



**WASTE-TO-WEALTH MANAGEMENT IN NORTH-EAST
NIGERIA: APPLICATION OF WASTE REDUCTION
MODEL FOR ENERGY**

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ABSTRACT

Given the inevitability of waste generation by all countries, the study explored waste-to-wealth values chain and energy saving from waste management in North-East Nigeria via application of Waste Reduction Model (WARM-Model). Survey research design using interview as a primary means of data collection for the study was used. With the help of purposive and snowballing sampling techniques, primary data were collected from the waste dealers directly and complemented by other secondary sources for the analysis. The collected data were analyzed using E-Views econometric software and Microsoft Excel in the estimation of waste generated, energy saved and the profitability of waste management by the activities of waste dealers in the study areas of the region. The study explores challenges in waste management and proffer appropriate strategy for handling the waste. The three most populous and most waste generating North-Eastern states were found to be Bauchi, Borno and Adamawa. All were investigated as representative of the region. The outcome unveils huge amount of wealth from trading various recyclable waste materials and energy saved via WARM-Model application. Bones and rubber have respective least gross margin of gain of three hundred thousand Naira (N300,000.00) and three hundred and ninety-nine thousand nine hundred Naira (N399,900.00) but are relatively easy to gather within short period of two to three weeks. An estimated 585,116.2515 kWh of energy is saved from recycling 30 tons of metal/iron which is gathered within an average of 21 days by a waste dealer among many waste dealers in the region. Further outcomes of the study are of help in enticing will-be participant in waste-to-wealth value chain in North-Eastern Nigeria, reducing cost of waste evacuation on the site of government, a guide for informed policy on environmental waste management

capable ensuring environmental safety and wealth creation. Establishment of waste recycling plant to help manage the increasing waste in North-East Nigeria is recommended.

Keywords: Recycling, Scrap, Waste-to-wealth, Energy, Environment, North-East, Nigeria

INTRODUCTION

Wastes are generally unwanted by the society due to numerous negative consequences attached to it, as such if there is way of preventing it completely many countries would have applied it for centuries. However, waste reduction is possible via responsible utilization of resources, re-use and recycling of discarded materials back to useful and valuable forms. Absence of such measures may lead to accumulation of environmentally harmful garbage that harbors all sorts of disease-causing germs, bacteria and other dangerous living organisms and objects.

The world generates 2.01 billion tons of municipal solid waste yearly, 33 percent or more of that is not environmentally managed in a safe manner despite the annual collection of 11.2 billion tons out of the accumulated solid waste globally (World Bank, 2022a & UNEP, 2022). This suggests urgent attention is needed to managed waste for environmental safety and economic prosperity globally.

In low-income countries, over 90% of waste is often openly burned or disposed in unregulated dumps. These practices create serious health, safety, and environmental consequences. Poorly managed waste serves as a breeding ground for disease vectors, contributes to global climate change through methane generation (World Bank, 2022b), and CO₂ emissions.

In trying to figure out some of the causes of waste generation, it is said that there is a positive correlation between waste generation, population and income level. But the trend of positive correlation has different magnitude. Daily per capita waste (waste per population) generation in high-income countries is projected to increase by 19 percent by 2050, compared to low- and middle-income countries where it is expected to increase by approximately 40% or more (World Bank, 2022a).

Sub-Saharan Africa is one of the fastest growing regions where more than fifty percent of waste generated is currently openly dumped, in fact 93 percent of waste is dumped

in low-income countries and the trajectories of waste growth will have vast implications for the environment, health, and prosperity, thus requiring urgent action (World Bank, 2022a).

Nigeria is the giant of Africa in terms of population and GDP. Sub-Saharan Africa is one of the fastest growing regions where more than fifty percent of waste generated is currently openly dumped, in fact 93 percent of waste is dumped in low-income countries. Nigeria is a low-income country, and the total quantity of waste generated in low-income countries is expected to increase by more than three times by 2050 (World Bank, 2022a), this is both a threat to environmental sustainability and an opportunity for waste-to-wealth creation. This is because out of the waste dumped, studies have shown that valuable recyclable materials are retrievable (Ikechukwu, 2015; Lambu, 2016; Chukwu, 2018; Anierobi *et al.* 2022).

In Nigeria, given the established nexus among low level of income and population with waste generation, the over 26 million population of North-East region becomes suitable area for evaluating waste-to-wealth management. The socio-economic value chain of the waste-to-wealth activities in the North-Eastern region and its derivable benefits towards addressing the effects of global climate change phenomenon in the city cannot be over-emphasized.

Waste management via recycling salvage the environment and create economic gains, for instance, “for every tonne of paper recycled, 17 trees and 50 per cent of water can be saved, moreover, recycling creates jobs” (UNEP, 2022). As such, there is the need for studies on waste-to-wealth.

Many studies on waste management and waste-to-wealth value chain have been recorded in the literature. But very few focus on quantification of the estimate of municipal solid waste out of which the valuable recyclable material can be retrieved. Furthermore, the specific precise buying and selling price of the several waste materials also received little attention in addition to quantification of energy savings from waste recycling.

North-East region of Nigeria seems to be less studied on waste-to-wealth literature despite existence of studies. This study therefore intends for fill such gaps and give empirical estimates of several recyclable waste prices, monetary gains obtainable from the waste, explore and unveil ways of handling challenges of waste-to-wealth venture in the North-East Nigeria.

This study will serve as a stepping stone for future studies and policy materials. The study will avail and entice would-be participant in waste-to-wealth value chain and further strengthen public authorities' attention on waste management for environmental safety, employment and wealth creation.

LITERATURE REVIEW

Concept of Waste and Waste-to-Wealth Management.

The concept of waste received literary attention for decades, for instance, Dijkema, *et al.* (2000) pointed out that, wastes are materials that people would want to dispose off even when payments are required for their disposal. Wastes have also been defined as any product or material which is useless to the producer (Basu, 2009). Waste is also seen as non-value-added physical material occurring in business practices and services (Perey., *et al.*, 2018). While Tchobanoglous *et al.* (1993) describe solid waste management as the effective supervision, handling, keeping, collecting, conveying, treatment and disposal of waste in a manner that safeguard the environment and the public.

Waste-to-Wealth Literature

Ikechukwu (2015). Conducted the study in Rivers state and focus on scrap metal in Obio/Akpor local government to ascertain the profitability and capacity of the scavenger venture to generate wealth to the public and the government. Primary data being the main focus, the data were analyzed using the simple percentage, chi-square. The primary data was obtained from field survey and oral interviews. Sets of estimated monthly incomes of 50,000 to 250,000 were revealed without recourse to nitty-gritty of how the income were realized, the highest (modal) being 100,000. The focus was on scavengers not the waste dealers, and one cannot precisely say whether a scavenger buy the scrap metal or pick it for free from waste dump. Hence the uncertainty of the real profit realizable.

Lambu (2016) Applied purposive sampling in capturing the dumpsites or waste-dumping points as well as the market points for the sales of the waste materials. Interview results described the occupation as derogatory unhygienic nature with a negative social stigma. However, the study discovered a huge gain in the scavenging and the actors are showing high interest in the occupation especially that no base capital is needed in the start of the business.

Chukwu (2018). Gave overview of various wastes-to-wealth strategies like open loop and close loop but without estimation of the wealth or the waste. It was also revealed that Clean post-consumer and industrial commingled (mixed) plastic materials can be moulded into a variety of new products that command very high prices in the consumer market.

Sandhu and Waheed (2021) used a visual survey, questionnaire survey, and in-depth interviews in data collection to explore the potential of revenue generation and job creation from the trash in Islamabad. Estimated 2830 tons of municipal waste based on daily average rate of 1.0 kg/capita/day was generated by the area. From the study conducted an average recyclable are sold for Rs.30/kg although with associated management cost.

Anierobi *et al.* (2022, September) a study conducted in Enugu metropolis on waste-to-wealth business adopted a qualitative survey research design. Using stratified and simple random sampling technique, a survey was conducted in eight selected neighborhood and orally interviewed waste pickers. Findings showcase ineffective waste management system and huge financial gains from waste product, amount realized from the waste materials sales range from N100 to N5000 per kilogram (Naira/Kg) depending on the type of waste product. However, only conversion of waste-to-wealth in Naira/Kg was revealed by the study no buying and selling price to show the gain.

The Need for Waste Management

Absence of proper waste management brings huge economic loss in the waste venture and high cost of perpetual importations of products like paper that can be reproduce via recycling, loss of employment opportunities and volatility in products prices (Ezeudu *et al.*, 2021). There is high tendency of supply shocks in looking for new raw materials for production instead of simply recycling the recyclable dumped materials that were regarded as waste, back to useful products. This help save the time to be wasted in search of raw materials.

One very important aspect of waste management is that potential damage to humans, plants and animals were said to be minimized with proper waste management of recyclable materials (Maiyaki *et al.*, 2019). Oyedotun *et al.*,(2020) revealed the need for policy intervention on the basis of the recognition by the communities of

inefficiencies in waste management. Similarly, Okafor *et al.*,(2020) stated the existence of absence of proper system waste management in Nigeria. This suggests a gap for provision of strategies of waste management in Nigeria, this gave the needed impetus for this paper, which briefly attempt to highlight some strategies for not only managing some of the Nigeria's common wastes like plastics, rubber and iron metal but also proffer ways of converting the waste to huge wealth via recycling following a circular model approach of waste management that is capable of generating employment amidst WARM-Model.

The literature reviewed have succeeded in revealing the: existence indiscriminate waste disposal in Nigeria, negative effects of waste disposal and wealth loss from not managing the waste, the room for policy intervention due to the inefficiencies in waste management in general, and inability of the previous studies to estimate waste from North-East and the derivable wealth from the recyclable waste in Nigeria. Thus, this paper will bring fort the estimate of the wealth generated from waste and justify the need for informed policy advice on waste management for wealth creation and environmental safety.

Waste Management Strategies

Wastes management differ according to: different waste characteristics or nature of the waste materials, the targeted end product, the recycling equipment at disposal of the recycling plant and according different environments' traditions of handling waste materials. However, there are general and common waste management strategies of triple "R"; the first R implies Reduce (moderation in consumption and minimization of avoidable wastages), then Reuse (making subsequent usage of useful discarded materials than looking for new one) and Recycle (re-producing useful products from discarded or unwanted material) waste material.

Relying on the information from field survey observation and interview conducted in this study, the common waste materials for recycling in North-East Nigeria are metal/iron, rubber and plastic waste materials.

Plastic, Rubber and Metals (Ferrous metal i.e. Iron & Steel) Waste Management in North East Nigeria.

Provision of disposal bins and training on industrial and domestic source-segregation of waste materials by private and public authorities is a first step in efficient waste

management via recycling. Recycling of plastic waste follows after source segregation and post consumption picking of the plastics, then sorting based on colour and type of plastic, washing and removal of non-plastic materials, drying, shredding and crushing by machines, washing and drying again, melting to create pellets for sale, or reproduction of different products of choice from the melted plastic like application of pyrolysis for diesel production. Similar melting and remoulding strategy is applied for rubber recycling.

In North-East Nigeria, for those not having the capacity to apply all the recycling steps above, plastics and rubber are gathered, weighted in kilograms (kg) or tons and sold directly to designated waste dealers for onward delivery to recycling companies. This help reduce the accumulation of such waste materials that usually become environmental menace if not attended to. The monetary valuation per kg of such waste were evaluated in subsequent part of this work.

Metal (ferrous metal) are recycled by remelting, recasting, and redrawing at the recycling plant. The process follows waste-dump picking or direct weighted purchase in kg per naira from owners of scrap-metal or scavengers, waste dealers buy, gather and load trailer-full (at least 30 tons) of the metals at their business premises and transport same to recycling companies for sale at higher margin relative to the cost of acquiring the metals including transport, storage, loading and other logistics expenses. The process is not only much cheaper than producing new metal from the basic ore but also wealth-creating and environmentally friendly as it helps reduce the difficult to degrade metal waste dump.

METHODOLOGY

Study Area

North-East is one of the most populous northern regions in Nigeria based on national bureau of statistics projection of population (NBS, 2017). Northern part of Nigeria harbours significant population and this in turn has the potential of increasing the level of consumption and waste generation by the huge population in the region. It is said that wastes usually are harmful by-product with profound health repercussions that necessitate management (World Bank, 2022).

The North-Eastern geo-political region of Nigeria has population of 26.26 million (NBS, 2017) and comprises of six (6) states with high growth rates: Adamawa with

2.9% population growth rate, Bauchi 3.4% population growth rate, Borno 3.4% population growth rate, Gombe 3.2% population growth rate, Taraba 2.9%, and Yobe 3.5% population growth rate, all of these states are generating waste materials and the population growth rates in all indicates more waste per person to be generated, hence the need for economically and environmentally viable waste management strategy that not only help in addressing environmental pollution, but also create sustainable means of earning a living in the region.



Fig 1: Map of Nigeria with North-East zone (Adamawa, Bauchi, Borno, Gombe, Taraba & Yobe)

Source: Legit (<https://www.legit.ng/1097007-nigeria-land-mass-by-state.html>)

Source of Data for the Study

All the Primary data were collected from interviews and observation from the metropolis of the three (3) most populous north-eastern states only as a representative of the region with six (6) states. Secondary data on population of the north eastern states and population growth rates for the estimation of future population were from demographic statistics bulletin of the National Bureau of

Statistics (NBS, 2020) as well as per capita waste generation rates sourced from world development indicators data base of World Bank. The interview is administered based on availability and features of targeted respondents in the respective states. Ten research assistants per state help in the primary data collection, that is two per area the question were structured inline with the study objectives and insights from empirical literature reviewed.

Variables of the Study

Waste dealers and available solid waste recyclable materials prices in the region are the variables of interest, the quantities and prices of waste material such as plastic bottles, disposed iron scraps, cartons, damage PVC pipes, animals' bones, are also assessed and evaluated in this study to revealed the wealth in the venture.

Method of Data Analysis

Interviewed waste dealers' output are analyzed with the help of statistical packages such as, E-Views econometric software and Microsoft excel and simple percentages. Descriptive statistics (with central tendencies) were also used in analyzing the data obtained from field survey, qualitative interview outputs were tabulated and presented alongside the secondary data for this study.

Research Design, Population and Sampling Technique

The data is mainly primary in nature collected from the participants (waste dealers) directly; in collecting the primary data, qualitative survey research design (using interview) was applied in consideration of the low level of western education (i.e. literacy rates) in the (boys 50.5%, girls 31.8%, average = 41.15%) and among those engaging in waste-to-wealth business in the region generally, the study opt for interview. Given the on and off nature of the targeted population for the study (waste dealers) in the metropolis of the identified states (Bauchi, Borno, Adamawa) for this study. Each of the states is divided into five sections (East, West, North, South and Central area) to cover the whole metropolis. One major dealer per section is interviewed, making five (5) per metropolis, but in each of the states there were at least ten (10) waste dealers operating in the metropolis. Combination of both purposive sampling and snowballing techniques were applied to respectively help in

interacting with those participants with requisite features, qualities and business experience that fit the structured interview questions. While snowballing was appropriately applied in helping the linkages of one participant with his/her colleague in business with same features (see McCombes, 2022) and business experience for the interview.

Initially this study targeted informal waste scavengers and waste dealers in the six (6) North East Nigerian states. However, due to absence of formal register for the waste scavengers and fixed location, time constraint and the fact that, whatever waste scavengers gather usually pass through the waste dealers, this study relied on information from waste dealers venture to ascertain the profitability of waste-to-wealth venture without completely undermining the activities or the money earned by the waste scavengers.

Furthermore, since the buying prices of waste by the dealers is the selling price of the scavengers. Note that from observation and some preliminary discussion with the waste dealers, most waste scavengers in the northern Nigeria use to pick the recyclable waste materials from trash free of charge, all the money they sell the materials is their gain. As such, covering waste dealer is reflective of the major gain in the waste-to-wealth business in the North East Nigeria.

RESULTS AND DISCUSSION

In line with the study objectives, total municipal solid waste generated by the city are estimated by multiplication of the municipal solid waste generation per capita and population of the city, this is in-line with estimated World Bank development indicators procedure of which similar process was applied in the work of Sandhu and Waheed (2021). Table 1 and 2 below are the estimated waste generated in the region for the respective states and per total population in each targeted area.

Table 1: Estimated Waste Generation Based on Waste Per Capita Per Day on 2012 And 2022 Minimum (Min.) Base Line Scenarios.

States	Population (2006 census)-A	Population (2019)-B	Min. waste per capita/Day@2012 base of 0.09 kg	Min. waste per capita/Day@2022 base of 0.11 kg
Bauchi	4,653,066	7,540,663	678659.7	829,472.93
Borno	4,171,104	5,751,590	517643.1	632,674.90

Adamawa	3,178,950	4,536,948	408325.3	499,064.28
Gombe	2,365,040	3,623,462	326111.6	398,580.82
Yobe	2,321,339	3,398,177	305835.9	373,799.47
Taraba	2,294,800	3,331,885	299869.7	366507.35
TOTAL	18,984,299	28,182,725	2536445	3100099.75

Source: Authors estimation (2023) based on World Bank estimation procedure for solid waste. Population figure is from NBS demographic bulletin of 2020.

The three (3) most populous states among the six (6) north-eastern states are the ones generating highest amount of waste even based on minimum based-line scenarios. Bauchi, Borno, and Adamawa respectively generate 678,659.7, 517,643.1 and 408,325.3 kg at 2012 based-line of 0.09 kg per capita per day waste. Similar trends were obtained using 2022 based-line of 0.11kg per capita per day, with Bauchi having the highest waste of 829,472.93 kg of waste.

Using both 2012 and 2022 minimum baseline scenarios for waste generation per capita per day, the three most populous North-Eastern states of Bauchi, Borno and Adamawa happened to be the most waste generating states in the region going by 2019 population. This study pays attention to the waste-to-wealth management in these states as a representative of the region. However, for the general estimation of the waste generation in the region as a whole, both average (Ave.) and minimum (Min.) wastes estimates at various scenarios based on population of the whole North-East region is computed and presented in table 2.

Table 2: Estimated Waste Generation for North-East Nigeria Based on Waste Per Capita Per Day on 2012 And 2022 Basis.

Year	North East Population	Ave. Waste per capita/Day kg @ 2012 base 0.65	Ave. Waste per capita/Day kg @2022 base 0.74	Min. Waste per capita/Day kg @2012 base 0.09	Min. Waste per capita/Day kg @2022 base 0.11
2012	23,064,564	14991966.6	17067777	2075811	2537102
2013	23,825,671	15486686.15	17630997	2144310	2620824
2014	24,612,026	15997816.9	18212899	2215082	2707323

2015	25,424,465	16525902.25	18814104	2288202	2796691
2016	26,263,866	17071512.9	19435261	2363748	2889025
2017	26,662,404	17330562.6	19730179	2399616	2932864
2018	23,000,120	14950078	17020089	2070011	2530013
2019	28,182,725	18318771.25	20855217	2536445	3100100
2020	29,097,745	18913534.08	21532331	2618797	3200752
2021	30,042,621	19527703.78	22231540	2703836	3304688
2022	31,018,333	20161916.56	22953567	2791650	3412017

Source: Authors estimation (2023) based on World Bank estimation procedure for solid waste. Population figure is from NBS demographic bulletin and year 2020 to 2022 are based on population growth rate from NBS.

The waste generations will continue to increase as population of the North East Nigeria grow reaching estimated 31, 018,333 million people, this estimate is based on respective north eastern population growth rates. Based on this trajectory, this is a pointer that recyclable waste will continue to increase indicating that waste-to-wealth value chain has the capacity to expand, while the waste has the capacity to go beyond the current level and if not manage will create an inhabitable environment full of trash. Based on minimum 0.09-kilogram (kg) waste per capita per day, the region produces 2.38 million wastes as reflected in the descriptive statistics table3. Going by 0.11 kg per capita per day waste generation scenario in 2022 following World Bank approach (World Bank,2022), estimated 3.4 million waste was generated.

Table 3: Descriptive Statistics of North East Population and Waste Generation Per Capita Per Kilogram (Kg), Based on 2012 and 2022 Minimum (Min) and Average (Ave) Daily Waste.

	NORTH POPULATION	EAST	MIN WASTE 2022 BASE ON 0.11	MIN WASTE 2012 BASE ON 0.09	AVE WASTE 2012 BASE ON 0.65	AVE WASTE 2022 BASE ON 0.74
Mean	26472231		2911945.	2382501.	17206950	19589451
Median	26263866		2889025.	2363748.	17071513	19435261
Maximum	31018333		3412017.	2791650.	20161917	22953567
Minimum	23000120		2530013.	2070011.	14950078	17020089

Source : Authors Computation using E-Views software version 10.

The north east based on the population growth rate has 31.01 million population and generate at least 2,530,013 on 0.11 kg of per capita per day waste going by World Bank benchmark minimum waste scenario. Also going by 0.74 kg average (AVE) per capita per day for 2022, the region produces the respective minimum and maximum of 17,020,089 and 22,953,567 with an average (mean) of 19,589,451 kg. This huge waste demands proper management and portray opportunity for turning waste-to-wealth in the region.

Valuation of Waste-to-wealth

Since the waste generation can differ according to the seasons, the survey was conducted at least two times a year to estimate the municipal solid waste generated and the average recorded. Thus, the survey was conducted from June,2022 (early rainy season period in North-East) to January, 2023 and the buying and selling prices obtained from the interview were used in computing the monetary average of wealth from the waste traded.

Table 4: Valuation of Recyclable Waste Material in the Most Populous North-Eastern States’ Metropolis

S/NO	RECYCLABLE	NAIRA PRICE PER KG IN BAUCHI		NAIRA PRICE PER KG IN BORNO		NAIRA PRICE PER KG IN ADAMAWA	
		BUY	SELL	BUY	SELL	BUY	SELL
1	Plastics	20	40	30	40	15	30
2	Metal / iron	160	200	170	190	160	200
3	Aluminum	500	700	NA	NA	500	700
4	Papers/ Cartons	40	80	50	70	20	60
5	Corper wire	3000	4000	3000	3400	3000	4500
6	Rubber	40	50	60	70	40	60
7	PVC pipe	20	40	40	65	30	50
8	Bones	15	30	30	35	30	40

Source: Authors’ Survey Interview, June 2022 to January 2023.

Table 4 revealed the respective buying and selling prices of the valuable recyclable waste materials, the buying prices reflect the per kg money going to the waste scavengers that mainly supplied the waste dealers with those materials. NA represent

not available, meaning the dealers are not trading in those materials. The selling prices represent average value obtainable when the dealers disposed the material in kg to big dealers or in tons to recycling plants.

Table 5: Average Gross Gains/Profit from Recyclable Waste for Bauchi, Borno and Adamawa North-Eastern States

S/N	Recyclables	Average Selling Price/ KG	Average Buying Price/ KG	Average Margin of gain /KG	Average Price/Ton(x1000)	Average Gross Margin of gain /30 Tons (Trailer full)	Average days per 30 tons last five years	Average days per 30 tons in 2022
1	Plastics	36.67	21.67	15	15000	450,000.00	60	15
2	Metal / iron	196.67	163.33	33.34	33,340.00	1,000,200.00	14	21
3	Aluminum	700.00	500.00	200.00	200,000.00	6,000,000.00	NA	NA
4	Papers/ Cartons	70.00	36.67	33.33	33,330.00	999,900.00	NA	30
5	Corper wire	3966.67	3000.00	966.67	966,670.00	29,000,100.00	NA	NA
6	Rubber	60.00	46.67	13.33	13,330.00	399,900.00	14	14
7	PVC pipe	51.67	30.00	21.67	21,670.00	650,100.00	NA	21
8	Bones	35.00	25.00	10.00	10,000.00	300,000.00	NA	21

Source: Authors' Survey Interview, June 2022 to January 2023.

Table 5 gives a summary of table 4 with additional column for the average days to accumulate trailer full (at least 30 tons) of waste materials for delivery to recycling company for the last five years and in 2022. Aluminum and corper wire are the most profitable with six (N6,000,000) and twenty-nine million one hundred

(N29,000,100) gross gain in Naira, but are the most difficult to gather. No one can tell how long it will take to gather trailer full of such recyclable materials.

Bones and rubber are the ones with respective least gross margin of gain of three hundred thousand Naira (N300,000.00) and three hundred and ninety-nine thousand nine hundred Naira (N399,900.00) but are relatively easy to gather within short period of two to three weeks. Bones are said to be easy to gather in places near abattoir and hotels and also during festive period, but their price become high only when it is burn-dried, which significantly reduce its weight. The gross gains exclude expenses like storage cost, transport, loading and security expenses of the business premises and other logistics.

Energy Saving from Waste-to-wealth Recycling

This study not only estimate the monetary Naira gains from sale of waste materials to recycling companies, but it also applies Environmental Protection Agency’s (EPA, 2022) Waste Reduction Model (WARM-MODEL) in estimating energy savings from waste materials sent to recycling companies by the waste dealers in the North-East Nigeria. Energy saved per ton (1000 kilogram (kg)) of each material is accumulated into ton of waste material in million British Thermal Units (BTU), which each BTU is equivalent to 0.000293071-kilowatt hour (kWh) or 1 million BTU equals 293.071 kWh. Each kWh cost N22.55 (0.05 US dollars) for residential and N36.15 (0.08 US dollars) for Industrial use as of year 2022 (Statista, 2023). One can easily see yet another relevance of waste management in monetary gains realizable.

Table 6: Evaluation of Energy Saved Per Ton of Recycled Waste Materials Using WARM-MODEL’s Values

S/NO	Waste materials for recycling	Ave. days per 30 tons in 2022	Values of Energy saved per ton of material recycled (million BTU)	Average energy saved per 30 tons of material recycled in each of the states (per BTU)	Average energy saved per 30 tons of material recycled in each of the states in kWh (BTU x 0.000293071)	Monetary value of money saved due to recycling N36.15/ kWh cost for industrial
1	Metal / iron	21	66.55	1,996,500,000	585,116.2515	21,151,952.492
2	Plastics (PET)	14	28.59	857,700,000	251,366.9967	9,086,916.9307
3	Papers/ Cartons(mixed)	30	20.56	616,800,000	180,766.1928	6,534,697.8697

Source: Authors’ computation using EPA’s WARM-Model (<https://www.epa.gov/warm>) and BTU to kWh conversion factors.

The three common waste materials (metal/iron, plastics and mixed papers) with available energy saving values from EPA’s WARM-Model were used. A ton of metal/iron recycled saves 66.55 million BTU, this gives 1,996,500, 000 BTU for 30 tons of waste materials (66,550,000 x 30 = 1,996,500,000). To convert the value to kWh, 1,996,500,000 x 0.000293071 which gives 585,116.2515 kWh energy saved per 30 tons or trailer-full of waste metal/iron sent for recycling. Following the work of Adamu *et al.*(2022) the monetary quantification per kWh of the energy were arrived at by multiplying the energy by the cost or price per kWh. Thus, for 30 tons of metal/ iron recycled, about N21,151,952.492 is saved. Similarly, respective 251,366.9967 and 180,766.1928 kWh energy each are saved whenever 30 tons each for plastic and mixed papers are recycled in just 14 and 30 days respectively. This represent contribution of a single waste dealer per 30 tons of each of the waste material sent for recycling that saves energy, which at least in each of the North Eastern states there are at least ten (10) waste dealers operating. Energy savings and recycling improves the environment by demanding less raw materials compared to virgin production and it also produce less greenhouse gas emissions. According to US Energy Information Administration (EIA,2021) there is 0.855 pounds of CO2 emissions per kWh of energy used.

Table 6: Outcome of Interview (Qualitative) Result from Structure Questions to Waste Dealers

S/No.	Interview Questions	Interview outcome
1.	Common obstacles that affect profit in the business.	1. Small capital base for the business 2. High transport cost 3. High storage cost
2.	Main destination(s) of the waste materials they trade.	1. Waste recycling companies in Lagos and Kano, Nigeria. 2. Resale of the material for re-use by members of the society.
3.	Most frequent waste material to gather and trade	1. Metal iron 2. Plastic

		3. Rubber
		4. Mixed papers
4.	Most difficult waste material to gather and trade	I. Corper wire II. Aluminum
5.	Average Time it takes to gather the require quantity to take to recycling company	It varies, as reflected in table5, but generally steady and revolve around 3 weeks
6.	Profitability of the business or otherwise	Profitable in general
7.	Major associated risk(s)	<ul style="list-style-type: none"> • Price crash at the recycling company while having stocks • Intrusion of criminals into the business • Health hazards
8.	Steps taken to mitigate major associated risk(s)	<ol style="list-style-type: none"> 1. Engaged in communication on market situations and provision of storage in event of price crash. 2. Start know your customer (KYC) and making union for registration to minimise intrusion of criminals 3. Very little effort is recorded on safety kits.
9.	Contribution to environment	<ol style="list-style-type: none"> 1. Help reduce drainage blockage 2. Reduce demand for fresh raw materials from nature
10.	Economic contribution	<ol style="list-style-type: none"> i. Create jobs and reduce unemployment ii. Source of income to many other businesses like drivers,

labourers doing the loading,
the security hired to dog-
watch the business premises.

Source: Survey Interview, June 2022 to January 2023.

The interview outcomes reveal that common obstacles that affect profit in the business are inadequacy of capital base, too much transport cost, paucity and expensive storage for the waste materials. Despite all the challenges there are huge wealth in waste-to-wealth business and job opportunities. The venture also play role in addressing drainage blockage thereby mitigating flood related problem indirectly and reducing government and private sectors' cost of waste evacuation. To create more employment opportunities and tackle too much transport cost of waste materials to the main destinations (Lagos and Kano) which are far away from North-Eastern states, government and other stakeholders should establish waste recycling companies in the North East region, this should be supported by sufficient electricity supply and security for its sustainable success.

Going by the outcome of the interview, Waste-to-wealth was found be source of raw material for industrial use and there by suppressing the demand for fresh raw material from the ecosystem and reduction in energy use for new production that may lead to greenhouse gasses emissions. The venture creates employment opportunities and in general it is quite profitable.

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Generally, the waste generations continue to increase as population of the North East Nigeria grow, based on these trajectories of population and per capita per day waste generations. This is a pointer that recyclable waste will continue to increase. Based on minimum 0.09-kilogram (kg) waste per capita per day at 2012 based line scenario, the region produce estimated 2.38 million wastes while at 0.11 kg per capita per day 2022 based line scenario the estimated waste increased to 3.4 million.

Various waste recyclable materials differ in values. Based on the trading activities on the waste materials in the three (3) most populous states (Bauchi, Borno and Adamawa) in the North East region of Nigeria. Aluminum and corper-wire are the most profitable with six million (N6,000,000) gross gain per 30 tons and twenty-

nine million one hundred (N29,000,100) gross gain in Naira, but are the most difficult to gather. No one can tell how long it will take to gather trailer full of such recyclable materials.

Bones and rubber are the ones with respective least gross margin of gain of three hundred thousand Naira (N300,000.00) and three hundred and ninety-nine thousand nine hundred Naira (N399,900.00) but are relatively easy to gather within short period of two to three weeks.

On the issue of energy saving due to recycling activities of waste-to-wealth ventures in North-East Nigeria. An estimated 585,116.2515 kWh of energy is saved from recycling 30 tons of metal/iron, such energy is valued at N21,151,952.492 millions of Naira which are gathered within an average of 21 days by a waste dealer among many waste dealers in the region. There are at least ten (10) waste dealers per state in the region. It is estimated that it takes respective 14 and 30 days for waste dealers to gather and sent trailer full (at least 30 tons) of plastic and mixed paper to recycling companies. This saved 251,366.9967 kWh energy for plastic waste and 180,766.1928 kWh for mixed paper virgin production.

It is therefor, recommended that government via financial institutions should make capital more accessible and affordable for the waste-to-wealth business. Waste recycling plants should be established in North-East Nigeria to reduce long travelling risk, create more green employment opportunities, instill confidence in waste-to-wealth business in the region and reduce cost of transportation and waste evacuation. To sustained the waste recycling plants, affordable and sufficient electricity and security should be made available to the recycling companies or plants in a form of public private sector partnership, grants and aids.

Future studies should incorporate both waste dealers and scavengers for more inclusiveness, also other regions in Nigeria and countries should conduct similar study on broader area to reflect also other stakeholders in the waste-to-wealth value chain in the country and beyond and GHG emissions saving from waste-to-wealth.

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