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Potential for Energy Recovery and Greenhouse Gas Mitigation from Municipal Solid Waste Using Waste-To-Energy Approach

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ABSTRACT

This research carried out to assess potential for energy recovery from the municipal solid waste of various municipalities of Nepal by implementing different waste to energy technologies like plasma arc gasification, conventional gasification, pyrolysis, incineration and anaerobic digestion plant and also the greenhouse gas mitigation achievable by the implementation of these technologies. It was found during the study that the total waste generated was 1435 tons per day with 0.3 kg per capita contribution. The major constituent of the waste was organic with 62 % of the total waste volume. On average, total moisture content in the waste was found to be 50%. The net energy available and, thus, lost after dumping of the solid waste was 71,895,000 MJ equivalent to 4262 MWh which can run a 52 MW plasma arc gasification power plant. The capacity of plasma arc gasification plant for Kathmandu Metropolitan city was found to be 19 MW. Cumulative reduction in GHG emission from all municipalities was found to be 80,555 tons of CO_2 eq per year by the implementation of plasma arc technology. Levelized cost of energy for plasma arc, gasification, pyrolysis, incineration, and anaerobic digestion plant were calculated to be NRs 8.5, 10, 11, 10 and 11 per kWh respectively. Hence, the plasma arc gasification technology can be deemed as the most feasible waste to energy technology in terms of environmental and economic prospects.

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TABLE OF CONTENTS

Copyright………… **2**

Approval Page……… **3**

Abstract………… **4**

Acknowledgements… **5**

Table of Contents…… **6**

List of Tables……… **10**

List of Figures……… **11**

List of Abbreviations **13**

CHAPTER ONE: INTRODUCTION **15**

1.1. Background 15

1.2. Energy against Waste 17

1.3. International practices in solid waste management 21

1.4. Solid waste management in Nepal 23

1.5. SWM in Kathmandu Municipality 24

1.6. Problem Statement 25

1.7. Objective 26

1.7.1. Main Objective 26

1.7.2. Specific Objectives 26

1.8. Research Gap 26

1.9. Methodology 27

CHAPTER TWO: LITERATURE REVIEW **28**

2.1. Composition of solid waste and waste-to-energy recovery technologies 28

2.1.1. Anaerobic digestion 28

2.1.2. Incineration 29
2.1.3. Briquetting 30
2.1.4. Fermentation 31
2.1.5. Pyrolysis and Gasification 31
2.1.6. Clean Development Mechanism (CDM) 32
2.1.7. Landfill gas (LFG) Collection and Utilization 32
2.2. Choice of feasible technology and other affecting parameters 32
2.3. Waste-To-Energy (W-T-E) treatment options 33
2.3.1. Anaerobic digestion 33
2.3.2. Incineration 34
2.3.3. Pyrolysis technology 35
2.3.4. Gasification technology 36
2.3.5. Landfill gas production and utilization 37
2.3.6. Bioreactor landfill 38
2.3.7. Plasma Arc Gasification Technology 38
2.3.8. Other emerging waste-to-energy technologies 40
2.4. Review of researches 41
2.5. Energy Bin 44
2.5.1. Working Principle 45
2.5.2. Features 45
2.5.3. Benefits of Energy Bin 46
CHAPTER THREE: METHODOLOGY 48
3.1. Research method 48
3.2. Data collection 48
3.2.1. Solid waste data 48
3.2.2. Waste categorization 50

3.2.3. Moisture Content in waste 50

3.2.4. Calorific value determination 51

3.2.5. Calculating energy efficiency of energy conversion system 51

3.2.6. Estimating the Energy Potential of MSW...52

3.2.7. GHG Calculations..53

3.2.8. Financial Calculations...53

3.2.9. Methods of Result Presentation 56

CHAPTER FOUR: RESULTS AND DISCUSSION 57

4.1. Solid waste generation 57

4.2. Categorical composition of the wastes 60

4.2.1. Household waste composition 60

4.2.2. Hospital wastes 60

4.2.3. Restaurant wastes...61

4.2.4. Hotels/Lodge wastes 62

4.3. Categorical redistribution of wastes...63

4.4. Moisture content of the wastes 64

4.5. Energy evaluation of waste 64

4.6. Capacity of Different WTE Technologies 67

4.7. Performance of Energy Bin Installed at Kathmandu Metropolitan City 69

4.8. GHG Mitigations 72

4.9. Air Pollution Mitigation..75

4.10. Validation...78

4.11. Financial Analysis of Different WTE Technologies 79

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS.....................83

5.1. Conclusion 83

5.2. Recommendation 84

REFERENCES……..85

ANNEX I: Municipalities of Nepal with Population..90

ANNEX II: Composition of Institutional Waste in the 58 Municipalities (%) 92

ANNEX III: Composition of Commercial Waste in the 58 Municipalities (%)...95

ANNEX IV: Composition of Institutional Waste in the 58 Municipalities (%)...98

ANNEX V: Waste Generation of Municipalities 101

ANNEX VI: Energy Potential of MSW of Different Municipalities 104

ANNEX VII: GHG Mitigation Calculation..107

ANNEX VIII: Performance of Energy Bin Installed at KMC.............................110

ANNEX IX: Capacity of Different WTE for all Municipalities 112

ANNEX X: GHG Mitigations for all Municipalities..115

ANNEX XI: Air Pollutions Mitigations for all Municipalities 118

LIST OF TABLES

Table 3.1: Sample design......49

Table 4.1: Generation of solid waste......57

Table 4.2: Categorization of wastes for energy evaluation......63

Table 4.3: Percentage of moisture content of the MSW......64

Table 4.4: Total weight of moisture content in MSW......64

Table 4.5: Total energy content of MSW......65

Table 4.6 Emission factors of air pollutants......75

Table 4.7 Validation of Production of energy......78

Table 4.8 Validation of GHG Mitigations......78

Table 4.9 Finanncial Analysis of different technologies......81

Table 4.10 Financial analysis of WTE technologies without subsidy......81

Table 4.11 Financial analysis of WTE technologies with subsidy......82

LIST OF FIGURES

Figure 1.1: Showing two models of resource use: 'A' linear or throughput economy, 'B' the cyclic or retentive economy (Grey, 1996) 18

Figure 1.2: Showing different phases of gas production at typical landfill site (Grey, 1996) 19

Figure 1.3: Comparative waste management practices in Europe (Helou et al., 2014) 21

Figure 1.4: Comparative waste management practices in Southeast Asian countries (Ngoc & Schniizer, 2008) 22

Figure 1.5: Waste generation of different Municipalities of Nepal 23

Figure 1.6: Waste production to collection ratio in different cities in Nepal (Sthapit, 2010)) 24

Figure 2.1: Model: EB-1000 Waste Capacity: 1,000kgs/Day Weight of the Plant: 18 Tons 44

Figure 4.1: Percentage share of total waste of municipalities of Nepal 57

Figure 4.2: MSW of Kathmandu metropolitan city 58

Figure 4.3: Composition of solid waste of municipalities of mountain region 58

Figure 4.4: Composition of waste of municipalities of hill region 59

Figure 4.5: Composition of waste of municipalities of Tarai region 59

Figure 4.6: Percentage share of household waste Composition 60

Figure 4.7: Percentage share of hospital waste composition 61

Figure 4.8: Percentage share of restaurant waste composition 62

Figure 4.9: Percentage share of hotel/lodge waste composition 62

Figure 4.10: Sources of waste 63

Figure 4.11: Energy potential of MSW 66

Figure 4.12 Waste to energy capacity 67

Figure 4.13 Capacity of different WTE technology for KMC 68

Figure 4.14 Capacity of different WTE technologies for all municipalities................68
Figure 4.15 Capacity of different WTE for major Municipalities of Nepal 69
Figure 4.16 Waste feeding into energy bin...70
Figure 4.17 Daily biogas production in energy bin 70
Figure 4.18 Electricity production from Energy bin..71
Figure 4.19 Capacity of energy bin plant for major municipalities.............................72
Figure 4.20 GHG mitigation of MSW...73
Figure 4.21 GHG mitigation of KMC from different technologies.............................74
Figure 4.22 GHG mitigation of all municipalities of Nepal 75
Figure 4.23 Air pollution mitigation of KMC 76
Figure 4.24 Air pollution mitigation of different municipalities.................................76
Figure 4.25 Air pollution mitigation of all municipalities...77
Figure 4.26 Total reduction in air pollutants 77

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AEPC	Alternative Energy Promotion Centre
ASEAN	Association of Southeast Asian Nations
CBS	Central Bureau of Statistics
CDEC	Community Development Environmental Committee
CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CO2	Carbon Dioxide
EC	European Commission
ENPHO	Environment and Public Health Organization
EU	European Union
GHG	Green House Gas
GoN	Government of Nepal
Gte	Gross Total Energy
HH	Household
IEA	International Energy Agency
IHPEC	Incentive for Hygiene and Planning Implementation Community
INGO	International Non-Governmental Organization
IPCC	Intergovernmental Panel on Climate Change
kg	kilo Gram
kJ	kilo Joule
LCV	Lower Calorific Value
LHV	Lower Heating Value
MJ	Mega Joule
WTE	Waste to Energy

MOFALD	Ministry of Federal Affair and Local Development
MPFS	Master Plan for Forestry Sector
MSW	Municipal Solid Waste
MW	Mega Watt
NEPAP	Nepal Environmental Policy and Action Plan
NFSS	Nepal Environment and Scientific Services
NGO	Non-Governmental Organization
Ne	Net Energy
NPR	Nepalese Rupees
NWMC	National Waste Management Council
PPA	Power Purchase Agreement
PPPUE	Private Public Partnership for Urban Environment
RDF	Refuse Derived Fuel
REDD	Reducing Emissions from Deforestation and Forest Degradation
RoW	Right of Way
SAARC	South Asian Association for Regional Cooperation
SWASTHA	Strengthening Water, Air, Sanitation and Hygiene Treasuring Health
SWM	Solid Waste Management
SWMRMC	Solid Waste Management Resource Mobilization Centre
UK	United Kingdom
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

CHAPTER ONE: INTRODUCTION

1.1. Background

There is a need to reduce the current levels of waste generation and increase in material and energy recovery, which are considered as the essential steps towards an environmental-friendly waste management system. Landfill is also no longer the first choice for disposal among the other methods such as recycling, composting and incineration, but a last step after all possible material and energy recovery in solid waste management practices. Initially, incinerators globally were used to reduce waste mass but energy is being recovered from incinerators nowadays. Electricity and heat is produced from the recovered bio-gas from landfill. From a mass view point of material recycling, composting of organic waste is considered as the most important system. (Khan, 2011)

The problems arising from solid waste can be solved by using innovative technologies. Nowadays, different types of waste-to-energy (W-T-E) technologies are available through which energy can be efficiently recovered and used, such as anaerobic digestion (i.e. both dry and wet, thermophilic and mesophilic), thermal conversion (i.e. rotary kiln incineration, mass burn incineration, starved air incineration, fluidized bed combustion, pyrolysis and gasification, plasma technology, thermo-chemical reduction, refuse derived fuel) and landfilling (i.e. landfill gas utilization and bioreactor landfill). Each type of technology handle the specific composition and quantity of solid waste (Idris, 2004). It seems to be difficult to propose suitable waste management plans and technologies without determining the quantity and composition of generated waste (Tatarniuk, 2007).

Solid waste is a by-product of human activities which tends to increase with rapid urbanization, improved living standards and changing consumption patterns. Management of increasing amounts of solid waste has become a major challenge in many cities in developing countries. If solid waste is properly used, it can be a valuable resource, but if it is not effectively managed, it can result in serious adverse impacts on environment and public health. Solid waste management is therefore a critical component within urban sanitation and it is also one of the most important and resource intensive services provided by municipalities. According to survey done by

Nepal's central bureau of statistics (CBS), most urban residents consider solid waste management as the important environmental problem in urban areas of Nepal.

In Nepal, urbanization is increasing at an alarming rate (3.43 % per year). It is putting immense pressure on municipal services. One of the problems of urbanization and increasing consumerism is the increase of waste. This waste is not being adequately managed and is therefore creating a serious health and environmental hazard (ENPHO, 2008).

In developed countries, the main motivations for waste reduction are frequently related to legislation, environmental protection, the scarcity of sites for landfills, and the risks associated with toxic materials. The same considerations apply in developing countries to large metropolitan areas that are subject to many economic and environmental pressures. Urban centers which do not have effective collection and disposal systems should not devote resources to developing waste reduction measures until adequate waste management systems are in place. For this, or other reasons, solid waste managers in developing countries tend to pay little attention to the issue of reducing organic wastes which make up from 50 % to 90 % of the total waste generated (Practical Action Nepal, 2008)

Management of solid waste is a growing concern in Nepal as urban population densities increase and flat usable land is in short supply. Although small urban centres were declared to be municipalities, they suffer from a lack of infrastructural and technical resources to tackle the problem of waste management. With increasing public awareness about good health and a clean environment, solid waste management has now come to the top of the priorities of the municipalities in Nepal. When the environmental impacts of proposed landfills are being investigated, it is often found that residents refuse to accept landfill sites near their homes and local leaders from various political parties are often involved in protest against proposed landfill locations. Though the Local Self Governance Act of 1999 has empowered municipalities to take every necessary action at the local level, the absence of elected representatives since 1998 has been causing difficulties in its implementation. Even though collection systems are still not in place, most of the municipalities are expressing their desire to develop final disposal systems. They are also promoting waste reduction, reuse and recycling among local communities. (Practical Action Nepal, 2008).

Municipal solid waste (MSW) is primarily waste which is produced by the household, but also includes some commercial and industrial waste that is similar in nature to household wastes and has been deposited in municipal landfill sites. MSW can be a liability if requiring disposal but also represents a considerable resource that can be beneficially recovered, for e.g., by recycling of materials such as aluminum cans, metal, glass, fibres, etc., or through recovery operations such as conversion to energy and composting. However, significant quantities of MSW continue to be disposed off in landfill largely due to its low cost and ready availability.

Nepal generally does not have the necessary skills or resources to manage the waste in the proper manner. The current legislations (Municipality Act 1992, Environment Protection Act 1996, Local Self Governance Act 1999) have empowered municipalities to take every necessary action at local level. On average the 58 municipalities in the country are spending about 13 percent of their total budget on waste management related activities (SWMRMC, 2008) but in most cases this amount is not being spent in an efficient manner.

1.2. Energy against Waste

The argument against land filling is that it is wasteful of natural resources (Griffiths, 2003). Figure 1.1 shows two types of resource economies. First ‘A’, there is linear or throughput economy in which raw materials and energy are used to manufacture goods and products disposed of at the end of their life. Waste, pollution and other environmental impacts are created at all stages – extraction of raw materials, generation of energy, manufacturing processes, use of products, disposal of materials. The economy behaves as though there is an unlimited supply of raw materials and energy, and an environment with unlimited capacity to absorb waste and pollution. The second, ‘B’ in the figure on the other hand illustrates a cyclic or retentive economy which aims to minimize the inputs of raw materials and energy, and the outputs of waste and pollution. This is achieved by minimizing resource use, extending product life, reusing, reconditioning and recycling products, and extracting energy from waste materials. It is no doubt that new raw materials and energy inputs are still required but the aim is to minimize environmental impacts without sacrificing economic well-being (Grey, 1996).

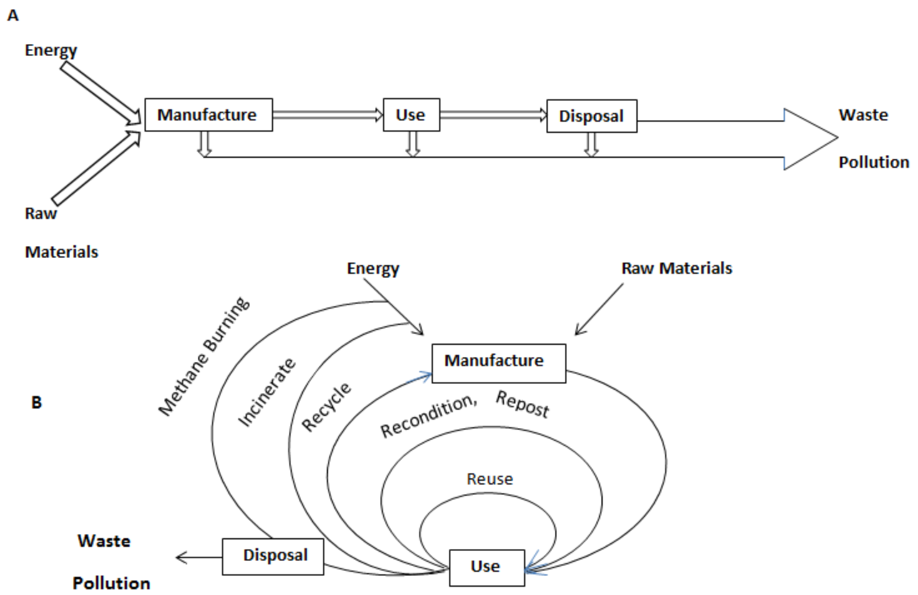

Figure 1.1: Showing two models of resource use: 'A' linear or throughput economy, 'B' the cyclic or retentive economy (Grey, 1996)

Moreover, along with economic aspects of land filling, there are other major issues of hazard to the environment, direct and indirect for short term as well as long term that could affect local area of land fill site or scale out to national level.

Leachates are the result of moisture present in the solid wastes compensated by frequent rainfalls infiltration in the area. In contact with municipal wastes, organic and inorganic constituents are dissolved to form highly toxic leachates. Conventional system of disposition pits allows the leachates to infiltrate deep into the aquifers with the presumption that the leachates gets filtered and diluted at acceptable levels. Leachates can be attenuated by natural process (absorption, microbial decomposition, precipitation, ion exchange or dilution) but the effectiveness is highly variable. There are countable numbers of cases where leachates have caused significant problems to downstream (IEA, 2003) leaving the leachates to degrade naturally would not be appropriate option.

Emission of greenhouse gases is another serious setback of dumping of wastes. Microbial decomposition endorsed by temperature, moisture content, aeration and composition determines the nature and amount of gas production in the site. The Figure 1.2 describes the different phases of gas production for typical municipal landfill site. In the figure the phase I is aerobic decomposition led by the oxygen present in the wastes in aid to aeration from the site. The phase II is an anaerobic fermentation of organic polymers to carboxylic acids, ammonia, hydrogen and carbon dioxide. In the phase III, methane gas production increases and carbon dioxide gas production decreases to an equal amount. The phase IV is the period of steady production of both the gases towards full decomposition in the long run. (Ragle et al., 1995).

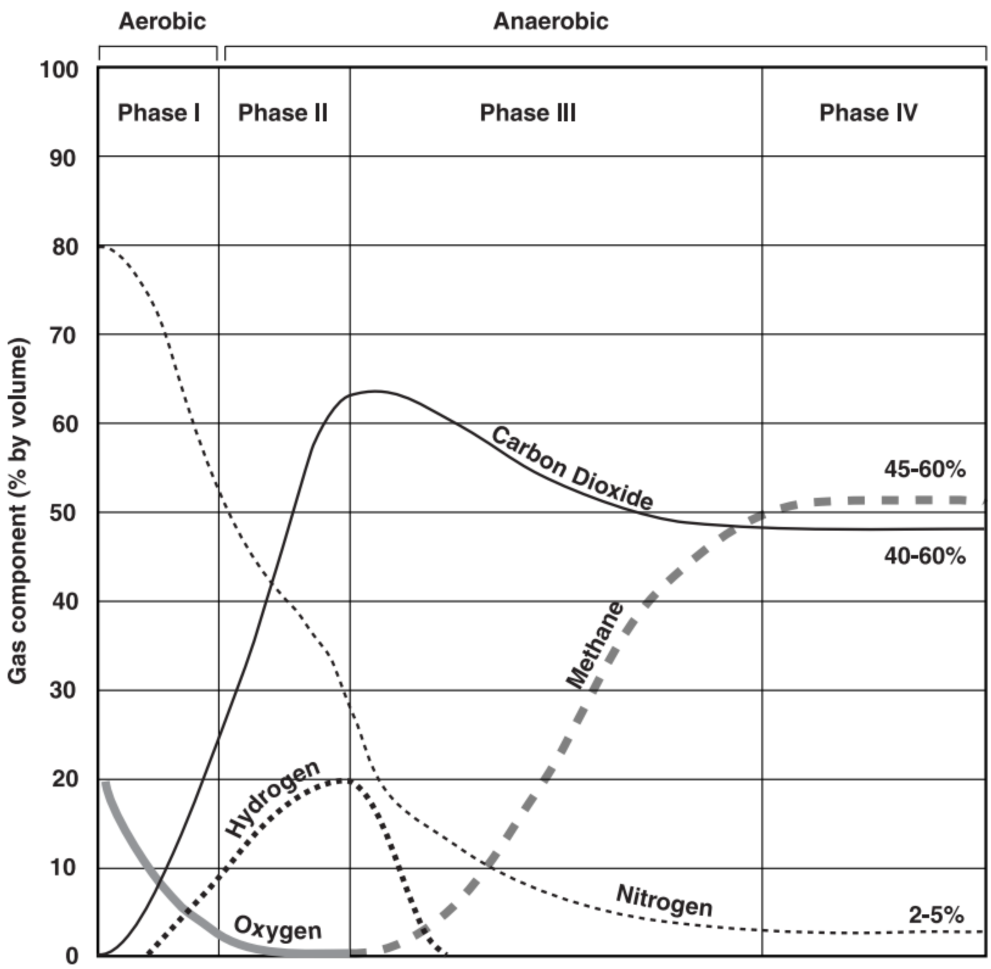

Figure 1.2: Showing different phases of gas production at typical landfill site (Grey, 1996)

Over long run, both the Gases; Methane and Carbon dioxide pose serious threat to global warming. Researchers have already proved Carbon dioxide as prime cause of global warming but recently we have begun to understand the role of Methane. But due to relatively short life time of about 12 years, we have not given considerable attention but the studies from United Nations Framework Convention on Climate

Change (UNFCCC) fourth assessment report confirms methane to be 25 times more effective at trapping heat in the atmosphere when compared to Carbon dioxide over a 100 year time period. The major sources of emission of methane in the atmosphere come from microbial decomposition in anaerobic environment of Lakes, paddy fields and municipal waste dumping sites (Forster et al., 2007)

As municipal dumping site is one of the sources for emission, it should be noted that these emission sites are confined to definite area thus we could rather harvest the gas for commercial use. The use on the one hand checks the emission while on the other hand benefits economically.

In addition to harvesting energy in the form of gas, there are other feasible options like briquetting and incineration. These options have grown considerably in developed countries. Moreover, developing countries are trying to imitate the technology adopted for such waste to energy conversion. Whilst the composition of MSW can be highly variable, particularly between developed and developing nations (Ogweleka & Ogwueleka, 2010), the removal of materials for recycling tends to leave a residue that has a significant calorific (heat) value making it suited to energy recovery operations. Typically, a ton of MSW has about one-third of the calorific value of coal (8-12 MJ/kg as received for MSW and 25-30 MJ/kg for coal) and can give rise to about 600 kWh of electricity (IEA, 2003).Thus, it has now become dire need for developing countries to upgrade into waste to energy (WTE) type in waste management.

Public perception and hostility are currently critical barriers hindering the deployment of energy recovery systems for MSW in several countries. Selective reporting on emissions has contributed to negative perceptions. For example, reporting emissions from 30-year-old facilities but not from new ones that meet the most stringent modern emission standards (Diaz et al., 2008).

Studies should play a significant role in removing misconceptions concerning MSW energy recovery by promoting information exchange and presentation of reliable data on emissions from state-of-the-art waste energy recovery facilities. MSW conversion-to-energy, like any other fuel-to-energy process, will generate emission of pollutants. However, all state-of-the-art MSW conversion-to-energy technologies are certified to meet the most stringent emission standards, including those for dioxins, furans and other toxic pollutants.

1.3. International practices in solid waste management

In the European Union (EU) the Landfill Directive (1999/31/EC), as well as many national regulations, will reduce by 65% of the 1995 level, the amount of biodegradable materials going to landfill by 2020. Many international communities have been practicing different mode of waste treatments as the EU countries in particular have set ambitious targets for reduction in the biodegradable component of MSW consigned to landfill and a consequent increase in MSW subjected to recycling and recovery operations. Some European countries, e.g., Sweden, Germany and the Netherlands, have already decided to ban the biodegradable fraction from landfills in the coming years. In state-of-the-art landfills the gas is extracted and used for energy purposes (Helou et al., 2014).

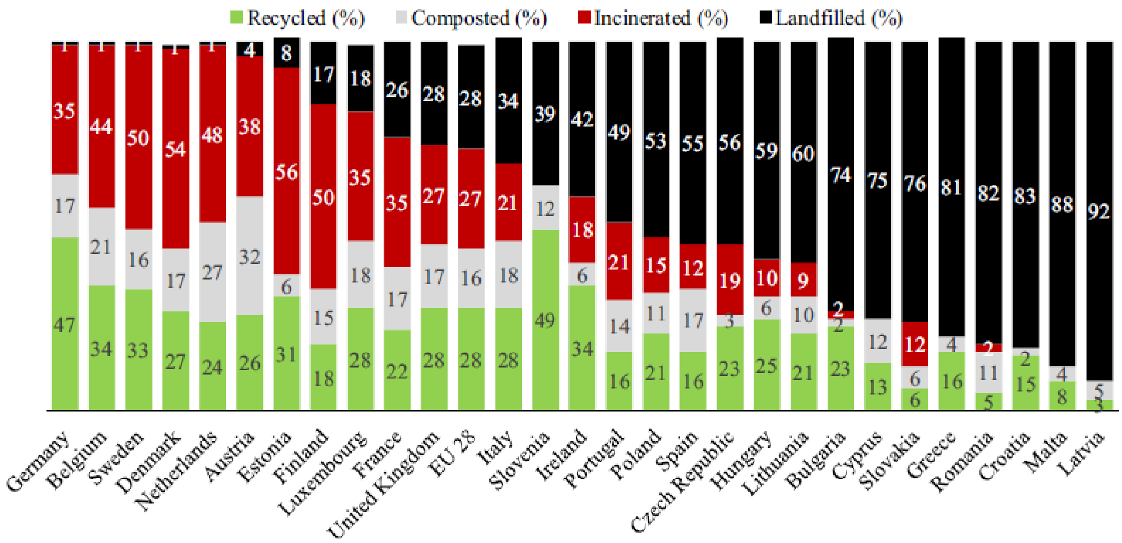

Figure 1.3: Comparative waste management practices in Europe (Helou et al., 2014)

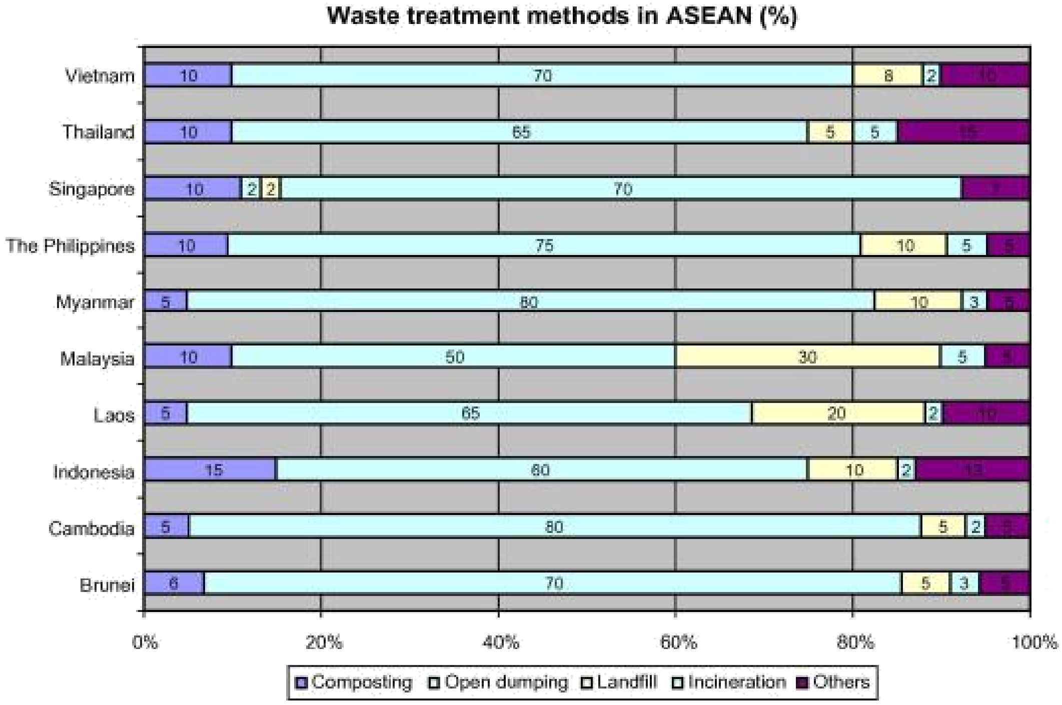

Figure 1.4: Comparative waste management practices in Southeast Asian countries (Ngoc & Schniizer, 2008)

Asian countries like Japan has been practicing Incineration as only option because this technology offers the capability to reduce the large mass of waste produced from densely populated areas, and because there is limited possibility of landfill due to costs ($70-$300 per tonne) and space shortage (Kobylecki et al., 2010).In Japan over 70% of waste mass is incinerated. Taiwan, due to shortage of landfilling sites has been working on incineration of MSW. By 2005, Taiwan has installed 21 MSW incinerators (Chang et al., 2007).

Converse to some of the European countries where recycling and composting is major practice while ASEAN countries have been practicing open dumping as major management option for municipal solid wastes. However, some countries like Malaysia, Laos, Indonesia, Myanmar, and the Philippines are practicing incineration as growing option for waste management. But the major portion of the wastes is open dumped in these countries (Ngoc & Schniizer, 2008).

1.4. Solid waste management in Nepal

The maximum waste generated in Nepal is in the capital city itself. Kathmandu municipality generates about 566 tons of waste each day. This figure is more than 3.5 times the waste generated in Pokhara which is next in the list with 117 tons a day. Similarly, Lalitpur Sub Metropolitan generates 84 tons of waste per day and is the third largest. In contrast, Dhulikhel and Bhadrapur produce the least waste per day with the figure of under 3 tons each day. Next in the list are Bhimeshwor, Jaleshwor, Narayan, and Amargadhi municipalities all with the generation less than 3 tons a day as shown in Figure 1.5.

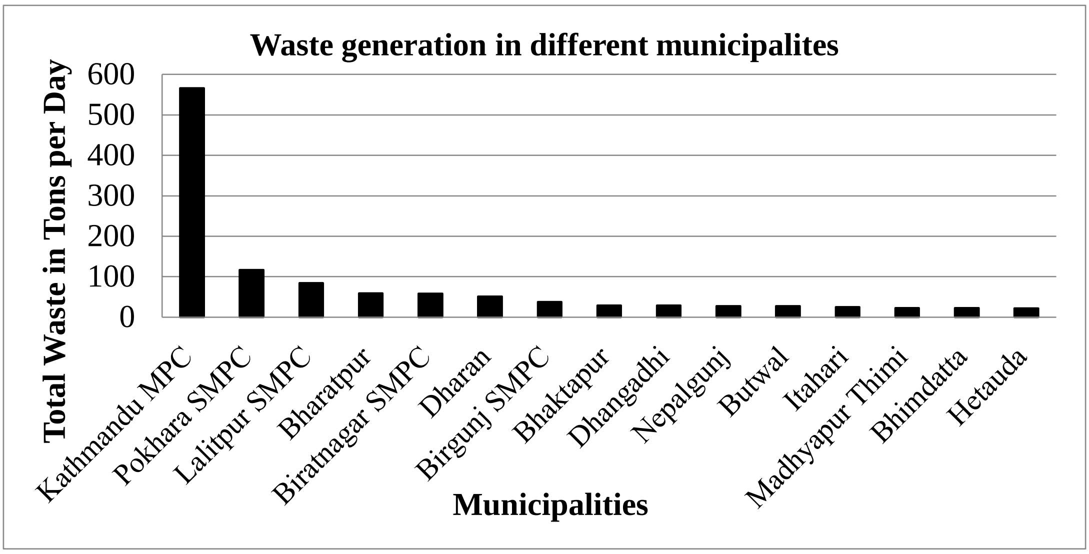

Figure 1.5: Waste generation of different Municipalities of Nepal

The waste collection ratio (total waste collection / total waste generation) of Dhangadhi is 1, i.e., all the waste generated in Dhangadhi is collected. In case of Kathmandu, over 90% of waste is collected. Whereas the collection ratios for Bhaktapur, Butwal, and Vyas municipalities have the collection ratio of over 80%, and the ratio for Lalitpur is under 80%. On the other side, the figures for Mechinagar, Bhimdatta and Tikapur municipality is less than 10% (Sthapit, 2010).

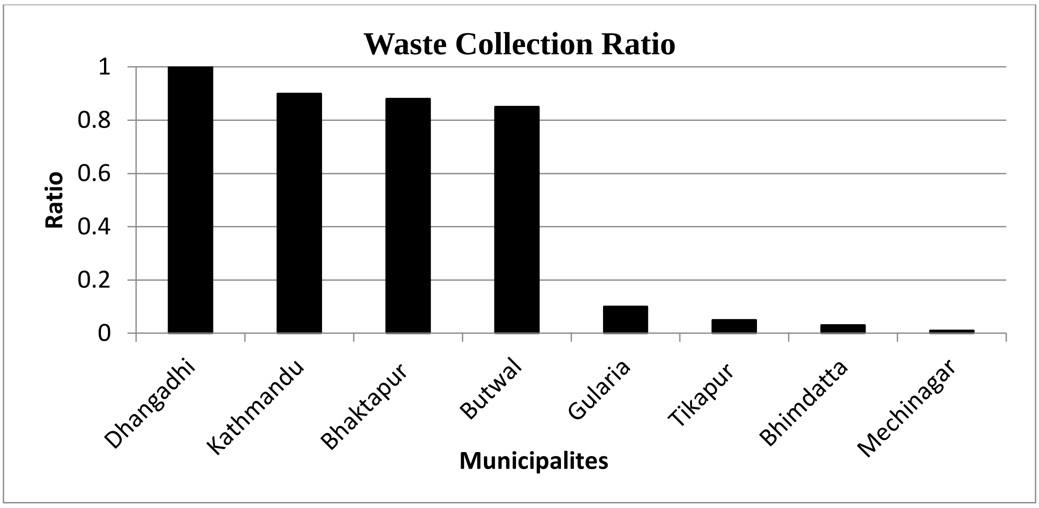

Figure 1.6: Waste production to collection ratio in different cities in Nepal (Sthapit, 2010))

Improper handling of solid waste and indiscriminate disposal in open spaces, road margins, tank beds, and etcetera, give rise to numerous potential risks to the environment and to human health. Direct health risks mainly concern those working in the field without using proper gloves, uniforms, and etcetera; a high percentage of waste workers and individuals who live near or on disposal sites are infected with gastrointestinal parasites, worms, and related organisms (Hand, 2007).

Thus solid waste management is the growing issue of the country. Composition and quantity of the solid waste is determined by the level of socio economic development of the people. Higher the socio economic status, higher is the generation of waste. Also the amount of non-biodegradable waste increases with increase in socio economic status (Sthapit, 2010).

1.5. SWM in Kathmandu Municipality

According to the base line study done in year 2016, the average per capita household waste generation rate in Kathmandu is 0.3 kg/person/day. This is similar to the average waste generation rate in urban areas of Nepal which is 0.25 kg/person/day considering the total populations of Kathmandu Metropolitan City in 2016 to be 2,100.000; the total amount of municipality waste generated comes out to be 566 ton per day. Population growth rate of the city is 4.35 % in 2016, this high growth rate is expected to increase the waste generation at even higher pace (KMC, 2016).

Various studies have shown that solid waste management is a major problem in the other municipalities. There is no organized door-to-door collection system. The waste segregation system at the source has not yet been strictly adapted by majorities of people. There is no permanent sanitary landfill site. Collected wastes are dumped haphazardly along river banks, ponds, by-pass roads and open spaces. Nearby areas of those places are prone to serious health hazard (ADB, Asian Development Bank, 2013).

1.6. Problem Statement

Solid waste is a global issue. Management of the solid waste have posed a serious problem. This is well justified by law of thermodynamics, where at each level, when the quality of product decreases, it is even more difficult to extract something out. And when we have very less extract with high input it would be unconventional and we simply throw it. This issue has concerned most to the managers.

Solid waste management has posed a new challenge in Nepal. The volumes of solid waste generated in the growing cities are increasing in rapid way. The increase in the volume can be attributed to the increase in the population of the urban areas. In contrast, the management of solid waste can be viewed as disappointing.

The other most obvious environmental damage caused by solid waste is aesthetic, i.e. waste that litter public areas is ugly and smelly. A more serious risk is the transfer of pollution to ground water and land as well as the pollution of air from improper burning of waste. Many waste activities generate greenhouse gases; e.g., landfills generate methane and refuse fleets are significant sources of carbon dioxide and nitrous oxide. Open burning dumpsites produce volatilized heavy metals (e.g. mercury and lead), dioxins, and furan. Leachates from unlined and uncovered dumpsites contaminate surface and ground waters.

There are alternatives available rather than simply throwing the by-products. This, in one hand reduces wastes to be dumped while on the other hand generates huge amount of energy and revenue for the country. More importantly, it reduces potent greenhouse gases and reduces potential areas that dumping site would otherwise take. Also, it reduces nuisance of vehicles, smells, and vectors to people living nearby.

Thus, the findings of the study could be reference to the other growing cities that are having trouble in finding places to dump the low quality energy.

1.7. Objective

1.7.1. Main Objective

To estimate the Potential for energy recovery and greenhouse gas mitigation from municipal solid waste using waste-to-energy approach

1.7.2. Specific Objectives

- To estimate the amount of waste generated from the municipality
- To estimate the energy content in the wastes
- To estimate the electricity potential of waste for different municipalities
- To calculate the reduction in amount of Air Pollutant and GHG emissions
- To compare the possible waste to energy technologies
- To carry out financial analysis of different WTE technologies

1.8. Research Gap

In previous research, the energy potential of waste was estimated by using anaerobic digestion technology. This research tries to implement other waste to energy technologies like plasma arc gasification, pyrolysis technology, incineration. Previous research have done only in certain area or ward of municipalities, this research tries to estimate the waste to energy potential of 58 municipalities by using different technologies and estimate the reduction in GHG emissions by implementing these technologies and ascertain the best technology by economically and environmental efficiency.

1.9. Methodology

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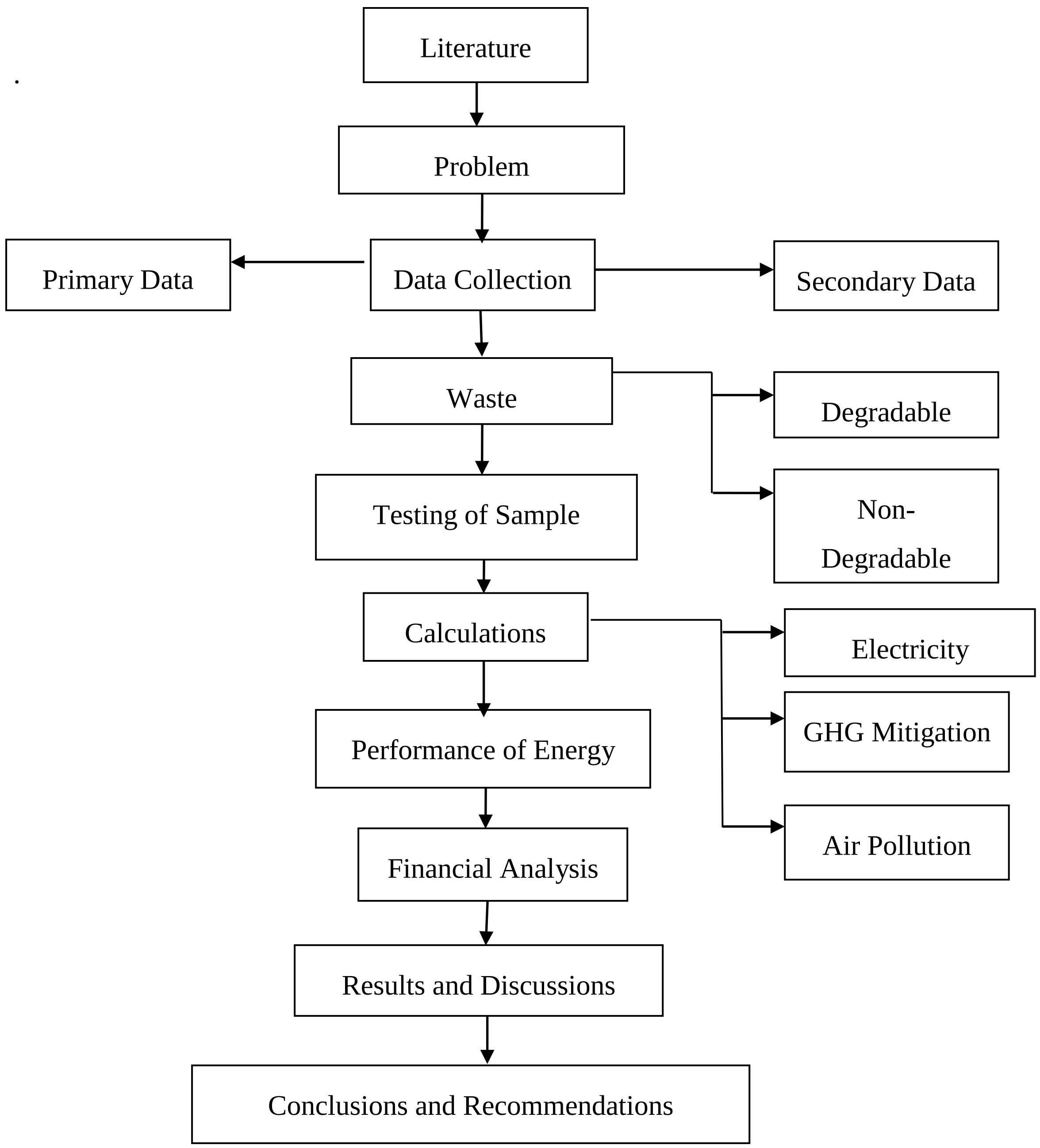

CHAPTER TWO: LITERATURE REVIEW

2.1. Composition of solid waste and waste-to-energy recovery technologies

Solid waste composition plays a vital role while developing a solid waste management system. This management system may include the recycling, composting, landfilling and any other waste to-energy technology strategies. Specific type of energy recovery technology depends on particular components of waste stream. So the technologically and economically suitability of certain waste-to-energy scheme is defined by characteristics of waste stream (Tatarniuk, 2007).

2.1.1. Anaerobic digestion

Anaerobic digestion facility has the ability to deal with degradable organic fractions of waste streams. Suitable internal system conditions are provided such as warm and moist to microorganisms to degrade organic waste to stabilize end product, which is free from pathogens and act as a soil conditioner (Varma, 2009). For anaerobic digestion quantity of organic components present in solid waste stream has an important value (Tatarniuk, 2007).

Anaerobic digestion can produce combustible gas suitable for driving a gas turbine. The gas is free of hydrogen chloride and other acidic gases. Anaerobic digestion does not require heating of the waste fuel to a high temperature, converting the moisture content to steam, and then cooling it down again while trying to recover its energy. Another important advantage of anaerobic digestion is that the nitrate content of the fuel is not destroyed. Nitrates are retained in the final, indigestible sludge, allowing it be used as a soil fertilizer. Retaining nitrates in the sludge may be energy efficient – the average natural gas consumption for anhydrous ammonia production is approximately 35 MJ of gas for 1 kg of fertilizer. The energy content of wet putrescible (waste capable of being decomposed by microorganism and of such character) is typically 4MJ/kg (Griffiths, 2003).

The most significant disadvantage of anaerobic digestion is that it is only effective for the putrescible part of the waste. If other waste, such as fragmented plastics and metal, is mixed in with the putrescible, then the final sludge is unsuitable for land spreading and its fertiliser content is lost. Anaerobic digestion is not very good at breaking down the cellulose in paper and wood; therefore, it can only extract a limited amount of the stored energy. However, if the waste is thermally treated before anaerobic digestion takes place, the cellulose is more easily (Griffiths, 2003).

It is estimated that 1 kg of organic solids derived from municipal waste digested at between 35 and 40°C will yield up to $0.35m^3$ of gas, with about 58% methane within 15 to 30 days (Diaz et al., 2008).

The energy content of methane gas at 20°C is 33 MJ/m3; hence, the potential energy output per kilogram of organic solids is 6.8 MJ/kg. This number is consistent with the calorific values of wet putrescible waste. The Steinmüller Valorga process, which has been operating in France since 1988, demonstrates that anaerobic digestion can be applied effectively to the organic screenings of a Refuse Derived Fuels (RDF) or waste recycling plant. (Griffiths, 2003).

2.1.2. Incineration

Incineration is the combustion of solid waste stream to produce gases, particulate emissions, ash and energy. Efficiency of incineration facility is directly linked with waste composition such as calorific values, inert fraction and moisture content conditions (Varma, 2009).

Municipal solid waste incineration is found at most advanced level of waste disposal/treatment hierarchy. Incineration can reduce the volume of MSW by 90% and its weight by 75% (Griffiths, 2003). Incinerator can be located at the centre of gravity of waste generation and thus reduces the cost of waste transportation. However, flue gas and ashes from incinerator tend to content unburnt carbon, heavy metals and organic toxins including Dioxin (Kobylecki et al., 2010).Deciding to incinerate wastes instead of other options takes careful consideration of criteria for success. The wastes must meet minimum calorific value requirement which must be greater than 6 MJ/kg throughout all seasons, and the specific composition is also important. Waste composition depends highly on socioeconomic condition, the degree of urbanization and industrialization.

Thus, before introduction of such advanced treatment plants, there must be comprehensive study on solid waste composition and availability (The World Bank, 1999). In the late 1900's, some of the European and Asian countries have jumped directly from simple dumping to incineration and they have found limited success.

Incineration is very much linked to the promise of revenue generation from electricity (Kwh) or heat (GJ) or combined electricity or heat. This revenue usually offsets per tonne operating cost by as much as 30% to 45% (Foundation, 2011). However, several other facts impact the total output of energy from the incineration. For example, net calorific value of MSW is reduced through recycling, source reduction of wastes, and seasonal variation in waste characteristics. Due to which less energy is produced and additional import of energy (usually natural gas) is needed to maintain thermal heat within the heat chamber. World Bank guide on incineration of municipal waste recommends that a Lower Heat Value (LCV) of 6000 KJ/kg (1435 Kcal/kg) during all the seasons is required for sustained combustion for adopting the thermal treatment process (The World Bank, 2010). This can substantially increase net operating costs.

2.1.3. Briquetting

Briquetting is the process of converting low density biomass into high density and energy concentrated fuel briquettes. It is the process of densification of biomass using some mechanical energy. This process is effective in increasing volumetric calorific value, thus it becomes easier to transport as fuel source in very rural sectors.

As the country's living standard improves, the consumption trend is inclined towards processed foods and more plastic derived materials. The urban growth in Nepal shows similar pattern of waste composition. In Kathmandu, the capital city, 17 percentage of total waste is composed of plastic and paper (SWMRMC, 2008) and similar trend of composition is seen in other growing cities like Butwal, Biratnagar and Pokhara. Plastic wastes, mainly polyethylene bags in MSW have high energy content, as much as kerosene. Such a high energy content which is imported from foreign countries should not be dumped in the landfill (Heejon et al., 2006).

Briquetting technology is one of the simple technologies practiced for making biomass-based fuels including wastes like milled paper, plastic and other combustible wastes. The municipal waste can be best recovered/reused by transformation into solid waste fuel briquettes either in the form of RDF, a compressed form of waste paper, plastics, wood chips and other combustible materials, or in the form of Selective fuel, a blend of combustible organic component such as plastics of MSW with low grade coal like lignite. In this light, waste-to-energy conversion would be an economical and eco-friendly way for addressing both the issues of waste management and energy shortage, both at the same time (Shrestha, 2011).

Utilization of plastics in briquettes improves fuel efficiency and this makes briquetting option a better option as fuel in industrial boiler, and Brick kilns with appropriate control measures (Shrestha, 2011). This waste-to-energy conversion option not only extends the life of landfill but also provides an alternative energy resource by utilizing wastes.

2.1.4. Fermentation

Fermentation is an alternative digestion process for cellulosic materials that can yield liquid fuel in the form of ethanol rather than methane gas. The ethanol is extracted by distillation. The fermentation process has to be proceeded by an enzymatic hydrolysis of the cellulosic material to produce sugars.

2.1.5. Pyrolysis and Gasification

Pyrolysis and gasification (P&G) technologies are designed to convert biomass that is rich in carbonaceous materials into carbon monoxide (CO) and hydrogen at high temperature by reacting with raw material under oxygen control environment (Varma, 2009). Pyrolysis technology is considered suitable for paper rich solid waste stream. These facilities are well known for mixed municipal solid waste with high amount of organics (Tatarniuk, 2007).

Pyrolysis is a chemical process for conversion of materials through the application of heat in an oxygen free atmosphere. The organic matter in solid waste is converted into gases, liquids and a solid char. Since volume reduction through pyrolysis is approximately 50 percent, it is valuable for reducing materials before further processing.

However, the operation's main benefit lies in the fact that the products from the decomposition of the organic matter – including paper and plastics – are valuable fuels in themselves. After the reaction is initiated through the use of an auxiliary fuel, a portion of the decomposed products can be used to make the process self-sustaining. Thus pyrolysis can be used directly in energy recovery.

2.1.6. Clean Development Mechanism (CDM)

The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol, allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO2, which can be counted towards meeting Kyoto targets. (UNFCC, 2012).

The CDM was designed to meet two objectives, namely to help Annex I Parties to cost-effectively meet part of their emission reduction targets under the Kyoto Protocol and to assist non-Annex I Parties in achieving sustainable development. While CDM projects create certified emission reductions (CERs) that project participants can sell to Annex I Parties to help them meet their Kyoto Protocol targets, they can also provide complementary benefits to non-Annex I Parties such as new investment, the transfer of climate-friendly technologies and knowledge, the improvement of livelihoods and skills, job creation and increased economic activity (UNFCC, 2012).

Municipal integration into CDM has triple benefits; one way the wastes will be managed in sustainable way, dramatic reduction in emission of dreadful GHGs and toxic chemicals and large number of people who are making their living from wastes will get benefits from incentives (GAIA, 2011).

2.1.7. Landfill gas (LFG) Collection and Utilization

Landfills produce landfill gas by the degradation of organic matter under anaerobic conditions. The evaluation of any landfill gas recovery project is highly effected by the composition of waste, specifically the organic fraction, moisture level, and the "degradation" factor of different waste components. Like those landfills with high food waste contents, relatively faster decay to generate landfill gas over short period of time (ENGINEERS, SCS, 2005).

2.2. Choice of feasible technology and other affecting parameters

The choice of a particular technology for the treatment of solid waste stream relies on important parameters such as environmental friendly, techno-economic viability, areal conditions and sustainability. "The important parameters that are considered generally for a sustainability analysis are the quantity of waste that can be handled, physical, chemical and biological characteristic of waste, land and water requirements, environmental sensitivity to locations, environmental implementations, capital investment, operation and maintenance costs, cost recovery, product utility, byproduct usability or reject disposal, requirement of pollution control installation etc." (Varma, 2009). Solid waste management system is also affected by social, economic and political outcomes. Varieties of solid waste management rules and regulatory requirements of a country play crucial role while it's waste management system development (Zaman, 2010).

2.3. Waste-To-Energy (W-T-E) treatment options

2.3.1. Anaerobic digestion

Anaerobic digestion is a process where biodegradable material is breakdown through microbes in the absence of oxygen. Special reactors are used for digestion process and controlled specific conditions are provided inside reactors such as pH, moisture content and temperature etc. The purpose of these conditions is to provide favorable environment to microbes and allow them to increase their number and to enhance the degradation process to produce methane (FCM, 2004). The organic fraction may contain yard waste, paper waste, food waste and any other type of organic matter. The anaerobic digestion process is highly successful if the wastes are containing high quantity of organics, primarily this process produces methane (CH4) and carbon monoxide (CO) and also with small fraction of other gas gases such as H2S (Tatarniuk, 2007). Anaerobic digestion basically consists of three steps. In first step, organic material is prepared through sorting, segregation and size reduction. In second step, favorable environmental conditions are provided to ensure digestion process through microbes such as pH up to 6.7 and maintain temperature about 55-60 degree centigrade. These components are well mixed for approximately 5-10 days, but in colder climate slurry is mixed at low temperature for long time. In third step, the residual sludge is disposed of, if it is contaminated, after treatment it is disposed of and it is an extra step. The microbes which have vital role are classified into two groups: one is the acid forming and second CH4 forming group. Acid forming group is used to treat complex organic components into simple acids and the CH4 forming bacterial group convert simple acids into CH4. The CH4 forming bacterial group is sensitive to different environmental factors; temperature is the core component, control of oxygen and also preventing from entrance of toxic substances into the system. Generation of CH4 can take place in two ways, either it is collected directly off of the landfill sites i.e. bioreactor landfill or sanitary landfill or pre-treated refused digested in digesters. Digesters are dived into high solid and low solid digesters. Low solid digester is well established as compared to high solid digester but it requires high amount of H2O added to waste (Tatarniuk, 2007).

- Advantages

Anaerobic digestion requires low capital and operational costs compared to thermal technologies. Surplus energy can be recovered in the form of CH4 and also revenue generated through its sale. Pollution control is possible through appropriate control technology. Anaerobic digestion diverts most of organic components from landfills and also reduces risk of gas and leachate production. Well maintained and controlled system ensures low level of environmental pollution (Gruner, 2007). After anaerobic digestion of waste, the waste can be aerobically treated and can get benefits in the form of produced gas and soil conditioner from process for energy production and soil amendment respectively (Tatarniuk, 2007).

- Disadvantages

Anaerobic digestion has some implication in economics and in practical parameters. Anaerobic digestion technology works well on pre-treated waste, like mixing of plastic with organic fraction may cause operational problems. Some anaerobic digestion facilities have ability to deal with mixed solid waste. Bad odor is produced during handling of material. Market value of end product may be lower because of the presence of toxic contaminants in it as it is difficult to get rid of them during processing. Anaerobic digestion has high cost for handling, storage, and processing (Gruner, 2007). Generally this process is used for the sewage and manure treatment because of their homogeneous in nature and also easy for microbes to degrade them. Mixing of these components with solid waste would enhance the microbial activity to degrade it (Tatarniuk, 2007).

2.3.2. Incineration

Incineration is also known as combustion (Tatarniuk, 2007)(Tat and thermal treatment of raw waste feed into the system Only the organic fraction such as plastic, combustible and putrescible are burnt in the system and as a result of which gases and residues are produced. According to (Zaman, 2010) end-product consists of carbon dioxide (CO2), water (H2O), incinerated bottom ash and small quantity of residual carbon. The treatment process requires enough quantity of oxygen (O_2) to oxidize the waste, and the typical temperature at about 850ºC. Incineration technology has the basic components, such as feeding chamber, combustion vessel, exhaust system and residual ash chamber. The feed stock should be well mixed, dried and heated for defined time period. Derived fuel systems, on-site commercial and industrial combustors, mass-fired combustors and modular combustor are the common incineration units in use (Tatarniuk, 2007).

- Advantages

Thermal treatment has ability to reduce volume of waste and considerable amount of solid waste diverts from landfills (STANTEC, 2010). According to the bottom ash from the system may have approximately 10% by volume and 20 to 35% by weight of original waste stream which is fed into the system. Thermal treatment facility has ability to recover energy, variety of chemicals and minerals could also be recovered and reused from waste stream. Incineration facilities have the ability to destroy number of toxic substances present in solid waste (STANTEC, 2010) .

- Disadvantages

Incineration of waste may contain heavy metals and there are also chances of dioxins in gases, ash and H_2O. Those communities living close to solid waste incineration facilities bear health problems and also a source of environmental pollution (EPA, 2004). These facilities having high capital and operational costs are yet unproven technologies (Gruner, 2007).

2.3.3. Pyrolysis technology

In pyrolysis, thermal degradation of biomass waste take place in the absence of O_2. Pyrolysis and gasification depends on external source of heat. In case of pyrolysis, the conversion of organic matter to liquid, solid and gaseous components takes place through thermal cracking and condensation. The produced gases from pyrolysis processes are used as an alternative fuel which substitutes the natural gas, char and pyrolysis oils are also produced from it. Combustion process requires temperature at about 815ºC (Tatarniuk, 2007). Both the pyrolysis and gasification systems having almost the same operations, these technologies convert waste stream to char, gases and liquids. However, a small amount of oxygen (O_2) or steam is required in the gasification process (STANTEC, 2010).

- Advantages

Pyrolysis technology has ability to divert large quantity of waste stream from landfills. It can produce different types of products like fuel oil, gases and also recover recyclables at the frontend of technology (STANTEC, 2010).

- Disadvantages

Pyrolysis technology has higher capital and operation costs (STANTEC, 2010). Products produced from pyrolysis are relatively less valuable (Tatarniuk, 2007).

2.3.4. Gasification technology

According to Tatamiuk (2007) gasification is a modified form of pyrolysis system, using small amount of O2 which produces sufficient heat that enables the system to be self-sustained. Due to partial combustion of organic waste stream resulting in the production of fuel gas that contains H2, CO and hydrocarbons. Vertical and horizontal fluidized bed combustion is the gasification types, which are very common in use. There are basically three gasification technologies are in use: high temperature gasification system, fixed bed and fluidized bed combustion technologies, although high temperature gasification technology has commercial scale value.

- Advantages

Gasification like pyrolysis have high tendency to reduce particulates and sulfur dioxide (SO2) emissions from process The syngas (consists of CO, H2 with little concentration of H2O, CH4, N2 and CO2) produced from gasification system can be used to generate heat and electricity. This technology is basically formulated to produce and use of syngas from system (STANTEC, 2010). Gasification is not an incineration system but a combustion technology, where efficiently energy is recovered from the system. This technology is more attractive due to high production of energy.

- Disadvantages

Gasification also has high capital and operational costs. It does not have ability to treat mixed municipal solid waste (MSW). The Gasification system has less ability to generate revenue from solid waste stream as compared to net investment costs. Residue from gasification may be hazardous due to contaminants present in solid waste used as a feed stock for processing. Gasification is not proven technology for non-organic fractions of waste stream treatment. It is highly expensive than the approved facilities (STANTEC, 2010).

2.3.5. Landfill gas production and utilization

Anaerobic digestion of organic components from solid waste stream which are helpful for the production of landfill gas (Willumsen & Terraza, 2009). Production of landfill gas from sanitary landfill facility is comparable with anaerobic digestion but make difference only at the operational control on sanitary landfill (Tatarniuk, 2007). From the total concentration of landfill gas, the CH_4 has 50% concentration level with 34 MJ/m^3 energy value (Willumsen & Terraza, 2009). The degradation of organic fraction in sanitary landfill subsists of following steps: aerobic, anaerobic (non- CH_4 production stage), anaerobic with CH_4 production build-up stage and at last anaerobic steady state level. Recovery and utilization of landfill gas consists of four main steps such as recovery system, a pumping of gas process, a transmission of gas and a utilization of gas process.

- Advantages

Appropriately capture of produced landfill gas from facility could be used as an alternative energy source and this method is also helpful in reduction of greenhouse gases (GHG) i.e. CH_4 and CO_2 emission (Willumsen & Terraza, 2009). Therefore a CH_4 greenhouse gas is 21 times stronger than CO_2 greenhouse gases (ENGINEERS, SCS, 2005). Collection of gas contributes in reduction of fire hazards, odors and vegetation damage. If we compare landfill gas and anaerobic digestion systems, landfill gas requires less operational and maintenance costs. Landfill gas is an important source of waste-to-energy and worldwide energy recovery projects on landfill sites are considerably increasing, approximately 10% growth rate per year since 1990 (Tatarniuk, 2007).

- Disadvantages

Landfill gas basically associated with two pollutants as the emission of biogas and percolated leachate. Produce leachate could be prevented and extracted either through natural impermeable bottom layer or through man-made structures such as piping network under landfills. Capture and utilization of produced gas could also be possible from landfills (Karapidakis, 2010). Landfill gas utilization could be possible to generate revenue, if it is located nearby its consumers. About 60% plant cost is associated with turbines or generators, so either the consumers must be near to it or purchase power at a higher cost.

2.3.6. Bioreactor landfill

Bioreactor landfill is relatively new technology for the processing of solid waste stream. This technology depends on particular design and operational system which accelerates the degradation of solid waste such as green waste, food waste, paper and other type of organic wastes. Its process is enhanced by adding optimum moisture content and enough micronutrients available for the organic matter degrading microbes. This technology has two important functions: one is the promotion of degradation of waste and second is reduction of time of waste stabilization. The steady levels of environmental performance parameters are the concept of landfill waste stabilization which includes the rate of landfill gas production, composition and concentration of leachate. The circulation of leachate in the system has an important role while degradation of organics in the system. The circulated leachate may contain some hazardous substances and also heavy metals (Warith, 2003).

- Advantages

Bioreactor landfill rapidly stabilizes waste stream and reduces time to be burden on environment in terms source of pollution. It is also beneficial because avoids from settlement of new landfill sites by providing airspace. Revenue could be generated through enhancement of gas production. Bioreactor landfill technology has advanced leachate collection and storage system and reduces its cost and toxicity (Warith, 2003).

- Disadvantages

Bioreactor landfill has high capital and operation costs as compared to sanitary landfills. This technology is not yet proven at commercial scale. It is also a major source of odor and increases instability of slope liners (Warith, 2003).

2.3.7. Plasma Arc Gasification Technology

Plasma arc technology uses plasma arc flame as a source of heat. This technology has ability to utilize organic and inorganic components of waste stream. At commercial level, a full pilot project is yet to be established (Kumar, 2000).This facility is proposed and cloud be used for hazardous waste treatment.

Plasma arc gasification is a high-temperature pyrolysis process whereby the organics of waste solids (carbon-based materials) are converted into syngas and inorganic materials and minerals of the waste solids produce a rocklike glassy by-product called vitrified slag. The syngas is predominantly CO and H_2. The high temperature during the process is created by an electric arc in a torch whereby a gas is converted into plasma. The process containing a reactor with a plasma torch processing organics of waste solids (carbon-based materials) is called plasma arc gasification. The plasma arc gasification reactor is typically operated between 7,200^{o}F and 12,600^{o}F.

In commercial practice, the plasma arc gasification process, is operated with an injection of a carbonaceous material like coal or coke into the plasma arc gasification reactor. This material reacts quickly with oxygen to produce heat for the pyrolysis reactions in an oxygen-starved environment. The carbonaceous materials as C that reacts with the O_2 to produce limited combustion but with the necessary heat for the syngas reactions. In addition, steam is added to the plasma arc gasification reactor to promote syngas reactions. The combustion reactions (exothermic reactions) supply heat with additional heat from the plasma arc torches for the pyrolysis reactions (endothermic reactions), yielding a temperature typically between 7,200^{o}F and 12,600^{o}F.

The inorganic minerals of the waste solids (MSW) produce a rocklike by-product. Since operating conditions are very high (7,200^{o}F to 12,600^{o}F), these minerals are converted into a vitrified slag typically comprising metals and silica glass. This vitrified slag is basically nonleaching and exceeds EPA standards. Metals can be recovered from the slag and the slag can be used to produce other by-products such as rock wool, floor tiles, roof tiles, insulation, and landscaping blocks, to mention a few. The vitrified slag, being environmentally acceptable as a recyclable by-product, is one of the more positive attributes of plasma arc gasification process for the management of MSW.

Another positive attribute of the plasma arc gasification process is that developments in the design of plasma arc gasification reactor have improved and lessened the need for pretreatment/preprocessing (Young, 2010).

2.3.8. Other emerging waste-to-energy technologies

According to (Kumar, 2000) and (Tatarniuk, 2007)these are more technologies, which are not in common use yet but may become more attractive options in future, are precisely described below.

2.3.8.1. Palletization

The process of producing fuel pallets from solid waste stream called palletization. The complete process consists of drying, removal of non-combustibles, grinding and mixing steps. Pellets having higher calorific value as compared to raw garbage and also known as refused derived fuel. These pellets could be used and valuable for the production of energy (Kumar, 2000).

2.3.8.2. Garret flash pyrolysis process

A low temperature technology is used for the production of fuel oil. Coarser waste like organic components first shredded to reduce its size and convert to various fuel oils at about 500ºC (Kumar, 2000).

2.3.8.3. Fermentation process

Fermentation technology utilizes biological conversion technique to produce ethanol. Appropriate feedstock for this process is wood, agriculture residues, grasses and the organic fractions of municipal solid waste (Tatarniuk, 2007).

2.3.8.4. Refused derived fuel (RDF)

Refused derived fuel is a process where efficiently remove the inert fractions from waste and produces a uniform fuel that could be used in waste-to-energy plants and also in other thermoelectric plants as an alternative fuel source. During the processing of waste stream to refused derived fuel it could be possible to add calcium (Ca), which is helpful in reduction of hydrogen chloride emissions during combustion process (Themelis & Kim, 2002).

2.3.8.5. Fluidized bed combustion

Fluidized bed combustion technology only utilizes the combustible fractions, after the removal of inert substances from waste like glass and metals etc. The required feedstock is fed up on the top of a fluidized bed of sand or limestone. Typically, the temperate requires for this process is in the range of 830 to 910ºC

2.4. Review of researches

ENPHO; Water Aid; End Water Poverty, 2008 have studied the management practices of Solid waste in various municipalities of Nepal and found that many municipalities are struggling with the management problem of municipal solid waste. Municipalities are spending significant resources to address this problem, but the overall situation is far from satisfactory and rapid and haphazard urban growth is making the problem worse. However several municipalities have demonstrated ways to effectively manage using simple measures (ENPHO, 2008).

There is change in culture of solid waste disposal towards more sustainable waste management. These changes have driven through some of the international agreements, such as the Rio Earth Summit, at a European level, such as Fifth Action Program (1993-2000) and national drivers, such as the strategy for sustainable waste management in England and Wales (Aspinwall & Cain, 1997).

The baseline for proper solid waste management and its associated awareness aspects is the need of the proper co-ordination between different levels of the community, organizations, and concerned authority (Joshi, 2000).

Municipality solid waste management in UK is dominated by land filling, however, environmental, policy based and financial pressures are causing a move towards alternative methods of dealing with wastes. The problem in finding land fill sites and the changing EU and national policies on waste management are leading to a fundamental review of the existing county strategy based on land filling (Grey, 1996).

Studies are shifting from waste disposal techniques toward viewing wastes as potential resource. Because reclamation usually consumes less energy than producing new materials, increasing reclamation not only reduces pollution but also saves energy. Study further emphasises on comparative study on different technologies that would provide optimum benefit in resource recovery, waste minimization, environmentally suitable and economically viable options (Iranpour et al., 1999).

The subsistence needs of an expanding world population and the rising expectations stimulated by the promise of technology and the reality of the global communication revolution have increased world demands for materials and energy. Resource recovery, not just in the case of municipal solid waste but also with regard to other waste streams must be implemented in order to keep depleting resources in the economic system rather than dispensing them in a way which defies reuse (Lesher, 1974).

Study by Cilinskis & Zaloksnis, 1996 for the Rega city, Latvia, is based on past and present practices of many cities and countries in order to raise environmental standards and propose ways towards sustainable development in general. The study on solid waste management suggested institutional changes, modern collection and recycling, new landfill construction in the first stage and biogas plant and incinerator construction in the later stages.

World is facing dual crisis of increasing waste and global climate change. Substituting fossil fuels with waste biomass-derived cellulosic ethanol is a promising strategy to simultaneously meet part of our energy needs, mitigate greenhouse gas (GHG) emissions, and manage municipal solid waste. The report found waste biomass-derived cellulosic ethanol potential in relation to socio-economic development across 173 countries show up to 82.9 billion litres of waste paper based cellulosic ethanol can be produced worldwide, replacing 5.36% of gasoline consumption with accompanying GHG emissions saving of between 29.2% and 86.1% (Z. et al., 2009).

In EU MSW management is normally seen as major decision making issue for sustainable development. Facing all regulatory agencies, industrial, and municipalities in the EU, whereas the southern EU countries (e.g. Portugal, Greece, Spain) require developing measures to implement more integrative SWM system and reach the objectives of the EU directives, the central EU countries (e.g. Germany, Austria, The Netherlands, United Kingdom, France) and certain Northern countries (e.g. Norway) need models and tools in order to rationalize their technological choices and management strategies (Pires et al., 2010).

One of the basic institutional requirements for the implementation of a reliable system of the waste management is the establishment of comprehensive control mechanism. It emphasizes the enforcement of measures to be more effective by licensing of waste disposal facilities, prosecuting and implementation of waste management plans (GTZ, 1996).

The accumulation of waste within the city is the result of overconcentration of population and lack of coordination among various urban agencies. The report shows that lack of strong legal provision to control the negative behaviours of people is also responsible for the dirtiness of the city.

The study found that landfill disposal and waste-to-energy (WTE) incineration remain the two principle option for managing municipal solid waste. One critical determinant of the acceptability of these options is the different health risks associated with each. The overall results indicate that the individual cancer risk for both options would be considered generally acceptable, although the risk from landfilling is approximately 5 times greater than from WTE treatment: the individual non-cancer health risks for both options would be considered generally unacceptable (Moy et al., 2008).

The haphazard disposal of urban and industrial waste is one of the causes of water pollution in Bagmati River in Kathmandu. The report further claimed that 90% of the pollutants in Bagmati River were solid wastes that are responsible for the generation of fuel gases in the river, degrading the ecology and surrounding environment (NESS, 1995).

The result indicates that the per capita waste generation is still low as compared to other developed countries and about two-third of the waste materials are organic in Kathmandu metropolitan city (Dangi et al., 2010).

Municipal solid waste is suitable for briquette formation. Though high energy is achieved through gasification, MSW is not suitable for gasification and therefore it has to be dried, shredded or disintegrated and compacted into suitable form- briquette. This research provides a good overview of the parameter of the technologies of briquetting and material composition for producing briquette from municipal waste (Krizan et al., 2011).

Solid waste generation by urban household in Kathmandu valley in 2001 was 900 metric tonnes per year and KMC alone produced 310 tonnes of garbage every day. They also highlighted that the percentage of organic materials in the solid waste of Kathmandu valley decreased to 52.2% in 1995 from 67.6% in 1976. Meanwhile, plastic increased from 3% to 5% and glass from 1.3% to 3.6% in 1995 from 1976 (Devkota et al., 2003).

Market and methodologies for briquettes has found that there is ever expanding demand of briquettes from biomass as Nepal is one of the high biomass energy consuming country in Asia. But, according to him, the supply is rather fulfilled by part time and community based producers and there is huge potential for commercial production as majority of the consumers are from urban settlements due to energy crisis like shortage of petroleum products and lack of electricity (Khanal, 2011).

2.5. Energy Bin

Energy Bin (Figure 2.1) is multi-stage digestion system that converts bio-degradable waste into bio energy. This includes conversion of solid/wet bio-degradable wastes like food, industrial, animal and human waste into clean bio-gas, solid manure and liquid manure that can be used in agriculture, thermal and electrical applications. The entire set up is easy to install and operate. Its PORTABLE nature makes it a PLUG-N-PLAY plant; the first of its kind in India. It's completely enclosed design makes it odorless, noiseless and aesthetically rich to suit modern residential, industrial, commercial and corporate facilities. The chamber for energy man is completely equipped with a control panel to monitor and set parameters. It's designed in a completely contemporary way.

Figure 2.1: Model: EB-1000 Waste Capacity: 1,000kgs/Day Weight of the Plant: 18 Tons

2.5.1. Working Principle

The wet waste that is collected is brought at the Energy-Bin. The Energy-Man sorts the wet waste and removes any metallic or other dry waste pieces from the feedstock. The filtered wet waste is then pumped into the crusher for faster and efficient digestion. The feedstock is fed into the Digester and X-Additives like enzymes and nutrients are introduced to further boost digestion process, improve effectiveness of the conversion and enhance the quality of Bio-Gas. This initiates an anaerobic reaction that converts the bio-degradable solid and liquid waste into bio-gas, liquid manure and solid manure. The entire progress can be monitored on the control panel set up in the Chamber for Energy-Man. All the parameters that affect the efficiency of conversion like temperature, pH levels, Microbial count, mixing, etc. can be controlled through a single dashboard. The bio-gas that is generated can be stored, used or piped via a Bio-Gas Balloon that is mounted on the top of the Energy-Bin.

2.5.2. Features

- Requires very less Electricity.
- No fresh water required to treat the waste.
- Digester made up of IS 2206 grade Steel and tested with 3X Operational Pressure.
- Working life of the plant: approx. 20 years.
- Equipped with an automatic temperature control system.
- Programmable Logic Control (PLC) based panel for ease of operation and control.
- Easy to use touch-screen panel interface (Human Machine Interface – HMI).
- Inbuilt smart online system which reads weight of the waste, pH of the digested slurry and temperature & gas output.
- Equipment such as Pressure Transmitters, Thermostats, pH Indicators, Solenoid Valves, Auto Gas Flare with Ionizers and Spark Ignition System to ensure Fully Automatic Operation and Complete Safety.
- Compact indigenous solid-liquid separator, a system that removes excess water from the digested slurry. The separated water is re-circulated back to the plant. Excess water, if any, can also be used for gardening purpose.

- Automatic pressure release system with both mechanical & electrical controls.
- Equipped with Submersible Agitator which avoids settling of the solids inside the digester by helping in smooth circulation of the slurry leading to better digestion.
- Designed to handle all types of biodegradable waste including fruit & vegetable peels, process & plate waste, used kitchen oil/grease, tissue paper & garden waste and more.
- Designed for shock-loading of waste.
- Ensures maximum volatile solids degradation and avoidance of heat losses.
- Neoprene balloon for Bio-Gas storage, tested to withstand the weather exposure for continuous running of minimum 5 years
- Advanced Industrial Burner designed for application along with ENERGY-BIN which ensures equivalent thermal transfer compared to the conventional LPG system.
- Available in 7 models: EB-100, EB-250, EB-500, EB-750, EB-1000, EB-1500 and EB-2000 with per day waste conversion capacity of 100, 250, 500, 750, 1000, 1500 and 2500 kgs. respectively.

2.5.3. Benefits of Energy Bin

It produces energy (Heat and Electricity) and Bio gas. Bio gas is a great substitute for LPG Cylinders & can take part load of power generation.

It transforms organic waste to high quality fertilizer. Energy-Bin system yields organic manure which is a better substitute to chemical fertilizer. The manure (liquid and solid) produced by Energy-Bin (anaerobic digestion), contains 3 Times more Nitrogen than the best compost made through open air digestion (aerobic digestion). Organic manure is cost effective and eco-friendly substitute to chemical fertilizers. They provide a sustainable source for nutrients and healthy soils in longer run.

It improves hygienic conditions through reduction of pathogens, worm eggs and flies. With scientific sludge treatment and by optimizing the treatment parameters, maximum amount of pathogens are killed. The principal organisms like Typhoid, Paratyphoid, Cholera and dysentery bacteria (in one or two weeks), Hookworm and bilharzias (in three weeks) are killed in the plant. Tapeworm and roundworm die completely when the fermented slurry is dried in the sun.

Environmental advantages through protection of forests, soil, water and air – The widespread production and utilization of biogas is expected to make a substantial contribution to soil protection and amelioration. Besides, more fodder becomes available for domestic animals. This, in turn, can lessen the danger of soil erosion attributable to overgrazing.

Global environmental benefit of biogas technology, a renewable source of energy is captured, which has an important climatic twin effect. The use of renewable energy reduces the CO_2 emissions through the reduction of demand for fossil fuels. At the same time, by capturing uncontrolled methane emissions, the second most important greenhouse gas is reduced. The reduction of 1 kg methane is equivalent to the reduction of 21 kg CO_2. In effect, this has a direct impact on “Global Warming” which is essentially caused by harmful emissions of CO_2 and Methane (CH_4).

An Energy-Bin plant is better than 15,000 trees. Therefore, Energy-Bin can take a massive load off the trees to absorb CO_2. Energy-Bin – From Waste to invest 1000 kg of kitchen waste produces 80-100 m^3 of biogas per day replaces 36 – 38 kg of LPG. 1000 kg of organic waste produces 80 – 100 kg of organic manure per day. So this mean Energy-Bin converts 1000 kg of organic waste generated every day to electricity that can light up, up to 25 2BHK flats per day. It can provide clean cooking gas to up to 80 apartments (4 family members per apartment) per day.

CHAPTER THREE: METHODOLOGY

The research work is based on primary and secondary data collection in order to respond to the research questions of the study. The secondary data were collected directly from concerned offices, research institutions like universities and NGOs, which are closely dealing with the solid waste management issues. After reviewing their reports, the primary data were also collected on the basic issues, which are not dealing with, or not clearly mentioned in reports through “key informed consent approach”. The secondary data come from a combination of electronic and printed form of materials such as published books, research papers, journals and articles etc. Primary and secondary data consist of composition and quantity of solid waste and environmental related issues of solid waste stream and also about waste-to-energy recovery technologies.

3.1. Research method

The study is based on the inflow and outflow of energy incorporated in the management of MSW. Thus, with the discussions, informal talks with concerned personnel and field data collection allowed the calculation of monitory inflow. The total energy content of the municipal wastes was calculated in the laboratory using Bomb Calorimeter. Other economically valuable wastes like papers, plastics, ferrous and non ferrous metals evaluations were done with the help of dealers from scrap collectors based on current market value.

3.2. Data collection

3.2.1. Solid waste data

Sample sites were categorized first into strata according to the amount of waste generated, and then the samples were drawn on the basis of percentage share of the total waste by each category.

Sample wastes were collected from door to door collection method. For the samples, each household was given a sample bag on which they collected and stored the one day waste. The next morning samples were collected providing next sample bag for following day. Samples were collected for two days to get mean value of amount and type of waste generated.

The sampling was conducted for the categories earlier defined, due to various reasons; the data from other important sources of waste generation could not be gathered. Such sources are industries, street waste, and street shops that open in the evening and close at late night.

Data collection in the industries was not kept in the priority because most of the wastes they produce are not collected by the municipal and secondary waste processing factory collects reusable or recyclable wastes. In case of street waste, there could not be representative samples, each corner of the collection differs from other and the composition does not remain same for all time. For street shops, the sampling time was the major problem and the wastes they generate were not considered of great volume.

For the sample determination, 5 samples from each category, except for hospital, were weighed for two days and samples were drawn on following basis.

Table 3.1: Sample design

Category	**Population**	**Waste (kg/HH)**	**Total waste (kg)**	**%share of waste**	**Total sample size**	**Sample size**
Households	240,122	1.3	312,160	55.10	73	35
Hospitals	180	43	7,740	1.40		1
Restaurant	6,250	29	181,250	32		27
Hotel/Lodge	3,100	21	65,100	11.50		10
Total			566,250	100		73

Sample Size: Sample size of the household was determined by using formula (C.R.Kothari, 2010).

$$Sample\ Size = \frac{\mathrm{NZ^2P(1-P)}}{Nd^2 + Z^2(1-P)} \qquad \text{Eq. (3.1)}$$

where, N= Population Size

Z=1.96

P=0.95

d = 0.05

3.2.2. Waste categorization

After the sample design, wastes were separately collected from the sample households, hospitals, restaurant, and hotel/lodges. Wastes from each category were separately segregated and weighted. The segregation was done into six titles; Organic wastes, paper wastes, plastic wastes, metal wastes, glass wastes, other (included textile wastes, electronic wastes, dusts and other miscellaneous) wastes. A total of 73 sample sites of defined strata were used for the determination of type and amount of wastes.

3.2.3. Moisture Content in waste

The sample was categorized into five strata: organic wastes, paper wastes, plastics wastes, other wastes (contained textile wastes, dusts, electronic wastes) and noncombustible wastes (merged group of metals and glass). From each redefined category, for the determination of moisture content in the municipal solid waste, 1 kg of sample was taken and the sample was heated at constant heat of 85^{0}C in an oven. Noncombustible wastes were not taken for determining moisture content. The sample was kept under constant heat until the concurrent reading was observed. Final weights were subtracted with initial value to get the moisture content.

Once the moisture content of the sample was defined, this was integrated into total waste and total moisture content and dry weight of the sample was drawn. This is important finding for the use of these MSW into waste to energy conversion system because moisture content is an important determinant factor in the energy content of waste substance. Moisture content is calculated as;

$$Moisture\ Content\ =\ \frac{Total\ moisture\ weight}{total\ municipal\ waste\ weight} X100 \qquad \text{Eq. (3.2)}$$

3.2.4. Calorific value determination

The calorific value or the heat of combustion of a sample is the number of heat units liberated by a unit mass of sample when burned with oxygen in an enclosure of constant volume (Parr Instrument Company, 2007).

Using bomb calorimeter, we get the high heating value of the fuel. To get the LHV, the molecular formula for the fuel must be known. This is obtained by the ultimate or elemental analysis.

To determine the calorific value of the MSW, Bomb calorimeter was used with dried standard 1gm sample in each of the four pre-defined categories (Organic, plastic, paper and other wastes). These samples were tested in the laboratory according to IP - 12 Standard using bomb calorimeter.

Lower heating value of samples was determined as the energy required to completely dry out the moisture content of the wastes were subtracted from gross calorific value of the wastes.

3.2.5. Calculating energy efficiency of energy conversion system

Here municipal solid waste is considered to be used without dried in the sun. The following equation is adapted from (Fobil et al., 2002)

$$Ne = Gte - Ed \qquad \text{Eq. (3.3)}$$

where, Ne - Net energy

Gte - gross total annual energy

Ed- energy required in drying the waste

But the energy required for drying MSW to a constant weight (Ed) is given by the sum of the energy required to raise the temperature of the water in waste from its initial temperature to a vaporization temperature of 100°C (HI) and the energy required to completely vaporize the water in the waste at 100°C or heat of vaporization (HV).

This means that,

$$Ed = HI + HV \qquad \text{Eq. (3.4)}$$

Therefore, Eq. (3.1) becomes,

$$Ne = Gte - (HI + HV) \qquad \text{Eq. (3.5)}$$

But, HI = mass (m) of moisture in MSW x heat capacity (c) of water in MSW x change in temperature (θ).

This implies that

$$HI = m \times c \times \theta \qquad \text{Eq. (3.6)}$$

But, θ = final temperature (100°C) – initial temperature of water in MSW assumed to be the average annual temperature in Municipality.

And HV = mass (m) of moisture in MSW x latent heat of vaporization (cV). This also implies that

$$HV = m \times cV \qquad \text{Eq. (3.7)}$$

Therefore, Eq. (3.5) becomes

$$Ne = Gte - (m \times c \times \theta + m \times cV) \qquad \text{Eq. (3.8)}$$

Energy efficiency of an energy conversion program

$$\eta = \frac{Ne}{Gte} \times 100\%. \qquad \text{Eq. (3.9)}$$

The potential net maximum recoverable energy depends largely on inherent physical characteristics such as moisture content and heating value of urban refuse in a given waste stream.

3.2.6. Estimating the Energy Potential of MSW

After getting the calorific value of each categories of waste, the total energy potential of MSW was calculated

$$Total\ Energy = \sum W_i \times CV_i \qquad \text{Eq. (3.10)}$$

where, W_i =dry weight of waste of constituent i

CV_i = Calorific Value of waste of constituent i

3.2.7. GHG Calculations

GHG mitigation by the waste to energy was calculated using following formula (Chen, 2016)

$$GHG\ mitigation = \sum (W_i\ X\ MF_i) \qquad \text{Eq. (3.11)}$$

where, W_i= weight of waste of constituent i (tone)

MF_i= mitigating factor (kg CO2-eq/tone)

3.2.8. Financial Calculations

Decisions about capital investment in different technologies involve comparisons of payments of money at different points of time. Whether to invest on a particular technology depends upon the costs involved in that activity and the benefits derived from it. The simple decision rule is that if the benefits exceed the costs, the project is worth undertaking, otherwise not. This chapter discusses about the methodology adopted to evaluate the viability of a project. The methodology of calculating net present value (NPV), internal rate of return (IRR) and levelized cost of energy (LCOE) is discussed.

Net Present Value (NPV)

The process of translating a future payment into a value at present is called discounting. The value at present of a future payment is called the present value (PV). And, the interest rate used to do the discounting is called the discount rate. The net present value (NPV) is the difference between the sum of the present value of future cash flows and the initial investment.

If PV is the present value, F is the future payments, and r is the discount rate. Then

$$PV = \frac{F}{1 + r} \qquad \text{Eq. (3.12)}$$

To obtain the formula for the case where the payment is two years in the future, the discounting should be done twice so that the corresponding formula for NPV would be:

$$NPV = \frac{F}{(1+r)^2} - I_o \qquad \text{Eq. (3.13)}$$

where, I_0 - Initial Investment

Similar reasoning implies that the net present value of a payment made in n years in the future would be:

$$NPV = \frac{F}{(1+r)^n} - I_o \qquad \text{Eq. (3.14)}$$

Likewise, the net present value of a series of payments made in several different years can be obtained by extending the aforementioned formula. For example, the net present value of a payment F made in 1 year, again in 2 years, and so on up to n years would be:

$$NPV = \sum_{k=0}^{n} \frac{F}{(1+r)^n} - I \qquad \text{Eq. (3.15)}$$

Internal Rate of Return (IRR)

Internal Rate of Return (IRR) gives the annual return for any capital investment. It is the discount rate for which the NPV of net benefit (benefits minus costs) is zero. Internal rates of return (IRRs) are of two types – financial and economic. Financial rates of return (FIRRs) are calculated only by considering private benefits and private costs, while economic rates of return (EIRRs) are calculated by considering social benefits and social costs. FIRRs refer to the internal rates of return from user's point of view while EIRRs refer to the internal rates of return from economic point of view. However, IRR itself does not, on its own, provide a criterion for selection of projects. It also has to be compared with market rate of interest, or social rate of interest. In this case, the following decision rule can be applicable:

- Select a single project if IRR is greater than market rate of interest or social discount rate; and
- In case of more than one project, rank the projects in descending order of IRR values and select the projects for which IRRs are greater, subject to fund availability.

Levelized Cost of Energy (LCOE)

The levelized cost of electricity (LCOE), also known as Levelized Energy Cost (LEC), is the net present value of the unit-cost of electricity over the lifetime of a generating asset. It is often taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime. LCOE is calculated by accounting for all of a system's expected lifetime costs (construction, financing, fuel, maintenance, taxes, insurance and incentives), which are then divided by the system's expected energy output (kWh). All cost and benefit estimates are adjusted for inflation and discounted to account for the time value of money. As a financial tool, LCOE is very valuable for the comparison of various generation options. A relatively low LCOE means that electricity is being produced at a low cost, with higher likely returns for the inventors. LCOE is calculated by:

$$LCOE = \frac{sum\ of\ costs\ over\ lifetime}{sum\ of\ electrical\ energy\ produced\ over\ lifetime} = \frac{\sum_{t=1}^{n} \frac{\mathrm{It} + \mathrm{Mt} + \mathrm{Ft}}{(1+\mathrm{r})^{\mathrm{t}}}}{\sum_{t=1}^{n} \frac{\mathrm{Et}}{(1+\mathrm{r})^{\mathrm{t}}}} \qquad \text{Eq. (3.16)}$$

where, , I_t: investment expenditures in the year t

M_t: operations and Maintenance expenditures in the year t

F_t: Fuel expenditures in the year t

E_t: electrical energy generated in the year t

r : discount rate

n : expected lifetime of technology

3.2.9. Methods of Result Presentation

Data obtained through primary and secondary sources were processed, analyzed and interpreted by using appropriate statistical tools, tables, graphs, charts and pictorial devices. Furthermore, Microsoft Excel was used during the analysis of data and its presentation. The synthesized data were presented in tables, bar diagrams, and pie charts.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1. Solid waste generation

According to the demographic records of the Municipalities of Nepal, the average number of persons per household was 5. The average household solid waste generation was calculated to be 0.8 kg/day.

Table 4.1: Generation of solid waste

Average HH waste (kg/day)	0.79
Average HH size (numbers of Members)	5.37
Average per capita HH Waste (g/capita/day)	170
Total HH Waste (tons/day)	770
Total Commercial Waste (tons/day)	450
Total Industrial Waste (tons/day)	65
Average per capita MSW (g/capita/day)	320
Total MSW Generation(Tons/day)	1,435
Total Estimation Collection of Waste (tons/day)	822

Figure 4.1 shows the composition of waste of municipalities of Nepal. Organic wastes were the most abundant ones sharing 62 % of total, while plastics and papers shared 11% and 10%. All other wastes shared only 17% of total.

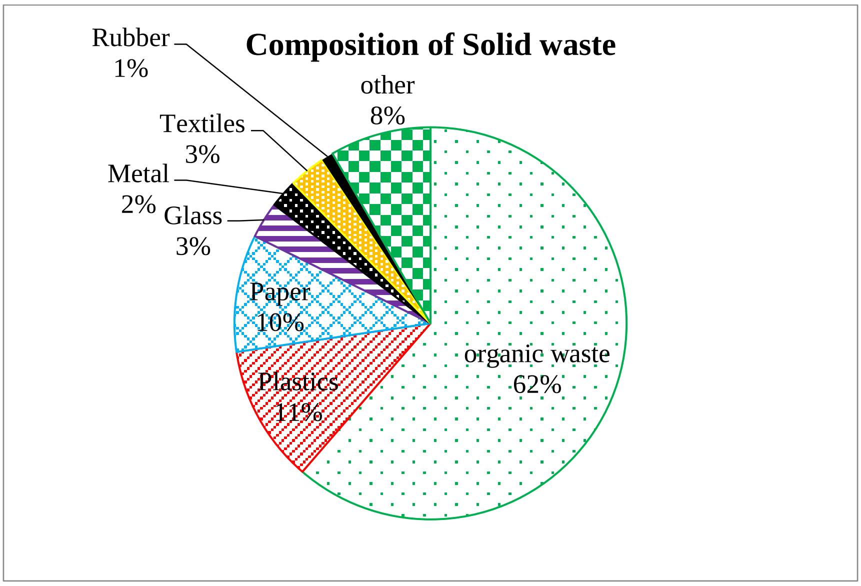

Figure 4.1: Percentage share of total waste of municipalities of Nepal

The municipal solid waste of Kathmandu metropolitan city contains 67 % organic waste, the share of plastic waste is 13 % and, waste contains 6.35 % paper waste and others contain 11 % waste as shown in Figure 4.2.

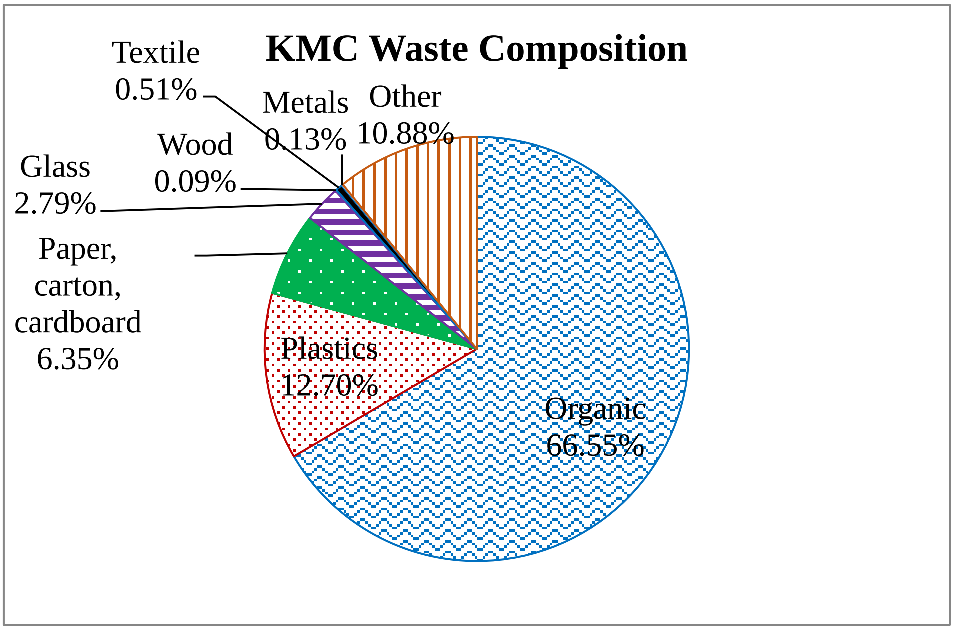

Figure 4.2: MSW of Kathmandu metropolitan city

The municipalities of the mountain region contain 51 % of organic waste of total generated waste. Plastic and paper waste have equal share of 11% of total waste as shown in Figure 4.3.

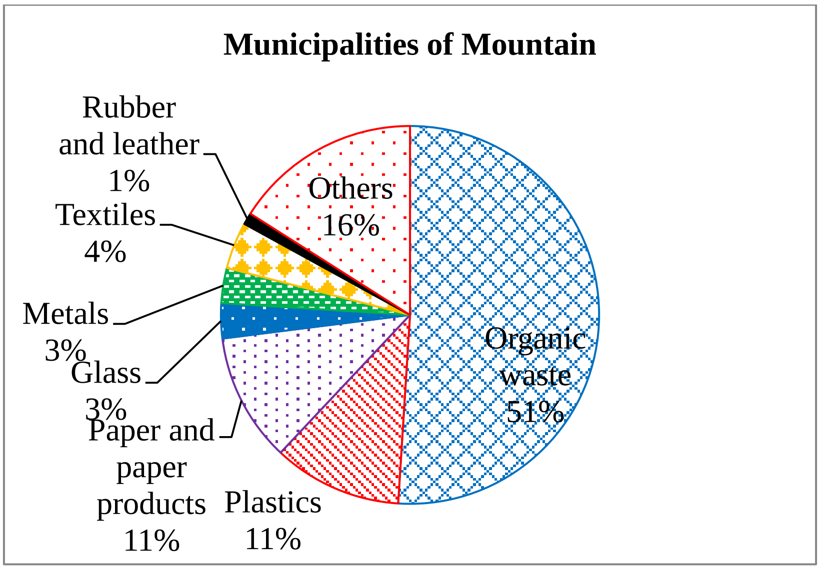

Figure 4.3: Composition of solid waste of municipalities of mountain region

The municipalities of the hilly region contain 65 % of organic waste of total generated municipal solid waste. The share of plastic and paper waste is 13% and 9 % respectively as shown in Figure 4.4.

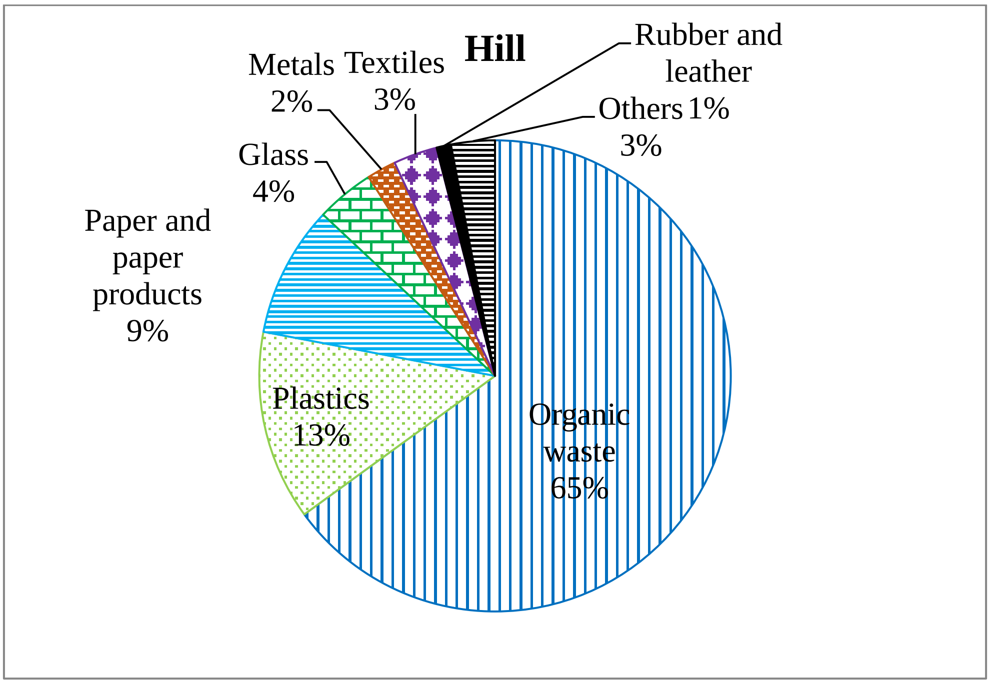

Figure 4.4: Composition of waste of municipalities of hill region

The municipalities of the tarai region contain 68 % of organic waste of total generated municipal solid waste. The share of plastic and paper waste is 10% and 9 % respectively as shown in Figure 4.5.

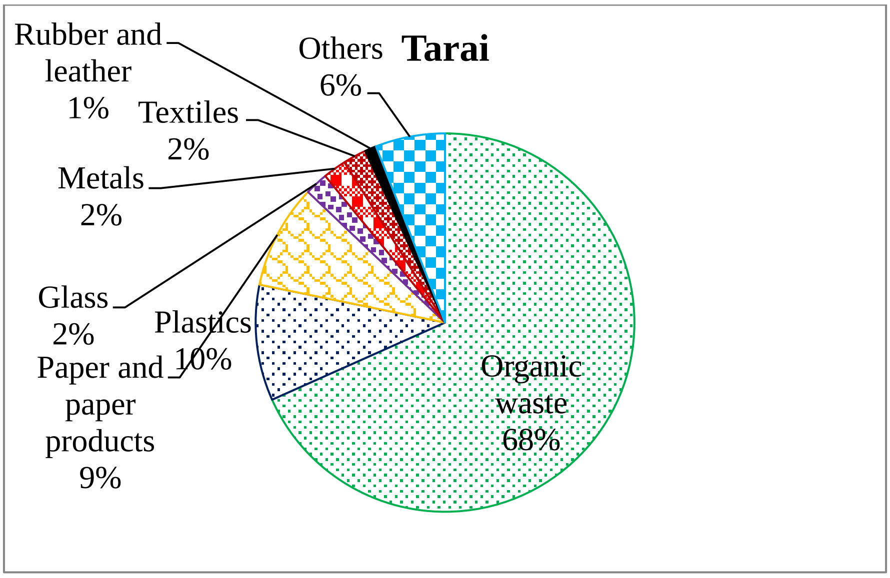

Figure 4.5: Composition of waste of municipalities of Tarai region

4.2. Categorical composition of the wastes

4.2.1. Household waste composition

The maximum share of the wastes that are dumped in the by the municipality has been of Household waste. Among the household waste, organic matter accounted for 85% as shown in Figure 4.6. These are mainly Kitchen wastes, while some were garden wastes. A total of 8% of Plastic wastes thrown out from the households were mainly polythene bags that could be reused. Paper waste constituted newspapers, note books. Glass wastes constituted very small proportion. Whereas, other wastes like electronic wastes, dusts etcetera accounted for 2.1% of total share.

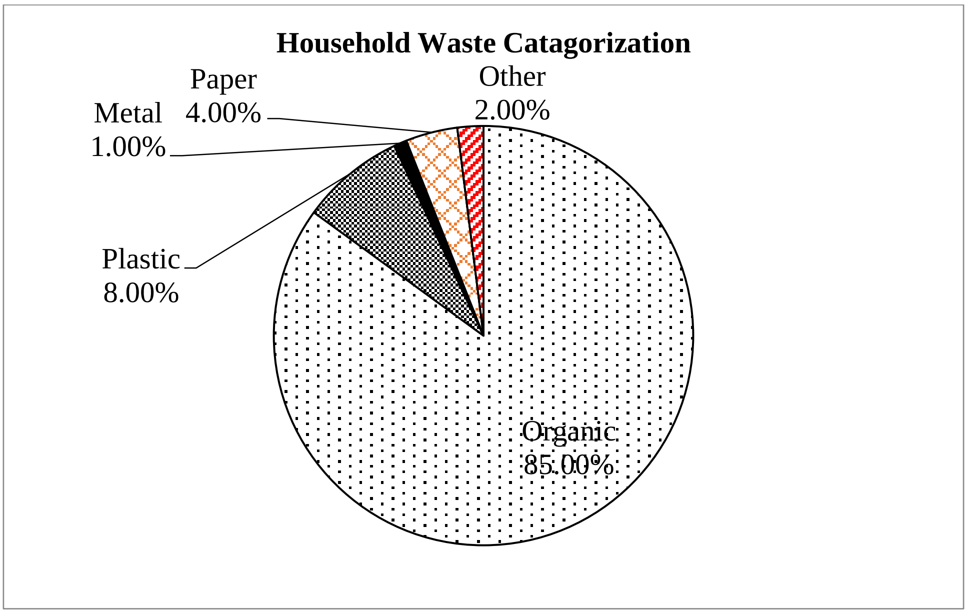

Figure 4.6: Percentage share of household waste Composition

4.2.2. Hospital wastes

Hospital waste was also one of the major contributors in context to hazard it contained in MSW. Though, Hospital wastes have less volume compared to other categories, it represents all types of wastes (Figure 4.7). Among all institutions sampled hospital was produced highest share of plastic waste among all sample categories. The organic wastes mainly composed of canteen wastes and garden litters. Though in insignificant amount, the medical and surgical wastes were also collected. Metal waste was also in higher proportion as it accounted 6% of total waste by weight. Paper waste constituted 8% of total composition.

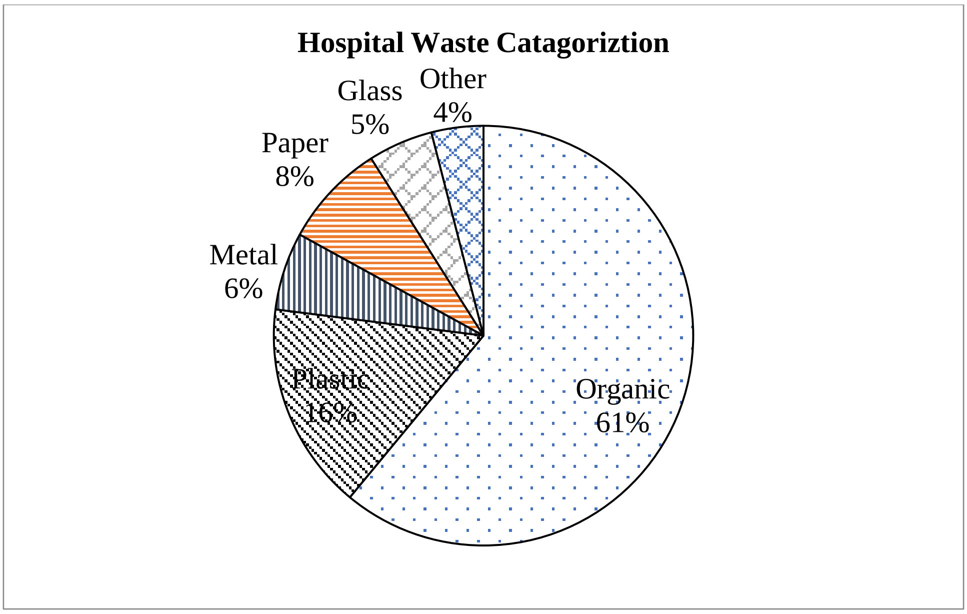

Figure 4.7: Percentage share of hospital waste composition

4.2.3. Restaurant wastes

Restaurants were dominant business sector with small and large restaurants. The mean waste generation of the waste per restaurant was about 25 kg per day. Among the waste, organic waste accounted for 65% (Figure 4.8) of share of waste daily. While 13% was of plastic wastes, paper waste was 7% of all waste. 5% of glass wastes are regularly dumped in the municipal dumping site. Other wastes like cottons, clothes, or electronic waste accounted for 10% of total share.

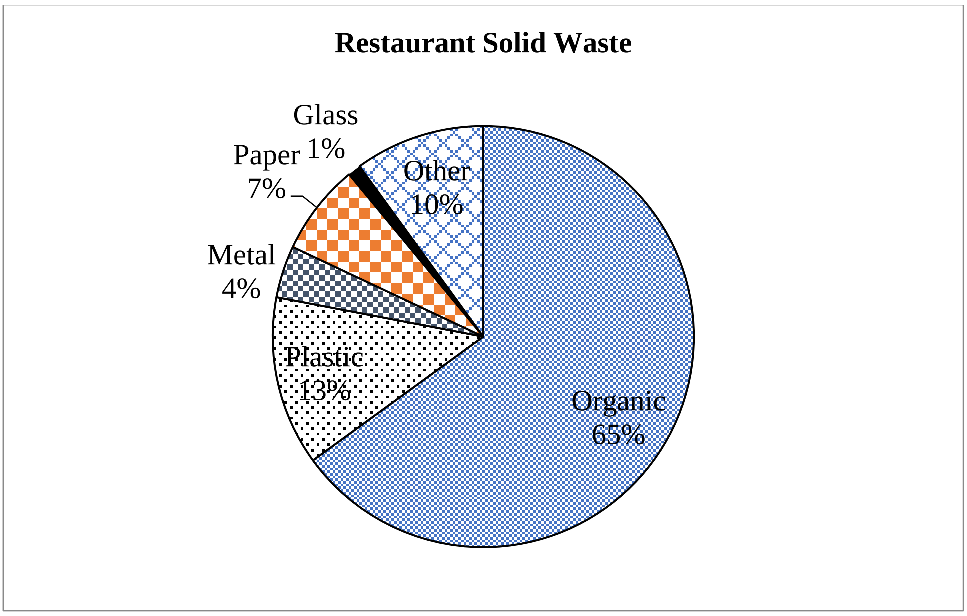

Figure 4.8: Percentage share of restaurant waste composition

4.2.4. Hotels/Lodge wastes

Thus, due to this reason there are high proportion of hotels and lodges serving people. The organic waste from hotels/lodge is 71 % of total waste of the metropolitan. Plastic and paper wastes accounted for 14% and 6% respectively, of the waste generated from the City (Figure 4.9).

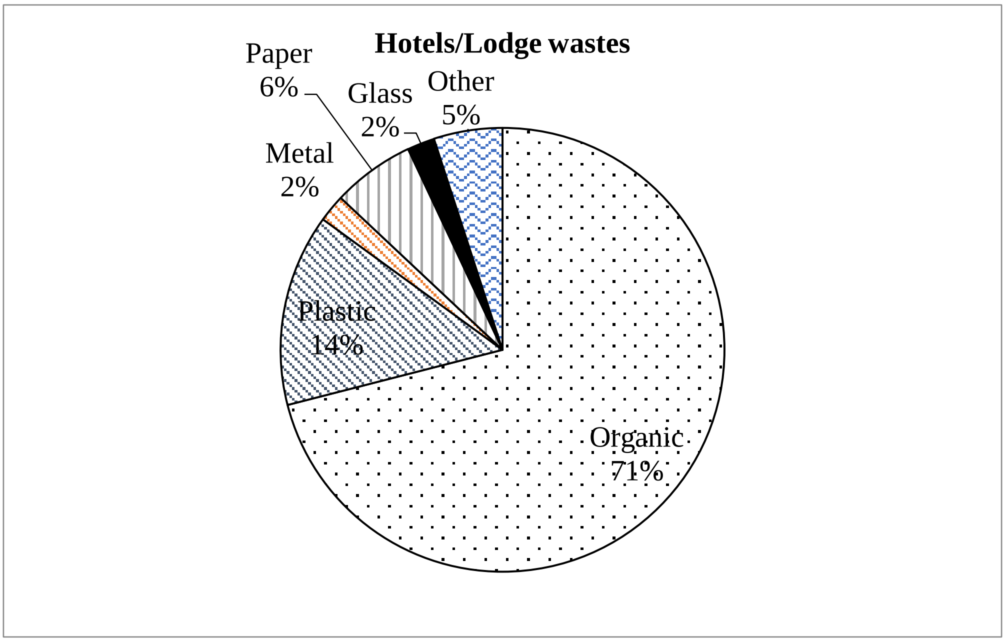

Figure 4.9: Percentage share of hotel/lodge waste composition

4.3. Categorical redistribution of wastes

The re-categorization of solid wastes into combustible and non-combustible wastes is done to determine the net energy content of the wastes. The weight of wet samples is presented in Table 4.2 below.

Table 4.2: Categorization of wastes for energy evaluation

Composition	Household (kg)	Hospital (kg)	Restaurant (kg)	Hotel/lodge (kg)
Organic	44.63	24.4	438.75	106.5
Plastic	4.2	6.4	87.75	21
Paper	2.1	3.2	47.25	9
Other	1.1	1.6	67.5	7.5
Non-combustible	0.47	4.4	33.75	6

The main source of the municipalities is house hold which produces nearly 50 % of solid waste then commercial sector produces 44 % waste and institutional waste production is nearly 6 % of total solid waste generation as shown in Figure 4.10.

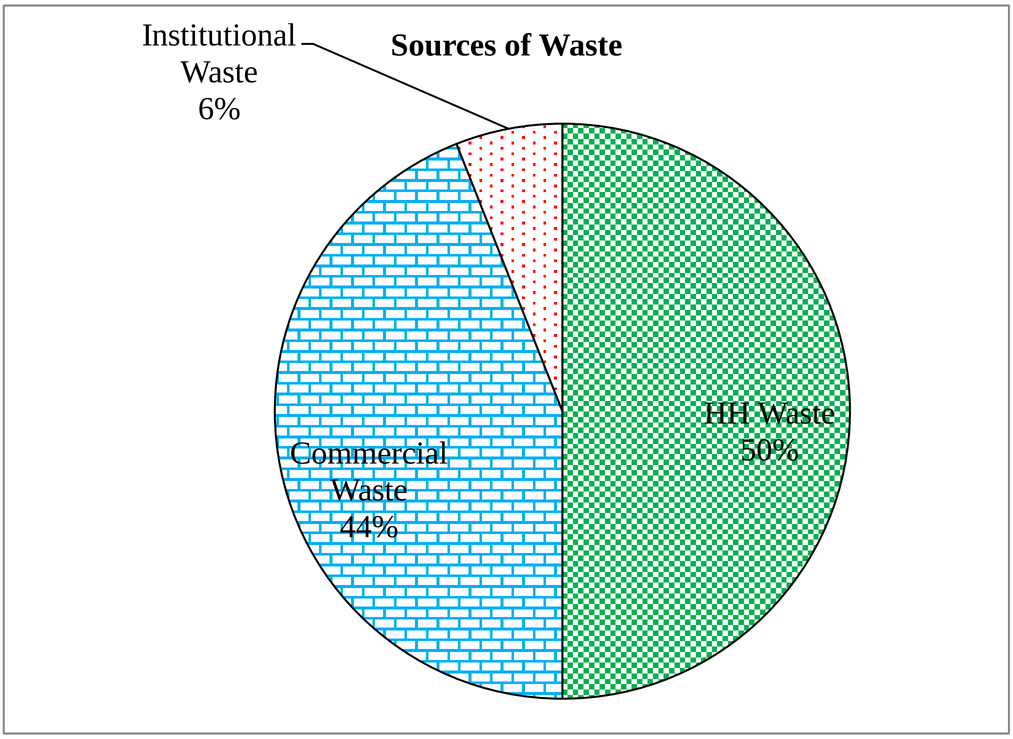

Figure 4.10: Sources of waste

4.4. Moisture content of the wastes

With the use of oven, at constant temperature of 85^0C, moisture content was determined for pre-defined categories (Table 4.2). After the determination of moisture content, the dry weights were extrapolated to get the moisture content in the total municipal solid waste (Table 4.3).

Table 4.3: Percentage of moisture content of the MSW

Type of waste	Quantity of waste (kg)	Dry weight (kg)	Moisture Content (kg)	Moisture content (percentage)	Dry weight (percentage)
Organic	1	0.3	0.7	70	30
Plastic	1	0.95	0.05	5	95
Paper	1	0.8	0.2	20	80
Other	1	0.9	0.1	10	90

The total weights of moisture content of municipal wastes of Kathmandu Metropolitan City are given in the Table 4.4.

Table 4.4: Total weight of moisture content in MSW

Type of Waste	Total Municipal Waste (kg)	Moisture Content (Percentage)	moisture Weight (kg)	Dry weight (kg)
Organic	376,670	70	263,670	113,000
Plastic	71,880	5	3,595	68,290
Paper	35,940	20	7,190	28,750
Other	81,580	10	8,160	73,420
Total	566,070		282,610	283,460

Now, the total moisture content in the municipal solid waste can be determined as follows:

$$Total\ moisture\ content\ = \frac{282611.5}{566077} \times 100 = 49.93\%$$

4.5. Energy evaluation of waste

The average energy content of these wastes is presented in Table 4.5. Among all categories, plastics have highest energy content and category organic has second most energy content in the waste stream. Paper and organic wastes have similar energy content per kg; however, high volume in the waste composition for organic waste has more contribution in energy content of overall MSW.

Table 4.5: Total energy content of MSW

S.N.	Type of waste	Dry weight in kg	MJ of Energy per kg	Total energy of MSW (MJ)
1	**Organic**	113,000	15.68	1,771,870
2	**Plastic**	68,280	40.61	2,773,170
3	**Paper**	28,750	15.64	449,690
4	**Other**	73,420	17.55	1,288,570
Total				**6,283,300**

Gross total energy (Gte) in the municipal solid waste was found to be 6,283,300 MJ. But this did not consider the heat required to convert moisture content in the waste to gas, i.e. Ed. Because, during conversion of waste to energy, all the wastes are accepted in the wet state and there is certain energy required to dry out that moisture from the waste to be able to accept as fuel. Thus, it is needed to subtract latent heat of vaporization from the gross total energy. This is also called as Net total energy (Ne).

Total moisture present in the waste is 282,610 kg (49.43% of total waste) and heat required to completely dry out this moisture we require specific heat capacity of water and latent heat of vaporization.

The average annual temperature of Kathmandu metropolitan is taken as 15^0C for the calculation of net energy. Specific heat capacity of water is 4.2 KJ/kg/ ^{o}C, i.e. 0.0042 MJ/kg/ ^{o}C and latent heat of vaporization of water is 2.44 MJ/kg. The gross total energy of the waste is 8.99 MJ/kg while net energy is found to be 7.46 MJ/kg. Therefore, 1.53 MJ/kg of energy is lost during moisture liberation. Hence, of the total energy, only 82.93% is available and the rest of the energy (17.17%) is lost due to moisture.

If this waste is consider as a waste to energy resource for Incineration, we could produce 35 MW of electricity. The electricity potential of Kathmandu metropolitan city is 14 MW from daily waste.

But the installation cost for incinerator is very high and we require highly skilled professional to run the power plant, this system should be considered with great care.

Energy Potential of major municipalities of Nepal

The graph (Figure 4.11) shows the energy potential of major Municipalities of Nepal. It can be observed that the most potential of the municipalities is Kathmandu with 1,745 MWh followed by Lalitpur Sub Metropolitan City at 278 MWh, Pokhara at 244 MWh. The least of the municipalities considered was that of Bhadrapur at 5.4 MWh.

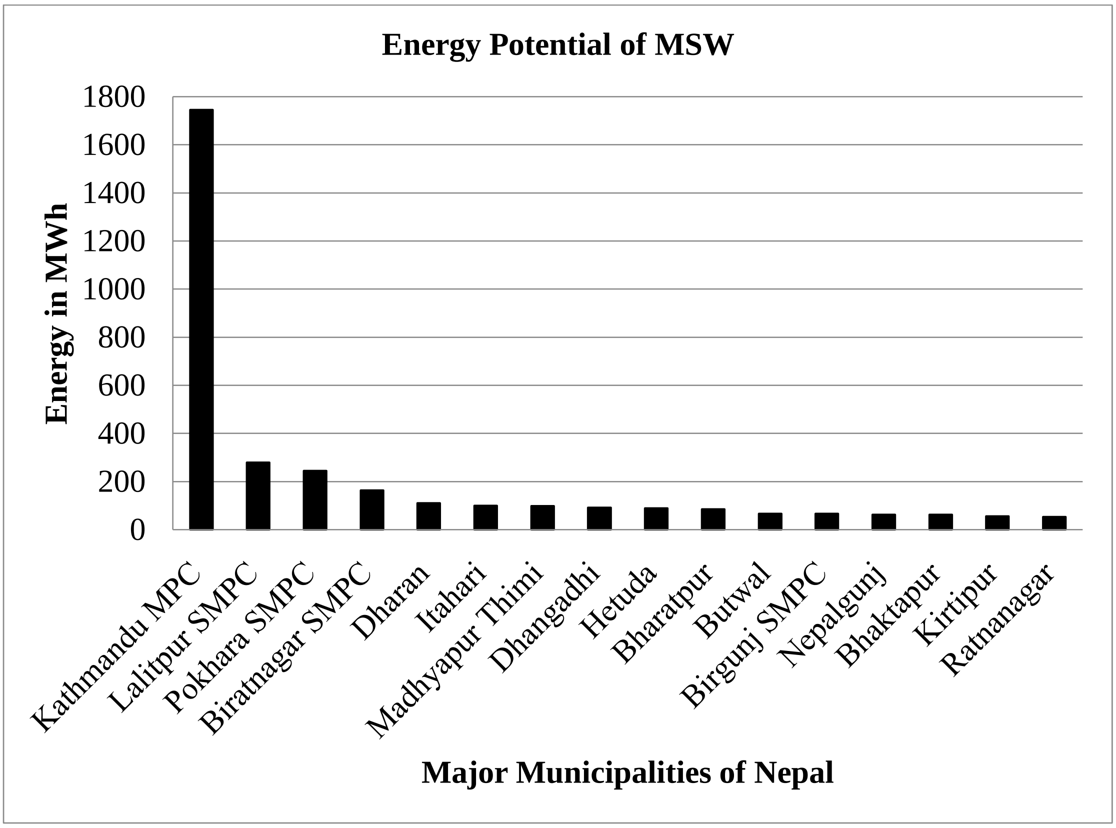

Figure 4.11: Energy potential of MSW

The graph (Figure 4.12) shows the size of the power plants that can be established in the major municipalities of Nepal. It can be observed that the capacity of the plant at Kathmandu is 14 MW followed by Lalitpur at 2.3 MW, Pokhara at 2 MW. The lowest is that of Bhadrapur at 44.35 KW.

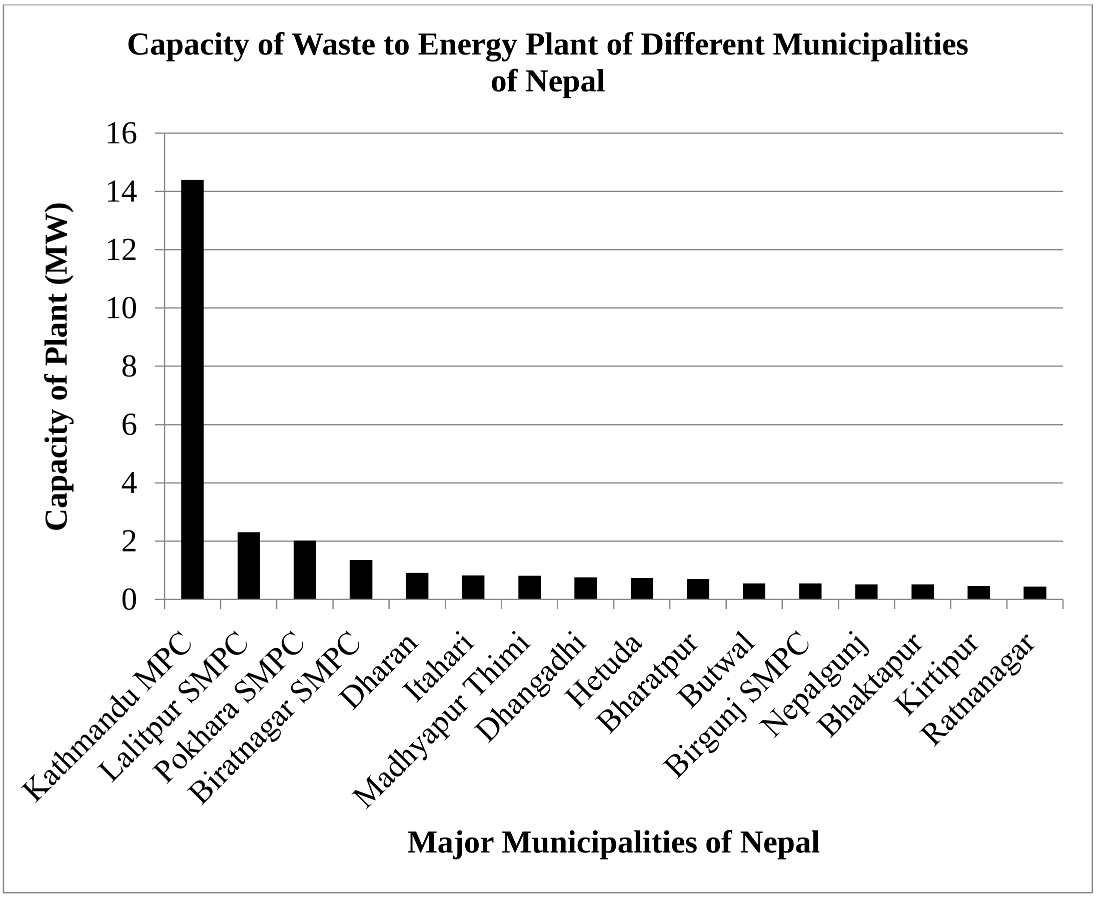

Figure 4.12 Waste to energy capacity

4.6. Capacity of Different WTE Technologies

The capacity of plasma Arc gasification technology can produce 19MW electricity from municipal solid waste of Kathmandu Metropolitan City. Similarly conventional gasification, pyrolysis, incineration technology and anaerobic digestion plant can produce 16 MW, 13.5 MW, 13 MW and 3.3 MW of electricity respectively as shown in Figure 4.13.

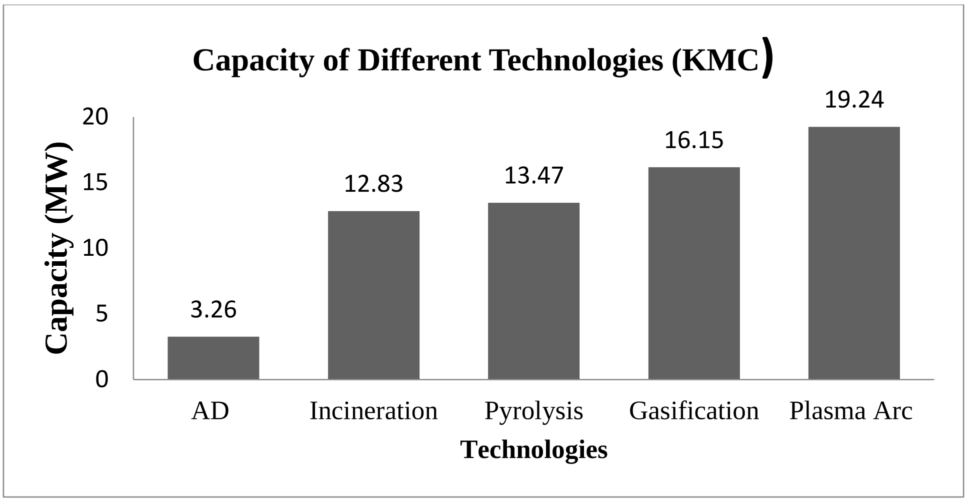

Figure 4.13 Capacity of different WTE technology for KMC

The total capacity of these technologies for all municipalities is shown in following graph. The total capacity of plasma arc gasification is 52 MW. Similarly conventional gasification, pyrolysis incineration technology and anaerobic digestion plant can produce 44 MW, 36.5 MW, 35 MW and 7.33 MW of electricity respectively as shown in Figure 4.14.

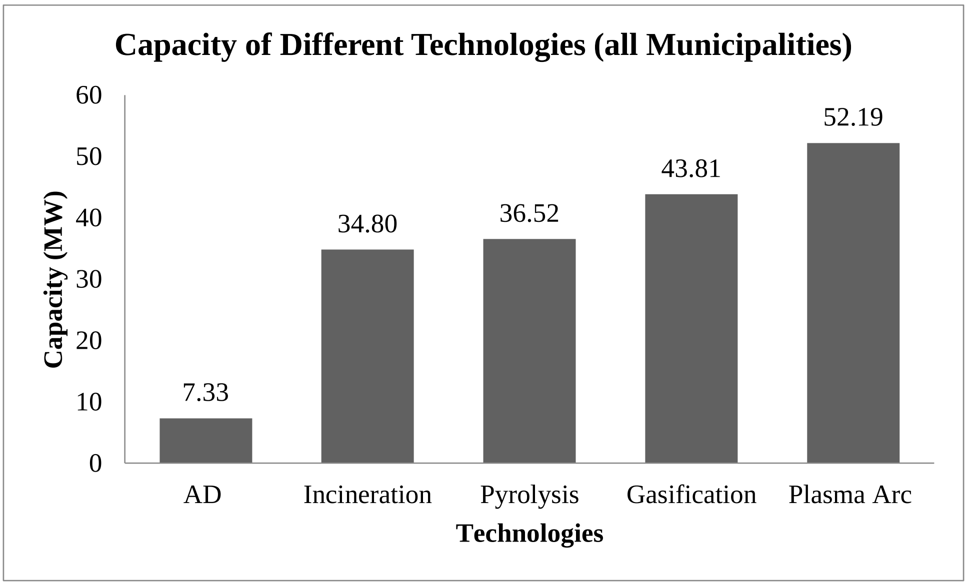

Figure 4.14 Capacity of different WTE technologies for all municipalities

Figure 4.15 shows the capacity of different WTE technologies for major municipalities of Nepal. The capacity of plasma Arc gasification technology can produce 19 MW of electricity from municipal solid waste of Kathmandu Metropolitan City. Similarly conventional gasification, pyrolysis and incineration technology can produce 16 MW, 13.5 MW and 13 MW respectively. Similarly plasma Arc gasification technology can produce 4 MW of electricity from municipal solid waste of Pokhara sub-Metropolitan City. Similarly conventional gasification, pyrolysis and incineration technology can produce 3.3 MW, 2.8 MW and 2.6 MW respectively for Pokhara.

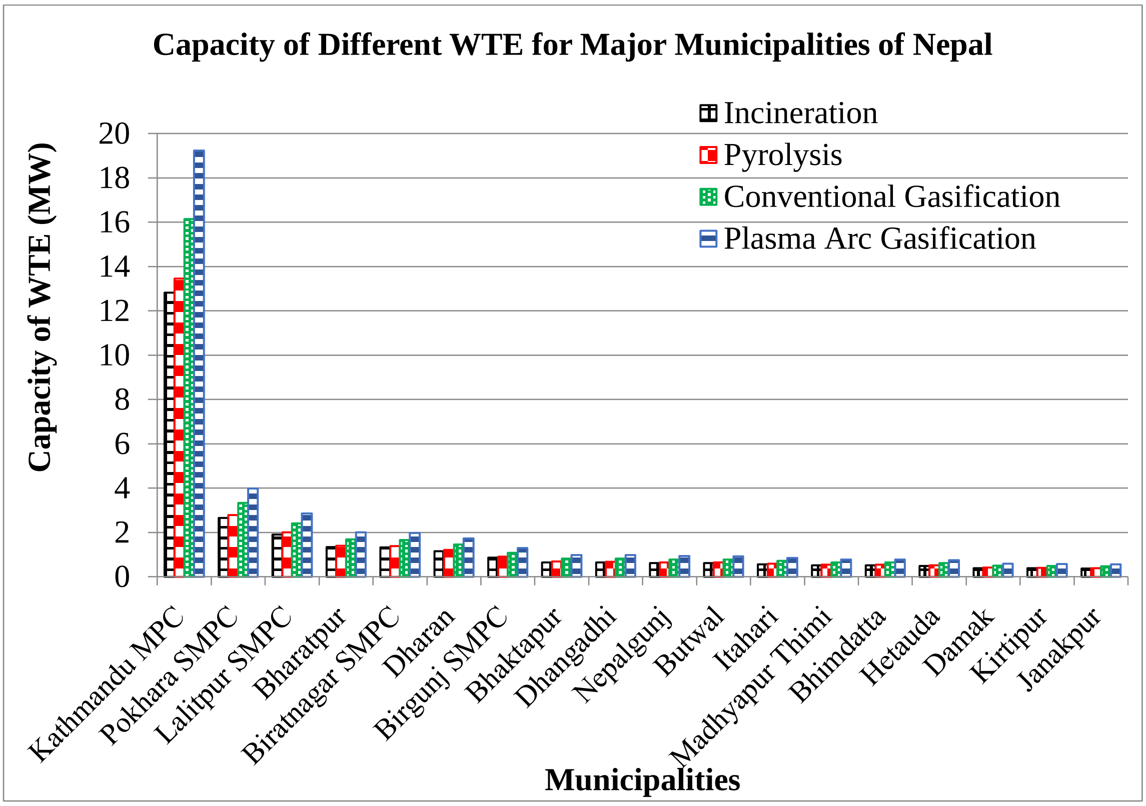

Figure 4.15 Capacity of different WTE for major Municipalities of Nepal

4.7. Performance of Energy Bin Installed at Kathmandu Metropolitan City

The maximum feeding is 4 ton and the minimum feeding for a day has been 0.5 ton, in the past month as shown in Figure 4.16. The temperature of the four compartments is in and around 30 degree Celsius. Till now gas is being used to operate the generator for the plant keeping the input source from NEA to bare minimum. There has not been any major problems while feeding and operation of the plant except occasional jams in the hopper due to inseparable organic waste with fiber.

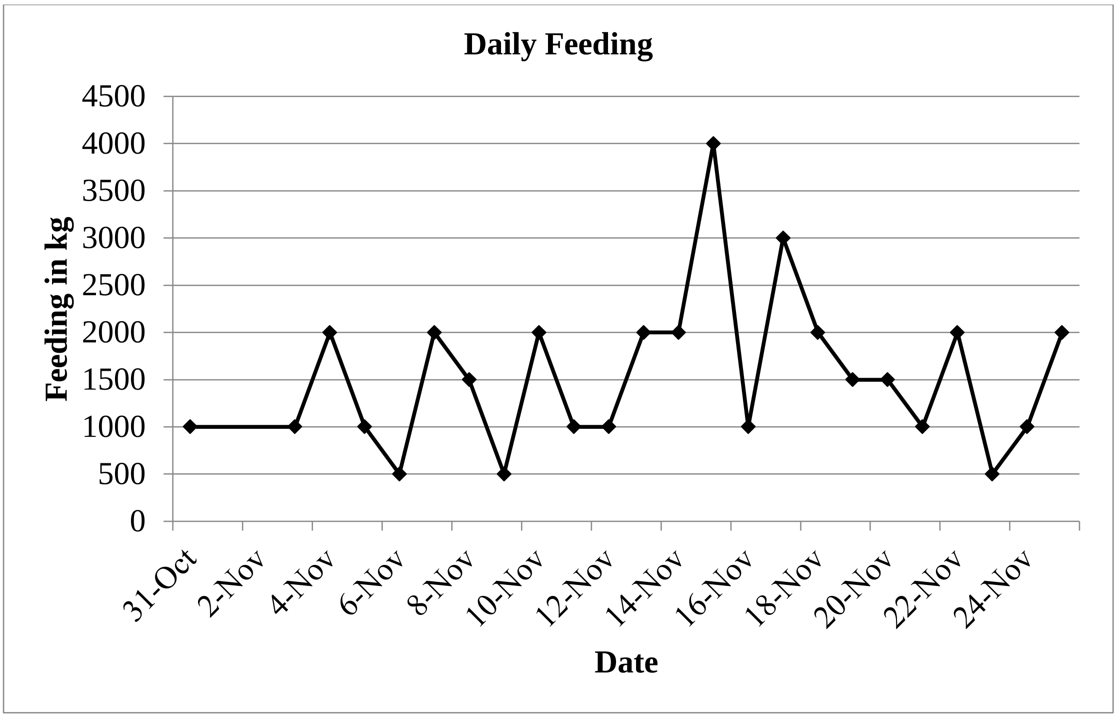

Figure 4.16 Waste feeding into energy bin

The daily bio-gas production from Energy bin is shown in following graph. The maximum production was found to be 42m^3 and minimum biogas production was found 4 m^3 as shown in Figure 4.17.

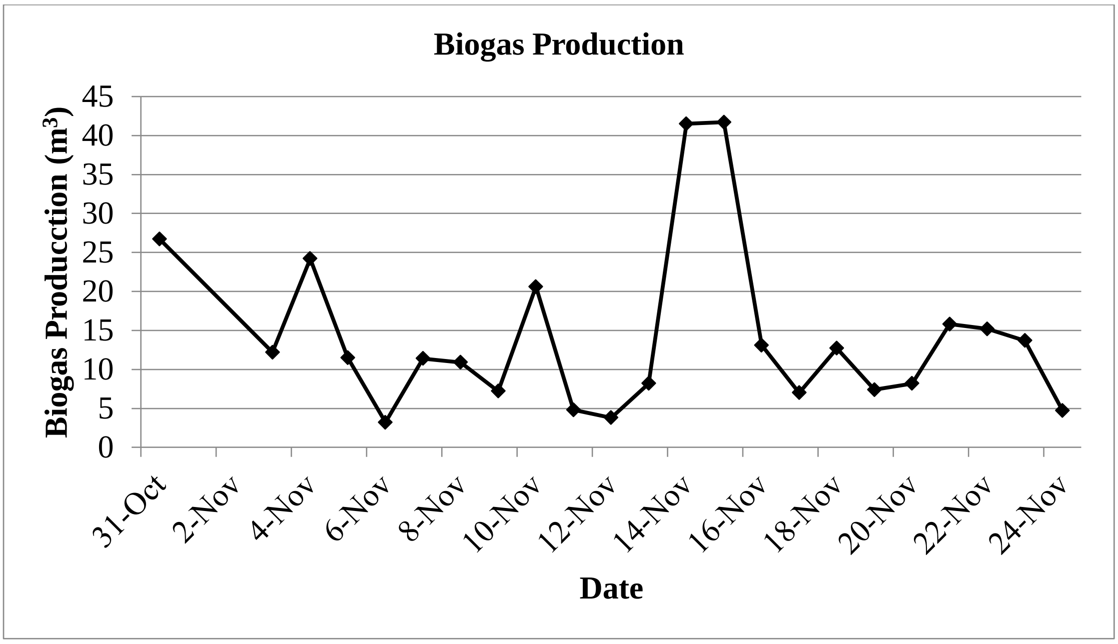

Figure 4.17 Daily biogas production in energy bin

Figure 4.18 shows the electricity production from energy bin installed at Kathmandu Metropolitan City office. The energy bin plant producing minimum 12 KW and maximum 14 KW electricity from organic solid waste. This electricity is solely used for operating its own units.

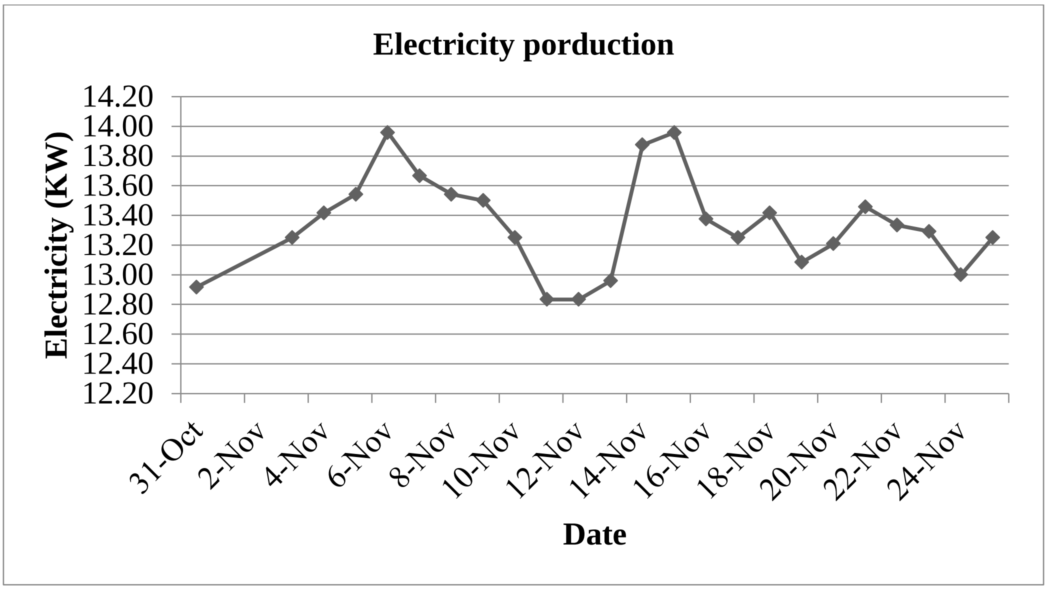

Figure 4.18 Electricity production from Energy bin

If the total organic waste is used for energy bin plant, the total capacity of plant is 3.26 MW for KMC, 438 KW for Pokhara and 416 KW for Lalitpur. The total capacity for all municipalities is 7.33 MW as shown Figure 4.19.

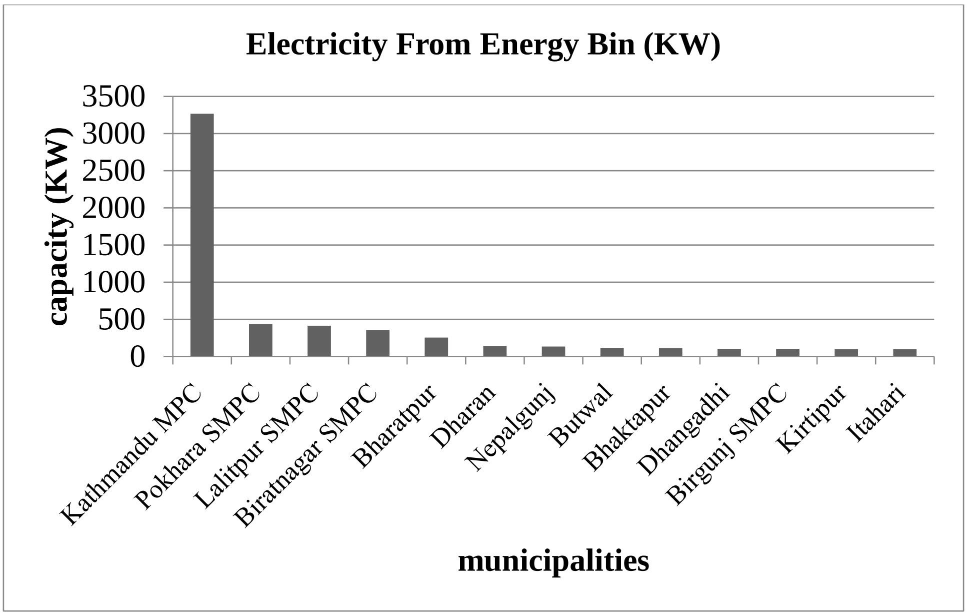

Figure 4.19 Capacity of energy bin plant for major municipalities

4.8. GHG Mitigations

The total GHG emission reduction achievable through the use of waste to energy schemes stands at 220 tons CO_2 equivalent per day.

The Figure 4.20 shows the plot of the GHG emission reduction of major municipalities of Nepal. Kathmandu has the highest potential at 87 tons CO_2 equivalent per day followed by Lalitpur at 15 tons CO_2 equivalent per day and Pokhara at 14 tons CO_2 equivalent per day.

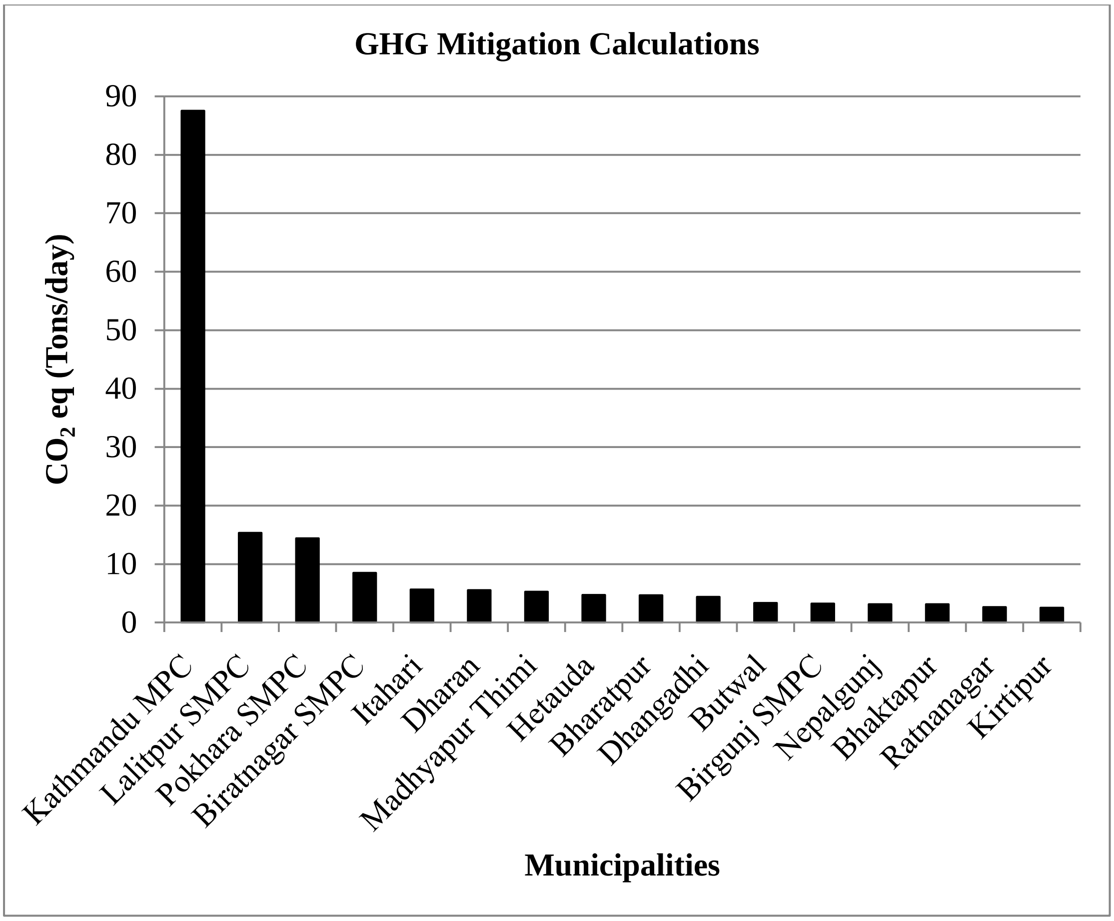

Figure 4.20 GHG mitigation of MSW

The Figure 4.21 shows the plot of the GHG emission reduction of Kathmandu metropolitan city by implementing different technologies. By implementing the plasma arc technology, 31,960 tons of CO_2 equivalents per year can be reduced. Similarly by implementing gasification, pyrolysis, incineration technology and AD plant 23,960 tons, 22,370 tons 20,770 tons and 4,511 tons of CO_2 equivalents per year can be reduced respectively.

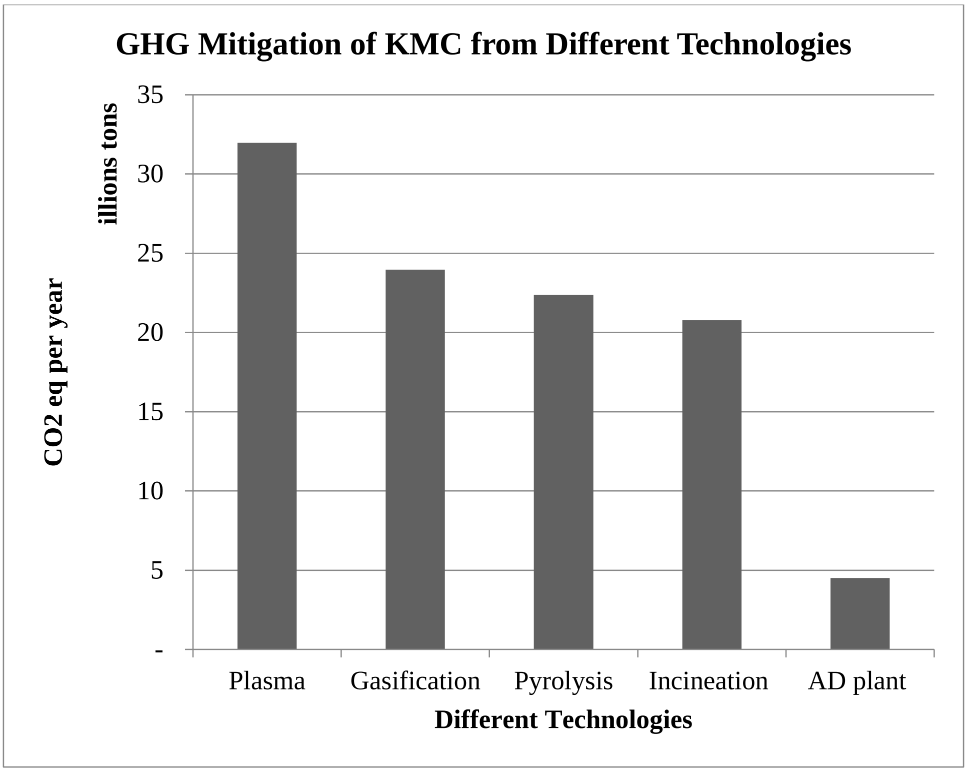

Figure 4.21 GHG mitigation of KMC from different technologies

The Figure 4.22 shows the plot of the GHG emission reduction of all municipalities of Nepal by implementing different technologies. By implementing the plasma arc technology, 80,550 tons of CO_2 equivalents per year can be reduced. Similarly by implementing gasification, pyrolysis, incineration technology and AD plant 60,410 tons, 56,390 tons, 52,360 tons and 37,270 tons of CO_2 equivalents per year can be reduced from all municipalities of Nepal.

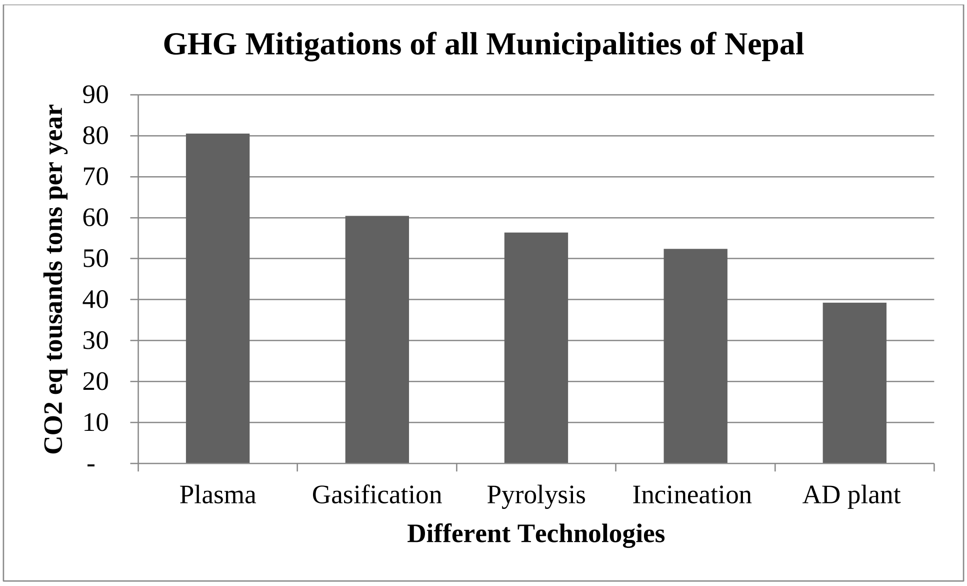

Figure 4.22 GHG mitigation of all municipalities of Nepal

4.9. Air Pollution Mitigation

Air pollutants Carbon dioxide (CO_2), Nitrogen dioxide (N_2O), Nitrous Oxide (NOx), Ammonia (NH_3), Particular Matter ($PM_{2.5}$), Methane (CH_4) And Carbon Monoxide (CO) can be reduced by implementing Waste to Energy Plant. The emission Factors of these pollutants are as shown in table (Quina et al., 2014). Using these factors (Table 4.6) the total air pollutions reduction was calculated.

Table 4.6 Emission factors of air pollutants

Pollutant	CO_2	N_2O	NOx	NH_3	$PM_{2.5}$	CH4	CO
kg per kg of waste	0.095	0.011	0.1133	0.022	0.0297	0.0275	0.275

Figure 4.23 shows the reduction in various air pollutants in Kathmandu with the implementation of waste to energy scheme. It can be seen that the total reduction in CO_2 stands at 19,620 tons per year, N_2O stands at 2,270 tons per year, NO_X, NH_3, $PM_{2.5}$, CH_4 and CO at 23,406 tons per year, 4,540 tons per year, 6,136 tons per year, 5,680 tons per year and 26,810 tons per year respectively by implementing the plasma arc technology.

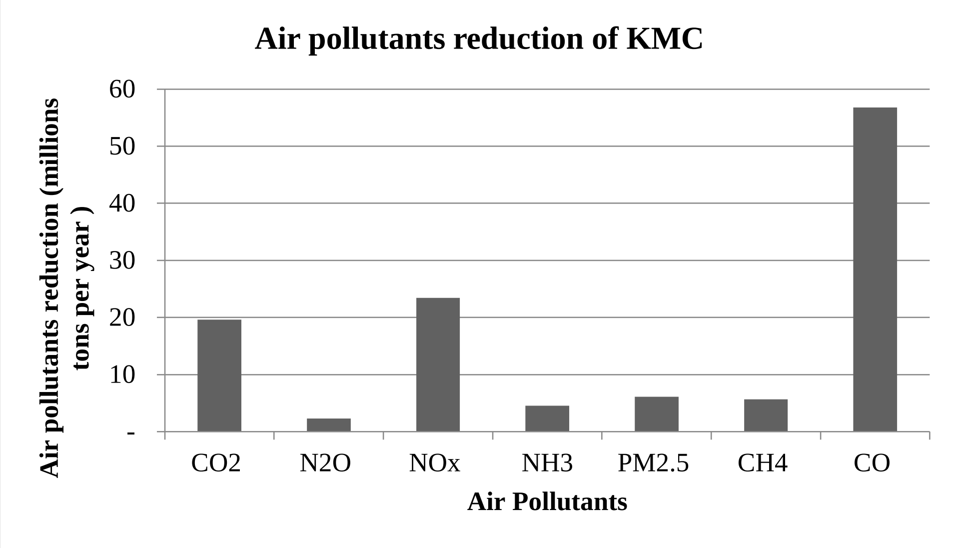

Figure 4.23 Air pollution mitigation of KMC

Figure 4.24 shows the reduction in pollution of the major municipalities of Nepal. It can be seen that the maximum pollution saving can be done in Kathmandu followed by Pokhara and Lalitpur.

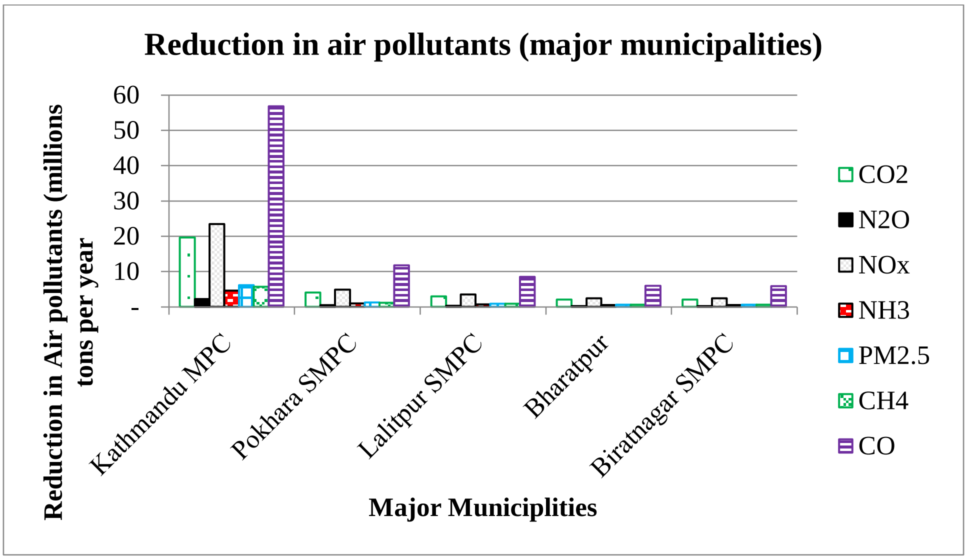

Figure 4.24 Air pollution mitigation of different municipalities

Figure 4.25 shows the total emission reduction of pollutants for all the municipalities considered. The total values for CO_2, N_2O, NO_x, NH_3, $PM_{2.5}$, CH_4, CO are 53,220 tons per year 6,160 tons per year, 63,470 tons per year, 12,320 tons per year, 16,639 tons per year, 15,410 tons per year and 154,060 tons per year respectively.

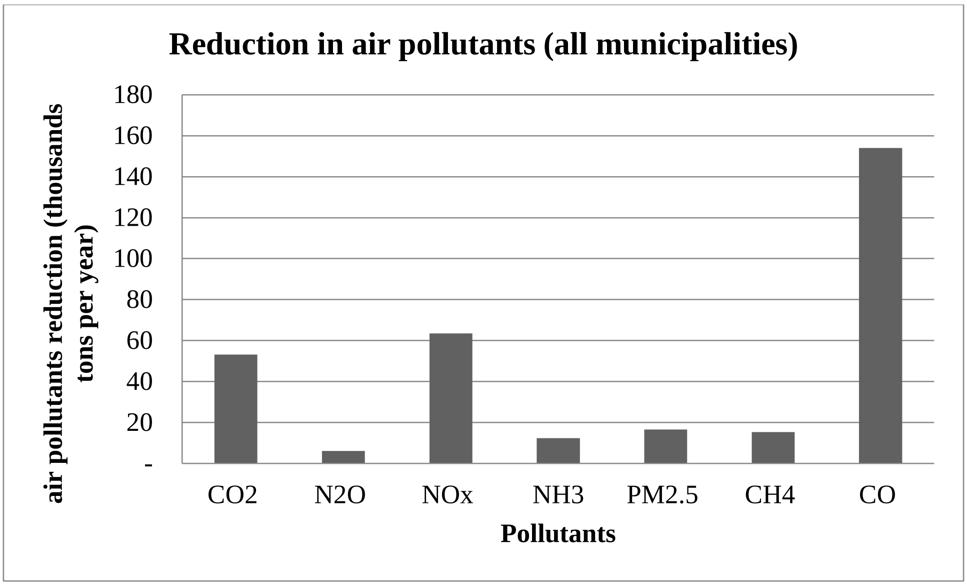

Figure 4.25 Air pollution mitigation of all municipalities

Figure 4.26 shows the total mitigation of pollutants for major municipalities of Nepal. The total values for Kathmandu is 118,780 tons per year followed by Pokhara Lalitpur, Bharatpur and so on 24,514 tons per year 17,646 tons per year 12,375 tons per year respectively. Total reduction in air pollutants of all municipalities is 321,300 tons per year.

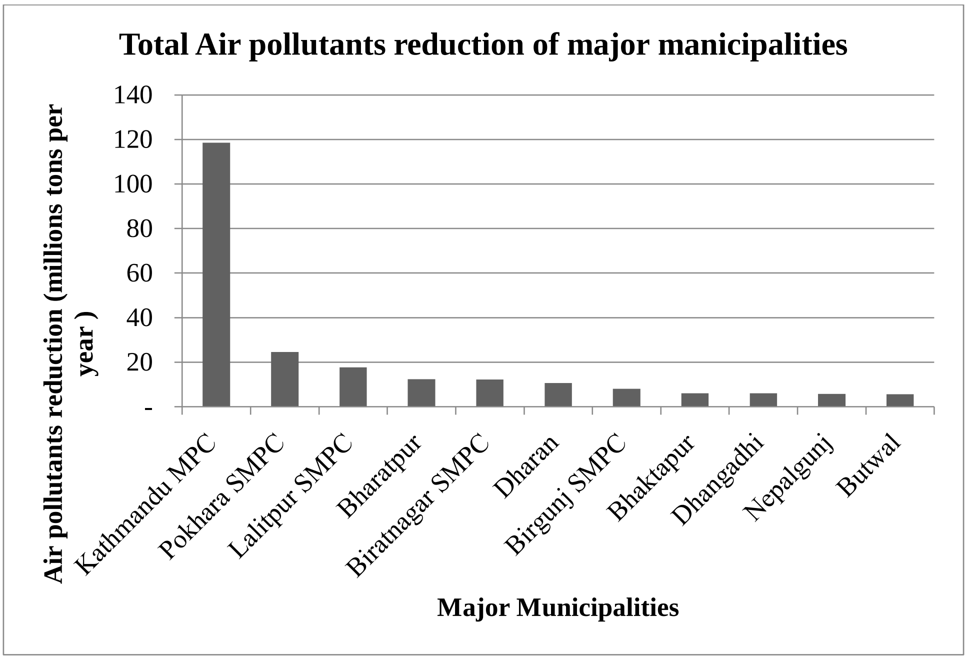

Figure 4.26 Total reduction in air pollutants

4.10. Validation

In previous research the capacity of anaerobic digester plant was 2.7 MW from organic waste of KMC (2013) while in this research the capacity of anaerobic digester plant was found 3.26 MW. It show the this research is comparable with the previous research

Table 4.7 Validation of Production of energy

Validation of GHG Mitigations				
Previous Research / Author	(Malla & Khatiwada, 2016) Kathmandu Valley	Author Kathmandu Valley	(Singh et al., 2014) (KMC)	Author (KMC)
Data used	2013	2016	2014	2016
Tons of CO2 eq per year	37,690	41,570	30,894	31,957

As the research done in 2014 by Singh et al, the GHG emissions from solid waste of KMC was 30,894 tons per year while in this research the GHG emissions from solid waste of KMC was found 31,957 tons per year. It shows that this research can be valid with the previous research.

Table 4.8 Validation of GHG Mitigations

Validation of Production of energy		
	Previous Research	Author
Year	2013	2016
Capacity of AD plant (MW)	2.7 (Shrestha et al., 2014)	3.26
Energy (KWh)	25,281,171 (Singh et al., 2014)	28,607,605

4.11. Financial Analysis of Different WTE Technologies

Service life: The literature indicates that the Service life of WTE plants ranges from 20 to 25 years (International Renewable Energy Agency, 2012). Therefore, the life of technologies was taken 20 years of operation.

Depreciation method: This research assumes a straight line depreciation starting from the first year of operation, with a zero salvage value.

Transportation cost: This research disregards waste transportation costs allowing for all technologies to be compared against each other after the waste is delivered to the WTE facility.

Environmental benefits: The research disregards the benefits of the WTE facility in land savings and reducing the national GHG emissions and, therefore, reducing air pollution levels.

Ownership, waste cost and availability: The research assumes that the WTE plant would be a municipality-owned. Therefore, the cost of the waste is Zero and the waste feedstock is continuously available.

Electricity cost: This research assumes that the electricity produced by the WTE plant is sold at a rate of NRs 8.5 /KWh, (4-12.50) which is the electricity consumption tariff for governmental institutions in Nepal.

Annual Inflation rates: it is assumes that the selling price of the generated electricity would be inflated at a rate of 5%, the selling price of the generated recycled waste and the cost of landfilling the resulting residual waste at a rate of 5% and the fixed and variable operation and maintenance expenditure

Capital Expenditure (CAPEX): The average CAPEX cost for WTE plant utilizing BFB gasification technology is 3925 USD/KW and 4339 USD/KW for the AD plant (International Renewable Energy Agency, 2012)

The plasma arc technology uses electricity generated by itself for gasification and supplies the final product as electricity to the grid, and the slag (the rock like byproduct) can be used as road construction material. The possibility of establishing a plasma arc gasification plant for management of MSW in KMC is economically analyzed. The following assumptions are taken for the economic analysis of Plasma Arc Gasification plant for conversion of MSW to the grid electricity.

- MSW collection in KMC was 566 t/day in 2016. Hence size of plant is 20 MW. The output of the electricity output will be 800 KWh per ton of MSW with input electricity of 200 KWh, thus the net electricity output will be 600 KWh per ton of MSW and gravel like by-product of 20% which can be used as road construction material.
- The capital cost is US$20 million for 20 MW plant with plasma technology (Young, 2010). The exchange rate of US$ is taken as equivalent to NRs.107. the residue can be sold at NRS 1600 /t. The KMC budget for collection of MSW was 4000/t. hence the tipping fee or MSW collection charge as revenue for the plant as NRs 4000/t in 2016.
- The plant service life is taken as 20 years without any salvage value. Operation and maintenance costs and depreciation are taken as 5% of net revenue from sales of grid electricity and 5% of capital cost respectively. Escalation rate for electricity sales and O&M costs are taken as 5%. The discount rate is taken as 12 % i.e., the existing market rate. There will be full income tax exemption for the service life of the project and it has to be handed over after 20 years.
- The tariff taken is as per current PPA rate of NEA ie weight average tariff of NRs 6/KWh

Based on the above assumptions, a discounted cash flow (DCF) analysis was conducted for 20 years and Net Present Value (NPV) was calculated at the discount rate of 12 %.

Considering the assumptions above, the values of NPV were calculated accordingly for the various technologies. NPV for the Plasma, Pyrolysis, Gasification, Incineration and Anaerobic Digester Plant was calculated to be 2660, 1390, 1500, 1180, 890 Million NRs. Respectively. Similarly the internal rate of return for the technologies was calculated at 19%, 15 %, 16%, 14% and 13 % respectively. It can be seen that the plasma technology is most feasible technology. It has the highest NPV and the lowest payback period (Table 4.9).

Table 4.9 Finanncial Analysis of different technologies

Technology	Plasma	Pyrolysis	Gasification	Incineration	AD plant
Plant Capacity (MW)	19	13.5	16	13	4
Capital cost (NRs) million	12,290	10,530	9,730	14,050	6,250
NPV (NRs) million	2,660	1,390	1,500	1,180	890
IRR (%)	19	15	16	14	13

Levelized Cost

The levelized cost of electricity (LCOE), also known as Levelized Energy Cost (LEC), is the net present value of the unit-cost of electricity over the lifetime of a generating asset. It is often taken as a proxy for the average price that the generating asset must receive in a market to break even over its lifetime. Considering above mentioned capital cost, service life, operation maintenance cost, depreciation, escalation rate and discount rate the levelized cost of energy for plasma technology was found NRs. 8.5 per KWh. Similarly levelized cost of energy for gasification technology, pyrolysis technology, incineration technology and AD plant was found NRs. 9.5, NRs. 11, NRs. 10 and NRs. 11 per KWh respectively.

Table 4.10 shows the NPV calculation for the various technologies considering tariff rate as Rs. 6. It can be seen that the value of NPV is negative for all the technologies considered. Hence a subsidy scheme will be required if the tariff is set as Rs. 6.

Table 4.10 Financial analysis of WTE technologies without subsidy

Technology	Plasma	Pyrolysis	Gasification	Incineration	AD plant
Plant Capacity (MW)	19	13.5	16	13	4
Capital cost (NRs) million	12,290	10,530	9,730	14,050	6,250
NPV (NRs) million	(1,650)	(1,250)	(1,150)	(1,050)	(755)

Table 4.11 shows the NPV calculation for the various technologies considering Rs.6 as tariff and with a subsidy of Rs. 250,000 per KW. It can be seen that the NPV goes to positive for all the technologies. Like with the tariff rate of Rs. 10, Plasma Technology is the most economically feasible technology since it has the highest NPV and IRR with Rs. 6 as tariff and subsidy of Rs. 250,000 per KW.

Table 4.11 Financial analysis of WTE technologies with subsidy

Technology	**Plasma**	**Pyrolysis**	**Gasification**	**incineration**	**AD plant**
Plant Capacity (MW)	19	13.5	16	13	4
Capital cost (NRs) million	12,290	10,530	9,730	14,050	6,250
NPV (NRs) million	2,550	1,150	1,450	1,150	780
IRR (%)	19	15	16	14	13

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The total waste generated by the municipalities of Nepal is 1,435 tons per day with per capita waste generation of 0.32 kg, which is consistent with other major cities in Nepal. Total industrial waste production was found to be 65 tons/day, commercial waste was found to be 450 tons/day, and similarly household waste production was found to be 770 tons/day. Collection efficiency of Kathmandu was found to be the highest at 87 % while the lowest was of Gulariya at 9% of the municipalities that had data available.

The total energy potential of the considered municipalities of Nepal was found to be 4260 MWh. This translates to an incineration power plant of 35 MW. Pyrolysis can power 36.5 MW plant combined nationwide. Conventional Gasification can power 44 MW plant and plasma arc technology can power plant 52 MW whereas anaerobic digestion can produce 7.33 MW of electricity.

For Kathmandu, the total energy potential was found to be 1745 MWh which translates to 19 MW electricity plant if we implement plasma arc technology. Similarly the total energy potential of Lalitpur and Pokhara were found to 2.3 MW and 2 MW respectively.

The total GHG emission reduction achievable with the implementation of waste to energy plant was estimated to be 80,550 tons of CO_2 equivalents per year by implementing plasma technology. For Kathmandu this reduction potential stood at 31,960 tons of CO_2 equivalent per year followed by Lalitpur at 5,600 tons of CO_2 equivalent per year by using plasma technology.

The levelized cost of energy for plasma arc, gasification, pyrolysis, incineration, and anaerobic digestion plant were calculated to be NRs 8.5, 10, 11, 10 and 11 per kWh respectively.

Hence, the plasma arc gasification technology can be deemed as the most feasible waste to energy technology in terms of environmental and economic prospects.

5.2. Recommendation

- This thesis covers only 58 of the 217 Municipalities in Nepal due to lack of data on solid waste generation. The energy potential of missing municipalities can be estimated following the same methodology used in this thesis after acquiring relevant data on solid waste generation.
- This thesis considers using all the components of solid waste, plants using different components of solid waste can be studied.
- Energy potential reflected in this thesis is based on the baseline data, future research can relate this potential with population growth, GDP and relevant factors.
- This thesis estimates the total capacity of different technologies combined. Further research can segregate the size of the plant of different technologies and suggest multiple plants.
- This thesis reflects the GHG emissions in totality based on the emission factors. GHG emission of each gas can be calculated.
- Similarly future research can also be done on the net GHG reduction due to the various waste to energy technologies.
- This thesis considers only electricity as the useful energy. Studies can be done on production of bio-fuel, briquettes, compost from organic solid waste.
- Municipalities can put efforts on establishing waste to energy plants to generate electricity, effectively manage solid waste, eliminate the need of dumping and landfill sites. This will also help in reducing the burden to the environment by reducing pollution.
- Financial Analysis has only been done for Kathmandu Metropolitan City. The same can also been done for other municipalities.

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ANNEX I: MUNICIPALITIES OF NEPAL WITH POPULATION

(Ministry of Local Government , 2016)

SN	Municipality	No of ward	Population(2068)	Area (sq m)
1	Amargadhi	11	22,241	138.95
2	Baglung	11	30,763	18.35
3	Banepa	11	24,894	5.56
4	Bhadrapur	15	50,249	73
5	Bhaktapur	17	83,658	6.56
6	Bharatpur	29	199,867	242.3
7	Bhimdatta	19	106,666	171.24
8	Bhimeshwor	13	23,337	65.04
9	Bidur	11	27,953	33.48
10	Biratnagar SMPC	22	204,949	58.48
11	Birendranagar	25	93,718	169
12	Birgunj SMPC	30	204,816	75.2
13	Butwal	22	138,742	101.5
14	Byas	14	46,877	86
15	Damak	19	75,743	70.63
16	Dasharathchanda	13	17,427	55.01
17	Dhangadhi	20	137,666	231.53
18	Dhankuta	15	36,619	110.8
19	Dharan	27	137,705	192.5
20	Dhulikhel	13	19,210	21.4
21	Dipayal Silgadhi	14	26,508	73.98
22	Gaur	13	35,370	21.53
23	Ghorahi	11	65,107	74.45
24	Gorkha	15	39,263	85.8
25	Gulariya	14	57,232	95.14
26	Hetuda	29	152,875	261.4
27	Ilam	9	19,427	26.63
28	Inaruwa	10	28,923	22.36
29	Itahari	26	140,517	93.7
30	Jaleshwor	18	41,941	29.6
31	Janakpur	27	168,617	99.9
32	Kalaiya	25	86,318	64.8
33	Kamalamai	18	41,117	207.95
34	Kapilvastu	19	43,471	63.3
35	Kathmandu MPC	35	1,003,285	49.45
36	Khandbari	13	26,658	91.03
37	Kirtipur	19	67,171	14.76
38	Lahan	22	79,689	147.5

39	Lalitpur SMPC	30	254,308	24.9
40	Lekhnath	18	68,622	121.6
41	Madhyapur Thimi	17	84,142	11.11
42	Malangawa	13	30,292	13.7
43	Mechinagar	13	57,909	55.72
44	Narayan	9	21,995	67.01
45	Nepalgunj	28	146,424	94.6
46	Panauti	13	28,312	31.73
47	Pokhara SMPC	29	313,841	225.7
48	Putalibazar	13	31,338	70.14
49	Rajbiraj	10	38,241	11.96
50	Ramgram	13	28,973	34.72
51	Ratnanagar	19	69,851	68.6
52	Sidharthanagar	13	64,566	36.03
53	Siraha	17	59,037	67.1
54	Tansen	15	31,161	21.72
55	Tikapur	9	56,983	67.11
56	Triyuga	17	71,405	319.88
57	Tulsipur	20	85,601	180.8
58	Waling	11	24,199	34.76

ANNEX II: COMPOSITION OF INSTITUTIONAL WASTE IN THE 58 MUNICIPALITIES (%)

SN	Municipality	Organic waste	Plastics	Paper/ paper products	Glass	Metals	Textile	Rubber/ Leather	Other
1	Amargadhi	13.36	13.14	63.74	1.12	5.68	0.98	1.06	0.92
2	Baglung	25.7	22.67	46.96	0.41	0.99	0.34	0.04	2.9
3	Banepa	15.13	31.17	42.75	2.47	3.9	0.24	4.33	0
4	Bhadrapur	16.52	5.72	77.76	0	0	0	0	0
5	Bhaktapur	30.35	18.77	29.35	2.95	3.15	3.46	1.68	10.29
6	Bharatpur	30.84	18.89	49.37	0	0.38	0	0.3	0.22
7	Bhimdatta	24.3	12.05	32.63	0.42	0.41	0.92	1.19	28.08
8	Bhimeshwor	11.74	4.97	46.21	0	0.12	0.12	0	36.83
9	Bidur	15.17	24.54	55.53	0	1.49	1.49	1.79	0
10	Biratnagar SMPC	41.56	19.48	35.49	0	1.54	0.39	0	1.54
11	Birendranagar	24.62	21.84	51.41	1.78	0.03	0.2	0	0.12
12	Birgunj SMPC	16.99	21.54	50.18	0	0	0	0	11.29
13	Butwal	24.48	17.32	29.55	0	0.35	2.36	2.58	23.37
14	Byas	42.11	21.02	29.9	1.63	0.69	0.72	0.61	3.33
15	Damak	38.04	12.16	20.95	0.02	8	1.66	0.61	18.56
16	Dasharathchanda	10.2	11.16	36.31	7.97	12.71	5.44	5.01	11.21
17	Dhangadhi	16.36	17.59	50.89	0.73	1.99	0.27	0	12.17
18	Dhankuta	16.9	20.8	40.25	0	0.46	0	0.46	21.12
19	Dharan	22.39	21.29	37.81	3.7	3.89	2.26	1.18	7.47
20	Dhulikhel	36.25	15.22	48.53	0	0	0	0	0
21	Dipayal Silgadhi	18.3	27.93	34.71	3.88	1.21	0.92	1.61	11.43
22	Gaur	22.42	6.59	21.87	4.44	0	0	0	44.68
23	Ghorahi	21.38	17.32	39.33	2.5	0.43	3.67	0.39	14.98
24	Gorkha	18.03	26.47	45.55	1.82	2.5	0	0	5.64

SN	Municipality	Organic waste	Plastics	Paper/ paper products	Glass	Metals	Textile	Rubber/ Leather	Other
25	Gulariya	8.95	11.28	56.74	0.08	0	0	0.62	22.33
26	Hetuda	8.01	29.61	49.09	0.98	1.33	1.3	0.08	9.61
27	Ilam	60.1	6.83	16.34	1.96	0.97	0.88	0.82	12.1
28	Inaruwa	1.5	4	40.8	0	0.59	0.88	0	52.23
29	Itahari	25.64	24.9	40.13	2.95	0	0	0	6.38
30	Jaleshwor	17.09	35.7	46.44	0.77	0	0	0	0
31	Janakpur	11.23	25.58	43.38	0	0	0	0	19.81
32	Kalaiya	9.98	11.24	36.08	0	7.51	1.39	0.47	33.33
33	Kamalamai	12.28	17.48	50.12	4.54	1.93	0	1.74	11.91
34	Kapilvastu	0	16.63	83.37	0	0	0	0	0
35	Kathmandu MPC	20.29	24.55	44.28	1.37	1.13	3.89	1.14	3.35
36	Khandbari	4.94	22.7	58.79	0.91	1.18	3.18	0.99	7.31
37	Kirtipur	22.13	14.31	59.55	3.25	0	0.77	0	0
38	Lahan	27.95	14.3	50.87	0.01	1.17	0	0.52	5.19
39	Lalitpur SMPC	14.53	23.05	41.05	0.11	1.43	0	0.19	19.64
40	Lekhnath	11.19	11.51	48.58	6.17	1.92	0	2.39	18.24
41	Madhyapur Thimi	0.77	19.18	60.2	0.1	0	0	0.83	18.92
42	Malangawa	5.85	21.57	28.23	5.7	0.73	4.78	0	33.14
43	Mechinagar	24.74	15.32	44.62	5.65	0	0	3.89	5.78
44	Narayan	16.56	29.03	54.41	0	0	0	0	0
45	Nepalgunj	39.3	13.02	44.24	0	1.92	0	0	1.53
46	Panauti	33.67	16.54	44.43	0.07	0	3.01	0.65	1.63
47	Pokhara SMPC	26.19	8.14	65.35	0	0	0	0	0.32
48	Putalibazar	1.63	33.64	53.04	0	0	0	0	11.69
49	Rajbiraj	12.32	10.51	40.09	1.13	0.51	1.03	0.12	34.3
50	Ramgram	19.84	7.28	31.47	10.62	1.44	0.06	0.38	28.92

SN	Municipality	Organic waste	Plastics	Paper/ paper products	Glass	Metals	Textile	Rubber/ Leather	Other
51	Ratnanagar	10.26	18.94	60.31	0.2	0.62	0.21	0.93	8.53
52	Sidharthanagar	1.08	23.21	75.71	0	0	0	0	0
53	Siraha	29.1	4.17	43.19	0.27	2.57	1.56	2.66	16.49
54	Tansen	22.92	11.25	24.05	5.16	1.91	4.02	3.75	26.94
55	Tikapur	27.92	19.16	47	0	4.6	0	0	1.32
56	Triyuga	10.89	14.34	67.24	0	3.21	1.46	0.45	2.41
57	Tulsipur	2.94	20.53	56.97	0	2.31	0	0	17.26
58	Waling	41.57	10.99	17.08	2.12	1.91	0.92	0.36	25.06
Average Composition		**21.73**	**20.76**	**44.53**	**1.17**	**1.22**	**2.07**	**0.82**	**7.71**

ANNEX III: COMPOSITION OF COMMERCIAL WASTE IN THE 58 MUNICIPALITIES (%)

SN	Municipality	Organic waste	Plastics	Paper and paper products	Glass	Metals	Textile	Rubber and Leather	Other
1	Amargadhi	35.13	19.28	27.43	15.11	2.92	0.03	0.12	0
2	Baglung	41.14	14.96	26.91	13.67	1.37	0.38	0.53	1.04
3	Banepa	41.28	17.47	23.89	8.08	2.62	0	0.81	5.86
4	Bhadrapur	24.35	61.71	11.99	0	0	0	0	1.95
5	Bhaktapur	38.73	21.29	18.03	2.14	6.2	0.73	0.37	12.51
6	Bharatpur	56.76	8.73	23.7	6.46	0.95	3.09	0	0.32
7	Bhimdatta	34.41	21.71	19.46	2.26	1.51	7.31	0.89	12.45
8	Bhimeshwor	25.04	35.2	16.66	5.79	0	0.21	0	17.12
9	Bidur	53.03	22.43	17.02	5.73	0.77	0.98	0.05	0
10	Biratnagar SMPC	58.53	18.86	19.11	0	0	0	2.18	1.32
11	Birendranagar	25.07	6.01	9.98	39.59	0.58	9.3	7.71	1.77
12	Birgunj SMPC	34.65	19.15	31.77	8.81	2.58	0	0	3.04
13	Butwal	41.08	20.77	19.67	6.67	1.6	0	0	10.21
14	Byas	47.24	15.85	21.56	5.98	3.19	3.43	1.19	1.55
15	Damak	52.04	11.34	17.48	0.64	6.44	0.35	3.02	8.7
16	Dasharathchanda	24.04	16.56	35.37	1.23	6.84	3.51	2.71	9.75
17	Dhangadhi	22.78	27.5	12.15	14.71	4.7	3.1	5.56	9.5
18	Dhankuta	37.93	17.42	21.07	0	4.16	8.15	0	11.28
19	Dharan	25.57	18.27	17.09	7.99	6.76	4.23	0	20.09
20	Dhulikhel	67.18	14.36	7.18	8.24	0	0	0	3.04
21	Dipayal Silgadhi	27.95	32.41	17.25	17.47	2.05	0	2.87	0
22	Gaur	46.32	9.68	15.44	0	0	0	0	28.57
23	Ghorahi	40.49	22.51	21.44	6.64	2.56	0	1.44	4.92

SN	Municipality	Organic waste	Plastics	Paper and paper products	Glass	Metals	Textile	Rubber and Leather	Other
24	Gorkha	51.46	26.69	13.5	0	3.95	0	0	4.4
25	Gulariya	18.08	37.19	29.7	2.52	0.47	0	0.56	11.5
26	Hetuda	31.64	28.3	18.44	6.15	6.05	0.83	0	8.59
27	Ilam	56.13	14.04	11.73	2.41	5.05	3.04	4.11	3.5
28	Inaruwa	45.37	9.02	13.26	0	1.09	0	0	31.27
29	Itahari	23.13	36.17	30.41	0.53	2.52	2.63	0	4.61
30	Jaleshwor	38.23	51	7.85	0	0	0	2.92	0
31	Janakpur	38.62	22.82	28.38	0	0	0.61	1.52	8.06
32	Kalaiya	44.07	23.69	20.41	0	2.26	0	0	9.57
33	Kamalamai	37.54	17.04	29.36	7.07	1.02	0	0	7.96
34	Kapilvastu	46.04	24.28	21.34	0	0	0	8.34	0
35	Kathmandu MPC	45.44	24.29	23.29	2.86	2.65	1.03	0	0.45
36	Khandbari	29.2	20.89	32.31	5.36	4.07	3.29	0.19	4.69
37	Kirtipur	65.77	25.99	5.45	2.79	0	0	0	0
38	Lahan	42.46	33.41	14.96	0.72	4.98	0	0	3.48
39	Lalitpur SMPC	39.36	21.05	30.14	1.01	0.25	0.06	0.16	7.97
40	Lekhnath	33.59	19.5	32.45	6.05	0.98	0	0	7.43
41	Madhyapur Thimi	22.05	28.04	25.37	1.12	0	0	0.17	23.26
42	Malangawa	23.91	17.72	28.16	7.67	1.56	9.57	6.94	4.47
43	Mechinagar	32.91	24.65	31.85	1.33	4.08	0	1.26	3.93
44	Narayan	44.93	16.84	33.06	1.82	3.36	0	0	0
45	Nepalgunj	54.96	13.67	16.34	11.23	3.49	0.31	0	0
46	Panauti	36.09	47.55	14.16	0.91	0	1.3	0	0
47	Pokhara SMPC	47.23	12.6	24.68	6.14	1.44	6.95	0.13	0.84
48	Putalibazar	23.87	28.42	24.1	0	0	0	0	23.62
49	Rajbiraj	46.42	12.94	23.5	0.85	3.08	1.03	0.61	11.58

SN	Municipality	Organic waste	Plastics	Paper and paper products	Glass	Metals	Textile	Rubber and Leather	Other
50	Ramgram	43.12	21.83	22.31	0	1.18	5.33	0	6.23
51	Ratnanagar	38.12	22.96	26.24	4.3	2.7	2.43	1.29	1.96
52	Sidharthanagar	37.44	47.14	15.13	0	0.3	0	0	0
53	Siraha	48.36	7.64	27.99	7.35	1.97	0.44	2.14	4.11
54	Tansen	46.49	10.8	24.53	3.36	1.57	0.2	0.29	12.76
55	Tikapur	28.4	18.44	33.05	5.58	9.27	5.27	0	0
56	Triyuga	51.93	13.9	17.49	1.49	0	6.13	0	9.08
57	Tulsipur	38.47	17.01	13.64	14.32	9.47	0.08	1.46	5.55
58	Waling	51.04	12	15.59	9.64	1.39	1.95	0	8.4
Average Composition		**43.24**	**22.09**	**22.76**	**3.88**	**2.3**	**1.51**	**0.5**	**3.72**

ANNEX IV: COMPOSITION OF INSTITUTIONAL WASTE IN THE 58 MUNICIPALITIES (%)

SN	Municipality	Organic waste	Plastics	Paper and paper products	Glass	Metals	Textile	Rubber and Leather	Other
1	Amargadhi	71.5	9.13	11.88	1.35	0.21	3.79	1.04	1.09
2	Baglung	40.44	24.18	15.83	8.19	2.36	3.92	2.8	2.28
3	Banepa	68.11	11.19	9.14	1.33	1.83	1.19	0.32	6.9
4	Bhadrapur	72.99	11.58	8.04	0	0	6.27	0.62	0.5
5	Bhaktapur	77.48	8.52	6.79	0.55	0.79	0.69	0	5.19
6	Bharatpur	78.96	4.63	7.84	3.08	1.74	2.32	1	0.43
7	Bhimdatta	48.17	8.16	5.99	4.92	1.13	2.3	0	29.32
8	Bhimeshwor	56.68	5.56	8.63	0	0	0	2.58	26.55
9	Bidur	70.19	12.04	7.21	3.7	0.15	5.62	0	1.09
10	Biratnagar SMPC	85.77	5.05	5.18	1.03	0.22	1	0.43	1.32
11	Birendranagar	73.95	11.06	10.15	0.94	1.08	0.76	0.06	2
12	Birgunj SMPC	58.48	13.7	7.44	9.99	1.06	0	0	9.32
13	Butwal	74.6	8.82	5.73	1.99	1.57	1.57	1.42	4.3
14	Byas	70.87	10.89	7.97	2.92	0.59	2.06	1.05	3.66
15	Damak	63.4	5.35	6.51	0.66	1.06	2.12	1.23	19.67
16	Dasharathchanda	35.64	8.19	34.17	2.51	1.41	4.19	1.18	12.7
17	Dhangadhi	68.13	13.11	10.07	2.67	1.08	0	2.3	2.65
18	Dhankuta	59.61	17.86	11.9	0	1.28	3.05	0.25	6.04
19	Dharan	58.34	15.49	11.3	2.43	6.24	2.96	0.75	2.48
20	Dhulikhel	52.61	17.65	7.11	11.1	0.53	3.88	0.46	6.68
21	Dipayal Silgadhi	43.64	15.14	9.49	19.02	3.83	5.66	2.69	0.52
22	Gaur	76.78	2.51	2.29	0.3	0.31	0.69	0	17.12
23	Ghorahi	80.63	8.34	5.44	0.78	0	0.63	2.5	1.68

SN	Municipality	Organic waste	Plastics	Paper and paper products	Glass	Metals	Textile	Rubber and Leather	Other
24	Gorkha	48.16	12.33	20.43	2.69	0.83	0.49	0	15.06
25	Gulariya	56.33	9.46	5.48	1.18	7.91	0	2.08	17.55
26	Hetauda	50.93	18.92	18.39	2.15	0.17	2.79	0.86	5.79
27	Ilam	57.98	9.18	14.22	4.51	3.84	2.38	4.1	3.78
28	Inaruwa	56.27	5.79	6.54	1.28	0.13	0.2	0.26	29.54
29	Itahari	61.23	12.56	19.35	1.49	0	2.05	0	3.32
30	Jaleshwor	70.13	17.11	9.05	0	0	1.12	2.59	0
31	Janakpur	71.53	17.23	10.51	0	0.41	0	0.32	0
32	Kalaiya	66.6	4.36	5.38	0.93	0.49	3.14	0.41	18.69
33	Kamalamai	62.72	11.17	7.88	3.04	2.61	1.84	1.73	9
34	Kapilvastu	81.72	8.52	6.36	0.48	0.36	2.56	0	0
35	Kathmandu MPC	64.24	15.96	8.66	3.75	1.72	3.4	1.12	1.15
36	Khandbari	46.82	14.76	13.33	4.9	4.94	6.85	0.4	8
37	Kirtipur	74.34	15.06	8.01	0.62	0.23	1.47	0.27	0
38	Lahan	84.52	7.93	5.61	0.1	1.04	0	0.65	0.14
39	Lalitpur SMPC	77.94	9.81	5.23	1.99	0.66	0.74	0.75	2.86
40	Lekhnath	59.8	9.12	10.63	10.13	1.73	0	0	8.59
41	Madhyapur Thimi	48.86	12.78	9.83	1.98	0.03	0	1.74	24.78
42	Malangawa	60.45	6.63	5.63	4.44	2.61	4.64	2.14	13.46
43	Mechinagar	70.19	12.87	11.93	0.92	1.73	0	0.86	1.5
44	Narayan	84.62	6.95	5.83	0	0.71	0.76	1.13	0
45	Nepalgunj	76.27	12.75	6.94	0.09	0.84	1.91	0.52	0.67
46	Panauti	82.95	7.82	5.06	0	0	1.78	0.47	1.93
47	Pokhara SMPC	62.65	8.8	11.61	4.54	5.74	2.21	2.82	1.63
48	Putalibazar	71.84	8.69	3.86	11.82	0	0.23	0	3.57
49	Rajbiraj	80.04	8.02	3.93	1.27	0.95	2.4	0.11	3.29

SN	Municipality	Organic waste	Plastics	Paper and paper products	Glass	Metals	Textile	Rubber and Leather	Other
50	Ramgram	51.06	7.83	15.34	0.1	0.28	3.33	0.52	21.54
51	Ratnanagar	74	20	2	1	0.67	1	0.33	1
52	Siddharthanagar	64.15	16.54	15.22	2.09	1.99	0	0	0
53	Siraha	67.78	3.58	6.01	0.34	1.59	1.48	4.31	14.91
54	Tansen	44.18	10.25	10.11	6.4	5.06	3.86	3.63	16.52
55	Tikapur	61.77	9.1	12.87	3.64	6.26	6.36	0	0
56	Triyuga	55.55	4.75	18.25	0.5	3.81	2.75	2.13	12.26
57	Tulsipur	85.87	4.77	6.38	2.65	0.33	0	0	0
58	Waling	47.24	11.28	10.53	5.14	2.61	4.33	0	18.87
Average Composition		**66.37**	**11.97**	**8.95**	**3.07**	**1.88**	**2.22**	**1.07**	**4.48**

ANNEX V: WASTE GENERATION OF MUNICIPALITIES

SN	Municipality	Average HH waste kg/day	Average HH size (numbers of Members)	Average per capita HH Waste (g/capita/day)	Total HH Waste (tons/day)	Total Comercial Waste (tons/day)	Total Industrial Waste (tons/day)	Average per capita MSW (g/capita/day)	Total MSW Generation(Tons/day)	Organic waste (Kg/day)	Plastics (kg/day)	Paper and paper products (kg/day)	other (kg/day)
1	Amargadhi	0.5	5.92	84.43	1.88	0.55	0.08	112.57	2.5	1548.10	288.20	425.20	112.36
2	Baglung	0.66	4.66	142.49	4.38	4.1	0.37	287.81	8.85	3553.10	1756.32	1970.42	475.36
3	Banepa	1.36	5.64	240.8	5.99	1.05	0.54	344	8.56	4594.93	1022.03	1029.18	576.26
4	Bhadrapur	0.39	4.81	80.2	1.5	0.13	0.06	106.93	1.99	1136.42	257.36	182.84	113.39
5	Bhaktapur	0.85	5.47	155.43	13	7.2	0.62	345.4	28.9	13049.13	2756.85	2362.83	1753.89
6	Bharatpur	1.25	5.66	220.04	32.52	6.82	0.8	400.06	59.12	29795.54	2252.18	4560.87	1452.48
7	Bhimdatta	0.6	5.58	107.53	11.47	1.3	1.14	215.05	22.94	6249.45	1355.55	1312.02	3929.68
8	Bhimeshwor	0.41	4.52	91.24	2.13	0.22	0.12	121.66	2.84	1276.46	201.83	275.92	663.03
9	Bidur	0.47	4.81	97.21	2.72	2.87	0.17	205.94	5.76	3456.92	1012.95	778.99	212.63
10	Biratnagar	0.68	4.8	142.39	29.18	25.48	3.7	284.78	58.37	41478.85	6999.88	7693.88	1701.39
11	Birendranag	0.62	5.88	104.9	5.47	3.18	0.46	174.83	9.12	4955.54	896.56	1109.06	751.61
12	Birgunj	0.84	6.14	137.23	19.08	2.67	0.27	274.46	38.17	12129.01	3183.42	2403.30	1862.47
13	Butwal	0.56	5	112.1	13.56	8.4	0.39	224.21	27.13	13661.95	3008.22	2544.51	1857.20
14	Byas	0.41	4.23	97.5	4.25	2.46	0.64	168.58	7.35	4443.58	987.26	1060.46	442.49
15	Damak	0.62	5.34	115.84	8.77	1.85	0.32	231.69	17.55	6644.65	717.90	961.35	2248.81
16	Dasharathcha	0.85	5.96	142.28	2.48	0.25	0.31	189.71	3.31	975.59	279.11	1048.40	494.78
17	Dhangadhi	0.71	5.16	138.45	14.41	11	0.4	276.9	28.81	12388.77	4984.51	2991.15	2715.87

18	Dhankuta	0.69	4.78	143.4	4.07	2.91	0.42	260.73	7.4	3600.87	1321.18	1266.52	954.61
19	Dharan	1.17	5.53	212.31	25.46	7.53	0.44	424.62	50.92	16877.30	5413.16	4330.22	3412.07
20	Dhulikhel	0.64	5.59	115.16	1.87	0.55	0.08	153.54	2.5	1382.30	421.21	211.27	222.79
21	Dipayal	0.56	6.42	86.92	2.3	0.72	0.11	124.17	3.29	1225.09	612.30	380.65	226.21
22	Gaur	0.73	7.38	99.02	3.5	1.31	0.19	141.46	5	3336.69	227.18	323.97	1006.11
23	Ghorahi	0.46	3.92	117.91	7.68	1.52	0.15	196.51	12.79	6839.90	1008.64	802.68	468.94
24	Gorkha	0.56	4.12	136.46	4.62	0.22	0.06	194.94	6.6	2349.02	644.25	1000.90	728.43
25	Gulariya	0.76	6.46	116.97	6.69	3.9	0.57	194.94	11.16	4524.61	2147.58	1848.33	1796.67
26	Hetauda	0.81	5.29	153.98	13.19	7.68	1.12	256.63	21.98	9237.33	5000.62	4391.64	1980.90
27	Ilam	1.14	5.66	201.34	3.91	1.63	1.26	366.08	7.11	3939.20	673.85	953.09	592.15
28	Inaruwa	1.36	4.88	277.89	8.04	1.16	0.27	396.98	11.48	5054.45	580.95	789.79	2789.07
29	Itahari	1	5.12	196.1	15.07	8.77	1.28	326.83	25.12	11584.05	5383.62	6096.67	1452.37
30	Jaleshwor	0.52	6.1	85.7	2.12	0.62	0.09	114.27	2.83	1739.16	711.06	282.33	96.76
31	Janakpur	0.61	6.08	101	9.94	1.23	0.77	168.33	16.57	7671.58	2190.31	1727.79	172.40
32	Kalaiya	1.43	6.28	227.1	9.8	3.67	0.53	324.43	13.99	8197.06	1356.28	1467.51	2549.39
33	Kamalamai	1	5.74	174.41	7.17	1.37	0.36	249.15	10.24	5055.53	1097.27	1147.66	1015.24
34	Kapilvastu	0.71	6.16	114.97	3.55	2.21	0.05	191.61	5.92	3918.54	847.36	739.08	275.19
35	Kathmandu	1.1	4.74	232.31	233.07	203.49	29.58	464.61	466.14	248191.81	93887.58	80674.71	16474.60
36	Khandbari	0.56	5.04	111.36	2.97	0.53	0.17	159.09	4.24	1553.71	587.68	667.09	498.18
37	Kirtipur	0.89	5.84	151.75	10.19	5.93	0.86	252.91	16.99	11665.73	3198.89	1651.53	177.97
38	Lahan	1.42	6.06	235.08	7.98	1.02	0.68	335.83	11.39	7367.85	1070.84	946.19	102.42
39	Lalitpur	0.9	4.84	185.91	42.15	36.8	5.35	371.82	84.3	48113.55	13114.49	15492.14	4953.54
40	Lekhnath	0.5	4.47	112.52	6.69	0.77	0.28	187.54	11.16	4290.60	792.51	1097.04	637.66
41	Madhyapur	0.7	5.12	136.72	11.5	10.04	1.46	273.44	23.01	7843.96	4564.94	4556.52	5431.01
42	Malangawa	1.9	7.18	264.2	6.64	0.66	0.12	377.43	9.49	4178.71	583.07	593.56	1486.95
43	Mechinagar	0.33	4.38	76.44	4.43	0.73	0.45	127.4	7.38	3460.99	819.03	961.79	146.79
44	Narayan	0.48	5.4	89.37	1.97	0.57	0.08	119.16	2.62	1936.36	256.13	346.82	37.23

45	Nepalgunj	1.13	6.06	186.34	13.75	8.59	0.48	372.67	27.5	15396.83	2989.87	2570.21	453.61
46	Panauti	0.6	4.94	121.86	3.45	0.9	0.11	174.09	4.93	3223.62	715.93	350.88	156.49
47	Pokhara	0.97	4.4	220.97	58.55	27.29	4	441.94	117.11	50618.24	8916.54	16146.83	6062.08
48	Putalibazar	0.55	4.55	121.81	3.82	0.18	0.13	174.01	5.45	2789.37	426.85	259.78	189.20
49	Rajbiraj	1.39	5.24	265.59	10.16	1.68	0.38	379.41	14.51	8958.74	1072.16	946.43	824.85
50	Ramgram	0.7	5.64	123.62	3.58	0.07	0.28	176.6	5.12	1913.68	315.98	652.91	925.27
51	Ratnanagar	0.74	4.74	155.83	7.26	6.7	0.38	311.65	14.53	7965.43	3062.29	2132.46	553.39
52	Sidharthanag	0.78	5.52	141.38	9.13	0.77	0.29	217.5	14.04	6148.32	1940.39	1725.65	0.00
53	Siraha	0.57	6.12	93.63	2.7	0.59	0.05	133.75	3.86	2129.93	143.82	349.01	599.41
54	Tansen	1.19	5.22	228.12	7.11	4.3	0.43	379.91	11.84	5238.82	1241.55	1877.03	2291.79
55	Tikapur	0.58	5.76	100.9	5.75	3.35	0.49	168.17	9.58	4639.98	1234.87	2077.50	542.89
56	Triyuga	0.45	6.08	74.6	5.33	2.6	0.36	124.33	8.88	4350.20	666.20	1669.53	1310.58
57	Tulsipur	0.54	4.64	115.91	6.05	1.46	0.2	178.32	9.31	5762.68	577.99	699.07	106.97
58	Waling	0.68	4.62	147.92	3.58	1.64	0.25	227.57	5.51	2632.17	628.10	675.35	1006.89
Total/Average Value		**0.79**	**5.37**	**170.12**	**769.6**	**447.17**	**65.01**	**317.22**	**1,435.05**	**718242**	**204405**	**199590**	**86073**

ANNEX VI: ENERGY POTENTIAL OF MSW OF DIFFERENT MUNICIPALITIES

SN	Municipality	population (2011)	Total Energy (MJ)	Total Energy (KWh)	Total Energy (MWh)	Capacity of Ideal plant (MW)	Plant Capacity (MW)	Plant Capacity (KW)
1	Kathmandu MPC	1,003,285	62,833,071	1,745,364	1,745	73	14.4	14,399
2	Lalitpur SMPC	254,308	1,004,355	278,988	279	12	2.3	2,302
3	Pokhara SMPC	313,841	879,883	244,412	244	10	2.0	2,016
4	Biratnagar	204,949	588,308	163,419	163	7	1.3	1,348
5	Dharan	137,705	396,301	110,084	110	5	0.9	908
6	Itahari	140,517	361,411	100,392	100	4	0.8	828
7	Madhyapur	84,142	355,805	98,835	99	4	0.8	815
8	Dhangadhi	137,666	330,899	91,917	92	4	0.8	758
9	Hetuda	152,875	322,610	89,614	90	4	0.7	739
10	Bharatpur	199,867	307,054	85,293	85	4	0.7	704
11	Butwal	138,742	241,493	67,081	67	3	0.6	553
12	Birgunj SMPC	204,816	239,358	66,488	66	3	0.5	549
13	Nepalgunj	146,424	227,098	63,083	63	3	0.5	520
14	Bhaktapur	83,658	225,008	62,502	63	3	0.5	516
15	Kirtipur	67,171	201,762	56,045	56	2	0.5	462
16	Ratnanagar	69,851	191,033	53,065	53	2	0.4	438
17	Bhimdatta	106,666	160,179	44,494	44	2	0.4	367
18	Gulariya	57,232	155,641	43,234	43	2	0.4	357
19	Kalaiya	86,318	149,513	41,531	42	2	0.3	343
20	Janakpur	168,617	144,930	40,258	40	2	0.3	332

21	Tansen	31,161	132,226	36,729	37	2	0.3	303
22	Sidharthanagar	64,566	125,372	34,826	35	1	0.3	287
23	Baglung	30,763	116,634	32,398	32	1	0.3	267
24	Rajbiraj	38,241	108,376	30,104	30	1	0.2	248
25	Damak	75,743	106,501	29,584	30	1	0.2	244
26	Tikapur	56,983	104,036	28,899	29	1	0.2	238
27	Inaruwa	28,923	100,124	27,812	28	1	0.2	229
28	Dhankuta	36,619	98,834	27,454	27	1	0.2	226
29	Kamalamai	41,117	96,508	26,808	27	1	0.2	221
30	Lahan	79,689	89,427	24,841	25	1	0.2	205
31	Ghorahi	65,107	88,538	24,594	25	1	0.2	203
32	Triyuga	71,405	87,755	24,376	24	1	0.2	201
33	Birendranagar	93,718	83,648	23,236	23	1	0.2	192
34	Banepa	24,894	83,023	23,062	23	1	0.2	190
35	Byas	46,877	79,248	22,013	22	1	0.2	182
36	Lekhnath	68,622	74,555	20,710	21	1	0.2	171
37	Malangawa	30,292	73,064	20,296	20	1	0.2	167
38	Bidur	27,953	68,446	19,013	19	1	0.2	157
39	Ilam	19,427	65,805	18,279	18	1	0.2	151
40	Kapilvastu	43,471	64,718	17,977	18	1	0.1	148
41	Mechinagar	57,909	62,231	17,286	17	1	0.1	143
42	Waling	24,199	60,967	16,935	17	1	0.1	140
43	Gorkha	39,263	59,933	16,648	17	1	0.1	137
44	Tulsipur	85,601	59,843	16,623	17	1	0.1	137
45	Panauti	28,312	49,646	13,791	14	1	0.1	114
46	Khandbari	26,658	46,196	12,832	13	1	0.1	106

47	Gaur	35,370	44,405	12,335	12	1	0.1	102
48	Ramgram	28,973	43,976	12,216	12	1	0.1	101
49	Jaleshwor	41,941	40,674	11,298	11	0	0.1	93
50	Dipayal Silgadhi	26,508	37,721	10,478	10	0	0.1	86
51	Dasharathchanda	17,427	36,290	10,080	10	0	0.1	83
52	Putalibazar	31,338	35,827	9,952	10	0	0.1	82
53	Siraha	59,037	29,402	8,167	8	0	0.1	67
54	Dhulikhel	19,210	28,915	8,032	8	0	0.1	66
55	Bhimeshwor	23,337	27,716	7,699	8	0	0.1	64
56	Amargadhi	22,241	25,496	7,082	7	0	0.1	58
57	Narayan	21,995	23,917	6,644	7	0	0.1	55
58	Bhadrapur	50,249	19,353	5,376	5	0	0.0	44
Total		**5,373,789**	**71,895,057**	**4,262,585**	**4,263**	**178**	**35.2**	**35,166**

ANNEX VII: GHG MITIGATION CALCULATION

SN	Municipality	Dry weight (Kg) of organic waste	Dry weight (Kg) plastic waste	Dry weight (Kg) of paper waste	Dry weight (Kg) of other waste	GHG mitigation of organic waste (kg CO2-eq/tone)	GHG mitigation of plastic waste (kg CO2-eq/tone)	GHG mitigation paper waste (kg CO2-eq/tone)	GHG mitigation other waste (kg CO2-eq/tone)	Total GHG mitigation
1	Amargadhi	464	274	340	101	77	108	192	23	401
2	Baglung	1,066	1,669	1,576	428	177	661	891	98	1,827
3	Banepa	1,378	971	823	519	229	384	465	119	1,198
4	Bhadrapur	341	244	146	102	57	97	83	23	260
5	Bhaktapur	3,915	2,619	1,890	1,578	650	1,037	1,068	363	3,118
6	Bharatpur	8,939	2,140	3,649	1,307	1,484	847	2,062	301	4,693
7	Bhimdatta	1,875	1,288	1,050	3,537	311	510	593	813	2,228
8	Bhimeshwor	383	192	221	597	64	76	125	137	401
9	Bidur	1,037	962	623	191	172	381	352	44	949
10	Biratnagar SMPC	12,444	6,650	6,155	1,531	2,066	2,633	3,478	352	8,529
11	Birendranagar	1,487	852	887	676	247	337	501	156	1,241
12	Birgunj SMPC	3,639	3,024	1,923	1,676	604	1,198	1,086	386	3,273
13	Butwal	4,099	2,858	2,036	1,671	680	1,132	1,150	384	3,347
14	Byas	1,333	938	848	398	221	371	479	92	1,164
15	Damak	1,993	682	769	2,024	331	270	435	466	1,501
16	Dasharathchanda	293	265	839	445	49	105	474	102	730
17	Dhangadhi	3,717	4,735	2,393	2,444	617	1,875	1,352	562	4,406
18	Dhankuta	1,080	1,255	1,013	859	179	497	572	198	1,446
19	Dharan	5,063	5,143	3,464	3,071	840	2,036	1,957	706	5,540
20	Dhulikhel	415	400	169	201	69	158	95	46	369

21	Dipayal Silgadhi	368	582	305	204	61	230	172	47	510
22	Gaur	1,001	216	259	905	166	85	146	208	606
23	Ghorahi	2,052	958	642	422	341	379	363	97	1,180
24	Gorkha	705	612	801	656	117	242	452	151	963
25	Gulariya	1,357	2,040	1,479	1,617	225	808	835	372	2,241
26	Hetauda	2,771	4,751	3,513	1,783	460	1,881	1,985	410	4,736
27	Ilam	1,182	640	762	533	196	254	431	123	1,003
28	Inaruwa	1,516	552	632	2,510	252	219	357	577	1,405
29	Itahari	3,475	5,114	4,877	1,307	577	2,025	2,756	301	5,659
30	Jaleshwor	522	676	226	87	87	268	128	20	502
31	Janakpur	2,301	2,081	1,382	155	382	824	781	36	2,023
32	Kalaiya	2,459	1,288	1,174	2,294	408	510	663	528	2,109
33	Kamalamai	1,517	1,042	918	914	252	413	519	210	1,393
34	Kapilvastu	1,176	805	591	248	195	319	334	57	905
35	Kathmandu MPC	74,458	89,193	64,540	14,827	12,360	35,321	36,465	3,410	87,556
36	Khandbari	466	558	534	448	77	221	302	103	703
37	Kirtipur	3,500	3,039	1,321	160	581	1,203	746	37	2,568
38	Lahan	2,210	1,017	757	92	367	403	428	21	1,219
39	Lalitpur SMPC	14,434	12,459	12,394	4,458	2,396	4,934	7,002	1,025	15,358
40	Lekhnath	1,287	753	878	574	214	298	496	132	1,140
41	Madhyapur Thimi	2,353	4,337	3,645	4,888	391	1,717	2,060	1,124	5,292
42	Malangawa	1,254	554	475	1,338	208	219	268	308	1,004
43	Mechinagar	1,038	778	769	132	172	308	435	30	946
44	Narayan	581	243	277	34	96	96	157	8	357
45	Nepalgunj	4,619	2,840	2,056	408	767	1,125	1,162	94	3,147
46	Panauti	967	680	281	141	161	269	159	32	621
47	Pokhara SMPC	15,185	8,471	12,917	5,456	2,521	3,354	7,298	1,255	14,428

48	Putalibazar	837	406	208	170	139	161	117	39	456
49	Rajbiraj	2,688	1,019	757	742	446	403	428	171	1,448
50	Ramgram	574	300	522	833	95	119	295	192	701
51	Ratnanagar	2,390	2,909	1,706	498	397	1,152	964	115	2,627
52	Sidharthanagar	1,844	1,843	1,381	-	306	730	780	-	1,816
53	Siraha	639	137	279	539	106	54	158	124	442
54	Tansen	1,572	1,179	1,502	2,063	261	467	848	474	2,051
55	Tikapur	1,392	1,173	1,662	489	231	465	939	112	1,747
56	Triyuga	1,305	633	1,336	1,180	217	251	755	271	1,493
57	Tulsipur	1,729	549	559	96	287	217	316	22	843
58	Waling	790	597	540	906	131	236	305	208	881
Total		**215,473**	**194,184**	**159,672**	**77,465**	**35,768**	**76,897**	**90,215**	**17,817**	**220,697**

ANNEX VIII: PERFORMANCE OF ENERGY BIN INSTALLED AT KMC

Date	Daily Feeding Amount (kg)	Nature/Type of Waste	Biogas Production	Electricity PRODUCTION (kWh)	ELECTRICITY (kW)
31-Oct	1000	Vegetable Residues	26.7	330	12.92
3-Nov	1000	Vegetable Residues	12.2	325	13.25
4-Nov	2000	Vegetable Residues	24.2	320	13.42
5-Nov	1000	Vegetable Residues	11.5	315	13.54
6-Nov	500	Vegetable Residues	3.2	310	13.96
7-Nov	2000	Vegetable Residues	11.4	322	13.67
8-Nov	1500	Vegetable Residues	10.9	310	13.54
9-Nov	500	Vegetable Residues	7.2	331	13.50
10-Nov	2000	Vegetable Residues & Fruits	20.6	328	13.25
11-Nov	1000	Vegetable residues	4.8	325	12.83
12-Nov	1000	Vegetable Residues	3.8	328	12.83
13-Nov	2000	Vegetable Residues	8.2	333	12.96
14-Nov	2000	Vegetable Residues	41.5	308	13.88
15-Nov	4000	Vegetable Residues	41.7	321	13.96
16-Nov	1000	Vegetable Residues	13.1	313	13.38
17-Nov	3000	Vegetable Residues	7	312	13.25

18-Nov	2000	Vegetable Residues	12.7	308	13.42
19-Nov	1500	Vegetable Residues	7.4	318	13.08
20-Nov	1500	Vegetable Residues	8.2	312	13.21
21-Nov	1000	Vegetable Residues	15.8	322	13.46
22-Nov	2000	Vegetable Residues	15.2	321	13.33
23-Nov	500	Vegetable Residues	13.7	310	13.29
24-Nov	1000	Vegetable Residues	4.7	308	13.00
25-Nov	2000	Vegetable residues + 120 kg cow dung	12.4	320	13.25

ANNEX IX: CAPACITY OF DIFFERENT WTE FOR ALL MUNICIPALITIES

SN	**Municipality**	**Total MSW Generation(Tons/day)**	**Incineration**	**Pyrolysis**	**Conventional Gasification**	**Plasma Arc Gasification**
1	Kathmandu	566	12.83	13.47	16.15	19.24
2	Pokhara SMPC	117.11	2.65	2.79	3.34	3.98
3	Lalitpur SMPC	84.3	1.91	2.01	2.41	2.87
4	Bharatpur	59.12	1.34	1.41	1.69	2.01
5	Biratnagar	58.37	1.32	1.39	1.67	1.98
6	Dharan	50.92	1.15	1.21	1.45	1.73
7	Birgunj SMPC	38.17	0.87	0.91	1.09	1.30
8	Bhaktapur	28.9	0.66	0.69	0.82	0.98
9	Dhangadhi	28.81	0.65	0.69	0.82	0.98
10	Nepalgunj	27.5	0.62	0.65	0.78	0.94
11	Butwal	27.13	0.62	0.65	0.77	0.92
12	Itahari	25.12	0.57	0.60	0.72	0.85
13	Madhyapur	23.01	0.52	0.55	0.66	0.78
14	Bhimdatta	22.94	0.52	0.55	0.65	0.78
15	Hetauda	21.98	0.50	0.52	0.63	0.75
16	Damak	17.55	0.40	0.42	0.50	0.60
17	Kirtipur	16.99	0.39	0.40	0.48	0.58
18	Janakpur	16.57	0.38	0.39	0.47	0.56
19	Ratnanagar	14.53	0.33	0.35	0.41	0.49

20	Rajbiraj	14.51	0.33	0.35	0.41	0.49
21	Sidharthanagar	14.04	0.32	0.33	0.40	0.48
22	Kalaiya	13.99	0.32	0.33	0.40	0.48
23	Ghorahi	12.79	0.29	0.30	0.37	0.43
24	Tansen	11.84	0.27	0.28	0.34	0.40
25	Inaruwa	11.48	0.26	0.27	0.33	0.39
26	Lahan	11.39	0.26	0.27	0.33	0.39
27	Gulariya	11.16	0.25	0.27	0.32	0.38
28	Lekhnath	11.16	0.25	0.27	0.32	0.38
29	Kamalamai	10.24	0.23	0.24	0.29	0.35
30	Tikapur	9.58	0.22	0.23	0.27	0.33
31	Malangawa	9.49	0.22	0.23	0.27	0.32
32	Tulsipur	9.31	0.21	0.22	0.27	0.32
33	Birendranagar	9.12	0.21	0.22	0.26	0.31
34	Triyuga	8.88	0.20	0.21	0.25	0.30
35	Baglung	8.85	0.20	0.21	0.25	0.30
36	Banepa	8.56	0.19	0.20	0.24	0.29
37	Dhankuta	7.4	0.17	0.18	0.21	0.25
38	Mechinagar	7.38	0.17	0.18	0.21	0.25
39	Byas	7.35	0.17	0.17	0.21	0.25
40	Ilam	7.11	0.16	0.17	0.20	0.24
41	Gorkha	6.6	0.15	0.16	0.19	0.22
42	Kapilvastu	5.92	0.13	0.14	0.17	0.20
43	Bidur	5.76	0.13	0.14	0.16	0.20
44	Waling	5.51	0.12	0.13	0.16	0.19
45	Putalibazar	5.45	0.12	0.13	0.16	0.19

46	Ramgram	5.12	0.12	0.12	0.15	0.17
47	Gaur	5	0.11	0.12	0.14	0.17
48	Panauti	4.93	0.11	0.12	0.14	0.17
49	Khandbari	4.24	0.10	0.10	0.12	0.14
50	Siraha	3.86	0.09	0.09	0.11	0.13
51	Dasharathchanda	3.31	0.08	0.08	0.09	0.11
52	Dipayal Silgadhi	3.29	0.07	0.08	0.09	0.11
53	Bhimeshwor	2.84	0.06	0.07	0.08	0.10
54	Jaleshwor	2.83	0.06	0.07	0.08	0.10
55	Narayan	2.62	0.06	0.06	0.07	0.09
56	Amargadhi	2.5	0.06	0.06	0.07	0.09
57	Dhulikhel	2.5	0.06	0.06	0.07	0.09
58	Bhadrapur	1.99	0.05	0.05	0.06	0.07
Total		**1435**	**34.8**	**36.5**	**43.8**	**52.2**

ANNEX X: GHG MITIGATIONS FOR ALL MUNICIPALITIES

S.N.	Municipalities	GHG (CO_2 eq kg per day)	Plasma (CO_2 eq kg per year)	Gasification (CO_2 eq kg per year)	Pyrolysis (CO_2 eq kg per year)	Incineration (CO_2 eq kg per year)
1	Kathmandu	87,555.67	31,957,819.81	23,968,364.86	22,370,473.87	20,772,582.88
2	Lalitpur SMPC	15,357.55	5,605,507.50	4,204,130.63	3,923,855.25	3,643,579.88
3	Pokhara SMPC	14,428.41	5,266,368.46	3,949,776.35	3,686,457.92	3,423,139.50
4	Biratnagar	8,528.82	3,113,020.55	2,334,765.42	2,179,114.39	2,023,463.36
5	Itahari	5,658.54	2,065,366.53	1,549,024.90	1,445,756.57	1,342,488.24
6	Dharan	5,540.48	2,022,274.92	1,516,706.19	1,415,592.44	1,314,478.70
7	Madhyapur	5,291.73	1,931,479.93	1,448,609.94	1,352,035.95	1,255,461.95
8	Hetauda	4,736.32	1,728,756.99	1,296,567.74	1,210,129.89	1,123,692.04
9	Bharatpur	4,693.26	1,713,041.45	1,284,781.09	1,199,129.01	1,113,476.94
10	Dhangadhi	4,406.32	1,608,305.95	1,206,229.46	1,125,814.17	1,045,398.87
11	Butwal	3,346.62	1,221,515.89	916,136.91	855,061.12	793,985.33
12	Birgunj SMPC	3,273.45	1,194,809.45	896,107.09	836,366.61	776,626.14
13	Nepalgunj	3,147.18	1,148,722.41	861,541.80	804,105.68	746,669.56
14	Bhaktapur	3,118.03	1,138,080.52	853,560.39	796,656.37	739,752.34
15	Ratnanagar	2,627.14	958,904.58	719,178.44	671,233.21	623,287.98
16	Kirtipur	2,567.71	937,213.12	702,909.84	656,049.18	609,188.53
17	Gulariya	2,240.60	817,819.30	613,364.47	572,473.51	531,582.54
18	Bhimdatta	2,227.66	813,094.40	609,820.80	569,166.08	528,511.36
19	Kalaiya	2,109.48	769,961.31	577,470.98	538,972.91	500,474.85
20	Tansen	2,050.78	748,534.72	561,401.04	523,974.31	486,547.57
21	Janakpur	2,022.69	738,281.92	553,711.44	516,797.34	479,883.25

22	Baglung	1,826.70	666,746.04	500,059.53	466,722.23	433,384.93
23	Sidharthanagar	1,816.15	662,895.63	497,171.73	464,026.94	430,882.16
24	Tikapur	1,747.04	637,669.36	478,252.02	446,368.56	414,485.09
25	Damak	1,501.01	547,868.57	410,901.43	383,508.00	356,114.57
26	Triyuga	1,493.18	545,010.91	408,758.18	381,507.63	354,257.09
27	Rajbiraj	1,448.02	528,528.06	396,396.05	369,969.64	343,543.24
28	Dhankuta	1,446.42	527,944.63	395,958.48	369,561.24	343,164.01
29	Inaruwa	1,404.59	512,674.65	384,505.99	358,872.25	333,238.52
30	Kamalamai	1,393.45	508,610.14	381,457.61	356,027.10	330,596.59
31	Birendranagar	1,240.95	452,946.22	339,709.67	317,062.36	294,415.04
32	Lahan	1,218.64	444,805.25	333,603.93	311,363.67	289,123.41
33	Banepa	1,197.79	437,194.36	327,895.77	306,036.05	284,176.33
34	Ghorahi	1,179.96	430,684.61	323,013.46	301,479.23	279,945.00
35	Byas	1,163.62	424,722.19	318,541.65	297,305.54	276,069.43
36	Lekhnath	1,139.67	415,978.80	311,984.10	291,185.16	270,386.22
37	Malangawa	1,003.54	366,292.18	274,719.14	256,404.53	238,089.92
38	Ilam	1,003.04	366,110.66	274,582.99	256,277.46	237,971.93
39	Gorkha	962.54	351,325.75	263,494.32	245,928.03	228,361.74
40	Bidur	949.34	346,509.77	259,882.33	242,556.84	225,231.35
41	Mechinagar	945.59	345,140.56	258,855.42	241,598.39	224,341.36
42	Kapilvastu	904.95	330,306.87	247,730.15	231,214.81	214,699.46
43	Waling	881.06	321,585.61	241,189.20	225,109.92	209,030.64
44	Tulsipur	842.54	307,528.90	230,646.68	215,270.23	199,893.79
45	Dasharathchanda	729.88	266,406.63	199,804.97	186,484.64	173,164.31
46	Khandbari	703.11	256,633.61	192,475.21	179,643.53	166,811.85
47	Ramgram	700.82	255,798.46	191,848.85	179,058.92	166,269.00

48	Panauti	620.86	226,615.25	169,961.43	158,630.67	147,299.91
49	Gaur	606.33	221,310.07	165,982.56	154,917.05	143,851.55
50	Dipayal Silgadhi	510.23	186,235.59	139,676.69	130,364.91	121,053.14
51	Jaleshwor	501.75	183,139.37	137,354.52	128,197.56	119,040.59
52	Putalibazar	456.08	166,467.78	124,850.84	116,527.45	108,204.06
53	Siraha	442.00	161,331.47	120,998.60	112,932.03	104,865.46
54	Bhimeshwor	401.46	146,533.30	109,899.98	102,573.31	95,246.65
55	Amargadhi	400.96	146,351.78	109,763.84	102,446.25	95,128.66
56	Dhulikhel	368.91	134,652.45	100,989.34	94,256.71	87,524.09
57	Narayan	357.26	130,398.50	97,798.88	91,278.95	84,759.03
58	Bhadrapur	259.53	94,727.08	71,045.31	66,308.96	61,572.60
Total		**220,697**	**80,554,560**	**60,415,920**	**56,388,192**	**52,360,464**

ANNEX XI: AIR POLLUTIONS MITIGATIONS FOR ALL MUNICIPALITIES

SN	Municipality	CO_2 (kg per year)	N_2O (kg per year)	NOx (kg per year)	NH_3(kg per year)	C (kg per year)	CH_4 (kg per year)	CO (kg per year)	Total (kg per year)
1	Kathmandu	19,626,050.00	2,272,490.00	23,406,647.00	4,544,980.00	61,357,230.00	5,681,225.00	56,812,250.00	173,700,872.00
2	Pokhara	4,060,789.25	470,196.65	4,843,025.50	940,393.30	12,695,309.55	1,175,491.63	11,754,916.25	35,940,122.12
3	Lalitpur	2,923,102.50	338,464.50	3,486,184.35	676,929.00	9,138,541.50	846,161.25	8,461,612.50	25,870,995.60
4	Bharatpur	2,049,986.00	237,366.80	2,444,878.04	474,733.60	6,408,903.60	593,417.00	5,934,170.00	18,143,455.04
5	Biratnagar	2,023,979.75	234,355.55	2,413,862.17	468,711.10	6,327,599.85	585,888.88	5,858,888.75	17,913,286.04
6	Dharan	1,765,651.00	204,443.80	2,105,771.14	408,887.60	5,519,982.60	511,109.50	5,111,095.00	15,626,940.64
7	Birgunj	1,323,544.75	153,252.55	1,578,501.27	306,505.10	4,137,818.85	383,131.38	3,831,313.75	11,714,067.64
8	Bhaktapur	1,002,107.50	116,033.50	1,195,145.05	232,067.00	3,132,904.50	290,083.75	2,900,837.50	8,869,178.80
9	Dhangadhi	998,986.75	115,672.15	1,191,423.15	231,344.30	3,123,148.05	289,180.38	2,891,803.75	8,841,558.52
10	Nepalgunj	953,562.50	110,412.50	1,137,248.75	220,825.00	2,981,137.50	276,031.25	2,760,312.50	8,439,530.00
11	Butwal	940,732.75	108,926.95	1,121,947.59	217,853.90	2,941,027.65	272,317.38	2,723,173.75	8,325,979.96
12	Itahari	871,036.00	100,856.80	1,038,825.04	201,713.60	2,723,133.60	252,142.00	2,521,420.00	7,709,127.04
13	Madhyapur	797,871.75	92,385.15	951,567.05	184,770.30	2,494,399.05	230,962.88	2,309,628.75	7,061,584.92
14	Bhimdatta	795,444.50	92,104.10	948,672.23	184,208.20	2,486,810.70	230,260.25	2,302,602.50	7,040,102.48
15	Hetauda	762,156.50	88,249.70	908,971.91	176,499.40	2,382,741.90	220,624.25	2,206,242.50	6,745,486.16
16	Damak	608,546.25	70,463.25	725,771.48	140,926.50	1,902,507.75	176,158.13	1,761,581.25	5,385,954.60
17	Kirtipur	589,128.25	68,214.85	702,612.96	136,429.70	1,841,800.95	170,537.13	1,705,371.25	5,214,095.08
18	Janakpur	574,564.75	66,528.55	685,244.07	133,057.10	1,796,270.85	166,321.38	1,663,213.75	5,085,200.44
19	Ratnanagar	503,827.75	58,337.95	600,880.89	116,675.90	1,575,124.65	145,844.88	1,458,448.75	4,459,140.76
20	Rajbiraj	503,134.25	58,257.65	600,053.80	116,515.30	1,572,956.55	145,644.13	1,456,441.25	4,453,002.92
21	Sidharthana	486,837.00	56,370.60	580,617.18	112,741.20	1,522,006.20	140,926.50	1,409,265.00	4,308,763.68
22	Kalaiya	485,103.25	56,169.85	578,549.46	112,339.70	1,516,585.95	140,424.63	1,404,246.25	4,293,419.08
23	Ghorahi	443,493.25	51,351.85	528,924.06	102,703.70	1,386,499.95	128,379.63	1,283,796.25	3,925,148.68
24	Tansen	410,552.00	47,537.60	489,637.28	95,075.20	1,283,515.20	118,844.00	1,188,440.00	3,633,601.28

25	Inaruwa	398,069.00	46,092.20	474,749.66	92,184.40	1,244,489.40	115,230.50	1,152,305.00	3,523,120.16
26	Lahan	394,948.25	45,730.85	471,027.76	91,461.70	1,234,732.95	114,327.13	1,143,271.25	3,495,499.88
27	Gulariya	386,973.00	44,807.40	461,516.22	89,614.80	1,209,799.80	112,018.50	1,120,185.00	3,424,914.72
28	Lekhnath	386,973.00	44,807.40	461,516.22	89,614.80	1,209,799.80	112,018.50	1,120,185.00	3,424,914.72
29	Kamalamai	355,072.00	41,113.60	423,470.08	82,227.20	1,110,067.20	102,784.00	1,027,840.00	3,142,574.08
30	Tikapur	332,186.50	38,463.70	396,176.11	76,927.40	1,038,519.90	96,159.25	961,592.50	2,940,025.36
31	Malangawa	329,065.75	38,102.35	392,454.21	76,204.70	1,028,763.45	95,255.88	952,558.75	2,912,405.08
32	Tulsipur	322,824.25	37,379.65	385,010.40	74,759.30	1,009,250.55	93,449.13	934,491.25	2,857,164.52
33	Birendranag	316,236.00	36,616.80	377,153.04	73,233.60	988,653.60	91,542.00	915,420.00	2,798,855.04
34	Triyuga	307,914.00	35,653.20	367,227.96	71,306.40	962,636.40	89,133.00	891,330.00	2,725,200.96
35	Baglung	306,873.75	35,532.75	365,987.33	71,065.50	959,384.25	88,831.88	888,318.75	2,715,994.20
36	Banepa	296,818.00	34,368.40	353,994.52	68,736.80	927,946.80	85,921.00	859,210.00	2,626,995.52
37	Dhankuta	256,595.00	29,711.00	306,023.30	59,422.00	802,197.00	74,277.50	742,775.00	2,271,000.80
38	Mechinagar	255,901.50	29,630.70	305,196.21	59,261.40	800,028.90	74,076.75	740,767.50	2,264,862.96
39	Byas	254,861.25	29,510.25	303,955.58	59,020.50	796,776.75	73,775.63	737,756.25	2,255,656.20
40	Ilam	246,539.25	28,546.65	294,030.50	57,093.30	770,759.55	71,366.63	713,666.25	2,182,002.12
41	Gorkha	228,855.00	26,499.00	272,939.70	52,998.00	715,473.00	66,247.50	662,475.00	2,025,487.20
42	Kapilvastu	205,276.00	23,768.80	244,818.64	47,537.60	641,757.60	59,422.00	594,220.00	1,816,800.64
43	Bidur	199,728.00	23,126.40	238,201.92	46,252.80	624,412.80	57,816.00	578,160.00	1,767,697.92
44	Waling	191,059.25	22,122.65	227,863.30	44,245.30	597,311.55	55,306.63	553,066.25	1,690,974.92
45	Putalibazar	188,978.75	21,881.75	225,382.03	43,763.50	590,807.25	54,704.38	547,043.75	1,672,561.40
46	Ramgram	177,536.00	20,556.80	211,735.04	41,113.60	555,033.60	51,392.00	513,920.00	1,571,287.04
47	Gaur	173,375.00	20,075.00	206,772.50	40,150.00	542,025.00	50,187.50	501,875.00	1,534,460.00
48	Panauti	170,947.75	19,793.95	203,877.69	39,587.90	534,436.65	49,484.88	494,848.75	1,512,977.56
49	Khandbari	147,022.00	17,023.60	175,343.08	34,047.20	459,637.20	42,559.00	425,590.00	1,301,222.08
50	Siraha	133,845.50	15,497.90	159,628.37	30,995.80	418,443.30	38,744.75	387,447.50	1,184,603.12
51	Dasharathch	114,774.25	13,289.65	136,883.40	26,579.30	358,820.55	33,224.13	332,241.25	1,015,812.52

52	Dipayal	114,080.75	13,209.35	136,056.31	26,418.70	356,652.45	33,023.38	330,233.75	1,009,674.68
53	Bhimeshwor	98,477.00	11,402.60	117,446.78	22,805.20	307,870.20	28,506.50	285,065.00	871,573.28
54	Jaleshwor	98,130.25	11,362.45	117,033.24	22,724.90	306,786.15	28,406.13	284,061.25	868,504.36
55	Narayan	90,848.50	10,519.30	108,348.79	21,038.60	284,021.10	26,298.25	262,982.50	804,057.04
56	Amargadhi	86,687.50	10,037.50	103,386.25	20,075.00	271,012.50	25,093.75	250,937.50	767,230.00
57	Dhulikhel	86,687.50	10,037.50	103,386.25	20,075.00	271,012.50	25,093.75	250,937.50	767,230.00
58	Bhadrapur	69,003.25	7,989.85	82,295.46	15,979.70	215,725.95	19,974.63	199,746.25	610,715.08
Total		**53,223,351**	**6,162,704**	**63,475,849**	**12,325,408**	**166,393,000**	**15,406,759**	**154,067,595**	**471,054,669**