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Resilience in waste management: A socioeconomic context for managing spent lithium batteries in Southeastern Nigeria

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A B S T R A C T

The global value chain (GVC) recognizes post production processes that involve socio economic engagements of stakeholders with electrical and electronic equipment (EEE or e-products) at their near or end of life. This paper attempts to measure some of the key social, economic, environmental, and sustainability indicators in line with GVC for lithium-ion batteries from e-products at their near or end of life. The assessment was based on the socioeconomic impacts on the battery sector for managing spent lithium-ion (Li-ion) batteries in Southeastern Nigeria. The study methodology highlighted strategic features in line with socioeconomic assessment by deploying questionnaire administration. Ten (10) local government areas (LGAs) were purposely selected from five mutually exclusive States, with 100 stakeholders investigated. Descriptive statistics were used to analyze data for innovation potentials for the battery recycling/refurbishing sector, and discussed accordingly under sustainability, social, economic and environmental impacts. The socioeconomic drivers (or outcomes) for the recycling and refurbishing of lithium ion batteries touched on self-sustainability, institutionalization, service demand, service utilization and prevalence.

1. Introduction

Owing to its great energy density, precise and reliable recharging capability, the lithium-ion (Li-ion) battery, is considered an established technology with a promising energy-storage for the future (Larcher & Tarascon, 2015; Liang et al., 2019). Also, the characterized high energy density, nominal voltage, lifespan, power density, and low cost of Li-on batteries (Jonas, Martina, Marcel et al., 2022) have gained significant attention and applications cutting across powering and driving several electrical and electronic equipment (EEE or e-products) in the information and communication technology (ICT) sector, and its usage at electric vehicle (EV) industries. Lithium-ion batteries are deployed as the main component for the smart battery management system (BMS) of the electric vehicles (Jonas et al., 2022), and as the primary energy source for powering several e-products like the mobile phone, smart watches, laptop computers, portable electronic devices (PEDs), power banks, calculators, cameras, power tools, car key fobs, etc. (Nnorom et al., 2009; IATA, (n.d.); Liang et al., 2019). Recent trends in global value chain (GVC) research shows that the pricing for Li-ion batteries is poised to decline further, but with a simultaneous increase in demand and usage in diverse applications, and a consequential rapid growing market (Muhammad et al., 2019; Sofeast, 2022). Consequently, the amount of disposal for some of ICT or e-products powered with Li-ion batteries has been adduced to increase at a high rate, as a result of the transboundary movement of e-products from the global North to Africa and Asia countries where markets are flooded with large volumes of used and obsolete e-products (e-waste) (Nnorom et al., 2009; Basel Convention, 2011; 2013; Okorhi et al., 2017). These days, the short product lifecycle and rapid innovations in e-products have also resulted in the huge number of rather functional and near end-of-life products being thrown away (Ojiyovwi et al., 2020).

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On the other hand, the refurbishing and recycling of Li-ion batteries at their end-of-life are said to be a challenging task on the GVC because of their non-linear, highly time variant and complex electrochemical system designs. Both Jonas *et al.* (2022) and the National Environmental Standards and Regulations Enforcement Agency (NESREA) (NESREA, 2022) proffered a need for the recycling of spent lithium batteries that is backed with a well-grounded policy frameworks. They suggested that this should cover current practices in material collection, segregation, transportation, handling, and recycling with specifics for incentives and other socioeconomic benefits. Just as, the International Energy Agency (IEA) (Outlook, 2020) posited that an economic viability and market incentives for a formal Li-on battery recycling have been restrained mainly because of low raw material prices and a small volume recovery of spent Li-on batteries. In support of the GVC, Porter's hypothesis suggested that a well-designed environmental policy which includes market incentives could inspire the introduction of innovative technologies and minimize waste generated (Porter & van der Linde, 1995a,b). The subsequent application of this theory is thought to have produced various results, but researchers mostly submitted that policy formulation and public participation are critical factors to realizing such incentives. Yet, market-based environmental tools are often purported as more "business friendly" than customary commands and control policies (Cooper and Vargas, 2004). This paper therefore intends to unveil the socioeconomic attributes for refurbishing and recycling lithium batteries in line with some GVC multifaceted assessment and attributes. Hence, the specific objective is to determine the socioeconomic impacts on the battery sector for managing spent lithium batteries in Southeastern Nigeria.

2. Management strategies deployed for spent Li-on batteries in Southeastern Nigeria

The management strategies deployed for the recovery, handling and control of spent lithium ion (Li-ion) batteries are anchored on legislations, regulations, decrees and edicts promoted by the five state governments that constitute Southeastern Nigeria as well as guidelines championed by the Federal Government of Nigeria (Shorinwa, 2023). Table 1 gives a list of the contemporary policy framework deployed in Southeastern Nigeria.

Table 1

Environmental Policy Instruments for Waste Management in Southeastern Nigeria

S/N	Regulations/Laws/Legislations/Acts/ for waste management	Year Enacted	Proponent (Originator)	Domiciliation	Currently Applicable
1	Abia State Basic Environmental Law, 2004	2004	Abia State Government	Abia State	Yes
2	Abia State Basic Environmental (Amendment No. 1) Law, 2013	2013	Abia State Government	Abia State	Yes
3	Anambra State Public Health Law, 2006, Law No. 3, 2006	2006	Anambra State Government	Anambra State	Yes
4	Anambra State Waste Management Authority Law, 2015	2015	Anambra State Government	Anambra State	Yes
5	Ebonyi State Environmental Protection Law, 2015, Law No. 009 of 2015	2015	Ebonyi State Government	Ebonyi State	Yes
6	Enugu State Waste Management Authority Law, 20th July, 2004	2004	Enugu State Government	Enugu State	Yes
7	Imo State Environmental Transformation Commission (ENTRANCO) (2008, Law No. 3)	2008	Imo State Government	Imo State	Yes
8	Imo State Waste Management Agency Law 2020 (Law No. 5, 2020)	2020	Imo State	Imo State	Yes
9	Harmful Waste (Special Criminal Provisions) Act Cap H1 LFN 2004	2004	Federal Government of Nigeria	Nation-wide	Yes
10	National Environmental Protection (Waste Management) Regulations S.I.15 of 1991	1991	Federal Government of Nigeria	Nation-wide	Yes
11	National Environmental (Sanitation and Wastes Control) Regulation S.I.28 of 2009	2009	Federal Government of Nigeria	Nation-wide	Yes
12	National Environmental (Electrical/Electronics Sector) Regulations S.I. No. 23 of 2011	2011	Federal Government of Nigeria	Nation-wide	Yes
13	National Environmental (Battery Control) Regulations	2022	Federal Government of Nigeria	Nation-wide	Yes

The policy framework adopted and implemented in Southeastern Nigeria is built on these policy instruments listed in Table 1. In general, some of the sectional management strategies for spent battery waste are drawn from these guidelines to accommodate legislative and regulatory contexts, measures for handling and controlling spent lithium batteries, categorization of lithium batteries, cascade applications and second life for spent batteries, technologies and frontiers for managing waste lithium batteries, among others. It should be noted that, with the exception of the National Environmental (Battery Control) Regulations (NESREA, 2022) which is exclusively for battery management but awaiting the assent of the Federal Government of Nigeria, the other policy instruments listed captures beyond management of batteries to general e-wastes and other hazardous wastes.

The Basel Convention (2011) stratified the GVC actors in the e-waste sector in Nigeria into two – the informal and formal sectors. Accordingly, Okorhi et al. (2017) and Ojiyovwi et al. (2020), posited that records revealed that the collection, intermediate storage, handling and refurbishing of e-waste in Southeastern Nigeria takes place predominantly in the informal recycling sector. The purported recycling of e-waste, including lithium batteries, is executed mainly by a group of inexperienced individuals, undocumented-businesses, low-class illiterates, and with little technical know-how in formal recycling. Okorhi et al. (2015) described the process as a more of crude dismantling on sites of end-of-life e-waste and the subsequent recovery of valuable parts or components for reuse or repair purposes – a process that could be classified as more are less recovery rather than recycling or refurbishing. Another report further suggested that several consumers in Southeastern Nigeria still practice stockpiling at homes, warehouses and offices, engaging in indiscriminate disposal of their spent lithium batteries, and with nearly 70% of the populace disposing of spent batteries together with other types of waste (Okorhi, 2018). That report concluded that the factors influencing the final disposal of end-of-life e-products includes: the high cost of disposal of perilous items, anticipated monetary rewards for end-user on items at the near end-of-life, availability of storage space for stockpiling e-waste, fast obsolesce of new e-products, nonexistence of formal recycling facilities and associated huge cost of recycling disused e-products. As a result, this has given rise to fresh business opportunities under the GVC for players (scavengers and recyclers) in the recovery, collection, merchandising, repairs, refurbishing and reprocessing of disused and stockpiled e-products (Ayodeji, 2011; Basel Convention, 2013; EU Commission, 2019; Ojiyovwi et al., 2020; European Association of National Collection Systems for Batteries, EUCOBAT, 2022).

3. Socioeconomic factors for refurbishing e-products and components from e-waste

The concept upon which the socioeconomic factors for refurbishing e-products and its components from e-waste in Southeastern Nigeria is derived from a conceptual framework titled "…assessment of management strategies for disused lithium batteries from e-products" (Fig. 1 by Shorinwa, 2023). It gives a representation of the Inputs, Process, Outputs and Outcomes from the policy framework deployed in the management of lithium batteries in Southeastern Nigeria. While each component of the policy framework reflects socioeconomic factors, the indicator under Outcomes gives a clearer measurement of the socioeconomic impacts of managing lithium-ion batteries in Southeastern Nigeria (Shorinwa, 2023).

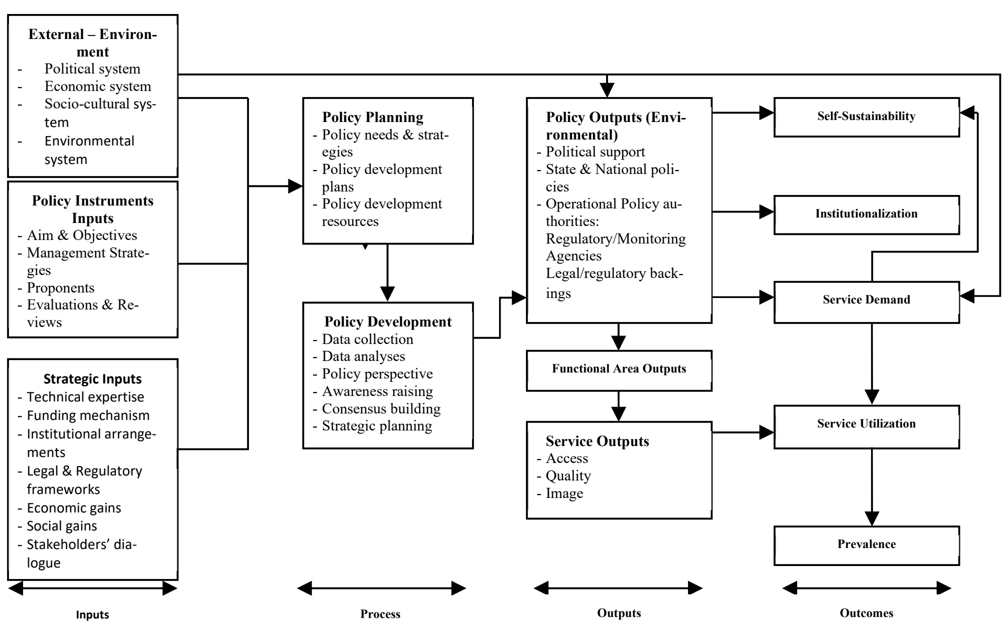

Fig. 1. Conceptual framework for assessing management strategies for spent lithium batteries from e-products (Shorinwa, 2023)

The extent of economic development of a place is an important factor for the quantity and composition of e-waste generated (Basel Convention, 2013). Also, the function of e-waste management tasks, the technical and organizational nature of appropriating solutions largely depends on the economic context of a town and on the economic situation in that exact area of a settlement (Schübeler et al., 1996; Okorhi, et al, 2017). Consequently, the authors focus discussions mainly on the "Outcomes" of the policy framework depicted in figure 1 with a view to achieving the aim of this paper. This is because the Outcome – sustainability, institutionalization, service demand, service utilization and prevalence – connects indicators for assessing the socioeconomic impacts of managing spent Li-ion batteries in Southeastern Nigeria.

4. Materials and methods

The methodical formation for this paper is based on observations and literature reflecting policy institutionalization, self-sustainability and management strategies for spent lithium (Li-ion) batteries, as well as results from field survey carried-out on Li-ion battery management in Southeastern Nigeria. The survey was conducted in five mutually exclusive strata of States (Abia, Anambra, Ebonyi, Enugu and Imo) with 10 local government areas (LGAs) purposely selected. Based on the socio-economic demographic representations and anecdotal high volume of Li-ion batteries generated, two (2) LGAs from each State were purposefully chosen. A set of distinct questionnaires were administered to traders, recyclers and technicians to assess the "socioeconomic impacts of refurbishing e-products…" in Southeastern Nigeria. From a population of 400 stake-holders (Table 2), a category of 100 sample size representatives of the respondents who are involved in the merchandising, repairs, installations, recovering, reused, scavenging, etc. of e-products powered with Li-ion batteries were assessed. The investigative survey deployed a quantitative method for data collection to measure Li-ion battery needs and demands; spent battery recovery, handling and disposal; reuse/repair measures; associated jobs; incomes to traders and technicians; as well as technology frontiers for recycling. Linear regression analysis proves the extent of reliability at a 95% confidence level on the data elicited.

Table 2
Schedule of Questionnaire Administered

Stakeholders	Number Administered	Number Retrieved	% of Number Retrieved	Number of Valid Retrieved Questionnaire	% of Valid Retrieved Questionnaire
Monitoring/regulatory Agencies	50	45	90.00	45	11.51%
Merchants, distributors and techni-cians	100	98	98.00	98	25.06%
End-Users/ Consumers	250	248	99.20	248	63.43%
Total	**400**	**391**	**97.75%**	**391**	**100%**

Source: Field Survey (2022)

5. Results and discussions

5.1 Managerial framework for e-waste by policy administrators

We recall that the aim of this paper is to unveil the socioeconomic attributes for refurbishing and recycling lithium (Li-ion) batteries in Southeastern Nigeria by measuring the policy outcomes with indicators in the global value chain (GVC) of managing wastes from Li-ion batteries. Research have shown that certain socioeconomic attributes that promotes refurbish-ing and recycling of e-waste include employment and job creations, monetary reward for service delivery, social services for individuals and the community, as well as environmental sanitation purposes (Okorhi *et al*., 2017; Ojiyovwi et al., 2020). Additional variables measured for this study include the net costs for refurbishing, local economic growth, the use of elec-tricity and freshwater for refurbishing processes, material recovery rates, toxicity, new jobs for the unemployed, as well as safety of workers and the environment.

Table A1 revealed key socioeconomic attributes that attract the need for refurbishing and recycling spent lithium ion bat-teries in Southeastern Nigeria to include employment and jobs creations, monetary rewards, social services, environmental sanitation, among others factors. Forty one (41) (45%) respondents posited that the provision of employment and job crea-tion are most prominent attributes for engaging in the refurbishing and recycling of spent lithium ion batteries. This was followed with monetary rewards as adduced by 31 (34%) respondents. The third attribute was environmental sanitation as submitted by 11 (12%) respondents. While other attributes, including social services were considered to be least by 9 (10%) respondents. Consequently, 27 (32%) of these respondents posited that the net costs for refurbishing and recycling spent lithium batteries in their firms/businesses ranges between ₦0 to ₦300,000 (or US$0 - US$652) annually. In their reports, Fan, Li., Wang, et al. (2020) and Piątek, Afyon, Budnyak, et al. (2021) had argued that there are limited studies on recycling of Li-ion batteries with high net costs for refurbishing, and that the associated low-cost elements with such batteries gives them little consideration for economic interest in recycling perspective.

Preliminary reports from Southeastern Nigeria had revealed an establishment based at Nnewi in Abia State that mainly engages in the manufacture and formal recycling of automobile batteries (Isaac, 2018; Shorinwa, 2023). Union Autoparts Manufacturing Company, Nnewi is a renowned multi-million dollar lead-acid battery firm established for the Nigeria and West Africa markets (Isaac, 2018). The study equally considered eliciting information on Li-ion battery management from this firm since lithium batteries are now frontier in electric automobiles and Union Autoparts Manufacturing Company is a major player in the battery sector in Nigeria. However, the survey revealed that 25 (30%) respondents admitted that the process of refurbishing and recycling spent Li-ion batteries has no clear potential for local economic growth in Southeastern Nigeria. While another 34 (40%) respondents affirmed that their involvement in the sales, reuse, repairs, installations, scav-enging and recovery of spent Li-ion batteries has little impact on local economic growth. Observations from a field survey showed that informal recycling of spent Li-ion batteries takes place within the informal sector of the e-waste value chain. Further to the other factors considered, we deduced the economic perspectives for recycling batteries in the study area to be influenced by the two types of batteries (Li-ion and acid-lead) involved. The different notion by actors in the two battery sectors present a reason for the apparent viability for lead-acid batteries as against the economic impracticalities with Li-ion batteries recycling.

The technicalities involved in the refurbishing and recycling of materials occasionally involve the use of electricity, water and other supports at savage sites. Twenty nine (29) (36%) respondents admitted that the entire process does not require the use of electricity. While 13 (16%) respondents submitted to the use of electricity to a very small extent. And another 26 (33%) respondents opined that there is a moderate use of electricity in the refurbishing and recycling process. The implication is that electricity is useful to a large extent (64%) in the management of spent Li-ion batteries. On the other hand, the amount of freshwater applied and released during the processing of spent Li-ion batteries is generally considered to be low. First, more than half of the actors (51 (56%) respondents) posited that the amount of freshwater used and released during the processing is very low. Another 22 (24%) respondents admitted to the moderate use and release of freshwater in the recycling and refurbishing of spent Li-ion batteries. Thirdly, 14 (15%) respondents applied and released a high volume of freshwater for these purposes. It was just 2 (2%) respondents that did not consider the application of freshwater during the processing of spent Li-ion batteries. The implication of these results is that freshwater is an essential commodity needed to a small extent for the refurbishing and recycling of spent lithium ion batteries in Southeastern Nigeria.

In another instance, data from the survey revealed that material gains from refurbishing and recycling of spent lithium ion batteries are inadequate. Thirty five (35) (37%) respondents admitted that their efforts to recover materials from spent Li-ion were fruitless. In addition, 24 (26%) respondents opined that they had very low recovery rates of materials from the recycling and refurbishing process of spent lithium batteries. While, 21 (26%) respondents submitted to generating a moderate amount of materials from the recycling/refurbishing processes of spent lithium batteries. In addition, 11 (12%) respondents admitted to getting high quantity rates of materials recovery from the recycling/refurbishing process of spent lithium batteries. Further observations on field revealed that many actors consider the direct gains of components from obsolete e-products to include near of life lithium ion batteries. These results speak more of little gains for formal recycling of spent lithium batteries. Besides, 33 (36%) respondents admitted that there was no case of toxic emissions during the process of recycling and refurbishing processes for spent lithium batteries. Another 27 (30%) posited that there are releases of trivial amounts of emissions during the process of recycling and refurbishing spent lithium batteries. Nevertheless, (21) (23%) respondents adduced the toxic emissions released to be of great extent, and another 10 (11%) respondents submitted that the degree of toxic emissions release in the processes of refurbishing and recycling of spent Li-ion batteries is to a very great extent. It is worth knowing that lithium ion batteries are classified as hazardous components in e-products, and therefore should be handled with uttermost care (NESREA, 2009; 2011; Basel Convention, 2011; NESREA, 2022).

The survey equally confirmed that the GVC processes of recycling and refurbishing of lithium ion batteries create a small number of jobs for previously unemployed persons in the society. Although, thirty two (32) (35%) respondents debunked that such processes create new jobs for previously unemployed persons in the community. Whereas, 36 (40%) respondents slightly agreed and another 23 (25%) respondents strongly agreed that the processes of recycling and refurbishing of lithium ion batteries create jobs for previously unemployed people in the society. The implication here is that there are few job opportunities for the previously unemployed in the recycling sector for handling spent Li-ion batteries. Then again, these players also have hesitations for their health when dealing with end-of-life Li-ion batteries. Thirty six 36 (40%) respondents agreed that there are no health issues arising from the processes of recycling and refurbishing of spent lithium ion batteries on site. But 31 (34%) respondents admitted that they do experience some form of challenges within the working environment while processing disused Li-ion batteries. Another 24 (26%) respondents submitted these health issues are relatively negligible. These health reservations may be adduced to the social strata of those individuals as earlier described and their focus on making income against the long term health effects. Moreover, the assessment question on safety of employees in the recycling sector also revealed a similar trend of assertions in the future. Just thirty one (31) (34%) respondents claimed to be unsatisfied with the workplace safety practices and prevention of injury incidents for people working within sites and nearby residents. Also, 42 (46%) respondents admitted to a small extent that the safety measures put in place are adequate to prevent injury incidents in the processes of recycling and refurbishing lithium ion batteries. Nowadays, health and safety of employees are pertinent issues in the workplace. Global work practices emphasize the need to secure, among others, the health and safety of workers (See Appendix).

5.2 The socioeconomic drivers for recycling and refurbishing lithium ion batteries

The variables for socioeconomic impacts were measured under employment and job creations, monetary reward for service delivery, social services for individuals and the community, health and environmental purposes, net costs for refurbishing, local economic growth, the use of electricity and freshwater for refurbishing processes, material recovery rates, toxicity, new jobs for the unemployed, as well as safety of workers and the environments. We then re-grouped these variables under the following indicators: self-sustainability, institutionalization, service demand, service utilization and prevalence. Table 3 gave a summary of the socioeconomic drivers for recycling and refurbishing lithium ion batteries in Southeastern Nigeria.

This is detailed to reflect the outcomes or drivers of socioeconomic factors, attributes or indicators, descriptions of indicators, socioeconomic impacts, and remarks to rethink the policy direction for recycling spent lithium ion batteries in the study area.

Table 3
Socioeconomic drivers (outcomes) for recycling and refurbishing lithium ion batteries

Outcomes (Drivers)	Description(s)	Attributes (indicators)	Impacts	Remarks
Self-sustainability	Practices that generate gains by enabling or aiding self-sustenance and minimize wastes during the processes of recovering valuable materials and components from e-products	• Toxicity level	• Moderate	The level of toxicity in components of the environment needs to be measured periodical in recycling sites for Li-ion batteries
		• Health and safety of workers and the environments	• Low	Health conditions for recyclers should be done routinely.
Institutionalization	This involves commitments to processing materials during recycling.	• Net costs for refurbishing,	• High	Introducing frontier technologies in recycling of Li-ion batteries would cut down the net cost for material recovery.
		• Use of electricity	• Moderate	Electricity usage should be minimized
		• Freshwater for refurbishing processes	• Low	Freshwater usage is adequate
Service demand	Demand Services refers efforts and any other materials or services demanded and rendered by recyclers to the final users. There are no financial incentives for recyclers to encourage decisions that might result in underutilization	• Employment and job creations	• Low •	Jobs creation in recycling should be encourage by training recyclers.
		• New jobs for the unemployed.	• Low	New jobs could be created in the value chain of recycling Li-ion batteries by reviewing and focusing strategies for recalling disused e-products.
		• Local economic growth	• Low	Policy direction should be focused on local economic growth in the processing spent Li-ion batteries.
Service utilization	This is based on appropriateness of care and service provided from the Li-ion battery recycling and the existence of coverage within the study area.	• Social services to individuals and the community,	• Moderate	Sensitization and education of end-users on the need to provide spent Li-ion battery for recycling is key to material recovery.
		• Monetary reward for service delivery	• Low	Recycling charges could be moderated with reduction in cost implications for recycling process.
Prevalence	This is the rate of recycling of Li-ion batteries within the study area.	• Material recovery rates	• Low	Circular economy should be ensured. A process where all materials are nearly recovered for same or another purposeful use.

6. Conclusions and policy recommendations

The study provides baseline information on the socioeconomic impacts for refurbishing spent lithium ion (Li-ion) batteries from e-products in Southeastern Nigeria. Traders, recyclers and technicians processing end-of-life batteries were assessed on the socioeconomic impacts of refurbishing spent Li-ion batteries with emphasis on indicators that reflect self-sustainability, institutionalization, service demand, service utilization and prevalence. The results revealed that the net cost for refurbishing spent lithium ion batteries is on the high side. But the use of electricity during recycling processes, and the level of toxicity generated were both considered moderate. Thirdly, the reported health effects of recyclers and use of freshwater for the process of refurbishing activities were considered low and acceptable. In addition, employment and job creations in the battery recycling sector, new jobs for the unemployed, monetary reward for service delivery as well as viability of local economic growth were equally considered as low impacts. To sum up, the material recovery rates were equally reflected as low impact.

The paper therefore resolved that circular economy should be ensured for the purpose of total materials recovery, sustainability, and averting environmental footprints. For control purposes and safety, the level of toxicity, amount of electricity and freshwater usage in Li-ion batteries recycling sites should be assessed periodically. Health conditions for people around the workplace and environs should be routinely checked for total wellness. There is also a need to introduce innovative technologies in processing end-of-life Li-ion batteries and thereby cutting down the net cost for material recovery. The policy framework for managing spent lithium ion batteries should be targeted with strategies that would create new and more jobs for players in the battery sectors thereby growing the local economy too. Lastly, all stakeholders should be sensitized, educated and trained on needs and strategies for recycling of their obsolete Li-ion batteries.

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Appendix

Table A1

Socioeconomic attributes for refurbishing and recycling spent lithium ion batteries in South-Eastern Nigeria

Statistics

		Which of these socio-economic attributes attracts the refurbishing and recycling lithium batteries in South-Eastern Nigeria?	What are the net costs and capital costs for refurbishing and recycling lithium batteries annually in your firm/business?	sumf
N	Valid	92	27	92
	Missing	207	272	207
Mode		1	0	16
Range		5	300000	29
Minimum		1	0	3
Maximum		6	300000	32

Frequency Table

1. Which of these socio-economic attributes attracts the refurbishing and recycling lithium batteries in South-Eastern Nigeria?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Employment/Jobs	41	13.7	44.6	44.6
	Monetary reward	31	10.4	33.7	78.3
	Social service	1	.3	1.1	79.3
	Environmental sanitation	11	3.7	12.0	91.3
	Others	8	2.7	8.7	100.0
	Total	92	30.8	100.0	
Missing	System	207	69.2		
Total		299	100.0		

2. What are the net costs for refurbishing and recycling lithium batteries annually in your firm/business?

	Net Cost (₦)	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	7	2.3	25.9	25.9
	2,000	1	.3	3.7	29.6
	7,000	1	.3	3.7	33.3
	50,000	3	1.0	11.1	44.4
	70,000	1	.3	3.7	48.1
	80,000	1	.3	3.7	51.9
	100,000	1	.3	3.7	55.6
	120,000	2	.7	7.4	63.0
	150,000	4	1.3	14.8	77.8
	180,000	1	.3	3.7	81.5
	200,000	1	.3	3.7	85.2
	210,000	1	.3	3.7	88.9
	230,000	1	.3	3.7	92.6
	250,000	1	.3	3.7	96.3
	300,000	1	.3	3.7	100.0
	Total	27	9.0	100.0	
Missing	System	272	91.0		
Total		299	100.0		

Sumf

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	3	1	.3	1.1	1.1
	12	2	.7	2.2	3.3
	13	2	.7	2.2	5.4
	14	2	.7	2.2	7.6
	15	3	1.0	3.3	10.9
	16	18	6.0	19.6	30.4
	17	7	2.3	7.6	38.0
	18	1	.3	1.1	39.1
	19	1	.3	1.1	40.2
	20	2	.7	2.2	42.4
	21	5	1.7	5.4	47.8
	22	4	1.3	4.3	52.2
	23	4	1.3	4.3	56.5
	24	11	3.7	12.0	68.5
	25	4	1.3	4.3	72.8
	26	6	2.0	6.5	79.3
	27	7	2.3	7.6	87.0
	28	6	2.0	6.5	93.5
	29	5	1.7	5.4	98.9
	32	1	.3	1.1	100.0
	Total	92	30.8	100.0	
Missing	System	207	69.2		
Total		299	100.0		

Statistics

		Does the process have potential for local economic growth?	Is the application of electricity (low, moderate or high) during the savaging lithium batteries?	How much of freshwater is applied and released during the processing?	What is the recovery rates of materials from the recycling/refurbishing process of lithium batteries?	Are toxic emissions involved during the process?	Does the recycling/refurbishing of lithium batteries create jobs for previously unemployed persons in the society?	Are people working within this environment having health challenge arising from the recycling of lithium batteries?	Is the workplace safe to prevent injury incidents from people working within and nearby residents?
N	Valid	84	80	91	91	91	91	91	91
	Missing	215	219	208	208	208	208	208	208
Mean		2.73	2.71	1.70	2.63	2.56	2.52	2.58	2.35
Median		3.00	3.00	1.00	3.00	2.00	3.00	3.00	2.00
Mode		1[a]	4	1	4	1	1	1	1
Range		4	3	4	3	4	4	4	4
Minimum		1	1	1	1	1	1	1	1
Maximum		5	4	5	4	5	5	5	5

a. Multiple modes exist. The smallest value is shown

Frequency Table

3. Does the process have potential for local economic growth?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	25	8.4	29.8	29.8
	Very Small Extent	9	3.0	10.7	40.5
	Small Extent	25	8.4	29.8	70.2
	Great Extent	14	4.7	16.7	86.9
	Very Great Extent	11	3.7	13.1	100.0
	Total	84	28.1	100.0	
Missing	System	215	71.9		
Total		299	100.0		

4. Is the application of electricity (low, moderate or high) during the savaging lithium batteries?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low amount	13	4.3	16.3	16.3
	Moderate used	26	8.7	32.5	48.8
	High amount	12	4.0	15.0	63.8
	No electricity used	29	9.7	36.3	100.0
	Total	80	26.8	100.0	
Missing	System	219	73.2		
Total		299	100.0		

5. How much of freshwater is applied and released during the processing?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low amount	51	17.1	56.0	56.0
	Moderate used	22	7.4	24.2	80.2
	High volume	14	4.7	15.4	95.6
	No water used	2	.7	2.2	97.8
	5	2	.7	2.2	100.0
	Total	91	30.4	100.0	
Missing	System	208	69.6		
Total		299	100.0		

6. What is the recovery rates of materials from the recycling/refurbishing process of lithium batteries?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Very low amount	24	8.0	26.4	26.4
	Moderate amount	21	7.0	23.1	49.5
	Huge quantity	11	3.7	12.1	61.5
	No Material recovered	35	11.7	38.5	100.0
	Total	91	30.4	100.0	
Missing	System	208	69.6		
Total		299	100.0		

7. Are toxic emissions involved during the process?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	33	11.0	36.3	36.3
	Very Small Extent	15	5.0	16.5	52.7
	Small Extent	12	4.0	13.2	65.9
	Great Extent	21	7.0	23.1	89.0
	Very Great Extent	10	3.3	11.0	100.0
	Total	91	30.4	100.0	
Missing	System	208	69.6		
Total		299	100.0		

8. Does the recycling/refurbishing of lithium batteries create jobs for previously unemployed persons in the society?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	32	10.7	35.2	35.2
	Very Small Extent	13	4.3	14.3	49.5
	Small Extent	23	7.7	25.3	74.7
	Great Extent	13	4.3	14.3	89.0
	Very Great Extent	10	3.3	11.0	100.0
	Total	91	30.4	100.0	
Missing	System	208	69.6		
Total		299	100.0		

9. Are people working within this environment having health challenge arising from the recycling of lithium batteries?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	36	12.0	39.6	39.6
	Very Small Extent	9	3.0	9.9	49.5
	Small Extent	15	5.0	16.5	65.9
	Great Extent	19	6.4	20.9	86.8
	Very Great Extent	12	4.0	13.2	100.0
	Total	91	30.4	100.0	
Missing	System	208	69.6		
Total		299	100.0		

10. Is the workplace safe to prevent injury incidents from people working within and nearby residents?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Not at all	31	10.4	34.1	34.1
	Very Small Extent	20	6.7	22.0	56.0
	Small Extent	22	7.4	24.2	80.2
	Great Extent	13	4.3	14.3	94.5
	Very Great Extent	5	1.7	5.5	100.0
	Total	91	30.4	100.0	
Missing	System	208	69.6		
Total		299	100.0		

Source: Field survey (2022)