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Review

Sustainable development of Nigeria's solid minerals through metal recycling: a review

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Abstract: Metal recycling as a path way to sustainable development of Nigeria solid minerals deposits has been reviewed. This paper brings to bear the United Nations Sustainable Development Goals (2015-2030), classification of solid mineral deposits in Nigeria, potential contribution of the solid mineral sector to the nation's gross domestic product (GDP), lifetime (lifecycle) management of a mineral resource, sustaining mineral resource through metal recycling (use of secondary materials) with some of its accompanying benefits, economics of metal recycling and the need for environmental impact assessment when sitting a recycling plant. The review has revealed the following; Metal recycling could oil the nation's wheel of realising some of the objectives of the United Nations Sustainable Development Goals(SDGs), every state in Nigeria has at least one solid mineral deposit, one tonne of steel made from recycled steel translates to saving 1,115kg of iron ore, 625kg of coal and 53kg of limestone, recycling results in reduction of about 200 million tonnes yearly of CO_2 emissions, recycling also results in 76%, 40% and 86% reduction in water pollution, water usage and air pollution respectively and energy savings derivable from recycling 39% aluminum, 31% copper, 74% lead, 42% steel and 20% zinc are 95%, 85%, 60%, 62-74% and 60% respectively. Therefore, metal recycling provides one of the viable tools for sustaining the nation's solid mineral deposits especially the metallic ores for the benefit of generations yet to be born.

Keywords: *metal recycling, sustainable development, solid minerals*

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Introduction

Upon commencement of oil production in Nigeria's Niger-Delta region in the 1950s, the nation has operated an economy which is solely dependent on the revenue derived from this commodity such that the solid minerals sector continues to be allocated the back seat in the assembly of national economic policies and programs. The drop in revenue derived from the sale of crude oil in the global market now calls for drafting of a sustainable development template or lifecycle management policy for the nation's solid minerals sector with metal recycling as a viable tool.Sustainable development may be defined as the type of development that provides for the needs of present generation while making provisions for the natural resource base to meet the needs of future generations (Nishimatu, 2016).It is a tool which ensures that development serves present and future generations through integration of social, economic and environmental factors into planning, implementation and decision making (Mayer and Baxter, 2012).

Similarly, Anderson *et al* (1990) described recycling as the selection, classification and reintroduction of waste as feed stock to produce the same, or a very similar product, to the initial material**.**

We live in a world characterized by an ever-increasing human population which faces the challenge of managing her scarce resources derived from non-reproducible mineral on the one hand and renewable but low yielding biological (agricultural) resources on the other hand. While activities such as mining which according to Peele and Church (1941) is perhaps the second oldest human endeavor may be responsible for the former, climate change is the underlying factor sabotaging the later. Suspension of mining activities in the country and the consequent blockage of miners' source of livelihood is not the philosophy behind this technical paper. It has however been observed that there are few viable medium or large scale scrap metal recycling plants especially in the Northern part of Nigeria. Thus, this paper focuses on exploring the potential benefits of driving the Nigerian economy through the metal recycling subsector while substantially conserving the solid mineral deposits for the benefit of generations unborn now that the nation is taking steps towards economic diversification with strong bias for solid minerals.

United Nations sustainable development goals

It is imperative to get a broader view of the content of this paper via the mirror of the conceptual frame work of the United Nation's sustainable development goals. Galach (2016) noted that many countries of the world on September 25, 2015 adopted set goals as part of a new sustainable development agenda with each goal having specific targets to be achieved by the year 2030.The goals are as itemized on Table 1.

Classification of solid mineral deposits in Nigeria

Maliki et al. (2016) broadly classified Nigeria's mineral resources as follows; industrial minerals (barite, kaolin, gypsum, feldspar, limestone), energy minerals (bitumen, coal, uranium), metallic ore minerals (gold, cassiterite, columbite, iron ore, lead-zinc, copper), construction minerals (granite, gravel, laterite, sand), precious stones (sapphire, tourmaline, emerald, topaz, amethyst, garnet).In their work on resources estimate of mineral occurrences in Nigeria, Adelabu and Kasim (2010), indicated that every state in Nigeria has at least one solid mineral deposit. Among these, iron ore, gold, lead/zinc, coal and limestone have been found to be in commercial quantities at various locations in the country. However, products of metallic ores such as scrap iron/steel made from iron ore and scrap zinc are the most recycled.

Table 1. Sustainable Development Goals (2015-2030)

Goal	Objective
One	No poverty
Two	Zero hunger
Three	Good health and well-being
Four	Quality education
Five	Gender equality
Six	Clean water and sanitation
Seven	Affordable and clean energy
Eight	Decent work and economic growth
Nine	Industry, innovation and infrastructure
Ten	Reduced inequalities
Eleven	Sustainable cities and communities
Twelve	Responsible consumption and production
Thirteen	Climate action
Fourteen	Life below water
Fifteen	Life on land
Sixteen	Peace justice and strong institutions
Seventeen	Partnerships for the goals

Source: Gallach (2016)

Potential contribution of the solid mineral sector to the nation's GDP

Bello (2016) reported that the solid mineral sector provides a viable alternative to petroleum for foreign exchange earnings. The commercial value of Nigeria's solid minerals has been estimated to run into hundreds of trillions of dollars, where 70 per cent of these are buried in the bowels of Northern Nigeria but on a broader note, 44 solid minerals are found in commercial quantity many of which are metallic and are spread across the 36 states and the FCT .Out of these, seven strategic solid minerals are being prioritized and promoted for private sector participation and investment by the federal government. The selected solid minerals are shown on Table 2. Similarly, the National Bureau of Statistics (NBS) reported as follows:

1. As at 2014, the contribution of solid mineral sector to the Nigerian economy was one per cent
2. It has the potential to increase to at least five per cent by the year 2017 and ten per cent by the year 2020
3. It is also capable of creating three million direct and indirect jobs by the year 2017

As indicated on Table 2, these minerals are characterised by uneven distribution and unlike agricultural or forest products, cannot reproduce or be replaced.

Table 2. Some minerals found in commercial quantity across Nigeria

S/n	Mineral	Location	Classification	Reserve estimate
1	Gold	Maru, Anka, Malele, Tsohon Birnin Gwari, Kwaga, Gurmana, Bin Yauri, Okolom, Dogondaji and Iperindo	Metallic Mineral	Proven reserve of commercial quantity
2	Coal	Spreads across 17 coal fields	Energy mineral	Over six hundred million tones
3	Bitumen		Energy mineral	42 billion tones almost as twice the existing reserve of crude oil
4	Limestone	Sokoto, Gombe, Benue, Kogi, Ogun, Edo, Oyo and Cross River State	Industrial mineral	2.3 trillion metric tones
5	Iron Ore	Kogi, Enugu, Niger, Zamfara and Kaduna	Metallic mineral	3 billion tones
6	Lead/zinc	Plateau	Metallic mineral	10 million tones
7	Baryite	2million metric tones	Industrial mineral	Benue, Nasarawa, Plateau, Cross River

Source: Bello (2016); Maliki et al. (2016)

De la Vergne (2014) mentioned that a mineral deposit may be considered a depleting asset whose production is restricted to the area in which it occurs. These factors constitute limitations on a mining outfit in the areas of business practices, financing, and production practices; thus, a mining company must discover additional reserves or purchase them to remain relevant in the mining business because mineral assets are constantly being depleted (Noronha, 2016). These factors in themselves could constitute platforms for material (metal) recycling to thrive.

Lifetime (lifecycle) management of a mineral resource

Although ore deposits such as pyrite, magnetite, haematite, bauxite with other elements and silica, are abundant in the earth crust, there is still need to manage these resources for the benefit of future generations.Vydra (2016) defined lifecycle management as the measure of how materials, products and infrastructure can best be managed from an environmental perspective through a complete product cycle. Virtually all materials are made from resources which have a lifespan or lifetime and may be calculated from equation (1):

$$\text{Lifetime} = \frac{\text{Reserve}}{\text{Rate of Usage}} \text{ ----------- } 1$$

This equation is subject to alteration as the numerator depends on factors such as discovery of new deposits and development of alternative methods to process lean reserves thought previously to be economically nonviable (De la Vergne, 2014). The denominator is subject to factors that affect usage, which may be as a result of the substitution of materials in component manufacture: For instance, the substitution of PVC for copper in household water distribution fittings and aluminium for copper in electrical transmission lines decrease the rate of usage of copper ore. Another typical example is the substitution of composites for steel in automobile bodies. In the overall analyses, these substitutes which in themselves are partly recyclable would affect positively the rate of extraction of pyrite and magnetite (or haematite) deposits respectively. Further, nonferrous metals, such as aluminium, copper, lead, nickel, tin, zinc constitute some of the few materials that are not biodegradable or lose their chemical or physical characteristics in the recycling process. As a result, nonferrous metals have the capacity to be recycled an infinite number of times (Isri.org).

Sustaining mineral resource through metal recycling (use of secondary materials)

The use of secondary raw materials as suggested by scrap metal recycling translates to minimal use of natural resources which otherwise would be required to manufacture new metal compounds. To minimize waste over the life cycle of materials, recycling and reuse of waste is essential. Scrap metal recycling is a global practice and the industry constitutes a rich field of metal varieties. Thus, scrap metals may be broadly categorized into ferrous and non-ferrous. Metals which contain iron as their principal element are known as ferrous while non-ferrous are without iron ore. The process of recycling scrap varies with metals but ultimately results to an equivalent metal quality. Commonly recycled non-ferrous metals are aluminium, zinc, tin, nickel, lead and magnesium. For example; the electric arc furnace for steel making derives its major raw material from scrap metal thereby producing high quality tool steel. Both primary and secondary producers employ copper scrap where blast furnace, reverberatory furnace or electric arc furnace is the methods: the electric arc furnace employs about 80% scrap copper as raw material. The Institute of Scrap Recycling Industries data (2017) show that automobiles, steel structures, household appliances, railroad tracks, ships, farm equipment represent the various sources of scrap. In addition, scrap derived from industrial and manufacturing sources represents approximately half of the ferrous scrap supply.

Benefits of Metal Recycling

Economic/industrial growth

Nabea and Tiwari (2012) indicated that on one hand, about 4.6 million tons of iron, steel and stainless steel scrap is supplied to UK steel companies, 0.9 million tones to UK foundries and 6.1 million tons exported annually and for non-ferrous metals on the other hand, over one million tones has been processed in Spain and India approximately 45% of which was aluminum, 31% copper and little quantities of nickel, brass, zinc and lead. These indicate high economic value of scrap metals which is hardly discarded or land filled. Steel is the most recycled material both in the United States and worldwide. Statistics by The Institute of Scrap Recycling Industries Inc (2017) indicates that in the United States alone, 74 million metric tons of ferrous scrap was processed by the scrap recycling industry last year which accounts for over 55% of the total volume of all materials processed in the country. This trend is realizable in Nigeria and should be encouraged.

Energy savings

The concept of metal recycling can be significantly beneficial to the ecosystem in terms of energy savings. Monitz (2016) reported that the production of iron, steel and aluminium from their respective ores is a highly energy-intensive process; accounting for 10% of total manufacturing energy. While virgin raw materials require temperatures in the neighborhood of 900 ^{o}C, scrap aluminum melts at 660 ^{o}C using the single-process production method known as the Hall-Hèroult process (Nabea and Tiwari, 2012). As shown in Figure1, the energy required for secondary processing (recycling), is much less than that required for processing from raw materials (virgin resources), and hence the valuable resources (oil, coal, etc.) used to produce power are conserved by recycling such that the energy saved by can then be used for other purposes like powering automobiles.

Reduction in CO_2 emissions

Bassey et al. (2016) mentioned that the transport, storage and combustion of coal arising from the conventional coal mining technology for the purpose of production of iron/steel from processed ore generates pollutants such as Sulphur (iv) Oxide (SO_2), Nitrogen oxide(NO_2) and mercury. Thus, as indicated by Rawlings (2002), recycling does not only conserve material and energy resources, but can also minimise environmental pollution which is detrimental to man's wellbeing. Similarly, Nabea and Tewari

(2012) revealed that in Europe for instance, use of recycled metal promotes reduction of about 200 million tonnes yearly of CO_2 emissions. Besides this, use of recycled steel for instance results in 76%, 40% and 86% reduction in water pollution, water use and air pollution respectively. Further, Oloruntoba *et al.*, (2016) did describe metallic aluminium as non-toxic and can be safely recycled. All of these indicate that recycling contributes substantially to the UN agenda of green environment.

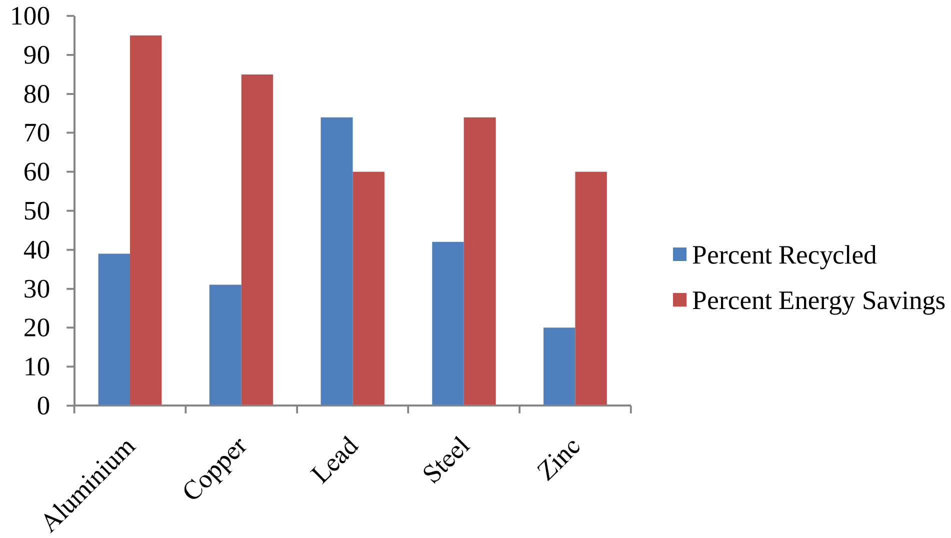

Figure 1. Energy savings derivable from recycling some metals.
Source: Nabea and Tiwari (2012)

Flexibility

Worthy of mention also is the flexibility advantage in this sense of metal recycling since smelting and refining generally take place in designated industrial area unlike mining activities which encompasses; prospecting, exploration, development, exploitation, and reclamation that must of a necessity take place around the mine environment. De la Vergne (2014) did mention as a matter of fact, that the time interval between discovery and actual start of production of a mine in a district where there is previously no established mining activity technically referred to as green field is on the average ten years. Similarly, the time between discovery and actual commencement of construction of a base metal mine is 10 years on the average but this period is less for a precious metal mine. Within this ten years therefore, much more could be achieved driving the economy via material recycling while the ore deposits are conserved.

Employment potentials

Nabea and Tiwari (2012) noted that in industrialized nations such as the United Kingdom, scrap metal recycling promotes industries such as foundries: Scrap from Ferrous materials on one hand averaged around 5% per annum for nearly 2 decades and has been predicted to maintain a steady growth being that metal manufacturing represents one of leading manufacturing sectors which employs more people than automobile and aerospace put together. Amatanweze and Ukoh (2016) linked underdevelopment of many nations of the world to over dependence of crude oil and the absence of viable metal production industry especially of iron and steel in those countries. Sourcing (or more informally scavenging) of secondary materials and transporting same to production vicinity is capable of generating a long convoy of jobs for the overall benefit of our economy. The scrap recycling industry in the United States employs more than 137,000 people (isri.org).This trend is realizable in our nation if all necessary strategies are set in place.

Survey of metal recycling companies in some states in Nigeria

The Figure gives an overview of metal recycling of a few states with Lagos having the highest number of scrap manufacturing companies (including suppliers) of 179 accounting for 50 percent of all the states captured in the data. This is followed by Ogun state which accounts for 37 percent perhaps owing to its proximity to Lagos.

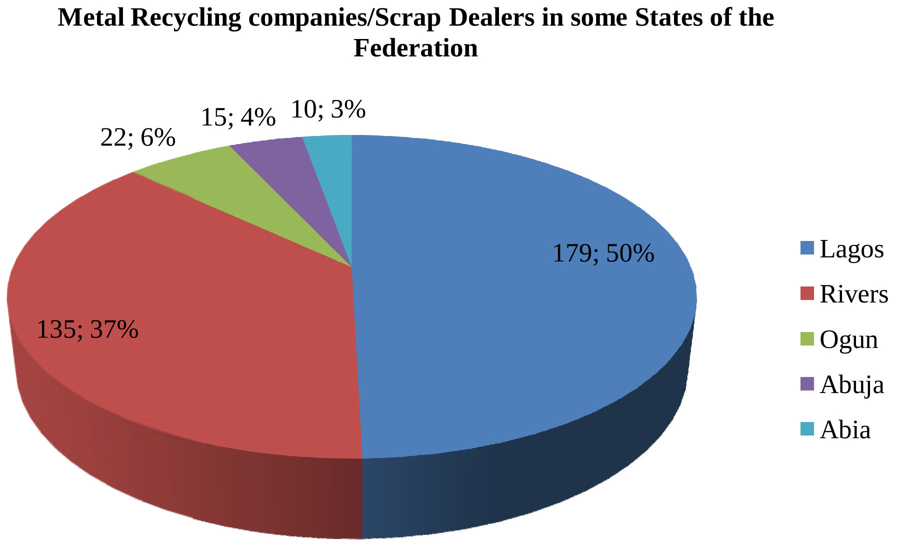

Figure 2. Metal recycling companies in some states.
Source: http://www.vconnect.com/nigeria/list-of-metal-recycling-companies_c70

Economics of metal recycling

In terms of economic life, metals (especially non-ferrous) are perhaps the most recycled. This is a product of economic evolution over the centuries. Non ferrous minerals found in the earth are typically lean (small deposit) and difficult to extract and refine which means that metals produced from the concentrated form (or deposit) are relatively higher in price (Vydra, 2016). Besides, De la Vergne (2014) did also indicate that the amount expended on diamond drilling and exploration development for the purposes of measuring a mineral resource should approximately equal 2% of the gross value of the metals in the deposit. Not this much is expended in sourcing and transporting secondary (scrap) materials for manufacturing. Furthermore, research has shown that for every tone of steel made from recycled steel, 1,115kg of iron ore, 625kg of coal and 53kg of limestone is saved

Environmental impact assessment

In locating a metal recycling plant, environmental impact assessment must of a necessity be carried out. Pacifica and Achieng (2009) defined Environmental Impact Assessment (EIA) as a study of the effects of a proposed project, plan or program on the environment. Emasuen *et al.*, (2011) noted that the philosophy behind an environmental impact assessment is to minimize the adverse effects of man's activity upon the environment. Only a systematic scientific investigation can reveal the connectivity between the various components of an environment. The whole of this process must include baseline information of the study area; climate, infrastructure, energy, water resources, vegetation and land use pattern.

Operational characteristics of mining and recycling

Figures 3 and 4 briefly describe the characteristics of the upstream and downstream operations in the metal manufacturing subsector: Whereas Figure 3 represents secondary material recycling; Figure 4 gives an overview of production of steel from iron ore. It is evident that Figure 4 comprises of several unit operations and is therefore more power and materials consuming. Thus, recycling provides an interim alternative for providing the nation's metal needs in the automobile and other relevant sectors as a way of the mineral resource base conservation for future generations.

Figure 3. Stock pile of scrap metal ready for shipment at Naraguta Jos, Plateau State

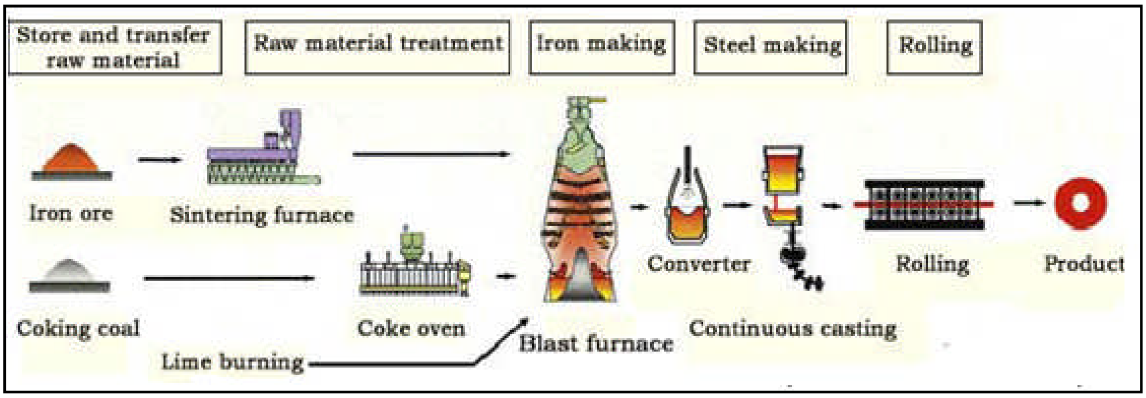

Figure 4: Steel making process from iron-ore:
Source: Lee (2006)

Conclusion

The objectives of the United Nations sustainable development goals 6, 7, 8, 12 and 13 which have been respectively highlighted as clean water and sanitation, affordable and clean energy, decent work and economic growth, responsible consumption and production and climate action could be realised through metal recycling. The review has also shown that the southern part of Nigeria has a larger concentration of metal recycling plants as shown on Figure 2.This may be due to the fact that the southern part of the country is more industrialized with higher quantity of metal scraps generated for use in the recycling plants.

Recommendations

The authors strongly recommend the following;

1. That the Federal Government of Nigeria integrates metal recycling in her national solid minerals development road map.
2. There is an urgent need for government to develop infrastructure such as power, railways and roads in order to encourage individuals and corporate bodies to invest in this money spinning and job creating venture all over the country. This will ease movement of raw materials to the plants and movement of products to the market.
3. Annual turn out of metal produced from scrap materials should be determined by the relevant agency of government. This statistics is needful for future national planning
4. Other sources of financing aside the conventional manufacturing financing (equity and bank loans) methods should be adopted by prospective investors in the domain of metal recycling

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