

IPAT ANALYSIS OF SOLID WASTE GENERATION AND TREATMENT IN SUB-SAHARAN AFRICA AND ITS IMPLICATION FOR CIRCULAR ECONOMY ADVANCEMENT

S. O. Iheukwumere¹, D. C. Onuoha², K. F. Nkwocha³, & C. Ukah²

¹Department of Geography and Meteorology, Nnamdi Azikiwe University, Awka Anambra State, Nigeria/Department of Urban and Environmental Management, Protestant University of Rwanda, Huye, Rwanda.

²Department of Environmental Management, Nnamdi Azikiwe University, Awka Anambra State, Nigeria.

³Department of Geography, University of Maiduguri, Borno State, Nigeria/ Islamic University in Uganda.



Corresponding Author's Email: so.iheukwumere@unizik.edu.ng

Abstract

Improper solid waste management is a significant issue in sub-Saharan Africa, contributing to greenhouse gas emissions and climate change. This study analyses solid waste generation and treatment in sub-Saharan Africa using the IPAT model, highlighting implications for circular economy advancement. The research design is based on a qualitative analysis of existing literature, using secondary data from various sources, including academic journals searched majorly through Google Scholar and ResearchGate, reports from institutions and international organizations. The study examines the impact of population growth, affluence, and technology on solid waste generation and treatment in Sub-Saharan Africa, and explores the potential for waste-to-energy technologies and circular economy practices to address waste management challenges in the region. Solid waste generation in sub-Saharan Africa is driven by population growth, urbanization, and changing consumption habits. The changing consumption habits are partly an effect of improved socioeconomic status. Improvement in socioeconomic status has evidently resulted in more waste generation. Waste generation is expected to triple to 516 million tons/year by 2050. The region's capacity to manage the generated waste is low but gradually improving. The region's population could serve as a market for recycled products, and adopting waste-to-energy technology could bridge the energy gap, saving billions in future damages and fostering a more prosperous future through circular economy principles. Sub-Saharan Africa's rapidly growing population, increasing affluence, and inadequate waste management technologies pose significant environmental, social, and economic challenges to sustainable development. The region's waste management challenges can be addressed by adopting sustainable waste management technologies, investing in waste management infrastructure, and promoting circular economy practices. By transitioning to a circular economy, Sub-Saharan Africa can create new business opportunities, jobs and economic growth while reducing waste generation and environmental pollution.

Originality/Value

The originality of this lies in its application of the IPAT model to analyse solid waste generation and treatment in Sub-Saharan Africa, highlighting implications for circular economy advancement. The study provides valuable insights into the region's waste management challenges and opportunities, offering practical recommendations for policymakers and stakeholders. Its findings and recommendations have significant value for promoting sustainable development and circular economy practices in Sub-Saharan Africa.

Keyword: Waste, Waste Generation, Circular Economy, IPAT, Sub-Saharan Africa.



1. Introduction

Any material or item that the owner discards, plans to discard, or is compelled to throw away is considered waste. Waste is sometimes a subjective concept, because items that some people discard may have value to others. This has brought about changes in the analogy with the saying “one man’s waste, another man’s resources”.

The source of solid waste is not in doubt. They are byproducts of human processes and activities. These wastes by their nature have raised concerns of environmental impacts. Solid waste management has become a critical issue in sustainable development, with nations striving to minimize their environmental impacts (Sharma and Jain, 2020; Ahmad *et al.*, 2024; Akther *et al.*, 2025). Solid waste poses a great challenge with regards to its management and has been identified as one of the major challenges to reaching sustainability targets (Cucchiella, *et al.*, 2017; Bassey *et al.*, 2024).

In order to reduce impacts from solid waste, solid waste management methods, concepts and theories have been put forward. These include concepts like waste reduction, segregation, reuse and recycling as waste management concepts among others. Recently, circular economy has emerged as a waste management with emphasis on a cyclic loop resulting in less waste generation by refurbishing, reusing, and recycling of waste materials. This is based on the consideration that maintaining public health, avoiding environmental contamination, and advancing sustainable development largely depend on effective solid waste management.

While developed nations have advanced frontiers for effective solid waste management, developing nations especially in Sub-Saharan Africa have continued to dwell in outdated means of solid waste management involving generate and dispose tactics. When the world has advanced with principles of circularity in management of solid waste, developing nations are still grappling with initiation of circular economy initiatives. As noted by Folarin (2022), the developed economies have long embraced circular economy as a sustainable waste management option. There is a need for the developing nations in Sub-Saharan Africa to also move quickly in this direction. Using the Impact, Population, Affluence and Technology (IPAT) model as the primary determinant, this study intends to analyse the solid waste generation and treatment situation in Sub-Saharan Africa and emphasise its implications for the growth of the circular economy initiative, excluding other issues such as governance and policy.

2. IPAT Concept Explained

In order to analyse the solid waste management situation in sub-Saharan Africa, this paper employs the use of the IPAT Concept. The IPAT Concept was propounded by Ehrlich and Holdren in the early 1970s (Chertow, 2008). It was initially used to explain human impact on the environment. Ehrlich and Holdren noted that the intensity of any environmental impact (I) was determined by three major factors which are: (P) population, (A) affluence and (T) Technology. Though criticisms were put up against the concept, these criticisms are mainly based on the simplification of various complex processes and relationships of environmental impact, non-inclusion of feedback loops or non-linear effects, difficulty in the accurate measurement of variables.

Despite the criticisms against the concept, several scholars have employed the concept in explaining diverse environmental issues. Razak *et al.* (2015) used the IPAT model to analyze air pollution management in Malaysia. Dietz and Rosa (1997) in an earlier research had applied the model to estimate the effects of population, affluence, and technology on national CO₂ emissions. These

results confirmed the general value of the IPAT model as a starting point for understanding the anthropogenic driving forces of global change and suggest that population and economic growth anticipated over the next decade will exacerbate greenhouse gas emissions.

Zhang, et al (2024) studying energy consumption change in Beijing, constructed the IPAT model of energy consumption change in Beijing, their study breaks down the factors that cause the change in energy consumption in Beijing into population, affluence, and technological progress. Feng (2024), modified the model to more thoroughly analyse the mechanisms affecting environmental pollution in terms of urbanization level and industrial agglomeration. The study further revealed that the study validates the efficacy of the model in examining the relationship between urban environmental pollution and industrial agglomeration.

In addition to several applications of the models, variations have been made too. Silva et al. (2019, as cited by Silva et al., 2021) recently presented the IPAT-e equation as one more variant to IPAT and which has its innovative applicability on the study of publicly traded companies' impact on the environment. Silva et al. (2021) stated that STIRPAT is one of the main variants of the IPAT equation, which scope and efficacy have been widely discussed from the research project oriented by the human ecology structural theoretical setting once initiated by Dietz and Rosa in 1994.

3. Circular Economy Explained

Like other concepts that seek to ensure sustainable development and growth in our communities, the concept of circular economy has gained traction in recent years. Circularity is now acknowledged globally as the most promising solution to our planet's looming sustainability issues and pathway to healing the injuries caused already. A circular economy keeps materials and products in circulation for as long as possible (depicted in Figure 1). It is a revolution to the linear model in which resources are mined, transformed into usable products, and then become waste. A circular economy reduces material use, redesigns materials and products to be less resource intensive, and recaptures "waste" as a resource to manufacture new materials and products. Circular economy emphasizes on waste reduction, design and production of durable products that can be reused, and use of production materials that are recyclable.

According to Fan et al (2019); Fan and Fang (2020), Circular economy refers to a system that aims to minimize the use of energy, natural resources, and waste generation by closing loops of utilities and materials flows. It involves minimizing inputs of raw materials, reducing waste outputs, and reintegrating products into the system when they reach the end of their life. Circular Economy (CE) is a concept that would turn goods at the end of their service life into resources for others, closing loops in industrial ecosystems, minimizing waste and following sustainable methods (Valavanidis, 2018).

The idea of the circular economy is the most current effort towards sustainably integrating economic activity with environmental well-being. Circular economy is an important part of slowing climate change. Defined, deliberate and concise actions must be taken to address the climate crisis, and material recovery has an important role to play. Though circularity does not only focus on output, it is focused on what goes in (input = resources), how the input goes through the system (throughput = processed materials), and how it gets out of the system (output = waste). However, this paper is hinged on waste generation and treatment (output).

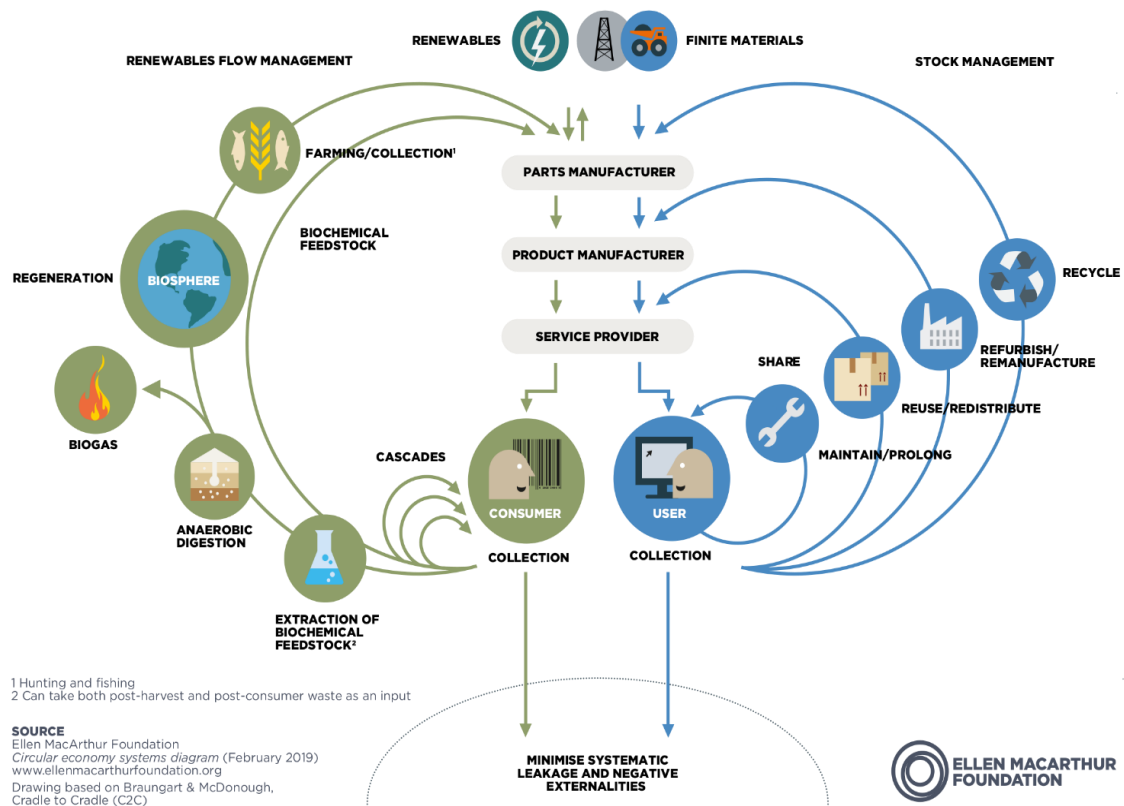


Figure 1: Circular Economy

Source: <https://www.ellenmacarthurfoundation.org/circular-economy-diagram>

4. Geographic Area of Focus

Sub-Saharan Africa is a term collectively describing all African countries below the southern end of the Sahara Desert belt comprised of 49 countries. Sub-Saharan Africa is made of countries in West, Central, East and Southern Africa. The countries in West Africa come under a regional bloc known as Economic Community of West African States (ECOWAS). While the main regional bloc for Central African countries is the Economic Community of Central African States (ECCAS), East African countries have East African Community (EAC) as its regional union. The Southern African Development Community (SADC) is the regional economic community for countries in the southern end of the African map.

ECOWAS countries include: Benin, Cape Verde, Côte D'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mauritania, Nigeria, Senegal, Sierra Leone, and Togo. While Burkina Faso, Mali and Niger have withdrawn from ECOWAS to form a regional alliance known as the Alliance of Sahel States (AES). the following West African countries are in ECCAS comprise of Angola, Burundi, Chad, Equatorial Guinea, Gabon, Cameroon, the Central African Republic, the Democratic Republic of Congo, the Republic of Congo, Rwanda and Sao Tomé and Príncipe. EAC's membership consists of eight states: Democratic Republic of the Congo, the Federal Republic of Somalia, the Republics of Burundi, Kenya, Rwanda, South Sudan, Uganda, and Tanzania. SADC member states are Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar,

Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, United Republic of Tanzania, Zambia and Zimbabwe.

According to Jobarteh (2025) 23 countries in SSA are low-income, 18 are lower middle-income, 6 are upper middle-income, and one is high-income. Jobarteh (2025) noted that in 2023, Sub-Saharan Africa's population was 1.2 billion people and will increase to 2 billion people by 2043. See figure 2.



Figure 2: Sub-Saharan Africa
Source: Tabutin and Schoumaker (2020)

5. IPAT Analysis

5.1. Impact

This refers to the effect of improper solid waste collection and treatment on the environment, such as greenhouse gas emissions and pollution. In developing nations, particularly those in Sub-Saharan Africa, inadequate municipal solid waste disposal and treatment have had serious negative impact on both the environment and public health. The impacts which include climate crisis, disease outbreaks and pollution are worsened by population growth, affluence and available technology for waste treatment (Okorondu, et al 2024; Liao, Lyon, Ying, and Hu 2024; Tal 2025; Njewa, Mweta, Sumani, and Biswick 2025; Population Connection 2026. Angwah and Matsui 2026).

5.2. Population

The environment can be greatly impacted by population size and growth rate, as a greater population tends to result in more resource use and consequently lead to increased waste production. According to UN Habitat, African Clean Cities Platform (2025), waste generation in Africa, like in other

developing regions in the world, is driven by population growth, rapid urbanization, a growing middle class, changing consumption habits and production patterns. The urban population in Africa is increasing at a faster rate than on any other continent (3.5% per annum).

Jobarteh (2025) projected that the population of SSA will increase to 2 billion people by 2043. In 2015, SSA had thousands of urban centres, of which two mega-cities had over 10 million inhabitants, three cities had between 5 and 10 million, and another 41 cities had populations between 1 and 5 million. SSA is experiencing an annual urban population growth rate of 4.1 percent (Saghir, and Santoro, 2018). This growth is a major challenge for understanding the relationship between MSW generation and waste management capacity of waste management agencies in SSA. According to Adedara, Taiwo and Bork (2023), the annual volume of waste generated in sub-Saharan Africa (SSA) increased from 81 million tonnes to 174 million tonnes per year between 2012 and 2016 and is projected to reach 269 million tonnes in 2030. In 2018, SSA's municipal solid waste (MSW) collection coverage was estimated at 44%. Yamauchi (2022), noted that the amount of waste generated in Sub-Saharan Africa is estimated to increase from 174 million ton/year in 2016 to 516 million ton/year in 2050, a threefold increase.

It is essential to note that although Scarlat et al. (2015) also projected that SSA MSW generation would rise to an estimated 172.47 million tonnes per year in 2025, interestingly, this figure had already risen to 174 million tonnes as of 2016 as reported by Kaza et al. (2018). Following the high frequency of MSW generation occasioned by rising population in SSA, the already deficient waste collection systems may further worsen without prompt, adequate remediation measures. Sub-Saharan Africa is experiencing rapid population growth, with the region's population projected to double in the next 30 to 40 years. This growth rate is significantly higher than the global average, with an annual population growth rate of 2.5% in 2022, compared to 0.8% globally. UN Habitat, African Clean Cities Platform (2025) asserts that Sub-Saharan Africa is forecast to become the dominant region globally in terms of total waste generation if current generation trends persist. SSA countries like Nigeria generates over 32 million tonnes of waste annually and it is forecasted to rise to 107 million tonnes by 2050 (Anyago, 2022). While Nigeria's population is projected to reach 400 million approximately by 2050.

In Ghana, the projected population for 2050 is about 50 million (Ghana Statistical Service, 2024). With Ghana's population projected to reach about 50 million by the year 2050, the magnitudes of solid waste generated is anticipated to also surge enormously (Nabegu, 2010; Abdel-Shafy, and Mansour, 2018). In Ethiopia waste generation is projected to rise from 2025 estimated 8 million tonnes to 18 million tonnes by 2050. Ethiopia's population is projected to reach about 225 million from its 2025 figure of about 129 million people (World Bank, 2018; Hirpe and Yeom, 2021; Kazawadi, Ntalikwa, and Kombe, 2021; African Export-Import Bank, 2024)

5.3. Affluence

Affluence affects level of consumption and economic activity per capita. Lifestyle and behavioural changes are easily catalysed by wealth and ability to acquire any desired item. People's spending habits tend to shift as their income rises, which has a greater effect on the amount of waste generated. The more people get wealthier, the more waste they are likely to generate per capita. A World Bank report estimates that 0.51 kilograms of waste is generated daily by each Nigerian (Anyago, 2022). Nigeria's GDP (purchasing power parity) is \$6,340. South Africa generates about 0.63kg per person per day with an estimated population of about 63 million as at 2024 and GDP per capita (PPP) of \$16,000. Ethiopia has a range of 0.25kg to 0.49kg per person per day and a GDP of

\$4,050. While the per capita waste generation rate in Tanzania is 0.45kg per day with a GDP of \$4,130.

Accra Metropolitan Assembly (2022) reporting the research by the Directorate of Research, Innovation and Consultancy (DRIC) of the University of Cape Coast (UCC) on municipal solid waste characterization and landfill emissions in the city of Accra and neighbouring municipalities within the Greater Accra Metropolitan Area (GAMA), stated that the per capita waste generation rate for households, markets and institutions was 0.70kg per household, 1.32 kg per shop and 0.83 kg respectively. The GDP of Ghana is \$6,905. According to the study whilst average per capita generation rates within low-income areas is 0.51 kg, that of their high-income counterparts stands at 0.91 kg; confirming already known trends in which the affluent in society is reported to spend more and thus generate more waste than their urban poor counterparts. South Africa, Ghana and Nigeria with relatively higher GDPs than other SSA countries such as Tanzania and Ethiopia have higher per capita generation rates.

Solid waste generation in sub-Saharan Africa is approximately 62 million tonnes per year and it spans a wide range from 0.09 to 3.0kg per person per day with an average of 0.65kg/capital/day (Hoorweg *et al.*, 2014; Orhorhoro and Oghoghorie, 2019). Waste generation is currently lower in SSA than in the developed world as evident from the per capita generation rate in North America and Europe where waste collection is higher and treatment is in its advanced stage. Having examined the impact of affluence on waste generation and treatment in SSA countries, it is necessary to compare waste generation and treatment between SSA and some developed countries. In 2018, the U.S. produced a staggering 292.4 million tons of municipal solid waste. This comes out to about 4.9 pounds (2.2kg) per person per day (Ehinger, 2024), with a population of about 342,034,432 people (The United States Census Bureau, 2025). Despite representing only 4% of the global population, Americans collectively account for a considerable 12% of the world's waste stream. This startling figure points to consumption and disposal habit that is fuelled by their relative ability to acquire those commodities. United States Environmental Protection Agency (USEPA) (2024) stated in agreement that the amount of waste produced is influenced by economic activity, consumption rate, and population growth. Developed societies, such as the U.S., generally produce large amounts of municipal solid waste and commercial and industrial wastes. Among industrialized nations, the U.S. is one of the largest generators of municipal solid waste per person on a daily basis.

The EU generated 225.7 million tonnes of waste in 2020. People in the EU generated an average of 505 kilograms of waste in 2020. Denmark and Luxembourg were the biggest generators of municipal waste in 2020, with 845kg and 790kg per person, respectively. Close behind were Malta with 643kg and Germany with 632kg (World Economic Forum, 2022). These are significantly above the EU average of 513 kilograms. Akther *et al.* (2025) revealed a positive relationship between GDP, the service sector, and municipal waste, indicating that economic growth and expansion in European countries increase waste. It is therefore obvious that consumption rate rather than population growth is responsible for the disparity in the waste generation rate between SSA and the developed countries. One factor that could account for this phenomenon is the factor of affluence.

Overall, there is a positive correlation between waste generation and income level. By 2050, the amount of waste generated per person is predicted to rise by 19 percent in high-income countries and by at least 40 percent in low- and middle-income countries. At the lowest income levels, waste creation first declines, and as income levels rise, it does so more quickly than it does at higher income levels. By 2050, it is anticipated that the overall amount of waste produced in low-income nations would have increased by more than three times. The majority of the world's waste is produced in the East Asia and Pacific region (23 percent), while the Middle East and North Africa

region produces the least amount (6 percent). The fastest-growing regions, however, are Sub-Saharan Africa, South Asia, the Middle East, and North Africa, where it is anticipated that the total amount of waste generated would more than quadruple, double, and double by 2050, respectively. See Figure 3.

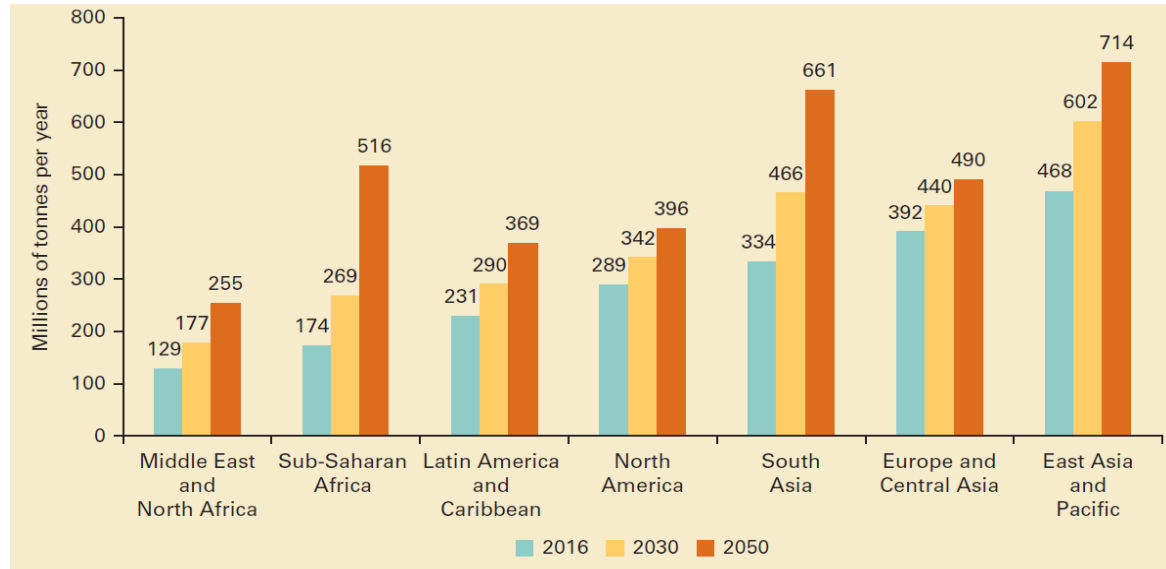


Figure 3: Projected waste generation, by region (millions of tons/year)
The World Bank (2025)

The relationship between affluence and waste generation is complex and multifaceted. Affluent countries have more financial resources to invest effectively in waste management systems than poorer SSA countries. In SSA less than half of the waste generated is collected formally. Waste collection is often non-existent in rural areas. In some SSA countries like Nigeria, waste management is handled at subnational level, making waste management financing a problem for poorer sub-nationals. In Ghana, about 12,710 tonnes of solid waste is generated every day, with only 10 percent collected and disposed of properly (Afriyie and Lusigi, 2022). Douiti, et al (2017) have stated that waste management institutions in Ghana were faced with financial difficulties, understaffing and poor logistics amongst several other issues. The case is no different in Tanzania (Omar and Bullu, 2022) and Nigeria (Akanwa et al 2025).

On the other hand, affluent countries have gone beyond investing in just waste collection systems to investing in waste transforming systems. For instance, countries like United States, Germany, China, Japan and Sweden have implemented advanced waste-to-energy technologies, which allow them to generate electricity from waste while minimizing landfilling.

5.4. Technology

Technology plays a crucial role in determining the environmental impact of human activities. Cleaner technologies can reduce environmental impact, while polluting technologies can exacerbate it. Technology cannot be subtracted in the equation of circularity. At a time when waste is becoming so diverse in its origin and forms, diverse techniques are also required in the collection, treatment, recycling and disposal processes of generated waste. Many cities and towns in Sub-Saharan Africa struggle to offer adequate waste collection, disposal services and treatment due to the crude implements, inadequate sophistication and low technology employed (Ferronato and Torretta, 2019; Kumar, et al 2022; Adedara, et al, 2023). Amidst these issues, population growth, the region's fast

urbanisation and changing consumer patterns have continued to expose the inadequacy of existing techniques and systems.

In sub-Saharan Africa, most of the generated solid waste is burnt at source, dumped in open pits or uncontrolled landfills, where material recovery facility is nonexistent or minimal (Orhorhoro, and Oghoghorie, 2019; AUDA-NEPAD, 2022; African Clean Cities Platform, 2023). Retrieval of perceived useful materials are usually done from waste dumps by artisanal/informal waste collectors (who are usual not recognized or integrated into formal systems by the government), see Figure 4.



Figure 4: Waste pickers at Dandora dumpsite, Kenya

Source: Donovan and Obiria (2022)

In many communities in SSA, waste collection facilities are not just insufficient but inappropriate too. Waste collection systems are often overworked by rapid growth in population, urbanization and waste generation. Trucks loaded with waste head to dumpsites where the wastes are offloaded for incineration or burying. According to AUDA-NEPAD (2022), 19 of the world's 50 biggest dumpsites are found in Africa and are mostly located in Sub-Saharan Africa. However, informal waste pickers have found a way to retrieve recyclables from these dumpsites with inadequate or even no use of PPEs. Collected materials are then sold based on local weighting system to off-takers or local industries for recycling into various products for the local markets. Interestingly, a number of sub-Saharan African nations are gradually initiating and applying improved waste management technologies, leveraging partnership with international and local entities.

UNEP (2017) and AUDA-NEPAD (2022) revealed that Koshe dump site which is the only landfill in Addis Ababa was transformed by the Ethiopian government into a waste-to-energy plant in 2017. The landfill was repurposed and revolutionised to incinerate about 1,400 tonnes of waste materials every day in order to produce electricity. As a result, about 80% of Addis Ababa's trash was recycled into energy, and the city was able to augment about 30% of residential electricity.

In SSA, South Africa has made notable progress by utilizing MSW feedstock, anaerobic digestion, landfill gas, and incineration technologies to generate between 900 kWh and 9 MWh of energy daily (Mbazima, et al, 2022; Umar, et al. 2024). According to Umar et al (2024), South African waste

disposal and management companies have invested in new technologies that can efficiently manage waste collection. For example, these companies leverage user-friendly smartphone applications to facilitate prompt service, extra pickups, and bill payment through push notifications. Consequently, this technology has effectively enhanced cost-effective waste collection costs by simplifying the waste material collection processes. In addition, this technology has introduced automated waste management sensors that trigger instant alerts every time a container is full and needs service.

In 2024, Lagos State Nigeria, signed with Harvest Waste to build a waste to energy plant on a landfill site in the town of Epe about 20km east of Lagos. When completed will have a capacity of up to 75MW. The plant will handle 2,250 tonnes of waste a day, diverting some 95% of the city's waste from landfill (Rogers, 2024; Ibrahim, 2024).

As earlier stated, several sub-Saharan African countries are increasingly adopting sustainable waste treatment solutions. However, beyond the modern sophistication of formal recycling and circularity practices, several small-scale informal recycling hubs exist in SSA. These informal recycling businesses most often deal directly with the informal waste pickers, which is a contributor to the unavailability of data on recycling in SSA. Informal waste recycling has been practiced for a fairly long time in SSA at small scale and rudimentary level. This account for the many pollution incidences attributed to informal recycling activities in SSA. Andeobu, et al (2023), noted that informal e-waste recycling practices are a major cause of environmental pollution in Africa. Abogunrin-Olafisoye and Adeyi (2025) specifically referring to waste electrical electronic equipment asserts that informal recycling practices in Nigeria are characterized by primitive techniques, such as burning and dismantling, leading to air, water, and soil pollution. From situational analysis, it is safe to state that informal recycling in SSA is predominant laden with crude technology. While formal recycling is gradually tooting with advanced technology for material recovery and energy production through incineration.

Waste incineration for energy is popular in Europe, where nearly one quarter of all municipal solid waste is incinerated. France alone has 126 waste-to-energy plants, while Germany has 121 and Italy 40 (UNEP, 2017). In the EU, the share of waste treatment increased from 45.9 per cent in 2004 to 59.1 per cent in 2020. While the share of disposal fell from 54.1 per cent to 40.9 per cent in the same period. In 2020, the share of recycling in total waste treatment was 39.9 per cent in the EU. The recycling rate varied considerably from 5.2 per cent in Romania to 83.2 per cent in Italy. The recycling rate was higher than the EU average in France (54.2 per cent) and Germany (44 per cent), the two leading countries in terms of the highest amounts of waste generated (Yanatma, 2023).

6. Implication for Circular Economy Advancement

Based on deductions from the IPAT analysis, the following are the observed implications of the solid waste collection and treatment situation for circular economy advancement in SSA:

Countries such as Angola, Mauritius, and Cape Verde, heavily relying on landfills (70%, 90%, and 91% full, respectively), face significant economic damage. Angola, for instance, could witness economic damage rising from \$153 million in 2012 to a projected \$1.7 billion in 2060 due to landfill reliance. Additionally, nations with growing populations and economies, including Ethiopia, Nigeria, the Democratic Republic of Congo, South Africa, Tanzania, Madagascar, Mozambique and Uganda, risk economic losses exceeding \$2 billion each by 2060 without improved waste management practices (Folarin, 2022; Debrah, et al 2022; Africa Energy Portal 2023; AR Managing Editor 2023; Dennison, et al 2025).



Waste management facilities such as material recovery and waste-to-energy incinerators are expensive to build, so for companies to make a profit and to recover the investment they need a guaranteed stream of waste. Sub-Saharan African countries like Nigeria, Congo, South Africa, Tanzania, Madagascar, Mozambique, and Uganda are projected to have increasing waste stream capable of feeding material recovery and waste to energy facilities.

Sub-Saharan Africa's population is a large market for international trade. The same population could serve also for well recycled products within the region. High trade volume of recycled products will not only enhance environmental quality, it will preserve the vast resources of Sub-Saharan Africa.

There are subsisting energy issues in Sub-Saharan Africa, therefore, adoption of waste to energy technology will bridge the energy gap to an extent. Sub-Saharan African countries have an opportunity to turn their waste challenges into a sustainable energy solution, saving billions in future damages and fostering a more prosperous future.

The livelihoods of thousands of informal waste reclaimers can be enhanced by diverting waste from landfills and dumpsites to reuse, recycle, and recover facilities. This can also result in the creation of new business possibilities and job opportunities. Unfortunately, the current co-mingling of organic waste with other fractions of waste impedes the possibilities of effective material recovery, recycling and waste to energy. This is compounded by inappropriate and inadequate waste collection facilities, non-inclusion of smart technology in waste collection and treatment.

Non affluent SSA countries usually have low budgetary allocation for solid waste management. The low budgetary allocation's ripple effect then cascades into inability to procure appropriate and sufficient waste collection and treatment facilities, operation of weak organisational structures, operating with less qualified personnel or less manpower, a lack of enforcement, these issues are exacerbated by corruption, low public awareness, conflict, political instability, and a lack of political will are some of the current causes of Africa's poor waste management, especially in Sub-Saharan Africa. A governance breakdown lies at the core of the issue (Godfrey *et al*, 2020).

The review by Maphosa and Maphosa (2020) revealed that lack of policy and limited recycling infrastructures were the main barriers to effective e-waste management. Importantly, policies encouraging private investment in clean waste management practices can lead to economic, social, and environmental benefits. For instance, the Nigerian national government and some sub-nationals have drafted policies towards encouraging individual and corporate participation in circularity. Nigeria has taken deliberate steps and made conscious efforts to promote the adoption of circular economy principles and practices in the country and mainstreaming such into National Development Plans and cascaded to the sub-nationals. These efforts include: drafting of National Policies on Solid waste, Plastic waste and Battery waste Management, Inclusion of the circular economy principles in the revised Nationally Determined Contribution (NDC) (2021), ongoing development of National Policy on E-waste Management and off-grid energy equipment, establishment of the Nigeria Circular Economy Working Group. Interestingly, Nigeria is a member of the Global Plastic Action Partnership (GPAP) and has domesticated the GPAP into the Nigeria's National Plastic Action Partnership (NPAP). Nigeria is in the membership of the Africa Circular Economy Alliance (ACEA). Nigeria has also established and implemented Extended Producer Responsibility (EPR) programmes such as: Food and Beverages Recycling Alliance (FBRA), E-waste Producer Responsibility Organization (EPRON), Alliance for Responsible Battery Recycling (ARBR).

In addition to advocacy for huge investments in material recovery and waste to energy facilities from government and private investors, artisanal recycling in parts of sub-Saharan Africa can be

integrated into formal structures with provisions of subsidies, grants, low interest loans and training. This will provide recyclers with knowledge, technology and equipment for advancing the tenets of circularity. Unsupervised artisanal recycling could harm the environment and defeat the aim for which the principle of circular economy is being advanced.

Landfills contribute to climate crisis and encourage the loss of usable gases. During the decomposition of the landfilled waste, Carbon dioxide, methane, nitrates, and hydrogen sulphides are released, polluting air and water. The environment and public health are greatly impacted by inadequate municipal solid waste management in Sub-Saharan Africa. Sub-Saharan African countries must give waste reduction, reuse, recycling, material and energy recovery top priority in order to address issues of poor waste management. Waste reduction, reuse, recycling, and energy recovery are necessary ideologies to follow to foster green and sustainable economic growth as advocated by the circular economy principle.

7. Conclusion

To guarantee proper environmental preservation and prevent potential additional contamination from poorly managed solid waste, Sub-Saharan Africa must adopt sustainable waste management technologies for collection and treatment of waste. The implementation of sustainable waste management strategies will thereby guarantee the achievement of Africa's agenda, aimed at creating economically and ecologically resilient and sustainable African communities. The IPAT analysis of solid waste generation and treatment in Sub-Saharan Africa (SSA) reveals significant environmental, social, and economic implications for the region's transition to a circular economy. The region's rapid population growth, increasing affluence, and inadequate waste management technologies pose substantial challenges to sustainable development. SSA's population is projected to double in the next 30-50 years, leading to increased waste generation and management challenges. Rising income levels and changing consumption patterns contribute to increased waste generation, with affluent countries generating more waste per capita. Inadequate waste management technologies and infrastructure hinder effective waste collection, treatment, and recycling in SSA. Improving waste management technologies by investing in waste management infrastructure and circular economy practices can create new business opportunities, jobs and economic growth.

Recommendations

- Encouragement of waste reduction, reuse, recycling, and energy recovery through policy incentives, education, and community engagement.
- Considering that SSA's population and waste generation is expected to increase over the next few years, efficient waste collection systems should be built, so as to avoid situations where there's excess waste generated but not enough gets to the recycling chain.
- Governments and private investors should invest in modern waste management facilities, including material recovery and waste-to-energy systems.
- Provide training, subsidies, and low-interest loans to informal waste reclaimers to enhance their contribution to effective waste collection and recycling.
- Collaboration with local and foreign experts including international organizations and countries like Sweden with advanced waste management structure, to share knowledge, technologies, and best practices in waste management and circular economy development.



References

- Abdel-Shafy, H. I., and Mansour, M. S. M. (2018). Solid waste issue: sources, composition, disposal, recycling, and valorization. *Egyptian Journal of Petroleum*, 27(4) 1275-1290, 10.1016/j.ejpe.2018.07.00.
- Abogunrin-Olafisoye, O. B., and Adeyi, O. (2025). Environmental and health impacts of unsustainable waste electrical and electronic equipment recycling practices in Nigeria's informal sector. *Discover Chemistry*. 2(4). <https://doi.org/10.1007/s44371-024-00075-x>
- Accra Metropolitan Assembly (2022). Accra's per capita waste generation rate is 0.70kg per day – Report. <https://ama.gov.gh/news-details.php?n=OTU3NTU5MjUxNXMwNTcwcDYxczhxczFzb3lzc3M0MHI2cHM5NDYw==>
- Adedara, M. L., Taiwo, R., and Bork, H. R. (2023). Municipal Solid Waste Collection and Coverage Rates in Sub-Saharan African Countries: A Comprehensive Systematic Review and Meta-Analysis. *Waste*, 1(2), 389-413. <https://doi.org/10.3390/waste1020024>
- Africa Energy Portal (2023). Africa: From Trash to Power - How to Harness Energy from Africa's Garbage Dumps - and Save Billions in Future Damage. <https://africa-energy-portal.org/news/africa-trash-power-how-harness-energy-africas-garbage-dumps-and-save-billions-future-damage>
- African Clean Cities Platform (2023). Mismanaged Municipal Solid Waste in Africa. <https://www.africancleancities.org/about-accp/africas-waste-problems#:~:text=More%20than%2090%25%20of%20waste,air%2C%20soil%2C%20and%20water>
- African Export-Import Bank (2024 April). Ethiopia Country Brief. Available at: https://media.afreximbank.com/afrexim/Ethiopia-Country-Brief_2024.pdf
- Afriyie, K., and Lusigi, A. (2022). Ghana tackles urban waste management. <https://www.undp.org/blog/ghana-tackles-urban-waste-management#:~:text=With%20rapid%20global%20population%20growth,collected%20and%20disposed%20of%20properly>
- Ahmad W., Hassan M., Masud S. F., Amjad M. S., Samara F., Zeshan, Anwar M, Rafique M. Z., and Nawaz, T. (2024). Socio-economic benefits and policy implications of generating sustainable energy from municipal solid waste in Pakistan. *Energy and Climate Change*, 5. <https://doi.org/10.1016/j.egycc.2023.100124>
- Akanwa, A. O., Chinwendu, E. S., Mbabazi, J., Nshimyimana, E., Okonkwo, A. U., Iheukwumere, S. O., Agbili, M., and Umeora, C.O. (2025). Plastic Footprints and Environmental Implications in Awka, Anambra State, Nigeria: Insights from Rwanda's Policy Framework for Sustainable Solutions. *COOU African Journal of Environmental Research*, 6(2), 161-183.
- Akther, A., Tahrim, F., Voumik, L. C., Esquivias, M. A., and Pattak, D. C. (2025). Municipal solid waste dynamics: Economic, environmental, and technological determinants in Europe. *Cleaner Engineering and Technology*, 24(2025), 1-12. <https://doi.org/10.1016/j.clet.2024.100877>

- Andeobu, L., Wibowo, S., and Grandhi, S. (2023). Informal E-waste recycling practices and environmental pollution in Africa: What is the way forward? *International Journal of Hygiene and Environmental Health*, 252, <https://doi.org/10.1016/j.ijheh.2023.114192>
- Angwah, L. T., & Matsui, K. (2026). A Review of the Impacts of Improper Solid Waste Disposal Practices on Public Health in Sub-Saharan Africa. *Waste*, 4(2), 13. <https://doi.org/10.3390/waste4020013>
- Anyaogu, I. (March 23, 2022). Nigeria's 32m-ton annual solid waste ripe for investments. *Business Day*. <https://businessday.ng/big-read/article/nigerias-32m-ton-annual-solid-waste-ripe-for-investments/>
- AR Managing Editor (2023). Transforming Sub-Saharan Africa's Waste Crisis: A Call for Sustainable Solutions to Save Billions in Future Damages. Retrieved from <https://www.africanresearchers.org/transforming-sub-saharan-africas-waste-crisis-a-call-for-sustainable-solutions-to-save-billions-in-future-damages/>
- AUDA-NEPAD (2022). What A Waste: Innovations in Africa's Waste Material Management. Retrieved from: https://www.nepad.org/blog/what-waste-innovations-africas-waste-material-management#_ftnref12
- Bassey, U., Tom, A., Okono, U., John, M., Sinn, M., Bassey, A., Luke, U., and Narra, S. (2024). Characteristics and management of municipal solid waste in Uyo, Akwa Ibom state, Nigeria. *Sci Rep* 14, 10971. <https://doi.org/10.1038/s41598-024-61108-0>
- Chertow, Marian. (2008). The IPAT equation and its variants. *Journal of Industrial Ecology*, 4(4). 13 - 29. 10.1162/10881980052541927.
- Cucchiella, F., D'Adamo, I., and Gastaldi, M. (2017). Sustainable waste management: Waste to energy plant as an alternative to landfill. *Energy Convers. Manage.* 131, 18–31. <https://doi.org/10.1016/j.enconman.2016.11.012>
- Debrah, J. K., Teye, G. K., and Dinis, M. A. P. (2022). Barriers and Challenges to Waste Management Hindering the Circular Economy in Sub-Saharan Africa. *Urban Science*, 6(3), 57. <https://doi.org/10.3390/urbansci6030057>
- Dennison, M. S., Paramasivam, S. K., Wanazusi, T., Sundarrajan, K. J., Erheyovwe, B. P., and Marshal Williams, A. M. (2025). Addressing Plastic Waste Challenges in Africa: The Potential of Pyrolysis for Waste-to-Energy Conversion. *Clean Technologies*, 7(1), 20. <https://doi.org/10.3390/cleantechnol7010020>
- Dietz, T., and Rosa, E. A. (1997). Effects of population and affluence on CO2 emissions. *Proceedings of the National Academy of Sciences of the United States of America*, 94(1), 175–179. <https://doi.org/10.1073/pnas.94.1.175>
- Donovan, L., and Obiria, M. (June 2, 2022). A toxic trash site in Kenya is making women sick. <https://fullerproject.org/story/women-waste-pickers-kenya-dumpsite-reproductive-health/>
- Douti, N. B., Abanyie, S. K., Ampofo, S. and Nyarko, S. K. (2017) Solid Waste Management Challenges in Urban Areas of Ghana: A Case Study of Bawku Municipality. *International Journal of Geo- sciences*, 8, 494-513. DOI: [10.4236/ijg.2017.84026](https://doi.org/10.4236/ijg.2017.84026)
- Ehinger, B. (2024). How Much Garbage Does the US Produce: A Quantitative Overview. <https://wasteremovalusa.com/blog/how-much-garbage-does-the-us-produce/>

- Fan Y., and Fang, C. (2020). Circular economy development in China-current situation, evaluation and policy implications, *Environmental Impact Assessment Review*, 84. <https://doi.org/10.1016/j.eiar.2020.106441>
- Fan, Y. V., Lee, C. T., Lim, J. S., Klemes, J. J., and Le, P. T. K. (2019). Cross-disciplinary approaches towards smart, resilient and sustainable circular economy. *Journal of Cleaner Production*, 232, 1482-1491. <https://doi.org/10.1016/j.jclepro.2019.05.266>
- Feng, S. (2024). IPAT Model Construction of Industrial Agglomeration and Urban Environmental Pollution in the Big Data Age. *Polish Journal of Environmental Studies*. <https://doi.org/10.15244/pjoes/191605>
- Ferronato, N., and Torretta, V. (2019). Waste Mismanagement in Developing Countries: A Review of Global Issues. *International journal of environmental research and public health*, 16(6), 1060. <https://doi.org/10.3390/ijerph16061060>
- Folarin, O. (2022). Achieving Sustainable Solid Waste Management in Sub-Saharan Africa: The Option of Valorisation and Circular Economy Model. In book *Waste Management, Processing and Valorisation*. https://doi.org/10.1007/978-981-16-7653-6_15
- Ghana Statistical Service (2024, 3rd July). Monthly Press Release. Retrieved from: https://statsghana.gov.gh/gssmain/fileUpload/pressrelease/10_World%20Population%20Day%202024%20press%20release%20from%20GSS_shared.pdf
- Godfrey L., Ahmed M. T., Gebremedhin K.G., Katima J.H.Y., Oelofse S., Osibanjo, O., Richter U.H., and Yonli, A. H. (2020). Solid Waste Management in Africa: Governance Failure or Development Opportunity? *IntechOpen*. Doi: 10.5772/intechopen.86974.
- Hirpe, L., and Yeom, C. (2021). Municipal Solid Waste Management Policies, Practices, and Challenges in Ethiopia: A Systematic Review. *Sustainability*, 13(20), 11241. <https://doi.org/10.3390/su132011241>
- Hoornweg, D; Thomas, L; Otten, L (2014). Composting and its Application in Developing Countries. Urban Waste Management Urban waste management. Working Paper 8, Urban Development Division, Washington DC, World Bank.
- Ibrahim, A. (July 27, 2024). Lagos waste-to-energy plant faces opposition from environmentalists. *Business Day news*. <https://businessday.ng/news/article/lagos-waste-to-energy-plant-faces-opposition-from-environmentalists/>
- Jobarteh, M. (2025) Sub-Saharan Africa. Published online at futures.issafrica.org. Retrieved from <https://futures.issafrica.org/geographic/regions/sub-saharan-africa/>
- Kaza, S.; Yao, L.; Bhada-Tata, P.; Van Woerden, F. (2018). *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*; World Bank: Washington, DC, USA.
- Kazawadi, D., Ntalikwa J, and Kombe, G. (2021) Biowastes as a potential energy sources in Africa. *Intech*
13. <https://doi.org/10.1039/C7RA00172J>. <https://www.intechopen.com/books/advanced-biometric-technologies/liveness-detection-inbiometrics>. <https://doi.org/10.1016/j.colsurfa.2011.12.014>
- Kumar, C., Bailey-Morley, A., with Kargbo, E. and Sanyang, L. (2022) Waste management in Africa: a review of cities' experiences. ODI Working Paper. London: ODI www.odi.org/en/publications/waste-management-in-africa-a-review-of-cities-experiences

- Liao, H., Lyon, C. J., Ying, B., and Hu, T. (2024). Climate change, its impact on emerging infectious diseases and new technologies to combat the challenge. *Emerging microbes & infections*, 13(1), 2356143. <https://doi.org/10.1080/22221751.2024.2356143>
- Maphosa, V., and Maphosa, M. (2020). E-waste management in Sub-Saharan Africa: A systematic literature review. *Cogent Business & Management*, 7(1). <https://doi.org/10.1080/23311975.2020.1814503>
- Mbazima S. J, Masekameni MD, and Mmereki D. (2022). Waste-to-energy in a developing country: the state of landfill gas to energy in the Republic of South Africa. *Energy Explor Exploit* 2022;40:1287–312. <https://doi.org/10.1177/01445987221084376>
- Nabegu, A. B. (2010). An analysis of municipal solid waste in Kano Metropolis, Nigeria. *J. Hum. Ecol.*, 31(2), 111-119, 10.1080/09709274.2010.11906301
- Njewa, J. B.; Mweta, G.; Sumani, J.; Biswick, T. T. (2025). The impact of dumping sites on air, soil and water pollution in selected Southern African countries: challenges and recommendations. *Water Emerging Contaminants and Nanoplastics* 2025, 4, 3. <http://dx.doi.org/10.20517/wecn.2024.71>
- Okorundu, J., Agidi, V., Nwaogu, C., Diagi, B., Ajiere, S., and Alabi, B. (2024). Solid Waste Management Practices in Sub-Saharan Africa and Its Impact on Climate Change and Planetary Health. Doi: 10.1007/978-3-031-72740-5_7.
- Omar, H., and Bullu, S. (2022). Assessment of solid waste management practices in Tanzania's cities. *Global Journal of Engineering and Technology Advances*. 13. 108-119. 10.30574/gjeta.2022.13.1.0180.
- Orhorhoro, E. K. and Oghoghorie, O. (2019). Review on Solid Waste Generation and Management in Sub-Saharan Africa: A Case Study of Nigeria. *J. Appl. Sci. Environ. Manage.* 23(9) 1729-1737. Doi: <https://dx.doi.org/10.4314/jasem.v23i9.19>
- Population Connection (2026). Ten Ways Population Growth Impacts the Environment. <https://populationconnection.org/blog/world-environment-day/>
- Razak, M. I., Norizan, N. S., Kodri A. N. M., Ruslan A. F., Fuzi, S. F., Ramlan, A. F., and Yahaya, F. Y. H. (2015). IPAT Model Analysis for Air Pollution Management in Malaysia. *International Journal of Economics, Commerce and Management*, 3(5), 439-449.
- Rogers, D. (May 28, 2024). Dutch firm to build 75MW waste-to-energy plant in Lagos. <https://www.globalconstructionreview.com/dutch-firm-to-build-75mw-waste-to-energy-plant-in-lagos/>
- Saghir, J., and Santoro, J. (2018). Urbanization in Sub-Saharan Africa: Meeting Challenges by Bridging Stakeholders. <https://www.csis.org/analysis/urbanization-sub-saharan-africa>
- Scarlat, N.; Motola, V.; Dallemand, J.F.; Monforti-Ferrario, F.; Mofor, L. (2015). Evaluation of Energy Potential of Municipal Solid Waste from African Urban Areas. *Renew. Sustain. Energy Rev.*, 50, 1269–1286.
- Sharma, K. D. and Jain, S. (2020). Municipal solid waste generation, composition, and management: the global scenario. *Social Responsibility Journal*, Vol. 16 No. 6, pp. 917-948. <https://doi.org/10.1108/SRJ-06-2019-0210>
- Silva, B. A., Constantino, M., Moraes, P. M., Herrera, G. P., Oliveira, O. S., Santos S. A. L., Kulevich, R. A., Porfirio, G., and Costa, R. B. (2021). Econometric analysis of IPAT-e: A



- new tool for the environmental impact assessment of publicly traded companies. *Environmental Impact Assessment Review*, 89, 2021. <https://doi.org/10.1016/j.eiar.2021.106586>
- Tabutin, D., and Schoumaker, B. (2020). The demography of Sub-Saharan Africa in the 21st century. Retrieved from: <https://shs.cairn.info/journal-population-2020-2-page-165?lang=en>
- Tal, A. (2025). The Environmental Impacts of Overpopulation. *Encyclopedia*, 5(2), 45. <https://doi.org/10.3390/encyclopedia5020045>
- The United States Census Bureau (2025). U.S. and World Population Clock. <https://www.census.gov/popclock/>
- The World Bank (2025). WHAT A WASTE 2.0: Trends in Solid Waste Management. https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html?ref=goodoil.news
- Umar, Y., Yakubu, R. O., Abdulazeez, A. A., and Muzan W. I. (2024). Exploring Nigeria's waste-to-energy potential: a sustainable solution for electricity generation, *Clean Energy*, 8(6). 82–95, <https://doi.org/10.1093/ce/zkae080>
- UN Habitat, African Clean Cities Platform (2025). Africa's Waste Problems. <https://unhabitat.org/african-clean-cities-africas-waste-problems>. Accessed 28/02/2025
- UNEP (2017). Ethiopia's waste-to-energy plant is a first in Africa. Retrieved from: <https://www.unep.org/news-and-stories/story/ethiopias-waste-energy-plant-first-africa>
- United States Environmental Protection Agency (USEPA) (2024). Report on the Environment. <https://www.epa.gov/report-environment/wastes#note1>
- Valavanidis, A. (2018). Concept and Practice of the Circular Economy. https://www.researchgate.net/publication/326625684_Concept_and_Practice_of_the_Circular_Economy
- World Bank (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Available online: <https://openknowledge.worldbank.org/handle/10986/30317>
- World Economic Forum (2022). Circular Economy: Here's how much waste people in the EU produced in 2020. <https://www.weforum.org/stories/2022/02/municipal-waste-european-union-eurostat-circular-economy/>
- Yamauchi, H. (2022). Common Challenges in SWM in Africa learned from survey by JICA. Retrieved from: https://unhabitat.org/sites/default/files/2022/08/Session%282%29-1b_EN.pdf
- Yanatma, S. (October 17, 2023). Italy, Belgium, Latvia: Which European countries are the best and worst at recycling? Euro News. <https://www.euronews.com/green/2023/10/17/italy-belgium-latvia-which-european-countries-recycle-the-most>
- Zhang, Z., Mu, X., and Hu, G. (2024). Analysis of influencing factors of energy consumption in Beijing: based on the IPAT model. *Environ Dev Sustain* 26, 12569–12588. <https://doi.org/10.1007/s10668-023-03900-y>