Battery Recycling

Second Life Batteries Market Assessment

May, 2021

Executive summary (1/2)

Battery recycling value chain

There could be an opportunity to localize and **create value from battery recycling** in Nigeria, while having the added benefit of **avoiding significant environmental and health hazards** from the sector

There are two value chains for consideration:

- **Lithium-ion batteries (LIB)** is a **nascent market with limited competition**, but a tougher set of **barriers** to overcome
- **Lead-acid batteries (ULAB)** is a better **developed market**, with existing market infrastructure, but is **much more competitive.**

Feedstock landscape in Nigeria

Lithium-ion batteries (LIB) – There is projected to be **6.5-10k tonnes of LIB feedstock by 2025**, enough for the facility with 5,000 tonnes throughput; but this requires that **50-80%** of LIB waste is **collected**

- **Consumer electronics** – specifically mobile phones and laptops
  - The LIB waste market from consumer electronics is projected to deliver **4-5k tonnes** of LIB waste by 2025, with **growth of 5.5%** driven by population and income growth
  - While the feedstock is available, the **principle challenge** facing recyclers will be the **collection of LIB waste**. OEMs are the traditional method of collection in other markets, however, in Nigeria, there is neither regulatory enforcement nor any economic value for them to collect
  - **Success** in collection of feedstock will require **building a supply chain from the intermediary collection points** (e.g., second-hand electronics SMEs) and providing an **economic incentive for informal collectors.**
- **New energy sources** – specifically solar home systems and mini-grids
  - The LIB waste market for new energy sources is currently very small, but is projected to deliver **2.5-5k tonnes** of LIB waste by 2025 (**~40% of total market**), with the growth driven by improved market economics and aggressive promotion by the Nigerian government (5 Mn Solar Naija programme)
  - **Collection** could be **targeted towards distributors and OEMs** (for solar home systems) and the **developers** (for mini-grids), who have much higher collections rates (>40% for solar home systems, and ~90% for mini-grids) than in consumer electronics. Furthermore, effort could be made to encourage government to further enforce collection of waste by OEMs.

Executive summary (2/2)

Feedstock landscape in Nigeria (con't.)

Used lead-acid battery – There is projected to be **105-154k tonnes of ULAB feedstock by 2025**, enough for the facility with 5,000 tonnes throughput; but **existing competitors** who collect and refurbish batteries (e.g. informal collectors) need to be **incentivized financially to collect for licensed recyclers**

- The ULAB waste market from **generators** is projected to deliver **60-90k tonnes** of waste by 2025, with **growth of 8%,** while **auto vehicles** could also deliver **45-63k tonnes**, driven by underlying economic and demographic growths
- While **~95% of all ULAB waste is already recycled** or refurbished for reuse by the informal sector to capture significant market value, recycling practices constitute an **environmental and health hazard** for the workers and communities
- To reduce the contamination, **informal networks** of collectors and recyclers could be **financially incentivized to collect for licensed recyclers.**

Overview of the e-waste value chain in Nigeria

Feedstock landscape in Nigeria – Lithium-ion battery

Feedstock landscape in Nigeria – Used lead-acid battery

Second life battery demand

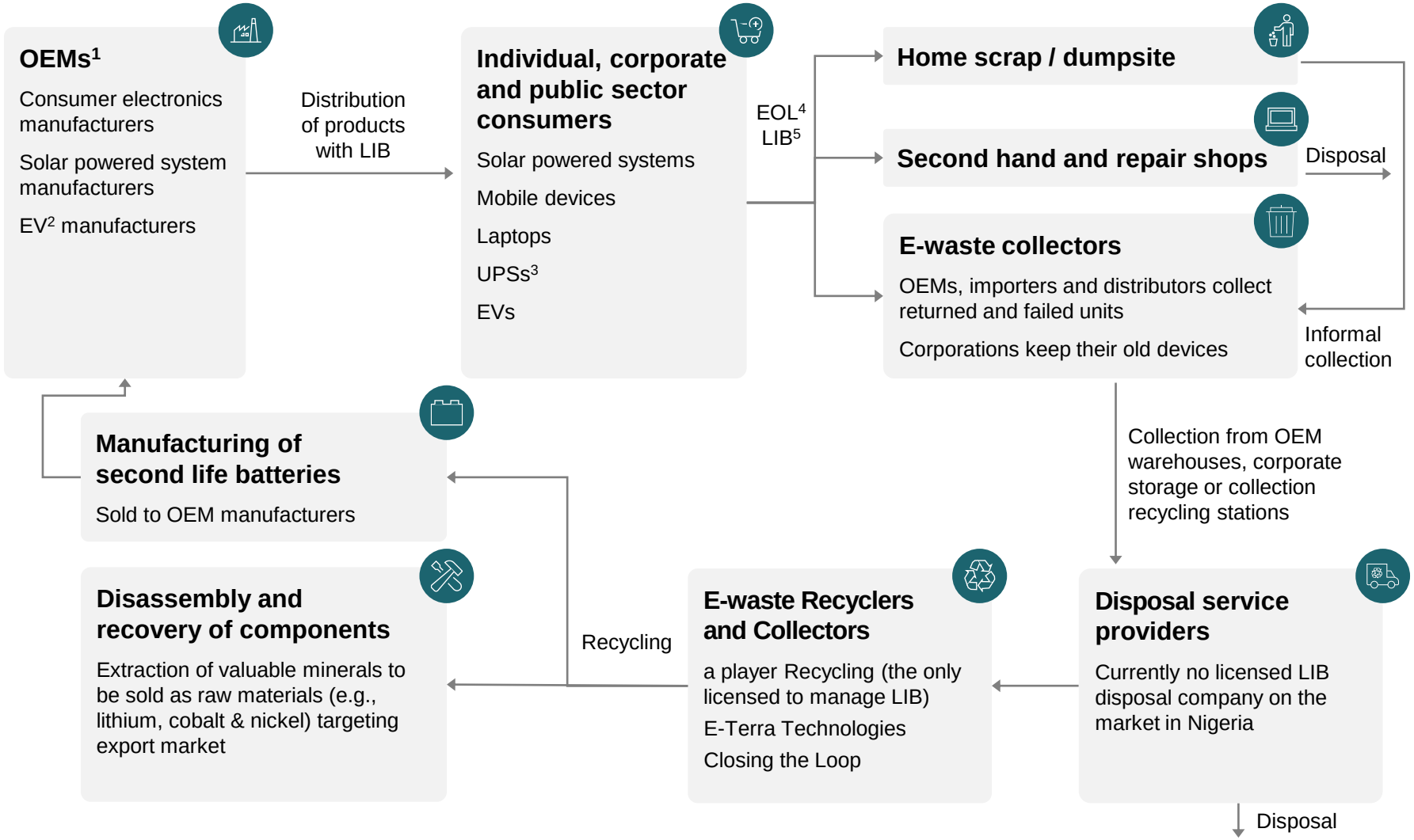
There is an opportunity to capture value from battery waste through recycling while also averting the environmental and safety hazard in Nigeria

Battery type	Use cases	User groups	Collectors	Current state of recycling
Lithium-ion battery (LIB)	 Consumer electronics (phones, tablets, laptops and power banks)  Solar powered systems (solar home systems, rooftop solar PV panels and batteries, solar mini-grids)  Electric and hybrid vehicles (E2W and E4W[1])	▪ Individual owners ▪ Large corporations ▪ Public institutions	▪ Formal sector – OEM (returned and failed devices) – Existing recyclers and disposal service providers – Retail shops drop-off stations – Electronic device repair shops (failed unusable batteries) – Garbage collector companies – Importers and distributors ▪ Informal sector – Electronic device repair shops – Garbage collectors	▪ Most LIB waste ends up **mixed with municipal solid waste** as there is no market value of recycling for the informal sector ▪ Not recycled LIBs constitute a **security hazard** as they could overheat and cause explosion and fires ▪ LIBs could be **recycled for their components** or **refurbished for second life** battery pack
Used lead-acid battery (ULAB)	 Automobiles (personal vehicles, trucks) and motorcycles  Construction machinery  Generators and uninterruptible power supplies (residential vs. commercial)	▪ Individual owners ▪ Commercial users ▪ Public institutions	▪ Formal sector – Existing recyclers – Car battery charging and maintenance shops – Car battery shops – Garbage collector companies – Importers and distributors – Public institution utility warehouses ▪ Informal sector – Battery waste recyclers – Garbage collectors	▪ **~80% of e-waste recycling** happens through **informal collectors** who are not aware of the dangers of lead ▪ Even some **recycling companies are not providing protective equipment to the workers** and **have been contaminating soil and the environment** leading to ~20 micrograms[2] of lead in children in the surrounding communities and

1. Electric two wheel and electric four wheel
2. Lead levels over 5 micrograms could cause cardiovascular problems and over 10 micrograms learning disabilities

Source: Business Today 2018, Dying in instalments: How lead battery recyclers are poisoning Nigerians (Part I)

In Nigeria, consumer electronics and solar powered systems are the main sources of LIB waste that could be used to manufacture second life LIB



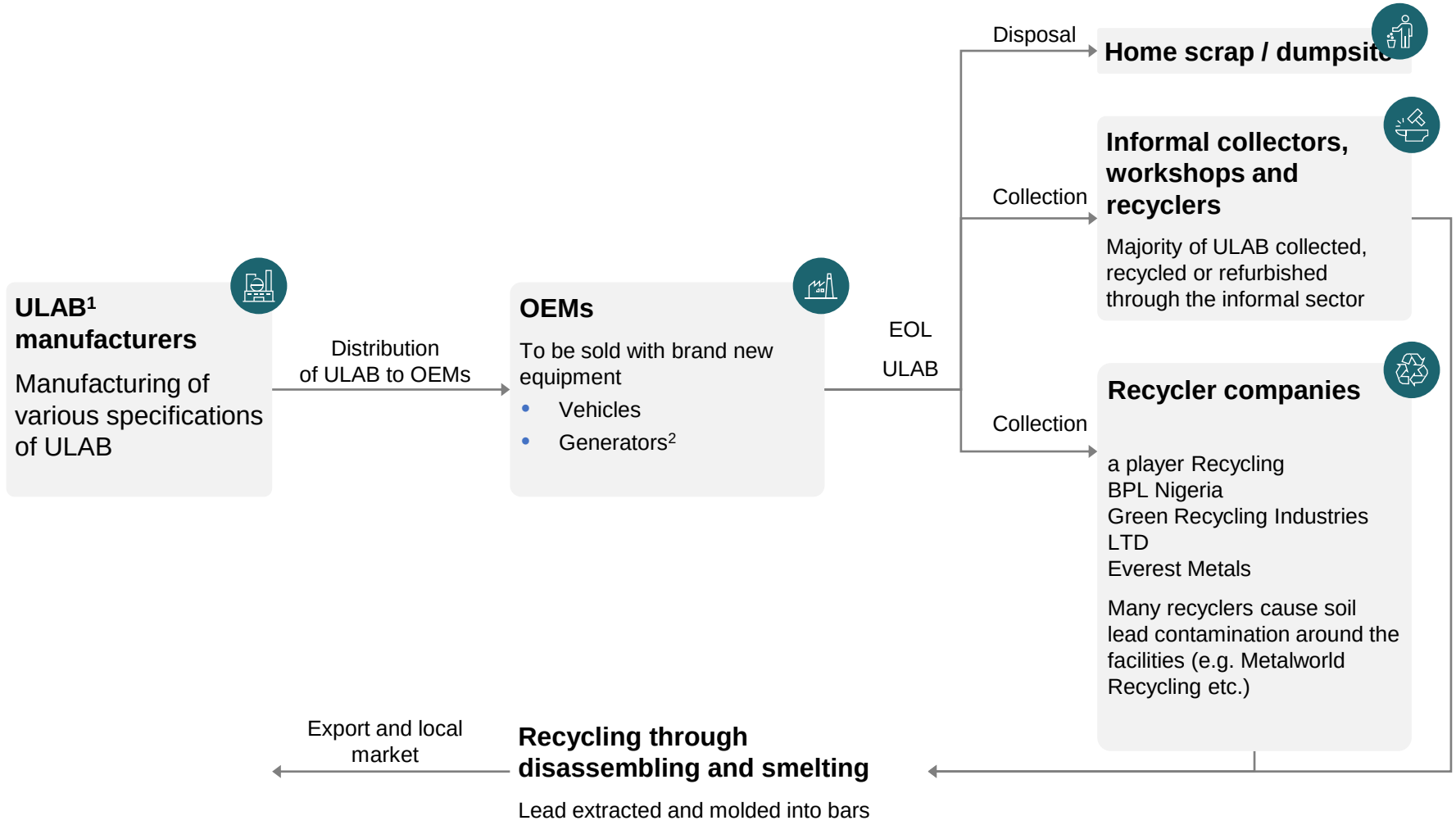
Key takeaway

- Currently, **consumer electronics** and **solar power systems** are key sources of LIB waste
- LIB waste **does not have market value**, hence it is largely uncollected by informal sector
- Key **collectors are OEMs and corporations** that have used devices with LIB
- Depending on remaining energy levels, LIB could be either **turned into second life LIB or disassembled to recycle** its components

1. Original equipment manufacturers | 2. Electric vehicles | 3. Uninterruptible power supply | 4. End-of-life | 5. Lithium-ion Batteries

SOURCE::Desk research

End-of-life automotive and automatic generator batteries are key sources for ULAB waste, primarily collected by the informal sector to extract components and refurbish



Key takeaway

- End-of-life **vehicle** (e.g. car and motorcycle) and **generators** are the key sources of ULAB waste
- Currently ULAB waste is **collected** mainly through the **informal sector either for refurbishing or disassembly** to recover lead
- Informal collectors are **unaware of the environmental and health risks**
- **Majority of ULAB is recycled** and lead is extracted

1. Lead-acid battery
2. UPS with lead-acid batteries could also be relevant

SOURCE: Desk research

Overview of the e-waste value chain in Nigeria

Feedstock landscape in Nigeria – Lithium-ion battery

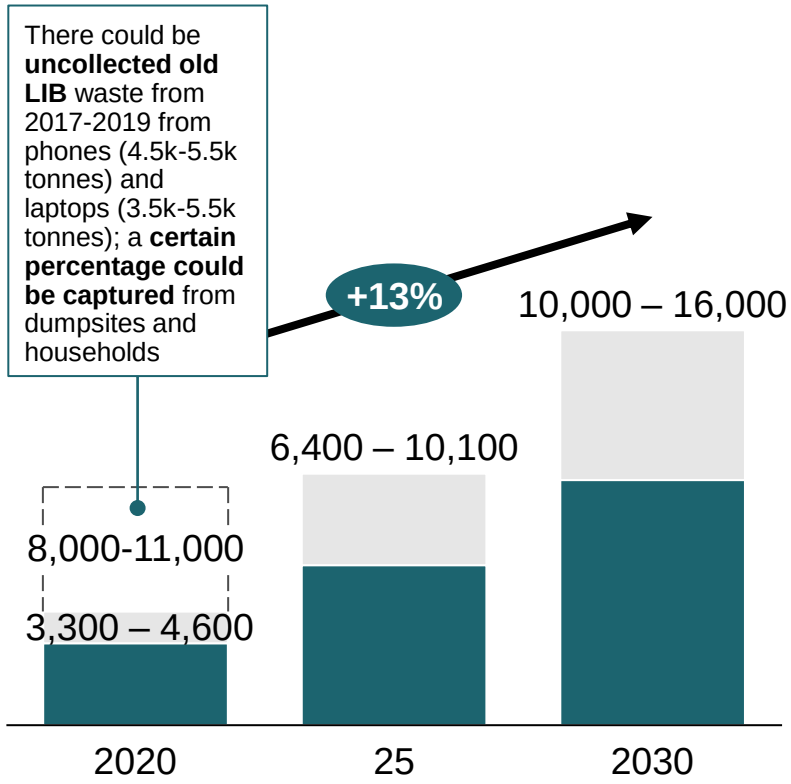
Feedstock landscape in Nigeria – Used lead-acid battery

Second life battery demand

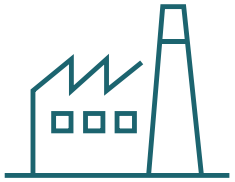
There is projected to be enough LIB feedstock by both 2025 and 2030 for the facility with 5,000 tonnes throughput, but only if a player could collect 50-80% of LIB waste

The total LIB waste is estimated to reach 6-10k tonnes by 2025…

Total volume of LIB waste generated in Nigeria, metric tonne per year



… that is theoretically sufficient feedstock for the planned 5,000 tonnes annual facility capacity…



5,000 tonnes target capacity for the LIB recycling and repurposing facility

… but it could only be realized if a player could collect 50-80% of the waste in 2025

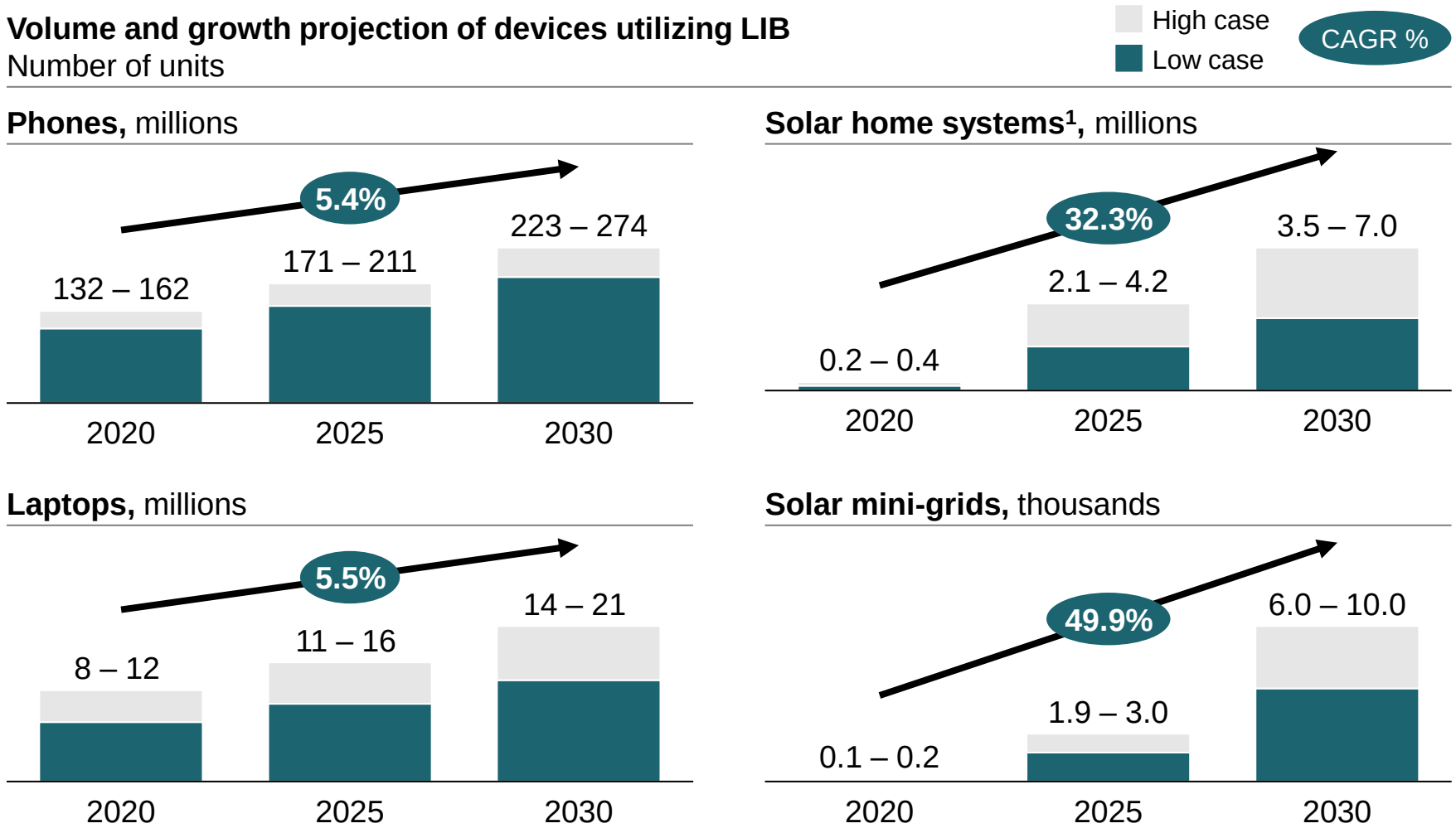
SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

Preliminary

LIB utilization in Nigeria is expected to grow due to population growth, increased income and Government support to shift towards alternative energy

Volume and growth projection of devices utilizing LIB

Number of units



Key takeaway

- **Population and income growth coupled with need for alternative energy are key drivers** for growing consumer electronics and solar powered devices usage

1. Excluding Pico lanterns

SOURCE: Statista 2018, Consumer Electronics Market in Nigeria | Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

Preliminary

Currently, phones and laptops contribute 52% and 40% to LIB waste but solar powered devices are projected to dominate the market by 2030

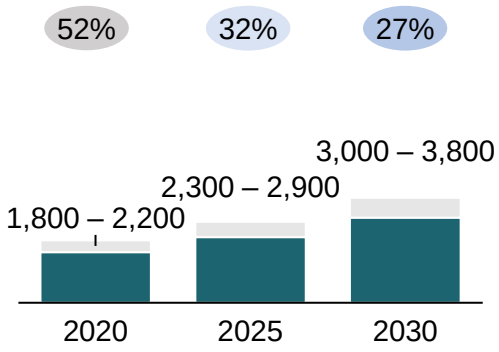
Percentage of total waste per year per device

2015 | 2020 | 2030 | CAGR %

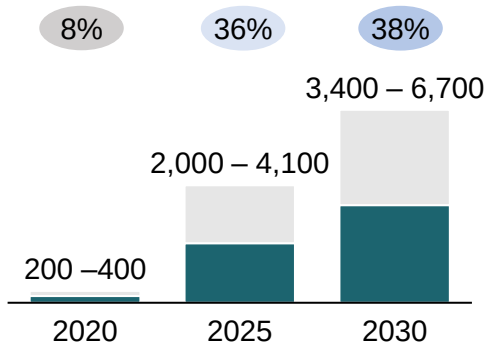
Volume of LIB waste generated per use case, Metric tonne per year

High case
Low case

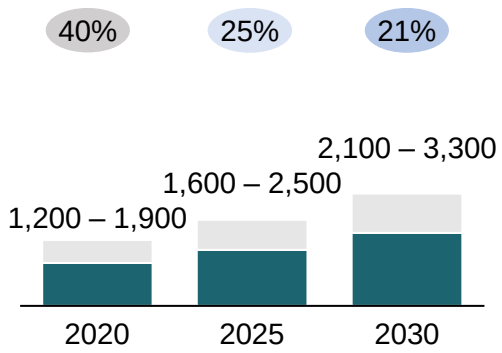
Phones



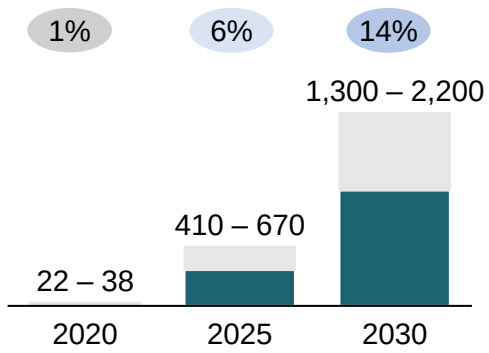
Solar home systems[1]



Laptops

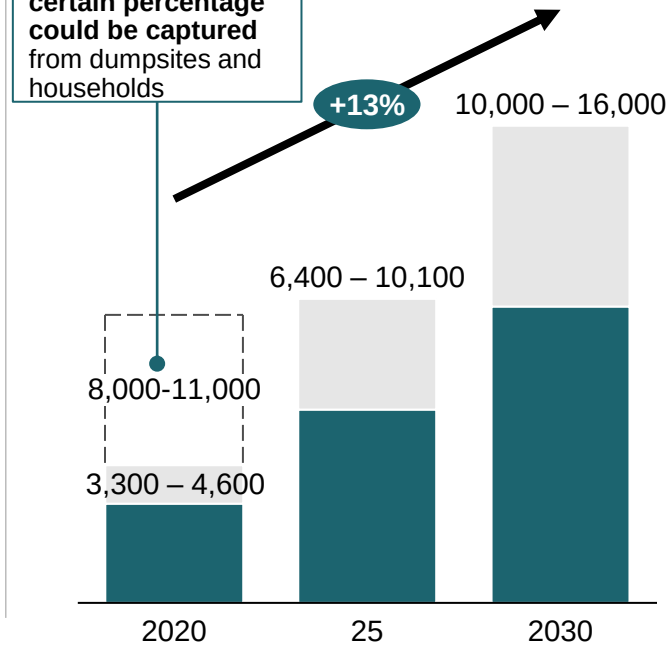


Solar mini-grids



Total volume of LIB waste generated in Nigeria, Metric tonne per year

There could be **uncollected old LIB** waste from 2017-2019 from phones (4.5k-5.5k tonnes) and laptops (3.5k-5.5k tonnes); a **certain percentage could be captured** from dumpsites and households



Key takeaways

Phones and laptops are the **main sources of LIB waste** currently

Solar powered devices are expected to contribute to **more than 50% by 2030** driven by the heavy battery sizes and government initiatives to expand access to off-grid electricity

Additional source of LIB waste are:

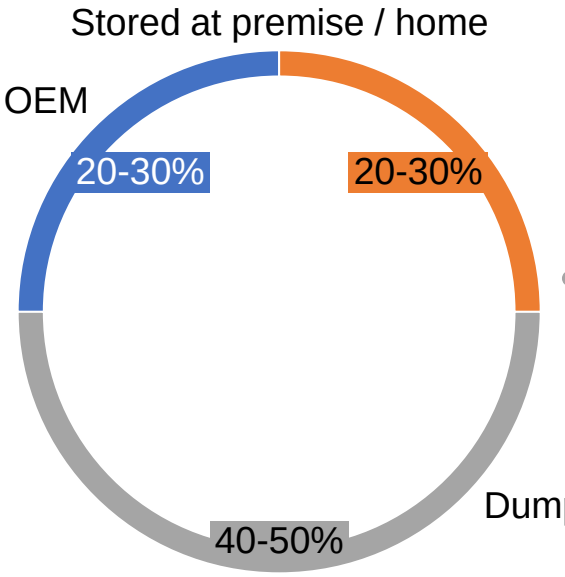
- **Tapping into** the **uncollected** LIB waste from **phones** (4,500 – 5,500 MT) and **laptops** (3,500 – 5,500 MT) from 2017 - 2019
- Rise in the number of **hybrid electric vehicles** and their battery waste expected to increase **from 2025**
- Tapping into **e-waste in the region** if import is legalized

1. Excluding Pico lanterns

SOURCE: Statista 2021, Consumer Electronics Market in Nigeria | Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

Only 20-30% of the LIB waste is collected by OEMs, importers and distributors particularly by large corporations, while majority of LIB waste remains difficult to reach

Distribution of LIB waste by waste location, Thousand Metric Tonne



- OEMs and distributers or importers collect returned and faulty products on warranty or through official maintenance for a fee
- Only large corporations follow this practice

- Some end users tend to keep their e-waste as they do not know what to do with them
- Some consumer collection points are established and more are planned to tap into this portion

- 60-70% of LIB waste in the dumpsite is estimated to come from secondhand and repair shops, the rest from households as people do not know the value of their e-waste
- According to experts, 40-50% of e-waste is estimated to be collected, dismantled and exported that contain LIB as well
- Exporters and recyclers together with EWCAN[1] collect waste from OEMs but also from dumpsites and buy from informal collectors who normally would not collect LIB waste as it lacks direct market value

Key takeaway

- Currently, **majority of the LIB waste is in dumpsites while larger corporations also collect** their returned product
- **Informal sector plays minimal role** in LIB waste collection as there is **no economic value** unless they receive fee for collection
- As a result, **60-80% of LIB is not formally collected** and likely in storage or dumpsites while the rest is exported in components

1. E-waste Collector Association Nigeria

SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

While phones can ultimately end in a dumpsite, they go through intermediary collection points on multiple occasions that could be targeted to collect battery waste easier

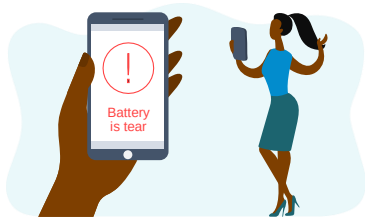
Intermediary collection points, easier to target to collect phones and batteries

Phone gets a lithium-ion battery at the manufacturing or assembly site

Phone is imported into Nigeria

Distributor receives the phone and sells to shops

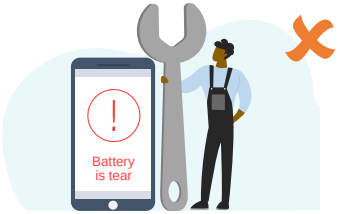
Customer buys phone with warranty



Phone is not working after 1 year as battery is tear

Customer brings it back to seller/OEM as it still has warranty, battery is replaced

Phone battery is very tear after 2 years, warranty is out



Customer brings phone to second hand/repairs shop

Phone cannot be repaired so customer either 1) leaves the phone behind and the repair shop tries to resell it or throws it out on the street 2) gives the phone to a relative or 3) keeps the old phone at home

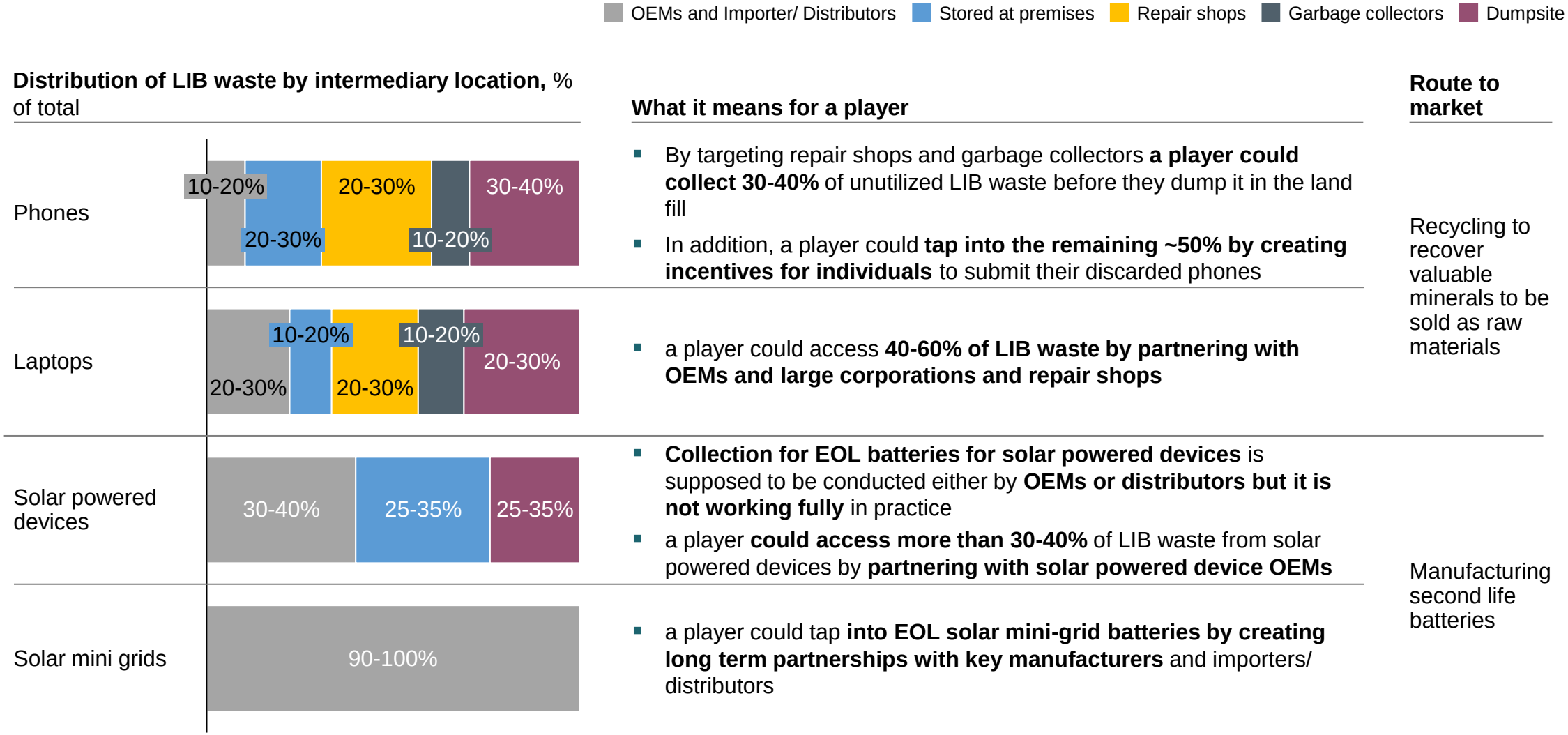
Informal pickers collect phone waste from the street or the dumpsite that still has some power in

Informal collector resells phone or pieces of the phone

And the cycle of reuse continues through new users, repairs at second hand shops until most of the energy can be captured from the phone and until it ends in the dumpsite

SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

Before ending up in the dumpsite, 20-30% of phones and laptops are bought into second hand and repair shops where they could be collected, while ~40% of solar powered systems are likely already collected by distributors



SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

Overview of the e-waste value chain in Nigeria

Feedstock landscape in Nigeria – Lithium-ion battery

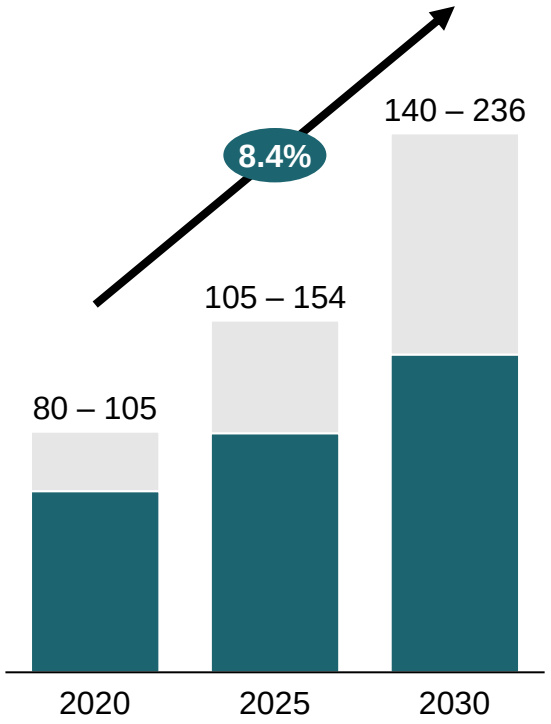
Feedstock landscape in Nigeria – Used lead-acid battery

Second life battery demand

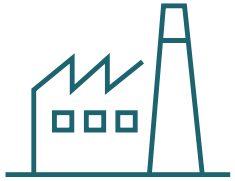
There is enough ULAB feedstock for the facility with 5,000 tonnes throughput, but a player needs to incentivize informal recyclers that currently reuse ~95% of ULAB

The total ULAB waste is estimated to reach 105-154k tonnes by 2025…

Total volume of ULAB waste generated in Nigeria, thousand metric tonne per year



… that is sufficient feedstock for the planned 5,000 tonnes annual facility capacity…



5,000 tonnes target capacity for the ULAB recycling and repurposing facility

… but a player needs to incentivize informal recyclers that currently reuse almost all ULAB

- Informal collectors, recyclers and sub-standard formal recyclers dismantle and smelt ULAB to capture significant market value from the ULAB
- However, most workers are unaware that refurbishing and dismantling are done in an environmental hazardous way that endangers the workers' and communities' health
- a player could financially incentivize collectors and raise their awareness about the health risks to gather sufficient feedstock and be able to recycle ULAB in a safe manner

SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

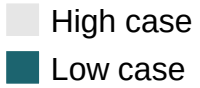
Preliminary

Key use cases for ULAB in Nigeria are for automotives and generators with automatic starters that are growing due to population, GDP and income growth

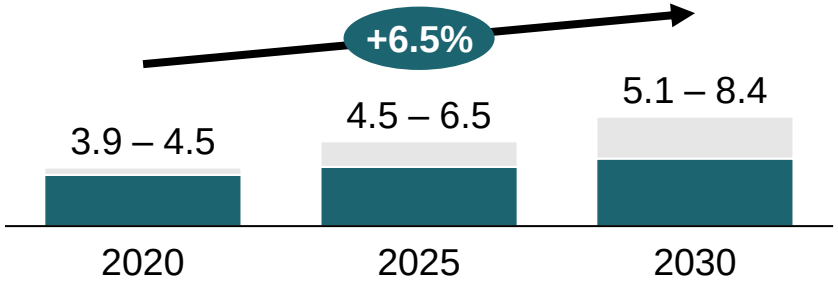
CAGR %

Volume and growth projection of devices utilizing ULAB

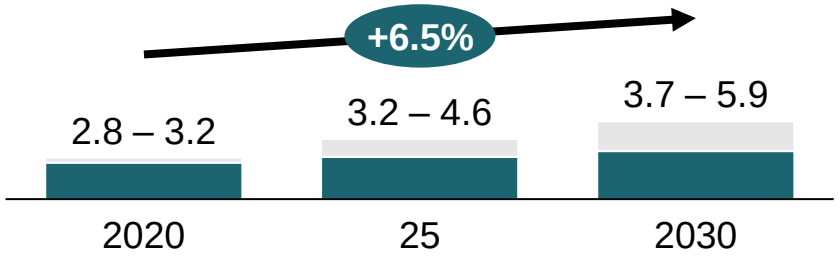
Number of units (millions)



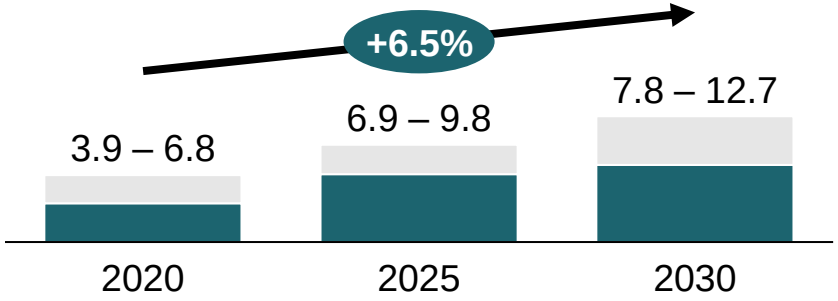
Passenger cars



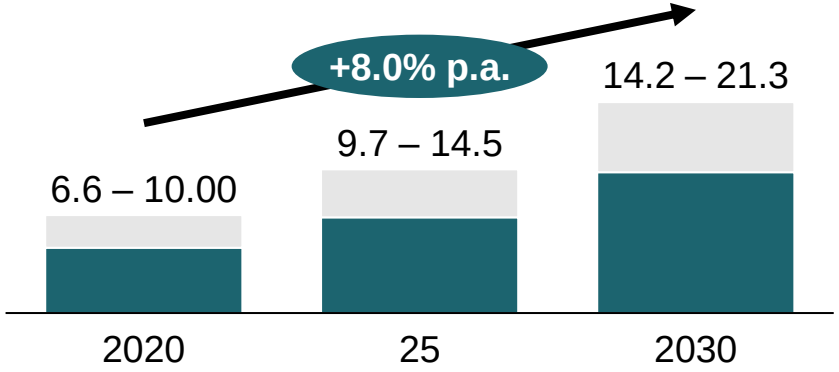
Commercial vehicles, buses and heavy trucks



Motorcycles



Generators with automatic starters



Growth drivers

Rise in income level coupled with population growth would drive the growth of number of automobiles and generators

SOURCE: Nigerian Bureau of Statistics 2018, Road Transport Data

Currently, 80-105 thousand metric tonnes of ULAB waste is generated and is expected to reach 105-154 thousand metric tonnes by 2025

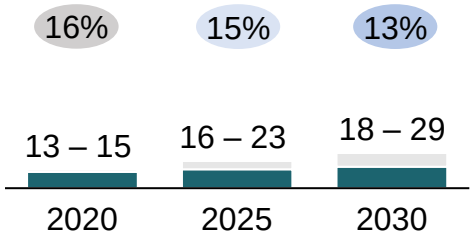
Percentage of total waste per year per device

2015 2020 2030 CAGR %

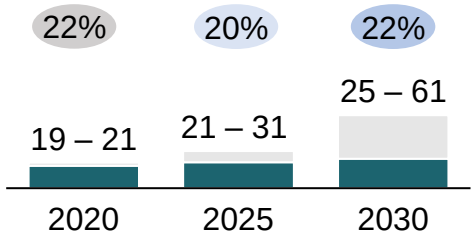
Volume of ULAB waste generated per use case,
Thousand Metric Tonne

High case
Low case

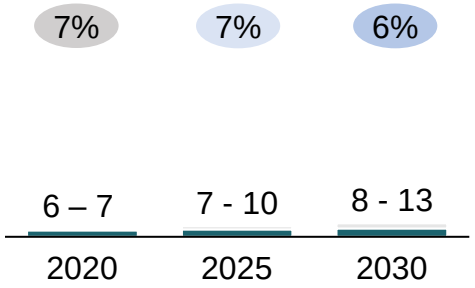
Passenger cars[1]



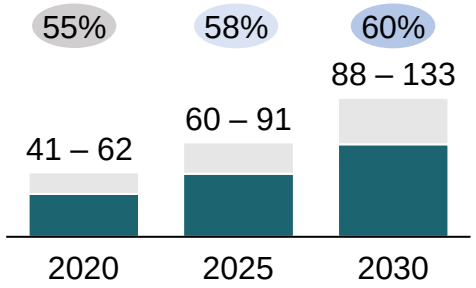
Commercial vehicles, buses and heavy trucks[2]



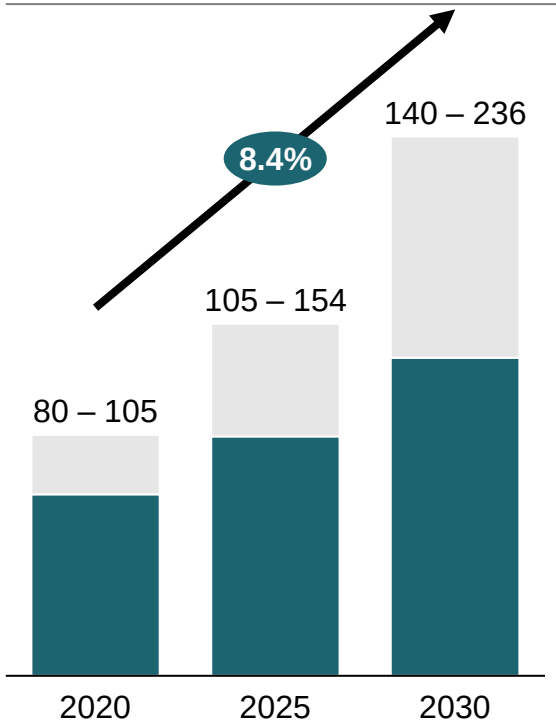
Motorcycles[3]



Generators with automatic starters[4]



Total volume of ULAB waste generated in Nigeria,
Thousand Metric Tonne



Key takeaway

End-of-life batteries from automatic **generators** are the main source for ULAB with **commercial vehicles, buses and heavy trucks**

As projected **feedstock is more than 20-30x higher by 2025 than the planned 5,000** metric tonnes ULAB recycling throughput, the main **challenge** is expected to **incentivize informal collectors and small battery workshops** to hand in batteries

SOURCE: PowerStream, 2021, Sealed Lead Acid Battery Size Chart

As ULAB collection already generates revenue for the informal sector, it has to be incentivized to deliver to recycling facilities that are up to standards, otherwise they would further pollute the environment and endanger the communities' health

While lead-acid battery recycling is providing significant income to informal collectors, it is also posing a serios health and environmental risk to Nigerians working in and living near recycling plants...

Due to the **economic benefits** of extracting and selling lead, the **majority of ULAB is recycled** in the informal sector and in **substandard recycling plants**

Surrounding soil has become polluted and unsafe for agriculture **due to efflux from recyclers**, as it holds more than 10 times the upper limit of lead per kilo of soil[1]

Furthermore, **blood tests from children and adults** living near recycling plants revealed that they have more than **10 micrograms of lead per deciliter of blood**, which is a high degree of risk and **graded as lead poisoning** according to WHO guidelines

…hence minimizing the health and environmental hazard requires a multi-sectoral effort to create awareness and reduce demand for informally recycled lead

Raise **community's awareness of the dangers of lead** to **people's health** and the **environment**

Develop attractive **incentives for the informal sector** to **collect and sell** the lead-acid batteries to recyclers

Establish a **recyclers, government and international buyers coalition** so that buyers commit to only buy from licensed recyclers that would **minimize the export of lead from substandard facilities**

1. US Environmental Protection Agency (EPA) allows no more than 400 milligrams per kilo near the settlement.

Source: Business Today 2018, Dying in instalments: How lead battery recyclers are poisoning Nigerians (Part I), Interview with e-waste expert

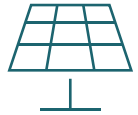
Overview of the e-waste value chain in Nigeria

Feedstock landscape in Nigeria – Lithium-ion battery

Feedstock landscape in Nigeria – Used lead-acid battery

Second life battery demand

Need for replacement batteries for solar powered TV sets and lanterns would drive demand for second life LIB in Nigeria

Second life battery use cases	1st life application	2nd life application
 **Pico lanterns**	Not a priority application for now as 1st life application is not possible due to OEM restrictions to utilize brand new batteries Potential future opportunity: ▪ Local solar home system assembling could be approached in the future ▪ Global OEMs might allow local distributors to exchange EOL batteries with other batteries due to the global sustainability push	Opportunity market for end-users who would want to replace old batteries as cost of battery versus acquiring new device is low
 **Solar powered TV set**		
 **Solar home systems**		Opportunity might be limited because the price of acquiring the device is assumed to be similar to the price of the battery
 **Solar mini-grids**		Potential opportunity, however due to the higher investment, customers might prefer longer lasting new batteries

Key takeaway

- Immediate opportunity on the market for **second life batteries is for Pico lanterns** and solar powered **TV sets**
- Solar home system and solar mini-grids could be relevant if the **cost of replacing the batteries is less than ~40% of purchasing a new device**[1]

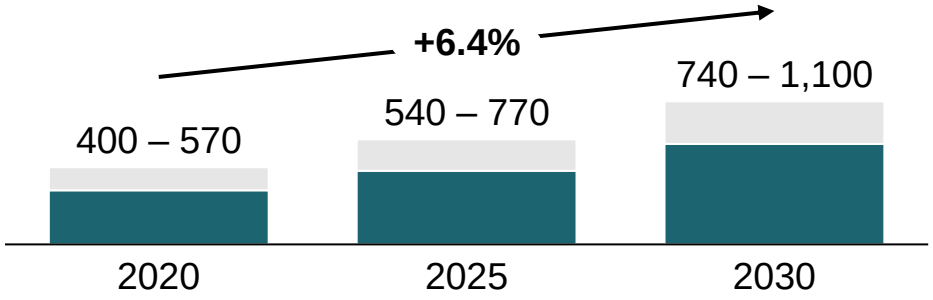
1. Based on expert input

SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

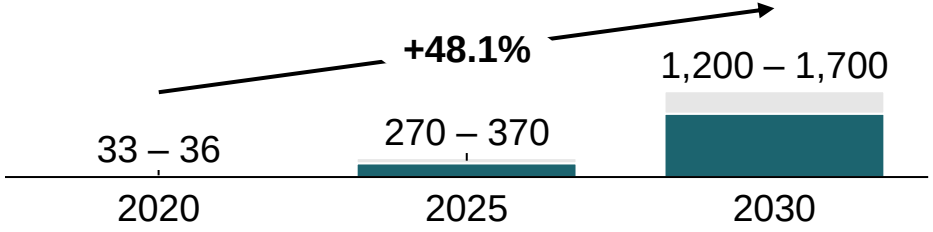
Currently there are between 400-570k lanterns and 33-36 thousand solar powered TV sets, and TVs and mini-grids are expected to grow exponentially due to the Government program

High case
Low case

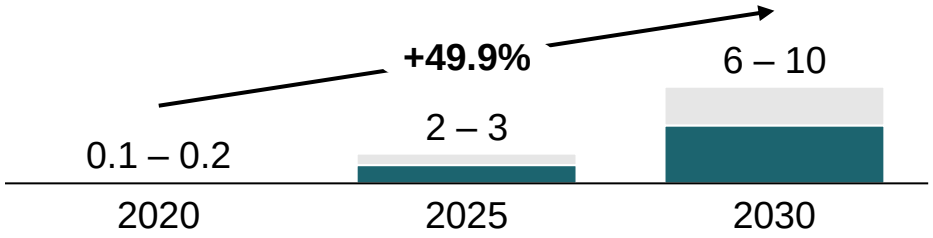
Number of pico lanterns, Thousand Units



Number of solar powered TV sets, Thousand Units



Number of solar mini-grids, Thousand Units



Rational

While Nigeria has higher proportion of larger systems compared to West Africa, lanterns are projected to still remain important, particularly in rural areas

National financing program funded by development partners for solar home systems could support the medium to large systems with appliances as it offers grants for businesses to install a minimum number of devices every quarter.[1] Assuming Nigerian sales would reach current Kenyan TV set sales in 8-10 years

Government initiative to install 10,000 mini-grids by 2030

Key takeaways

- While **pico lanterns** are expected to lose some of their dominance, they would **still remain a significant** user of second life LIBs
- **Government initiatives** are expected to **propel** the growth of solar-powered **television** sets and **mini-grids** in the coming years

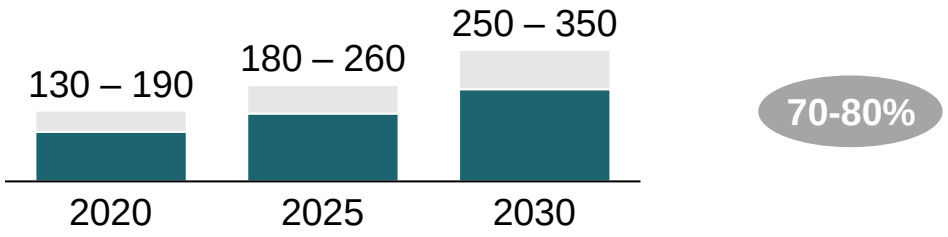
1. Gogla, 2019: Global Off-Grid Solar Market Report

130-210k lantern units and 40-60k TV battery units could be targeted for second life batteries by 2025

High case
Low case

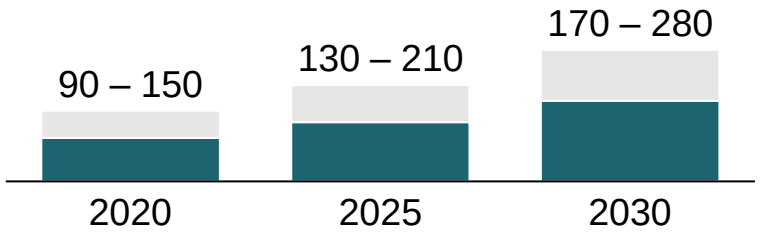
X% % of users willing to use second life batteries

Number of replacement batteries for lanterns, Thousand Units

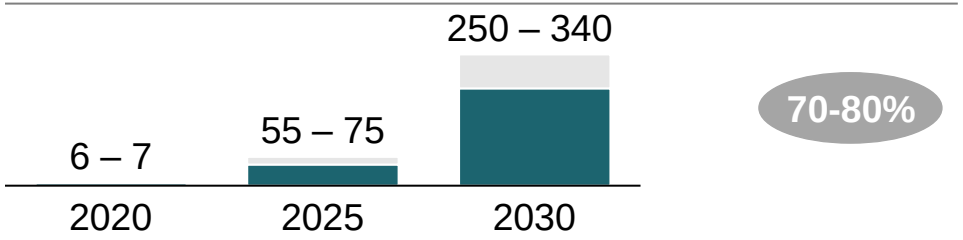


70-80%

Demand for second life batteries for lanterns, Thousand Units

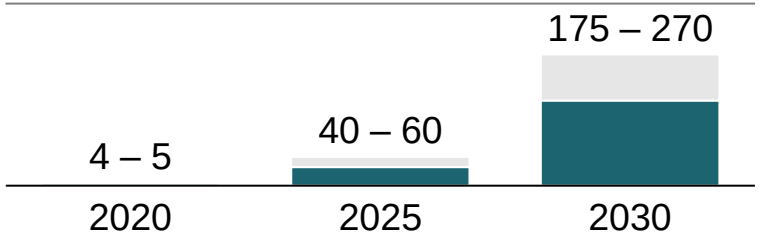


Number of replacement batteries for solar powered TV Sets, Thousand Units

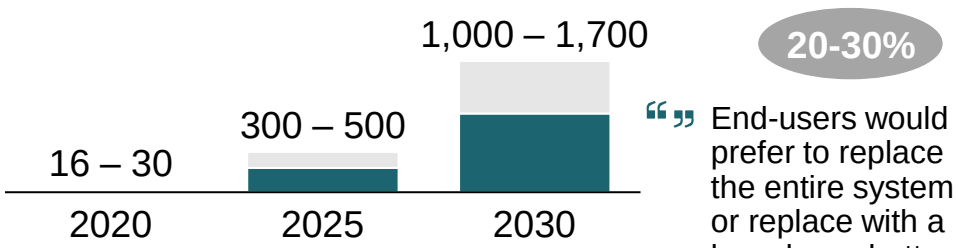


70-80%

Demand for second life batteries for solar powered TV sets, Thousand Units



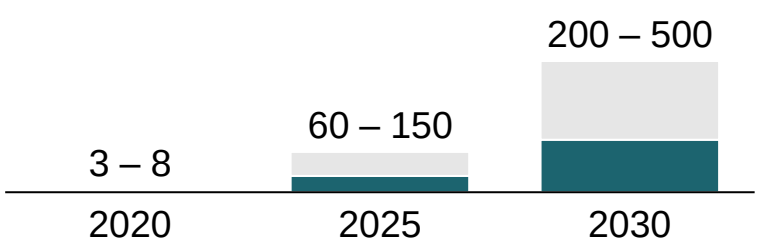
Number of replacement batteries for solar mini-grids, Units



20-30%

"End-users would prefer to replace the entire system or replace with a brand new battery with longer life

Demand for second life batteries for mini-grids, Units



Key takeaway

- Current opportunity would be from Pico Lanterns with about 130-210k units requiring replacement batteries by 2025 if the cost of replacing the battery is affordable
- While demand for larger size batteries for solar powered TVs would grow rapidly over the forecast period

"End-users would go for second life batteries as long as it is durable and affordable

SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

1. As distributors have strict contracts with OEMs for using original parts, targeting consumers who are looking for replacement batteries is more feasible for second life battery application

Due to stringent OEM arrangements, local suppliers are not allowed to use non-original components...

Importers and assemblers of solar-powered devices currently have **stringent contracts** with suppliers to **supply original OEM components**, **making second life batteries a less appealing**

However, with the **shift towards sustainable and circular manufacturing**, **OEM constraints would also loosen**, making second life batteries a viable option in the near future

...leaving consumers with the option of paying a premium fee for OEM new batteries or discarding their units

Nigerian consumers prefer to repair and reuse electrical equipment until end-of-life of device

However, they **have limited options to get replacement batteries**

Consumers would **either get less costly imported batteries** or **discard their units because original replacement batteries** from distributors **are expensive**

Consumers searching for low-cost replacement batteries could find second life batteries to be a viable choice

It could be a **feasible choice for Nigerian consumers**, given that **second life batteries are reliable and cost less** than imported brand-new replacement batteries

Furthermore, **having a warranty would make the second life battery more appealing** to consumers

SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

2. Cost competitiveness and durability are the key drivers for end users to switch to second life LIB, perceptions against second life however play a smaller role

⊕ Positive influencer of purchasing decision ≈ Factor does not influence decision

Customer preferences

Potential preferences	Description	Implication
Low cost ⊕	Customers are likely to choose second life batteries as long as battery cost is ~40% lower than a new device	▪ Review prices of target devices on the market ▪ Develop pricing relative to device price
Durability ⊕	Hours of service and useful life of battery are important switching factors	▪ Provide and act on warranty for battery ▪ Emphasize durability in messaging
Perception on second life battery ≈	In certain markets, second life batteries have negative perception, however most Nigerian customers are used to second-hand electrical equipment, while growing youth and middle class might prefer sustainability element of second life batteries	▪ Communicate second life nature of battery but with putting emphasis on cost and durability

Assumptions

Assumptions and data sources for phones

Low case number of phones

Assumption		Values	Rational of assumption		
Number of subscribers in 2019 (Mn)		185	Statista[3]		
		Low case		**High case**	
% of dual sim devices		48%	Device Atlas[4]	20%	Company input
Number of SIMs per device	**Dual SIM device**	2	Assumption		
	Single SIM device	1	Assumption		
Growth rate for 2020-2030		5.3%	Volume projection from 2021 – 2030 was conducted based on growth of subscribers from 2015 – 2019 by Statista[3]		

General assumptions for waste creation

Average battery size (grams)[5]	44	**End-of-life period for phones[6]**	3 years

1. Basel Convention 2012, e-Waste Country Assessment Nigeria
2. World Bank, where GNI per capita started to go to 0, population growth was used
3. Statista 2019, Number of mobile cellular subscriptions in Nigeria
4. Device Atlas, 2019, Dual SIM smartphone usage
5. Deloitte, 2015, Smartphone batteries
6. Wearhouse 2020, How Long Do Mobile Phones Last?

Assumptions and data sources for laptops

Low case number of laptops

Assumption	Values	Rational of assumption
Number of laptops in 2020 (Mn)	8.0	Statista[1]
Growth rate for 2020-2030[1]	5.5%	Projected growth rates for 2020 – 2025 growth rates by Statista[1]

High case number of laptops

Assumption	Values	Rational of assumption
Number of laptops in 2010 (Mn)	9.6	Basel Convention[2]
Growth rate for 2010-2020[1]	2.6%	Volume projection from 2010 – 2020 was conducted based on population growth for the same period projected by World Bank[3]
Growth rate for 2020-2030[1]	5.5%	Projected growth rates for 2020 – 2025 growth rates by Statista[1]

General assumptions for waste creation

Average battery size (grams)[4] 616

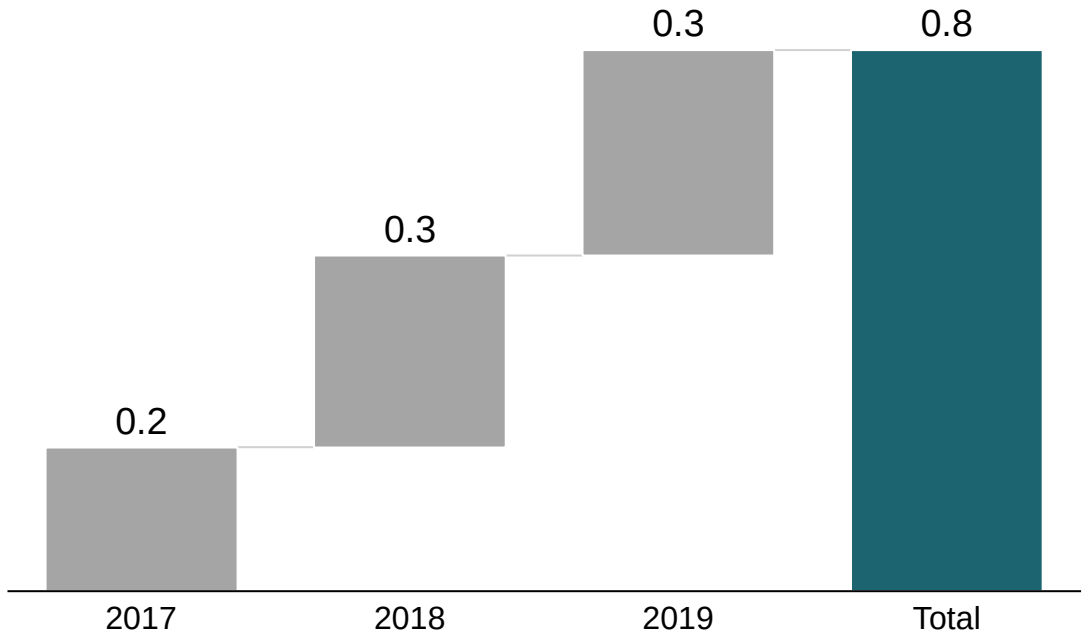
End-of-life period for laptops[5] 4 years

1. Statista 2019, Number of mobile cellular subscriptions in Nigeria
2. Basel Convention 2012, e-Waste Country Assessment Nigeria
3. World Bank 2020, Nigeria Population Growth
4. HP 2020, 12 cell laptop battery specification
5. School of Engineering and Technology National University 3678 Aero Court, San Diego 2009, Life Cycle Assessment of a Laptop Computer and its Contribution to Greenhouse Gas Emissions

Assumptions and data sources for solar home systems (1/2)

General assumptions for waste creation	Value taken	Rational of assumption
End-of-life period for solar home systems	6 years	Based on expert interview

Number of solar home systems (including lanterns) sold in Nigeria[1] (million units)



Battery details per type of device[2]

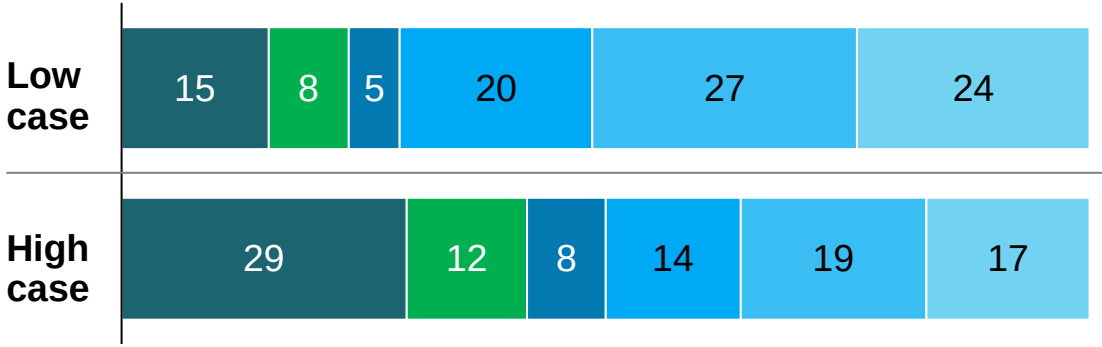
Device type	Capacity (Wp)	Weight of battery (grams)
Lantern	0 – 1.5	41
	1.5 – 3.0	175
	3 – 10	900
SHS	11 – 20	1,700
	21 – 49	5,200
	50 – 100	7,500

1. Gogla 2019, Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data
2. Battery requirements calculated based on solar panel output and optimal Ah as battery need based on which product specifications have been search for weight

Assumptions and data sources for solar home systems (2/2)

Segmentation of total volume in 2019 and in 2030 into SHS and other types of solar devices

% of total solar powered devices

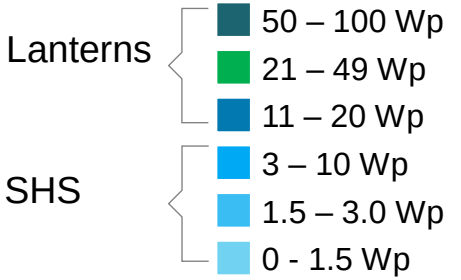


Rational of assumption

West Africa distribution of solar devices based on Gogla[1]

Nigeria assumed to have more of the larger capacity solar devices as compared to other West Africa countries

Device types



Volume projection		Values taken							Rational of assumption
		2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027-2030 growth** (%)	
Low case	Projected number of solar home systems sold in Nigeria (Mn)	0.2	0.4	0.6	1.1	1.6	2.1	2.47	6.4%	50% of Government target of 5 Mn additional unit assumed to be achieved by 2026
		2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027-2030 growth** (%)	
High case	Projected number of solar home systems sold in Nigeria (Mn)	0.4	0.7	1.2	2.2	3.2	4.2	5.4	6.4%	100% of Government target of 5 Mn additional unit assumed to be achieved by 2026

1. Gogla 2019, Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data

Assumptions and data sources for solar mini-grids

xx **Number of mini-grids**

Number of mini-grids installed per year

Number of units

Low case		Assumption	High case		Assumption
2020	100	**1000 mini-grids** to be installed in Nigeria by **2023**	175		**1,500 mini-grids** will be installed in Nigeria by **2023**
2021	200		350		
2022	265		450		
2023	335		525		
2024	435	1000	700	1500	
2025	535	**60%** of Government initiative to install 10,000 mini girds by 2030 accomplished About **100 mini-grids** to be installed **every year**	875		**100%** of Government initiative to install 10,000 mini girds by 2030 accomplished About **175 mini-grids** to be installed **every year**
2026	635		1,050		
2027	735		1,225		
2028	835		1,400		
2029	935		1,575		
2030	990		1,675		
Total	**6,000**		**10,000**		

General assumptions for waste creation

Average battery size (Kg)	1,312	**End-of-life period for solar mini-grids**	6 years

SOURCE: Industry expert in Nigeria with 10 year of experience in electrical maintenance, renewable energy and power sector

Assumptions and data sources for vehicles

Low case number of vehicles

Assumption	Values	Rational of assumption
Total number of vehicles in Nigeria 2018 (millions)[1]	11.8	NBS[1]
Number of cars imported per year (millions)[2]	0.4	Globalnews Wire

High case number of vehicles

Assumption	Values	Rational of assumption
Total number of generators in Nigeria 2016 (millions)	24.2	Industry expert[1]
Number of cars imported per year (millions)[3]	1.3	Techpoint Africa / UN

General assumptions for waste creation

End-of-life period for vehicle battery	4 years

1. Nigerian Bureau of Statistics 2018, Road Transport Data
2. Globenewswire 2020, The Automotive Industry in Sub Saharan African Countries
3. Techpoint Africa 2020, Nigerias Automotive Industry

Assumptions and data sources for generators

Low case number of generators

Assumption	Values	Rational of assumption
Total number of generators in Nigeria 2016 (millions)[1]	24.2	Industry expert[1]
% of generators with automatic starter[1]	30%	Only 30% assumed to have lead-acid battery attached for automatic startup
Growth rate[2]	8.0%	CAGR between 2018-2019[1]

High case number of generators

Assumption	Values	Rational of assumption
Total number of generators in Nigeria 2016 (millions)	24.2	Industry expert[1]
% of generators with automatic starter[1]	20%	Only 20% assumed to have lead-acid battery attached for automatic startup
Growth rate[2]	8.0%	CAGR between 2018-2019[1]

General assumptions for waste creation

Average battery size (grams)[4] 25,000

End-of-life period for phones[5] 4 years

1. Industry expert in Nigeria with experience with 10 year of experience in electrical maintenance, renewable energy and power sector
2. Trad Map 2018, Generator Import into Nigeria
3. Waste 360, Waste lead-acid batteries
3. PowerStream 2021, Sealed Lead Acid Battery Size Chart

Assumptions and data sources for solar powered TV sets

Low case number of solar powered TV sets

Assumption	Values	Rational of assumption
Number of laptops in 2019 H2 (thousand)	13.6	Gogla[1]
Growth rate for 2020-2029	34%	To reach the current annual sales volume in Kenya[1] in 10 years
Growth rate for 2030[1]	6%	CAGR between 2018-2019[1]

High case number of number of solar powered TV sets

Assumption	Values	Rational of assumption
Number of laptops in 2019 H2 (thousand)	13.6	Gogla[1]
Growth rate for 2020-2027[1]	45%	To reach the current annual sales volume in Kenya in 8 years
Growth rate for 2028-2030[1]	6%	CAGR between 2018-2019[1]

General assumptions for waste creation

End-of-life period for laptops	5 years

1. Gogla 2019, Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data