiary of the Ibeto Group. The company specialises in lead acid battery manufacturing with a recycling facility to support its backward integration strategy

Challenges

- *Poor enforcement of existing regulations regarding waste management*
- *High cost of sourcing input from informal collectors due to competition with international buyers*
- *Lack of technical know-how to properly manage slag, a hazardous waste produced during the recycling process.*

Key takeaways

- *Collaborations with regulatory agencies to guide policy formulation, review draft policies and raise awareness to educate end-users about the need for proper disposal of their solar components.*
- *Working closely with research teams across the country including the University of Ibadan (UI) to understand best practices for managing slag.*

Proposed solar waste initiatives

- *The Company seeks to automate its processes by purchasing an automatic battery cutting machine in order to reduce the time spent on processing spent lead acid batteries.*

E-waste management | Recycling companies in Nigeria

The Company's battery recycling unit ensures regular supply of input for its manufacturing unit. This saves Union Autoparts the cost of sourcing such input from foreign countries

Business model of the Company

01 Receive used batteries	There are designated collectors working with the Company to collect used lead acid batteries for recycling from end-users
02 Battery separation and processing	Batteries bought from collectors are first separated before they are sent to the recycling facility for further processing
03 Recycle used batteries	The Company's recycling capacity is estimated at 160,000kg per day. However, due to challenges in sourcing input from collectors, actual volumes recycled is estimated at 45% - 50% of its capacity.
04 Re-use secondary lead for battery manufacturing	Upon recycling of the spent batteries, the extracted lead ingots are used by the battery manufacturing unit of the Company
05 Export of excess secondary lead	Excess secondary lead that is not used by the manufacturing plant is exported to other countries as a source of revenue generation.

Recommended policy actions

Proper enforcement of existing regulations targeted at proper waste management.

Price regulations to ensure fair and efficient pricing of used batteries from collectors.

Implementation of regulations that ensure a level playing field for both formal and informal players regarding environmental sustainability.

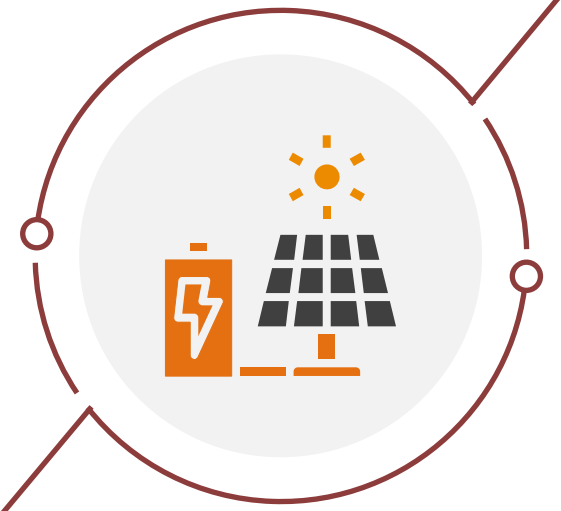
E-waste management | Recycling companies in Nigeria

The Company's battery recycling unit ensures regular supply of input for its manufacturing unit. This saves Union Autoparts the cost of sourcing such input from foreign countries

Value addition of Union Autoparts Manufacturing Company

Domestic battery recycling unit

The presence of a recycling unit to supply raw materials for the Company's manufacturing plant is a unique backward integration model.

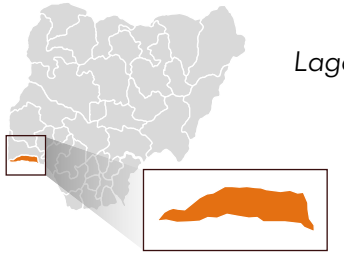
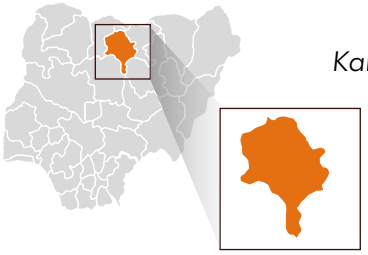
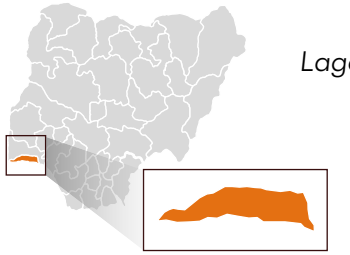


Processing of battery casing

The Company also processes (including washing and crushing) battery containers. The processed component, which is useful to produce automobile parts, serves as an extra source of income for the Company.

E-waste management | Informal collectors

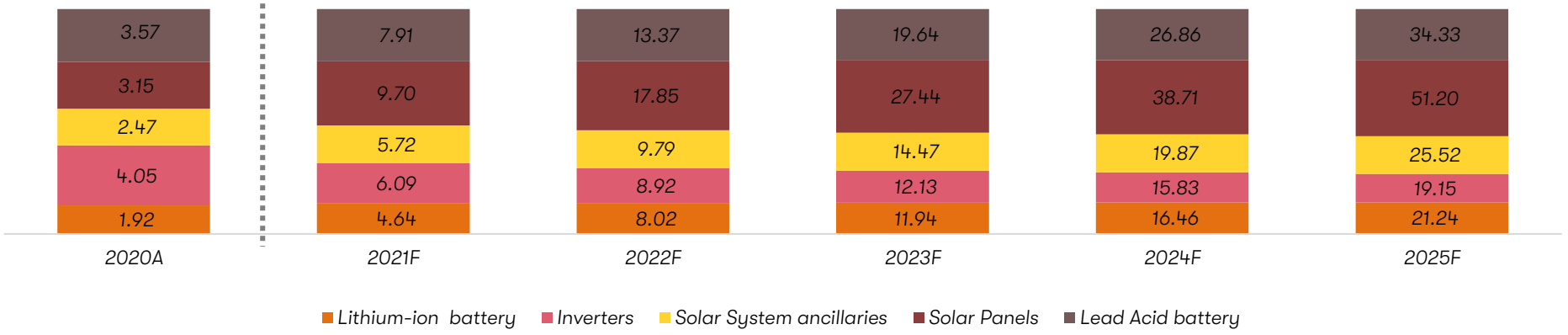
Informal collectors play a crucial role in the solar waste value chain in Nigeria as they collect waste from end-users and sell to recycling firms

	Buyers Deals	Alhaji Lukman and Sons	Lordly Tech Investment
Location			
Business model	• *Buyers Deals collects solar components including panels, inverters and batteries from middlemen. The solar components collected are recycled, resold or re-used.* • *The business exports certain components to countries such as India or China. Components that are still functioning are re-used in the installation arm of the business.*	• *The business model of this collector involves the purchase of solar waste from households, which is subsequently sold to recycling firms.* • *Waste is also collected from dumpsites with little to no financial implications.*	• *The business is located within the Oshodi area of Lagos state, which facilitates easy access to e-waste suppliers.* • *Lordly Tech also enjoys the benefit of low sourcing cost as suppliers deliver waste to the business regularly.*
Challenges	• *Limited access to finance for the procurement of modern equipment* • *Difficulty in collecting waste from industrial and non-industrial users*	• *Lack of required resources (land, equipment)*	• *Lack of capital required to scale up the business*

E-waste management | Commercial viability of recycling in Nigeria

The profitability of solar recycling is expected to increase as solar waste increases and higher recycling efficiency is achieved

Recycling profitability (NGNm)



Source: Primary research and Deloitte analysis

Minimum economic quantity

Source: Primary research and Deloitte analysis

E-waste management | Commercial viability of recycling in Nigeria

The profitability of solar recycling is expected to increase as solar waste increases and higher recycling efficiency is achieved

Overview:

- *The profitability of each component largely depends on the recycling cost per component.*
- *Solar recycling profit is expected to grow steadily at a CAGR of 58.4% as the volume of solar waste in Nigeria increases.*
- *Please refer to Appendix A5 for our detailed approach and methodology*

Capital expenditure

- *Capital expenditure (CAPEX) represents majority of recycling cost at about 83.6% of total cost and an average of 70.0% CAPEX to revenue ratio. CAPEX largely includes infrastructure cost and equipment cost.*

Operating expenses

- *Operating expenses include cost of input scrap components, payroll, fueling, and others. The cost of scrap components varies significantly as scrap components are usually obtained through a bid process by corporate users.*

Revenue

- *The revenue derived per component depends on the volume of scrap components, the efficiency achieved in recycling each component and the selling price of each component.*
- *Presently, battery recycling has the highest recycling efficiency rate with about 95%-99% efficiency.*

Minimum economic quantity

- *Iterative calculation to show the minimum recycling volume to be achieved per component for a solar waste recycling company in Nigeria in order to make profit, holding every other factor constant.*
- *This means that recycling facilities for solar panels must have a minimum capacity of 60,000kg per annum to be profitable followed by ancillary components with a minimum capacity of 47,000kg per annum.*

Source: Primary research and Deloitte analysis

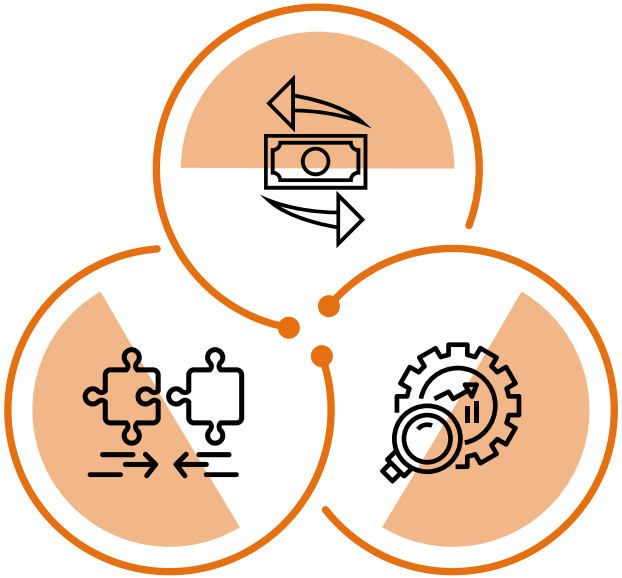
E-waste management | Commercial viability of recycling in Nigeria

Government agencies and corporate stakeholders can support recycling companies and enhance their profitability by enforcing necessary regulations and providing adequate capital

Government and corporate intervention points

Financing

Recycling companies require more capital to enable them acquire more scrap components from collectors for processing. Access to more funds would also enable recycling companies upgrade their infrastructure and equipment to achieve better recycling efficiency ratio.



Policy formulation and implementation

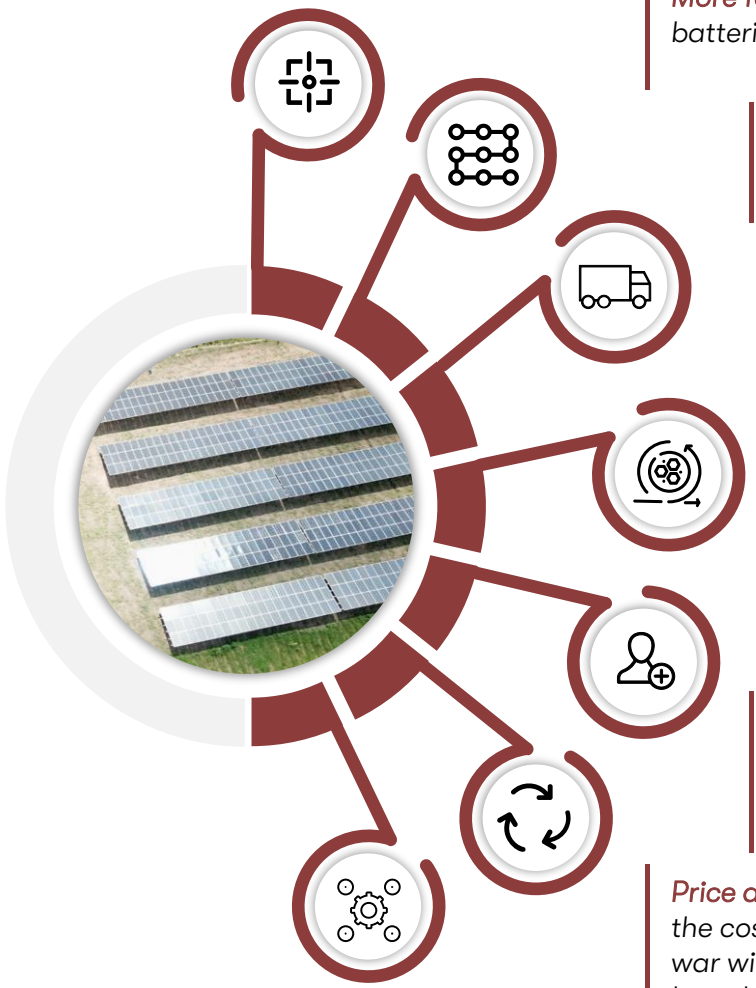
Government policies play a vital role in regulating the operations of recycling companies. Government policies that standardize the costs and benefits in the recycling industry e.g., price regulations of scrap solar components would ensure profitability and sustainability of the recycling industry.

Research

Market research on recycling best practices is an important factor to ensure recycling efficiency and profitability. Government agencies or investors can offer grants to recycling companies to ease the burden of research on these companies and improve their efficiency

E-waste management | Recycling trends

There is a thriving informal collection network, which is responsible for supplying the necessary input for formal recyclers. The absence of domestic manufacturers for the re-use of recycled components leads to the export of these components to other countries



More focus on lead acid battery – recycling activities in Nigeria focus more on lead acid batteries with little to no attention on recycling of panels, lithium-ion batteries and inverters

Thriving informal collection network – informal collectors are essential players in the value chain as they supply the necessary feedstock for formal recyclers.

Inadequate transport system – the absence of road networks and designated vehicles for the collection of solar waste from remote areas often results in collectors limiting their activities to certain locations.

Export model – formal recyclers speciailsing in lead acid batteries either export used batteries as waste or as lead acid ingots to other countries such as India, South Korea, USA amongst others.

Preference for Commercial & Industrial (C&I) end-users – formal recyclers often have signed agreements with C&I consumers to pick up their used batteries and inverters. The preference for C&I end-users increases the risk of improper disposal of solar waste by non-industrial consumers.

Limited off takers for recycled components – the common practice of exporting pure lead ingots by formal recyclers is due to the absence of domestic battery manufacturers that require the ingots as essential inputs. This is the primary objective behind the establishment of battery manufacturing units by formal recyclers.

Price disparities between formal and informal players – formal recyclers who must account for the cost of recycling waste in an environmentally friendly manner, are often involved in a price war with informal recyclers. Buyers of scrap batteries prefer to buy from informal players who have lower operating costs and tend to charge lower than formal players.

04

Benchmark analysis

Benchmark analysis | Overview

Overview

We conducted a benchmark analysis using countries from developed and emerging economies.

Developed economies chosen are significantly ahead of Nigeria in terms of economic metrics and solar waste management techniques. However, these countries provide a road map for Nigeria on its journey to becoming an efficient solar waste management country.

On the other hand, emerging/frontier economies chosen have similar features to Nigeria's economic metrics. In terms of solar waste management, these countries provide learning points for Nigeria in the near term.

Developed and emerging economies

Developed economies

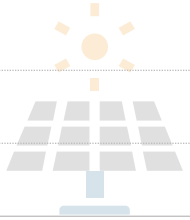
- *More advanced economies with more mature capital markets, higher standards of living and better developed infrastructure compared to emerging economies.*

Emerging/frontier economies

- *Exhibit rapid growth and development*
- *Tend to have lower household incomes and less mature capital markets than developed countries.*

Developed economies

- *European Union*
- *USA*
- *Japan*

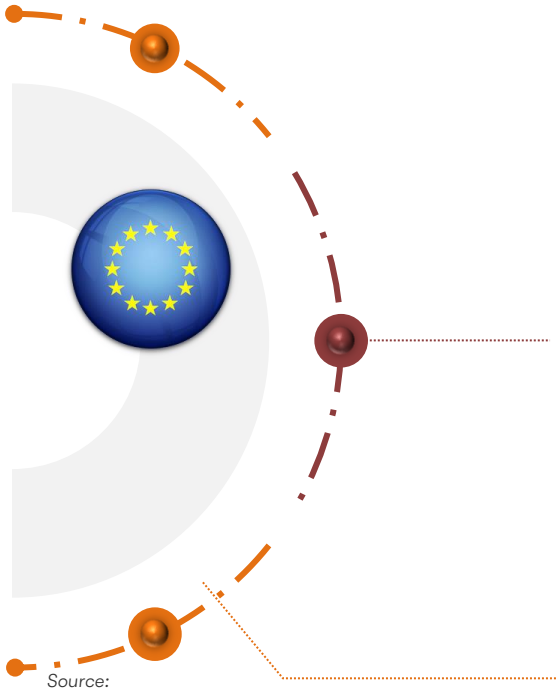


Emerging/frontier economies

- *China*
- *Kenya*
- *Rwanda*
- *Ghana*
- *Angola*
- *India*
- *Senegal*
- *Zambia*

Benchmark analysis | European Union

The EU introduced its WEEE directive in 2003 to promote the re-use and recycling of WEEE in order to reduce waste from EEE. The Directive sets criteria for collection, treatment and recovery of key solar components including batteries and panels



Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019)
2 Eur-Lax

Lead acid batteries

- *Used lead acid batteries within the region are recycled using FenixPB recycling technique which is a water-based process that aims to produce lead oxide that is fit for reuse.*
- *The approach first desulphurises the battery paste before undergoing a series of chemical treatments in water-based solutions.*

Lithium-ion batteries

- *Common recycling processes for Lithium-ion batteries are pyrometallurgical, hydrometallurgical and mechanical separation/treatment. Recycling Li-ion batteries within the region begins with a mechanical processing to obtain materials without changing their chemistry. Materials obtained are refined using either pyrometallurgical, hydrometallurgical or a combination of both*

Panels

- *PV panels were included under the EU's WEEE Directives in 2012. the EU parliament mandated the collection and recycling of panels with prescribed minimum targets.*
- *Disposal process of PV panels in the EU differs according to the type of panels:*
  - *Silicon-based modules are crushed before their components are separated. Glass recyclers often participate in the recycling process.*
  - *Non-silicon-based panels require various recycling technologies such as chemical bath technologies .*

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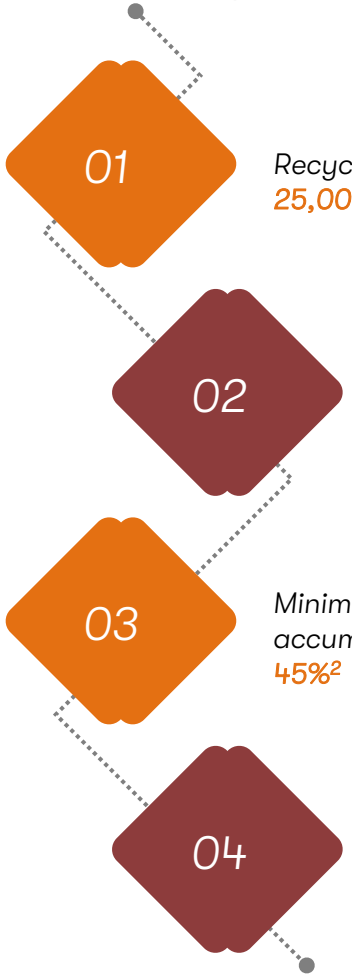


Recycling capacity in Europe exceeds 25,000MT[1]

Minimum recovery target for PV panels under the WEEE directive is 85%[2]

Minimum collection rate of batteries and accumulators under the WEEE directive is 45%[2]

Minimum reuse and recycle target for PV panels under the WEEE directive is 80%[2]

Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019)
2 Eur-Lax

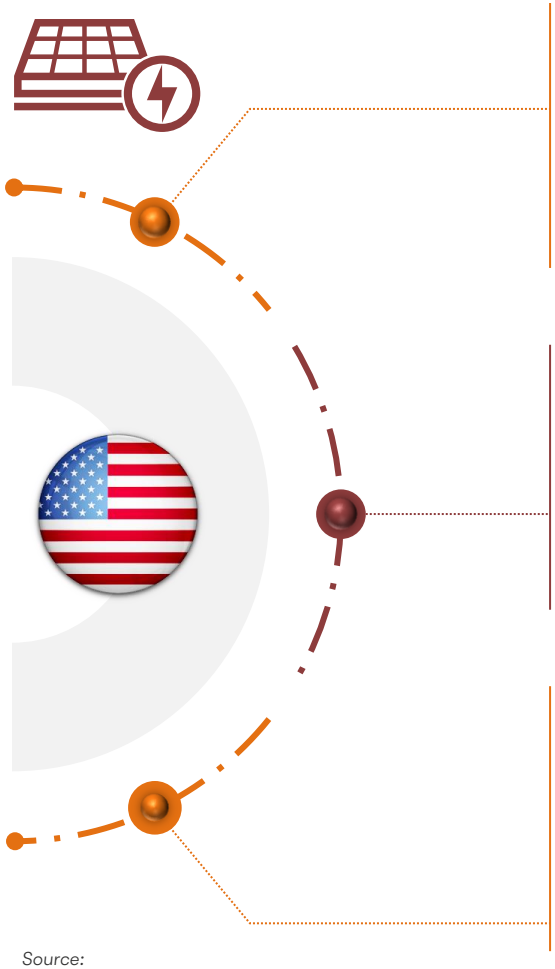
Key takeaways

Under the EU law, producers are required to ensure proper recycling of solar components. Producers bear the responsibility for collecting, treating and recycling solar components. This encourages producers to design solar products that are ecofriendly and easier to recycle.

The European Commission is funding several demonstration projects through its Circular Business Models for the Solar Power Industry program aimed at developing a Product-Service System (PSS). This model allows for solar PVs and batteries to be installed at the end-user's site, but the supplier retains ownership of the solar components. At the end of their useful life, the supplier takes back the components and is responsible for their re-purposing or recycling. This helps to take burden of proper disposal from the end-users.

Benchmark analysis | USA

Solar e-waste is managed differently across the USA. In 2020, Washington launched its Photovoltaic Module Stewardship and Takeback Program, requiring manufacturers to bear the cost of recovering end-of-life panels. California is also managing its solar waste by discouraging improper disposal at landfills



Lead acid batteries

- *Different states have unique laws about the management of lead-acid batteries. Within the region, most retailers collect used batteries at their EOL. Batteries are first crushed into smaller pieces before separating the plastic components which are ultimately reprocessed for the manufacturing of new plastic products*

Lithium-ion batteries

- *Common recycling processes for Lithium-ion batteries within the region are pyrometallurgical and hydrometallurgical. As at 2019, there were three recycling facilities for Li-ion batteries spread across Pennsylvania, Florida and Virginia.*
- *The Battery Council International (BCI) is raising awareness about the dangers involved in recycling lithium-ion batteries using lead acid battery pallets*

Panels

- *Photovoltaic Module Stewardship and Takeback Program (Washington): This is a first of its kind program in the USA requiring manufacturers to take responsibility for the formulation, implementation and financing of a collection system and reuse and recycle plan at no cost to the end-user.*
- *The classification of solar panels as universal waste under California's Hazardous Waste Control Law prevents PV panels from being sent to landfills.*

Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019); 2 IEA International Energy Agency. End-of-; life management (Solar Photovoltaic Panels).; 3 Battery Council International (BCI)
4 Call2Recycle

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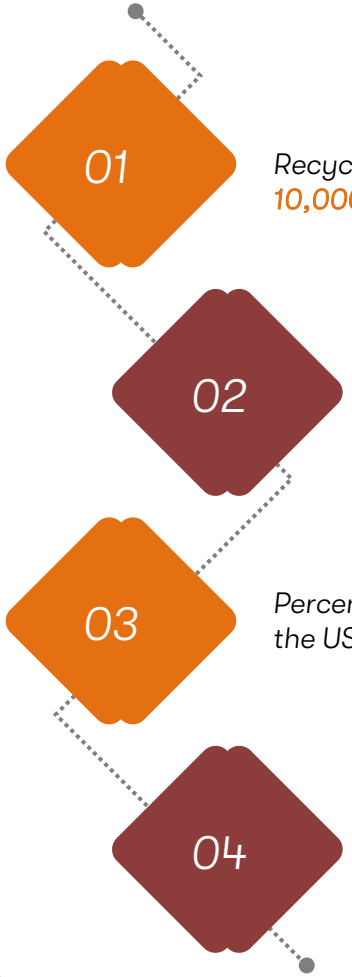


01 — Recycling capacity in the USA exceeds **10,000MT**[1]

02 — The US is estimated to generate **170,000 – 1m tonne**[2] of solar panel waste by 2030

03 — Percentage of lead acid batteries recycled in the USA is **99%**[3]

04 — Number of batteries recycled by the country's largest battery recycling program in 2020 was **8.4m pounds** [4]

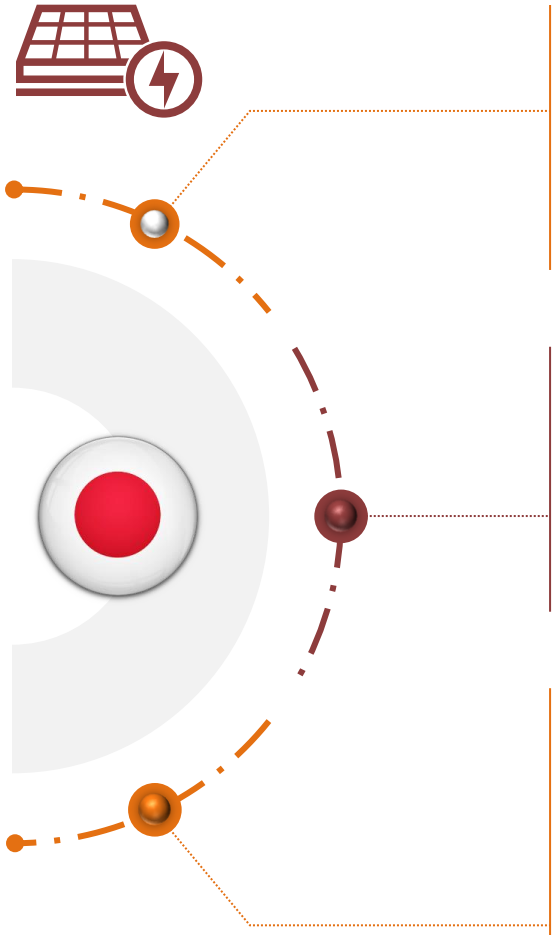
Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019); 2 IEA International Energy Agency. End-of-; life management (Solar Photovoltaic Panels).; 3 Battery Council International (BCI)
4 Call2Recycle

Key takeaways

- Solar e-waste in the USA is managed differently across the various states. The region is yet to adopt a federal approach to managing its solar waste. This approach has provided states with the flexibility and autonomy to adopt unique approaches to addressing solar waste. However, the absence of a federal, overarching directive on solar e-waste could result in inequality across states. Currently, Washington and California are the only states with policy frameworks for addressing their solar waste. There is a need for the region to adopt a federal approach to solar waste or risk inequality across states in the long term.
- First Solar Inc. is the largest solar panel manufacturer in the USA. In addition to its state-of-the-art PV solar modules, the company is also an industry leader in solar panel recycling. First Solar has achieved a recovery rate of 90% for both semiconductor materials and glass. WeRecycle Solar is another leading company offering recycling services for solar PV cells, batteries, inverters and other solar components

Benchmark analysis | Japan

Japan is projected to be among the top contributors of solar panel waste due to recent trends in the solar market. Since 2013, the Japanese government has worked with various private companies on solar panel recycling



Lead acid batteries

- *Japan operates a voluntary battery recycling system through the Battery Association of Japan (BAJ). The BAJ developed the Environment Charter to provide guidelines that would assist member firms in (but not limited to) battery recycling and disposal. It provides guidelines for recycling marking for easy battery tracking and identification.*

Lithium-ion batteries

- *Lithium-ion batteries are collected using one major collection scheme – Japan Portable Rechargeable Battery Recycling Center (JBRC). JBRC collects batteries from registered retailers through collection boxes. Households are also encouraged to return batteries to retailers with recycling support. The predominant recycling method used in Japan is Hydrometallurgy.*

Panels

- *The Japanese government has worked with several private companies on the recycling of panels which has yielded positive results. The NPC Group Plc developed the 'the hot knife method' which is an efficient method of separating the panel cells from the glass in about 40 seconds. The hot knife method involves placing the panel in between two rollers which move it until it runs into a sharp, hot steel blade usually 1cm thick and 1m long.*

Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019)
2 Report – Global Solar Panel Recycling Market

Benchmark analysis | Japan

Japan is projected to be among the top contributors of solar panel waste due to recent trends in the solar market. Since 2013, the Japanese government has worked with various private companies on solar panel recycling

01 *Japan recycles >6000[1] tons of lithium-ion batters annually*

02 *Estimated solar waste by 2030 is 0.2m MT[2]*

03 *Estimated solar waste by 2050 is 6.5m MT[2]*

04 *Producers of solar products are not currently mandated to collect their product when they reach their EOL.*

Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019)
2 Report – Global Solar Panel Recycling Market

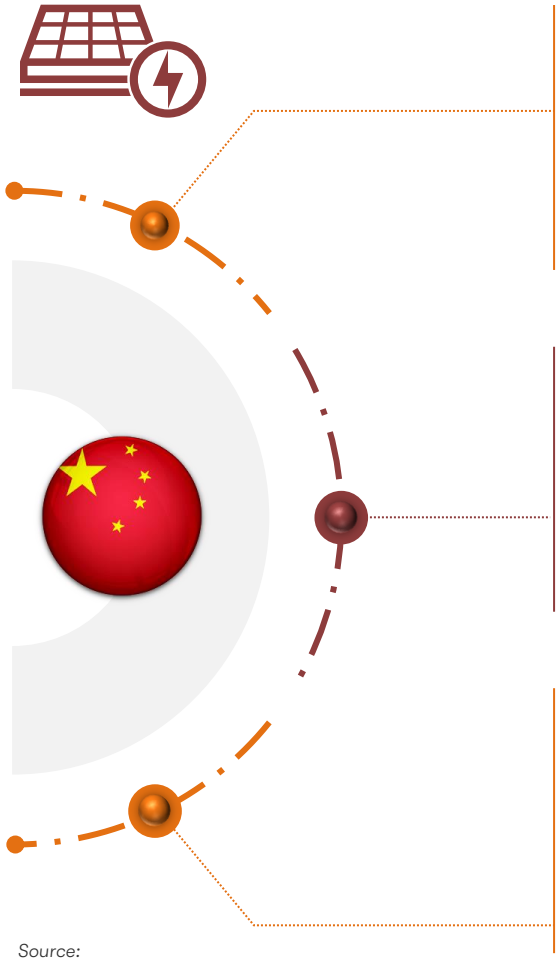
Key takeaways

Government partnerships with various private companies concerning research on efficient methods of recycling PV waste has resulted in new and improved recycling methods as well as higher recycling capacity in Japan.

While there are currently limited laws aimed at achieving proper solar waste management, the Japanese government is increasingly getting involved in the solar waste sector. The government is actively involved in R&D activities, model projects and dissemination of guidelines which are targeted at building a framework for proper disposal and recycling of solar waste in Japan. For example, the Japan Photovoltaic Energy Association (JPEA) published voluntary guidelines on the disposal of solar PV modules in 2017.

Benchmark analysis | China

China is a leading country in solar PV generation with a total installed capacity exceeding 200GW. The Ministry of Ecology and Environment is responsible for managing the waste from the various solar components. In 2019, the Ministry introduced an action plan for preventing pollution from used lead acid batteries



Lead acid batteries

- *China's Ministry of Ecology and Environment (MEE) launched the 'Action Plan for Prevention and Control of Used Lead-Acid Battery Pollution' with a battery collection target of 70% by 2025. MEE proposed the following initiatives for lead acid battery disposal: centralized collection, extended liability system for producers, amongst other initiatives.*

Lithium-ion batteries

- *China is the fastest growing country in the global lithium-ion battery recycling market.*
- *Most common method of recycling lithium-ion batteries is the hydrometallurgical technique with recycling facilities concentrated in the Hunan and Hubei provinces.*

Panels

- *China is the leading producer of solar panels in the world. However, the country's waste management technique is insufficient to accommodate the influx of solar e-waste in the near term.*
- *The long distance between the solar farms and recycling facilities in China often result n the disposal of panels through landfills. Unfortunately, the landfills do not meet international and safety standards and are slowly reaching their maximum capacity.*

Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019); 2 IEA International Energy Agency. End-of-life management (Solar Photovoltaic Panels).
3 Ministry of Ecology and Environment of the People's Republic of China

Benchmark analysis | China

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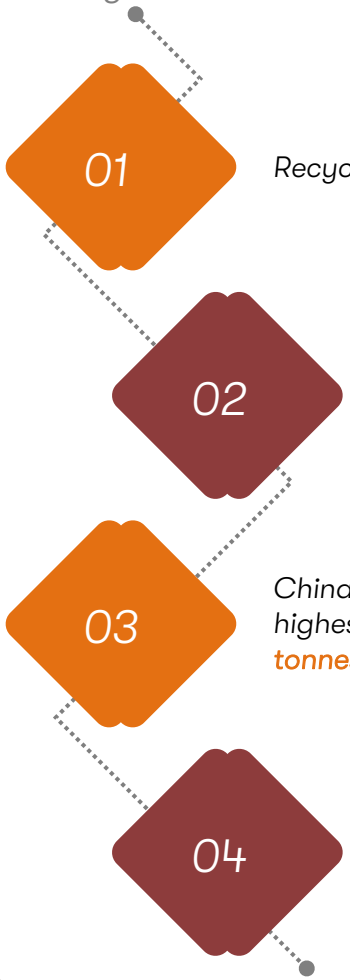


01 — Recycling capacity in China exceeds 31,000MT[1]

02 — China's PV waste by 2030 is estimated at 200,000 – 1.5m tonnes[2]

03 — China is estimated to accumulate the highest amount of PV waste of 13.5 – 20m tonnes[2] by 2050

04 — Collection target of used lead acid batteries by 2025 is 70%[3]

Source:
1 Global capacity for the recycling of spent Li-Ion batteries (Mayyas et al. 2019)
2 IEA International Energy Agency. End-of-life management (Solar Photovoltaic Panels).
3 Ministry of Ecology and Environment of the People's Republic of China

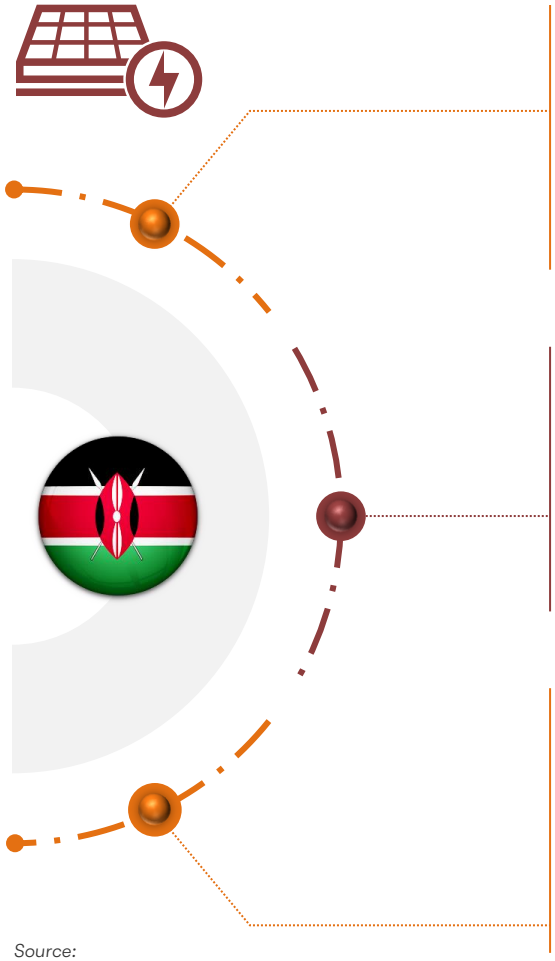
Key takeaways

China is investing in research & development initiatives aimed at improving the manufacturing techniques of solar modules as well as promoting technological advancements in recycling mechanisms. Programmes such as the National high-tech R&D for PV recycling and Safety Disposal Research are expected to result in the introduction of regulations aimed at addressing growing panel waste volumes.

China generates a significant amount of solar electricity and is home to some of the world's largest solar plants including Tengger Desert Solar Park, Yanchi Ningxia Solar Park, Datong Solar Power Top Runner Base and Longyangxia Dam Solar Park with a combined capacity of over 4,000MW. The solar plants are however commonly located in remote regions, a considerable distance from the location of the recycling facilities available within the region. The distance often adds to the cost of disposing solar panels at the end of their useful life.

Benchmark analysis | Kenya

Solar waste management in Kenya is still at the development stage; however, Kenya has benefited from various non-government associations and bilateral donors such as GOGLA, USAID etc.



Lead acid batteries

- *Kenya's take back scheme for lead acid batteries is not efficient enough to ensure that end-users dispose their spent batteries properly to regulated organizations rather than diverting them to informal collectors.*

Lithium-ion batteries

- *Lithium-ion batteries from Kenya are currently recycled in Belgium, which is home to one of the largest Lithium-ion battery recycling plant in Europe. The cost of collecting and exporting Li-ion batteries to Belgium however impairs the economic gain of recycling them. The predominant recycling method adopted in Belgium is Pyrometallurgy.*

Panels

- *In Kenya, a large proportion of solar waste comes from Pico Solar Systems. Approximately 3% - 4% of total e-waste produced in 2018 comprised of Pico solar systems and Solar Home Systems i.e., a stand-alone system suitable for residential use, consisting of PV module, stand alone inverter and battery system. Most EOL panels from Kenya are taken to a facility in Dubai for recycling as there are not a lot of recycling facilities in Kenya.*

Source:
1 Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. Energy Research & Social Science.; 2 GOGLA e-waste module briefing 3
3 DFID, 2016

Benchmark analysis | Kenya

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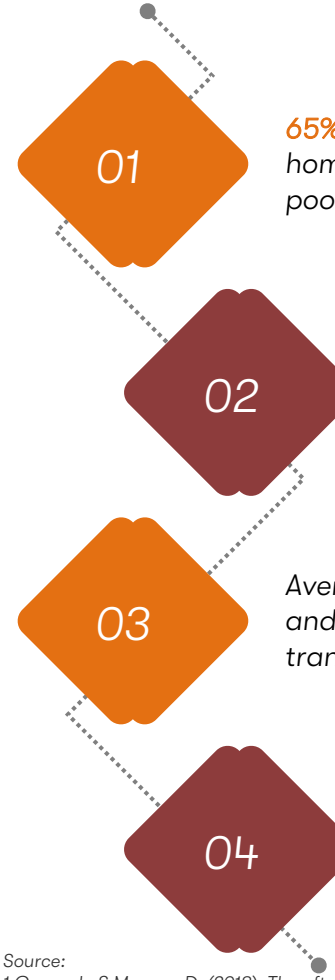


01 — 65%[1] of solar products are kept or left in the home when they stop functioning due to the poor efficiency of the collection scheme

02 — WEEE centre is the only registered e-waste recycler in Kenya

03 — Average distance between collection centres and recycling plants is 300km^2 with transport cost at 50ksh^2 per km

04 — 4.8m^3 off-grid solar products with a combined weight of 4,000 tons[3] is expected to reach its EOL in 2021

Source:
1 Cross, J., & Murray, D. (2018). The afterlives of solar power: Waste and repair off the grid in Kenya. Energy Research & Social Science
2 GOGLA e-waste module briefing 3
3 DFID, 2016

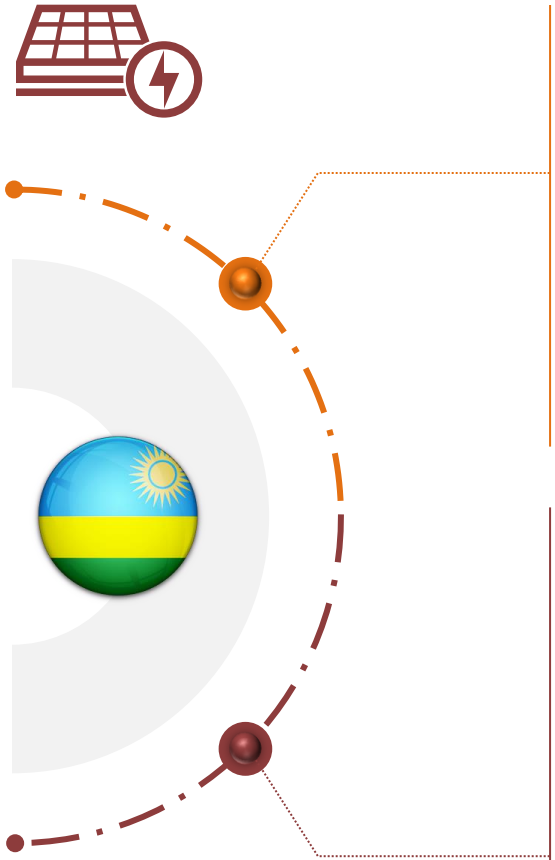
Key takeaways

Specialist recycling companies in Kenya typically focus on commercial or public sector solar end-users. This practice has forced households to dump their solar waste at urban dump sites via informal collection. This has severely impaired proper solar waste management in Kenya and shows the need for unique solutions for all categories of solar end-users (industrial and non-industrial).

Kenya is a leading market in terms of solar penetration and recycling. Over the years, the country has achieved solar advancement through initiatives that has attracted global solar financing agencies such as GOGLA and USAID to support solar companies through donations, awareness campaigns and competitions.

Benchmark analysis | Rwanda

In 2019, the Government of Rwanda signed the Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems, which required private importers of off-grid solar products to be take responsibility for the safe disposal of end-of-life Solar Home Systems, following the principles of extended producer responsibility



Lead acid batteries

- *Enviroserve Rwanda Green Park (ERGP), which was established in 2018 under a Public Private Partnership (PPP) arrangement, dismantles solar devices and other e-waste. This facility is proposed to establish a lead acid recycling line for the treatment of lead acid batteries.*
- *The current practice is to collect used lead acid batteries and export them to ERPG's parent company Enviroserve Services Dubai, for recycling.*

Lithium-ion batteries

- *As with lead acid batteries, ERGP is the main collector of lithium-ion batteries. The batteries collected are sent to Enviroserve Services for treatment.*
- *The ERGP facility is also proposed to establish a pre-treatment line for lithium-ion batteries*

Source:
1 Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems, June 2019
2 Environmental Code of Practice (Used/Spent Battery Management and Disposal under the Renewable Energy Fund Project)

Benchmark analysis | Rwanda

In 2019, the Government of Rwanda signed the Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems, which required private importers of off-grid solar products to be take responsibility for the safe disposal of end-of-life Solar Home Systems, following the principles of extended producer responsibility

There are 16 e-waste collection points spread across different districts. . The objective is to have a collection point in each of the 30 districts of the country.

Enviroserve is the leading recycler with limited operations (collection of batteries and panels)

The Ministerial Guidelines provides that importers will be accountable for safe disposal of their solar products

Average e-waste generated is 10,000 – 15,000 tonnes annually, with collection rate of 40%. Solar e-waste accounts for c.10% of annual collection.

Source:
1 Ministerial Guidelines on Minimum Standards Requirements for Solar Home Systems, June 2019
2 Environmental Code of Practice (Used/Spent Battery Management and Disposal under the Renewable Energy Fund Project)

Key takeaways

Rwanda's significant advancement in the area of e-waste management has so far been fostered through a PPP arrangement. The PPP model allows private sector players to deploy their expertise, while leveraging on the support of the government to promote sustainable e-waste management practices.

Rwanda Energy Private Developers (EDP), an association of private companies in the energy sector, was established with the objective of collaborating with the government in the areas of policy formulation and development of cost-effective approaches to providing energy access. The association has achieved a reduction in the solar e-waste disposal cost, which was hitherto considered a deterrent to proper disposal among users.

Benchmark analysis | Ghana

The Ghana Ministry of Environment is in partnership with international development agencies, to create an effective e-waste management system

Regulatory Framework

- *E-waste management in Ghana is regulated by the provisions of the Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917).*
- *The Government of Ghana is working with a German development agency, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, to improve the policy framework for sustainable management of e-waste at macro level.*
- *The Ministry of Environment also partners with GIZ to train the informal players on sustainable waste management practices.*

Business models

- *An incentive-based system of e-waste collection was established by the Ministry of Environment in Ghana. This system is expected to apply to all categories of e-waste, including solar e-waste. A pilot of this incentive system was launched on cables to assess its effectiveness.*
- *The pilot system offers an alternative for informal players to handle e-wastes properly.*
- *These informal players are incentivised based on the net value of components collected plus a service charge.*
- *The informal players in Ghana operate under associations, through which they are hired for collection and dismantling of components.*

Source:
1 German Federal Ministry for Economic Cooperation and Development (BMZ) (2019)

Benchmark analysis | Ghana

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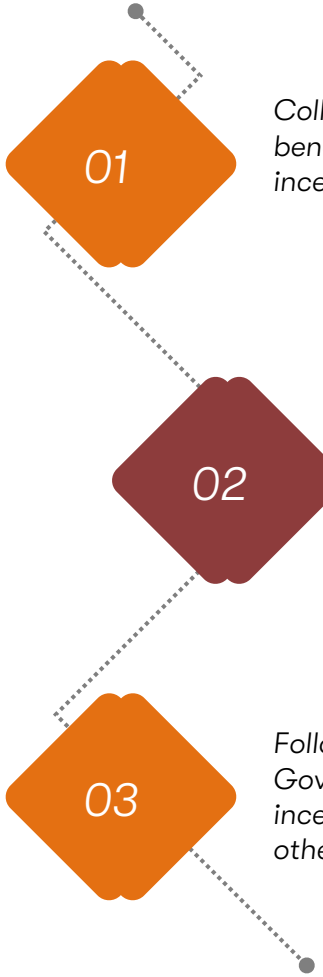

Collectors and the populace are expected to benefit from the long-term impact of the incentive-based system of waste collection.

In motivating collectors to properly deposit e-waste components, an interface is created between the informal and formal players in the sector

Following the success of the pilot, the Government of Ghana plans to roll out the incentive-based system of collection across other e-waste categories.

Source:
1 German Federal Ministry for Economic Cooperation and Development (BMZ) (2019)

Key takeaways

Ghana's partnership with international development agencies such as German Federal Ministry for Economic Cooperation and Development (BMZ) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, exposes it to international current practices in e-waste management. Partnerships of this nature can also lead to consultations with experienced partners and informed policy formulation. This model can be replicated in Nigeria to achieve effective waste management.

Benchmark analysis | Angola

Angola's approach to sustainable e-waste management is based on a partnership arrangement with an international e-waste management company

Regulatory Framework

- *The Ministry of Environment is responsible for the administration of regulations regarding waste management in Angola.*
- *There are no specific regulations on the management of solar e-waste; however, the Government of Angola partners with SGS Renovo for the management of e-waste.*

Business models

- *The model operated under the partnership with SGS Renovo involves the inspections of imports, which is a proactive approach to prevent shipment of EOL components into the country.*
- *It also operates the principle of extended producer responsibility, with the objective of generating revenue for the management of e-waste, including the establishment of e-waste recycling facilities.*

Source:
1 German Federal Ministry for Economic Cooperation and Development (BMZ) (2019)

Benchmark analysis | Angola

Angola's approach to sustainable e-waste management is based on a partnership arrangement with an international e-waste management company

01

Although current e-waste management capacity in Angola is limited, import inspection reduces the occurrence of imported solar e-waste in the country.

02

Solar e-waste management activities in Angola are minimal, as there are currently no specific binding regulations on handling of solar e-waste.

03

Most of the e-waste generated in Angola are either exported to neighbouring countries for recycling or dismantled by informal players.

Source:
1 German Federal Ministry for Economic Cooperation and Development (BMZ) (2019)

Key takeaways

The partnership with an entity like SGS Renovo allows for the inspection of imports, which reduces the occurrence of imported e-waste. A similar approach can be adopted in Nigeria to reduce imported e-waste.

Benchmark analysis | India

Activities in the solar e-waste management value chain in India is growing as a result of the increase in the use of solar energy. There is expected to be more activities in the coming years, as India is expected to be the 4th highest solar waste contributor by 2050, according to the International Renewable Energy Agency

Regulatory Framework

- *In India, solar waste management is regulated under the Ministry of New and Renewable Energy (MNRE).*
- *There are no specific policies regulating solar e-waste in India. Solar wastes are covered under the general waste regulations.*
- *Lead acid battery waste management in India is treated as general electronic waste; hence, it comes under the Ministry of Environment, Forest, and Climate Change.*
- *Retailers are to only sell Used Lead Acid Batteries (ULABs) to registered (formal) recyclers. The recyclers are mandated to use environmentally friendly processes to recycle the ULABs [4].*
- *India is yet to have a devoted PV waste management or recycling policy.*

Business models

- *Components are collected and recycled within the country by different players in the value chain.*
- *India has a low PV panel collection rate, because most PV panels in India, were installed between 2017 and 2019. Currently, less than 5% of the spent lithium-ion batteries are being collected.*
- *The cost of recycling lithium-ion batteries in India is relatively high at 1.2USD to 1.3USD per kg. This cost includes collection cost, transport cost, and management of the resource. It takes a minimum of five years to recover costs.*
- *PV damaged during installation are usually stored in the premises of installers/developers until enough volumes are accumulated for treatment.*
- *The cost of collection, transport and disposal to treatment plants is borne by the holders of the waste i.e. the installers/developers.*

Source:
1 Managing solar PV waste in India, 2021.
2 Central Pollution Control Board (CPCB)
3 Bridge to India (BTI)
4 Gupt 2014

Benchmark analysis | India

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01

The capacity of e-waste dismantlers and recyclers is about 0.4m² which constitutes 22% of estimated e-waste volume, and not all of them recycle solar waste

02

Solar PV waste in India is estimated to reach 200,000[3] tons by 2030 and around 1.8m by 2050

03

The solar capacity of India has grown at a 10-year CAGR of 26%, from 3GW to 31GW[3]

04

India's solar capacity is aimed to reach 100GW by 2022 growing at a CAGR of 55%[3] between 2019 and 2022

Source:
1 Managing solar PV waste in India, 2021.
2 Central Pollution Control Board (CPCB)
3 Bridge to India (BTI)
4 Gupt 2014

Key takeaways

Associations drive various initiatives, which have ensured both corporate and individual awareness and participation in solar waste management.

Having enabling laws, which foster growth and development of associations can compliment the efforts of the government in managing e-waste

Benchmark analysis | Senegal

Senegal's approach to e-waste management is evolving as players in the informal sector take an active role in the collection and disposal of e-waste in the country

Regulatory Framework

- *The Government of Senegal is working with Global Green Growth Institute (GGGI) on the revision of a draft decree relating to the management of all categories of WEEE, including solar waste.*
- *The revised decree is expected to expand the definition and classification of e-waste, notably to include solar components.*
- *The validated version of this decree is due for submission and signature in August 2021.*
- *The environmental regulators have established a strategic committee, consisting of key stakeholders, for the management of e-waste in the country*

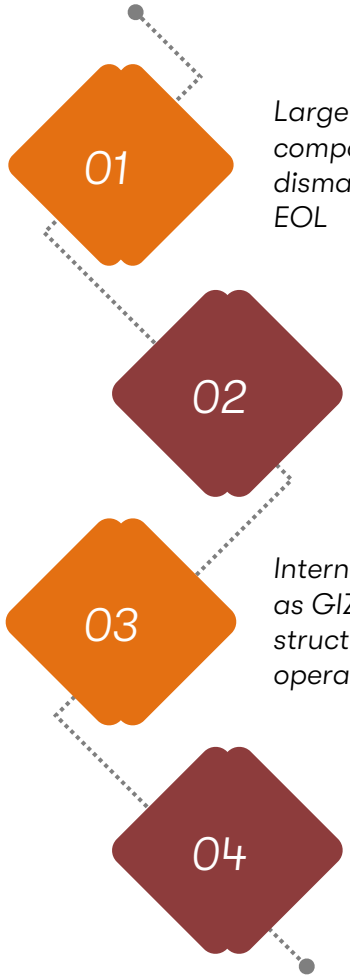
Business models

- *The e-waste sector is mainly dominated by informal collectors of spent components. Informal players go a step further from collecting solar waste components to dismantling them.*
- *Lead acid batteries are recycled mainly at a facility established by a battery manufacturer, Pagrik.*
- *Panels used in mass electrification projects are collected and dismantled by international partners on the projects.*
- *Inverters are mainly dismantled by private and informal players.*
- *They work through associations that hire workers to collect and dismantle the components.*
- *Industry associations work with a training programme, which was designed to build capacity among the informal players on dismantling techniques.*

Source:
1 Global Green Growth Institute representative from Senegal (Senegal et al. 2021)

Benchmark analysis | Senegal

Senegal's approach to e-waste management is evolving as players in the informal sector take an active role in the collection and disposal of e-waste in the country



Large solar fields and industrial users of solar components provide for collection and dismantling by international partners at the EOL

Under the 50,000 streetlight programme run by the Fonroche Company, collection and disposal of waste at EOL is to be carried out by specialised entities abroad. This provision was not made for previous project of this nature.

International and development institutions such as GIZ and GGGI support the Government in structuring the sector and establishing an operational framework for e-waste management

There is currently no company involved in recycling or disposal of lithium-ion batteries in Senegal.

Source:
1 Global Green Growth Institute representative from Senegal (Senegal et al. 2021)

Key takeaways

Engagement of informal players through industry associations, is an effective strategy adopted in Senegal. Initiatives targeted at informal players are channeled through these industry associations. Industry associations can be leveraged to reach these players in advancing sustainable e-waste management practices.

Benchmark analysis | Zambia

Solar Aid, a private sector player in Zambia is driving efforts towards reducing household solar e-waste, by extending the life of the solar components through repairs and end-user education

Regulatory Framework

- *The Department of Environmental Management under the Ministry of Water Development, Sanitation and Environmental Protection, is responsible for the regulation of WEEE in Zambia.*
- *The Environmental Management Act No 12 of 2011 (Section 58) is the regulation guiding e-waste management and is currently enforceable in Zambia. The existing regulation is based on a broad categorisation of waste and is interpreted to include solar e-waste.*
- *The regulation requires manufacturers and importers to ensure that waste generated from their products are collected and properly treated at EOL.*

Business models

- *Lead acid batteries are recycled in-country and some are shipped to neighbouring countries like Tanzania for recycling.*
- *There is currently no infrastructure for the management of Lithium-ion batteries in Zambia; however, it appears that they are largely exported for recycling.*
- *There is also no capacity for the management of solar panels, except for efforts driven by Solar Aid, to extend the life of the components through repairs and reuse. This is aimed at reducing household solar e-waste generation.*
- *The main industry association is Solar Industry Association Zambia (SIAZ) and its objective is to expand access to solar power.*

Source:
1 Primary research interviews
2 The Environmental Management Act 2011
3 Beyond the Grid Fund for Africa

Benchmark analysis | Zambia

Solar Aid, a private sector player in Zambia is driving efforts towards reducing household solar e-waste, by extending the life of the solar components through repairs and end-user education

01

Zambia is a beneficiary of the Swedish government-funded programme, Beyond the Grid Fund for Zambia

02

Solar e-waste management is in the nascent stage of development in Zambia, with a few active players operating in the space.

03

Private sector players are driving mass education and incentives to encourage end-user to repair and reuse components, as against outright disposal.

Source:
1 Primary research interviews
2 The Environmental Management Act 2011
3 Beyond the Grid Fund for Africa

Key takeaways

Zambia is positioned to have better informed household users, as a result of mass education and sensitisation carried out by private sector players. Similar private sector driven mass education can be replicated in Nigeria, to reduce household solar e-waste.

There are existing regulations aimed at addressing the proper treatment of solar e-waste in Zambia; however, the low success achieved is due to non-enforcement of the provision. Similar regulations exist in Nigeria but are not broad enough to encompass solar e-waste.

Benchmark analysis | Solar companies across Africa

Solar companies in Africa are often beneficiaries of grant funding by impact investors. The grants provided have supported industry players to create awareness, launch take back schemes and establish dismantling and recycling facilities

Company	Location	Stakeholder category	Solar waste management initiatives/projects
enviroserve Saving the planet. Naturally.	 Rwanda		• *Enviroserve currently has over 10 collection points in Rwanda and aims to expand its collection points to all 30 districts in the country.* • *The company was an awardee in the 2020 Global Leap Awards Solar E-waste Challenge and proposed to achieve the following:* – *Conduct nationwide consumer awareness campaigns to educate end-users on the location of collection points* – *Improve the company's processing capacity through the procurement of essential equipment*
d.light	 Kenya		*As a beneficiary of the 2020 Global Leap Awards Solar E-waste Challenge, the company aims to:* • *Establish collection points at its experience centres and regional distribution locations* • *Encourage households to exchange their non-functioning solar products for a new and verified d.light product*

 *Recycler*

 *Distributor*

Source: Global LEAP Awards Solar E-Waste Challenge I Round 1

Benchmark analysis | Solar companies across Africa

Solar companies in Africa are often beneficiaries of grant funding by impact investors. The grants provided have supported industry players to create awareness, launch take back schemes and establish dismantling and recycling facilities

Company	Location	Stakeholder category	Solar waste management initiatives/projects
SOLIBRIUM-SOLAR Nuru Maishani	 Kenya		• *I2G: This project, which is funded by CLASP, has the following objectives:* – *To address the information and infrastructure gap of solar e-waste in western Kenya.* – *To launch take-back/buy-back schemes based on reuse, refurbishment and recycling of solar waste.* • *Rewmos: This is a joint project by Solibrium Solar Ltd, REPIC and Myclimate with the aim to:* – *Reduce the adverse environmental impacts of SHS at their EOL* – *Identify a viable business model that is attractive to key stakeholders including wholesalers, manufacturers and end-users*
WeTu	 Kenya		• *Establish seven e-waste collection points situated in fishing communities* • *Consumer awareness campaigns with the objective to incentivize end-users to return their EOL solar products in exchange for clean water vouchers.* • *Establish a pre-processing/dismantling facility*

 *Recycler*

 *Distributor*

Source: Global LEAP Awards Solar E-Waste Challenge I Round 1

Benchmark analysis| Disposal gaps

Current disposal techniques in maturing economies is largely unsuitable for the Nigerian context due to certain challenges in Nigeria's regulatory approach regarding solar waste management

	Disposal technique	Limitation in the Nigerian context
Kenya	*Export of solar waste to recycling facilities in other countries including Dubai and Belgium.*	*The profitability of the export model of solar waste management in Nigeria will depend on quicker approval processes for shipping permits.*
Rwanda	*Private importers are responsible for safe disposal of SHS under the principles of producer responsibility*	*Importers play an essential role in the supply of solar components to Nigeria. Monitoring their activities requires collaborations between the customs and other regulatory agencies*
European Union	*Product Service System where ownership of solar components is retained by suppliers who take back the components from end-users at the end of their useful life.*	*The retained ownership model requires a sophisticated tracking system to enable suppliers track their components across the nation*
USA	*Photovoltaic Module Stewardship programme in Washington which prohibits manufacturers from selling modules within the state without a recycling plan for the units sold.*	*This disposal technique requires a highly equipped enforcement agency with an updated database of solar manufacturers operating within the state. The model also requires the imposition of sanctions to deter manufacturers from selling units without a recycling programme.*

- *Suitable solar waste management solutions for Nigeria will consider the following:*
  - *Capacity of existing regulatory agencies to monitor the activities of industry players within the solar sector*
  - *Level of awareness of end-users about the health and environmental benefits of proper waste disposal*
  - *Accessibility of recycling centres for end-users*

05

Regulatory overview

Regulatory overview | Overview

Overview

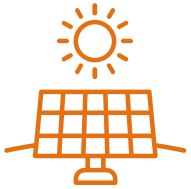
There are regulatory gaps that exist in Nigeria's solar e-waste management vis-à-vis the models that exist in matured economies including European Union, USA, Japan, China, Rwanda and Kenya

Proposed policies and guidelines to encourage solar waste management in Nigeria can be adopted based on existing regulatory framework in these mature markets.

With solar e-waste volumes estimated to jump by 10.5% in the next 10 years, there is need for the federal government to introduce regulatory initiatives in order to hedge against the environment and health risks associated with improper waste management.

Regulatory overview | Overview

Countries	Regulations for general e-waste disposal	Regulations for current solar e-waste disposal	Proposed regulations for future solar e-waste
European Union	✓	✓	✓
USA	✓	✓	✓
Japan	✓	✗	✓
China	✓	✗	✓
Rwanda	✓	✗	✗
Kenya	✓	✗	✗
Nigeria	✓	✗	✗



Source: Deloitte analysis

Regulatory overview | Current regulations

To ensure the proper management of the estimated waste, there is need for regulations that are targeted specifically at solar waste

Current e-waste regulations

01

Environmental Impact Assessment (EIA) Act Cap 131 LFN 1992

- Provides for the need to conduct an EIA study for any development project that is likely to have adverse environmental effects.

02

Hazardous Waste (Criminal Provisions) Decree No. 42 of 1988

- Prohibits depositing and dumping of harmful waste on any land, territorial waters and related matters.
- Importation ad transportation of harmful e-waste is also prohibited.

03

The National Environmental Protection (Waste Management) Regulations S.I.15 of 1991

- This Act is aimed at limiting the level of toxic substances released into the air, water or land of Nigeria's ecosystems.
- Any discharge, including solid, gaseous and liquid waste from any industry or facility should be reported to the nearest office of the Agency every month through a Discharge Monitoring Report.

04

National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009

- The Act provides that no person shall engage in any activity that is likely to generate hazardous waste without permission. Every person who generates hazardous waste shall ensure the proper treatment of such waste
- The Act also prohibits the export or transit of hazardous waste without permission
- Non-compliance to this Act is punishable with a fine of N5million or imprisonment for five or more years.

Regulatory overview | Current regulations

To ensure the proper management of the estimated waste, there is need for regulations that are targeted specifically at solar waste

International treaties ratified by Nigeria

Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal regulates movement of hazardous wastes within and outside Nigeria

Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa

Proposed regulations

Federal Ministry of Environment

- *The Federal Ministry of Environment is currently working on policy formulation to regulate the processing and recycling of e-waste. The policy would ban the burning and dumping of E-waste in open spaces due to dioxins released by some of the hazardous components of electronic waste.*
- *The Ministry in collaboration with other state environmental agencies are also soliciting for informal recyclers to be registered in order to monitor and regulate their activities.*

NESREA

- *NESREA intends to effectively implement and build on the EPR programme through partnerships with state owned agencies to monitor and ensure manufacturers comply. This will be done through effective supervision of their activities and sanctions will be put in place for defaulters*

Regulatory overview | Current regulations

Extended Producer Responsibility (EPR) is an environmental policy approach adopted by NESREA which extends the responsibility of producers to the post-consumer stage of their products life cycle

Extended Producer Responsibility (EPR)

Policy objective

- *EPR, which was introduced by the Federal Government through NESREA was documented to ensure that manufacturers of electrical/electronic products have a scheme in place for collecting products that have reached the end of their useful life*
- *The programme seeks to adopt a collaborative approach between the government, waste management stakeholders and end-users towards achieving a zero-waste society.*

Role of producers

- *Under the EPR programme, producers are responsible for the entire lifecycle of the product including the take back, recycling and disposal of the product.*
- *The programme also allows for a third-party organization, Producer Responsibility Organisation (PRO), to assist producers in managing the mandatory take back scheme or other product stewardship programmes.*

Role of NESREA

- *Under the EPR programme, NESREA has the following duties:*
  - *Register and accredit recyclers*
  - *Conduct public awareness campaigns about the Programme*
  - *Impose penalties for non-compliance*
  - *Establish appropriate reporting mechanism with PROs*
  - *Issue appropriate permits*

Regulatory overview | Current regulations

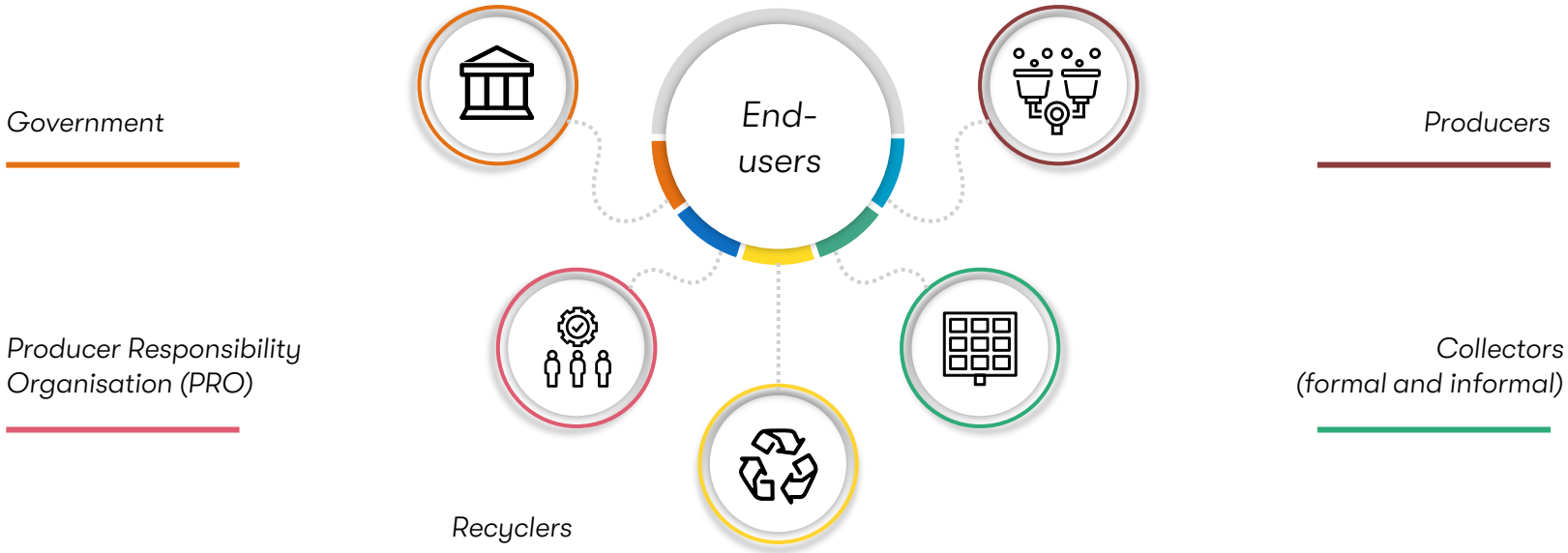
Extended Producer Responsibility (EPR) is an environmental policy approach adopted by NESREA which extends the responsibility of producers to the post-consumer stage of their products life cycle

Extended Producer Responsibility (EPR) by the Nigerian Communications Commission (NCC)

01 Nigerian Communications Industry E-waste Regulation 2018

- *The objective of the regulation is to provide the necessary regulatory framework for managing e-waste in the telecommunications industry.*
- *The Nigerian Communications Commission (NCC) mandates manufacturers of electrical and electronic products to collect products that are at their end of life through retailers and vendors for recycling or refurbishing.*

Key stakeholders in the EPR



Regulatory overview | Current regulations

Challenges such as poor implementation, inadequate technical know-how, limit the effectiveness of regulatory authorities in their efforts to address improper waste management

Regulatory authorities

National Environmental Standards and Regulations Enforcement Agency (NESREA)

Established by law in 2007, NESREA is charged with the responsibility of the protection and development of all environmental laws in Nigeria, this include enforcement of laws pertaining to electronic waste disposal and recycling.
Key elements of the Agency's enforcement strategies are inspection, compliance monitoring, legal action and prosecution.

Defaulters shall on conviction, be liable to a fine of N1,000,000 and an additional fine of N 50,000 for every day the offence subsists.

NESREA also issues a permit to importers of Used Electrical and Electronic Equipment relating to handling, transportation and recycling

The mandate of NESREA includes development of new, and review of existing national environmental laws and regulations regarding electronic waste management

NESREA issues and regulates the issuance of Environmental permit to enable businesses and industrial facilities (e.g., Recycling facilities, IT companies) whose operations may have potential impact on the environment to be environment-friendly in their operations and also comply effectively with existing e-waste regulations.

All organizations that process or generate electronic waste are obligated to register with NESREA and receive a permit.

NESREA mandates these organizations to dispose their waste at recycling facilities and collect a certificate of destruction to ascertain compliance.

Regulatory overview | Current regulations

Challenges such as poor implementation, inadequate technical know-how, limit the effectiveness of regulatory authorities in their efforts to address improper waste management

Challenges	Proposed remedial actions
Poor implementation	Existing policies are not properly enforced and implemented. The deployment of monitoring teams across Nigeria and stringent fines and penalties for non-compliance would encourage stakeholders to adopt proper waste management techniques.
Duplication of policies by agencies	Regular stakeholder meetings where different Agencies highlight their regulatory efforts towards waste management. This will encourage synergy rather than duplication of efforts among regulators.
Inadequate technical know-how	Partnership with domestic and international private sector players in the solar waste management industry. The nature of the alliance should allow experts in the field to provide technical assistance to regulators on best practices for solar waste recycling.

Other waste management regulators

- Federal Ministry of Environment
- Lagos State Waste Management Authority (LAWMA)
- Lagos State Environmental Protection Agency (LASEPA)

Regulatory overview | International models

The European Union's WEEE Legislation is divided into the following directives

Waste Electrical & Electronic Equipment (WEEE) legislation

Waste Framework Directive ("Directive 2008/98/EC")

- *This directive sets the basic concepts and definitions related to waste management, such as definitions of waste, recycling, recovery. The directive incorporates the "polluter pays principle", where the "polluter" (usually the producer) bears the expense of pollution prevention and control measures.*
- *The directive also requires member states to adopt waste management programmes that are evaluated frequently.*

Battery Directive ("Directive 2006/66/EC")

- *Under this directive, battery producers are responsible for minimizing harmful effects of waste batteries on the environment, by paying for the collection, treatment, recycling and disposal of batteries at the end of their useful life.*
- *Producers must register with the appropriate environmental regulator as well as finance public awareness campaigns to encourage proper battery waste disposal.*

European WEEE Directive 2012/19/EU

- *The directive provides for the creation of collection schemes where consumers return their WEEE free of charge.*
- *These schemes aim to increase the recycling and/or re-use of WEEE. It also seeks to improve the environmental performance of all operators involved in the life cycle of EEE, especially the operators directly involved in the collection and treatment of WEEE.*

Regulation about future e-waste

- *The European Parliament adopted the European Commission's Circular Economy Action Plan in February 2021.*
- *The Plan is a building block of the European Green Deal and seeks to ensure a green future for the region while protecting the environment and empowering consumers. The Commission plans to propose legislation that will ensure that products sold in the EU market are designed to last longer and can be reused, repaired and recycled.*
- *The European Parliament has urged the Commission to propose new legislation in 2021 to introduce product-specific and/or sector specific targets for recycled content.*

Regulatory overview | International models

The US does not have any federal legislation for solar waste recycling or disposal. Only California and Washington currently have legislation for the disposal of solar e-waste

USA

California Bill SB-489 Hazardous Waste Control Law

- *Initiatives such as the California Solar Initiative, net energy metering program and California Renewables Portfolio Standard Program has increased the use of solar energy systems. The state government is formulating the recycling and disposal framework to accommodate the solar components when they reach the end of their useful life.*
- *The Hazardous Waste Control Law was approved in 2015 with the intention to*
  - *Authorize PV modules to be managed as universal waste which allows waste from this component to be streamlined in existing systems*
  - *Promote a comprehensive and innovative system for the reuse, recycling, and proper disposal of EOL PV modules*
  - *To encourage the PV module industry to develop a framework for recycling EOL modules in a convenient and cost-efficient manner*
  - *Design PV modules for extended life, repair, and reuse as well as promote collection and recycling services for the modules at the end of their useful life.*

Regulation about future e-waste

- *Arizona lawmakers are considering a bill that would require solar panels to be recycled. The proposed Bill, which has already cleared the House Natural Resources, Energy and Water Committee, would require solar panels to be recycled at an approved recycling facility. The aim of the Bill is to put a recycling framework in place before the solar panels in use within the state reach the end of their useful life.*
- *If approved, the regulation would impose a $5 per panel fee on the seller or lessor of the panels except for manufacturers with their own recycling program. Manufacturers will also be required to submit annual reports to the state. The Arizona solar industry stakeholders are however skeptical about the cost implications of the bill on consumers and the industry.*

Regulatory overview | International models

The US does not have any federal legislation for solar waste recycling or disposal. Only California and Washington currently have legislation for the disposal of solar e-waste

USA

Washington Solar Incentives Job Bill (ESSB 5939)

- *The Solar Incentives Job Bill requires manufacturers to manage and finance the safe recycling of solar units at end of their useful life and at no cost to the previous owner of the product*
- *This Bill which was signed into law in July 2017, requires manufacturers to finance and manage a product stewardship program that ensures used solar units are recycled.*
- *The stewardship requirement prohibits manufacturers from selling solar modules within the state without a recycling program for their units. The requirement covers solar modules, freestanding off-grid power generation systems, electric vehicle charging stations and solar fencing and solar powered streetlights.*
- *The Bill also requires manufacturers to provide regional take back locations while providing the flexibility for manufacturers to either collect discarded modules individually or in partnership with other companies.*
- *The Department of Ecology is responsible for providing guidance to manufacturers in developing their recycling programs.*

Regulatory overview | International models

The e-waste legislation for the following countries segregates duties of policy implementation to national and state/district/province levels

China	Japan
Circular Economy Promotion Law	**Basic Act on Establishing a Circular Society**
• This law is formulated for the purpose of promoting the development of the circular economy and improving resource utilization efficiency.	• The law was introduced to move the country from being a mass production, consumption and disposal society to a country that promotes the efficient use and recycling of substances from production to distribution, consumption and disposal.
• The law establishes a State Council responsible for coordinating and supervising the development of the circular economy of the whole nation.	• The law gives specific responsibilities for national governments, local governments, businesses and individuals.
• The responsibility of implementing a circular economy is also segregated into the state and county level.	• The national government is responsible for overseeing the implementation of circular economy activities in the country while the state government is responsible for ensuring that waste products are properly recycled in their local government area.
• One of the methods by which the circular economy plan has been implemented is through the creation of specially designated regions for technological and industrial development known as "industrial parks"	• Businesses also bear the responsibility of ensuring that raw materials are fully utilized and disposed properly.
• For example, the Suzhou New District is a 52-square-kilometre region for technological and industrial development, where approximately 4,000 manufacturing firms operate. Manufacturers located within the park have the advantage of re-using materials from other manufacturers rather than procuring new materials.	• The Circular Economy policy in Japan was developed in such a way that old materials or products are easily collected, and the cost of return and recovery have been added to a product's cost.

Regulatory overview | International models

The e-waste legislation for the following countries segregates duties of policy implementation to national and state/district/province levels

Kenya	Rwanda
Environmental Management and Co-ordination Act (No. 8 of 1999)(Rev 2012)	**National E-waste Policy**
• This law sets up a council/ committee at national and provincial/district level to be responsible for the management and protection of the environment.	• The E-waste policy was developed to provide comprehensive guidance for the efficient and effective management of discarded EEE through appropriate legal and regulatory instruments.
• Furthermore, the Kenya Ministry of Environment and Natural Resources in conjunction with the United Nations Development Programme developed a Nationally Appropriate Mitigation Action ("NAMA") on a circular economy solid waste management approach for urban areas in Kenya.	• This policy states that the government shall: – Promote the establishment of e-waste management facilities (dismantling facilities, collection centers and drop off points) to ensure proper disposal and recycling of E-waste. – Develop sustainable models for e-waste management such as Public Private Partnerships (PPP) and; – Engage EEE producers/importers through the Extended Producer Responsibility in strategic partnerships.
• The NAMA is divided into two distinct phases: – Infrastructure development phase will focus on developing the infrastructure required to collect and recycle waste daily. This phase establishes the recycling points, the composting facilities and the pilots for new recycling processes. – Full-scale operations phase will build on the experience gained during the first phase and will scale the operations of the nationally appropriate NAMA from phase 1. Private sector companies will participate in operating the collection points and the composting facilities.	• The policy also states that the government would be responsible for developing plans to attract private investments in e-waste management as well as adopting innovative financial models and instruments to finance the sustainable management of e-waste.

Regulatory overview | International models

Self regulating associations in the following countries are highlighted below:

	European Union	USA	China
Self regulating association	PV Cycle	Solar Energy Industries Association (SEIA)	China Association of Circular Economy (CACE)
Business model	• Members of the Association pool their resources and expertise together to offer all forms of waste management services at the most efficient cost	• SEIA has a national PV recycling program in which a preferred recycling partners are chosen through an evaluation process. The vendors offer pricing and program benefits which are exclusive to SEIA members. Such benefits include exclusive pricing regardless of size/volume, engagement in improving the recycle process in the region amongst others.	• CACE influences industry standards by conducting extensive research on the strategies and policies related to the circular economy in China. • The association's research papers serve as a framework for government authorities to formulate or revise policies.
Financing	Financed by member companies	Financed by member companies	Government funded
Government support & collaboration	None	SEIA works with regulators to develop enforceable policies and processes to guide waste management behavior of key stakeholders.	CACE was formed by an act of legislation and is working with the Chinese government to implement the Circular Economy Promotion Law as well as improve regulations and policy mechanisms.

Regulatory overview | International models

Self regulating associations in the following countries are highlighted below:

	Japan	Kenya	Rwanda
Self regulating association	Japan Photovoltaic Energy Association (JPEA)	Kenya Renewable Energy Association (KEREA)	Energy Private Developers (EPD)
Business model	• The operations of the JPEA relies primarily on research about the Japanese PV power generation industry. • In achieving this, the association is divided into several Committees with unique responsibilities. • The Recycling Committee oversees preliminary research about recycling PV systems in order to establish guidelines for the management and disposal of the modules.	• KEREA collaborates with the private sector, relevant government institutions as well as training institutions to provide members with capacity building and financing solutions. • The. association offers curriculum development for renewable energy training programs. In addition to curriculum development, KEREA proposes to equip training institutions to offer the specialized courses	• EPD acts a bridge between their member companies and investors seeking to participate in the Rwandan energy sector. The association positions its members to become the preferred local partners for international investors. • Members provide market orientation to international investors and facilitate their connection with key stakeholders in the Rwandan energy sector.
Financing	Financed by members	Financed by members	Investor financing
Government support & collaboration	None	KEREA works collaboratively with regulators to reasonably develop enforceable regulations and manageable processes for compliance.	EPD is working closing with the Rwandan government in achieving its Electrification Goal of achieving 100% electrification by 2024.

Regulatory overview | Activities of industry associations

Self regulating associations play a complementary role in the management of solar waste. They support regulatory agencies to raise awareness, formulate policy guidelines and conduct R&D to ensure each stakeholder takes responsibility for proper disposal of solar waste

Industry association	Initiatives targeted at solar waste management
Global Off-Grid Lighting Association (GOGLA)	• GOGLA was established in 2021 as a global association for the off-grid solar energy industry. Their primary service offering is to assist the industry in building sustainable markets and profitable businesses that delivery quality and affordable off-grid electricity products and services. • To encourage proper off-grid solar e-waste management, GOGLA launched an e-waste toolkit which is aimed at supporting and educating its members on the need to improve their e-waste management operations. The toolkit is designed and developed with the objective of supporting both start-up companies at the early stage of e-waste operations and companies at an advanced stage of e-waste operations. • The toolkit is funded by a Swedish development finance institution, Swedfund. Learning materials about e-waste management in the off-grid solar sector launched so far by GOGLA include: – Module 1: Introduction to recycling – Module 2: Design for reduction of e-waste – Module 3: financials of solar e-waste – Module 4: Policy and regulation – Module 5: E-waste and the consumer – Module 6: Take back and collection • GOGLA also operates the Global Leap solar e-waste challenge which seeks to identify and fund innovative approaches to solar e-waste management in Sub-Saharan Africa. Within two years, the annual solar waste challenge has provided over $2million in grant funding to industry players with unique solar waste solutions.

Regulatory overview | Activities of industry associations

Self regulating associations play a complementary role in the management of solar waste. They support regulatory agencies to raise awareness, formulate policy guidelines and conduct R&D to ensure each stakeholder takes responsibility for proper disposal of solar waste

Industry association	Initiatives targeted at solar waste management
Renewable Energy Association of Nigeria (REAN)	• REAN is an independent, non-profit industry association founded by stakeholders in the renewable energy sector in Nigeria with the objective to guide advocacy, policy formulation and investment in the sector. The role of the Association is to promote strategies that improve the contribution of renewable energy to 40% of the national energy mix by 2030. • The Association introduced the Used Lead Acid Batteries (ULAB) policy as a social instrument to complement the efforts of regulatory agencies such as the Federal Ministry of Environment and NESREA. REAN outlined its responsibilities as well as the responsibilities of other stakeholders including operators, battery producers, retailers/dealers and customers in proper disposal of lead acid batteries as follows: • REAN: The Association is responsible for developing internal policies for members regarding the management of ULAB and promoting R&D activities targeted at ULAB management. • Operators: Renewable energy operators are responsible for implementing a take-back contract with end-user to collect EOL batteries. Installers are also responsible for providing data on the quantities and types of batteries installed and locations of installations. • Battery producers: Manufacturers and importers have the responsibility to support collection of EOL batteries. They are also responsible for properly labeling batteries to educate consumers on the hazardous contents. • Retailers and dealers: Both parties have the responsibility to ensure that batteries sold are properly labeled. They can also provide collection/drop off services to end-users.

Regulatory overview | Activities of industry associations

Self regulating associations play a complementary role in the management of solar waste. They support regulatory agencies to raise awareness, formulate policy guidelines and conduct R&D to ensure each stakeholder takes responsibility for proper disposal of solar waste

Industry association	Initiatives targeted at solar waste management
Alliance for Responsible Battery Recycling (ARBR)	• ARBR is the Producer Responsibility Organisation (PRO) for the battery sector under the Extended Producer Responsibility (EPR) programme approved by NESREA. The primary objective of ARBR is to synchronize the activities of stakeholders of the battery sector in order to prevent the potential hazards associated with dirty battery recycling in Nigeria. ARBR also promotes the responsible usage of batteries through safe handling and storage practices. • ARBR introduced a battery stewardship programme which aims to establish an effective take back scheme of EOL batteries and introduce a database for manufacturers or importers of batteries. The database of battery producers, collectors and recyclers is used to access the efficiency of recycling operations in Nigeria.

Regulatory overview | Regulatory gaps

Government regulations addressing solar e-waste management in Nigeria are benchmarked against international models using the following metrics:

Benchmark	The Nigerian situation	Proposed remedial actions
Take back and recycling of PV panels (WEEE directive in the EU)	• There is currently no regulation aimed at ensuring the proper collection and recycling of PV modules.	• Regulations requiring solar energy companies to be responsible for the recovery of their products at the end of their useful life. • Manufacturers can be required to possess take back infrastructure as an initial minimum requirement. The inclusion of recycling infrastructure as a requirement can occur in the long term • Suggested government agency: Ministry of Environment
Battery producers responsible for battery waste collection, treatment, recycling and disposal (Battery directive in the EU)	• Collectors and recyclers often engage in indiscriminate disposal of batteries without any regulatory consequences. However, REAN has introduced a guideline for used lead acid battery recycling.	• Regulations requiring battery producers to make provisions to finance the collection, treatment and recycling of the volume of batteries they produce. • This would encourage environmental considerations by manufacturers during the design stage of their products. • Suggested government agency: Ministry of Environment
Stewardship program for solar products (Photovoltaic Module Stewardship and Takeback Program in Washington)	• Regulatory authorities have neglected the need for proper management of waste from solar panels.	• Regulations that require manufacturers to develop and finance stewardship program for their components. • Regulatory authorities can mandate manufacturers to provide evidence of the programs before granting the required permits. • Suggested government agency: Ministry of Environment

Regulatory overview | Regulatory gaps

Government regulations addressing solar e-waste management in Nigeria are benchmarked against international models using the following metrics:

Benchmark	The Nigerian situation	Proposed remedial actions
Development of industrial parks (Suzhou Industrial Park in China)	• The Lekki Free Zone is currently being designed to function as an industrial park. The project is aimed at developing and managing a Free Zone which will attract investments and create jobs.	• Inclusive plans for the development of designated regions for industrial development across the Federation. • Suggested government agency: Ministry of Industry, Trade and Investment
Comprehensive framework for the efficient management of discarded EEE (WEEE directive in the European Union)	• Nigeria has some regulations around harmful waste and a guide for importers of EEE, but there is no comprehensive guide/policy around the disposal and management of solar e-waste.	• Regulations that provide comprehensive guidance for the effective management of e-waste from disposal, to collection and then to recycling. • Suggested government agency: Ministry of Environment

Regulatory overview | Regulatory gaps

Self regulating associations addressing solar e-waste management in Nigeria are benchmarked against international models using the following metrics:

Benchmark	The Nigerian situation	Proposed remedial actions
National PV recycling program (Solar Energy Industries Association in the USA)	• Little to no attention is given to the proper management of panel waste by both government regulators and self-regulating associations.	• Existing solar industry associations can have periodic evaluation meetings to select a recycling company who would handle the recycling obligations of all the members of the association at a discounted price.
Waste management services for solar energy companies (PV Cycle in European Union)	• There is no known member-based organization/association that offers waste management services for solar waste components or other e-waste components	• Existing solar industry associations in Nigeria can organize its members to pool resources and expertise together to offer waste management services especially in the form of collection of used solar components
Collection and management of information on PV modules and other solar components in the country (China Association of Circular Economy)	• Data gathering and research on solar components deployed in Nigeria is limited by lack of finance and poor access to certain remote areas.	• Industry associations can collaborate with solar energy companies who will be responsible for collating and managing relevant data and information on solar energy components in the country.
Collection and recycling infrastructure (Enviroserve Rwanda)	• Most recycling companies are unable to offer collection services due to the lack of finance to procure necessary equipment for collecting solar waste e.g., designated vehicles.	• Industry associations and green financiers can consider partnering with Enviroserve Rwanda to participate in the Nigerian solar e-waste sector. • Enviroserve currently operates Rwanda's only state-of-the-art dismantling and recycling facility. • The provision of appropriate government, technical and financial support can encourage the company to successfully build an e-waste recycling facility in Nigeria

06

Summary of opportunities and recommendations

Summary of opportunities and recommendations | Overview

Chapter Overview

This chapter provides an overview of the economic and non-economic value creation opportunities that exist in the end-of-life stage of solar energy components.

With solar e-waste volumes estimated to grow steadily in the coming years, there are potential economic benefits to improving Nigeria's recycling capacity. This includes investment opportunities for waste collectors and recycling companies, the creation of new industries, job creation as well opportunities for green financers and other entrepreneurs.

The Chapter also identifies the need for the government to introduce new policy initiatives if Nigeria is to stand a chance at mitigating the risks associated with improper disposal of e-waste in the coming years.

Summary of opportunities and recommendations | Overview




Opportunities	Green financiers	Entrepreneurs	Management authorities
Entry of formal recycling companies to the solar e-waste sector	●	●	●
Re-use of recycled components	●	●	●
Improved financing for solar e-waste value chain	●	●	●
Improved regulation for improper disposal of solar e-waste	●	●	●

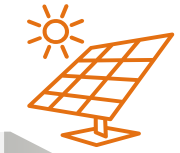
● Positive ● Neutral ● Negative

Summary of opportunities and recommendations | Opportunities

Inefficiencies in the current collection process provides financial and non-financial opportunities for investors, donors and industry associations

Challenges of solar waste collection in Nigeria

Absence of formal collection centers spread across the nation for easy disposal of solar waste by end-users	Lack of awareness by both collectors and end-users, about the dangers associated with improper solar waste management	Little to no guideline regarding the operations of informal collectors
Absence of a central database to track key stakeholders in the solar sector and the volumes of components manufactured, imported and installed	Absence of collection boxes and drop off points which encourages improper disposal by end-users	Long distance between end-users and existing recycling facilities encourage informal collectors to dump components at landfills
Dearth of infrastructural facilities for transporting solar waste to recycling facilities	Absence of incentives/rewards that encourage end-users to return EOL components to formal collectors and recyclers	Poor enforcement of existing policies such as the Extended Producer Responsibility



Steps to establishing a formal collection process

01

Identification of informal collectors

The first step is to identify the informal collectors across different regions, especially within states that generate the most volume of solar waste. In the short term, the identification process can be conducted using field workers, who work closely with local governments and community members. In the long term, collectors can be identified using online registration portals.

02

Informal sector engagement

Informal collectors typically have access to solar end-users and are valuable stakeholders in the solar e-waste management value chain. Once identified, informal collectors should be engaged using these approaches:

- *Sensitisation on the health and environmental impact of improper disposal of solar waste*
- *Trainings/certification on sustainable solar e-waste collection and recycling techniques*

03

Involvement of the informal sector in solar waste management

The third step is to connect informal collectors with formal recycling facilities. Collaboration between both parties will enable collectors to provide feedstock for recyclers.

Summary of opportunities and recommendations | Opportunities

Proper disposal of solar waste by end-users provides an opportunity for recyclers to generate foreign exchange earnings either through the export of the waste collected or recycled materials

Waste disposal opportunities	Costs	Benefits
Export of waste collected t to other countries for proper recycling. (An example is the export of tonnes of Li-ion batteries by Hinckley recycling and Closing the Loop in 2020)	• Collection costs • Shipping costs • Packaging and storage costs • Other indirect costs including lengthy approval process, logistic challenges	• Payment by receiving country for components exported. This is useful for generating foreign exchange earnings. • Prevents health and environmental risks associated with improper disposal
Export of recycled components to other countries	• Collection costs • Recycling costs • Shipping costs • Packaging and storage costs • Other indirect costs including lengthy approval process, logistic challenges	• Payment by receiving country for components exported. This is useful for generating foreign exchange earnings. • Improved recycling capacity
Re-use of recycled materials for domestic production	• Collection costs • Recycling costs	• Improved recycling capacity • Cheaper input costs for manufacturing companies

Summary of opportunities and recommendations | Opportunities

Proper disposal of solar waste by end-users provides an opportunity for recyclers to generate foreign exchange earnings either through the export of the waste collected or recycled materials

Incentivising solar waste suppliers

End users

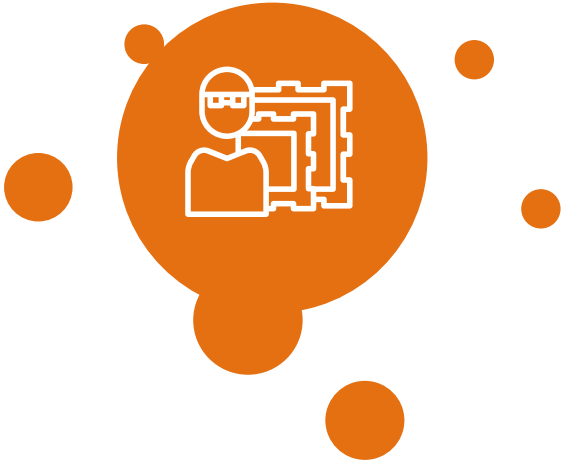
End users can be nudged to dispose their EOL solar components by providing a discount on their next purchase or including a recycling fee in the initial purchase price.

Producers

Nationwide implementation of the EPR is limited by insufficient private investment to set up enough recycling centres for onward transmission of waste by producers.

Collectors

Collectors must be paid fairly for the solar components they collect. This will discourage collectors from prioritizing monetary benefits over environmental sustainability.



Summary of opportunities and recommendations | Recommendations

Federal, state and local governments play a significant role in managing solar waste. The Federal Government through Ministries, Departments and Agencies (MDAs) is expected to coordinate the activities of other stakeholder categories including investors, producers, importers and end-users

Regulatory overview	Role in solar waste management
1. Federal government 	• Introduction of enabling laws that encourage stakeholders to take responsibility for proper waste disposal. There is also a need to deploy and empower enforcement agencies to ensure execution of the regulations introduced. • Development of specific guidelines aimed at proper waste disposal from electrification programmes such as the Solar Power Naija, Nigeria Electrification Project • Provision of financial and non-financial incentives which could include facilitating land approval processes for situating recycling facilities, shipping permits • Improve business environment to enable efficient waste management operations. This includes the provision of road networks and other infrastructural facilities • Investor relations which includes holding roadshows to attract potential investors and managing the PPP arrangements that exist between Federal/state/local governments and investors.
2. State governments 	• Register and regulate activities of solar industry players within the state • Work closely with industry associations as they launch awareness campaigns and formulate policy guidelines targeted at proper solar waste management
3. Local governments 	• Coordinate and monitor the activities of informal collectors through an updated database, setting up monitoring teams to ensure collectors maintain international best practice in their operations • Provision of drop off points and collection boxes to encourage end-users to properly dispose solar components at the end of their useful life • Support awareness campaigns to educate community members on the dangers of improper disposal of solar waste

Summary of opportunities and recommendations | Recommendations

Each stakeholder category has a unique role to play in ensuring proper waste management. Efforts of the following categories are designed to complement activities of regulatory agencies

Industry associations

Includes self regulating associations

- *Introduce consumer awareness campaigns to educate end-users about the dangers of improper solar waste management*
- *Regular training sessions for collectors and recyclers to keep them up-to-date on international best practices*
- *Engage suppliers to ensure the standardisation of products sold to end-users.*
- *Promote R&D activities targeted at proper disposal of solar waste and provide regular updates on research findings*

Donors

Includes corporate donors, private foundations

- *Provision of grants targeted at:*
  - *Developing a database and tracking system for solar waste in Nigeria*
  - *R&D activities to encourage cost-efficient and environmentally friendly recycling techniques*
- *Encourage suppliers of solar components to provide proof of collection/take back schemes (e.g., Memorandum of Understanding with recycling facilities) of solar components before approving grant submissions*

Investors

Includes angel investors, impact investors, venture capitalists

- *Capital expenditure (CAPEX) support for the procurement of necessary infrastructural facilities and Personal Protective Equipment (PPE) for recyclers and collectors*
- *Technical assistance to investees including capacity building, human resource support*
- *Establishment of training centres for educating informal collectors on waste collection best practices.*

Other stakeholders

Includes producers, distributors, importers, retailers and end-users

- *Register, participate and adhere to guidelines of industry associations*
- *Proper record management by suppliers of solar components for easy identification of EOL components*

07

Appendices

Appendices | A1: Scope

Market research study

- *Ascertain the projected volume of solar e-waste in Nigeria*
- *Detail out various disposal and recycling techniques used by both industrial and non-industrial end-users in the country to ensure sustainability of the environment*
- *Highlight the disposal and recycling techniques adopted in maturing economies*
- *Identify the formal and informal players in the industry*
- *Ascertain the capacity and capabilities of solar e-waste recycling plants in the country to safely refine and dispose of e-waste in an environmental and sustainable way*
- *Identify the current gaps in Nigeria's disposal and recycling techniques vis-à-vis international best practices*
- *Detail out the regulatory bodies within the solar e-waste industry in Nigeria including:*
  - *Self regulating associations*
  - *Government regulation*
  - *Commercially driven initiatives*
- *Identify regulatory best practices of solar e-waste disposal and recycling techniques in maturing economies*
- *Identify the regulatory gaps that exist in solar e-waste disposal in Nigeria and the proposed remedial actions for bridging the gap*
- *Outline business opportunities along the solar e-waste value including investment and job creation opportunities*
- *Policy recommendations for the solar e-waste industry*

Appendices | A2: Terminology

The following technical terms are used throughout the report

Terminology	Description
Electronic waste ("E-waste")	• *The term refers to refuse generated by electronic devices including mobile phones, computers etc. at the end of their useful life. Due to the toxic materials contained in most of these devices (e.g., beryllium, mercury, lead, cadmium etc.), an improper disposal poses serious environmental and health risks.* • *E-waste management continues to be of public and political interest owing to the increased generation of e-waste, the potential recycling value of recovering the components of electronic devices and the health and environmental risks.*
Photovoltaic panels ("PV Panels")	• *Refers to a solar panel designed to transform solar energy into electricity.* • *PV Panels converts energy from solar radiation into electricity for both domestic and commercial applications*
Extended Producer Responsibility ("EPR")	• *Refers to a practice in which producers take responsibility for managing the disposal of the products that they producer. In other words, it is a policy approach that involves shifting the responsibility of disposing e-waste (financial and non-financial responsibility) towards the producers and away from the government. EPR also involves incentivizing producers to consider the environmental implications of their products.*

Appendices | A2: Terminology

The following technical terms are used throughout the report

Terminology	Description
Thin-film solar panel	• Refers to a solar cell that involves depositing thin layers of photovoltaic material on a substrate (e.g. glass, stainless steel, plastic). Thin film panels are often smaller than traditional silicon solar and are resistant to high temperatures. • Other advantages of thin film solar panels include its flexibility, versatility,
Pyrometallurgy	• A recycling method that consists o thermal treatment of minerals and concentrates to facilitate the physical and chemical transformation in materials. Pyrometallurgical processes often consist of calcining, roasting, smelting and refining. The recycling method requires energy either in the form of combustion or from electrical heat to sustain the temperature at which the recycling process occurs.
Hydrometallurgy	• A recycling method that uses aqueous solutions in order to recover metals from ores, concentrates and recycled/residual materials. Hydrometallurgy is often divided into leaching, solution concentration and purification and metal/metal compound recovery.
Pico Solar System	• Small and light weight solar systems used to generate small amounts of power using a wide range of energy efficient and portable devices. Pico Solar Systems are typically smaller and cheaper than traditional solar systems but still capable of providing electrical power for low power gadgets. Power generated from Pico Solar Systems range from as little as 0.1watts-peak to as high as 20 watts-peak.

Appendices | A3: Glossary

Glossary of terms

EEE	Electric and Electronic Equipment
EIA	Environmental Impact Assessment
EOL	End-of-Life
EU	European Union
Kg	Kilograms
Km	Kilometre
Kt	Kilotonnes
MT	Metric Tonnes
NESREA	National Environmental Standards and Regulations Enforcement Agency
PV	Photovoltaic
R&D	Research and Development
WEEE	Waste Electric and Electronic Equipment

Appendices | A4: Geo political zones

The six geo-political zones in Nigeria are divided as follows:

North Central	Niger, Kogi, Benue, Plateau, Nasarawa, Kwara and FCT
North East	Bauchi, Borno, Taraba, Adamawa, Gombe and Yobe
North West	Zamfara, Sokoto, Kaduna, Kebbi, Katsina, Kano and Jigawa
South East	Enugu, Imo, Ebonyi, Abia and Anambra
South South	Bayelsa, Akwa Ibom, Edo, Rivers, Cross River and Delta
South West	Oyo, Ekiti, Osun, Ondo, Lagos and Ogun

Appendices | A5: Methodology and assumptions

Methodology and assumptions

	Households	Corporates	Suppliers (including importers, distributors, wholesaler, retailers and installers)
Sample size	781	50	180
Sample method used	Modified multi-stage random sampling method	Purposive sampling (sampling technique where researchers use their expert knowledge to select a nonrandom sample that is representative of the population)	Purposive sampling (sampling technique where researchers use their expert knowledge to select a nonrandom sample that is representative of the population)

Appendices | A5: Methodology and assumptions

Methodology and assumptions

Profit

- *Annual profit is calculated as the difference between estimated total expenditure (operating and capital expenditure) and the estimated revenue.*

Revenue

- *The base revenue was derived from primary research conducted and represents the average income of recycling companies in Nigeria generated from recycling of each component.*
- *We have assumed that revenue will grow in line with the expected volume of solar waste in Nigeria per component.*

Capital expenditure

- *The base CAPEX was derived from primary research conducted and it includes the average annual infrastructure cost, equipment cost, labour cost and power generation costs incurred by recycling companies in Nigeria, apportioned per solar component.*
- *To forecast CAPEX, we derived the average 5yr CAPEX growth of comparable companies from CAPIQ and applied this to the CAPEX of the base year.*

Operating expenditure

- *The base operating expenses was derived from primary research conducted and it includes the average cost of scrap components, fueling cost, rent, payroll and other expenses.*
- *To forecast operating expenses, we applied the forecast inflation rate derived from The Economist Intelligence Unit (EIU) to the operating expenses of the base year.*

Appendices | A5: Methodology and assumptions

Methodology and assumptions

Steps in estimating waste volume

1 Step 1

Obtained the total quantity and weight of solar components installed by leading solar system distributors, mini-grid developers and installers in Nigeria, as at 31 August 2021.

- *The solar components include lead acid and lithium-ion batteries, solar panels and inverters.*
- *These components are from solar home systems and mini-grids.*

2 Step 2

Based on the number of existing solar systems installed and the estimated useful life of each component, we projected the volume of solar e-waste by:

- *Projecting the quantity of solar component that will expire in each year based on the useful life;*
- *Multiplying the quantity expiring in each year by their weight to derive the total volume of solar waste in the year*

Impact of technology on weight

- *We noted that efficient solar components tend to be lighter. Hence there is a direct relationship between the rate of efficiency and the decline in the weight of solar components.*
- *The conversion rate of solar panels have increased by 6% in the last decade. Therefore, we assumed a conservative discount rate of 3% upon replacement to account for improving technology. This will reduce the weight per unit over the forecast period.*
- *The conversation rate of lithium-ion batteries have increased by 150% in the last decade. We have assumed a conservative discount rate of 12.5% upon replacement to account for improving technology, which will lead to an increased capacity of the batteries and ultimately reduce the weight per unit.*

3 Step 3

- *We assumed that expired solar components will be replaced upon expiration.*
- *Specific growth rates have been applied to the different components.*

Appendices | A5: Methodology and assumptions

Methodology and assumptions

Projected cumulative solar waste volume(kg)

Components	2021	2025	2030	2035	2040
Lead acid batteries	3,313,918	8,326,178	15,150,279	28,150,790	49,088,244
Lithium-ion batteries	-	620,325	1,571,850	2,410,611	3,122,630
Inverters	-	11,040	72,074	139,460	213,860
Panels	-	1,056,345	2,659,607	4,211,701	7,918,566
Total	3,313,918	10,013,888	19,453,809	34,912,562	60,343,300

Source: Deloitte Analysis

Limitations

- For the purpose of this research, we have estimated the e-waste from solar panels, inverters, lead acid batteries and lithium-ion batteries only.
- We have not taken into consideration recycling or other waste management measures.

Assumptions

Components	Average lifespan	Average weight*
Lead acid battery	3 – 5 years	98 kg
Lithium-ion battery – mini-grid	10 years	38 kg
Lithium-ion battery – SHS	5 years	5 kg
Panel - SHS	5 years	7.9 kg
Panel – mini-grid	20 – 25 years	20 kg
Inverter – mini-grid	10 years	20.6 kg
Inverter – micro-grid	10 years	21.5 kg

** The weight used in our calculation is based on the actual weight of the solar components provided by the players*

Growth rates assumption

Components	Annual growth rate
Lead acid battery	10%
Lithium-ion battery	1%
Panel	1%
Inverter	2%

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