POTENTIAL OF USING MUNICIPAL WASTE FOR ENERGY IN KATHMANDU: BIOGAS & INCINERATION

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DAAYITWA
NEPAL PUBLIC SERVICE FELLOWSHIP
SUMMER 2014

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1. INTRODUCTION

1. 1. BACKGROUND

Rapid population growth and urbanization in developing countries have led to the generation of large quantities of solid wastes and consequential environmental degradation. 90-95% of all waste in the world is landfilled or disposed in open dumps, creating considerable nuisance and environmental problems. Often lack of technical knowledge, financial and human resources coupled with existing policies limit the extent to which landfills can be built, operated and maintained at minimum standards of sanitary practice.

Civilization of Kathmandu began & developed around Bagmati river banks. Things were manageable at those times as people lived in harmony with nature. Industrialization changed everything. At the end of the 20th century Kathmandu saw massive rise of urbanization. Concentrated population packets at different parts in Kathmandu Valley merged into the continuous city of more than three million people. Among the cities in Nepal, Kathmandu is the largest city.

Ever growing population have its own problem. One of the most challenging part of urbanization is is management of waste, generated by this large population. Production of Waste generation has continually grown with the number of population residing and their changing lifestyle. Solid waste generation of the Kathmandu city is expected to be more than 500 Tonne/day in coming year. It has made waste collection expensive affair and process of waste handling, transportation and disposal cumbersome.

Solid wastes are those organic and inorganic waste materials produced by various activities of the society, which have lost their value to the first user. Improper disposal of solid wastes pollutes all the vital components of the living environment (i.e., air, land and water) at local and global levels. The problem is more acute in developing nations than in developed nations, as their economic growth as well as urbanization is more rapid. There has been a significant increase in MSW (municipal solid waste) generation in Nepal in the last few decades. This is largely because of rapid population growth and economic development in the country. Due to rapid growth of urban population, as well as constraint in resources, the management of solid waste poses a difficult and complex problem for the society and its improper management gravely affects the public health and degrades environment.

Waste referred as rubbish, trash, garbage, or junk is unwanted or unusable material. According to European councils' directive "Waste is any substance or object which the holder discards or intends or is required to discard." Waste if it is hazardous or toxic, it could even be a harbinger of disease and death, not just for living beings, but for all that sustains life, for example, water, air, soil and food.

Solid waste can be defined as any solid or semi-solid substance or object resulting from human or animal activities, discarded as useless or unwanted. It is an extremely mixed mass of wastes, which may originate from household, commercial, industrial or agricultural activities.

Solid waste is a broad term, which encompasses all kinds of waste such as Municipal Solid Waste (MSW), Industrial Waste (IW), Hazardous Waste (HW), Bio-Medical Waste (BMW) and Electronic waste (E-waste) depending on their source & composition. It consists of organic and inorganic constituents which may or may not be biodegradable. On one hand, the recyclable components of solid waste could be useful as secondary resource for production processes. On the other hand, some of its toxic and harmful constituents may pose a danger if not handled properly. Source reduction, recycling and composting, waste-to-energy conversion facilities, and land filling are the four basic approaches to waste management.

1. 2. MUNICIPAL SOLID WASTE

Municipal solid waste (MSW), also called Urban Solid Waste, and is a waste type that includes predominantly household waste (domestic waste) with sometimes the addition of commercial wastes, construction and demolition debris, sanitation residue, and waste from streets collected by a municipality within a given area. They are in either solid or semisolid form and generally exclude industrial hazardous wastes.

MSW can be broadly categorized into five broad categories as-

- Biodegradable waste: food and kitchen waste, green waste (vegetables, flowers, leaves, fruits), paper (can also be recycled).
- Recyclable material: paper, glass, bottles, cans, metals, certain plastics, etc.
- Inert waste: construction and demolition waste, dirt, rocks, debris.
- Composite wastes: waste clothing, Tetra Packs, waste plastics such as toys.
- Domestic hazardous waste (also called "household hazardous waste") & Toxic waste: medication, e-waste, paints, chemicals, light bulbs, fluorescent tubes, spray cans, fertilizer and pesticide containers, batteries, shoe polish.

Sources	Typical waste generators	Solid waste contents
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, batteries, oil, tires), and household
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food Wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food Wastes, glass, metals, special wastes, hazardous wastes.
Institutional	Schools, hospitals, prisons, Government centers.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes.
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, Landscaping, parks, beaches, recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
Process (Manufacturing, etc.)	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing.	Industrial process wastes, scrap materials, off-specification products, slay tailings.
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides).

Table 1: Sources of waste, waste generators & solid waste contents

can produce heat and energy when burnt. The chemical formula of the hydro-carbon is CH4 where C stands for carbon and H for hydrogen and chemically the gas is termed as methane gas. The chemical formula of some other commonly used hydrocarbons derived from fossil oil viz. petrol, kerosene, diesel, etc. are C6H14 , C9H20 and C16H34 respectively. Unlike these hydro-carbons which are derived from direct chemical processes, bio-gas is produced through a bio-chemical process in which some bacteria convert the biological wastes into useful bio-gas comprising methane through chemical interaction. Such methane gas is renewable through continuous feeding of biological wastes and which are available in plenty in rural areas in the country. Since the useful gas originates from biological process, it has been termed as bio-gas in which methane gas is the main constituent.

The gas thus produced in a bio-gas plant does not contain pure methane and has several impurities. A typical composition of such gas obtained from the process is as follows:

Composition	Percentage
Methane	60.0%
Carbondioxide	38.0%
Nitrogen	0.8%
Hydrogen	0.7%
Carbon-monoxide	0.2%
Oxygen	0.1%
Hydrogen Sulphide	0.2%

Table 2: Composition of Biogas

The calorific value of methane is 8400 kcal/ m3 and that of the above mixture is about 4713 Kcal/ m3. However, the bio-gas gives a useful heat of 3000 kcal/m3. If similar heat values are to be obtained from other sources of fuel, the equivalent quantities of those fuel have to be substantial. Methane is about 20 times more potent greenhouse gas than carbon dioxide if released into the atmosphere. Furthermore, its use for power generation produces heat and emits carbon dioxide and some other gases but despite that biomethane has a number of environmental benefits which make it a green source of energy. Organic matter from which biomethane is produced would release the gas into the atmosphere if simply left to decompose naturally, while other gases that are produced during the decomposition process such as nitrous dioxide for instance further contribute to the greenhouse effect.

Bio methane production eliminates the release of a great deal of methane and other harmful gases into the atmosphere. This is due to the fact that its production eliminates exposure of the decomposing organic matter to the air which prevents methane and other gases from escaping into the atmosphere. In addition, biomethane reduces the need for fossil fuels by which it further reduces the emissions of greenhouse gases into the air. By reducing the need for firewood, helps preserve the forests which in turn helps lower concentration of carbon dioxide in the atmosphere as the trees absorb carbon dioxide while releasing pure oxygen. The use of organic matter for biomethane production also improves hygienic conditions and quality of life in the rural areas, and reduces the risk of water pollution.

	Percentage	Quantity
Organic	65%	390 Tonne/Day
Combustibles		
Paper	8.9%	**53.4 Tonne/Day**
Plastic	8%	**48 Tonne/Day**
Total		101 Tonne/Day
Total Waste	**100%**	**600 Tonne/Day**

Table 3: Components in Municipal Waste in Kathmandu (2018 AD)

Since bio-methane is chemically identical to natural gas, it can be used for the same applications as natural gas. It can be used for electricity generation, water heating, space heating, cooking as well as to fuel vehicles.

1. 4. SCOPE OF PRODUCTION OF BIOGAS/BIO METHANE FROM MSW IN KATHMANDU

Solid Waste in Kathmandu alone was 408 T/day in 2010. It is expected to reach 548 T/day in 2015. Solid Waste production in whole Kathmandu valley including surrounding Municipalities and villages was 1029 Ton/day which is expected to reach 1553 T/day in 2015. According to a study almost 66% of solid waste in Kathmandu is organic waste while another 19% is combustible or recyclable. Around 65 per cent of municipal solid waste is biodegradable. A ton of biodegradable waste can produce 25-30 kg of methane, about 150 kg of carbon dioxide and 50-60 kg of organic manure. It will not only generate precious bio-methane but will also reduce solid disposable mass. By converting biomass into biogas solid mass disposable will be reduced by more than 50%. It means KMC will e able to use existing dumping sites for double time than they are planned for.

From Table 3, it can be safely said that by 2018 AD, biogas plant can be designed to handle almost 400 T/day solid waste. In the meantime another type of waste to energy plant can also be established to utilize almost 20-50 T/day combustible paper and plastic. After segregation of recyclable plastic and paper, remaining materials can be incinerated to generate power and hot water. Electricity can be used to run plants machinery while hot water can be used to heat digesters. Any remaining electricity can be sold to national grid for additional income.

The study looked at plants with capacity of 100,000 and 200,000 tonnes per year, with 10% and 30% non-organic material. Both wet and dry anaerobic digestion technologies were considered.

Waste Stream	Selected Technology
100,000 tonnes per year, organics with up to 30% unintentional material	Wet, Mesophilic, Single-Stage Digestion
200,000 tonnes per year, organics with up to 30% unintentional material	
100,000 tonnes per year, organics with up to 10% unintentional material	Dry, Thermophilic, Single-Stage Digestion
200,000 tonnes per year, organics with up to 10% unintentional material	

Table 4: Technology for Waste Selection

	Characteristics	Parameters	Values		
1	Waste	t/d	100	200	300
2	Biogas production	m^3/d	30360	60720	91080
3	Electrical power consumption	kW	169	338	506
4	Heat power consumption	kW	726	1418	2179
5	Area required	ha	4	8	11
6	Solid bio-fertilizer	t/d	45	90	135
7	Liquid bio-fertilizer	m^3/d	18.75	36.25	56.25

Table 5: Biogas Production and different parameters

Hence, it is advised that the project can have multiple stage of development. Best way to build it will be 100,000 tonne/year capacity plant in first phase and expand it to 200,000 tonne/year.

2. BIOGAS PRODUCTION PROCESS

2. 1. PRODUCTION PROCESS

The process of bio-gas production is anaerobic in nature and takes place in two stages. The two stages have been termed as acid formation stage and methane formation stage. In the acid formation stage, the bio-degradable complex organic compounds of solids and cellulose presents in the waste materials are acted upon by a group of acid forming bacteria present in the dung and reduce them into organic acids, CO_2, H_2, NH_4 and H_2S. Since the organic acids are the main products in this stage, it is known as acid forming stage and this serves as the substrates for the production of methane by methanogenic bacteria.

In the second stage, groups of methanogenic bacteria act upon the organic acids to produce methane gas and also reduce CO_2 in the presence of H_2 to form methane (CH_4). At the end of the process the amount of oxygen demanding materials in the waste product is reduced to within the safe level for handling by human beings. There are four types of methano-genic bacteria; Methano- bacterium, Methano-spirillium, Methano-coccus and Methano-circina. These bacteria are oxygen sensitive and photo-sensitive and do not perform effectively in the presence of oxygen and light.

2. 2. ANAEROBIC DIGESTION PROCESS - BACKGROUND INFORMATION

Anaerobic digestion occurs naturally wherever high concentrations of wet organic matter accumulate in the absence of dissolved oxygen. Anaerobic microorganisms digest the organic material producing carbon dioxide and methane that can be collected and used as a fuel (biogas). The stabilized solid residue, which averages 40- 60% by weight of the feedstock, can be used as soil conditioner material.

Anaerobic digester systems, (also called fermentation, gasification or methanization), use closed reactors to control the anaerobic process and to collect all of the biogas fuel produced. The yield of biogas depends on the composition of the waste feedstock and the conditions within the reactor. For example, the rate of anaerobic digestion can be increased by operating in certain temperature ranges. The modern anaerobic digestion treatment processes are engineered to control the reaction conditions to optimize digestion rate and fuel production.

Details about Biogas production process can be obtained from Appendix 2

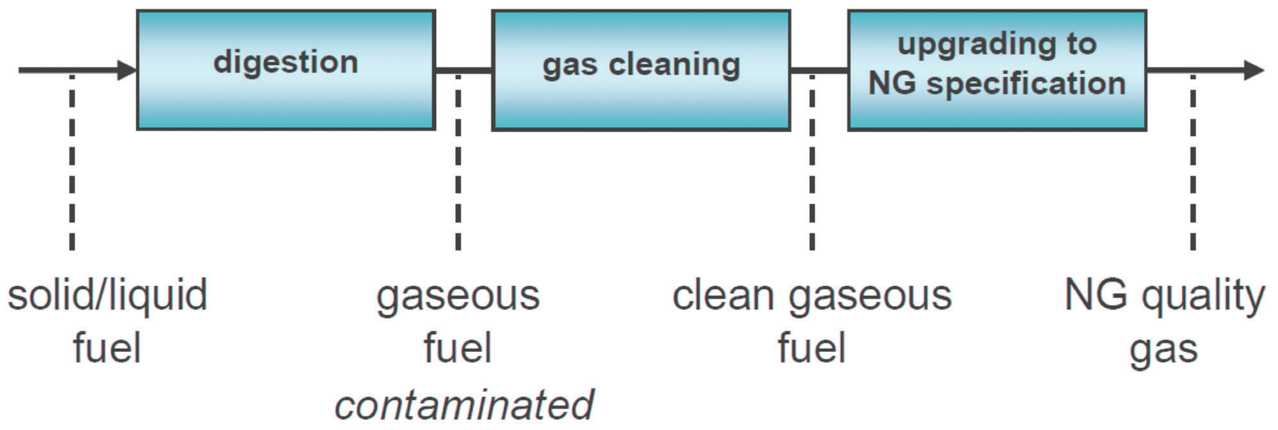


Figure 1: Typical Manufacturing process of Bio-CNG from Biogas

Biogas consists of gases other than methane like CO_2 and H_2S. These gas are separated in the process called scrubbing. The resulting gas is 99% Methane which can be compressed to produce Bio-CNG.

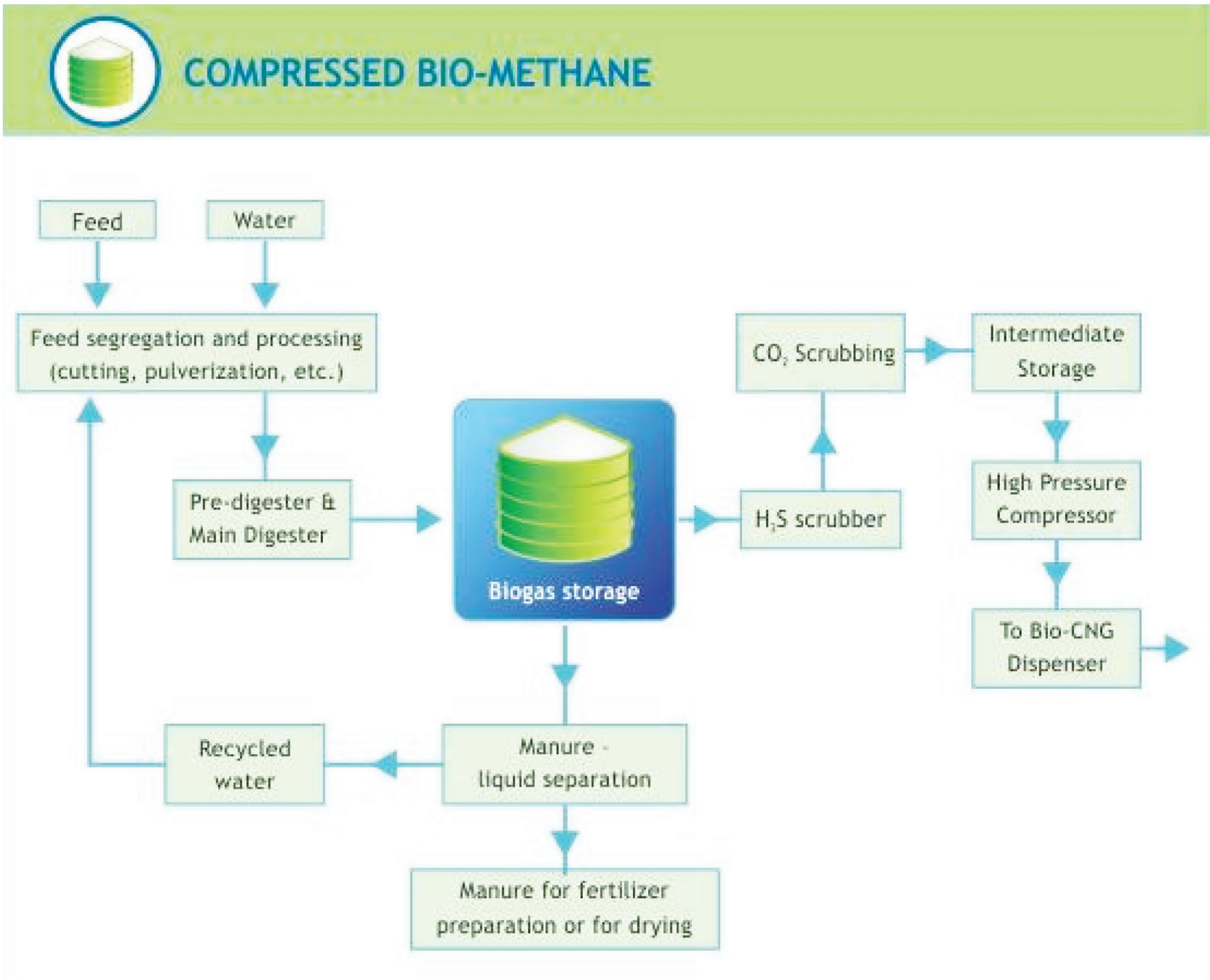


Figure 2: Typical Manufacturing process of Bio-CNG from Biogas

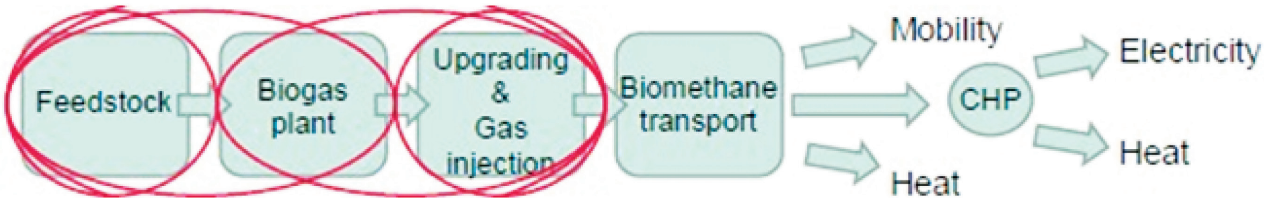


Figure 3: Biomethane Business Model

1. Produce the Bio-methane and sell it as CNG gas which can be either used by CHP plant to generate electricity and heat or for transportation. In both case role of project will be limited to supplying of compressed methane (CNG) gas.

2. Use CHP plant to produce generate electricity and heat. Electricity can be sold to utility company while hot water can be used to heat biomass in digesters.

3. Install the Compressing and bottling plant and sell gas in CNG canisters. Install refilling station in different part of the city.

Among these option second option would have been better if feed in tariff of Nepal Electricity Authority (NEA) would have been attractive. But it is quite unlikely that loss making NEA will give any preferential treatment to the project. So, third option seems to be quite attractive due to following reason.

1. It will give opportunity for the company to establish bottling and refilling business as subsidiary.

2. The CHP plant will operate only at 60-65% efficiency out of which almost half is in form of hot water. As there is not industrial complex or hotels near the proposed plant, almost all hot water will go wasted.

3. As the cost of CNG is almost similar to highly taxed LPG, project will earn more.

4. Company can collaborate with Hotel owners and industrialists to setup CHP plants in their premises.

AD Plant Scenario	Net Tonnes Diverted/Year	GHG Emission Reduction (Including Carbon Sequestration) (tonsCO_2/year)
100,000 tpy; 30%	76,300	18,700
100,000 tpy; 10%	91,000	18,400
200,000 tpy; 30%	152,600	37,300
200,000 tpy; 10%	182,000	36,800

Table 6: Environmental Benefits of Anaerobic Digestion

2. 3. SITE SERVICES AND REQUIREMENTS

The facility will require basic services common to any waste management facility, including water and sewer, electrical grid connection, natural gas connections and access roads for entry to and exit from the plant. The locations of access roads are shown in the conceptual site plan. This layout is based on one-way, counter-clockwise truck traffic flow (best arrangement for large trucks) with road turning radii suitable for full size transfer trailers.

2. 3. 1. Waste Receiving

Similar to other waste management facilities, the anaerobic digestion plant would have an area for receiving solid waste. The waste reception system will include the following components:

Weigh Scale

Trucks would be weighed before and after unloading their cargo onto the tipping floor. The weigh scale would be sized and rated for the capacity expected from a full-length (16-17 m) transfer trailer carrying in excess of 30 tons.

Tipping Floor

The tipping floor must be enclosed inside the building, to minimize odor emissions from the waste being received. On the tipping floor, an operator will visually inspect the waste and remove large non-digestible items as well as other unacceptable items, such as household hazardous waste (HHW), before the waste is fed into the process. The tipping floor has been sized for two days storage, allowing for plant downtime and 4-day weeks. For the 100,000 tpy (400 tpd) plant capacity, daily variations in waste delivery truck quantities and capacities of 25% can be expected (i.e., +25% represents design case). Based on an on floor material density for the 30% unintentional waste stream of approximately 250 –300 kg/m3 (275 kg/m3 average) and an average pile height of 4m, a total of 900 m2 of tip floor storage is required. The tip floor has been set at twice this area (1800 m2) to facilitate truck drive through and tipping, front-end- loader movement, rejects bin and main feed conveyor/bag breaker.

Liquid Waste Holding Tank
Liquid wastes from Industrial, Commercial and Institutional sources could comprise up to 25% of the waste input to the facility. Liquids would generally be brought in by vacuum trucks and would bypass the tipping floor. Liquid wastes would not need to go through the pre-processing system, and in most cases would be suitable for direct feed to the digesters (via the wet processing pulpers described below).

Holding capacity for incoming liquids would be required, which would consist of a tank that the wastes would be pumped into by the incoming tanker truck. Based on a daily waste input of 400 tonnes and a maximum liquid input of 25%, approximately 100 tonnes of liquid waste (or 100 m3 at an estimated specific gravity of 1.0) could be expected daily. A 200 m3 tank providing 2 days storage is proposed. This could be a concrete underground tank to conserve site space, however high water table concerns in rainy season will likely dictate the need for an above-ground tank.

Pumping of liquids into the holding tank would be achieved using the pumps on the tanker trucks, but pumping capability will be required to convey liquids from the holding tank to the pulpers.

2. 3. 2. Front-End Pre-Processing
With the relatively high residue content of this waste stream and the presence of recyclable materials, significant front-end pre-processing will be required to both capture the recyclable materials and remove non-digestible contaminants so as to make the waste stream suitable for anaerobic digestion.

The front-end pre-processing system would be comparable to the front-end system installed at the City's Dufferin Transfer Station AD facility. For a 400 tpd facility, it is anticipated that a MRF having capacity of 15-20 tph (as is the case at the Dufferin facility) operating over 3 shifts would be required.

The key processing components of the MRF are described below.

Bag Breaker
Solid wastes would likely first pass through a bag breaker, a mechanical device that uses sharp edges to tear open plastic bags, releasing their contents. The need for a bag breaker will depend on the City's waste collection approach ultimately adopted and the ability of the downstream trommel screen to successfully open bags. Some of the plastic bags will stay on the bag breaker's knives, but the majority of plastic must be removed by a subsequent separation step (the trommel). The bag breaker would be installed on the main tip floor with waste fed directly to it using the front-end- loader.

Trommel Screen
A trommel screen is a large rotating drum containing openings of various sizes, normally installed at a slight decline to move material through the unit as it rotates. Trommel drums for waste screening are typically constructed of steel plate with holes drilled through the plate, while wire mesh style trommels are more typical for soil screening applications. Trommels for waste screening can be equipped with steel knives welded to the drum interior to assist in opening bags.

For this waste stream, a trommel with two opening sizes would be used to separate the material into "fines" (first opening size), "middles" (second opening size, set at larger than the first opening size) and "overs" (all remaining material). Anything that is smaller than the first opening size of the screen will fall through to a conveyor belt as fines. Objects larger than the first opening size will continue tumbling through the trommel and either fall through the next opening size as middles or be discharged off the end of the trommel as overs.

The opening size to separate fines would likely be from 40-50 mm. At this size, the fines will contain a high percentage of organic material suitable for digestion although grit and broken glass will also be present, which will be mostly removed in the pulper stage described below. The opening size for the middles cut is typically 150-250 mm and is set to isolate the recyclable materials fraction (plastic containers, metal cans). This cut will subsequently be conveyed past manual picking and mechanical separation steps to capture the individual recyclable material streams.

Any remaining material in the trommel discharges off the end as the overs cut. This fraction typically contains paper, OCC, boxboard, textiles and plastic film, some of which is well suited for digestion. A subsequent picking station(s) is normally used on the overs conveyor to capture valuable materials or to remove materials that are unsuitable for the subsequent wet processing/digestion steps.

Ideally, the fines, middles and overs conveyors are recombined (after recyclable materials and unwanted materials are "negatively" sorted) so that all organics are directed to the digestion phase.

Picking Lines or Mechanical Removal of Glass and Plastic

The manual picking of waste is something that may eventually be phased out due to the health hazards of manual waste handling, but it remains the most effective method of recovering containers. Plastic containers such as PET and HDPE are the recyclable materials that are expected to be recovered by manual sorting of the middles stream. Only experience will demonstrate whether glass bottles can also be captured by this means. It is expected that a very high degree of glass breakage will have occurred by this point in the process, thus manual picking will not likely be practical. The downstream wet processing system must capture the majority of the broken glass.

If picking lines are not to be used because of human health issues, other mechanical means of sorting, such as flats-round separation, could be used for some recovery of containers. If picking lines are utilized, the picking stations would be housed within a controlled atmosphere enclosure.

Baler

Based on the anticipated recyclable materials quantity captured from this waste stream (see mass balance, Figure 4.2), a baler having capacity for some 35 bales per day will be required.

Magnetic Separation

The recovery of ferrous metals from the waste stream is achieved by means of a strong magnet suspended above the middles conveyor belt. Normally the conveyor containing the recombined fines, middles and overs streams is equipped with a magnetic head pulley to provide the plant with two-stage magnetic separation.

Eddy Current Separation

An eddy-current separator, located on the middles conveyor downstream of the magnetic separator, introduces eddy currents which cause a strong repelling force between the separator and aluminum. Aluminum is thus repelled off the middles conveyor to a storage bin while all other materials continue on to the recombining conveyor described above.

Wet Separation

The MRF components described above are all dry pre-processing steps that would be common to facilities employing either wet or dry AD technologies that are processing a high-residue waste stream. Wet separation, however, is unique to wet AD technologies as a pre-digestion step. Some dry technologies use a wet separation step after the material has been digested, which can reduce contaminants in the output product but does not protect digestion equipment and removes fewer contaminants than pre-digestion wet separation.

In general wet separation involves mixing with water to produce a pumpable pulp, from which heavy non-digestibles (such as glass and grit) are removed by settling then flushing through a de-gritter and light non-digestibles (such as plastic film) are removed by raking off floatables from the pulp. The pulping device serves two other important functions, namely to defibre the material thus increasing its surface area and better preparing it for digestion and secondly, initiating the digestion process by using process water that already contains micro-organisms.

2. 3. 3. Anaerobic Digestion Process: Wet, Mesophilic, Single-Stage

For the purposes of this report, a wet, mesophilic, single-stage anaerobic digestion process is assumed for the scenario of processing organics with up to 30% unintentional material. This is principally due to the inherent use of the wet separation step, which is effective at removing the high contaminant levels (which is expected in SW of Kathmandu city) of plastic film as well as glass and grit.

The digester would be sized for approximately 15 days retention time. For the 100,000 tpy plant capacity, it is anticipated that three digesters, each of approximately 4500 m3 capacity would be employed. The digesters would utilize a gas mixing system.

2. 3. 4. Solid-Liquid Separation

Following digestion, the digested solids would require dewatering before being sent to the final curing location. This dewatering would occur by means of screw presses and/or centrifuges. A polymer solution would be added prior to the presses to flocculate the solids and facilitate solids separation. Most of the water removed at this stage would be recycled to the pulping and wet separation stage of the front-end processing. The remainder would be wastewater, which may require some treatment for the reduction of nitrogen, phosphorus and suspended solids.

2. 3. 5. Post-Digestion Processing of Digestate

The dewatered solid digestate requires final aerobic curing, to ensure full stabilization and pathogen reduction, which occurs when the material self-heats to over 550 C. Due to the extensive space requirements involved in windrow composting, this step would be done offsite at another facility.

The digestate exiting from the pressing stage could be discharged directly into a waiting container (trailer, lugger or roll-off) or would require an intermediate storage area, from which it would be loaded onto trucks for hauling to the final composting site. For this waste stream, it is estimated that the digestate mass would be equal to approximately 49% of the mass of the total input to the plant, or 49,000 tonnes per year. This equates to a daily digestate output of approximately 200 tonnes or 100 tonnes per operating shift, based on a 2-shift hauling operation. It is proposed that a single transfer trailer bay be provided for the 100,000 tpy plant with two or three trailers having to be regularly shuttled each shift.

The material would be composted at a facility with the capacity for an input of 200 tonnes per day. The curing time required would be three to four weeks and possibly longer. Also, a bulking agent may be necessary to increase the pore space within the piles, absorb moisture, and add carbon to increase the C:N ratio. This could be chipped yard waste or another relatively inert organic material. It would be added to make up approximately 20% by mass of the composting material.

At a windrow height of 2.5 m and compost feedstock density of approximately 0.6 tonnes/ m3, with a curing time of 28 days it is estimated that approximately 1.3 ha would be required for curing of the digestate. Compost bulking and area requirement calculations can be found in Appendix A. It is noted that there are currently no operating facilities in the province with the capacity to process the required volume of material that would result from this plant.

2. 3. 6. Liquid Treatment

It is expected that the mass of liquid effluent generated at the plant which is not recycled and therefore needs to be treated and discharged could be equal to approximately 21% of the mass of the total input to the plant, or 21,000 tonnes per year. At a density of 1 tonne/m3 and discharging six days a week, this equates to 67 m3/ day of wastewater to be treated and sent to disposal.

The main parameters of concern would be suspended solids, nitrogen and phosphorus. A wastewater treatment process consisting of a clarifier and aeration tank could be installed if necessary. Alternatively, liquid waste can also be sold as liquid fertilizer to farmers. However, provision of waste water treatment would be kept in place should there be lack of interest from farmers.

2. 3. 7. Biogas Collection and Refining

The biogas produced in the digester would be collected by piping and would need to be treated and pressurized for transport to the market. Biogas is produced from the digester at approximately 100% humidity. To reduce corrosion in piping and gas utilization equipment, moisture removal would be necessary. This would consist of a knockout device for condensate removal.

It may be necessary to remove hydrogen sulfide (H2S) from the biogas. Sulfides would be removed by a chemical scrubber. The H2S content of the gas out of the digester could be in the range of 200-2500 ppm. The gas would come out of the digester at a pressure of less than 1 psi. A compressor would be used to compress the gas for digester mixing and pipeline delivery to the compressor and bottling plant.

2. 3. 8. Environmental Control Systems

The facility will include control measures for odour, noise and litter. Odour would be addressed by a biofilter. All of the process buildings would be maintained under negative air pressure, and this air would be exhausted through a biofilter. In addition, certain equipment items containing high odour sources (for example; waste dissolver, bag breaker, trommel) would be directly vented to the odour control ducting network. The biofilter would be sized at approximately 75 m3/hr per m2 of biofilter surface area (at 200 mm pressure drop). This translates into a typical air change rate in the process buildings of about 3 air changes per hour, and also allows approximately 25% additional flow for direct venting of odorous equipment sources. The biofilter would be equipped with a humidification system (both in the media bed and for the incoming air stream) and utilize a control system to monitor important operating parameters.

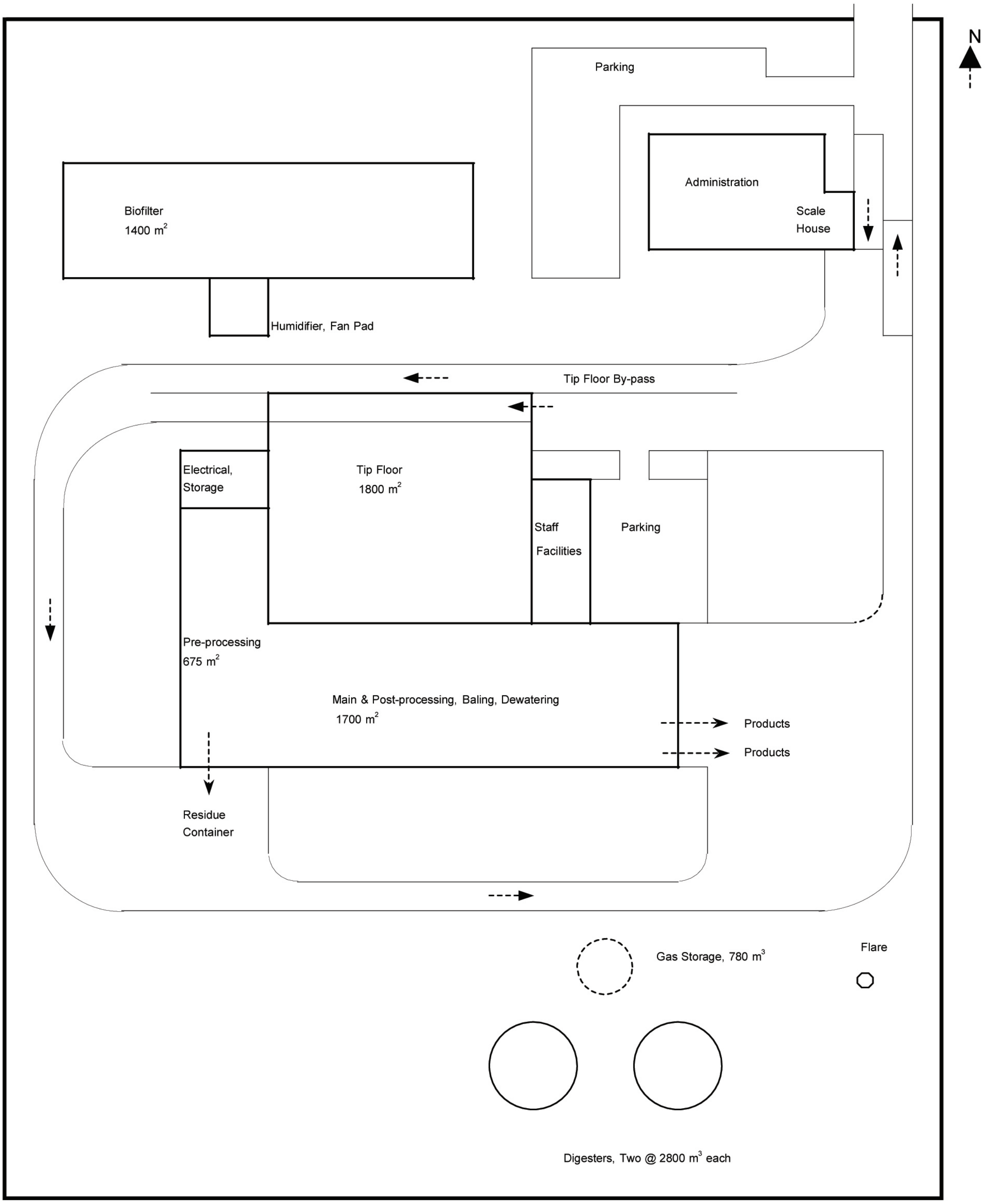
Noise control would primarily be achieved by ensuring process building doors are normally closed (which also addresses odour control) and utilizing enclosures for noisy equipment items if located outside (compressors for example). A drive-through tip floor, as proposed, with fast closing doors should mean that noise and odour escape is minimized. Berms and landscaping would also serve to mitigate noise to a certain extent. The main areas with a potential for release of litter would be the tipping floor and the digestate loading area. Both of these would be enclosed inside the building. Fencing the site and conducting daily litter removal patrols would be typical of a facility of this nature.

2. 4. PLANT LAYOUT

The layout of the plant is presented in Figure 2.1. This is a generalized layout for planning purposes, with some major components shown. The layout has been configured to readily allow for expansion to the 200,000 tpy capacity. This site plan allows for expansion to a 200,000 tpy facility, which requires 3.2 hectares. If a smaller plant were developed and no expansion was planned for, then a correspondingly smaller site would be required.

2. 5. PROCESS FLOW AND MASS BALANCE

Figure in next page shows the flow of materials through the process. The mass balance is approximate and can vary substantially with feedstock and technology, therefore the numbers given represent a range of about plus or minus 20%. It is estimated that 100,000 tonnes per year of source-separated organic waste with up to 30% unintentional material will yield approximately 8,960,000 m3/yr of biogas, 49,000 tonnes/yr of digestate, and 21,000 m3/yr of wastewater.



100,000 TPY, Dry, Thermophilic, Single-Stage
(10% Unintentional Material)
Conceptual Site Plan - 3.2 Ha Site

Bidur Raj Gautam
Dayitwa Fellow- Investment Board Nepal
Scale: 1:1000 (approx)

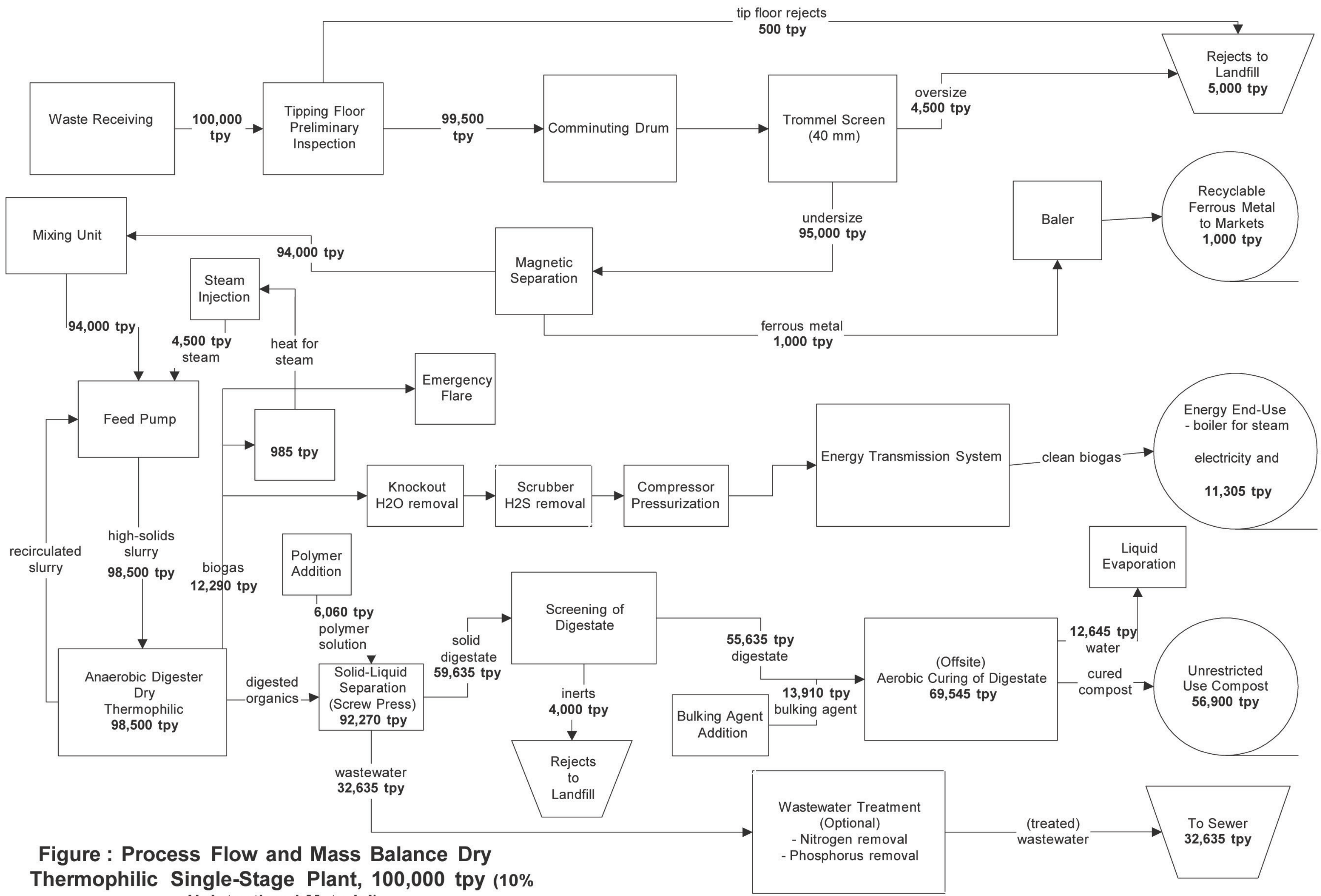


Figure : Process Flow and Mass Balance Dry Thermophilic Single-Stage Plant, 100,000 tpy (10% Unintentional Material)

3. COST & INCOME

3. 1. COST ESTIMATES

The capital and operating costs for a 100,000 tpy wet mesophilic plant are presented on the following pages. These are general estimates, scaled up from cost estimates for Toronto's pilot facility at the Dufferin transfer station, which is a wet, mesophilic plant.

It is estimated that a 100,000 tpy wet mesophilic plant would have a capital cost of approximately $36,385,000, and an operating cost of approximately $6,440,000 per year. This cost estimate does not include the costs of biogas utilization and transmission equipment.

Capital Cost Estimate - 100,000 tpy Wet, Mesophilic, Single-Stage (30% Unintentional Material)

General Site Works

Land costs	0
General (clearing, dewatering, signage, geotechnical investigations, etc.)	200,000
Roadways and parking lot paving (7,000 m2 x $40/m2)	100,000
Utility connections, lighting, buried piping (sewer, gas, water), utility relocations, etc.	100,000
Sub total:	**400,000**

Buildings

Tip floor (1,800 m2 x $1,000/m2)	900,000
Pre-processing, Baling, Dewatering building (1,800 m2 x $1,200/m2)	1,080,000
Wet processing building (675 m2 x $1,200/m2)	305,000
Electrical, storage room building, staff facilities (400 m2 x $800/m2)	160,000
Administration area including laboratory, scale house (650 m2 x $1,000/m2)	325,000
Entry and exit scales (20 m scales in pit)	150,000
Miscellaneous (small structures, overhead truck doors, monorail hoist, sort platforms etc.)	150,000
Sub total:	**3,070,000**

Major Tankage

Digesters (3 x 4,500 m3 glass lined steel)	4,460,000
Process water storage tank (650 m3)	200,000
Gas storage tank (780 m3)	275,000
Sub total:	**4,485,000**

Pre-Processing Equipment (incl. electrical & instrumentation)

Bag breaker, trommel screen	250,000
Conveyors, mag separator, eddy current separator	5,050,000
Baler and feed conveyor system	350,000
Miscellaneous (compactor, platforms, catwalks, hoppers, etc.)	250,000
Sub total:	**1,350,000**

Wet Processing Equipment (incl. electrical & instrumentation)

Pulpers, tanks, degritters, conveyors, digester preheating, etc.	1,500,000
Screw presses (4)	5,00,000
Process piping, valves, pumps, small tanks	250,000
Miscellaneous (compressor, mixers, clarifier, platforms, catwalks, hoppers, etc.)	250,000
Sub total:	**2,000,000**

Odour Control

Biofilter (concrete walls, media support, media, etc.)	250,000
Blowers, ducting, humidity control, other controls, etc.	150,000
Sub total:	**400,000**

Miscellaneous

Plumbing, fire protection, containers, inspections, etc.	150,000
Sub total:	**150,000**

Total of above:	**11,885,000**
Unforeseen and Estimating Allowance (20%):	2,370,000
Engineering & Contract Administration (13%):	1,540,000
Grand Total:	**15,802,000**

All costs are in US Dollars

Annual O&M Cost Estimate - 100,000 tpy Wet, Mesophilic, Single-Stage (30% Unintentional Material)

Staff Requirements (based on 3 shift operation)	**$/yr**
1 Plant Manager (12k)	12,000
6 Process Control Operators (6k)	36,000
2 Tip Floor Operators (5k)	10,000
2 Maintenance Technicians (4k)	8,000
2 Scale Operators (4k)	4,000
1 Reception (4k)	4,000
1 Marketing Mgr (4k)	4,000
8 Sorters (3k)	24,000
1 lab technician (4k)	4,000
Sub total including 1.5 factor for O'head/benefits	
Sub total:	**106,000**
Utilities and Fuel (assumes no cogen unit on site)	
Fuel (2 vehicles x 10 l/hr x 20 hrs/d x 250 d/yr x $0.7/L)	70,000
Water (10,600 m3/yr x $1/m3)	10,600
Natural gas	0
(not req'd, assumes biogas used to satisfy heat load)	
Electricity (estimated 6.3 million kw.hr/yr)	378,000
Sub total:	**458,600**
Maintenance	
6% of Capital Cost	948,000
Sub total:	**948,000**
Total:	**1,512,000**
Unforseen at 20%:	302,300
Grand Total (excludes land costs, property taxes):	**1,814,000**

All costs are in US Dollar (1 USD = NRs 87)

3. 2. INCOME ESTIMATES

Considering the plant size of only 100,000 T/year which will process almost 300 T/day sorted solid waste, it is estimated that 8,960,000 m3/yr of biogas, 49,000 tonnes/yr of digestate, and 21,000 m3/yr of liquid fertilizer will be produced.

Biogas	0.25/m3	8960000	2,240,000
Solid Fertilizer	USD 25/tonne	49000	980,000
Liquid Fertilizer	USD 10/m3	21000	210,000
Subtotal			USD 3430000
Recyclable material revenues (approx. 6,300 tpy x $20/t)			126000
Carbon Credit:	to be Assessed		
Total:	**Over USD Three & Half Million /year only**		

It means the plant will make saving of more than USD 1.7 Million every year.

This analysis has assumed

- There would be no subsidy from government or Non-government Agencies on any equipment or construction of the plant.
- There would be no tax benefit
- Land will be given by KMC/Government without cost.
- Cost of Biogas has been assumed to cost 30% lower than current Nepal Oil Nigam LPG gas.
- Cost of financing has been incorporated in capital cost @12% interest rate

This costing and income generation is estimation only.