Review Article

Advance in Environmental Waste Management & Recycling

Solid Waste Management in Response to Global Warming and Climate Change in Suryabinayak Municipality, Bhaktapur District, Nepal

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Abstract
The study aims to focuses on waste-to-energy and especially its current status and benefits, with regard to GHG, renewable energy production and slurry management based on an experience in Nepal. An environment pollution and climate change happened due to green house gases (GHG) emission. As we know that the most of the anthropogenic emission of GHG results from the combustion of fossil fuels but we should also know that environmental concerns such as waste management also contribute for Global Warming. The solid waste management is based on an understanding of MSWs composition and physiochemical characteristics. The results show that organic matter represents 69% of waste, followed by paper-cardboard 7%, plastic 8%, miscellaneous 13%, metal 1% and glass 2%. The major source of GHG from landfill sites which produce significant methane and carbon dioxide gas. The main impact of the methane is on global scale, as a greenhouse gas. Although levels of methane in the environment are relatively low, its high "global warming potential" (21 times that of carbon dioxide) rank it amongst the worst of green house gases. The main cause to increase atmospheric temperature due to highly production of GHG (CH_4, CO_2 & N_2O etc). GHG mitigation measure in the waste include source reduction through waste prevention, recycling, composting, waste to energy incineration and methane capture from landfills and waste water. Specific mitigation option include use of 3R principle; waste segregation, reduction at source; composting anaerobic digestion for biogas; sanitary landfill sites with methane capture; healthcare waste management; proper statutory framework; public participation; private sector partnership; tax waiver for recycling enterprises; and financial management. Regulation is required to ban of recyclable waste in landfill.

Keywords: Solid Waste Management, Green House Gas, Waste, Energy, Global Warming, climate change.

Introduction
Background
Suryabinayak Municipality is a municipality in Nepal that was created by merging the previous 4 VDCs of Katunje, Sipadol, Nankel and Chitpol in December 2014. The name is coined based on Suryavinayak Temple, which is located in the municipality. In March 2017, under new local restructuring, Suryabinayak Municipality was expanded including Anantalingeshwor Municipality adding 4 previous VDCs of Sirutar, Gundu, Dadhikot and Balkot. The centre of this municipality is located at Katunje. According to the 2011 Nepal Census, Surybinayak Municipality has a population of 78,490.

Table 1: Distribution of Population by Wards in Suryabinayak Municipality

S.N.	Municipality/ Wards	Population	Area (Square Km)
1	Ward 1	6581	2.95
2	Ward 2	9497	1.86
3	Ward 3	6384	0.97
4	Ward 4	9568	4.9
5	Ward 5	10560	2.85
6	Ward 6	8937	1.47
7	Ward 7	5689	7.43
8	Ward 8	9876	8.11
9	Ward 9	5509	6.8
10	Ward 10	5619	5.07
	Total	78220	42.41

Source: http://103.69.124.141

Solid waste management has become the burden for the municipalities. Different technology introduced for the solid waste management in different countries. This is crucial issue for an environmental problem, global warming and climate change. Some of the municipalities have used bio-gas plant for waste management. When making new strategic decision related to energy system and waste management it is therefore of importance to consider the environmental implications. The Kathmandu valley municipality produces 620 tons/day solid waste.

Municipal Solid Waste (MSW) contains organic as well as inorganic matter. Part of organic matter is more as compared to inorganic matter. The latent energy present in its organic fraction could be recovered for gainful utilization through adoption of suitable waste processing and treatment technologies. The recovery of energy from solid wastes also offer a few additional benefits i.e. 1) The total quantity of solid waste gets reduced up to 90%, depending upon the waste composition and the adopt of technology; 2) demanding for land, which is already scarce in cities; for landfill site 3) the cost of transportation of waste to far-away landfill sites also get reduced; and 4) reduction in environmental pollution.

It is, therefore, only logical that, while every effort should be made in the first place to minimize generation of waste material and to recycle and reuse them to extent feasible, the option of energy recovery from wastes to be duly examined. Wherever feasible, this option should be incorporated into the over-all scheme of waste management. The study aims to focuses on waste-to-energy and especially its current status and benefits, with regard to Green House Gas, renewable energy production and slurry management in Nepal. A waste hierarchy is used in waste policy making and is often suggested. Different versions of the hierarchy exist but in most of the cases the following order suggests:

1. Reduce quantity of waste
2. Reuse
3. Recycle the materials
4. Biogas plant
5. Landfill

The first priority is to reduce the quantity or volume of waste that generally accepted. However, the remaining waste needs to be taken care of as efficiently as possible. The hierarchy after the top priority is often contested and discussions on waste policy are in many countries intense. Especially the order between recycling and waste to energy (Biogas plant) is often discussed.

Table 2: Distribution of Municipal Solid Wastes

Municipal Solid wastes	Industrial	Housekeeping wastes, packaging, food wastes, wood, steel, concrete, bricks, ashes, hazardous wastes, e-wastes
	Commercial & Institutional	Paper, Cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous waste, e-wastes
	Construction and Demolition	Wood steel, Concrete, soil bricks, tiles, glass, plastics, insulation, hazardous waste etc
	Municipal Services	Street sweeping, landscape & tree trimmings, sludge, wastes from recreational areas
	Residential	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood glass, metals, ashes, special wastes (bulky items, consumer electronics, white good, battery, oil, tires), household hazardous wasteswastes
	Process Wastes	Scarp material, off specification product, slag, tailings, top rocks, process water and chemicals
	Medical Wastes	Infectious wastes (Bandages, gloves, cultures, swabs, blood & bodily fluids) ,hazardous wastes (sharps, instruments, chemicals), radioactive wastes, pharmaceutical wastes
	Agriculture wastes	Spoiled food wastes, rice husks, cotton stalks, coconut shells, pesticides, animal excreta, soiled water, silage effluent, plastic, scarp machinery, veterinary medicines

Source: Hoomweg & Bhada-Tata (2012); ETC/SCP, 2013

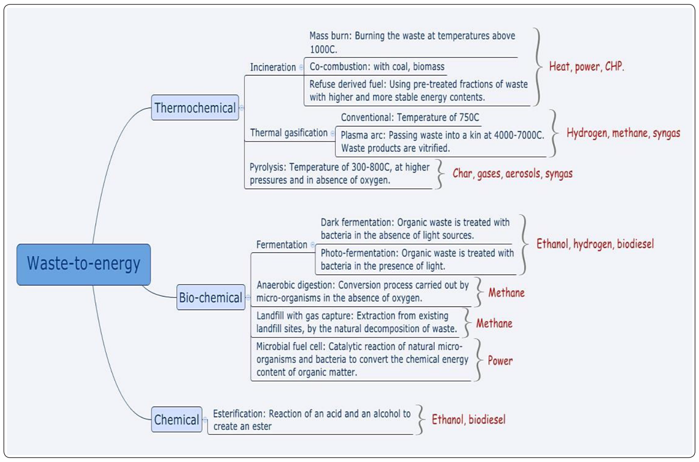
Composition of Global Municipal wastes

Source: Hoornweg & Bhada-Tata, 2012

Table 3: Approximate net calorific values for common MSW Fractions

Fraction	Net Calorific value (MJ\kg
Paper	16
Organic Material	4
Plastics	35
Glass	0
Textiles	0
Other Materials	11

Source: ISWA, 2013



Biogas plant

Historical Development of Biogas in Nepal

The history of biogas in Nepal goes back to 1955, when a late Father B.R. Saubolle, a Belgian School Teacher at St. Xavier's School, Godavari in Kathmandu, built a demonstration plant of used oil drum. The development of biogas got its momentum after the world energy crisis in 1973, which caused the global interest in this sector. In 1975, as a part of energy Research and Development Group (ERDG), a Biogas Development Committee (BDC) was formed (Ghimire, 2000). When the Ministry of Agriculture observed the fiscal year 1975/76 as the "Agriculture Year", biogas was included as a special programme for its effectiveness in controlling deforestation and preventing burning of animal dung which otherwise could be used as fertilizer (IOE,2001). In 1975/76, two hundred and fifty family size biogas plants were installed by private contractors under the supervision of Department of Agriculture. All those plants were floating drum design based on Khadi and Village Industries Commission (KVIC) India (GGTKYS, 2000).

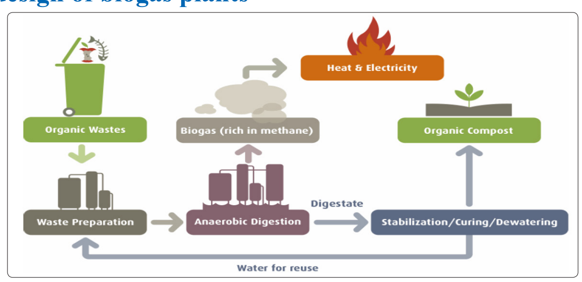
Agriculture Development Bank (ADB) of Nepal played an active role in the promotion of biogas technology. Similarly, Development and Consulting Services (DCS) of United Mission to Nepal (UMN), Balaju Yantra Shala (BYS) and Agricultural Tool Factory (ATF) were the pioneering agencies to make biogas programme success (IOE, 2001). The Gobar Gas and Agricultural Equipment Development Company Pvt. Ltd (GGC) were formed in 1977 as a private company for research, development and dissemination of the technology throughout the country. Research on various design of biogas plants such as floating drum, concrete fixed dome, precast tunnel, plastic bio-digester, ferro-cement gas holder, brick mortar dome were carried out and experimented. Among the various designs, the fixed dome design (GGC model, 1990) has become popular in Nepal (Devkota, 2001).

Table 4: Biogas plant installed & average gas production in Nepal

Particulars	Average No	Avg biogas production per day (in kg)	Biogas produced per day (in kg)	Annual Production of Biogas	Produced Annually in MT
Hotel (Residential, Resort, Restaurants Slaughter house, etc)	2500	10	25000	9125000	9125
Police Camps	2350	15	35250	12866250	12866.25
Army camp	75	15	1125	410625	41063
Educational Institution (canteen, hostels, etc)	300	8	2400	876000	876
Hospitals	300	8	2400	876000	876
Municipalities	133	500	66500	24272500	24272.50
Village Personal Usage)	100000	1	100000	36500000	36500
Villages (Commercial Production)	5000	30	150000	54750000	54750
Farm (poultry, Agriculture Farms, etc)	2000	8	16000	5840000	5840
Commercial Production	20	500	10000	3650000	3650
Household Production	200000	2	400000	146000000	146000
TOTAL PRODUCTION IN NEPAL			808675	295166375	295166.38

Source: http://www.newbusinessage.com/MagazineArticles/view/1530

The design of biogas plants



Source: Iona Capital, 2016

Figure 2: Illustration of AD process treating Biogradable MSW

The anaerobic digestion process occurs in municipal steps and involves a community of micro organism, as follow:

- Hydrolysis- complex polymers are broken down by hydrolytic enzymes into simple sugar, amino acids and fatty acids
- Acidogenesis - Simple monomers are broken down into volatile fatty acids
- Acetogenesis - the products of acidogenesis are broken down into acetic acid
- Methanogenesis - methane and carbon dioxide are produces

There are many types of AD systems that operate in different ways as well. They are usually classified as follows:

- Meso-philic or the rmophilic: The former system operates at temperatures between 25-45C, while the latter process requires higher temperatures of 50-60C. Thermo-philic systems have a faster biogas production per unit of feedstock and m3 digester, and are more effective at clearing the life state of pathogens. As they need more energy for heating, these systems have higher costs and require more management than meso-philic ones.
- Wet or Dry: This refers to the AD feedstock, but the difference between the two is not significant. Wet AD is 5-15% dry matter

and be pumped and stirred; while dry AD is over 15% dry matter and can be stacked. Dry AD tends to be cheaper to operate as there is less water to heat and there is more gas production per unit of feedstock. In contrast, wet systems require lower capital costs for installation, but dry system tends to be favored for MSW treatment.

- Continuous Flow or Batch Flow: Most AD plants operate with a continuous flow of feedstock because the costs are lower and tend to give more biogas per unit of input. It is technically challenging to open the digester and restart the system from cold every few weeks. However, there are dry systems that operate on batch flow, and multiple batch digesters with staffered changeover time can be used to overcome peaks and troughs in gas production.
- Single or Multiple Digester: AD occurs in different stages, and wet systems may require multiple digesters to ensure efficiency of the process. Multiple digesters have higher capital and operating costs, require more management, but can offer more biogas per unit of feedstock.
- Vertical Tank or Horizontal plug flow: Vertical tanks take feedstock in a pipe on one side and digestive overflows through pipe on the other. Horizontal plug flow is chosen when there is more solid feedstock. The former is cheaper and simple to operate, but presents the risk of having the feedstock for inappropriate periods of time resulting in possible economic losses. The latter is expensive to build and operate, but the rate feedstock flow in the digester can be highly controlled.

The choice of AD technology will depend on many factors such as type of feedstock, co/single digestion, space (e.g. plants will have a small footprint in urban areas), desired output (e.g. more biogas for energy production, waste mitigation, bedding, digestive), infrastructure and available grants/financing. It is very flexible as it can be designed in multiple ways, according to context which is intended to operate.

The feedstock usually requires pre-treatment, depending on the kind available. For instance, waste food from supermarket will required removal of all packaging and screening for contaminants such as plastics and grit; while others such as manure or waste crops will need to be homogenized to reach the consistency desired for optimum fuel output.

AD is a promising technology with multiple benefits for a wide range of stakeholders ranging from the local community, farmers to government. It is considered to be optimum method for handling food waste in an environmentally safe way. While it is not a new technology, since it dates from as back as 1800s, and experienced continuous growth and technical development throughout the recent years, the market is rather small with huge room for expansion. In the Nepal for instance, the biggest drawback for the development is lack of feedstock access. This is not given by a lack of organic waste in general, but by the inability to readily access the streams, large proportion of it remaining in the residual waste streams. It has been observed that the AD capacity exceeds the actually available food waste, even though it is estimated that Nepal produces …..tones of food waste per year. Appropriate regulation to incentivize more effective separation of waste at source and preventing the disposal of organic waste in landfills is necessary to increase feedstock, which will enable better use of existing AD capacity.

Landfill with Gas capture

Landfills are a significant source of greenhouse gas emissions, and methane in particular can be captured and utilized as an energy source. Organic materials that decompose in landfills produce a gas comprised of roughly 50% methane and 50% carbon dioxide, called LFG (Landfill gas). Methane is a potent greenhouse gas with a global warming potential that is 25 times greater than co2.Capturing methane emissions from landfills is not only beneficial for the environment as it helps mitigate climate change, but also for the energy sector and community. Application for LFG include direct use in boilers, thermal uses in kilns (Cement, pottery, bricks), sludge dryers, infrared heaters, blacksmithing forges, leachate evaporation and electricity generation to name a few. LFG is increasingly being used for heating of processes that create fuels such as biodiesel or ethanol, or directly applied as feedstock for alternative fuels such as compressed natural gas, liquefied natural gas or methanol. The project that used cogeneration (CHP) to generate electricity and capture the thermal energy is more efficient and more attractive in this sense.

The process of capturing LFG involves partially covering the landfill and inserting collection systems with either vertical or horizontal trenches. Both systems of gas collection are effective, and the choice of design will depend on the site-specific conditions and the timing of installation. This can also be employed in combination and an example is the utilization of a vertical well and a horizontal collector. As gas travels through the collection system, the condensate (water) formed needs to be accumulated and treated. The gas will be pulled from the collection wells into the collection header and sent to downstream treatment with the aid of a blower. Depending on the gas flow rate and distance to downstream processes, the blower will vary in number, size or type .The excess gas will be flared in open or enclosed conditions to control LFG emission during start up or downtime of the energy recovery system, or to control the excess gas, when the capacity for the energy conversion is surpassed.

The LFG treatment of moisture, particulates and other impurities is necessary, but the type and the extent will depend of the sort of energy recovery used and the site-specific characteristics. Minimal treatment can be employed for the boiler and most internal combustion systems, while other internal combustion system, gas turbine and micro turbine applications will require more sophisticated procedures with absorption beds, biological scrubbers and others, to remove substances such as siloxane and hydrogen sulfide.

One million tons of MSW in the USA produces around 12.33 m^3 per day of LFG and will continue to produce it for another 20 to 30 years after the MSW has been landfilled.LFG is considered a good source of renewable energy, and has a heating value of about 500 British thermal unit (Btu) per standard cubic foot. Benefit of using this waste to energy process go beyond abatement of GHG emissions and offset the use of non-renewable resources, to include other economic advantages such as revenue for landfills, energy costs reduction for LFG energy users, sustainable management of landfills, local air quality improvement and job creation.

Managing solid waste is one of the major challenges in Urbanization. A survey conducted in 58 municipality of Nepal in 2012 found that average municipal solid waste generation was 317 grams per capita per day. This translates into 1435 tons per day or 52,400 tons per year of municipal solid waste generation in Nepal. Many of these technically and financially constrained municipalities are still practicing roadside waste pickup from open piles and open dumping crating major health risks.

Advantages of Biogas

1. Biogas is Eco-friendly

Biogas is a renewable, as well as a clean, source of energy. Gas generated through bio-digestion is non polluting; it actually reduces greenhouse emission (i.e. reduces the greenhouse effect). No combustion takes place in the process, meaning there is zero emission of green house gasses to the atmosphere; therefore, using gas from waste as a form of energy is actually a great way to combat global warming.

2. Biogas Generation reduces soil and water pollution

Biogas reduces landfill waste, augmenting the environment, hygiene, and sanitation. Overflowing landfills don't only spread foul smells- they also allow toxic liquids to drain into underground water sources. Consequently, yet another advantage of biogas is that biogas generation may improve water quality. Moreover, anaerobic digestion deactivates pathogens and parasites; thus, it's also quite effective in reducing the incidence of waterborne diseases. Similarly, waste collection, and management, significantly improves in areas with biogas plants. This, in turn, leads to improvements in the environment, sanitation, and hygiene.

3. Biogas generation produces organic fertilizer

The by-product of the biogas generation process is enriched organic (digestive), which is a perfect supplement to, or substitute for, chemical fertilizers. The fertilizer discharge from the digester can accelerate plant growth and resilience to diseases, whereas commercial fertilizers contain chemicals that have toxic effects and can cause food poisoning, among other things.

4. Simple and low–cost technology that encourages a circular economy (Fig. 2).

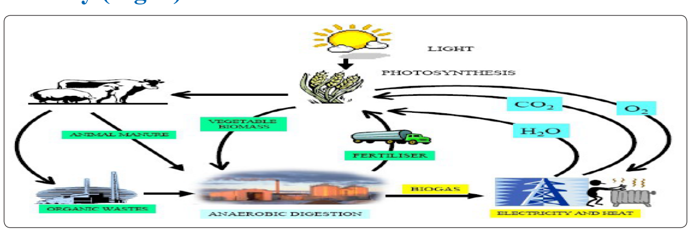


Figure 3: The Biogas Cycle

The technology used to produce biogas is quite cheap. It is easy to set up and needs little investment when on a small scale. Small biodigestor can be used right at home, utilizing kitchen waste and animal manure. A household system pays for itself after a while, and the material used for generation are absolutely free. The gas manifested can be used directly for cooking and generation of electricity. This is what allows the cost of biogas production to be relatively low.

Farm can make use of biogas plants and waste products produced by their live stock every day. The waste products of one cow can provide enough energy to power a light bulb for an entire day .In large plants, biogas can also compress to achieve the quality of natural gas, and utilized to power automobiles. Building such plants requires relatively low capital investment, and creates green jobs.

5. Healthy cooking alternatives for developing areas

Biogas generator saves women and children from the daunting task of firewood collection. As a result, more time is left over for cooking and clean. More importantly, cooking on a gas stove, instead of over an open fire, prevents the family from being exposed to smoke in the kitchen. This helps to prevent deadly respiratory diseases. Sadly, 4.3 million people a year die prematurely from illness attributable to household air pollution caused by the inefficient use of solid fuels for cooking.

Disadvantages of Biogas

Few technology advancements

An unfortunate disadvantage of biogas today is that the system used in the production of biogas are not efficient .There are no new technologies yet to simplify the process and make it abundant and low cost. This means large scale production to supply for a large population is still not possible. Although the biogas plants available today are able to meet some energy needs, many governments are not willing to invest in sector.

Contains impurities

After refinement and compression biogas still contains impurities. If the generated bio-fuel was utilized to power automobiles, it can corrode the metal parts of the engine. This corrosion would lead to increased maintenance costs. The gaseous mix much more suitable for kitchen stoves, water boilers, and lamps.

Effect of Temperature on biogas production

Like other renewable energy sources (e.g. solar, wind) biogas generation is also affected by the weather. The optimal temperature bacteria need to digest waste is around 37C. In cold climates, digesters required heat energy to maintain a constant biogas supply.

Less suitable for dense Metropolitan Areas

Another biogas disadvantages is that industrial biogas plants only makes sense where raw materials are in plentiful supply (food waste manure). For this reason, biogas generation is much more suitable for rural and suburban areas.

Bio-Slurry

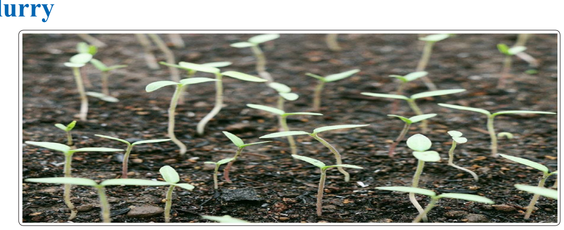


Figure 4: Bio-slurry

In addition to the use as a fertilizer, bio-slurry (biogas residue) can be used for many other purposes, including:

a. Fixing Soil Physical Condition
Trial that lasted ten years in China showed that the application of bio-slurry is considered ideal for use in seedlings, and to improve soil conditions due to excessive use of chemical fertilizers.

b. Application of Pesticides
Bio-slurry spraying, with a few dose or no pesticides, could control red spider and leafhoppers that disrupt vegetables, wheat, or cotton plants. The impacts of bio-slurry mixed with 15-20% pesticide in pest control equals with the impacts of pure chemical pesticides. Besides being able to control the pollution,

it also can reduce the cost.

c. Seeding

Research shows that the application of bio-slurry to the seed millet/barley could control barley yellow mosaic virus very effectively. This virus causes one of the most severe diseases in barley plants. This technique could control 90% of the virus and increases millet production by 20-25%. The bio-slurry layers could prevent pathogens and eggs of pests to infect the seed.

d. Animal Feed

Dried bio-slurry could potentially be used as a feed supplement to cattle, pigs, and poultry. Most of ammonia nitrogen in slurry can be utilized by a growing bacterial biomass, to be converted into amino acids. In addition, the fermentation process also produces B12 vitamin in considerable amounts.

e. Fish Farming

Bio-slurry as a by-product of fermentation in anaerobic biogas reactor has been in fish ponds with good results. In an experiment that carried out for two years, the production of fish in various types increased from 7.1% to 26.6% compared to fresh manure.

f. Mushroom Cultivation

In China, bio-slurry application for mushroom cultivation has resulted in the production of 7.43 kg/m3, or 15.4% higher than the use of conventional media. These results concluded that the use of bio-slurry gives better results in the cultivation of mushrooms.

g. Cultivation Earthworm

Bio-slurry can be used as feed for earthworms after aerated for a week.

Conclusion and Recommendations

Conclusion

All sorts of waste materials are generated in the Nepal cities as in other countries. However, in the absence of well-planned, scientific system of waste management (including waste segregation at source) and of any effective regulation and control of rag-picking, waste burning and waste recycling activity, left over waste at the dumping yards generally contains high percentage of inert (>40%) and of put resile organic matter (30-60%). It is common practice of adding the road sweeping to the dust bins. Papers and plastics are mostly picked up and only such fraction which is in an unrecoverable form remains in the refuse. Paper normally constitutes 3-7% of refuse while the plastic, content is normally less than 1%.The calorific value on dry weight (high calorific value) varies between 800-1100kcal/kg Self-sustaining combustion cannot be obtained for such waste and auxiliary fuel will be required. There have been growing problem of waste management in the urban areas and the increasing awareness about the ill effects of the existing waste management practices on the public health, the urgent need for improving the overall waste management system and adoption of advanced, scientific method of waste disposal.

Recommendations

The following recommendations have been put forward:

1. The Policy, key strategy & framework developed for the managing organic composting and landfill operations, to properly guide local bodies in effective.
2. Strictly follow the 3R (Reduce, Reuse & Recycle) principle for effective management of MSW.
3. Aware the public for MSW and enhancement of public participation and consultation would be effective in advancing MSW practices;
4. The current practice of open dumping and open burning system should immediately stop and support for advancement of technology for MSW management.
5. Local body should create opportunity for private sector in MSW.
6. The basic data for MSW will play an important role for planning, monitoring and implementation progress.
7. Local body should provide effective service for public so that public willing to pay for service charge.
8. A policy of clean development mechanism and carbon trading in international market will be beneficial to sustain the technology in rural area and gradual poverty reduction.
9. The government should formulate provisions for hotels, restaurants, military and police camps, hospitals, hostels, household units, farms across the country to install and use biogas plant based on their own capacity of production and consumption.

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