

Research Article

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Building a Local Circular Economy Through Waste Valorisation in Bamenda, Cameroon

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ABSTRACT

In Sub-Saharan African cities, municipal waste has become a major issue, transforming potential green spaces into unsightly brown landscapes. One strategy to address this problem is to convert these wastes into environmental and economic assets by implementing a local circular economy. The concept of a circular economy emphasises that waste, when properly managed, can be turned into a resource, adding value to the production chain. For instance, the city of Bamenda in Cameroon produces a large amount of municipal solid waste, including scrap metal, agricultural waste, paper, plastics, and more. Data collected from the Regional Delegation of Environment, Protection of Nature, and Sustainable Development was used to compile a list of businesses and non-governmental organisations involved in waste valorisation. These waste valorisation facilities were then visited to assess their adherence to the 10-Rs (Recycle, Refuse, Rethink, Reduce, Repair, Refurbish, Remanufacture, Repurpose, Reuse, Recover), number of employees, materials valorised, and their economic turnover. The results revealed that a variety of solid wastes were valorised, including plastics (24.2%), metals (45.5%), food waste (6.1%), animal waste (9.1%), as well as paper, glass, and tyres (3%) respectively. Specifically, copper (1.62 US\$/kg) and aluminium (0.54 US\$/kg) generated higher profits in the local waste economy due to their relatively scarce nature compared to scrap iron (0.11 US\$/kg). Although plastics (0.15 US\$/kg) have a higher unit value than iron, they are less favoured due to their bulkiness and lower weight. The local circular economy has provided a source of income for 91.9% of the operators in Bamenda. However, some challenges persist in the circular economy sector, including poor waste sorting at the source, insufficient investment capital and technology, a lack of government assistance, and illegality of certain waste management operations. To address these issues and foster economic growth, efforts should focus on public awareness campaigns, education, training, and increased capital investments. These initiatives would not only create more wealth but also help reduce unemployment in Bamenda and its surroundings.

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Introduction

The generation of waste is unavoidable due to urbanisation, economic growth, and population increase [1,2]. As cities expand and offer more products and services to citizens, they face significant waste management challenges [3]. The World Bank estimated global waste production at 1.3 billion tons per year, expected to increase to 2.2 billion tons by 2035 [2]. In 2020, cities generated 3.05 billion tons of solid waste, averaging 0.84 kg per person per day [4]. With rapid population growth and urbanisation, annual waste generation is projected to increase by 70% from 2016 levels to 3.40 billion tons by 2050. Efficient solid waste recycling has become a global concern for sustainable and environmentally sound management in the 21st century [5]. Despite efforts to promote reuse, recycling, and energy recovery from waste, large amounts of waste materials still end up in landfills [6]. The global trend in the waste sector is shifting from waste collection and disposal dominance to waste minimisation and recycling [7]. The Bureau of International Recycling (BIR) reported that 2.12 billion tons of waste are dumped every year, while recycled materials currently supply 40% of the world's raw material needs, conserving

precious primary resources [8]. However, waste disposal in landfills is the least favoured strategy in the waste management hierarchy and has significant repercussions on the global climate, contributing to climate change [9].

The European Union predicts that by 2050, the earth will require the resources of three planets to sustain current lifestyles if the ongoing exploitation of resources continues [10]. There is a global shift in the waste sector from a focus on collection and disposal to prioritising waste minimisation and recycling [11,12]. The Bureau of International Recycling (BIR) reported that 2.12 billion tons of waste are dumped annually [8]. According to Planet Aid in the last 50 years, humans have consumed more resources than in all previous history, and 40% of the world's raw material needs are supplied by recycled materials, helping to conserve primary resources [8]. While using the earth's natural resources, billions of tons of waste end up in landfills each year. Waste disposal in landfills has significant repercussions on the global climate, exacerbating climate change [13]. The transition to a circular or zero-waste economy, where resources are reused, repaired, repurposed, or recycled, is crucial [10]. The transition to a circular economy involves four major steps: recycling resources and energy recovery; reducing the demand for resources and recovering waste;

employing a multi-level approach and finding a way to achieve sustainable development and close relationships with innovation [9]. Additionally, different innovative and sustainable anaerobic digestions have been optimised globally to effectively manage food waste [14].

In developing countries, there is a significant potential to improve the management of Municipal Solid Waste (MSW) and to reap environmental and economic benefits. Currently, there is little focus on sustainable waste management, particularly in African cities, where waste recycling is mainly driven by poverty and socio-economic needs rather than by deliberate policy. Although 70-80% of the waste generated in Africa is recyclable, only about 4% is currently being recycled. It is estimated that fully leveraging recycling opportunities could inject an additional \$8 billion into Africa's economy annually. Ferranto et al., revealed that:

‘... the implementation of effective solid waste management strategies in developing countries is crucial for global sustainability ... many barriers need to be addressed, including environmental policies, investments, social inclusion, and public awareness, particularly in low to middle-income countries. The Circular Economy could provide a solution to improve solid waste management practices worldwide by emphasising waste valorisation and recycling to stimulate developing economies...’

The First National Forum on Waste in Cameroon aimed to promote the concept of a circular economy. The forum recommended the promotion of energy recovery through renewable energy development and encouraged the private sector to focus on ecologically sound waste management practices. Additionally, the forum proposed a Plan of Action, which includes developing a Global Vision with specific objectives for implementing the circular economy in MSW. The objectives for MSW include achieving a 70% waste collection rate at the national level, implementing sorting in major cities, and reaching a 60% recycling rate for the collected waste.

Bamenda, like other urban areas in Cameroon, has witnessed an increase in waste generation due to population growth. The waste generated includes both biodegradable and non-biodegradable waste, such as plastics, glass, metal, and food waste. The city generates approximately 132-170 tons of solid waste per day, with biodegradable waste making up 64% and non-biodegradable waste 36%. With the growing population, waste generation is expected to increase. The Bamenda City Council, responsible for waste management, has delegated waste management to the Hygiene and Sanitation Company (HYSACAM). According to the HYSACAM report, the city currently generates around 132 tons of Municipal Solid Waste per day, a figure that is expected to increase to about 200 tons per day. Various entities within the city, including transport agencies, workshops, commercial centres, academic institutions, offices, and residential areas, contribute significant quantities of waste daily, ranging from food waste to electronic waste and textiles. These waste materials hold considerable potential, which, if harnessed, could create wealth and improve the livelihoods of the inhabitants.

Analytical Framework (Ultimate Circular Economy)

Societies have traditionally followed a linear economy model, where most resources are extracted, processed into products, and then disposed of after a short lifespan, leading to a "take, make, waste" process. In this model, only a small percentage of materials are reused or recycled, and the rest are treated as waste, leading to high financial, social, and environmental costs. This linear economy assumes an unlimited supply of raw materials and the capacity to dispose of waste in the natural environment. However, this approach is not sustainable given the growing population and the need to preserve the planet's health. Continuing to extract natural resources such as minerals and fossil fuels has an increasing environmental impact, and certain resources are finite, making current consumption levels incompatible with achieving the United Nations Sustainable Development Goals (UNSDGs). An alternative approach is to build sustainable economies that recognise the value of natural resources through a ‘circular economy’ (Figure 1) (10-Rs). This involves implementing strategies such as refusing to make products with limited function, rethinking product use to be more intensive, reducing manufacturing and usage inefficiencies through eco-design, reusing discarded products, repairing and maintaining defective products, refurbishing old products, remanufacturing new products using parts of discarded ones, and repurposing parts of discarded products. products, and recycling and recovering materials.

The components and strategies of a circular economy model were first identified in the early 1980s and refined in the following decades [15,16]. These earlier models referred only to waste management processes of collection, separation, recycling, and reuse. Within the first quarter of the 21st Century, many circular economy strategies are emerging and applied by individuals, businesses and governments. These go beyond dealing with waste to include better product design, reduced consumption and sustainable materials management. The aim is to use resources most efficiently for the longest possible time. The resources circulate through various processes, being reused, repaired, redesigned or remanufactured, which reduces the need for new raw materials and minimises waste. When faced with persistent environmental problems such as climate change, resource scarcity and biodiversity loss, adopting resource circularity makes sense. Despite these strengths, society is slow to adopt this model or has simply failed to take the actions necessary for large-scale change.

Speeding up the transition to a circular economy involves a large shift in business and consumer thinking, demanding the adoption of sustainable production and consumption processes. Fuenfschilling and Truffer identify breaking down long-standing, rigid and interdependent system structures as the main challenge [17]. The difficulty stems from enacting large-scale socio-institutional change, which may require radical new ways of thinking and adjustment to normal customs and beliefs [18]. Moving from the established way of thinking involves the development of new laws and policies, which need to be revised, redesigned or new business models that integrate industries and incorporate a longer-term perspective, the internalisation of the environmental and social costs of extraction, production and disposal, innovative technologies, and changes in consumer use patterns.

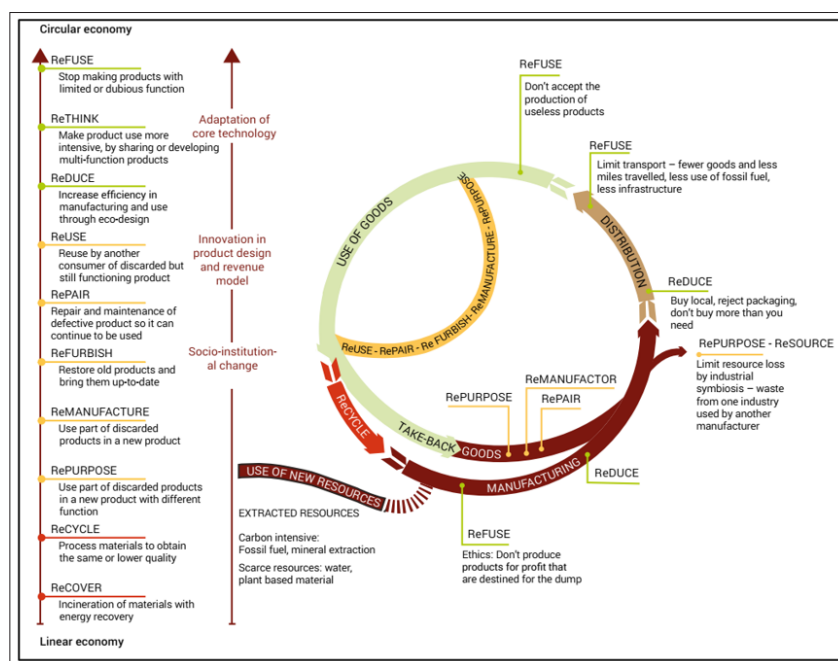


Figure 1: Circular Economy Model for Municipal Waste Management
Source: [5].

Actions that can Contribute to Accelerated Transformation Include:

- Decreasing demand for raw materials by increasing the efficiency and utility of raw materials in supply chains
- Replacing fossil-based, scarce and non-sustainably produced raw materials with sustainable, renewable and readily available raw materials.
- Developing innovative low-carbon production methods and smart product design
- Promoting smart consumption (reuse, smart design, extension of product life through design and repair, use of secondary and recycled materials, sharing economy)

The circular economy promotes a production and consumption model that includes resources restoration and regeneration where possible [18]. It ensures that the worth of products, materials, chemicals and resources is maintained in the economy at their highest utility and value for as long as possible [19,15]. The circular economy means reducing waste during production, ensuring asset recovery, including waste utilisation, and developing obsolescence prevention pathways in product and urban system designs through sustainable materials management. It also means ensuring product and service delivery with energy and materials from renewable sources, while changing business models to match these objectives [19,20]. The circular economy also preserves raw materials, thereby decoupling economic growth from the use of resources and their associated environmental externalities, including carbon emissions. In some cases, the appearance of growth decoupling in one sector or territory can mask a continued environmental and social impact somewhere else (Ward et al.), as well as substituting one non-renewable resource for another (cleaner energy systems that replace fossil fuels still require non-renewable resources) and shifting the cost somewhere else (importing resource-intensive consumer goods from developing countries) [21].

Conceptual Framework (Integrated Sustainable Waste Management-ISWM)

Integrated waste management planning is a dynamic tool including aspects that range from policy-making and institutional

different roles and interests concerning waste management; the challenge of the Integrated Sustainable Waste Management process is to get them to agree to cooperate for a common purpose, that of improving the waste system.

Second dimension: Waste system elements refer to how solid waste is handled and where it ends up. Particularly, this last point has important environmental implications, and for this reason, several national environmental ministries have taken the idea of a waste management hierarchy as an operational policy guideline. The waste management priorities are also a cornerstone of the Integrated Sustainable Waste Management approach and give priority to waste prevention, minimisation, recycling, reuse and other forms of recovery of materials for valorisation.

Third Dimension: Integrated Sustainable Waste Management refers to sustainability aspects. These aspects can be defined as principles or lessons through which the existing waste system can be assessed and with which a new or expanded system can be planned. For the new or the expanded system to be sustainable, it needs to consider all of the technical, environmental, health, financial-economic, socio-cultural, institutional, legal and political aspects.

To ensure sustainable waste management through the implementation of these concepts in the City of Bamenda, the various dimensions must be integrated. It suggests that technical, but also legal, institutional and economic linkages are necessary to enable the overall system to function or operate. The concept does not indicate how finances can be generated in the management and treatment of waste for sustainable development. The concept does not bring out the income generation aspect to make waste a source of income rather than a problem to solve. The aspect of natural resource sustainability is not very clear in the concept. This brings us to another concept, the circular economy concept, which brings out the economic aspect of waste management. In the context of this study, using the city of Bamenda, the Integrated Sustainable Waste Management concept is relevant for two main purposes. First, to plan and monitor existing waste management systems and secondly, to plan a new waste management system using the integrated approach and including appropriate technologies to ensure sustainable economic investment decisions for sustainable development.

Study Area and Methods

Study Area

Bamenda is the headquarters of the Northwest Region and doubles as the divisional headquarters of the Mezam Division. It is the biggest metropolitan town in the Region and is located to the southeast of the Region. It is made of three Sub-Divisions (Bamenda I, II, III) with a surface area of 391 km² and a population of about 496 931 inhabitants in 2012 with a 4.9% annual growth rate. Bamenda is located 366 km Northwest of the Cameroon capital, Yaoundé. Bamenda is known for its cool climate of about 27 °C and 68% humidity with a picturesque hilly location [22]. Bamenda Municipality is located to the West by Mbatu, Nchomba, and Bali, to the North by Bafut and part of Tubah, to the South by Santa, and to the East by Tubah. It is situated between Latitude 5°56'0 North and Longitude 10.16° East and has an average altitude of 1610 above sea level (Figure 3).

As of the 2016 estimate, the population of Bamenda City is 527,400 inhabitants (Ntoban and Fogwe,), after Douala, Yaounde and Maroua [23]. This population cut across Bamenda I (Mendakwe), Bamenda II (Mankon), and Bamenda III (Nkwen) Municipalities.

Bamenda was chosen for this study because it is reminiscent of Cameroon's cities in terms of administration, population growth, and size. The city is the regional capital of six other Divisions that make up the North West Region (Bui, Momo, Ngoketunja, Dunga–Mantung, Menchum Boyo, and Mezam Division where the city is located. Bamenda is a major road junction to other regions and cities, such as Bafoussam in the West, Douala in the Littoral, Yaounde in the Centre, and Kumba in the Southwest Region.

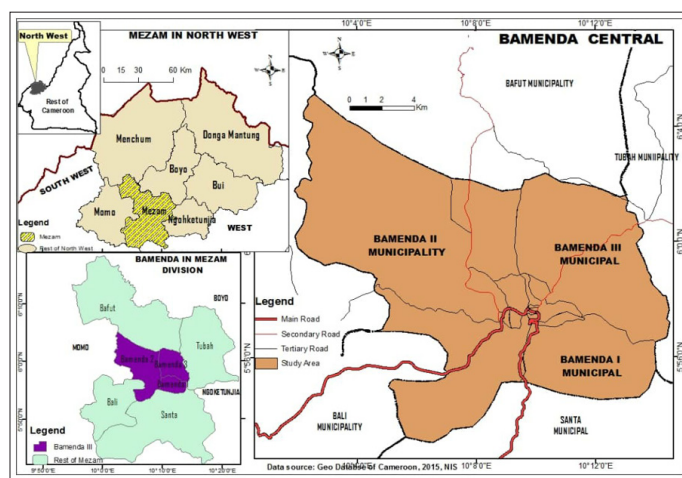


Figure 3: Location of Bamenda Municipalities (Bamenda I, II & III)
Source: Geo database of Cameroon, 2015, NIS Yaounde

The other divisions surrendering the city, like Menchum and Donga-Mantung, are directly linked to Nigeria, making the city a business hub. The free flow of goods from Nigeria through Ekok-Mamfe to Bamenda has also contributed to the economic growth of the city, thus influencing the quantity and composition of waste generated.

Methodology

A descriptive survey design was used to meet the objective of assessing the level of wealth creation in solid waste valorisation in Bamenda. It is an evidence-based study where data were procured from waste valorisers, documentation from the Northwest Regional Delegation of Environment, Protection of Nature and Sustainable Development (RD-MINEPDED) and sampling from waste dumps. It cuts across the various forms of solid wastes: agricultural, commercial, and household. Data were obtained through questionnaires administered to 33 waste valorisers in Bamenda (NGOs, CIGs and private enterprises). The questionnaires were administered on a one-to-one basis. Respondents were selected following their sector of activity, availability, and willingness to participate. Reports were consulted at the RD-MINEPDED to extract categories and approximated quantities of wastes valorised in Bamenda. Waste samples were collected from trash cans and dumpsites using the quartering technique to determine 100-200 kg of a waste sample that was sorted to determine the composition of the different recyclables present in the solid waste stream generated. The waste samples collected were mixed thoroughly, and the quartering method was used to extract 100 kg using a scale balance. The 100 kg solid waste was then sorted to get the different compositions.

Results

Types of Solid Waste Collected and Valorised in Bamenda

The types of solid waste collected and valorised by waste management stakeholders at Bamenda include plastics, scrap metal, textiles, glass, electronic wastes, papers, tyres, and food and animal wastes (Figure 4). Results show that 24.2 % of the

solid waste valorised by stakeholders is plastic waste, 45.5% valorises scrap metal (iron and aluminium), 3.0% valorises textile waste, glass/bottles, electronic waste, papers, and tyres, 6.1% valorise food waste (kitchen waste), and 9.1% valorise animal waste. From the results, scrap metal is the most valorised type of solid waste in Bamenda, with a 45.5% rate of valorisation. The next type of solid waste valorised is plastic, with 24.2%, followed by animal and food waste with 9.1% and 6.1% respectively.

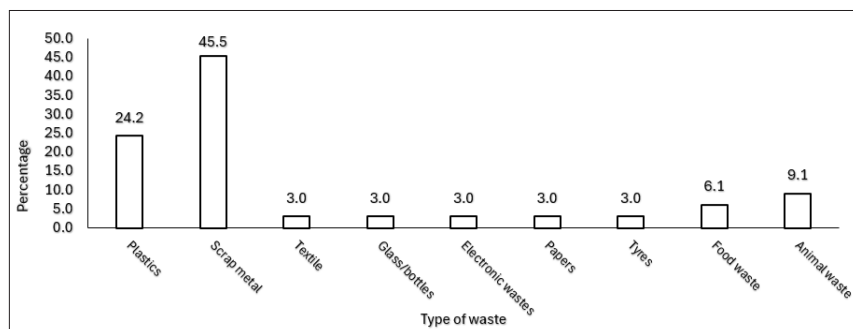


Figure 4: Types of Wastes Collected and Valorised

The level of valorisation of the other types of waste is still very low, with only 3.0%. Dumpsites with different types of waste can be collected and valorised. It is worth noting that the different types of waste present in the different dumpsites reflect the activities of the people living in that part of the city. Bamenda II and Bamenda III, which are at the hub of business and commercial activities, had much waste made of plastics and metals. The dumpsite beside the Food and Nkwen Markets had a lot of food waste (biodegradable waste). The dumpsites in Bamenda had a lot of organic waste (household waste) and paper because this is an administrative and residential area (Table 1).

Table 1: Solid Waste Collected for Valorisation in Bamenda 2015-2020

Location	Waste enterprises	Solid waste collected	Qty valorised (Kg)	% valorised
Bamenda II & III	Scrap metal dealers	Scrap iron, aluminium	7,699,200	99.3
Bamenda I & Bamenda III	Link packaging & RD-MINEPDED	Plastic	15831.7	0.2
Bamenda II	Boissons du Pays	Broken glasses/bottles, beer corks	4310	0.06
Bamenda II & III	BOCOM & TOTAL	Used filters, batteries, soil rag, plastic gallons, sand/ mud	22,479.2	0.3
Bamenda III	ENEO	Old electric poles	10,000	0.1
Bamenda II	Entrepreneur	Papers	3000	0.04
Total			7,754,820.9	100

Source: North West RD-MINEPDED

Scrap metal collection and valorisation dominated the waste sector in Bamenda, with 99.3% of the total solid waste collected valorised. The waste pickers sort the metals from dumps, roadsides, households, garages, and other institutions and sell them to the waste dealers. Some owners of the waste sell directly to the scrap iron dealers, such as scrap vehicles. This sector has been well established in Bamenda. The high rate of valorisation of scrap is because the waste is being valorised both in Bamenda and in Douala. Local waste valorisers use aluminium to produce household utensils and other objects.

Recycling Ventures in Bamenda

There are several waste recycling enterprises in Bamenda, but most of them are still operating on a small scale. Most of the enterprises are not organised into corporate bodies but are managed by individuals as private businesses. The various enterprises range from metal recyclers, plastic recyclers, organic waste recyclers, rubber/tyre waste, and glass/bottles. Thirty-three waste recycling enterprises were identified and sampled in Bamenda, including the Regional Delegation of Environment, Protection of Nature, and Sustainable Development (RD-MINEPDED) for the Northwest valorising solid waste in Bamenda. This service has a staff strength of 13. Most of these enterprises, especially those dealing with metallic waste, only collect the waste, store it, and transport it to other enterprises in other cities in Cameroon, such as Douala, for valorisation into usable products. Most of them cannot recycle the waste into finished goods.

The RD-MINEPDED was the only public institution identified to recycle solid waste in Bamenda I, even though on a very small scale. The valorisation is done for a demonstration to the public and students who come for an internship without any financial gain. The interns and the population are being trained so that they can use the activity to generate income. Plastic bottles are being recycled and reused to produce nursery pots for a tree nursery and to make flower beds and lawns. The interns are also trained to reuse waste tyres for gardening. Waste valorisation enterprises were not found in the Bamenda I Sub-Division because this area is for government offices and residences. Most of the waste enterprises were identified in Bamenda II and III (Tables 2 and 3), respectively.

Table 2: Ventures Recycling the Solid Waste in Bamenda II

Name of Enterprise	Location	Year of creation	Waste valorised	Number of workers	Category
Muluh Walters (Scrap metal dealer)	Meta Quarter	2005	Scrap metal (Fe, Al)	5	Private
Emma Electronic	Fon Street	2001	Electronic	3	Private
Tingu Jackson (Scrap metal dealer)	Small Mankon	2000	Scrap metal	6	Private
Agnam Simplicie (Scrap metal dealer)	Meta Quarters	2012	Scrap iron	2	Private
Ndonwi Gilbert (Scrap iron dealer)	Small Mankon	2015	Scrap iron	1	Private
NEPRO	Nitop I	2015	Plastics	4	CIG
Cho Finadaise (Plastic waste dealer)	Meta Quarters	2018	Plastics	0	Private
Ayeah Leonette	Small Mankon	2018	Tyres	1	Private
Nuvala Hilarius (Scrap iron dealer)	Ntarikon	2015	Scrap metal	2	Private
Khan Vitalis	Meta Quarters	2012	Glass/ bottles, Metal scraps	3	Private
Buma Federick (Scrap Iron dealer)	Old Town	2010	Scrap metal	2	Private
Cho Ivo Fungu	Meta Quarters	2011	Scrap metal	1	Private
Renewable Energy Technology	Nitop I	2017	Organic waste	2	CIG
Afri-Waste Management	Ntarikon	2018	Plastics, organic	2	CIG
Kamsu Jacqueline	Commercial Avenue	2017	Plastics	1	Private
EM Cameroon	Small Mankon	2011	Organic waste	5	Private
Blacksmith I	Ntarikon	2009	Aluminum	0	Private
Blacksmith II	Ntamulung	2003	Aluminum	0	Private
Boison du Cameroun	Ntarikon		Glass/ bottles, corks	2	Company

In Bamenda II, most of the enterprises were private and located mostly in Meta Quarters and Small Mankon. Most of these enterprises deal with scrap metal, iron and Aluminium. As compared to Bamenda I and Bamenda II, most of the solid waste valorisation ventures in Bamenda are found in Bamenda II. This is because Bamenda II is the Central Business District of Bamenda, with so many garages and markets supplying the waste raw material to the ventures (Table 3). The high population of Bamenda II, as compared to Bamenda I and III, has also attracted the location of these waste ventures due to the increased quantity of solid waste generated.

Table 3: Ventures Recycling the Solid Waste in Bamenda III

Ventures	Location	Year of Creation	Type of waste valorised	Number of workers	Category
CAYSDEP	Mile V Nkwen	2017	Plastic, scrap metal, paper, tryes, organic, paper	2	
NGO	Fon Street	2001	Electronic	3	Private
Link Packaging	Ntasen	2015	Plastic	6	Private Enterprise, CIG
Blacksmith III	Ndamukong	2015	Scrap Aluminum	0	Private
Fon Mbah Festus	Sisia Nkwen	2017	Scrap metal	1	Private
Kanga Justin	Mile II Nkwen	2012	Scrap metal, plastics	5	Private
CAFEM	Mile IV Nkwen	2017	Organic	2	CIG
New Vision for Eco-friendly Environment	Mile IV Nkwen	2019	Plastic, Organic	0	NGO
Royal Renewable Energy Cameroon	Mile IV Nkwen	2017	Organic	2	NGO
Blacksmith IV	K-Town Nkwen	2014	Scrap aluminium	0	Private
The Greens	Mile III Nkwen	2010	Plastics, tyres, textile	3	NGO
Traditional Biogas Construction Enterprise	Mile II Nkwen	2016	Organic	4	Private enterprise
Mbaku Emmanuel	Mile II Nkwen	2016	Plastic, scrap metal	2	Private
Blacksmith I	Ntarikon	2009	Aluminum	0	Private

Some 64% of the enterprises are privately managed by individuals, 33% of them operate as private corporate bodies such as companies, Common Initiative Groups, and Non-Governmental Organizations while 3% are in the public sector (Figure 5).

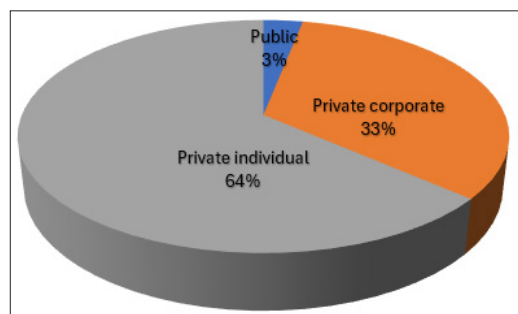


Figure 5: The Status of Waste Recycling Enterprises in Bamenda

Recycling Techniques

The different techniques used by enterprises in Bamenda to recycle solid waste are composting, melting, anaerobic digestion, incineration, and gasification (Figure 6).

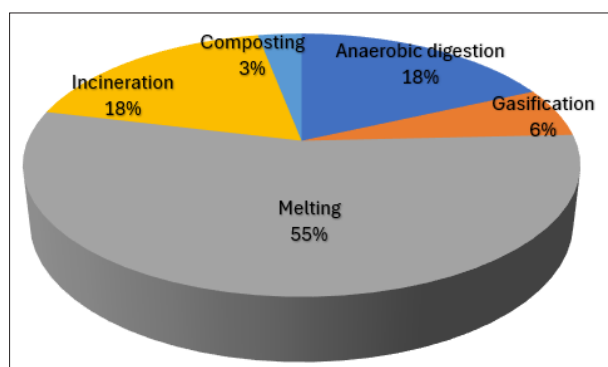


Figure 6: Technologies Used in Waste Recycling

The results show that 55% of the enterprises use melting technology with high temperatures, 18% use incineration technology, which is burning in an incinerator to generate energy, and 18% also make use of anaerobic digestion, which is the breaking down of organic waste in the absence of oxygen. 6% use gasification technology to generate biogas as a source of energy, and 3% use composting technology to generate compost manure, which is used as organic fertiliser to improve the soil quality for agriculture.

Recycling through the process of melting is being used by blacksmiths in Bamenda to produce aluminium pots and other utensils, such as knives, spoons, axes, and some farm tools, such as digging axes and harvesting spears. Under high temperatures, aluminium waste such as roofing sheets and canned drinks is melted to fabricate diverse products. Another Organisation that uses the technique of melting is NEPROF to recycle plastics into pavement blocks, tiles, and other products such as crosses, embankment blocks, and flower jars. The plastic is melted and mixed with sand to fabricate other objects.

Composting is being used to generate organic manure, which is being used to improve soil fertility. Many households use the process of composting household and agricultural waste to produce manure. This is done by the process of decomposition of organic matter. Many NGOs, such as CAYSPED, use this technology to produce composted manure, which is being sold to farmers. EM Cameroon, an enterprise in Bamenda, uses anaerobic

digestion to produce manure called EM Compost, which is used by farmers to grow crops. EM Cameroon uses animal waste from slaughterhouses, poultry, and piggery farmers to recycle through anaerobic digestion to produce manure. EM compost is very effective in the improvement of the soil because it contains effective microorganisms that help to regenerate the soil.

Gasification is another technology used in Bamenda to generate biogas. The waste is recycled by the construction of a waste digester, where the waste is converted into methane (CH₄). The gas is then transmitted through pipes into kitchens for energy. Many organisations/enterprises using this technique to generate energy in Bamenda include CAYSDEP (Cameroon Youths for Sustainable Development and Environmental Protection), Traditional Biogas Construction Enterprise, and Royal Renewable Energy Cameroon. Other techniques used in Bamenda to valorise solid waste include: reuse, remanufacture, and repair. Solid waste such as tyres is reused to manufacture furniture. Plastic waste and tyres are also used for gardening in Bamenda. Most households use plastic bottles and waste tyres to develop gardens within their backyards. The Green NGO has developed the use of plastic bottles to develop vertical gardens and is training many households in Bamenda.

The use of waste tyres for gardening in Bamenda is one of the contemporary urban agricultural methods to maximise space and increase food production. Most households in Bamenda use this technology to grow vegetables within the urban space. Also, Welders use waste iron and other metals to manufacture charcoal stoves, sawdust pots, baking tin, watering cans, and boxes used by students. The waste is being transformed into products that they supply to wholesale and retailers in commercial centres in Bamenda. Some of the waste is used to fabricate machines such as grinding mills, palm oil mills, and other machines. Some of the products are fabricated from waste metals. Some of the products generated in Bamenda from solid waste recyclables are presented (Figure 7).

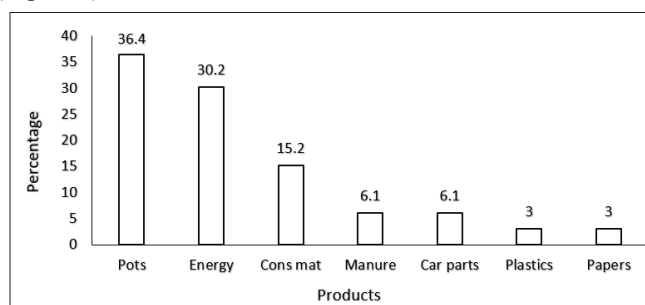


Figure 7: Products Produced from Collected Waste Recyclables

Results reveal that 36.4% of the products produced in Bamenda from recyclables are pots (aluminium) made by blacksmiths melting aluminium metals. 30.3% generate energy. This is mostly biogas derived from the digestion of organic waste to produce methane gas used as domestic fuel. Also, organic waste is used to produce organic charcoal, which is used for cooking. 15.2% of the recyclables are used to produce construction materials such as pavement tiles from plastics, waste tyres to build embankments, plastic waste to construct embankment blocks, and waste iron to produce building rods. 6.1% of the recyclables are used to produce compost manure used to improve the soil for agriculture. Also, 6.1% of the recyclables are used to produce vehicle spare parts. Tyres are used to produce vehicle shock absorbers and brake lining, and iron and aluminium are used to fabricate vehicle parts. 3.0% of the products are plastics and papers derived from waste recyclables. A variety of products are being generated from solid

waste valorisation in Bamenda. Most of these products use local technology and little energy for their production. These technologies are easily transferred from one family member to another or from the patron to the apprentice. Other groups are being trained to carry out the recycling process. Most of the products produced are locally consumed.

Economic Value of Solid Waste Recyclables in Bamenda

The economic value of solid waste generated in the Bamenda metropolis in monetary terms is still very low. Even though the unit value for individual waste is high (Table 4), the scale is still small.

Table 4: Economic Value of Solid Waste Types Valorised in Bamenda

Waste Type	UV/Kg in Bamenda (cost price) FCFA/USD	UV/Kg in Douala (Selling price FCFA/USD)	Profit/UV FCFA/USD
Scrap iron	50/0.08	140/0.22	90/0.14
Scrap aluminium	350/0.55	500/0.79	150/0.24
Plastics	50/0.08	150/0.24	100/0.16
Copper	1000/1.58	2000/3.14	1000/1.58
Organic	40/0.06	160/0.25	120/0.19

Results reveal that copper and aluminium generate a lot of profit in the waste economy with a very high unit value per kilogram, but the waste type is not readily available, unlike scrap iron. Plastics have a higher unit value than iron, but are very bulky to transport and have less weight in terms of kilograms than iron. The dealers will prefer to deal with scrap metal and iron more than plastics, even though both are readily available. Organic waste is usually valorised in Bamenda because of its weight and fast decomposition. The Unit Value of waste in Cameroon is higher and motivational to encourage more investors in the sector. In this study, an economic analysis was done for the production of 40 size 15 pots per month through the process of recycling using the data in Table 4 to calculate the economic benefit (Table 5).

Table 5: Economic Analysis for the Production of 40 (forty) Size 15 Pots per Month through the Process of Recycling in Bamenda

Pot size	Qty	Al Waste cost (FCFA/USD)	Charcoal cost (FCFA/USD)	Electricity cost (FCFA/USD)	Transport cost (FCFA/USD)	Labour cost (FCFA/USD)	Selling Price (FCFA/USD)	Monthly profit (FCFA/USD)
15	40	72,000/113.74	5,000/7.9	2,000/3.16	5,000/7.9	50,000/78.99	380,000/600.31	246,000/388.62

Total cost of Production: cost of Al waste + Cost of Charcoal + Cost of Electricity + Cost of Transport to the Market + Labour cost (72,000+5000+2000+5000+50000) = 134,000 FCFA
Selling/Supply Price: 9500FCFA × 40 pots = 380,000

Profitability: Selling/Supply price – Total production cost (380,00 – 134,000) = 246,000 FCFA

The analysis, it shows that a blacksmith who produces 40 size 15 pots per month can generate a net profit of 246,000 FCFA, which is greater than the salary of many state workers of categories 10 and 11.

Resource Value of Solid Waste Valorisation in Bamenda

The economic benefit of solid waste valorisation can be measured in terms of the recovery of valuable resources and energy that can be inserted into the economy. The benefit can be quantified in terms of resource value, which can be estimated in terms of the monetary value of the resources that can potentially be recovered through recycling and waste-to-energy applications. According to a study carried out in some African cities, the value of waste resources was quantified using the methodology that was applied in South Africa (AWMO), where the resource value associated with 13 solid waste streams was estimated [13]. In this methodology, data on solid waste generation and the various compositions are determined, and the percentage of valorisation of the different waste streams is measured to signal the maximum amount that could be recycled.

Assuming that all the solid waste generated in a municipality can be valorised (Recycled), this gives a maximum potential for the recyclables. This upper limit is theoretical because, in reality, not all waste generated can be recycled (EEA). To measure the resource value of solid waste that can be inserted in an economy, this methodology will involve quantifying the amount (tons) of waste generated by each of the recyclables and multiplying this amount by a representative unit value per ton of the recovered materials to arrive at an indication of the value of additional recoveries. This can be represented mathematically:

Resource Value = (Q1 × UV1) + (Q2 × UV2) + ... (Qn × UVn)

Where Q = Quantity of waste stream (n) available to the economy (tons)

UV = Unit Value per ton of waste stream (n) in Prices /ton (US\$/ton)

n = the waste recyclable

Using the African example of Municipal Solid Waste generation in some cities, which can be exemplified in Bamenda, the resource value of solid waste was calculated, focusing on some solid waste streams: organic waste, paper, glass, plastic, metals, and other waste. According to Africa Waste Management Outlook, the total municipal solid waste generated in Africa is 125 million tons per year, and approximately only 4% is being valorised, while the rest is disposed of (Table 6) [13].

Table 6: Municipal Solid Waste Generation and Average Composition in Selected African Cities and Relevant Unit Values

Waste stream	Composition (% of total)	MSW generated in urban areas in Africa/year (tons)	Average Unit Value (US\$/ton)
Organic	57	71,246,580	16.28
Paper	9	11,249,460	64.26
Glass	4	4,999,760	42.30
Plastic	13	16,249,220	269.28
Metals	4	4,999,760	195.95
Others	13	16,249,220	31.71
Total	100	125,994,000	-

Source: AWMA, 2018: 104

Considering the cities in Africa, these values are relatively the same in Bamenda and can determine the resource value. The resource values show different scenarios: Scenario 1, status quo (4% waste recovery); Scenario 2 (based on 25% waste recovery); Scenario 3 (based on 50% solid waste recovery rate); and Scenario 4 (based on 100% recovery rate).

The data shows that the percentage of waste recovered for valorisation (recycling) determines the resource value of the waste in monetary terms. Organic waste stands out as the most common type of solid waste in terms of composition generated in Africa, Cameroon and Bamenda in Particular with a resource value of US\$ 48,395,773/year for a 4% recovery rate, US\$ 89,973,581/year for a 50% recovery rate and US\$ 1,159,894,322/year for 100% recovery rate even though this is only theoretical it can be real in an institution (zero waste) concept. The greater the rate of recovery, the greater the resource value (Q) of the recyclables. The resource value of some solid waste types recovered per annum for a 4% recovery rate, which is the status quo for Africa (Table 7).

Table 7: Resource Value for Some Solid Waste Types Recovered within the Status Quo of 4% in African Cities, Equivalent to Bamenda City

Solid waste type	Composition per % of total	Amount Recovered (4%) in tons/year	Unit Resource value US\$	Total Resource Value US\$	Unit Resource Value in FCFA
Organic	57	2,849,863	16.28	46,395,773	8,140
Paper	9	449,978	64.26	28,915,612	32,130
Glass	4	199,990	42.30	8,459,594	21,150
Plastic	13	649,969	269.28	175,023,598	134,640
Metals	4	199,990	195.95	39,188,119	97,975
Others	13	649,969	31.71	318,593,207	15,855
Total	100	4,999,759	619.78	616,575,903	309,890

Considering some of the solid waste types collected in Bamenda, plastics have the highest resource value with a unit value of 134,640 FCFA per year, followed by metals with a resource value of 97,975 FCFA per year. These results indicate that only 4% of the total solid waste was recovered. The total resource value will increase as the percentage of solid waste recovery increases. If African countries, including Cameroon and Bamenda in particular, can increase the rate of waste recovery for recycling from the status quo of 4% to a higher percentage, say; 10%, 15%, 20% to 25% for the different waste streams, more resources will be acquired that will be injected into the economy of the countries for sustainability. An increase from the status quo of a 4% recovery rate to 25% will give a total resource value of US\$ 1,672,614,336/year, and 50% will give a total resource value of US\$ 3,663,821,878/year and a 100% recovery rate will provide a total resource value of US\$7,646,236, 963/year.

Discussion

Waste production creates employment opportunities for hundreds of thousands of poor people, youths, and women who tapped into the business of collection, sorting, sales, and recycling of waste materials [4,24]. 90% of waste in low-income countries are openly dumped or burned without valorisation [25]. This percentage is a reflection of the situation in Bamenda. The composition of plastic

(bottles, packaging, containers, bags, lids, cups) as a percentage of MSW for Sub-Saharan Africa is 13%, within the average percentage found in Bamenda. Papers with an average of 9%, glass with an average of 4%, metal (cans, tins, scrap vehicles) 4%, and others with an average of 13% are all lower than the percentages generated in Bamenda. The vision, therefore, is to create a city where people in poverty can gain employment through waste recovery.

The population of Bamenda keeps increasing, thus influencing the generation of solid waste in the city. A population of about 527,400 inhabitants [23]. As the population increases, economic activities also increase, which has resulted in an increase in the amount of waste generated. With the increased amount of waste generated, the quantity of waste recyclables is expected to increase for valorisation (reuse, repair, recovery, and recycling). The city of Bamenda produces approximately 18,800Kg/month (18.8 tons) of solid waste (HYSACAM). Considering that HYSACAM does not evacuate all the waste from Bamenda, and its scaling system is not accurate, the quantity generated is higher than the data provided for valorisation.

The availability of enterprises, NGOs, CBOs, CIGs, associations, and individual businesses ready to valorise waste in Bamenda

has contributed to enhancing the activity. Even though most of the enterprises are operating in the informal sector with no legal documents to function, the willingness to carry out waste valorisation as an economic activity is a major force in fostering the sector in Bamenda. Scrap metal and plastics are the most collected and lucrative solid waste valorised in Bamenda, which generates income for the waste operators. Aluminium waste recycling by blacksmiths is the most locally processed waste in Bamenda, as most of the waste collected is sold to companies in Douala. Several workers are specialised in the making of kitchen utensils from aluminium waste for their livelihood [13]. The use of wood processing waste like sawdust generated in sawmills has gained a potential market for biofuels (Lee et al.), as in the case of the Bamenda metropolis [26].

Solid waste valorisation has contributed to the economy of Bamenda, even though at an insignificant level. The activity has created job opportunities for the operators and a source of income to take care of their families. 81.8% of the operators have secured jobs and created employment for others in Bamenda. A study by the USEPA revealed that solid waste valorisation at a recovery rate of 80% of the waste can generate up to 2000 job opportunities in a city. In Bamenda, the recovery rate remains low at the status quo of 4% for most African countries.

Recycling and energy recovery can contribute to economic growth and job creation, and can also foster innovation and create new business opportunities [13]. The report also revealed that recycling and energy recovery allow for valuable materials and energy to be recovered and recirculated into the economy. This should have been the case in Bamenda to inject a reasonable contribution to the GNP of the country, but this is not the case due to inadequate investment capital and technology. The Cameroon government is encouraging the implementation of the circular economy concept in waste management in the country to create wealth, conserve resources, and improve the economy. A blend of the circular economy and the waste management hierarchy, integrating the 3-Rs concept, which has increased to 10-Rs (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover), fosters a circular economy for sustainable development.

Conclusion

Achieving solid waste valorisation in the Bamenda metropolis for the creation of wealth, there is an urgent need to raise awareness and change public opinion towards waste generation and management in Bamenda. Attitudes must change towards uncontrolled dumping, open burning of waste, and understanding solid waste as a resource rather than trash. Raising awareness will enable civil society, the media, and non-governmental organisations to actively participate in all aspects of waste management in the Bamenda Metropolis. To achieve a circular economy in the Bamenda Metropolis, the city council of Bamenda must elaborate a waste management plan. Training and education are also essential to raise awareness of the municipalities, private companies, and firms and provide them with the technical knowledge to implement and manage waste sustainably and enforce legislation. This bottom-up approach will enhance the level of waste management of the staff of municipalities and other actors in the sector. A 'top-down' training approach is also necessary to build an understanding of the importance of sound waste management at the political and senior government levels for better decisions to be implemented. Skills in project design, costing, and cost recovery from waste must be strengthened among government officials, agencies, structures, and institutions in charge of waste management. The informal

sector, as a major stakeholder in the waste management sector, must be recognised and promoted in Bamenda in the collection and recycling of solids through appropriate training in technologies. Awareness must be raised in the informal sector for the market of secondary materials generated from waste materials [27-36].

Measures must be put in place by the city council to facilitate the regular collection, verification, and analysis of data on the amount, sources, types, and composition of solid waste generated, recycled, and disposed of. The use of weighbridges should become standard practice to facilitate regular reporting of reliable waste data in the city. The data and information should be freely available and used for, among other things, planning, monitoring, evaluation, research, and decision-making on waste management. The data has to be collected on the economic, social, and environmental bases to enhance sustainability. Reliable data on the waste composition and waste quantities is essential to enable financing and innovation in waste valorisation. Waste policies and legislation must be strengthened in Bamenda. Policies such as waste separation at source should be promoted to make waste recycling and recovery easier and affordable, and to ensure the collection of clean recyclable waste streams with higher value. Strong institutions and an enabling governance environment that facilitates partnerships between the government, the private sector, civil society, consumers, and the informal sector must be implemented. At the same time, waste treatment technologies, services, and infrastructure must be carefully chosen in terms of their sustainability and appropriateness for local conditions. New technologies should be introduced progressively within the city, starting with low technology, low capital, labour-intensive, and culturally and ecologically acceptable technologies, and then to the most complicated and sophisticated ones. Technology that will encourage a shift from waste dumping towards value recovery should be enforced, which will create numerous opportunities for job creation and wealth.

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