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May 7-8, 2010

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# Small-scale decentralized and sustainable municipal solid waste management potential for Bangalore anchored around total recycle and biomethanation plants

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*Bangalore is among five largest cities of India producing about 3600 tons per day of municipal solid waste (MSW). MSW in Bangalore usually has a high percentage of fermentable organic components that degrade easily in nature. Presently, Bangalore employs a quasi-centralized collection system followed by an open-to-sky processing and land filling. A significant fraction also undergoes open dumping. Collection and transportation systems are today quite satisfactory; that does not allow anaesthetic accumulation of wastes in residential area or street corners. The informal sector for recycling is also quite active in collecting the recyclables from houses, open bins (wherever present), other collection /transportation systems as well as from dumping and processing sites. A few of the recyclers purchase recyclables from individual household, as is done in several parts of the country. The paper describes the potential for residential locality based recycling and processing systems involving total recovery and recycling of the recyclables and conversion of organic fermentables to biogas. In the past, a large number of such units have functioned achieving various levels of success – however none of them reported to be commercially viable. Most of such efforts did not sustain long periods and were often abandoned midway due to political and /or economic issues. In this paper we describe a locality based system and use its field data to show that commercially run processing systems can become viable. In order for this to happen, it is firstly necessary to achieve a high degree of non-organic waste recycling and in place of composting, the fermentable wastes are transformed to locally used biogas – this combination can alone be sustainable in today's state of art in this area.*

Bangalore city, one among the five metros in India, produces about 3600 tons per day (tpd) of municipal solid

wastes (MSW). A major constituent (72 %) of this is organic waste. Presently, Bangalore employs a quasi-centralized collection system coupled with generally an open-to-sky compost based processing and subsequent landfill based disposal. The collection and transportation systems are functioning quite satisfactory. This does not allow accumulation of wastes near residential areas or street corners. The waste collection system from house holds (HH) closely follows the Municipal solid waste (handling and management) MSW (H&M) Rules 2000, employing a variety of small powered and non-powered vehicles for direct door-to-door collection of wastes. The extent of wastes collected ranges from 75-90% of the total wastes generated. In order to avoid the multiple handling of wastes, the State Government has removed most of the open bins in residential areas. Residents now hand over wastes directly to collection workers. It also restricts accumulation of waste near residential area or near street corners. Informal sector for recycling is also quite active in Bangalore and is responsible for collecting the recyclables from open bins (wherever present), other collection systems and from dumping and /or processing sites. A few of these recyclers also purchase the recyclables from individual households. In this way, the informal sector, in various forms, is reported to be actively recovering the recyclable wastes without too much of Government interference (Van, 1994). However, earlier, when wastes were dumped by households in street bins, it provided a good opportunity for rag-pickers to recover most of the recyclables (Chanakya and Sharatchandra, 2005). It is also important that a decentralized and economically viable processing and management system is required for fermentable components of the MSW in order to be sustainable in the long run. In Bangalore, the informal sector does not participate in collection, processing or recycling of organic waste



components as reported for many other urban or peri urban cities of Karnataka (Nunan, 2000). It has been reported that till recently, about 60% of the MSW collected was dumped at about 60 known and unknown (unrecorded) dumping sites around Bangalore. Further, among these more than 35 sites received a mixture of domestic and industrial waste (Lakshmikantha, 2006). As Bangalore is rapidly complying with the MSW (H&M) 2000 rules, a large fraction of the MSW is reaching designated "integrated processing and landfill sites" around Bangalore.

Citizen, resident welfare associations (RWA) and non-governmental organizations (NGO) have in the past set up many small scale processing and treatment units. These small scale collection, treatment and processing units have over two decades achieved different levels of success of motivational (information, education and communication, IEC) activities. The city of Bangalore has a rich experience in decentralized, resident association, Non Government Organization (NGO) and other forms of small initiatives at resident locality based treatment and processing of MSW. The Bangalore city corporation (Urban Local Body, ULB) – Bruhat Bangalore Mahanagar Palike (BBMP) has been interested and supportive or supporting these small scale efforts in many ways in the past. It supports private and NGO initiatives as a way of expanding its own waste services throughout the city. A systematic waste management requires an active approach of ULBs along with public participation. In large metropolitan area (with a population of 1 million or more), it is difficult to have meaningful public participation, a decentralized system is needed to stimulate more active people's participation (Appasamy, 1994). In some of the latest trials, attempts have been made to carry out decentralized waste treatment by rapid aerobic composting with some degree of success (Subramanya, 2009, per. comm.) coupled to recovery, processing and sale of recyclables. Several small scale efforts have been tried to reduce the pressure on transportation of wastes from localities where they have been generated. Several resident welfare based organizations have in the past attempted to process MSW within the locality of its generation and the most recent one has been the Yelahanka New Town facility. This comprises of a primary segregation system that removes a lot of the recyclables and leaves behind the fermentables that is composted in 50 kg lots. The plastics (LDPE/HDPE) are washed with hot water, dried and melted into slabs and finally sent for re-forming or recycling. Composting as the main method for rendering acceptable the fermentable fraction of USW, especially in the residential areas, does not yield high throughputs for successful enterprises. Common factor among all of these systems has been the drive from the residents to keep their locality aesthetically and environmentally clean – usually anchored by a few elderly or retired personnel. Another feature of these systems has been a rather ephemeral period of successful operation. Most of these systems have functioned for a specific period because of the inspiration of a few in the locality and propped up due to a sense of civic responsibility among these few. With passing age and difficulty in sustaining the initial

zeal at a latter period, these initiatives have often reverted to the conventional, government run /mediated collection and disposal systems. The city of Bangalore is replete with such examples. In most of the cases economic sustainability or political will have been the weak link because of which such good efforts have come to a naught. A model that could then survive not merely on society's endogenous drive but also possesses economic and political sustainability – is of great importance.

Today we know that there are several small localities willing to operate decentralized MSW processing and treatment systems. Having established this fact, we attempt to examine the various combinations of costs and income sources that can be made financially and commercially viable /sustainable. Crucial to this has been the recent introduction of small scale bimethanation as a revenue generation option that removes the menace of odour and fly nuisance associated with aerobic composting attempts (Chanakya et al, 2009; Rahman et al, 2009). We attempt to show that such a combination would not only make decentralized MSW processing and treatment sustainable, it will also greatly reduce the costs of SWM transport at the city level and will pave way for many small entrepreneurs to carry out decentralized processing facilities and be economically, environmentally and socially sustainable.

### Changing composition of USW and its impact

In the last 20 years the composition of the wastes generated both at the residence levels as well as the city level has changed significantly. Tables 1 and 2 show the generation rates and physical composition of Bangalore MSW collected from different types of waste generators. MSW recorded, comprises of wastes generated from residences, markets, hotels and restaurants, commercial premises, slums, street sweepings and parks. Residences contribute 55% of total of wastes, which is highest among all sources (TIDE, 2000). Waste generated from hotels and eateries form about 20%, fruit and vegetable markets contribute about 15%, trade and commerce about 6% and from street sweeping and parks about 3%, . The slum areas contribute only 1% of total. This is because the slum population and area in Bangalore is low in comparison to other cities and towns. Table 2 shows the waste composition of Bangalore comprising predominantly fermentables (72%), and paper and cardboard (11.6%).

The high wet and fermentable waste content of Bangalore MSW requires its daily removal from places of generation. In a decentralized system, wastes gathered from primary collection by handcarts may be subject to immediate treatment by aerobic composting or bimethanation within the locality or ward. This will avoid transportation costs of around Rs1000-1500/t and thus will be more sustainable and economic. In the past a significant component of the wastes placed in open street bins were rapidly sought by rag-pickers who removed the recyclables. The impact of this is presented in Figures 1a, 1b and 2, which show that the percentage of organic waste will quickly increase in MSW from primary collection point to the time it reaches the dump site due to



multilevel recovery of recyclable wastes. This also changes the extent of decomposable component of the wastes and presents various other forms of environmental implications (Chanakya and Sharatchandra, 2005). As the wastes gradually becomes enriched with easy to decompose

**Table 1: MSW generation in Bangalore**

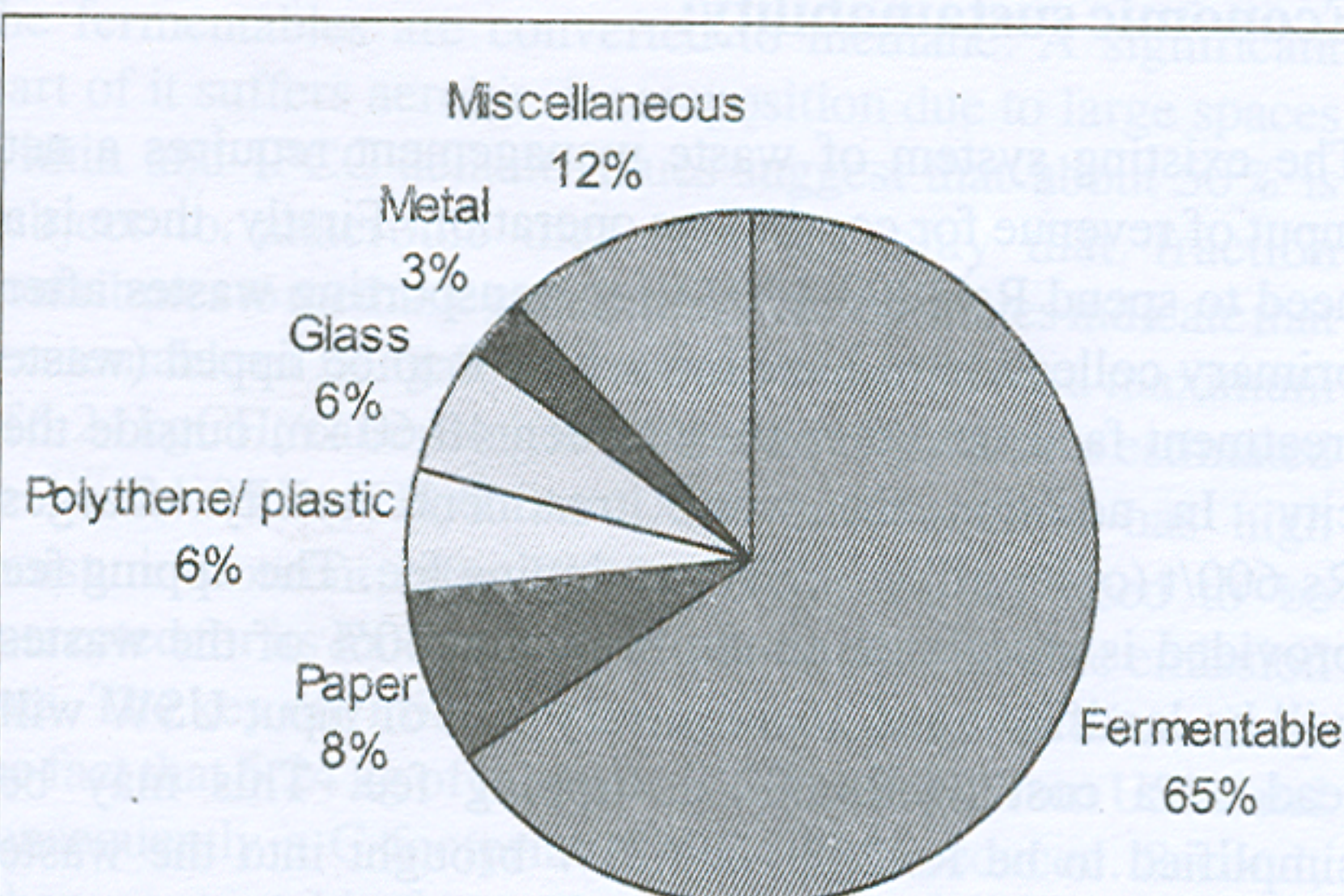
Source	Quantity (t/d)	Composition (% by weight)
Domestic	780	55
Markets	210	15
Hotels and eatery	290	20
Trade and commercial	85	6
Slums	20	1
Street sweeping and parks	40	3

Source: Chanakya and Sharatchandra, 2005

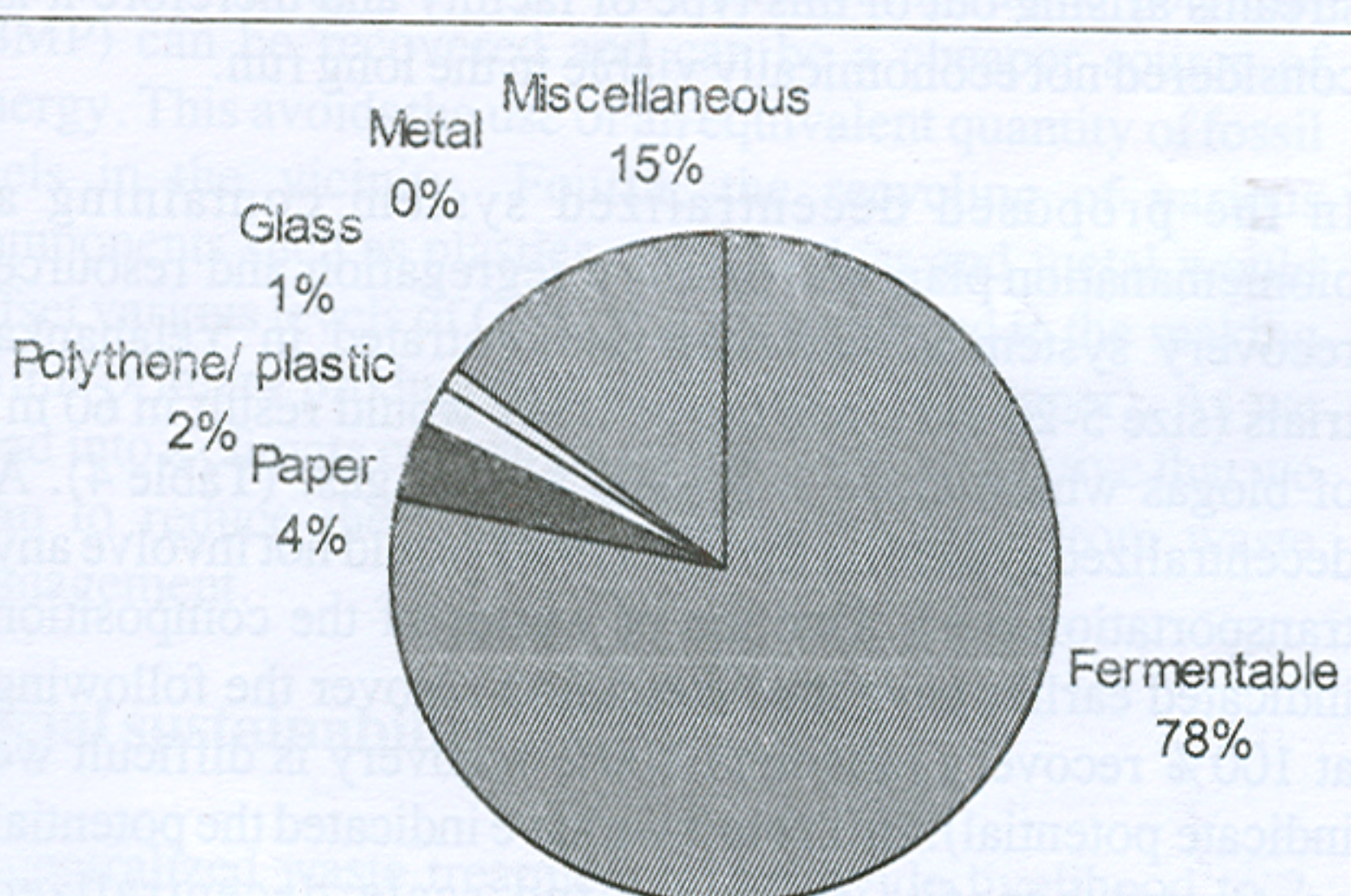
**Table 2: Physical composition of MSW in Bangalore**

Waste type	Composition (% by weight)						
	Domestic	Markets	Hotels and eatery	Trade and commercial	Slums	Street sweepings and parks	All sources
Fermentable	71.50	90	76	15.6	29.9	90	72
Paper and cardboard	8.39	3	17	56.4	2.49	2	11.6
Cloth, rubber, PVC, leather	1.39		0.33	3.95	0.54	0	1.01
Glass	2.29		0.23	0.65	8.43	0	1.43
Polythene/plastics	6.94	7	2	16.6	1.72	3	6.23
Metals	0.29		0.26	0.38	0.23	0	0.23
Dust and sweeping	8.06		4	8.17	56.7	5	6.53

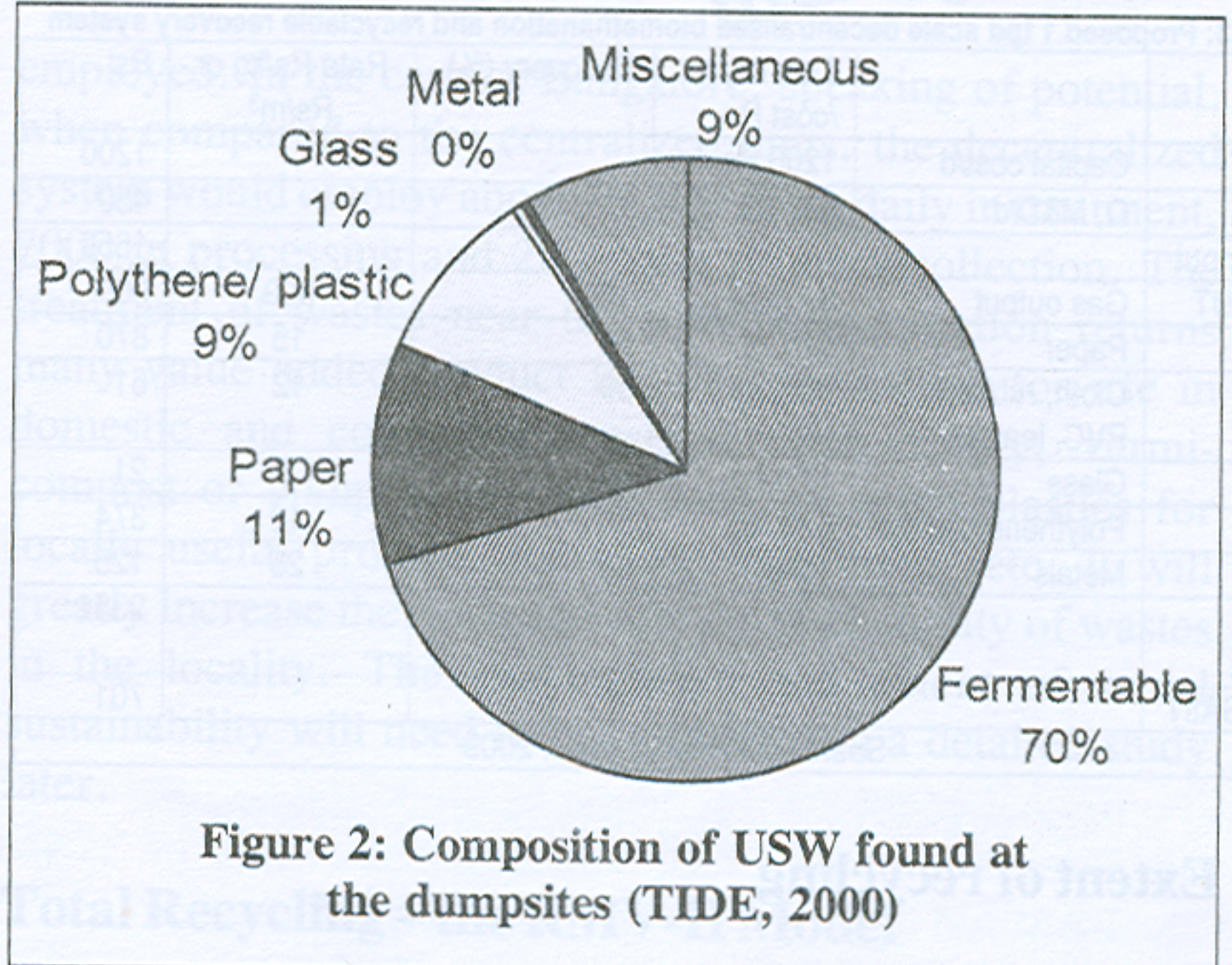
Source: TIDE, 2000



**Figure 1a: Composition of USW immediately after being placed in bins (Rajabapaiah, 1988)**



**Figure 1b: Composition of USW after ragpickers sort and recycled materials (Rajabapaiah, 1988)**



**Figure 2: Composition of USW found at the dumpsites (TIDE, 2000)**

materials, it also becomes easily amenable to anaerobic fermentation processes that convert the organic matter within to CO<sub>2</sub> and CH<sub>4</sub>, the latter being a greenhouse gas. From 1988 to 2000 there is a reasonable change in waste composition: fermentables, paper and plastic has content increased by 7%, 3% and 0.2%, respectively.

### Changing quantity

Growth of city area and increase in population (as well as population density) has increased the total quantity of MSW generated daily from 650 tpd (1988) to 1450 tpd (2000) and 3600 tpd (currently). With time there is slight change in composition of waste. The current estimates indicate that around 3600 tons of MSW is produced each day in the city. This has increased the per capita generation from 0.16 (1988) to 0.58 kg/d (2009). The rapid increase in the USW generation rate has been due to the rapid changes in lifestyles of the residents brought about by the high demands for software professionals and ancillary and support professions. The rapid increase from 1450 in 2000 to 3600 tpd in 2008-09 itself corroborates the above change and rising generation rate. This has brought about problems by the way of safe processing and disposal of USW around Bangalore. In addition, the city has expanded from about 200 km<sup>2</sup> in the 90's to about 800 km<sup>2</sup> of greater Bangalore. This has in the first place brought many of the traditional dumping sites close to the city or within its boundary and therefore a need to find new locations has arisen. The quantum of wastes generated is far greater than the capacity of the three permitted waste treatment and disposal sites, namely, Mavallipura, Mandur and Singehalli. As these locations are quite far-off, many of the trucks illegally dump on new locations on the roadsides and interior areas around Bangalore so as to reduce their transportation costs. The numbers of the shifting dumpsites has thus grown from the original reported 60 (Lakshmikantha, 2006) to much more than this number. There is now a need to determine the new locations where the city wastes are being dumped and assess the economic and environmental harm posed by these short term dumpsites.



Table 3: Proposed 1 tpd scale decentralized biomethanation and recyclable recovery system

		Quantity /cost Rs	Recovery (%)	Rate Rs/kg or Rs/m <sup>3</sup>	Rs
INPUT	Capital cost/d	1200 Rs			1200
	O, M&D/d	450 Rs			450
Total input					1650
OUTPUT	Gas output	60 m <sup>3</sup> /d	100	900	900
	Paper	116 kg	50	15	870
	Cloth, rubber, PVC, leather	10.1 kg	50	12	61
	Glass	14.3 kg	50	3	21
	Polythene/plastics	62.3 kg	50	12	374
	Metals	10 kg	50	25	125
Total output					2351
NET GAIN					701

Source: Chanakya et al., 2009

## Extent of recycling

Bangalore wastes have 21.27% of the recyclable materials: paper, polythene, cloth, rubber, glass and metals. Recyclable materials are one of the major sources of income. Seen below in Table 3, we indicate a hypothetical 1 tpd scale MSW based decentralized biomethanation and recyclable material recovery system. The results show that recovery of recyclable material of one ton waste will provide income of Rs.1451/t based on the known composition in 2000. A decentralized system with biomethanation and resource recovery through recyclable materials is currently running in Yelahanka New Town, North of Bangalore.

## Sustainability

Sustainability of a waste management system requires satisfaction of a minimum of three sustainability bottom-line factors namely, economic, environmental and social sustainability. At present, city employs a door to door collection system where waste is collected directly from households and is not dumped in the street bins as before. This provides little opportunities for conventional rag pickers to recover recyclables. From the primary collection activity, the collection personnel recover a few of the easily saleable recyclable materials from where it goes to dumpsite without any serious effort at segregation or treatment process. At two of the three processing sites, there are frontline segregation units that discard lighter materials and break polythene bags containing domestic wastes. This separates out plastics, rags and fluff, wet fermentables and also heavy materials such as metals, glass, tyres and stones. With such a pre-processing stage the fermentable content rises significantly. Earlier mentioned composition of MSW shows that it has 72% of fermentable waste, with high moisture content. This situation is conducive to processing of the fermentables by composting or biomethanation. When composting of such high moisture feedstock is attempted by conventional windrow based composting process it generates excessive amount of leachates, especially in the rainy season and its fermentation results in malodors due to inadequate supply of air (Chanakya et al., 2007). It is thus important that such wastes are treated rapidly in decentralized units of 5 to 10 tpd capacities. At this scale of 500-1000 tpd there are few working technologies capable of accepting typical composition of

Indian MSW for biomethanation. It is estimated that one ton of wastes requires about Rs.250 for processing by windrow composting (Basavaiah, 2008 per comm.). As a result a large quantity of wastes are found untreated at these large treatment facilities and it is therefore suggested that, when waste collection is zoned and collected zone-wise, the predominant resident and hotel wastes could be collected separately and treated nearer the site of production by biomethanation within each ward as has been done in the case of Yelahanka trial process with small scale (50 kg) composting units. This firstly avoids the need for transportation and thus saves the transportations costs. This has the capability of recovering a large extent of plastics and other recyclables making the overall process more sustainable, economically and environmentally speaking. The sustainability of such decentralized biomethanation systems is discussed later. Small scale biomethanation plants have been in operation in three towns of Karnataka on a trial basis and that in Siraguppa town has been in operation since 2003 (Rahman et al, 2009). At this location there are three 0.5 tpd capacity 3-zone fermenters daily fed a total of 1.5-2.5 t of secondary segregated USW of Sirguppa town. The digested material is then subject to vermi-composting and the recovered vermi-compost is re-used in various town gardens etc. making the overall process economically better than merely composting.

## Economic sustainability:

The existing system of waste management requires a net input of revenue for continuous operation. Firstly, there is a need to spend Rs.1000-1500/t for transporting wastes after primary collection to locations where it to be tipped (waste treatment facilities) that are between 40-60 km outside the city. In addition the waste treatment facility charges Rs.600/t (of landfilled USW) as tipping fee. The tipping fee provided is calculated on the basis that 30% of the wastes will be landfilled and consequently 3.3t of input USW will lead to a cost of Rs.600 as tipping fee. This may be simplified to be Rs.200/t of USW brought into the waste treatment facility. This indicates that there is a net input of Rs.1450/t of wastes brought in for treatment at the integrated waste treatment site. There is very little revenue streams arising out of this type of facility and therefore it is considered not economically viable in the long run.

In the proposed decentralized system containing a biomethanation plant and primary segregation and resource recovery system as has been demonstrated in Yelahanka trials (size 5-20 tpd), one ton of USW would result in 60 m<sup>3</sup> of biogas whose value is Rs.900 as fuel gas. (Table 4). A decentralized system on the other hand would not involve any transportation costs. One ton of wastes of the composition indicated earlier have the potential to recover the following at 100% recovery (although 100% recovery is difficult we indicate potential). In Table 3 we have indicated the potential costs and benefits from a 1 tpd scale decentralized biomethanation + recyclable recovery system. The results show that decentralized systems, not accounting for land



**Table 4: Income potential from a decentralized 1tpd system containing biomethanation plant where gas produced is converted to power or CNG.**

Invested capital (M)	1	0.5	Outputs	
Capital recovery /d, 10 yr	300	150	Gas output (m³/d)	60
Interest (SI, @ 15%)	450	225	RETURNED AS	
O,M&D@10%+5%lbr	450	225	Power (1.5 kWh/m³)	360
Profit	450	225	As gas	900
			Compost	270
	1650	825	Case 1, power	630
			Case 2, CNG	1170

Source: Chanakya et al., 2009

costs, are more profitable and hence higher in the scale of economic sustainability than centralized large waste treatment systems currently practiced. This is obvious that small scales, the extent of recovery of recyclables can reach nearly 100% and that at the dumpsite barely crosses 30% (visual estimate from one site in Bangalore).

## Environmental sustainability

Open dumping is conducive to the generation and release of GHGs, such as methane – having 21 times more GHG potential than CO<sub>2</sub> (Morgenstern, 1991). Methane is released when MSW with a high content of moisture, as found in Bangalore MSW, is dumped in the open rapidly and to a greater height. However, in this case not all the part of the fermentables are converted to methane. A significant part of it suffers aerobic decomposition due to large spaces within and IPCC default values suggest that about 50% is subject to anaerobic digestion and only that fraction contributes to methane generation. Our estimates indicate that fermentable of Bangalore waste has potential for a maximum of 6.24 kgCH<sub>4</sub>/t and using IPCC default this value is estimated to be 24.95 kgCH<sub>4</sub>/t. As USW in Bangalore has high moisture content, the IPCC default values need to be corrected for its moisture content to obtain sensible emission data. The key environmental sustainability gained here is by the fact that 6.24 kg of methane is not emitted from USW and consequently a C-footprint of 6.24 kg is reduced. Second, when accountable for such a level of C-footprint per ton USW, there is a cost avoided for methane not emitted. Third, if these fermentable wastes are used in decentralized manner to generate biogas, 70% of biochemical methane potential (BMP) can be recovered and can be a cheaper source of energy. This avoids the use of an equivalent quantity of fossil fuels in the vicinity. Fourth, the recycling of various components such as plastics, paper, glass and metal would offset various levels of GHG that are produced in the making of this primary product (not estimated in this paper). As we head into a climate conscious society, it is imperative that we plan to reduce the potential GHG emissions from waste management.

## Social sustainability

Decentralized waste treatment will provide livelihood to 2 persons /ton in the energy unit (biomethanation plant) as well as another two persons in the waste recycling unit. When collection is included, another 8 persons may be

employed. In the case of Bangalore, speaking of potential, when compared to the centralized units, the decentralized system would employ about 7000 persons daily in treatment, 7000 in processing and 28,000 in primary collection. The treatment of wastes near the point of generation returns many value added product locally such as gas for use in domestic and commercial uses in the locality, vermi-compost or compost for local uses, recycled plastics for locally useful products including road laying etc. It will greatly increase the trade and social responsibility of wastes in the locality. The exact nature and extent of social sustainability will need to be quantified in a detailed study later.

## Total Recycling – the RMV-II Model

RMV extension stage II, of Bangalore is a high income group area with a mixture of residential building and few small shops. BBMP is managing the MSW at this locality. The ward councillor was greatly interested in improving waste management system as it will give him political visibility, and at least one of the waste entrepreneurs also has political ambitions. Some of the families were aware of waste and its environmental impacts, so they were very keen to start a proper management of waste and to make their ward as the first zero waste emission ward of Bangalore. A 60 days project was started by NGO ‘Exnora Green Cross’ for 320 families of this locality. The project aimed to establish a SWM system in the whole area later on. The system would include primary collection with some gradually increasing source segregation (into organic and inorganic waste), storage and disposal of different types of solid waste in an environmentally friendly manner. Waste was collected twice in a day, but evening collection was very poor since most of the families would refuse to contribute to the evening waste collection. The central components of the whole system were the twice collection and separation of waste into reusable /recyclables (to be sold) and the composting of organic waste. Trained waste collectors were appointed for door-to-door collection and for waste segregation. Residents were motivated to store and hand over separated household garbage twice in a day. Initially only 25 houses hand over segregated household waste, but within 10-15 days the number of house became almost double. Everyday on an average around 2.6 kg fermentable wastes were coming from each of the families. The fermentables (including food waste and garden wastes) were composted on raised platforms to ensure better aeration and lower smell. This took about two months to convert these fermentables into compost. With the progress of time number of composting beds was increased which had also increased the associated problems like smell and flies. Although these problems were under kept to a minimum, the announcing of elections gave rise to political dissent and on the grounds of smell and the effort was to be stopped at least temporarily. After 21 days this project was stopped by ward councillor fearing loss of his re-election prospects. However, meticulous data has been collected as to the types and quantities of recyclables that were brought to this site. As these were segregated and kept ready for sales, it gave an



excellent record of the market value of the recyclables that were recovered (Table 5). Based on this project information, economic costs are calculated for decentralized waste management with compost plant as given in Table 5. Under the existing scenario, we calculate that with compost as the main product and in an enterprise mode and under conditions reigning in Bangalore the cost recovery period would be in the range of 4 years (Table 6, assuming 100% recycling). This is however up to plan and may not be achieved easily. However, when the recycling and recovery efficiency drops to 80% the project is in viable. An additional source of revenue needs to be identified to make the project economic. We then examine the conversion of the fermentables to biogas and expect that sale of biogas locally would offset the financial deficit projected here.

### Ultimate Sustainability – RMV-II with Anaerobic Digestion

The decentralized processing and recycling system based on compost and 100% recovery shows a small promise of profitability in an enterprise mode assuming this is carried out on a soft lease basis (no land costs). It is obvious that it is economic only at 100% recovery and this may be difficult to achieve. There is clearly a need for another source of revenue generation to make the enterprise profitable. Thus instead of aerobic composting the organic fraction (leading to only one saleable product – compost), it is proposed to convert it to biogas and compost (two saleable products) by installing a biomethanation plant of the CST design – similar to the one successfully operated for over 5 years in Siraguppa (Rahman et al, 2009). In this scenario, the extent of recyclables recovered and earnings accrued does not change from the previous scenario, the income from collection fees also remains the same. The various costs and returns on investment are worked out for a decentralized waste management with a biomethanation plant as the as given in Table 6. In this scenario, it is clear that under ideal situation of 100% recovery of recyclables, collection costs and biogas and compost revenues, the pay back period is only 2 years. Even under an 80% recovery situation, the viability is good.

The costs are calculated at a labour cost of Rs100/head per day (Bangalore rates) and a compost sale at Rs3000/t. In small towns these are different. The labour costs are lower (Rs 60), the collection fee could only be about Rs20/HH, the compost revenues are lower at Rs 2000/t and biogas value would be 20% lower. Similarly recyclables will also fetch a lower value. Thus when all the incomes from this system is lowered by 20% and compost value chosen at Rs2000/t and daily wage at Rs60/d, the biomethanation option is still viable (Table 7). This suggests that in a practical scenario biomethanation plant option is more economic and less sensitive to risks in comparison to aerobic compost plant. Along with economic sustainability, biomethanation options have many other livelihood options (Chanakya et al, 2009; not discussed here). Composting process also requires continuous use of water of around 200-300 litres per ton of waste (Patel, 2003), which limited its use in dry area or in

water scarce city like Bangalore. Daily collection of fermentables and its rapid feeding into the biomethanation plant overcomes and avoids the smell and insects, rat and dog problems. Biogas plant and composting bed give same quantity of compost, while compost beds take two to three months whereas in biomethanation plant it takes shorter period of 30d to decompose. The footprint would then be smaller. The enterprise could also claim C-credits (CERs) which become yet another source of revenues. Finally, it may be seen that the operation costs are high due to high involvement of labour. A major part of the labour is involved in segregation. As residents become aware and stakeholders the segregation needs would be low and labour deployment could be reduced by about 40% making the system even more profitable. In Bangalore, where demand of anaerobic compost is high, biomethanation would be a viable process with a pay back period as short as 2 years under ideal conditions and as much as 5 years under less ideal conditions. The advantage of biomethanation is even more pronounced in small towns where revenue streams from compost and recycling will be thinner. We thus show that biomethanation based decentralized system is ideal for Indian conditions for making decentralized MSW processing and treatment economically viable and sustainable in the long run.

### Conclusion

The costs of MSW collection, transport, processing and disposal is gradually becoming expensive and even less

**Table 5: Decentralized Waste Management with compost plant**

Decentralized Waste Management with compost		
Categories	Rs/year	Optimum Scenario
Capital Investment	206500.00	
Cap costs Rs/yr@10.00%	20650.00	
Depreciation	38225.00	
Maintenance	30975.00	
Operation cost (Rs/yr)	493946.00	
<b>Total expenditure per year</b>	<b>583796.00</b>	583796.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Compost sale	229950.00	183960.00
<b>Total net income per year</b>	<b>584469.11</b>	<b>467575.29</b>
<b>Surplus of income over expenditure</b>	<b>673.11</b>	<b>-116220.71</b>
<b>Capital Recovery Period</b>	<b>306.8</b>	

**Table 6: Decentralized Waste Management with biogas plant**

Decentralized optimum Waste Management with biogas plant		
Categories	Rs/year	Optimum Scenario
Capital Investment	586500.00	
Cap costs Rs/yr@10.00%	58650.00	
Depreciation	35425.00	
Maintenance	39975.00	
Operation cost	493946.00	
<b>Total expenditure per year</b>	<b>627996.00</b>	627996.00
Income from collection fee@Rs.30/HH	115200.00	92160.00
Income from recyclables	239319.11	191455.29
Income from biogas	325215	260172.00
Compost sale	229950.00	183960.00
<b>Total net income per year</b>	<b>909684.11</b>	<b>727747.29</b>
<b>Surplus of income over expenditure</b>	<b>281688.11</b>	<b>99751.29</b>
<b>Capital Recovery Period</b>	<b>2.1</b>	5.9



sustainable. There is a need to treat the MSW nearer the source so that segregation and recovery of recyclables are more efficient. This calls for a decentralized system within localities. Decentralized systems run so far have had aesthetic (smell and insect) and economic problems and have always been short lived. Running these sustainably in a decentralized manner requires firstly a good technology such as biomethanation (to first avoid smell and insects) that provides many more revenue streams (as from sale of biogas, C-credits, avoiding insecticides, avoiding methane emissions, compost, etc.) and secondly reasonably good recovery and sale of recyclables. In this paper we also show that the biomethanation based decentralized systems have lower business risks because of a large spread of revenue streams. This also avoids expenditure of over 1500/t for the municipalities and ULBs which becomes a big saving and can be invested in development. It is therefore important that this concept be tried with at various municipalities so that we could become zero-waste cities of the future.

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**Table 7: Composting and Biomethanation option for a small town scenario**

<b>A. Decentralized Waste Management with compost</b>		
Categories	Rs/year	Optimum Scenario
Capital Investment	206500.00	
Cap costs Rs/yr@10.00%	20650.00	
Depreciation	38225.00	
Maintenance	30975.00	
Operation cost (Rs/yr)	321146.00	
<b>Total expenditure per year</b>	<b>410996.00</b>	410996.00
Income from collection fee@Rs.20/HH	76800.00	61440.00
Income from recyclables	167523.38	134018.70
Compost sale	153300.00	122640.00
<b>Total net income per year</b>	<b>397623.38</b>	<b>318098.70</b>
<b>Surplus of income over expenditure</b>	-13372.62	-92897.30
<b>Capital Recovery Period</b>	-15.4	
<b>Assumptions of costs for a small town</b>		
Value of compost Rs/t	2000	
Value of Biogas (Rs/m3)	12	
Cost of Labour (Rs/person/d)	60	
Collection Fee (Rs/HH/month)	20	
Value of recyclables (less by 30%)	167523.38	
<b>B. Decentralized optimum Waste Management with biogas plant</b>		
Categories	Rs/year	Optimum Scenario
Capital Investment	586500.00	
Cap costs Rs/yr@10.00%	58650.00	
Depreciation	35425.00	
Maintenance	39975.00	
Operation cost	321146.00	
<b>Total expenditure per year</b>	<b>455196.00</b>	455196.00
Income from collection fee@Rs.20/HH	76800.00	61440.00
Income from recyclables	167523.38	134018.70
Income from biogas	260172	208137.60
Compost sale	153300.00	122640.00
<b>Total Gross income per year</b>	<b>657795.38</b>	526236.30
<b>Total net income per year</b>	<b>202599.38</b>	71040.30
<b>Capital Recovery Period</b>	2.9	8.3

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