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Economic Viability of Solid Waste Management For Environmental Sustainability In Kisii Town

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Abstract

Solid waste management (SWM) has potential for economic opportunities whose results take on economic, environmental, and social benefits to the human race. Waste management is imperatively growing challenge in the quest for sustainable urban development. Study sought to assess economic viability of solid waste management for environmental sustainability in Kisii town. Study adopted zero -waste and the circular economy theories and a cross-sectional research design. Data collection methods encompassed questionnaires and interviews using KOBO software. Data from interviews was analyzed using descriptive analysis. The results indicate that there is limited knowledge among residents on usage of solid wastes for economic value with 17% of respondents aware of the economic value of solid waste. Further, results show that 52% respondents were aware of the policies on economic recovery. Knowledge on specific laws guiding economic recovery (plastic recycling, E-waste, composting and biogas) was significantly low at; 37% for women, 36% for youths, and 29% for men. It was established that 83% of youths have a perception that waste is valuable, followed by 70% women and 52% men. Sustainable solid waste management practices and use of solid waste as an economic activity, results indicate that 94% of respondents practiced re-use, 87.7% composting, 58% recycling; other forms of recovery are rarely practiced. There existed few waste-to-resource activities in Kisii town which mainstreamed by the County government could spur the economy of the town. Study recommends that, both the county and national governments prioritise mainstreaming solid waste economic recovery by sensitizing people the value of solid wastes.

Keywords: *Economic viability, circular economy, solid waste management, environmental sustainability.*

INTRODUCTION

Proper solid waste management presents numerous opportunities to avoid adverse impacts associated with wastes. Resource recovery from wastes could enhance; economic, environmental, and social benefits which could foster sustainable urban development. Wastes provide sources of myriad opportunities for sustainable waste management; including composting for bio-fertilizers, energy recovery, employment opportunities to both youths and women, also opportunities for public and private investments as *(Manteaw and Boachie, 2019)* suggests. Poor economic valuation of solid wastes has resulted to huge loses of human and non- human resources in developing countries. The benefits accrued from economically recoverable wastes can propel development of urban areas economically and socially while conserving the environment *(Ogutu et al., 2020)*. Whilst there are challenges of solid waste

requiring attention, there are important economic chances for advancements that need to be grabbed to enable make growth and development of urban areas sustainable. *(Oluoko and Mutisya, 2019).* establish this potential and exploit it for sustainable urban development.
The global SWM outlook focus has shifted from disposal to addressing the problem at the source, through preventing and minimizing its generation, effective governance and adopting economic methodologies geared towards extracting value from waste in a circular economy system to enable sustainable solid waste management, environmental protection and also sustainable urban development *(Ogutu et al., 2020)*. Further, solid waste governance has changed from collection- --transportation and disposal to solve the burden from its source through preventing its generation, methods which are geared towards a circular economy and sustainable SWM thus promoting sustainable development *(Gupta and Goel, 2021)*.

Globally, many developed countries have adopted various waste management practices aimed at economic recovery such as; incineration, landfilling and regulated disposal of waste to find value from the wastes (OECD, 2019). Incineration for heat recovery and composting are desirable outcomes for waste to resources enhancing circular economy; a practice common in Vietnam (Hoang et.al, 2022). Recycling of municipal solid waste especially organic wastes provides opportunities for waste valorization leading to sustainable development (Ferranato et.al, 2018). Globally, 2.01 billion tonnes of municipal solid waste (MSW) were generated in 2016, about 37% of which was disposed of into landfills (Meng et.at 2021). The development of biofuels from waste impacts significantly on current waste treatment within the context of a more circular economy, while also providing low carbon renewable fuels for transport sectors. Municipal solid waste (MSW) has been identified as a useful bioenergy source as it has a high organic content such as paper, garden, and food waste. There is potential for waste-derived fuels to simultaneously address the environmental impacts of conventional treatment processes (Meng et.al, 2021). Sustainable solid waste management with the focus of economic recovery has five steps including: waste composition, waste sorting/segregation especially at source point, waste collection from all collection centres, waste transportation including taking precautionary measures in long distances and waste treatment which includes; composting, anaerobic digestion, incineration, reuse, recycle and safe landfill as the last option *(Ināra, 2017)*.

In developed countries solid wastes bring income in terms of collection fees, transportation, packaging and economic recovery. For example, France receives 12 billion in eco-fees since 1992, financing 73% of the gross reference costs of household packaging collection, sorting and processing operations; Netherlands: 2.5 billion of eco-fees since 2008. Bosnia-Herzegovina: Ekopak has contributed to recycling more than 100 000 tons of packaging waste since 2011. Eco-contributions to all European household packaging EPRs amount to 3.1 billion euros Austria: Around 1.08 million tonnes of packaging and waste paper were collected in Austria from households in 2021, despite the pandemic, the Ukraine war and associated economic effects. 15,000 customers of ARA were able to save remarkable 530,000 tonnes of CO2- equivalents by the recovery of packaging. Portugal: 980 M€ spent in support of municipal selective collection and sorting of packaging waste. Over 70 M€ invested in communication, education and awareness campaigns and over 13 M€ invested in research, development and innovation projects. Belgium: In 2021, thanks to the eco-contributions by the obliged industry, amounting to 200 million euros (€ 17/inhabitant), about 90% of all household packaging in Belgium was collected and recycled (WWF, 2022).

Knowledge on the physical composition is imperative to characterize and classify MSW for its proper management. The main materials in MSW generated by cities in many developing countries do not always comply with the classifications made by USA and EU-based environmental agencies. It was also evident that waste composition varied widely between bigger cities and smaller towns (APO, 2017). For example, organic materials accounted for about 55% of MSW in Kuala Lumpur, Malaysia compared to 63.7% in Terengganu, Malaysia, which has a municipality of about 0.5 million people (Jaafar et al., 2018). In Qatar, solid wastes were mainly organic materials (~60%) and recyclables (~40%) (Rehrah et al., 2016). Gustafsson et al. (2013) reported that the world food loss and waste from agricultural production amounted to 412.9 million tons per year, (Subhashish et al, 2019). Food waste from the kitchen and cafeteria is biodegradable, and as such a system for bio-gasification to useful fuel can be considered for harnessing the biodegradable waste compositions and used as organic fertilizers (Oluwatobiet.al, 2020). In Ecuador, windrow composting is being extensively used to recycle municipal solid waste (organic/biodegradable) for reducing cost of waste management and also used in vegetable culture (Gavilanes-Teran et al, 2016). According to the report of the International Energy Agency, the global demand for energy is developing countries (IEA, 2016). Waste-to-energy is a cleaner mode of energy generation. As it can help avoid the emission of CO2 (from fossil fuels) and CH4 (from landfills), it has widely been adopted on a global scale (Scarlat et al., 2018). Solid waste comprises two-thirds of biodegradable components which can be used to recover CO2 neutral energy while reducing the dependence on fossil fuel (Christensen et al, 2015). The CO2 load involves the direct emission from the unit while CO2 savings account for the materials recovered at the end of the process. On a global perspective, both North America and Europe represented 37.9% of CO2 emission (21.3% and 16.2% for each) due to scientific management of WTE installations while South America with just 5.36% of global WTE units shares 36% of the total CO2 emissions (Subhasish et al, 2019).

Many developing nations cite the dire need to modernize at the expense of environmental degradation. *(Ināra, 2017)*. In the past waste was viewed as a burden to urban communities thus burying and landfilling were the preferred methods of waste management becoming a destination of all wastes whether with economic value or not *(Taelman et al., 2018)*. The polluter pays principle rarely applies in developing countries where waste generators pay for waste collection services as *(Rodic et al., 2018)* postulates. This renders county authorities a high waste collection cost in which they find difficulties to pay dues for solid waste collection due to inadequate funding by the county governments and hence strategies need to be developed for a sustainable *ecosystem (Gupta and Goel, 2021)*. Source-separation and pre-treatment in composting process should be improved leading in an increase the quality of compost products and also have a positive effect on the performance of incinerator. Recycling reduces expenses of collection and landfilling significantly (Abdoli et.al 2016).

In Africa, according to *(Adeleke et al., 2021)*, argues that the cost of managing waste is increasing; there is therefore a need to prioritize and optimize waste management investment obtaining economic value from wastes to avoid overestimation and underestimation of resources. While analyzing waste management in cities of East Africa *(Aryampa et al., 2019)*, underscored that the most significant variables for solid waste management (SWM) are: generation of wastes, collection and disposal which are incapacitated by high number of residents which is ever rising, inadequate collection methods and improper disposal of wastes. These variables depict the inadequate practices employed in SWM practices in the East Africa

Community (EAC) which obstruct sustainable SWM. The Main setbacks to sustainable SWM include generation of enormous amounts of waste and further propelled by limited capacity, transportation, technological knowhow and financial inadequacies that city/town authorities cannot manage. Further, the EAC countries have not aligned their SWM practices to the waste management requirements acceptable worldwide.

In Kenya, the challenge of urban waste on the other hand can present great opportunities to youth and entrepreneurs to rescue the economy battered with COVID-19 *pandemic (Oluoko and Mutisya, 2019)*. Governing SW efficiently in Kenya is extremely important to achieving the right to a clean and healthy environment for all as enshrined in the constitution, improve the economy to create employment opportunities and wealth thus realizing the country's SDGs *(Andole, 2016)*. Additionally, Kenya's sustainable waste governance is key to delivery of the government's "big four" national priorities and for Kenya's blue economy with its aim on spurring economic development, enhancing health water and building safe environment *(Asefi et al., 2020)*. Historically, solid wastes have been viewed entirely as a problem and burden not as a resource and economically viable opportunity *(Taelman et al., 2018)*. Many studies done on SWM in Kenya focus on: generation, collection, transportation, disposal, the current practices, youth and women involvement, challenges of SWM and factors for increased generation and evolution of policies of SWM. The current state of linear fashion of SWM in Kenya from: waste generation, to collection, transportation and disposal at sites poses serious environmental challenges *(Wakhungu and Sunkuli, 2016)*. Also, poor linkage and use of regulations, poor formulation of plans, non- implementations of plans, inadequate budgetary allotment to SWM at local levels, poor cooperation of waste management services and the inability to value waste as a resource to exploit its usefulness are the major problems counties are grappling with in waste management *(Kanda & Cherono, 2020)*. Waste management services in the Kenyan current context predominantly is at the basic stage of: collection, transportation and disposal *(Ogutu et al., 2020)*. Nevertheless, the significance of potential economic value of waste currently is rapidly growing in the minds of urban residents who informally exploit these resources while the urban authorities are yet to. Comparative to the wasteful status quo in Kenya and other developing countries, generating progress presents sound economically viable opportunities *(Romero and Romero, 2018)*.

In Kisii town, residential and commercial buildings are now standing on sites that were previously used for collection or dumping wastes, coupled with the overfilling of the Nyambera dumpsite (Mecheo et,al, 2019). This has resulted in increased indiscriminate dumping of wastes in undesignated areas (along drains, rivers, lakes, and any open areas among others *(Moreka, 2017)*. Thus, the need to develop sustainable methodologies to collect and dispose solid wastes to enhance sustainability and spur economic development of the urban areas through using wastes as resources *(Muiruri et al., 2020)*. Therefore, economically viable activities mainstreamed by the county government in collaboration with other stakeholders could immensely generate income, create employment opportunities and sustainably manage solid wastes in the town, county and country. This study therefore will seek to assess economic viabilities for sustainable solid waste management and urban development in Kisii town- Kenya and other developing countries.

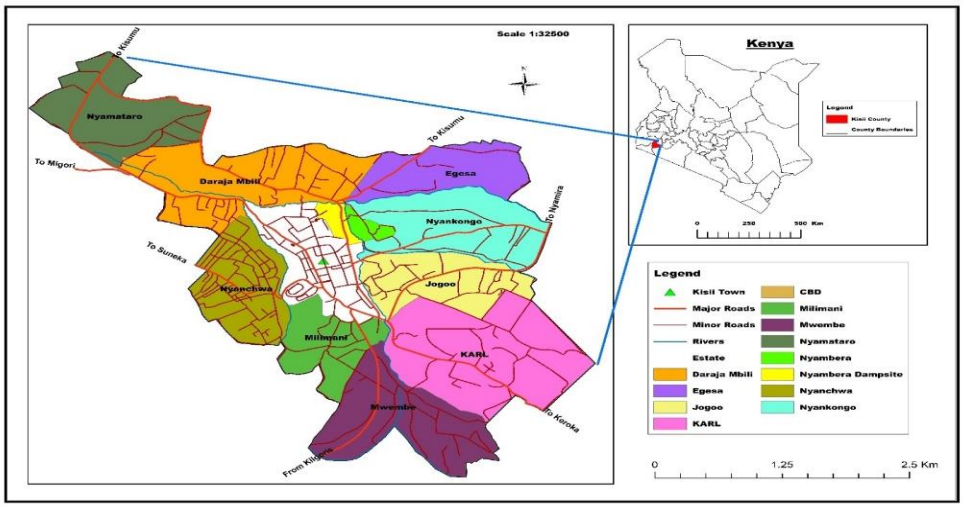
MATERIALS AND METHOD

Study Area

The study was carried out at Kisii town in Figure 1 which lies in Kisii County, Kenya. Kisii County is located in the Southern part of Nyanza region and is bordered by 5 counties with Nyamira to the east, Kisumu to the north, Homabay to the west, Migori south west and Narok to the south. Kisii town is located on Latitude: 0° 41' 0 S and Longitude: 34° 46' 0 E. Kisii is 309 km from Nairobi to the east-southeast. The town is situated at a height of 1,700 m (5,577 ft) asl. The town currently serves as the county headquarters of Kisii County in the larger Nyanza region. It covers 8 km^2 and it has recently sprawled to extend its boundaries by 29 km^2, a total of 37 km^2. The town's siting on highlands enhances growth of varied vegetation cover enabling the hinterland to produce a lot of food crops and vegetation G.O.K (2021). The area majorly receives orographic/ relief rainfall all year round, with two maxima's on April and October. Kisii town mainly consists of volcanic soils which favour the cultivation of cash and food crops. As of 2019, the town had a population of 112,417 (KNBS, 2019) making it the second most populous town in Nyanza region after Kisumu city. The town is the eighth most populous town in Kenya. Among Kenya's urban areas, Kisii town has a relatively high population density of 2,862 persons per km^2 (KNBS,2019). Kisii town is among the most densely populated areas in Kenya after the two cities of Nairobi and Mombasa. The economy of the town currently is obtained from bustling business activities and agriculture. Currently the town is the fastest growing in Western Kenya.

Figure 1

Map of Kisii Municipality



Source: Modified Kisii Topographical Sheet 130/2 G.O.K (2021).

Research design

This research adopted a cross-sectional research design where the variables were observed and analyzed how solid wastes can be economically spurring sustainable waste management and urban development. Both qualitative and quantitative methods were used. This research employed purposive and random sampling. Purposive sampling guided the selection of nth governance focus groups dealing with management and disposal of solid wastes. Random sampling was used to sample the staff working on the various sectors of SWM in Kisii town.

The study targeted governance of SW in Kisii town. Focus groups dealing with management of solid wastes formed the sample size. Using Yamane's formula: $n = N/1+N (e)^2$, the following sample size was determined.

Table 1
Sampling Criteria

Target Population/Focus group	Number of Staff	Sample Size
NEMA Kisii office	4	2
CEC and CO Environment	2	2
Directorate Environment	4	2
Directorate public Health (WM)	8	3
Directorate Municipality	10	4
SWM Staff	175	64
Private Organizations Collection	8	3
Private Organizations Recovery	2	2
TOTAL Total	201	82

Data Collection and Analysis

Data was collected using primary data collection such as questionnaires, use of Key Informant Interviews and observation (Creswell, 2014). Using ODK data was collected from the sample size. Questionnaires and focus group interviews were the preferred data collection tool for the three objectives. Questionnaires were useful in collecting data from waste management officers and SWM staff. Interview schedules were used for the SWM and governance officials. Data from interviews were analyzed descriptively where percentages, and charts were used to present the results. Data obtained from questionnaires was coded and analysis using Statistical Package for Social Science (SPSS), KOBO and excel spreadsheets. These results are presented using bar graphs, tables, pie charts and proportional circles.

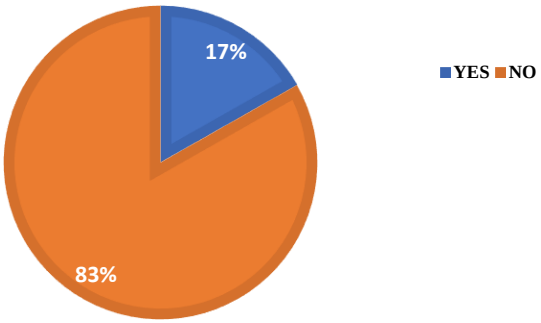
RESULTS

Perception on the economic value of waste in Kisii Town, Kenya

Figure 2

Perception on the economic value of waste in Kisii Town, Kenya

Perception of the economic value of solid waste

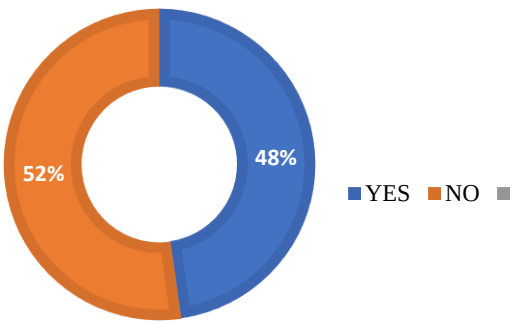


The study sought to determine the study respondent's perception of the economic value of waste. The results are indicated in Figure 2. Accordingly, a majority of the respondents (83%) did not perceive solid waste as having economic value. The results depict that majority of the respondents do not perceive waste being of economic value. This is attributed to the linear approach of waste management prevalent in the town. The respondents cited that they are not familiar that wastes can be as resources since majority of their wastes was mixed. The few who alluded that wastes can have economic value are those who engage in some form of composting, re-use and recycle. Most of the positive responses were from the county officials who have started to engage the public in composting.

Knowledge of policies/plans and agreements on the economic recovery of solid waste in Kisii town

Figure 3

Knowledge of policies/plans/agreements on the economic recovery



According to the research results, 48% of the participants are aware of the policies that support Kisii solid waste's ability to be recovered economically. However, 52% of the sample were

not aware. Those whose responses were yes majorly were NEMA and county officials who are privy to policies, plans and agreements that the county has endeavoured to establish.

Awareness of specific policies guiding economic recovery of wastes in Kisii Town, Kenya

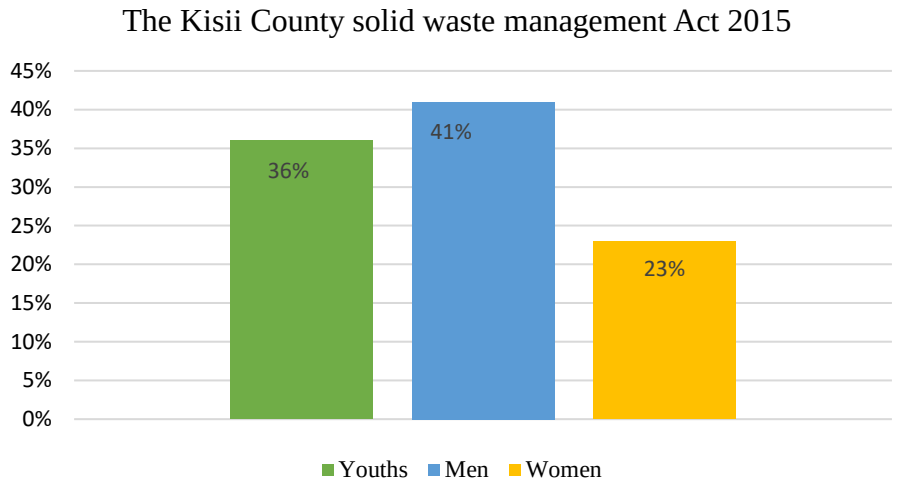
The current study investigated the awareness of the specific laws; Kisii solid waste management act 2015, E-waste recycling plan, plastic recycling policy 2019, composting policy 2022 and biogas as follows:

Awareness of the Kisii solid waste management Act 2015

This study sought to investigate the awareness of the respondents on the Kisii county solid waste management Act 2015 which stipulates the roles of waste collectors, transporters and business activities emanating from solid wastes (article 10 d).

Figure 4

Awareness of the Kisii solid waste management Act 2015



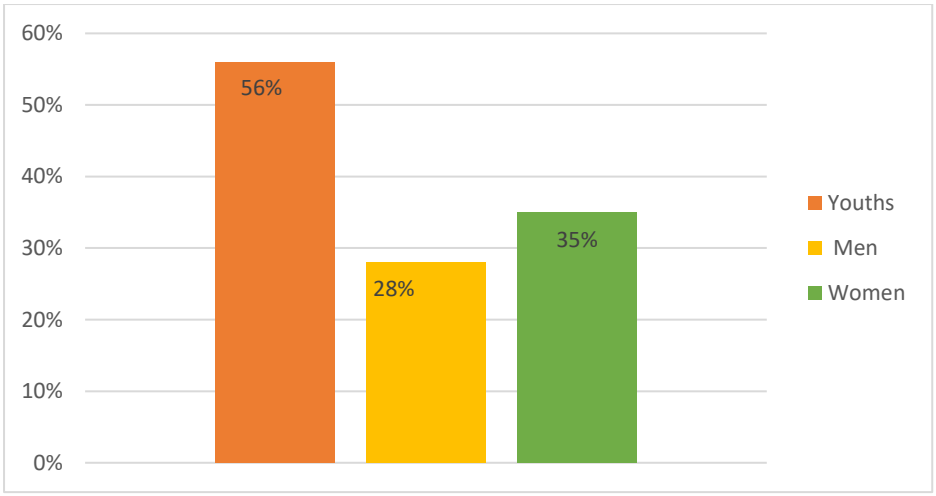
The results indicate that the is more popular to men at 41%, youths 36% and women are aware at 23%. This is shows that seven years after the act was made law still the residents are not conversant with it. The higher percentage of men conversant with the policy is attributed the county officials who formed part of the respondents, similarly some youths working in the waste sector are also informed unlike women.

Knowledge of Kisii county plastic recycling policy 2019

This study investigated the awareness of this plastic recycling policy initiated by the county government in the Kisii county ADP 2018-2019 among the various cadres of residents; namely the youths, women and men.

Figure 5

Awareness of the Plastic Recycling Plan



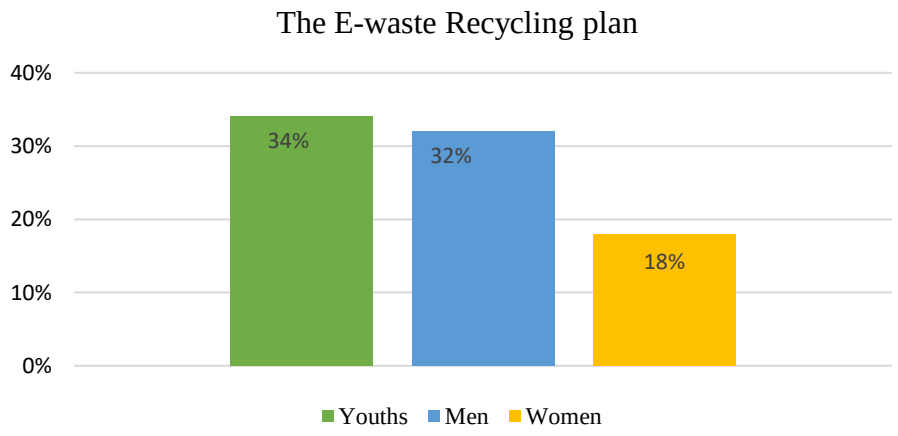
The results indicate that youths are more familiar to this policy than men and women at 56%, 26% and 35% respectively. From the responses obtained, more youths than men and women affirmed that the plastic recycling of 2019 is operational in Kisii ($youths$ 56% > $women$ 35% > $adult\ men$ 28%).

Knowledge of Kisii County E-waste recycling plan

The study sought to determine whether the residents are aware of the E-waste recycling plan initiated by the Kisii county ADP 2019-2020. The plan established by the collaboration between Malaysian government and Kisii county government.

Figure 6

Knowledge of the E-waste Recycling Plan.



The results indicate that this is the least known among the residents. None of the three groups of respondents is aware of the policy to even 40%. The youths are the leading in knowing the policy at 34%, followed closely by men at 32% and women at a distant 18%. Further analysis

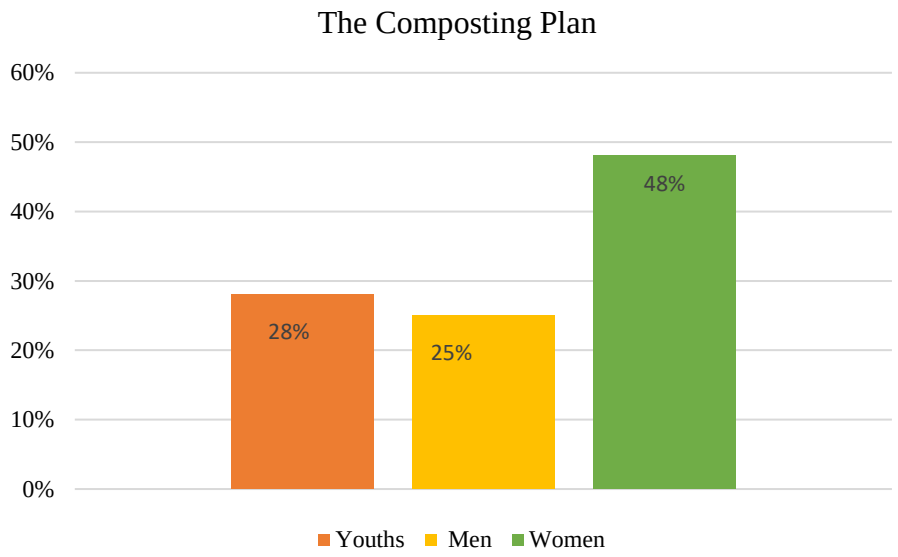
indicates a comparable percentage of youth and men agreeing to the application of the E-waste policy in Kisii town. Notably, the portion of youths affirming this policy is less compared to that of the plastic recycling policy 2019 ($E-waste, youths\ 34\% < plastic\ recovery, youth\ 56\%$). Kisii was the first Town in Africa to have an e-waste recycling plan. That followed a collaborative arrangement between the Kisii County Government, The Kisii University and the East African Compliance Recycling (EACR) to venture into recycling e-waste. In the arrangement, Kisii University provided a collection site while the County Government offered a forklift and baling machines. EACR gave a container in this project aimed at cleaning the environment while creating sustainable livelihoods for locals. This plan is still not known by the residents though it is an economically viable activity if effected.

Knowledge of Kisii County Composting Plan 2023

This study investigated awareness of this current policy according to the Kisii county CIDP 2023-2027 among the residents. This policy was enforced by the newly elected county government with an aim of mainstreaming composting for economic purposes in the county government as a way of solving the heaps of organic waste in Kisii town.

Figure 7

Knowledge of the Composting Plan 2023.



The results indicate that this latest policy is still not popular to the residents. Only women are more informed than youths and men. Women are leading in knowledge of this policy at 48%, while youths and men are less aware at 28% and 25% respectively. This is attributed to more women than men and youths are responsible in handling wastes in the households. The composting programme as enshrined in Kisii county CIDP 2023-2027, sensitization takes place during the day by estate visits of the county government officials. Majorly women are

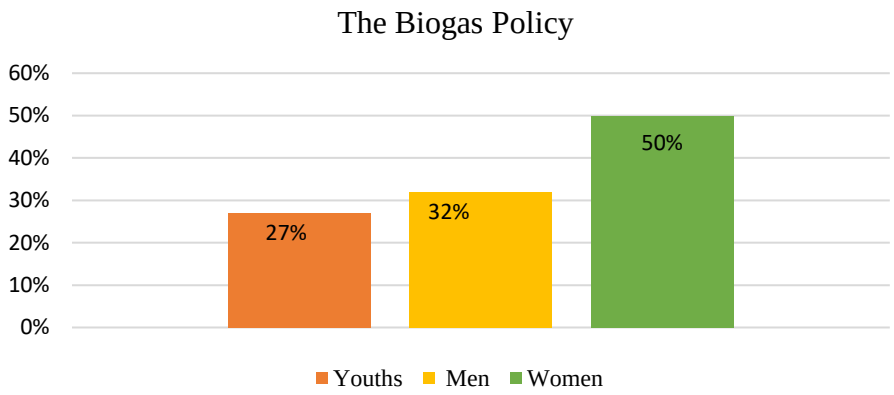
found present including care givers. Thus, their higher percentage of the knowledge of this latest plan by the current county government.

Knowledge of Kisii County Biogas Policy

The biogas policy is enshrined in the Kisii county ADP 2023-2024 which is to take off and production take off. This study This study sought to investigate the knowledge of the respondents about the biogas policy among the men, women and youths.

Figure 8

Knowledge of the Biogas Policy



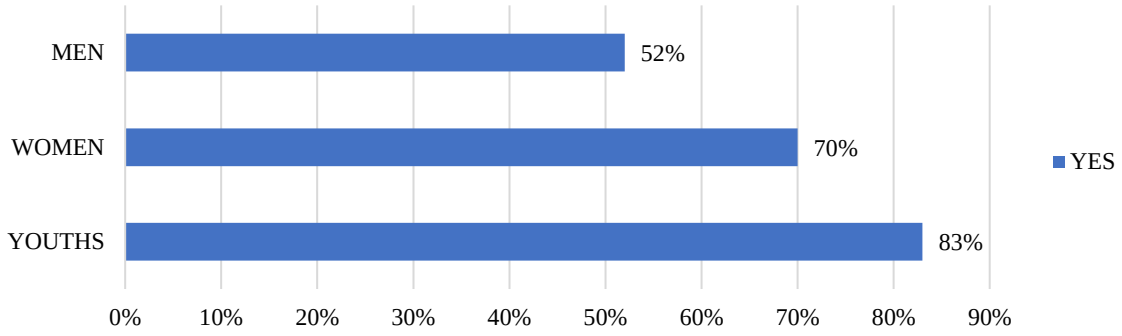
The results indicate that, women are more sensitized on the biogas policy than men and youths at 50% while men and youths are at 32% and 27% respectively. Further analysis indicates, women surpass youths and men in the affirmation of the applicability of the composting and biogas law in Kisii town.

Participants' Perception towards Economic Value of Waste in Kisii Town

It was important for the study to establish if solid wastes have an economic value in Kisii town. The study investigated the responses of three groups to establish their valorization of waste. The participants were categorized as youths, women, and Men as shown in *figure 9* below.

Figure 9

The perception towards economic value of waste in Kisii Town.



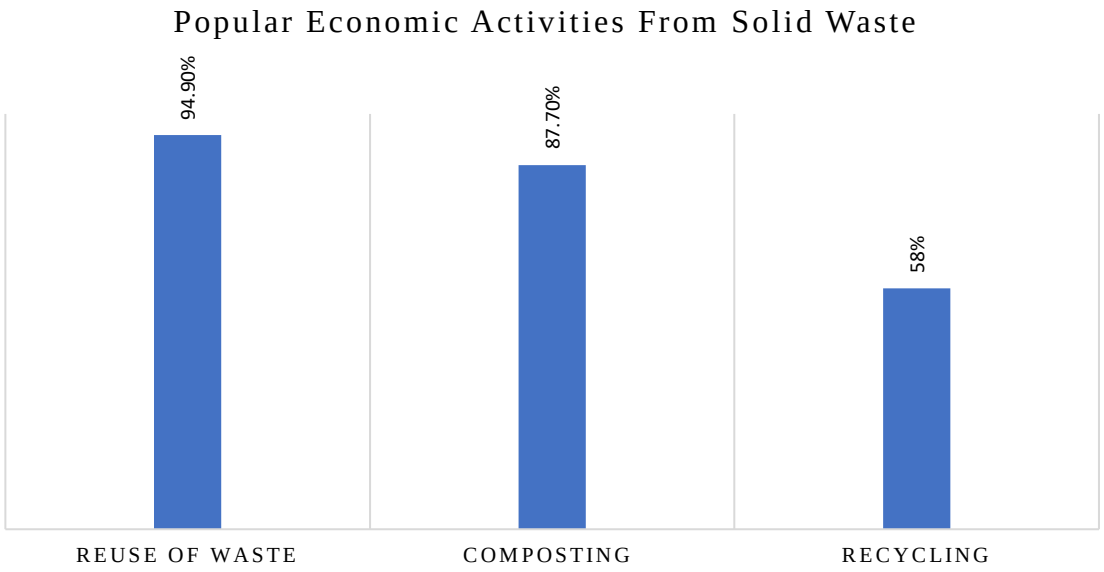
The highest affirmation of the economic value of waste by the youths is because they collaborate with the municipality department in waste sorting, collection, and transportation activities. Kisii town experiences few women who also participate alongside the youth in sorting and segregating wastes for reuse, recycle and composting. The responses obtained from the male respondents represent the views of the adults who once participated in the activities such as sorting wastes for economic value or working directly under the county departments that promote the need to find value in waste.

Popular Practices of Economic Activities from Solid Waste in Kisii Town

From the responses obtained, more youths than adult men and women affirmed that the plastic recycling of 2019 is operational in Kisii (youths 56%>women 35%>adult men 28%). Further analysis indicates a comparable percentage of youth and adult men agreeing to the application of the E-waste policy in Kisii town. Notably, the portion of youths affirming this policy is less compared to that of the plastic recycling policy 2019 (E-waste, youths 34%<plastic recovery, youth 56%). The positive responses regarding the perception of the economic value of waste prompted further research to establish the economic activities that result from waste in Kisii town. The economic activities investigated include reuse, composting, recycling, making granules, making briquettes.

Figure 10

Popular economic activities from waste in Kisii town



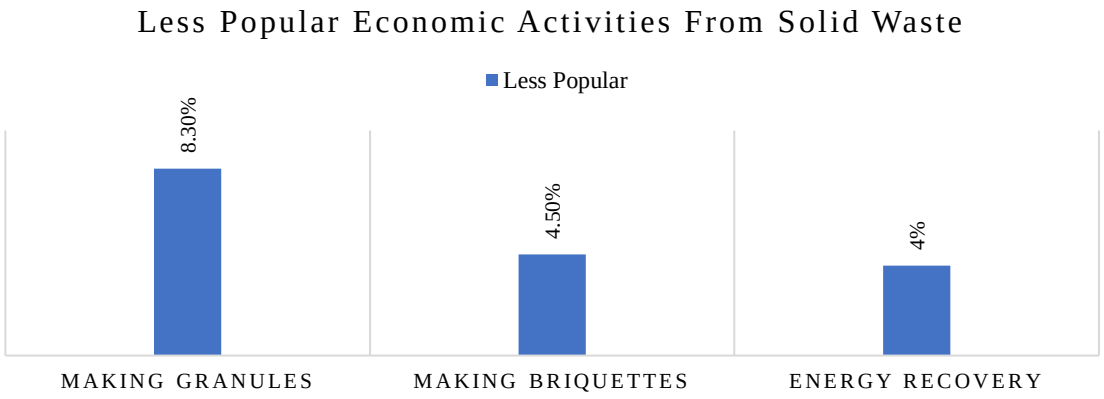
The study found reuse being the most common activity in Kisii town; where plastic bottles were separated from other wastes for reuse at source and at the Nyambera dumping site (94.9%) (**Error! Reference source not found.**). Similarly, composting of waste for other uses h ad an affirmation of 87.7% being championed by the County government administration though its monetary gain has not been valued. Recycling also happens in Kisii town with 58% confirmation from the respondents where some residents, business entities and youths separate metal materials wastes which are weighed and sold to middlemen who transport them outside the county for recycling.

Non-Popular Economic Activities from Solid Waste in Kisii Town

The study established there are non-popular economic activities from solid waste. Kisii town experiences minimal activities related to making granules, briquettes, and energy recovery from waste.

Figure 11

Less popular economic activities from solid waste in Kisii town



The analysis of the responses shows smaller portions affirming the three activities in the order 8.3%, 4.5% and 4% for granules, briquettes, and energy recovery respectively. This indicates that the economic recovery is at rudimentary stages of non-manufacturing. The few who gave positive responses alluded that they have heard these activities and could like to engage in them.

Specific Solid Waste Economic Activities Practised in Kisii Town

The results of the study are presented in Table 3, which is followed by a thorough analysis of the various initiatives being taken in Kisii town to generate income from solid wastes though the monetary value of these activities has not been established.

Table 3

Specific solid waste economic activities in Kisii town

	Policy	Yes %	No %
1	Recycling efforts geared towards generating income and sustainable solid waste management occur in Kisii town.	58.0 ± 2.6^{a}	42.0 ± 5.3^{b}
2	Composting for economic purposes is taking place from solid wastes in Kisi town.	87.4 ± 0.8^{a}	12.6 ± 1.6^{b}
3	Re-use of solid wastes for a sustainable economy is carried out from solid wastes.	94.9 ± 1.8^{a}	5.1 ± 3.6^{b}
4	There is a provision for the use of solid wastes for energy production.	37.5 ± 1.0^{a}	62.5 ± 2.0^{b}
5	The residents have a safe and sustainable disposal method in Kisii town.	13.6 ± 0.7^{a}	86.4 ± 1.4^{a}
	Pearson Chi-Square value (61.475^{a}), $Asymp.Sig.(2-sided) = 0.047$, letters ^{ab} in the same row differ statistically by Chi-square		

More than half (58%) of the research respondents statistically significantly agreed that Kisii town engages in recycling activities aimed at producing cash and sustainable solid waste management (Table 4.5). The survey also showed that composting is another commercial activity in Kisii. Table 4.5's results show that majority (87.4%) of the respondents indicated

that waste compositing is a viable economic activity in their county. Remarkably, majority of respondents had adverse responses concerning the utilization of solid wastes for energy production from energy recovery and safe and sustainable disposal of solid wastes.

Discussion

The results indicate that, only a very small number (17%) of the respondents are aware that solid wastes are used for economic activities while the vast majority (83%) of respondents, claimed that Kisii town does not use waste for economic purposes. The literature underscores that as they build their circular economies, several nations, have institutionalized a culture of the three Rs for sustainable SWM (Hannon and Zaman, 2018). Although Kisii County has made progress in educating its staff about solid waste management procedures, Kenyan rules emphasize the efficiency of waste collection, transportation, and disposal (Ogutu et al., 2020).

It is challenging for the general population in Kisii to understand economic possibilities of solid wastes because of the overall lack of knowledge, the general lack of empowerment on environmental morality and core values, and the negative attitude of the masses toward the treatment of solid waste. According to the research results, 48% of the participants are aware of the laws and policies that support Kisii's solid waste's ability to be recovered economically. However, 52% of the sample population voiced a different opinion on the same issue *(figure 2)*. This can be attributed to waste is not perceived by the public as a resource that may be used due to negative attitudes toward waste management, a lack of public participation, and empowerment regarding environmental principles and ethos.

From the responses obtained, men are more aware of the Kisii county solid waste management act 2015 at 41%, than youths at 36% and women at 23%. This is attributed to men being more knowlgeable than women and youths in laws, acts and bills. Also, there are more men working in the solid waste management sector followed by youths and the least are women. Results further indicate that more youths than men and women affirmed that the plastic recycling of 2019 is operational in Kisii ($youths\ 56\% > women\ 35\% > adult\ men\ 28\%$). Further analysis indicates a comparable percentage of youth and men agreeing to the application of the E-waste policy in Kisii town. Notably, the portion of youths affirming this policy is less compared to that of the plastic recycling policy 2019 ($E-waste, youths\ 34\% < plastic\ recovery, youth\ 56\%$). On the other hand, women surpass youths and men in the affirmation of the applicability of the composting and biogas law in Kisii town. The highest affirmation of the economic value of waste by the youths is because they collaborate with the municipality department in waste sorting, collection, and transportation activities. Kisii town experiences few women who also participate alongside the youth in sorting and segregating wastes for reuse. The responses obtained from the male respondents represent the views of the adults who once participated in the activities such as sorting wastes for economic value or working directly under the county departments that promote the need to find value in waste.

The study found reuse as the common economic activity in Kisii town is plastic bottles separation from other wastes for reuse at source and at the Nyambera dumping site (94.9%). Similarly, composting of waste for other uses had an affirmation of 87.7% being championed by the County government administration though its monetary gain has not been valued. Recycling also happens in Kisii town with 58% confirmation from the respondents where some residents, business entities and youths separate metal materials wastes which are weighed and sold to middlemen who transport them outside the county for recycling. Kisii

town experiences minimal activities related to making granules, briquettes, and energy recovery from waste at 8.3%, 4.5% and 4% respectively.

More than half (58%) of the sample's respondents statistically significantly agreed that Kisii town engages in recycling activities aimed at producing cash and sustainable solid waste management (Table 4.5). Though these recycling activities do not take place in the county and the monetary gain has not been quantified. The survey also showed that composting is another commercial activity in Kisii. Table 4.5's results show that a sizable portion (87.4%) of the respondents indicated that waste compositing is a viable economic activity in their county. Remarkably, 62.5% of respondents said that Kisii County has a rule allowing the utilization of solid wastes for energy production (Table 4.5). However, Kisii County has clear policies and plans that make it possible to collect solid waste for use in the economy (78.5%). Policymakers play an important role in stimulating environmentally sound actions and ambitions from industry, such as commitments to boost the uptake of recycled plastics. A recent example is the European Commission creating, in 2018, the Circular Plastics Alliance which commits to make the plastic model shift from a linear to a circular one. The Alliance gathers key stakeholders of the plastics value chain with the overarching objective of reaching 10 million tonnes of recycled plastics in European products by 2025. A similar collective initiative is the New Plastics Economy Global Commitment, led by the Ellen MacArthur Foundation and UN Environment and signed by more than 250 organizations, to eliminate plastic waste and pollution at source. The targets in the commitment include 100% of plastic packaging being easily and safely reused, recycled or composted by 2025 (Watkins 2020).

Inadequate public participation and workers to enhance the separation, on-source solid waste segregation has resulted to majority of the waste is dumped at the primary dumping site without being properly sorted out in Kisii town (Mecheo, Omondi, Abdirizak, 2019). However, several groups, including youths living on the streets, take advantage of the financial opportunity provided by extracting materials from waste for reuse or recycling (Mecheo, Omondi, Abdirizak, 2019). The gathering, cleaning, and treatment of water bottles to enable their usage in water refilling by small-scale water cleaning and packaging enterprises is a notable recycling operation. However, the reuse principle prevails, with 94.9% of respondents statistically substantially endorsing it in Kisii town (Table 4.5). The non-formal youth organizations and street children are completely in charge of segregating the solid wastes at the dump site, where they not only collect bottles but also turn them into reusable goods and sell to the public for reuse and recycling (Mecheo, Omondi, Abdirizak, 2019). The public buys the cleaned bottles and utilizes them to fetch substances like glue, kerosene, oil, and perfumes. This action has significantly reduced the amount of non-biodegradable solid waste generated at the primary dumpsite, leading to a tendency toward a circular economy.

The survey also showed that composting is a commercially viable activity in Kisii. Table 4.5's results show that a majority (87.4%) of the participants indicated that waste compositing is a viable economic activity in their county. Large amounts of gathered organic waste can be composted to create a useful product as part of a sustainable waste management strategy (Argun, et al., 2017). Composting as a fertilizer substitute has the potential to improve the soil's organic matter content, water permeability, particle-to-particle void ratio, and ultimately water-holding capacity. Correspondingly, the anaerobic digestion process utilized in compositing results in biogas that is high in methane and carbon IV oxide and can be used as a substitute fuel for transportation and cooking. If effectively implemented, these ideas are

essential for creating circular economies (Hoang et al, 2022). According to available literature, the majority of Kenyan laws and policies, however, seem to be geared toward collecting, transporting, and discarding solid waste (Moreka,2017). Because of this, it is unconvincing to claim that county governments in Kenya, including Kisii1, are fully capable of employing technology for financial gain from compositing.

Remarkably, 37.5% of respondents said that Kisii County has a rule allowing the utilization of solid wastes for energy production (Table 4.5). This implies that energy production is not popular to the residents. Similarly, Kisii County's policies and plans that make it possible to collect solid waste for use in the economy are not clearly understood by the respondents (48.5 %). This study has shown that the municipality department works with government organizations like NEMA, the Ministry of Environment and Natural Resources, and international investors to ensure proper management of solid waste, even though Kenyan policies place more emphasis on the collection, transportation, and disposal of solid waste (Kisii county finance act 2021). Available studies indicate the principle of 3Rs is a common practice in the Kenyan context where waste generators focus on the recovery, reuse recycle of the solid wastes generated (Kisii County ADP 2022-2023). Although Kenyan policies focus more on the collection, transportation, and disposal of solid waste, the current study has established that the municipality department liaises with government agencies such as NEMA, the Ministry of Environment and Natural Resources, and international investors in ensuring proper management of solid waste.

The development of biofuels from waste impacts significantly on current waste treatment within the context of a more circular economy, while also providing low carbon renewable fuels for transport sectors. Municipal solid waste (MSW) has been identified as a useful bioenergy source as it has a high organic content such as paper, card, garden, and food waste (Zamri et al, 2021). There is potential for waste-derived fuels to simultaneously address the environmental impacts of conventional treatment processes, while providing bio renewable fuels that avoid land use implications of crop-based fuels. However, achieving financial viability can be challenging, due to the complex composition of wastes and presence of contaminants that may inhibit bioprocesses (enzymatic hydrolysis, fermentation) (Yaashikaa et al, 2020). Comprehensive analyses of the environmental and financial performance of waste-based biofuels are needed to better understand the waste-to-biofuel opportunity, to target technology development, and to inform the role for regulation in encouraging the uptake of viable waste-to-fuel technologies (Hoang et al, 2022).

Utilization of wastes for biofuel production in the UK benefits from significant policy support and financial support for renewable fuels (RTFCs). A positive net present value can be achieved with ethanol production from MSW, but this arises due to the benefit of gate fees by diverting wastes to ethanol production and RTFCs, rather than from revenues from ethanol sales (Meng et at, 2021). As such, the financial viability of ethanol production from MSW is heavily dependent on its competitiveness with other waste treatment options, and on policy instruments, such as the UK's landfill tax, that provide financial disincentive to dispose of wastes in landfill. Comparatively low market value of ethanol at present would favour the bio-production of higher value commodity chemicals from MSW; in future, the strategic requirement for low carbon liquid fuels to meet net zero emissions targets (e.g., aviation, long distance transport) (Oluwatobi et al, 2020). Incineration with electricity generation is an environmental option, because this technology diverts the waste stream from landfill,

eliminates the large number of pollutants and recovers energy from waste (Vertakova et at, 2019). The municipalities intend to generate electricity from old landfill of the city with the help of the private sector (OWM, 2015), this work will reduce the GHG emissions dramatically (Abdoli et al 2016). The characterization qualitative–quantitative analysis of solid waste is the first step in the planning of integrated waste management. Knowing the composition of waste allows for defining the strategies for separation, collection, treatment alternatives such as recycling and composting, thus contributing to divert waste away from landfills (Nolasco et.al, 2020).

While revenue generated through other environmental taxes can potentially finance environmental projects, the fees paid by producers to EPR schemes directly provide financing for waste management infrastructure (WWF, 2020). EPR schemes have been successful in improving separate collection schemes, reducing disposal, and increasing the cost-efficiency of collection and recycling. Modulated fees based on eco-criteria have gained increasing attention in recent years. Such fee systems can have important implications on design, something which has not been achieved to a significant extent so far (Watkins, 2020). By introducing fees based on eco-criteria, producers are encouraged to place on the market products which are more respectful of the environment, preventing damage at the end-of-life phase. Such systems can trigger business innovation, provided that the fees and criteria are properly defined and the difference large enough to trigger change (Watkins, E and Gionfra S, 2020). Circular economy EPR schemes, if properly implemented, can be a powerful tool to drive the transition to a circular economy. This will enable them to meet recycling and collection targets in line with national or European legislation, by ensuring effective end-of-life collection and treatment and promoting reuse and recycling (Watkins, E and Gionfra S, 2020).

People used to look at waste as a nuisance when resources were abundant; fortunately, that thinking is slowly changing now mainly due to the depletion of natural resources. Clearly, there is now a positive trend of seeing waste as a resource. The “resource” perspective depends heavily not only on the volume, but also on the composition, which is closely tied to the socioeconomic status of the population (Dastjerdi et al, 2021). Adoption of incineration, AD and recycling technologies in alternative waste management scenarios instead of landfilling revealed financial benefits. As its cities grow rapidly and strive to achieve world-class status, investment in sustainable urban waste management systems towards a CE model is necessary to create environmentally friendly, livable, and sustainable cities nationwide. The results suggest that treatment of combustible and plastic wastes through incineration, employing AD process for food waste and landfilling of non-combustibles was most economical option (Dastjerdi et. al, 2021).

The increasing environmental awareness, stricter legislation, urban concentration, and population growth have contributed to the evolution of MSWM in China could contribute to waste digitalization in the era of 4IR. It is evident from the literature survey that digitalization is a driving force for China, helping it move towards low-carbon development strategies in the framework of CE. Harnessing digital solutions for the waste recycling industry is a viable solution to strengthen a circular, resource-efficient, and low-carbon economy. In the era of Industry 4.0, digital solutions have the ability to improve waste recycling practices (Kuwiawan et. al, 2022). The gains that had started being seen from the ban of single use plastic will be lost given that the containment measures of the COVID-19 pandemic involve

the use of one-use plastics in the form of PPEs (Kathambi and Obiero, 2022). It's imperative that the Kenyan government view municipal waste management as an essential service so as to find a lasting solution to the management of solid waste management including the used PPEs to avoid adverse effects on the environment.

CONCLUSION

In conclusion, respondents have minimal knowledge that solid wastes have economic value. The results imply that simple majority of residents are not well versed with the laws in place guiding economic recovery. The youths are more involved and are aware of economic recovery than women and men; their perception and engagement in diverse forms of waste recovery is superior to women and men. There are a few strides by the county government in composting as a waste recovery effort though this is at the preliminary stages. Composting faces a challenge of uncooperative residents who do not carry out on-source separation; also, a challenge of odour at the collecting centre at Agricultural Development Cooperation (ADC) land to the neighbourhood. Re-use is common economic recovery practice in Kisii town though it operates amongst informal groups if mainstreamed by the county government can bear great strides towards circular economy. Recycling and other methods of waste recovery for economic purposes are carried out at minimal levels by private organizations. Therefore, there exist few waste-resource activities in Kisii town. These if mainstreamed by the county government to full waste recovery activities could spur the economy of the town and foster sustainable waste management thus promoting circular economy.

RECOMMENDATIONS

This study outlines the following recommendations:

i. Both the county and national governments should prioritise mainstreaming solid waste economic recovery by sensitizing people the value of SWs.
ii. Public education through the media (radio, television, newspapers), banners, posters, public baraza and other methods be carried out to educate the general public SWM, laws, policies and regulations guiding economic waste recovery both at national and county levels.
iii. Promotion of recycling, re-use and waste to energy should be mainstreamed by the county government with adequate public participation and sensitization to enable the residents co-operate to realize economic benefits.
iv. Biomass take off and production and bio-energy production which is on paper should be implemented by the county government in collaboration with the private sector to enhance economic usability of wastes.
v. Finally, composting which has started in the town, should be enhanced to full realization and explore how to mainstream other forms of waste recovery to promote circular economy.

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