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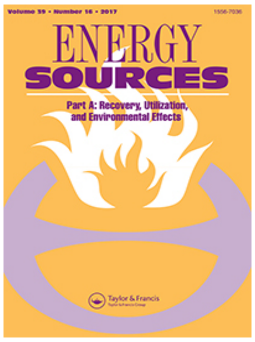


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# Energy recovery from municipal solid waste

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**ABSTRACT**

Kisumu City is fast urbanizing. Implying that challenges posed by improper management of Municipal Solid Waste (MSW) are increasing at both Kibuye market and Kachok dumpsite, within the City. This is a great hazard to inhabitants in terms of health and environment. This far, the City has been concentrating on addressing the issue of inadequate clean water supply, water hyacinth menace, sewerage management, to mention but a few. No special attention has been given to recover energy from MSW. This is very important as it will help to tackle the ever increasing volumes of MSW both at source of generation (Kibuye market) and disposal (Kachok dumpsite) and thus relieve the need for more land spaces for waste disposal, lessen potential methane emission sites and even provide cheap energy to the household(s), available market (s), and City at large.

This paper discusses the potential of recovering energy using available techniques/technologies based on characteristics of MSW in Kisumu City as well as related economics. Various literature reviews, interview-based questionnaire, field survey observations provide evidence for these. The economics of embracing briquetting/palletization technology are briefly reviewed; success of briquetting solely relies on partnering amongst all key stakeholders.

Also, this review offers any would-be investor(s) and/or researcher valuable information needed to invest in other waste management practices and/or glaring information gap that requires further interrogation in form of research.

**KEYWORDS**

Energy recovery; municipal waste management; Kisumu; Kibuye; Kachok



## Introduction

In Kenya, MSW management is a major challenge. A report by the World Bank (Hoorweg et al, 2012) shows that MSW volumes are increasing at an even faster rate than urbanization. This is due to increased consumption that translates into more waste generated. Another researcher (Munala et al, 2017) points to these ever increasing MSW generated in the City.

Kisumu City has several markets but Kibuye market is touted as the largest open-air market in the City and even to the larger East Africa region (Nodalis 2009). Kibuye market occupies about 6 acres of land. The market is divided into five major zones: upper outer, upper inner, central, lower, outside. These zones are further subdivided into other sections/sectors depending on line of trading such as vegetables, fish, cereals, shops, hotels to mention but a few. MSW emanating from these sections can be broadly classified into municipal (commercial and residential), construction, industrial, and demolition wastes as shown in Table 1. The heterogeneity of MSW consists of residues of nearly all materials used by humanity such as food and other organic wastes, papers, plastics, fabrics, leather, metals, glass, and other miscellaneous inorganic materials.

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**Table 1.** Generation rates for various sectors were estimated as follows.

| Sector | Daily tons | Weekly tons |
|---|---|---|
| Industries | 6.5 | 45.5 |
| Markets, commercial zone and institutions | 145 | 1,015 |
| Hospital/clinical waste | 12.5 | 87.5 |
| Others (construction waste, agricultural, dead animals etc) | 11.25 | 78.75 |

Most of MSW from the markets in Kisumu are normally transported to the official designated dumpsite known as Kachok (County Government of Kisumu 2015). Kachok dumpsite seats on an area of about 2.73 hectares. The history of the dumpsite and related details are provided elsewhere (County Government of Kisumu 2015). One major observable characteristic of this dumpsite is that the residents/inhabitants solely practice open-dumping in haphazard way as shown in Figure 1.

The daily generation of MSW in Kisumu is estimated at 400 tons per day (shown in Table 2), out of which a paltry 20% ends up in dumpsites (Julian and Stephanie 2013; NEMA 2015). Indicating that most of the wastes remain uncollected and are strewn all over the environment (County Government of Kisumu 2015). The same report (NEMA 2015) indicates that the quantity of MSW recovered and/or recycled is unknown.

In a study (Maoulidi 2012), many households in the informal settlements use rubbish pits on their plots; others dump wastes along footpaths and in drains due to lack of space for disposal. Some household's open-burn the waste due to inadequate and improper collection mechanisms (Rotich, Zhao, and Dong 2005).

Based on reviewed documents and other reports (Carl 2001), utilization of waste as a resource is not efficiently and properly performed in Kisumu City. In particular, energy recovery from MSW



**Figure 1.** Status of Kachok dumpsite (KISWAMP 2009).

**Table 2.** Kisumu City daily MSW generation and composition characteristics.

| Item | *Generated tons of municipal waste/day | Materials composition % | Annual (tons) |
|---|---|---|---|
| Organic waste | 235 | 63.1 | 85,850 |
| Waste paper | 46 | 12.3 | 16,735 |
| Plastics | 38 | 10.2 | 13,877 |
| Glass | 12 | 3.2 | 4,354 |
| Scrap metals | 5 | 1.3 | 1,769 |
| Others | 37 | 9.9 | 13,469 |
| Total | 373 | 100 | 136,054 |

[a]Includes industrial waste dumped at the city dumping site (Kachok) but excludes hospital waste

has not received much attention as a result of overshadowing with other general issues bedeviling the City. This calls for the integration of the 3Rs (County Government of Kisumu 2015): Reduce, Re-use, Recycle—together with a fourth R added for Recovery in the integrated waste management. According to a researcher (Areba 2010), the fundamental objective of solid waste management is to protect the health of population, promote environmental quality, develop sustainability, and provide support to economic productivity through utilization of waste as a resource. In the City, utilization of waste as a resource remains unexploited.

Kibuye and Kachok being the largest market and official dumpsite in the City, respectively, were selected as case study to assess their potentiality in recovering energy. From a study (Chartered Institution of Water and Environmental Management (CIWEM) 2014), the success of waste recovery must begin at source of generation through proper separation of wastes. More so, field study observations and questionnaire-based interviews shows that Kibuye market is a major source of MSW generation in the City. The objective of this paper is to present potential energy recovery options in Kisumu City based on available data.

## The need for energy recovery from MSW in Kisumu City

The concept of energy recovery means burning waste to produce energy in form of steam, heat, or electricity. In the context of previous studies (US-EPA, 2017), energy recovery ranks below source reduction and re-use/recycling but above disposal. However, not only can energy recovery reduce the volume of solid waste destined for dumpsite disposal, but also recover energy from waste burnt in a confined/controlled household utility device for example cooking jiko (United States Environmental Protection Agency (US-EPA) 2017). Energy recovery will thus be necessary to address the need for managing MSW at the market (the major source) up to dump sites; consequently, reducing the need for more land space for open dumping sites, recover other recyclable materials, reduce greenhouse gases, and even create more employment opportunities in the entire City.

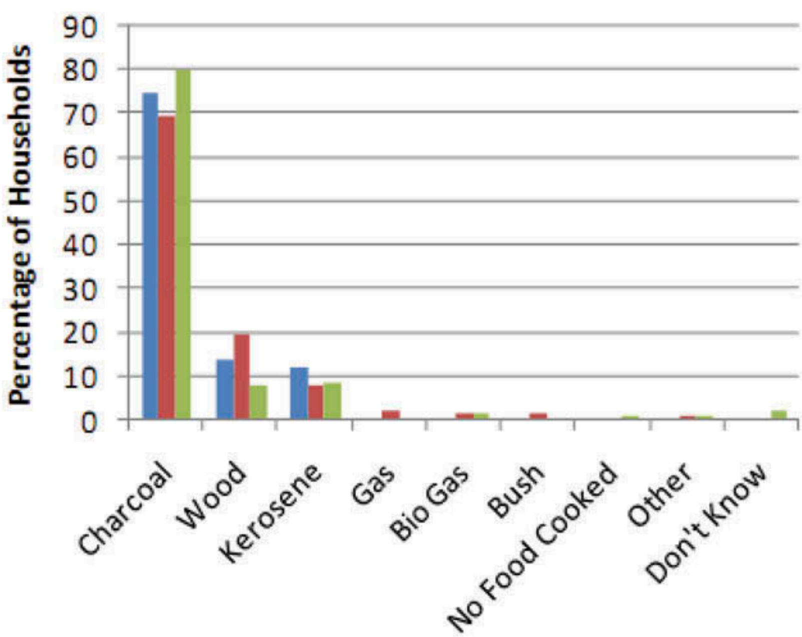


Figure 2. Type of energy used at the household level in the City (Maoulidi 2012).

A research (Maoulidi 2012), indicates that about 74% of the households use charcoal for cooking while about 15% rely on firewood. Figure 2 highlights the type (s) of energy used at the household level in the City. The heavy reliance on both charcoal and firewood is detrimental to both health and environment (Government of Kenya, 2007). Air pollution causes health-related problems while the environment degrades from cutting down of trees to harvest both charcoal and fire/fuelwood. A study shows that women, who form about 50% of the total population, are tasked with travelling long distances in search of firewood (Rotich, Zhao, and Dong 2005). The same study indicates that areas with no or little firewood use cow dung as a fuel. This clearly shows the very dire and great need for an alternative clean energy source, which can be recovered in available MSW.

## Benefits of recovering energy from MSW

The characteristics of MSW as presented in Table 2 help in making sound decision on the best management practice. For instance, the characteristics enable one to categorize MSW into either biodegradables or non-biodegradables. This helps in design of effective programs to divert recyclable and compostable materials from final disposal at dumpsite (County Government of Kisumu 2015). From Table 2, about 60% of MSW in Kisumu City is biodegradable thus presenting best raw material for either energy recovery or composting. However, this paper focusses on energy recovery aspect as this is in-line with the national government of Kenya's Vision 2030 (MOEP, 2014) and national energy policy (Ngusale, Luo, and Kiplagat 2014) to diversify her energy mix. This will reduce the usage of expensive alternative sources of energy such as kerosene and firewood or charcoal which are a major cause of health problems and environmental degradation, respectively (WM, 2010). Secondly, the County's plan to decommission and relocate Kachok dumpsite (KISWAMP 2009) should not be deemed as the best remedy to address MSW problem. This will simply transfer the MSW menace to another disposal site, compounding negative effects on Mother Nature thus hampering sustainable development.

The incorporation of energy recovery in MSW management at Kibuye market and consequently at Kachok dumpsite will help in curbing the need for more dumping sites for waste disposal, reduce greenhouse gas emissions, recovering additional recyclable materials, and even create more employment opportunities for local residents/inhabitants.

### *Greenhouse gas reduction*

The amount of greenhouse gases emanating from the dumpsite in Kisumu has not been quantified yet. This is due to non-existing landfill site in the City as open dumping is main mode of waste disposal (Munala et al. 2017). However, any biodegradable waste emits methane, a greenhouse gas, irrespective of the disposal method used (Waste Management (WM) 2010). The lack of data on amount of greenhouse gas emitted notwithstanding, substantial quantities of methane are generated at Kachok dumpsite. A study carried out at Kachok dumpsite (NEMA 2015) indicates that the human scavengers frequently cough and have respiratory problems. This warrants the need to process MSW through energy recovery rather than disposing as this reduces greenhouse gas emissions by one ton of carbon dioxide per ton of MSW processed (Cheng et al, 2010) . The avoidance of methane gas production in landfills or open dumpsites is appropriate as methane is 21 times more potent as a greenhouse gas than carbon dioxide (Talyan et al. 2007; Warmuzinski 2008). In addition, energy recovered from MSW emits less carbon dioxide than fossil fueled power plants, since 67% of the carbon dioxide emissions from energy recovered from MSW are mostly biogenic (Demirbas 2009).

### *Reduced fossil fuel use*

Recovering energy from MSW reduces dependence on fossil fuel. According to research (Psomopoulos, Bourka, and Themelis 2009), a ton of MSW burned could generate 550 kilowatt-hours of electricity commensurate to avoid the importation of one barrel of oil or the mining of a quarter of a ton of coal. Similarly, energy recovery from MSW reduces the need to transport MSW from one locality to another. This translates to reduced diesel fuel consumption for trucking as well as inter-city traffic congestion that is partly occasioned by the MSW transport trucks.

### Employment creation

According to a study (Central Bureau of Statistics, 2005), the City experiences the highest level of unemployment rate of about 30%. 52% of the population is engaged in informal activities that are characterized by low income and job insecurity. Energy recovery could aid in availing various employable options such as sorting of MSW, fabrication of energy recovery facility (ies), packaging of energy derived products, and even marketing. This will further improve the livelihoods of some City residents in terms of job security, healthy living, and conserved environment.

## Possible energy recovery options

### Biogas production

Biogas production takes place when organic matter is digested by enzymes and bacteria in the absence of oxygen (anaerobic digestion) (Braun, 2007). Based on available data, biogas production is the best energy recovery option as more than 60% of MSW in Kisumu is biodegradable (Munala et al. 2017; NEMA 2015). However, the main challenge lies in meeting the requisite process parameters for biogas production such as temperature, pH value, required Carbon (C), Nitrogen (N), Phosphorus (P), and Sulphur (S) contents.

For temperature, average temperatures in Kisumu range from 23.2°C to 29.4°C annually as depicted in Table 3 (webpage by WMO, 2017). These temperatures are way below the optimum range as either mesophilic or thermophilic operate optimally at 35–40°C or 55°C, respectively (Angelidaki et al, 2010; WEC, 2013).

For pH, bacterium to be used is pH-sensitive and thus a pH range of 6.7–7.5 is recommended (Lisa 2009). The presence of medical/hospital-related waste (s) in the disposed MSW (Munala et al, 2017; NEMA 2015) compromises this optimum pH range.

For C: N: P: S, the right C: N ratio is recommended (Braun, 2007). For instance, too much nitrogen in MSW increases ammonia production which slows down methane production while inadequate nitrogen inhibits the growth of micro-organisms decreasing methane production (Lisa 2009).

Therefore, a biogas system requires waste to be segregated at source. However, currently segregation of MSW is not practiced in the City (Munala et al, 2017). Similarly, maintaining a built biogas system is expensive in terms of operational costs and requisite optimal process parameters.

**Table 3.** Average temperatures in Kisumu in a year (webpage by WMO,2017).

| Month | Temperature range (C) |
|---|---|
| January | 23.8–30.6 |
| February | 24.1–30.8 |
| March | 24.1–30.4 |
| April | 23.4–28.8 |
| May | 22.8–28.2 |
| June | 22.2–27.9 |
| July | 21.9–27.7 |
| August | 22.2–28.2 |
| September | 22.8–29.4 |
| October | 23.8–30.5 |
| November | 23.7–30.1 |
| December | 23.5–29.9 |

### Open burning/incineration

This method significantly reduces solid MSW by 80–85% (Marie et al, 2010). For the City, this method is very expensive and not environmental friendly (Rogoff et al, 2011). Secondly, incinerator system (s) has to be situated on the outskirts of the City thus necessitating the need for transporting the MSW from within the City to incineration site (s). This may further complicate the traffic in the City simultaneously increasing pollutants emitted from diesel-powered transportation trucks. More so, most of the transportation trucks are dysfunctional and/or unroadworthy (Munala et al, 2017).

A study (Munala et al, 2017), estimates that a whopping 2.0 billion of Kenya shillings (Kes) is needed to invest in a viable incineration facility producing about 9 megawatts of electricity in the City. This amount is well above the current City's budget of Kes. 2.5 billion earmarked for all development programs annually (Munala et al, 2017).

### Densification/palletization

This refers to a process of putting together minute and loose waste particles together through a process of compaction. This produces a solid mass of specific shape and/or size which is a fairly uniform fuel that is ready for combustion in an energy utility device. The initial process entails separation/sorting of the energy combustibles to remove the inert and hazardous materials. Thereafter, the sorted materials are either ground or shredded and then mixed with a binder (if need be) then put in a densification device. The densified material is then sun-dried and transported or used at the point of production. Briquetting transforms MSW from a loose low density particle (s) in to a tightly bound rigid product of higher density value. The final rigid product can thus be easily handled and/or transported without disintegrating (Ngusale, Luo, and Kiplagat 2014). In a study (Velis et al. 2010), briquetting MSW achieves an increased calorific value and density of MSW. Potential benefits of briquetting include massive reduction in volume of materials, production of tangible product, increased ease of transport and economic activities with employment creation (Ngusale, Luo, and Kiplagat 2014). The techniques required for briquetting are not sophisticated as such and the facility for briquette production can be readily fabricated from locally available materials (Ngusale, Luo, and Kiplagat 2014). For the City, this will be the most viable waste to energy technology to begin with to curtail the ever growing MSW menace right from the household level up to the City level.

## Economics of energy recovery options

Generally, most energy recovery options require a huge amount of starting capital (Nickolas et al, 2013). However, the most abundant fraction which is organic in nature can be successfully utilized in waste to energy options for significant environmental benefits (Bernice et al. 2016). Briquetting can help ease the heavy dependence on charcoal, firewood, and even kerosene in urban and peri-urban areas in Kisumu at the same time providing a cheaper source of energy (Njenga et al. 2013b). The long distance (s) women have to traverse in search for firewood will be curtailed as they will embrace use of briquette for cooking and heating at household level. This avails an enabling environment for engaging in an alternative income generation venture thus making women more economically independent. Moreover, a study reveals that women spend 3–7 h per day near cooking devices preparing meals with their young children hovering around (WHO, 2011). This exposes both women and children to indoor smoke emanating from open fires utilizing firewood and/or charcoal, responsible for 39% and 12% annual deaths due to chronic pulmonary diseases in women and men, respectively (Rehfuess 2006). A clean burning briquette could help mitigate these deaths. For instance, a study indicates that the use of charcoal briquettes can contribute to the reduction of over 50% deaths of children below 5 yr due to pneumonia (WHO, 2016). Furthermore, charcoal briquettes form no soot under cooking pots in comparison to both charcoal and kerosene (Bernice et al. 2016); this reduces both time and water used for cleaning the cooking pots saving a great deal of resources.

## Conclusion

Challenges in the implementation of energy recovery options in the City are bound to be met. This includes environmental, economic, and social challenges. However, this calls for multi-disciplinary engagement of all stakeholders to curtail the normal public dissonance against energy recovery options being implemented in the City. This can be addressed as follows: energy recovery options do not compete with renowned traditional practices, in essence, they complement each other. The sorting out of materials for energy recovery ensures homogeneity in the fuel to be produced. MSW materials such as metals, glass, and other non-combustibles are removed prior to ant energy recovery option taking place. This mainly helps in improving the fuel characteristics of the remaining MSW. On the other hand, a study concluded that the overall individual cancer and non-cancer risks related to disposal in dumpsites was five times higher than the risks related to energy recovery options (Moy 2005).

Similarly, recovering energy from MSW at Kibuye market will substantially reduce the waste to be taken to Kachok dumpsite or any other dumpsite. This will help hamper the need for more land for MSW disposal as even the decommissioning and relocation of Kachok dumpsite to other areas is not easy.

For briquetting, success in briquette production and utilization lies in consistency of production, quality, and appropriate technology used. This thus calls for strong engagements of main stakeholders such as county government (s), waste generators, financiers, and others within the briquette value chain. This will enhance development of an all-inclusive policy framework that captures the needs and aspirations of all the stakeholders.


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