Waste to Energy in Kathmandu Nepal – A Way toward Achieving Sustainable Development Goals

Abstract

The Sustainable Development Goals (SDG) explicitly focus on responsible use of resources, production, and consumption, which comprises sensible waste management includes SDG 3, 7, 11 and 12. Yet, gaps between policies and current waste management practices are prevailing globally as well as nationally. This article discusses waste management (WM) in Kathmandu Metropolitan City (KMC) with a focus on cleaner technology. Waste management has always been an issue in KMC with almost all wastes being dumped directly to a landfill site. The article aims to points out challenge with current waste management based on literature- and document reviews. Further, it introduces and analyses technologies to convert waste into energy and evaluates the applicability of the Asian Develop Bank recommendations for waste management in KMC and suggests strategies towards aligning KMC waste management with Nepal's SDG agenda. Findings indicate that Kathmandu has huge potential for implementing waste to energy technologies, and anaerobic digestion seems one of the most promising technologies . Yet, the city lacks a proper waste treatment infrastructure and would benefit from a systematic alignment of technology, policy and environmental possibilities and challenges in both analysis, planning and design.

Keywords: waste management, landfill gas recovery, anaerobic digestion, methane, Sustainable Development Goals (SDG) ,

1. Introduction

Kathmandu Metropolitan City (KMC), with an area of nearly 51 km^2, is the largest municipality in Nepal and its economic center (Figure 1). It has the largest agglomeration of buildings in Nepal and has undergone rapid growth in the last few decades. Being the capital of the country, the job opportunities, quality education needs, and opportunities for business are some of the reasons the population of Kathmandu has rocketed in last few years and this trend is likely to continue in the near future. According to Central Bureau of Statistics (CBS) the population of KMC has increased from 671,846 in the year 2001 to 1,336,002 in 2019. The total number of households is estimated to be about 0.27 million while the population density is 26,196/km^2 (CBS, 2014, CBS, 2019). The rapid urbanization, change of lifestyle, economic activities and the population increase has not only resulted in increased urban development but has also caused serious impacts on the environment due to increased resource consumption, waste generation and air and water pollution.

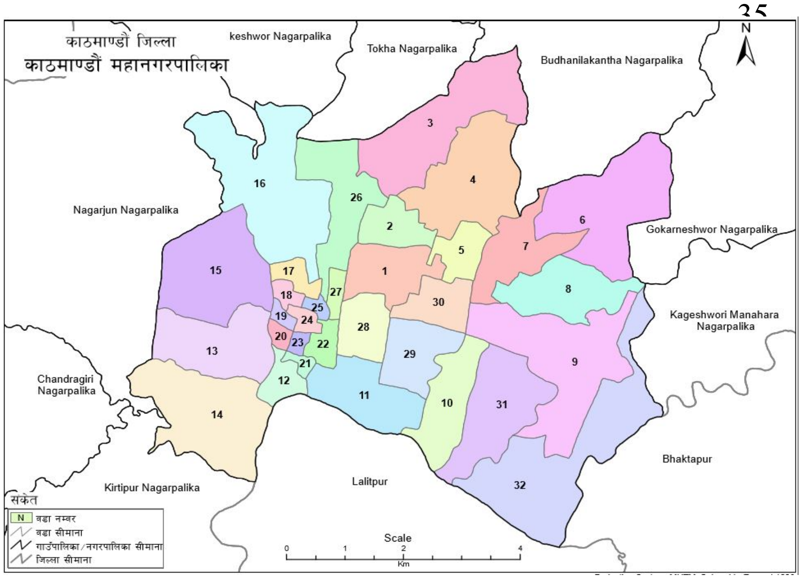

Figure 1. Geographical view of KMC (KMC, 2020)

The increase in the population of Kathmandu has led to the generation of huge volumes of solid waste that urgently needs to be sustainably managed. The Solid Waste Management (SWM) Act 2011 states that the local government is responsible for managing the solid waste in a systematic and effective way. Approaches involve implementing 3R principles, including reducing wastes at their source and reusing and recycling materials, and maintaining a clean and healthy environment through the reduction of adverse effects (SWM Act, 2011; UDM, 2015). Besides, the constitution of Nepal 2015 (2072 BS) also declared that the local government should be responsible for the management of municipal solid waste. This, has not, however, been carried out properly. In this study, scientific literature and public/legal documents on the KMC waste generation and management practices,were reviewed and available waste to energy (W2E) technologies were anaylized. Further,the applicability of the Asian Develop Bank (ADB) recommendations for waste management in KMC was appraised and and strategies of KMC waste management aligning with Nepal’s SDG agenda were suggested. In addition to that, an appropriate W2E technology has been identified considering available data and facts and the W2E potential of the city has been estimated.

2. Solid waste generation in Kathmandu Valley

Municipal Solid Waste (MSW) generation in Kathmandu can be divided into three different categories namely household, commercial and institutional. The average municipal solid waste generation rate in Kathmandu is estimated as 0.32 kg/capita/day (ADB, 2013). The estimated daily waste generation and the composition is given in Table 1 and 2, which shows the solid waste generation in Kathmandu valley has been increasing from 321 tons/day in 2011 to 440 tons/day in 2018. The growth of waste generation that can be observed in Table 1 is attributed to the growth in population since the per capita waste generation is considered as same as reported by other studies conducted (CBS, 2019). Table 2 shows that the composition of organic waste is consistently about 60% that is about 264 tons per day organic fraction of municipal solid waste (OFMSW) was generated only in KMC in 2018. `

Table 1. Municipal Solid Waste generation in KMC (CBS, 2019; Sodari and Nakarmi, 2018)

Year	Waste generation (tons/day)
2011	321
2012	334
2013	348
2016	409
2018	440

The average composition of the waste in the years 2004 to 2016 is shown in Table 2. In all these years organic waste is the dominant one in MSW (about 60%) followed by plastic wastes and papers (Table 2) (ADB, 2013; Singh et al., 2014; Dangi et al., 2009) thus it would be reasonable to assume that the composition is nearly same in these years. The composition of household, commercial and institutional waste varies relative to each other. For example, organic and plastic fractions in the household sector are 66% vs 22%, in the commercial sector are 43% vs 12%, and in the institutional sector are, 21 vs 22%. Therefore, it is important to develop strategies in managing the waste from different sectors differently. Furthermore, as seen from the trend from 2004 throughout 2016, the majority of wastes of Kathmandu is organic and it can be safe to assume that this trend will follow in the future as well.

Table 2. Composition of Waste in Kathmandu Valley (Dangi et al., 2009; ADB, 2013; Singh et al., 2014; UDM, 2015; CBS 2019)

Waste (%)	Moisture (%)	2004	2005	2007	2009	2013	2016
Organic	70	67	70.9	71	65.3	56	63.2
Plastics	5	16	9.2	12	11.2	16	10.8
Paper	20	10	8.5	7.5	9.3	16	9
Textile	-	4	3	0.9	2.4	1	2.3
Rubber/Leather	-	0.4	0.7	0.3	1.2	1	1.2
Metal	-	1	0.9	0.5	0.4	2	0.4
Inert	-	1	4.3	5	4.6	-	4.5
Glass	-	1	2.5	1.3	5.6	3	5.4
Others	10	0.2	-	0.7	-	4	1.2

3. Solid Waste management Practices in Kathmandu Valley

3.1. Past and present scenario of collection and disposal

In the Kathmandu valley the waste generation figures indicated in Table 1 have increased as the population has increased. The Solid Waste Management (SWM) Act 2011 (SWM Act, 2011) and Local Government Operation Act 2017 (Local Government Operation Act, 2017) state that the source segregation of solid waste and local government is responsible for the management of the solid waste in a systematic and effective way. While the act was designed to tackle the problem at a grass root level, it had failed to do so as reflected by the non segregated mixed waste dumped in a landfill site without recovery and recycling etc. Moreover, the reason behind the failure to implement the act could be the lack of willingness of the local government and thus lack of gaining the trust from the residents. Besides, there are frequent power struggle between local and central government. Whether the people segregate the waste or not, the collector mixes all the waste in a same truck and dumped in a landfill. There are no any innovative and effective action plan and practices initiated by local government that could gain trust of the residents. The practical problems to implement the act effectively are manifold, the steadily increasing volume of the solid waste, the lack of technical expertise at the local level, inadequate support and tools provided by national government and lacking the implementation capacity to successfully handle waste management (Dangi et al., 2017).

KMC has been offered support from different donor agencies for dealing with SWM. The German aid project was carried out in four phases from 1978 to 1993 and saw the establishment of a waste transfer center in Teku with a capacity of 15 metric tons per day and a Solid Waste Management and Resource Mobilization Centre (SWMRMC later named Solid Waste Management Technical Support Centre - SWMTSC) which now has been scrapped. The Japanese project established a temporary landfill site at Sisdole in 2005 as temporary landfill site for the operation of two years. However, it ended up being a permanent dumping site and is still accepting the majority of organic fraction of municipal solid waste (OFMSW) from the Kathmandu valley although it reached its maximum holding capacity long ago. Yet, despite international support KMC has not succeeded to establish coherent waste management practices.

In 2007 KMC decided to construct a permanent landfill at Banchare Danda in Nuwakot district 13 years ago. This construction has not yet been completed (Dawadi, 2018; Satyal, 2018;THT, 2017).

In 2017, a bio-methanization plant was set up in Teku, with the support from the European Commission and the government of Nepal and has a daily capacity to convert 3 tons of OFMSW into biogas. However, after the initial months of operation the plant has stopped functioning due to managerial and technical reasons.

Besides OFMSW, 40% MSW can be recycled and reused. This is mostly done by informal scrap dealers such as Kabbadiwala (Figure 2 and 3) (Luitel and Khanal, 2010; Pathak, 2013; Pathak and Mainali, 2019). The government municipal waste management service serves around 60% of the urban population, while private sector and NGOs manage 30% and the rest (10%) is handled by informal waste handlers (Dangi et al., 2017). An estimate shows that about 250 tons of recyclable

Figure 2. Door-to-door private waste collector

Figure 3. Informal Scrap Dealer

and reusable material are recovered daily by the private recyclers without any formal recovery or recycling programs and this has an economic value of nearly US$ 18 million annually in Kathmandu valley (Pathak and Mainali, 2019). Private waste companies such as Doko Recyclers and Khalisisi are filling the waste management gap and are even handling e-wastes and hazardous wastes that the government has failed to manage (Azoulay, 2018, Fleat-Asin and Munoz 2021).

3.2 Waste Management Act and Policy Framework

Various act and policies have been enacted in Nepal regarding solid waste management since the first act enforced in 1987. Since the waste collection, storage and disposal was centrally controlled until local self-governnance act 1999 (Local Self-Governance Act, 1999) was introduced, which for the first time authorized responsibility to local government (village committee and municipalities) to manage the waste in a decentralized way (Figure 4).

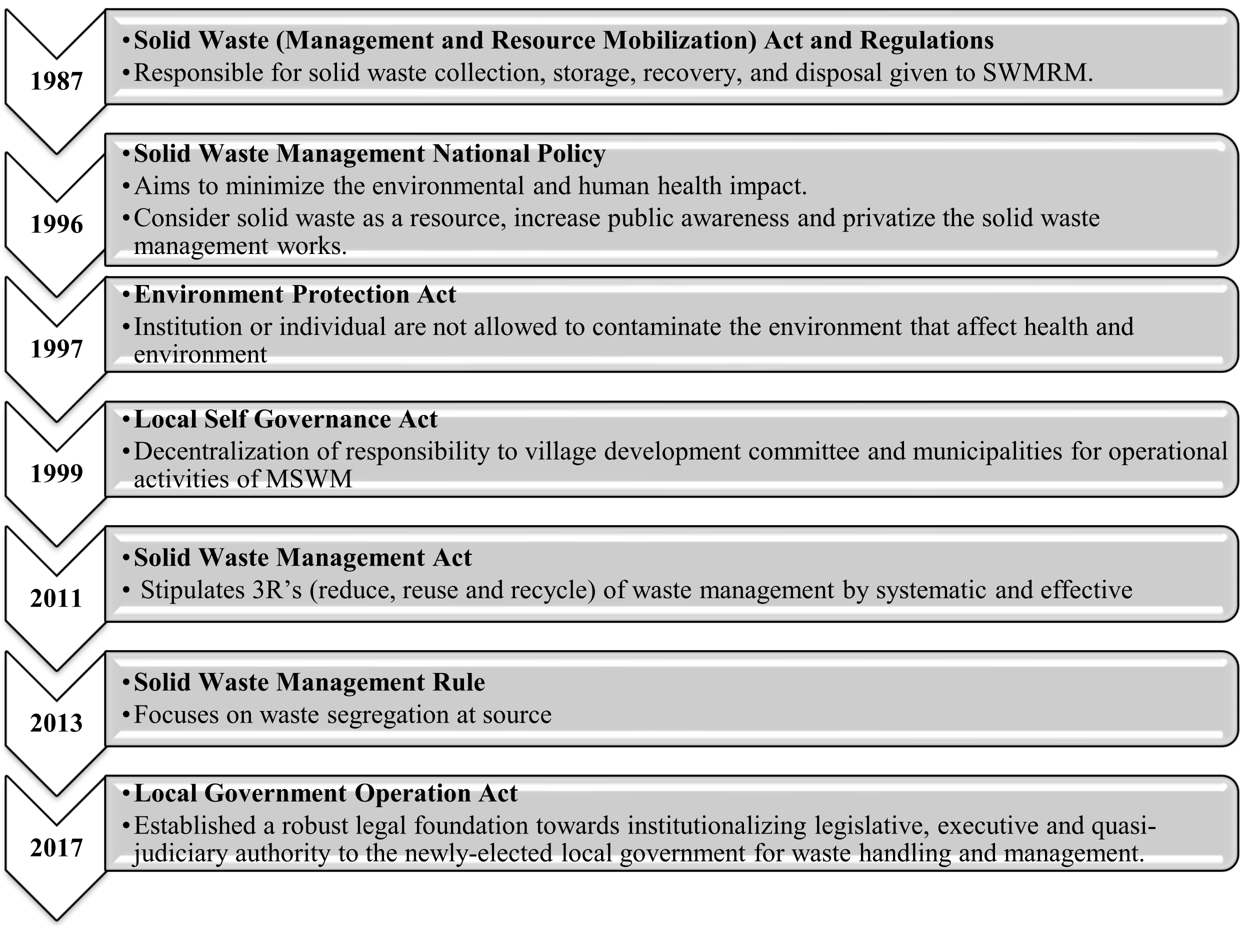

Figure 4. Solid waste management rules and regulation in Chronological order (Adapted from GC, R, 2018)

3.3 Problems of solid waste management in Kathmandu Valley

Despite the operation of Sisdole landfill, the accumulation of solid waste in Kathmandu is ongoing. (Pathak and Mainali, 2019; Azoulay, 2018). No alternative measures have been initiated or implemented to manage this problem. While the act and constitution delegate to local government the responsibility to manage wastes, many approaches have failed due to immature local autonomy systems, lack of local capacity and lack of operation and maintenance structures for machinery and equipment (Mmereki et al., 2016). There are labor intensive local approaches that use existing scavengers and informal waste pickers but the crowded medieval structures in KMC result in inadequate waste management (Dangi et al., 2015).

In their report 'Solid Waste Management in Nepal: Current Status and Policy Recommendations (ADB, 2013)' the Asian Development Bank (ADB) proposes the following eight key recommendations:

1. The promotion of 3R: Reduce, Reuse and Recycle;
2. The strengthening of the capacity of local bodies,
3. Increased public participation and consultation,
4. Improved cost recovery,
5. Improvements in Integrated Solid Waste Management,
6. Increased use of Public–Private Partnerships and Data Management,
7. Greater emphasis on updating, and dissemination.

Section 5 of this article will take a closer look how far these recommendations can be implemented in KMC waste management practice.

4. Waste to Energy Technology

The growing population has not only caused an increase in the total waste generated but also has generated an increasing demand for energy resulting in the idea that waste can be viewed as a resource for energy security (Stehlı, 2009; Ribić, 2017). While the theory of converting waste to energy is straightforward, its practical application tends to be complex as the type of system to be used depends not only upon the volume of the waste generated, but also its characteristics, composition, and state. In addition, it also depends on the technology chosen or the combinations of technologies used. Other issues include the trade-offs made, the economic status of the implementing body and the existing policies followed and their implementation on waste management (Chifari et al., 2018; Ribić, 2017; Psomopoulos, 2019). The conversion of waste into energy has not been widely implemented even in most developed nations; for instance in USA only 7.4% of the total waste generated is converted into energy (Psomopoulos, 2019). The European Union also struggles with their waste management. Some member countries still dispose of more than 80% of their waste directly to the landfill without any energy recovery (Hollins et al, 2017), the situations of developing countries are obviously no better than the developed countries. In KMC, almost all collected solid waste is landfilled without segregation, making it difficult to recover energy (Sodari and Nakarmi, 2018; Lohani et al, 2012; Taleghani et al, 2005).

There are various W2E technologies in practice that may be applicable for use in developing countries such as Nepal for the purpose of energy recovery which include: Incineration, Anaerobic digestion and Landfill with gas recovery (Taleghani et al, 2005). These W2E technologies are discussed in the following section in order to understand the potential of converting waste generated in Nepal into useful energy.

4.1 Incineration

Incineration is a very common and old method for waste management, where the waste is combusted to generate heat. In order to have a sustainable operation for an incinerator, the lower calorific value of the waste to be fed must be at least 7 MJ/kg and should never be lower than 6 MJ/kg (Lohani et al, 2012; Taleghani et al, 2005). Table 5 shows the calorific value of wastes that can be used to estimate the calorific value of different components of wastes available at different places. The high moisture content of OFMSW means the net calorific value of wastes is strongly reduced from the dry heat value.

Table 3. Average heating value of components in solid waste (Shrestha et al, 2014)

Component	Dry Heat Value (KJ/kg)
Plastic	26,284
Rubber	31,285
Leather	16,747
Textiles	16,049
Glass	116
Organic Waste	8,839
Paper	7,792
Metal	814

In order to estimate the calorific value of KMC waste, waste composition (Table 3) was assumed with calorific value of waste from Table 3 and adjusted for moisture content along with removal of metals, glass and inert materials for incineration. The heat content of waste estimated from the equation 1, for 2015 was 4.8 MJ/kg which is much lower than the critical value of 6 MJ/kg making incineration unsuitable for harvesting energy in KMC.

Lower Heat value of the component (H) = (1-w) * Hu – w * 2250 KJ/kg (Eq. 1)

Hu = calorific value of the dry matter in KJ/kg, w = water content,

latent heat of vaporization = 2250 KJ/kg

In addition, mostly the plastics and paper are already recycled through informal scavengers. Reducing the percentage, the composition of the waste would reduce the heating value to much less than 4.8 MJ/kg. Hence, incineration of KMC waste is not suitable which is furthermore hampered by the high cost, complexity and the chance of contamination by flue gases (Haukohl et al, 1999).

4.2 Anaerobic digestion

Anaerobic digestion (AD) is the biological breakdown of organic matter, such as dead plant and animal materials, animal faeces, and kitchen wastes in the absence of oxygen. It produces biogas, composed of mainly CH_4 and CO_2. The production of biogas and digestate slurry from anaerobic digestion is considered to be one of the most energy-efficient and environmentally beneficial technologies for bioenergy production (EPA, 2006; Abubaker et al., 2012), besides it reduces the volume and mass of the wastes as well as enriching the plant nutrients. Currently AD is the most common waste to energy technology being used in Nepal, having successfully been implemented in the management of domestic livestock waste in Nepalese context. More than 400,000 biogas plants, locally known as Gobar gas plants, are installed throughout the country (AEPC, 2018). The use of domestic biogas plants have saved time, fuel wood, increase cooking efficiency, reduced the risk of people getting attacked by wild animals while collecting fuel wood as well as reducing indoor air pollution (BUS, 2018; Lohani, 2011). In addition the large modern biogas plants (about 4000 m3 in size) has been gaining attention since past few years. As of 2018, five large biogas plants fed with livestock manure and OFMSW have been completed and are working for a different end-use purpose (compressed in a cylinder replacing Liquid Petroleum Gas (LPG), electricity generation, etc) at different parts of the country and more than 380 investors have shown interest for the construction of large biogas plants as municipal waste to energy projects (AEPC, 2018). Although there no large biogas plants installed at KMC, the increasing interest in large biogas plants could bring such initiatives in days ahead

The use of biogas production still has some challenges in KMC because the municipal wastes need to be properly segregated and there is a lack of a proper infrastructure for the application of the produced biogas. If the government is determined to solve solid waste management problem at KMC and prioritize biogas technology in its policy, it won't take much longer to establish infrastructure to convert OFMSW of KMC to biogas. As a hypothetical estimation that if 100% OFMSW of KMC goes to AD treatment, about [1]30294 m^3 of biogas per day can be generated which is nearly [2]1045 LPG cylinder per day equivalent (14.2 kg LPG cylinder). If the generated biogas is used to replace LPG cylinder for cooking about [3]15952 tons of carbon dioxide (CO2) avoidance would be possible.

The estimated amount of money saved by avoided LPG imports at the market price of LPG cylinder (Nepali Rupees NRs 1350 per LPG cylinder) could be about NRs 515 million. The byproduct of biogas plant digestate can be used as bio- fertilizer and this has a huge potential to substitute the imports and use of chemical fertilizer and help restoration of land in the region and avoidance of GHG emissions. Therefore, the implementation of this technology would be the key contributors to the Sustainable Development Goals (SDG) 7 (Affordable and Clean Energy) by the facilitation of clean energy and investment in energy infrastructure (Khan S. et al 2019), 11 (Sustainable Cities and Communities) via waste management while the LPG replacement and bio-slurry could be one contributors in compliance with SDG 13 (Climate Action) by reducing GHG emission and 15 (Life on Land) by reducing impact of wastes on land ecosystem. Due to the high content of nitrogen in the slurry, it is the competent replacer of the urea and the farmyard manure (fresh dung). The World Bank study of fertilizer usage on arable land revealed the noticeable reduction of use of urea, potassium and farmyard manure with the utilization of bio-slurry (WB, 2016).

4.3 Landfilling with gas collection

Most of the municipal waste around the globe finds its way to landfills. Landfilling is the most common method used in developing and least developed countries but developed countries are not an exception. Mostly in developing and least developed countries there is no sanitary landfilling practice and landfilling refers to simple dumping/disposeal of solid waste in an open space. This method is easy but is not environmentally sound as the breakdown of wastes generates methane

[1] Biogas generation of food waste is considered 0.45 m^3/kg VS, Total solid (30%) and volatile solid (85%) (Vögeli et al., 2014)

[2] 1 LPG cylinder equivalent 29 m^3 biogas

[3] 63g CO_2 emission per MJ LPG combustion, 1 m3 biogas = 22.9 MJ

which is a greenhouse gas (GHG) and is released to the atmosphere. However, modern regulated landfills attempt to capture and utilize the landfill biogas produced to generate electricity or heat. Although landfill requires large area compared to other waste to energy technologies, with appropriate treatment up to 90% collection efficiency can be reached (Figure 5) (Moya et al, 2017).

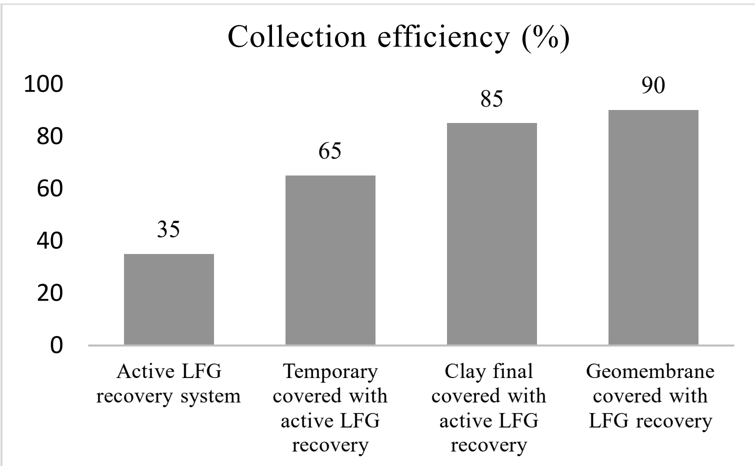

Figure 5. Collection efficiency of LFG for Landfill cells (Data taken from Spokas et al. (2006))

While KMC currently uses Landfill for its waste management, gas recovery has yet to be implemented and a far distant as no modern sanitary landfill is in practice. If landfill gas recovery were to be implemented in KMC, the theoretical estimation of landfill gas recovery from KMC waste would be 15840 m^3 taking average value of 200 m^3 landfill gas generation per dry ton of OFMSW (Themelis and Ulloa, 2006).

Assuming a temporary covered landfill cell with active LFG recovery and a collection efficiency of 65%, nearly 9500 m^3 per day landfill gas can be recovered.

From the theoretical estimation of AD and landfill gas, it can be observed that biogas recovery capability of AD is three times higher than that of landfill gas. Area requirement for the installation and operation of biogas plant is nearly 18 times less than the area required for sanitary landfill with gas recovery (CPHEEO, 2000). Besides, the time required for sanitary landfill construction, cost incurred for regular operation and high precaution required for environmental protection makes it less attractive compared with AD system.

4.4 Policy and ADB Key recommendations on Solid Waste Management in Nepal

The ADB Key recommendations suffer partly from the global theory - local application gap as many other sustainability policies (Singh and Keitsch, 2020). While ADB aims developing a generic WM framework for Nepal, the ability of such a framework to be realized through local solutions in specific contextual settings is limited. For example, ADB claims rightly that a "key to success would be the segregation of waste at source. This would require better public awareness of the benefits of waste segregation and recycling, and technical skills and knowledge among municipal staff" … and "Community participation needs to be ensured through information, education, and communication campaigns to enhance citizens' awareness ... Awareness should start from the basic "no littering" in public places (ADB, 2013)."[4]. Yet, ADB does not consider how difficult it is to create local awareness and commitment with very limited resources. As Dangi (2009) points out for KMC waste management: "Municipalities and local entities need the authority to craft their own projects and engage in creating resources with some help from the central government and aid agencies (2009, p.625)"[5]. Dangi suggest as a mitigation of the gap above that the existing waste management culture should be considered and ideally integrated in new environmental policies instead of completely redesign techno affine practices and abandon socio-cultural traditions. "Realising 'kuchikars' and 'kavadiwalas' as deeply rooted cultural, emotional, traditional, and social attachment in KMC, the importance the informal sector plays in undertaking urban environmental issues in developing countries…" should not be underestimated."[6]

4.5 KMC Waste to energy within the SDG

Nepal was one of the first countries to conduct an SDG baseline study, before the formal adoption of the SDGs in 2015. As a low-income country Nepal is focused on SDGs related to poverty, agriculture, healthcare, education, water and energy, and on ensuring 'access for all' to technology and services. Sustainable energy consumption and generation has high relevance for these factors.

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[4] Asian, Development Bank (2013) Solid Waste Management in Nepal: Current Status and Policy Recommendationshttps://www.adb.org/sites/default/files/publication/30366/solid-waste-management-nepal.pdf

[5] Dangi, M, Schoenberger B., Bohland, J. (2009) Assessment of environmental policy implementation in solid waste management in Kathmandu, Nepal

[6] Dangi MB (2009) Solid waste management in Kathmandu, Nepal: The anatomy of persistent failure. Doctoral dissertation, Johns Hopkins University, ProQuest LLC, Ann Arbor.

The new federal system of Nepal established in 2015 encourages both national, regional and local alliances in progressing towards realization of the SDGs.

While emerging technologies get more prominence in the WM sector in Nepal, the country is also increasingly moving towards the overarching SDG motto: Leave no-one behind. For waste to energy transitions in KMC this means to address all relevant metropolitan actors on an economic, environmental and social scale. Methodologically, mapping and inclusion of different stakeholders is key for holistic SWM. This concerns not only to individuals and groups on municipal level policy and waste management levels but also residents, grassroot actors and dwellers of informal settlements, whose behavior and perception can influence the entire SWM system. Inclusion of those stakeholders in mass meetings and focus group discussions can in turn inform planning- and decision-making on local and ward level.

Implementation of SWM strategies In Kathmandu relates overall mainly to SDG11 'Sustainable Cities and Communities' (Keitsch, 2020) The Nepal Government has special focus here on Target 11.6: "By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management" (Government of Nepal National Planning Commission 2017, p.66) and Target 11.7.a "Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning". A key factor for success of the SDGs depends on realizing holistic solutions for sustainable societies, addressing both biophysical, technological, socio-cultural and economic needs. Equally important to acknowledging the scientific and societal complexity of SDG challenges is engaging all members of society in meeting these challenges.Therefore, SWM in Kathmandu has to address and align technology, policy and environmental possibilities and challenges in both analysis, planning and design Solutions will then not only meet SDG 11 but simultaneously contribute to SDG 3 'Good health and well-being', SDG 12 'Responsible consumption and production' and SDG 7, Target 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix.

Conclusion

Kathmandu has huge potential for implementing waste to energy technologies but the city suffers from a proper waste treatment infrastructure. The per capita waste generation and the waste composition has been fairly consistent throughout the years with a per capita waste generation rate of 0.3 kg/cap/day with organic waste being the most dominant. The calorific heat value for incineration was calculated to be 4.5 MJ/kg which is inadequate to support an incineration facility. In Kathmandu, AD offers the best treatment method with a possible current capacity of nearly 30294 m^3 methane per day. The added advantage of AD that meets the situation in Kathmandu is the land requirement, requiring 18 times less area than landfill. The byproduct can be used as fertilizer for nearby agricultural areas such as Bhaktapur and Kavre. With the end of the lifespan of Sisdole landfill site, an AD plant could reduce the burden on the new proposed landfill site in Banchare Danda as well as expanding the use of the current landfill site at Sisdole for a few years and decreasing dependency on LPG. However, proper segregation of waste is required to successfully implement the use of AD, which requires a grass-roots approach and proper implementation of policies. This kind of study is way forward in showing the proposed waste to energy approaches in KMC waste management could promote in achieving several sustainable development goals including SDG 3, 7, 11, and 12,

References

Abubaker, J., Risberg, K., & Pell, M. (2012). Biogas residues as fertilisers – Effects on wheat growth and soil microbial activities. *Applied Energy*, *99*, 126–134. https://doi.org/10.1016/j.apenergy.2012.04.050

ADB, Solid Waste Management in Nepal 2013 : Current Status and Policy Recommendations. Asian Development Bank. https://www.adb.org/sites/default/files/publication/30366/solid-waste-management-nepal.pdf (date last accessed, 20 Oct., 2020)

AEPC, Alternative Energy Promotion Center, Ministry of Energy, Water Resources and Irrigation, Government of Nepal 2018. https://www.aepc.gov.np/statistic/biogas-plant (date last accessed, 20 Oct., 2020)

Azoulay, J.K. 2018. Waste Management in Kathmandu Littered Journey, New Spotlight. https://www.spotlightnepal.com/2018/07/02/waste-management-kathmandu-littered-journey/ (date last accessed, 20 Oct., 2020)

BUS, Biogas User's Survey 2017/18, Nepal Biogas Support Program, 2018. https://www.atmosfair.de/wp-content/uploads/anlage-6-monitoring-report-biogas-nepal.pdf (date last accessed, 20 Oct., 2020)

CBS, 2014. National Population and Housing Census 2011: Population Projection 2011-2031. Central Bureau of Statistics, *08*. http://cbs.gov.np/?p=2699 (last date accessed, 20 Oct., 2020)

CBS, 2019. Environmetntal Statistics of Nepal 2019. https://cbs.gov.np/environment-statistics-of-nepal-2019/ (date last accessed, 20 Oct., 2020)

Chifari, R., Piano, S.L., Bukkens, S.G.F. and Giampietro, M. 2018. A holistic framework for the integrated assessment of urban waste management systems, Ecol. Indic., 94, 24–36, 2018, doi: 10.1016/j.ecolind.2016.03.006.

CPHEEO, Manual on Municipal Solid Waste Management. 2000, http://cpheeo.gov.in/cms/manual-on-solid-waste-management.php (accessed on 20 Match, 2020).

Dangi M.B. 2009 Solid waste management in Kathmandu, Nepal: The anatomy of persistent failure. Doctoral dissertation, Johns Hopkins University, ProQuest LLC, Ann Arbor.

Dangi, M.B., Schoenberger, E. and Boland, J. J. 2015. Foreign aid in waste management: A case of Kathmandu, Nepal, *Habitat Int.*, 49, 393–402. doi: 10.1016/j.habitatint.2015.06.010.

Dangi, M.B., Schoenberger, E. and Boland, J.J. 2017. Assessment of environmental policy implementation in solid waste management in Kathmandu, Nepal, Waste Management. Reearch, 35(6), 618–626. doi: 10.1177/0734242X17699683.

Dawadi, B.K. 2018. KMC to be without landfill for months. myRepublica. https://myrepublica.nagariknetwork.com/news/kmc-to-be-without-a-landfill-for-months (date last accessed, 12 Sep., 2020)

EPA, United States Environmental Protection Agency, "Municipal solid waste in the United States: 2005 facts and figures," 2006.

Fleta-Asín, J., Muñoz, F (2021) Renewable energy public–private partnerships in developing countries: Determinants of private investment, Sustainable Development Early View, First published: 17 January 2021

GC, R. 2018. Waste to Energy Possibilities and GHG Emissions from Municipal Solid Waste Management Options in Kathmandu Metropolitan City. (Master). Lappeenranta University of Technology, MSc Thesis.

Government of Nepal National Planning Commission 2017, Nepal's Sustainable Development Goals Status and Roadmap: 2016-2030, https://www.npc.gov.np/images/category/SDG_Status_and_Roadmap_(2016-2030).pdf, last accessed 20 Dec, 2020)

Haukohl, J., Rand, T. and Marxen, U. 1999. Decision Makers' Guide to Municipal Solid Waste Incineration.

Hollins, O., Lee, P., Sims, E., Bertham, O., Symington, H., Bell, N., Pfaltzgraff, L. and Sjögren, P. 2017. Towards a circular economy – Waste management in the EU. https://www.europarl.europa.eu/RegData/etudes/STUD/2017/581913/EPRS_STU(2017)581913_EN.pdf

Khan, S. , Sharif A., Golpîra, H., Kumar, a. (2019) A green ideology in Asian emerging economies: From environmental policy and sustainable development, Sustainable DevelopmentVolume 27, Issue 6

KMC, 2020. Kathmandu Metropolitan City, Bagmati Province, Government of Nepal, https://www.kathmandu.gov.np/node/893 (date last accessed, 20 Oct., 2020)

Keitsch, M. 2020. Enhancing Collaboration Between Societal Stakeholders for Reduced Inequalities, Encyclopedia of the UN Sustainable Development Goals, Springer.

Local Government Operation Act, 2017. https://drive.google.com/file/d/0B0Jz0A3AUTXhbU9aeGdSYnFkQ0E/view (last date accessed 20 Oct, 2020).

Lohani, S.P., Satyal, A., Timilsina, S., Parajuli, S. and Dhital, P. 2012. Energy recovery potential from solid waste in Kathmandu Valley, 2nd International Conference on Development of Renewable Energy Technology (ICDRET), Proceedings, 98–101.

Lohani, S.P. 2011. Biomass as a Source of Household Energy and Indoor Air Pollution in Nepal, Iran. J. Energy Environ., 2(1), 74–78.

Local Self Governace Act, 1999. http://www.lawcommission.gov.np/en/wp-content/uploads/2018/10/local-self-governance-act-2055-1999.pdf (last accessed 20 Oct., 2020)

Luitel, K.P. and Khanal, S. N. 2010. Study of Scrap Waste in Kathmandu Valley, Kathmandu University Journal of Science and Engineering Technology, 6 (1), 116–122. doi: 10.3126/kuset.v6i1.3319

Mmereki, D., Baldwin, A. and Li, B. 2016. A comparative analysis of solid waste management in developed, developing and lesser developed countries, Environ. Technol. Rev., 5(1), 120–141, 2016, doi: 10.1080/21622515.2016.1259357.

Moya, D., Aldás, C., Jaramillo, D., Játiva, E. and Kaparaju, P. 2017. Waste-To-Energy Technologies: An opportunity of energy recovery from Municipal Solid Waste, using Quito - Ecuador as case study, Energy Procedia, 134, 327–336. doi: 10.1016/j.egypro.2017.09.537.

Pathak, D.R. 2013. Final Report on Recycled Materials from Solid Waste Stream in Kathmandu

Valley : Recovery and Economic values. file:///C:/Users/Lenovo/Downloads/ResourcesrecoveryfrommunicipalsolidwasteinKathmandu Valley.pdf (date last accessed, 20 Oct., 2020)

Pathak, D.R. and Mainali, B. 2019. Status and Opportunities for Materials Recovery from Municipal Solid Waste in Kathmandu Valley, 1, 436–443, doi: 10.1007/978-981-13-2221-1.

Psomopoulos, C.S., Bourka, A. and Themelis, N.J. 2008. Waste-to-energy: A review of the status and benefits in USA, Waste Manag., 29(5), 1718–1724, 2009, doi: 10.1016/j.wasman.2008.11.020.

Ribić, B., Voća, N. and Ilakovac, B. 2017. Concept of sustainable waste management in the city of Zagreb : Towards the implementation of circular economy approach Concept of sustainable waste management in the city of Zagreb : Towards the, J. Air Waste Manage. Assoc., 67(2), 241–259, 2017, doi: 10.1080/10962247.2016.1229700.

Satyal, U. 2018. Garbage management a serious concern for Kathmandu metropolis - The Himalayan Times, The Himalayan Times. https://thehimalayantimes.com/kathmandu/garbage-management-a-serious-concern-for-kathmandu-metropolis/ (date last accessed, 12 Sep., 2020)

Singh, R.K.,Yabar, H., Mizunoya, T., Higano, Y., and Rakwal, R. 2014. Potential Benefits of Introducing Integrated Solid Waste Management Approach in Developing Countries: A Case Study in Kathmandu City, Journal of Sustainable Development, 7 (6), 70–83, 2014, doi: 10.5539/jsd.v7n6p70

Singh, B. and Keitsch, M. 2020. Transdisciplinary collaboration in architecture and design, in: Keitsch, M. Vermeulen W. (eds), Aligning Diverse Practices of Transdisciplinary for Sustainability, Routledge

Shrestha, M.E.I., Sartohadi, J., Ridwan, M.K. and Hizbaron, D.R. 2014. Converting Urban Waste into Energy in Kathmandu Valley: Barriers and Opportunities, J. Environ. Prot., 5(9), 772–779. doi: 10.4236/jep.2014.59079.

Sodari, K.B. and Nakarmi, A.M. 2018. Electricity Generation Potential of Municipal Solid Waste of Nepal and GHG Mitigations," Journal of Institute of Engineering, 14 (1), 151–161, 2018, doi: 10.3126/jie.v14i1.20079

Solid Wste Management Act, 2011. http://extwprlegs1.fao.org/docs/pdf/nep137767.pdf (last date accessed 2 Feb., 2021)

Spokas, K., Bogner, J., Chanton J.P., Morcet, M., Aran, C., Graff, C., Moreau-LeGolvan, Y. and Hebe, I. 2005. Methane mass balance at three landfill sites: What is the efficiency of capture by gas collection systems?, Waste Management, 26(5), 516–525. doi: 10.1016/j.wasman.2005.07.021.

Stehlı, P. 2009. Contribution to advances in waste-to-energy technologies, J. Clean. Prod.,17(10), 919–931, 2009, doi: 10.1016/j.jclepro.2009.02.011.

Taleghani, G. and Kia, A.S. 2005. Technical-economical analysis of the Saveh biogas power plant, Renewable Energy, 30(3), 441–446. doi: 10.1016/j.renene.2004.06.004.

Themelis, N.J. and Ulloa, P.A. 2007. Methane generation in landfills, Renewable Energy, 32(7), 1243–1257. doi: 10.1016/j.renene.2006.04.020.

THT, 2017, September 1. Okaroauwa locals continue to obstruct waste disposal. *The Himalayan Times*. https://doi.org/https://thehimalayantimes.com/kathmandu/okharpauwa-locals-continue-obstruct-waste-disposal/ (last date accessed December 2, 2019)

UDM, 2015. Urban Development Ministry, Solid Waste Management of Kathmandu Metropolitan City, Environment Audit Report, 321–342.

Vögeli Y., Lohri C. R., Gallardo A., Diener S., Zurbrügg C., 2014, Anaerobic Digestion of Biowaste in Developing Countries: Practical Information and Case Studies. Swiss Federal Institute of Aquatic Science and Technology (Eawag), Dübendorf, Switzerland.

WB, World Bank, Nepal. 2016. Fertilizer consumption per unit of arable land, World Data Atlas. https://knoema.com/atlas/Nepal/Fertilizer-consumption (last date accessed December 2, 2019).