Chapter 4

Household Solid Waste Management in Jakarta, Indonesia: A Socio-Economic Evaluation

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Additional information is available at the end of the chapter

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1. Introduction

Rapid population growth in Jakarta has posed serious challenges. The urban population is expected to increase by 65% by 2030 compared to its level in 2006 (ADB, 2006). This condition presents a serious challenge for the management of waste in urban areas. The major urban centres in Indonesia produce nearly 10 million tonnes of waste annually, and this amount increases by 2 to 4% annually (Ministry of Environment, 2008). Jakarta uses a major landfill located at Bantar Gebang in the suburban town of Bekasi, and the landfill only absorbs approximately 6,000 tonnes per day. As the capacity of the landfill decreases over time, the waste service providers – in particular, the government – are confronted with the need to reorganise the present system for the treatment and management of solid waste. However, the issue of proper waste management is not just a government task but is a shared responsibility that includes the citizens and households of Jakarta, who are the main end-users of waste management facilities and services. When reorganising solid waste management systems, understanding the role of households, their attitudes, their waste handling practices and their interactions with other actors in the waste system is therefore essential (Oosterveer et al, 2010; Oberlin, 2011).

The largest stream of municipal solid waste in Indonesia flows from households followed by traditional markets (Aye and Widjaya, 2006). Solid waste management (SWM) usually relates to both formal and informal sectors. In Indonesia, the formal sector includes municipal agencies and formal businesses, whereas the informal sector consists of individuals, groups and small businesses engaging in activities that are not registered and are not formally regulated. In solid waste activities, the informal sector refers to recycling activities that are conducted by scavengers (itinerant waste pickers) and waste buyers. (Sembiring and Nitivatta, 2010).

Engineers and other decision-makers in the public domain have often found that their technical suggestions have been met with scepticism and even resistance by the public (Corotis, 2009). One of the solutions to dealing with this challenge is to conduct a quick scan, which is a first step toward collecting information about a particular issue in a specific context (Merkx, van der Weijden, Oostveen, van den Besselaar, and Spaapen, 2007). Quick scans may precede or run parallel to economic cost-benefit analyses, thereby making the inputs into the technical design-phase based on real-life conditions much more significant. Quick scans provide information regarding social (non)acceptance rates, and they can be used to determine expected levels of public acceptance. A social quick scan could thereby highlight aspects and dynamics that govern the so-called 'primary phase' of the solid waste management system in which households and informal waste pickers play an important role. Actors in the primary phase are responsible for the generation, collection, storage, and transportation of domestic solid waste. The behaviours and opinions of these actors are key variables that explain the success or failure of MSW policies. These variables, referring to the social dynamics of waste management, have not been discussed in-depth in the solid waste management literature, which is dominated by technical science and supply-side thinking. Therefore, studies focusing on interactions between the real-life conditions of householders (on the one hand) and the providers and regulators of solid waste management services (on the other hand) are crucial for developing and designing future waste management policies.

Prior studies (e.g., Bohma, Folzb, Kinnamanc, and Podolskyd, 2010; Aye and Widjaya, 2006; Sonneson, Bjorklund, Carlsson, and Dalemo, 2000; Reich, 2005) have discussed and estimated the impact of economic factors in domestic solid waste management. These studies have linked household participation and behaviour to economic assessments with the concept of willingness to pay (e.g., Purcell et al, 2010; Bruvoll et al, 2002; and Berglund, 2006), and the studies have discussed the role of economic factors in the feasibility of various socio-technological options and scenarios to be realised. The economic analysis of our study was performed against the background of five predetermined MSW management scenarios. In addition to the baseline scenario involving the use of a landfill, the scenarios proposed for this study include 20% recycling and 25% landfill usage combined with either communal composting (scenario 2), anaerobic digestion (scenario 3), centralised composting (scenario 4), or landfill gas for energy generation (scenario 5). This study also aims to estimate potential revenues from sorted recyclable materials. Moreover, householders' willingness to pay for other people to sort their waste is analysed under the assumption that the government authorities demand at-source waste sorting.

The first objective is to identify the existing situation, both for households' actual waste behaviours and for their perceptions regarding the present situation. The second objective is to understand the perception of households' roles and willingness to pay with respect to the possible future organisation of solid waste management, which is in line with the scenarios constructed in this study.

2. Scenarios for household solid waste management

Waste management options that would lower CH_4 and N_2O emissions would be regarded favourably (McDougall et al., 2001). Landfill gas consists primarily of methane and carbon dioxide, both of which are 'greenhouse gases', and landfill gas has therefore become significant in the debate over global warming and climate change. Methane is considered to be responsible for approximately 20% of the recent increase in global warming (Lashof and Ahuja, 1990), and landfills are thought to be a major source of methane. The Clean Development Mechanism (CDM) scheme allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol to implement emission-reduction projects in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each of which is equivalent to one tonne of CO_2, which can be counted toward meeting Kyoto targets (UNFCCC, 2011). A CDM project might involve, for example, landfill gas to energy (waste-to-energy) and anaerobic digestion, from which revenues are generated along with the greenhouse gas reduction.

One objective of this study is to evaluate the economy of each of the waste management scenarios. The scenarios were defined based on both existing and feasible treatment methods for household waste (e.g., IPCC (2006), Oosterveer and Spaargaren (2010), and Aye and Widjaya (2006)), whereas the fraction of waste treated per scenario – both the organic and inorganic fractions – was established using figures found in the literature, such as Japan Bank for International Cooperation (2008) and Yi, Kurisu, and Hanaki (2011).

The majority of biowaste (75%) is treated with the waste treatment method in each scenario, and the rest of biowaste that cannot be treated is disposed of in the landfill. In terms of recycling, 20% of the inorganic waste is assumed to be recycled, considering the portion of inorganic waste that is recyclable and can be sorted by householders. The non-recyclable fraction of inorganic waste is disposed of in the landfill. Prior to defining the scenarios, field observations were conducted. The following flow chart for the waste management system in Jakarta is based on these observations:

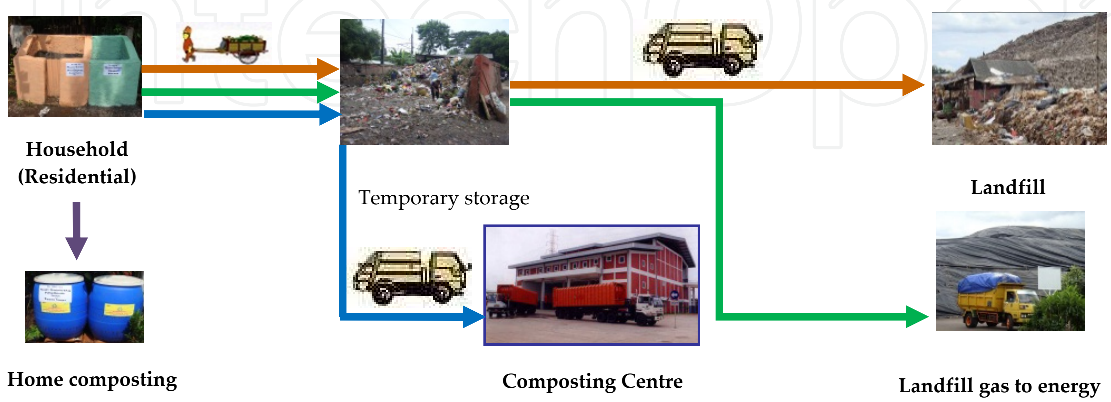

Figure 1. Flow chart of the household solid waste management system in Jakarta.

At few parts of Jakarta, the residents already employ source-separation for composting and recycling purposes. However most of Jakarta residents do not conduct at-source waste separation. Temporary storage sites are established to reduce hauling distances for the collection trucks, thereby lowering transportation costs. These sites are categorised as depots, and hand carts to transfer the waste to the garbage trucks are stored there. Depots also include a base for the handcarts, which is usually located on the side of the road, a trans-ship (shipping/transfer) site, and a waste collection point made of concrete. There are 1,478 temporary storage sites available in Jakarta (Cleansing Department, 2010). At the temporary storage sites, waste is transferred to waste trucks by either manual labour or shovel loader. The waste is subsequently transported to either a composting centre or a landfill. There is no intermediate treatment at these temporary storage sites; however, the efficiency of transfer to disposal and composting sites is increasing. According to the JETRO report (2002), the temporary storage sites increase the effectiveness of collection vehicles from 1.7 to 3 trips per day. (Pasang, 2007). This efficiency is due to the fact that the waste is pooled at the temporary storage sites and is easily collected and transported to the disposal site. By contrast, collecting the waste from various points would reduce the efficiency of collection.

The system boundaries and scenarios proposed in this study are as follows:

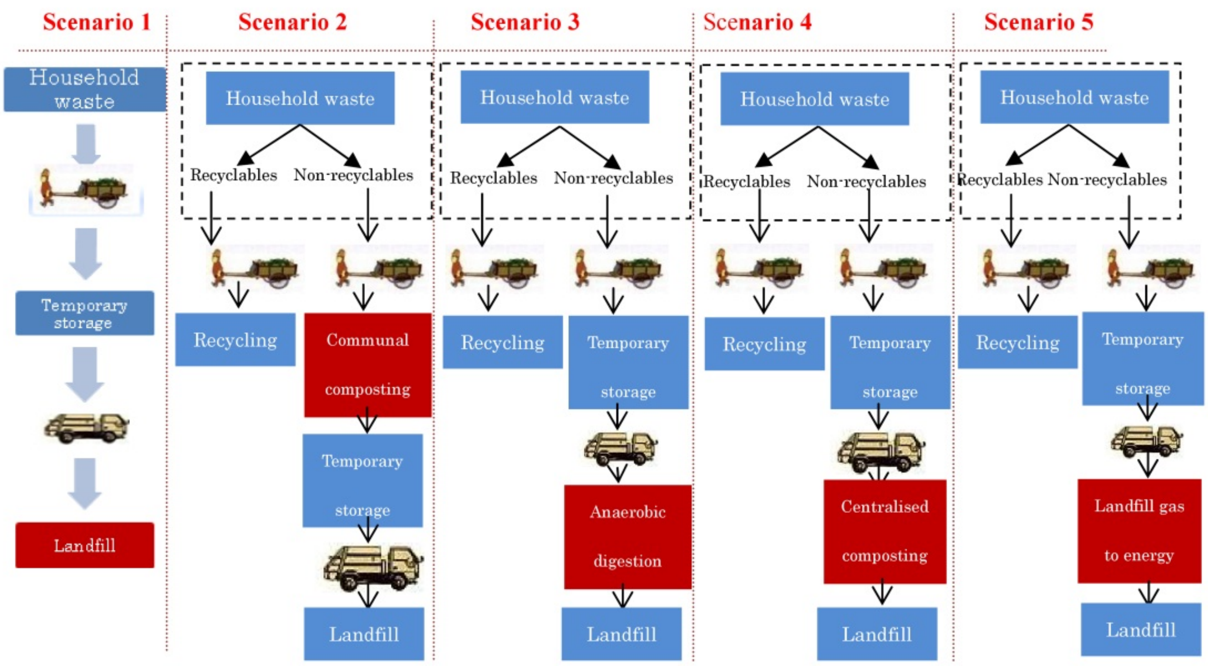

Figure 2. System boundaries and scenarios for waste management

This study compares five scenarios (see Fig. 2) for handling waste from households in Jakarta. The current operation of landfill use (open dumping) was included in the baseline business-as-usual (BAU) scenario for comparison. For the communal and centralised composting scenarios (scenario 2 and 4), the remaining waste or scrap that are not be composted would be delivered to the final disposal. As the incineration of waste is largely not feasible in non-OECD countries, due to cost and frequently unsuitable waste composition (UNEP, 2010), incineration is not included in the scenarios in this study.

Table 1 shows the fraction of each type of waste treated using the modes of treatment specified in each scenario. The fraction of waste treated per scenario was established with the help of figures found in such publications as the Japan Bank for International Cooperation / JBIC (2008); Yi, Kurisu, and Hanaki (2011); and Oberlin (2011). The majority of the biowaste (75%) is treated with the waste treatment method or technology characteristic of the particular scenario, and the rest of the biowaste that cannot be treated is disposed of in the landfill. In terms of recycling, 20% of the inorganic waste is assumed to be recycled, considering the portion of inorganic waste that is recyclable and can be sorted by householders. The non-recyclable fraction of inorganic waste is disposed of in the landfill. Waste pickers, part of the informal sector, play a role in sorting waste and extracting usable materials, such as metal and paper.

Waste types	Scenario 1	Scenario 2		Scenario 3		Scenario 4		Scenario 5	
	L	CC	L	AD	L	CE	L	LFE	L
Biowaste (%)	100	75	25	75	25	75	25	75	25
Inorganic waste (%)		0	100	0	100	0	100	0	100

L: landfill. CC: communal composting. AD: anaerobic digestion. CE: composting center. LF: landfill gas to energy.

Table 1. Fraction of waste treated per scenario[1]

The following table explains the characterisation of the terms 'biowaste' and 'inorganic waste'.

Waste category	Sub-categories	Type of waste	Composting and recycling potentials [a]
Food scraps (kitchen waste)	N/A	Biowaste	CO
Garden waste	N/A	Biowaste	CO
Paper & cardboard	Newspapers	Inorganic	RE
	Magazine	Inorganic	RE
	Other paper	Inorganic	NRE
	Card packaging	Inorganic	NRE
	Other card	Inorganic	NRE
Wood	N/A	Inorganic	NCO
Textile	N/A	Inorganic	NRE
Disposable diapers	N/A	Inorganic	NRE
Rubber & leather	N/A	Inorganic	NRE
Plastic	Refuse sacks	Inorganic	RE
	Other plastic film	Inorganic	NRE
	Clear plastic beverage bottles	Inorganic	RE
	Other plastic bottles	Inorganic	RE
	Food packaging	Inorganic	RE

[1] The fraction of "inorganic" waste to be recycled is assumed at 20%

	Other dense plastic	Inorganic	NRE
Metal	Steel beverage cans	Inorganic	RE
	Steel food cans	Inorganic	RE
	Batteries	Inorganic	NRE
	Other steel cans	Inorganic	RE
	Other ferrous metal	Inorganic	RE
	Aluminum beverage cans	Inorganic	RE
	Aluminum foil	Inorganic	RE
	Other non-ferrous metal	Inorganic	RE
Glass (pottery & ceramics)	Brown glass bottles	Inorganic	RE
	Green glass bottles	Inorganic	RE
	Clear glass bottles	Inorganic	RE
	Clear glass jars	Inorganic	RE
	Other glass	Inorganic	NRE
Other (ash, dirt, dust, soil, e-waste	N/A	Inorganic	NRE

[a] Based on Thanh, N.P., et al. (2010). CO: compostable. NCO: non-compostable. RE: recyclable. NRE: non-recyclable.

Table 2. Characterisation of waste based on types and the potentials for composting and recycling

3. Methodology

3.1. Social analysis materials and methods

For the purposes of this study, surveys were conducted in order to investigate the perceptions and behaviour of householders in terms of waste management. Householders were also observed to assess their willingness to sort waste, their willingness to pay, and their perceptions of their own role and that of waste service providers in order to improve performance in the future. Parts of the questionnaire were constructed with reference to previous studies (Bruvoll et al., 2002; Berglund, 2006), particularly the questions regarding personal motives and willingness to pay. These questions were complemented with issues beyond personal motives, such as likeliness to sort if benefits were provided, difficulties encountered in sorting, and participation in home composting and communal composting activities.

The questionnaire included both open and closed questions. The closed questions were designed for ease of answering by the respondents with the aim of collecting the maximum appropriate responses, whereas the open questions were intended to encourage respondents to provide further elaboration on certain questions.

The social and economic analyses of our study were performed through household surveys. The following areas were covered by the questionnaire:

- Part I: Demographic information concerning the respondents' educational background, family income, occupation, age, and household size.
- Part II: Questions concerning waste-related costs and revenues. Responses to these questions generate information on the cost of waste services, potential revenues from

the sale of recyclable waste, and costs of and revenues derived from composting activities.

- Part III: Questions concerning issues regarding waste sorting. Responses to these questions reveal willingness to sort, perceptions of sorting, and willingness to pay others to sort waste.
- Part IV: Questions concerning the solid waste management practices of households. Responses to these questions create a better understanding of waste storage, the scheduling and frequency of waste collection, and the perceptions of households in the primary phase of waste management systems.
- Part V: Questions regarding possible future roles in the waste management system. Responses to these questions reveal how respondents wish to participate in waste management in the future and future improvements to waste service provision.

3.2. Methods for the economic analysis

The financial and economic analysis refers to a prior study by Aye and Widjaya (2006). The costs and benefits of each of the waste management scenarios are estimated by processing information obtained from surveys of the landfill administrator, communal composting officers, the Cleansing Department, and householders. The study makes use of secondary data provided by the government and by the landfill gas-to-energy-generation administrator. These sources provided (sometimes confidential) information, such as landfill operation cost breakdowns and financial aspects of the certified emission reduction rights from the methane gas flaring project.

3.3. Sampling of respondents

A stratified random sample was used to select respondents. Stratified random sampling is a technique that attempts to ensure that all parts of the population are represented in the sample to increase the efficiency and decrease the estimation error (Prasad, N., s.a.). The sample used in this study was therefore based on population demographics and represented all families in Jakarta.

The survey was designed to consider the features of waste collection and of the disposal systems and flows. It was conducted in Central Jakarta, North Jakarta, West Jakarta, South Jakarta, and East Jakarta, the five municipalities of Jakarta city. Fig.3 shows a map of Jakarta City and the locations of the target areas corresponding to the five municipalities.

According to BPS Statistics Indonesia (2009), the percentages of the population of Jakarta with low, middle, and high incomes are 60%, 30%, and 10%, respectively. The annual average income of the low-income group is USD 2,284 or IDR 20.6 million per annum. The annual average income of the middle-income group is USD 5,356 or IDR 48.2 million, and the annual average income of the high-income group is greater than USD 14,198 or IDR 127.8 million.[2]

[2] 1 USD = 9,000 IDR

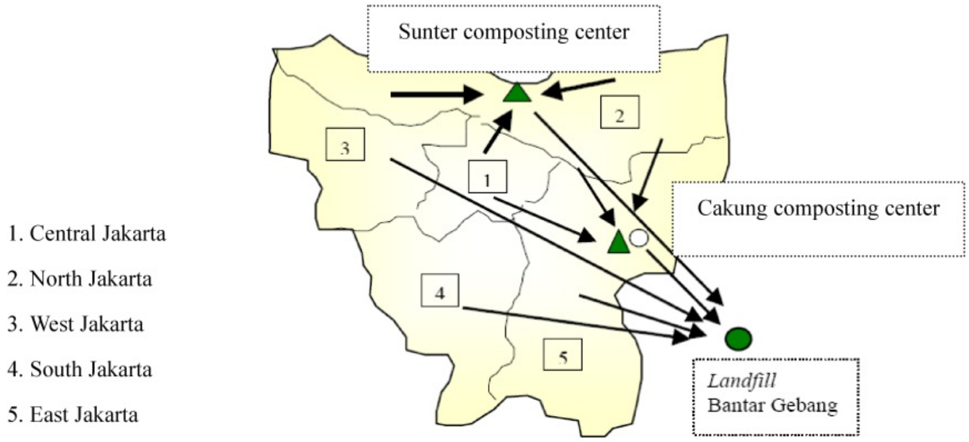

Figure 3. Waste Collection and Disposal Flow (JBIC, 2008)

To obtain a cluster sample, households were selected based on a zoning plan for the regions of the city. In addition, proportionate stratified random sampling was used. The household samples were divided according to the economic or income levels, and samples were taken from each income level within each region. The economic status of the respondents was determined from the responses to the questionnaires (Rahmawati et al., 2010). The questionnaires included demographic characteristics, such as family size. This information was used to estimate the amount of waste generated per capita.

The method of cluster sampling is applied, of which the selection of household sample is divided based upon the zoning of city region. Additionally, proportionate stratified random sampling where the household samples are divided upon the economic or income level and the samples were taken from each income level within each region. The economic statuses of respondents were determined by the responses of the questionnaires (Rahmawati et al, 2010). The questionnaires also cover the demographic characteristics such as the size of family to determine the amount of waste generated per capita.

The size of the sample was determined with the following statistical formula for estimating proportions in a large population (Dennison et al., 1996 and Mc. Call, C.H. Jr., 1982):

$$n = \pi (1 - \pi) Z^2/\epsilon^2 \quad (1)$$

where n is the estimated number of individuals required in the sample, π is the proportion to be estimated in the population, Z is the desired level of confidence, and ϵ is the acceptable level of error.

This study used a maximum error level of 0.05, with an associated 95% confidence level, as the desired reliability. A value of 0.50 was assumed for π. Substitution of these values in the equation above gave the required sample size of 384.2. The sampling interval (k) was determined as

$$k = \frac{N}{n} \quad (2)$$

where N is the population size and n is the sample size.

The population numbers that were previously divided according to the income level distribution were further divided by the number of sub-districts per region. Based on the sample size calculation for the Jakarta survey and the total number of 2,030,341 households in the city, the sample size was rounded to 100 respondents for each combination of sub-district and income level according to the regional and income level distribution.

4. Social and behavioural aspects of the scenarios

4.1. Characteristics of household respondents

Based on the sample of 100, 58% respondents were female, and 42% respondents were male. The ages of the respondents ranged from 15 to more than 55 years with the majority (29%) between 25 and 34 years. Twenty-three percent were between 35 and 44 years, 18% were over 55 years, 17% were between 45 and 54 years, and the remaining 13% were between 15 and 24 years. In terms of education level, 37% had tertiary education, 22% had secondary education, 17% had undergraduate education, 12% had a diploma, 9% had a primary school education, 2% had a postgraduate degree, and 1% had no education. The occupation for the majority was private employee (37%), whereas 34% were housewives, 10% did not specify their occupation, 7% were retirees, 5% were maids, 4% were students, and 3% were civil servants.

Regarding income level, 38% earned between IDR 651,000 and 1,290,000 (ca. USD 76.6 to 152) per month, 26% earned between IDR 1,290,000 and 5,000,000 (ca. USD 152 to 588) per month, 17% earned between IDR 5,001,000 and 10,000,000 (ca. USD 588 to 1,176) per month, 8% earned between IDR 10,001,000 and 15,000,000 (ca. USD 1,176 to 1,764) per month, 7% earned IDR 0 – 650,000 (ca. USD 0 to 76.6) per month, and 4% earned more than IDR 15,001,000 (ca. USD 1,764) per month.

4.2. People's behaviours concerning the waste management system

The majority of people surveyed (67%) store waste that is to be collected from the household for disposal in a plastic waste bin in front of their house; 14% store it in brick garbage bins, and 12% store it in plastic bags. The various types of waste storage containers located in front of houses in Jakarta are depicted in Fig. 4: plastic waste bins, brick garbage bins, and plastic bags.

Figure 4. Various devices for waste storage in front of houses in Jakarta (plastic waste bin, brick waste bin, and plastic bag)

Regarding the location of waste bins within the household, most of the people interviewed gather the waste in a container located in one main room of their residence (66%), rather than locating waste bins in every room (24%). The bins are normally are served by a daily schedule of waste collection (52%).

	Percentage of total respondents
Waste bins within the house	
Waste bins located in each room	24%
Waste bins is pooled in one main room	66%
Other	10%
Waste bins outside the house	
Brick garbage bin outside the house	14%
Plastic waste bin outside the house	67%
Plastic waste bags to be given to waste transporters for disposal	12%
Other	7%

Table 3. Location and storage of household waste

The time of waste collection varies widely, depending on the area of residence, but waste is primarily collected before 11 a.m. The waste collectors do not usually give any particular notification prior to collection, but instead they directly collect the waste in front of people's houses (55%), rather than providing notification by a loud call-out to the household.

The waste collectors who transport waste from households to the temporary storage site are informal workers hired by neighbourhood associations or private companies. These waste collectors all use hand carts with an average capacity of up to 100 kg. The average use period of a hand cart is 7 years, and their frequency of breakdowns is two or three times per year. When a hand cart breaks down, its repair is the responsibility of either the waste collector or the hirer, depending on the degree of damage and prior consent.

4.3. Communal composting

There are communal composting facilities for composting biowaste in several areas of the municipality. There are usually 10 neighbourhood units (*Rukun Tetangga*) within 1 neighbourhood cluster (*Rukun Warga*) in which approximately 680 households reside and are involved in the communal composting initiative (Waste Management Task Force, 2008). Each communal composting facility is usually equipped with a composter 2 x 3 m^2 in size that is used for composting biowaste. Composter is used as instrument to make decomposition of biowaste as fertilizer, which can be used for organic farming. A shredding machine is usually also available at the facility. Biowaste is collected by manual labourers who transport it to the composting facility.

Figure 5. Communal composter

Of all of the respondents surveyed in this study, 88% claimed that there are no communal composters in their area of residence. Among the respondents who indicated that communal composters are available, only 7% claimed to be actively involved in communal composting activities. These respondents were mostly housewives and retirees. All respondents who were actively involved in communal composting claimed that they do not receive any financial incentive whatsoever to participate in communal composting. All of the respondents who were actively involved in communal composting are users of compost produced by communal composters. As users of the product, these responders perceive the product as being of high quality (86%). The compost products are mainly purchased by householders and small to medium enterprises.

No	Statement	Strongly disagree	Partly disagree	Disagree	Agree	Partly agree	Strongly agree	Don't know
a.	I know that I can purchase / have access to compost produced from waste in the communal composter	0%	29%	0%	43%	14%	14%	0%
b.	I am a consumer of the compost produced from the communal composter	0%	0%	0%	57%	0%	43%	0%
c.	The compost produced by the communal composter is high quality.	0%	0%	0%	43%	14%	43%	0%

Table 4. Perceptions of respondents who are active in communal composting

Regarding home composting, of all of the respondents surveyed, 8% own and use a home composter. All of the respondents who conduct home composting use the product for personal purposes. The composters are purchased by householders who compost their organic household waste at home. The average cost of a home composter is 121 thousand IDR (approximately 14 USD). With an average production of 5.3 kg per month and taking into account the average price of regular compost of 7.7 thousand IDR per kg (ca. 0.9 USD per kg), these respondents have potential revenue of 41 thousand IDR per month (approximately 4.8 USD per month). The primary difference between home and communal composting is the instrument and location of composting.

Figure 6. Typical home composters

4.4. Landfill gas to energy

There are currently several private companies investing in and operating landfill gas to energy generation systems. In these waste-to-energy schemes, MSW is utilised as feedstock to generate energy. There are positive impacts from the implementation of waste-to-energy projects, such as green house gas (GHG) emission reduction, improved air quality in landfills, reduction of methane emissions through methane capture, leachate management, disease vector control (less disease contagion from rats, flies, and vermin to people in urban centres), reduced passive emissions of landfill gases (LFG), and reduced air pollution from landfill fires and open burning of household waste (UNFCCC, 2009).

Figure 7 shows the practice of using a geometrix membrane cell cover to provide anaerobic conditions for the waste, and gas collection pipes are used to harvest methane gas contained in the waste. This technology requires minimal initial capital investment.

Figure 7. Landfill gas to energy generation

4.5. Perceptions of roles within the waste management system

Apart from the waste collection and transportation fees that are charged by waste service providers, the perceptions of respondents regarding waste fees were studied. The questionnaire responses revealed that people generally perceive that they have paid a fee to the government. However, in reality, the government does not charge any fee for waste services. Waste fees vary in accordance with the agreement with the neighbourhood association, and they are collected from households to pay for the services of waste collectors at the average amount of USD 2.4 per month.

In terms of provision of services, the majority of respondents (44%) agreed that commercial services should be involved in managing waste, despite the consequences of increased fees. Forty-seven percent of the respondents strongly agree that waste management is a shared responsibility to which they should be held responsible as citizens. By contrast, almost 49% of the respondents strongly agree that government and waste providers are fully responsible and must provide better service.

Regarding the performance of service providers, 50% of the respondents agree that there is currently a lack of regular service for waste collection, 39% agree that there is pollution from litter that is not properly managed in their respective residential area and that there is scattered waste resulting from careless waste collection. Despite these shortcomings, 40% of the respondents still trust that their waste is properly managed, treated, and disposed of by their waste service provider.

No	Statement	Strongly disagree	Partly disagree	Disagree	Agree	Partly agree	Strongly agree	Don't know
a.	Municipal government is responsible for waste management as I pay a waste levy/fee to them.	10%	4%	16%	25%	16%	28%	1%
b.	Commercial services should be involved to manage the waste properly, even if increased market-rate fees are a consequence.	5%	1%	6%	44%	17%	25%	2%
c.	Waste management is a shared responsibility to which I am, as a citizen, also held responsible.	0%	1%	1%	37%	14%	47%	0%
d.	Government and waste providers are fully responsible and must provide better waste management service.	1%	1%	3%	33%	13%	49%	0%
e.	If household waste sorting is required, women should be the ones who conduct it.	25%	9%	34%	13%	13%	6%	0%
f.	Maids are the ones responsible for managing my household waste	29%	5%	36%	13%	9%	6%	2%
g.	There is a lack of regular waste collection services	3%	5%	12%	50%	11%	17%	2%

h.	There is pollution/littering that is not properly managed in my residential area	1%	16%	17%	39%	17%	9%	1%
i.	There is waste that is scattered as a result of careless collection	10%	10%	16%	33%	11%	20%	0%
j.	I trust that the waste is managed, treated, and disposed of properly by waste providers.	6%	12%	20%	38%	9%	14%	1%

Table 5. Perceptions regarding the current performance of waste management

4.6. People's willingness to sort and willingness to accept waste sorting practices

Regarding waste sorting, most of the people (81%) do not usually conduct waste sorting at home (e.g., sorting organic from inorganic waste). However their responses regarding agreement to consider waste sorting were quite high, with 73% indicating that they would consider sorting their waste at home. The respondents agree (34%) and strongly agree (25%) that if required, both sexes should be responsible for conducting sorting within the household.

Of all the respondents who have already incorporated waste sorting into their daily activities, 44% have been conducting waste sorting for less than a year, and 26% have been doing it for 1 – 5 years. The actors who motivate them to sort their waste include early adopting family members and neighbours (31%) and community leaders (25%).

	Percentage of total respondents
Respondent already conducts waste sorting at home	
Yes	19%
No	81%
Period for which waste has been sorted	
Less than 1 year	44%
1 – 5 years	26%
5 – 10 years	18%
more than 10 years	12%
Respondents who do not yet sort their waste but would consider it	
Yes	59%
No	22%
Do not know	81%

Table 6. Waste sorting activities of householders

The respondents who already conduct waste sorting mainly agreed that the reasons for them to sort waste are shown in table 7.

No	Statement	Strongly disagree	Partly disagree	Disagree	Agree	Partly agree	Strongly agree	Don't know
a.	It is recommended by my community group	6%	0%	18%	49%	12%	12%	3%
b.	To get additional income by selling recyclable/reusable materials to scrap dealers	6%	0%	18%	46%	12%	15%	3%
c.	To contribute to a better environment	0%	0%	6%	37%	21%	33%	3%
d.	To compost biowaste with my home composter	3%	0%	15%	43%	15%	18%	6%
e.	To compost biowaste at the communal composter	0%	0%	21%	43%	21%	9%	6%
e.	It is a pleasant activity in itself that brings me satisfaction	0%	9%	15%	43%	9%	24%	0%

Table 7. Reasons for sorting waste

Following the preceding section discussing the actual behaviours, in this section, we move on to address future behaviour, including the willingness to incorporate behavioural changes in the future. For this purpose, the respondents were given the following question: *"If the following benefits were provided, how willing would you be to sort waste?"*

Benefits/assistance provided	Willingness to sort waste						
	Least willing	Partly willing	Un-willing	Willing	Partly willing	Very willing	Don't know
Financial incentive	3%	5%	7%	35%	22%	22%	3%
Provision of knowledge on how to sort	3%	5%	6%	40%	16%	28%	2%
Free waste sorting bins	0%	1%	2%	32%	15%	49%	1%
Information about benefits of sorting for the environment	0%	3%	7%	34%	29%	26%	1%
Information about benefits of sorting for public health	0%	2%	6%	33%	26%	32%	1%
Information about how the sorted waste will be treated	0%	3%	6%	45%	27%	18%	1%
Free home composter for composting biowaste	4%	4%	5%	40%	28%	17%	2%

Table 8. Willingness to sort waste if the following benefits/assistance were provided

Most of the respondents were found to be willing to consider waste sorting if information on how the sorted waste will be treated is provided (45%), if knowledge on how to sort the waste properly is provided (40%), and if a free home composter for composting household biowaste is provided (40%). Financial incentives would also increase respondents' willingness to consider waste sorting (35%), as would free waste sorting bins (32%) and the provision of information on the benefits of sorting to the environment (34%) and public health (33%).

Forty-three percent of the respondents who already sort their waste agree that the unavailability of sufficient incentives/benefits to sort waste makes it difficult for them to sort waste, even though a mechanism for the treatment of sorted waste is already established. The respondents who have not yet practiced waste sorting agree (44%) that they know how to sort waste properly, but there is still a lack of information on the advantages of sorting (48%), and there is no assurance that the waste transporters will not mix the sorted waste at the temporary storage site (41%).

No	Statement	Strongly disagree	Partly disagree	Dis-agree	Agree	Partly agree	Strongly agree	Don't know
a.	Sufficient incentives/benefits for sorting waste are not provided	11%	4%	14%	43%	10%	17%	1%
b.	A mechanism for the treatment of sorted waste is already established	6%	11%	18%	37%	15%	8%	5%
c.	I know how to properly sort waste	6%	8%	19%	44%	9%	13%	1%
d.	There is a lack of information on the advantages of sorting	1%	1%	14%	48%	18%	16%	2%
e.	There is no assurance that the waste transporter will not mix the sorted waste at the transfer station.	2%	0%	10%	41%	11%	33%	3%

Table 9. Considerations that make it difficult or easy for respondents to sort waste

4.7. Willingness to pay others to conduct waste sorting

Willingness to pay (WTP) provides an indication of the extent to which sorting at the source is perceived as a cost for the household and of the size of this cost in monetary terms (Bruvoll et al, 2002). Debate on the best method for estimating WTP continues, whether open-ended or closed-ended questions should be included in the questionnaire. Sterner (1999) conducted studies on WTP aiming to ascertain how much people would be willing to pay in cash for environmentally sound waste management, and open-ended questions were used. Similarly, the study by Berglund (2006) used the open-ended question approach to prevent response bias.

Although some cost data on waste handling processes are relatively easy to extract from the literature and surveys, other data, such as the time devoted by households to sorting waste, are more difficult to obtain (e.g., Bruvoll, 1998; Reich, 2005). The value placed on the time households spend on sorting waste constitutes a substantial share of the total cost of recovery. One line of thought is that households' time devoted to sorting waste on a daily basis should be seen as a cost to society, due to the opportunity cost of the time in terms of foregone leisure (Berglund, 2006). If government authorities were to require at-source waste sorting, respondents' willingness to pay is shown in table 10.

	Percentage of total respondents
If the government requires waste sorting, the respondent is willing to pay someone to sort their waste	
Yes	42%
No, respondent will sort their own waste	57%
Do not know	1%

Table 10. Willingness to pay

The respondents who agreed to pay others to sort their waste are willing to pay an average of 16.5 thousand IDR (approximately USD 1.87) per month. Another means of determining WTP is to estimate the labour cost per hour of sorting.[3] The minimum regional wage in Jakarta is 1.1 million IDR (approximately USD 124) per month, as per Jakarta Provincial Governor Regulation No. 167/2009. This wage corresponds to USS$ 0.78 per hour, assuming a 20-day work month and an 8-hour workday.

4.8. People's perceptions of future roles in the waste management system

According to the responses to the questionnaires, if appropriate mechanisms, incentives, and technical information are provided, the majority of respondents agree to play future roles, such as

- Being involved in communal composting (37%) and home composting (31%)
- Learning to sort waste properly (50%).

Despite agreeing to adopt more roles in the future, most of the respondents do not wish to be involved in monitoring and evaluation of the overall waste management system in their community.

No	Statement	Strongly disagree	Partly disagree	Dis-agree	Agree	Partly agree	Strongly agree	Don't know
a.	I wish to be involved in community composting to produce compost from my household biowaste.	3%	4%	21%	37%	19%	14%	2%
b.	I wish to be able to produce compost from my household waste by using a home composter.	3%	9%	27%	31%	16%	12%	2%
c.	I wish to be able to sort waste properly.	3%	0%	4%	50%	12%	29%	2%
d.	I wish to be involved in the monitoring and evaluation of the overall waste management system in my community.	6%	11%	34%	25%	13%	9%	2%

Table 11. Roles respondents wish to play in the future if appropriate mechanisms, incentives, and technical information are provided

4.9. People's perceptions regarding future roles of other waste management actors

The majority of respondents strongly agree that there are several improvements and roles that the government and other waste management actors should make in the future, such as:

[3] Prior research by Sterner (1999) reported the average time spent on sorting is half an hour per week.

- Providing more regular waste collection (54%)
- Proper handling, treatment, and disposal of waste to reduce pollution (53%)
- Providing information to citizens regarding the methods of waste treatment and disposal and providing overviews on the waste management system (45%).

Forty-three percent of the respondents also agree that waste management actors should actively involve citizens in waste management decision-making processes.

No	Statement	Strongly disagree	Partly disagree	Dis-agree	Agree	Partly agree	Strongly agree	Don't know
a.	Provide more regular waste collection	0%	0%	1%	38%	7%	54%	0%
b.	Provide proper handling, treatment, and disposal of waste to reduce pollution.	0%	0%	0%	36%	11%	53%	0%
c.	Inform citizens concerning how the waste is treated and disposed of and the overall waste management system.	0%	0%	0%	36%	19%	45%	0%
d.	Actively involve citizens in decision-making regarding waste management issues.	1%	1%	6%	43%	16%	33%	0%

Table 12. Respondents' aspirations regarding future improvements and future roles of waste-system actors

5. Economic aspects of the scenarios

The economic assessments of the five scenarios distinguished here consist of cost-benefit analyses with two main components: an economic cost-benefit estimate and an ecological cost-benefit estimate. The first section focuses on the financial costs and benefits from an economic point of view, and the potential revenues from recycling sorted waste are estimated. The second section focuses on the benefits from greenhouse gas (CO_2) emission reduction and co-products, such as compost and electricity, the economic value of which is estimated.

5.1. Financial cost-benefit analysis of the waste management scenarios

The costs were estimated as follows:

$$\mathbf{C_{ET}} = C_L + C_C + C_E + C_P + C_{OM} + C_T, \tag{3}$$

where C_{ET} = estimated total cost, C_L= cost of land acquisition, C_C = construction cost, C_E= cost of equipment provision and installation, C_P = cost of planning, design, and engineering, C_{OM}= cost of operation and maintenance, C_T= cost of transportation.

The revenues were estimated as

$$\mathbf{R_{compost}} = (S_{compost} \times P_{compost}) \tag{4}$$

$$\mathbf{R_{electricity}} = (S_{electricity} \times P_{electricity}) \tag{5}$$

$$\mathbf{R_{product}} = R_{compost} + R_{electricity} \tag{6}$$

where

$R_{compost}$ = Revenue from compost (USD per annum)

$S_{compost}$ = Selling price of compost (per tonne)

$P_{compost}$ = Production of compost (tonnes per annum)

$R_{electricity}$ = Revenue from electricity (USD per annum)

$S_{electricity}$ = Selling price of electricity (USD per kWh)

$P_{electricity}$ = Production of electricity (USD per annum)

$R_{product}$ = Revenue from products

Because some of the values on which the estimates of this study were based are from documents that were published in different years (e.g., 2008 and 2009), the values of these parameters in the year 2011 were estimated from the existing values with the following formula:

$$p = \frac{y}{(1+r)^2} \tag{7}$$

where

p = Value for the present year (2011)

y = Value for year y (existing value based on the year for which the value was available in a published document)

r = Interest rate (annual) at 6.5%

t = Time disparity between the present year and the year for which the information was published

5.1.1. Scenario 1

The information on the quantity of waste disposed in the landfill is taken from a reference document, and the investment costs for Scenario 1 are based on the data obtained from the landfill operator PT Godang Tua (2011). There is no revenue from the products generated in the baseline scenario.

5.1.2. Scenario 2

Information on the quantity of waste composted by communal composting and land acquisition were estimated from the reference document JBIC (2008). Information regarding other investment costs and revenues was based on the survey of communal composting officers. The cost of labour is the labour cost at the communal composting site, which is IDR

200,000 per month per person or USD 847 per annum for a total of 3 labourers. The operation and maintenance (O&M) costs also include the cost of fuel for the waste shredders (USD 127 per annum), the costs of fermentation chemicals (USD 28 per annum), the purchase of additives, such as bran and molasses (USD 14 per annum), packaging costs (USD 11,294 per tonne per annum), and maintenance of the facility (USD 85 per annum). The average production of compost is 706 tonnes per annum with an average revenue of USD 118 per tonne.

5.1.3. Scenario 3

The costs and benefits of Scenario 3 are estimated based on the data from a prior study by JBIC (2008). The estimates include revenue from selling electricity to the grid with an estimated average production of 20 GW per annum and a selling price of USD 0.10 per kWh.

5.1.4. Scenario 4

The costs and benefits were estimated based on the data from JBIC (2008). The centralised composting in Scenario 4 is on a larger scale compared to communal composting, as the facility usually serves several areas of the municipality. The estimated production cost of compost at the centralised composting site is USD 47,000 per tonne per annum with an average selling price of USD 39 per tonne of compost.

5.1.5. Scenario 5

The cost-benefit estimate for Scenario 5 is based on UNFCCC (2009). Revenue derives from the sale of electricity with an estimated average production of 17.8 GWh per annum.

5.1.6. Transportation

Fuel consumption costs are added into the cost estimate for each scenario. The total fuel cost is assessed for transport from the temporary storage site of each municipality in Jakarta to the landfill, anaerobic digestion site, or communal composting facility. The total fuel consumption is determined from fuel efficiency (L/km) data, the distance from each area of the city to the solid waste disposal or treatment site, the waste load (tonnes per vehicle) based on JBIC (2008), the total waste transported per annum, and the total number of trips per annum. The price of diesel fuel in Indonesia at the time of study was USD 0.53 per litre. The field observations conducted in this study indicated that household waste that is placed in storage units in the front of houses is subsequently taken to a nearby temporary storage facility by waste transport operators using handcarts. The household waste is subsequently taken by waste trucks from the temporary storage facility to the landfill or to a composting centre.

The estimation also takes into account waste transportation-related costs, such as the wages for transporting waste from households to temporary storage and those for transporting waste from temporary storage to the waste treatment or disposal facility (USD per annum).

The data were obtained from surveys with the waste transporters. The revenues from the recycling of recyclables in each scenario except for the baseline scenario were estimated from the potential revenues (USD per annum).

The total transportation cost is estimated as

$$\mathbf{C_T} = \Sigma\ (F_{con}\ .\ F_i) + (W_H\,.\,H_T\ /\ H_S) + (W_T\,.\,T_T), \tag{8}$$

where

C_T = Cost of transportation

F_{con} = Fuel consumption (litres per annum)

F_i = Cost of fuel i (USD per litre)

W_H = Wage for transporting waste from households to temporary storage (USD per person per annum)

T_H = Number of household to temporary storage waste transporters

W_T = Wage for transporting waste from temporary storage to a waste treatment / disposal facility (USD per person per annum)

T_T = Number of temporary storage to waste treatment / disposal facility waste transporters

H_T = Total number of households

H_S = Total number of households served per waste transporter

The wages are estimated from the survey of waste transporters. The average wage for transporting waste from households to temporary storage is USD 1,115 per person per annum, whereas the average wage for transporting waste from temporary storage to waste treatment or disposal facilities is USD 1,501. This difference in wages is due to different wage systems. Those transporting waste from temporary storage to the waste treatment or disposal facilities have official contracts from the Cleansing Department. Those transporting waste from households to temporary storage typically have informal contracts with the neighbourhood associations, and their wages are lower than those of the official contract holders.

Subsequent to all values being estimated for the year 2011, the total cost per tonne of waste is estimated as follows:

$$\mathbf{C_T} = C_i\ /\ Q_i \tag{9}$$

The total revenue per tonne of waste is estimated as

$$\mathbf{R_T} = R_i / Q_i \tag{10}$$

where

C_T = Total cost per tonne of waste (USD per annum)

C_i = Total cost per tonne of waste treated per scenario i (USD per annum)

R_T = Total revenue per tonne of waste (USD per annum)

R_i = Total revenue from scenario i (USD per annum)

Q_i = Quantity of waste treated per scenario i (tonne per annum)

Note that the quantity of waste treated differs in each scenario due to the capacity of the waste treatment plant. Therefore, the estimation assesses the cost-benefit ratio per tonne of waste treated.

The cost-benefit estimates for each scenario are presented in Table 13.

	Scenario 1 (Landfill)	Scenario 2 (Communal composting)	Scenario 3 (Anaerobic digestion)	Scenario 4 (Central composting)	Scenario 5 Landfill gas to Energy
Quantity of waste (tonne per day)	6,000	200	250	1,000	298
Quantity of waste (tonne per annum)	2,190,000	73,000	91,250	365,000	108,919
Annual rate	6.5%				
Investment cost (in thousand USD per annum)**:**					
Land acquisition	92.6	0.13	134	258	65
Construction	3,145	1.2	740	359	0.141
Equipment	15	0.0	643	463	67
Planning, design and engineering	453	0.0	422	166	4,764
Total investment cost	3,706	0.14	1,939	1,246	138
Operation and maintenance cost	318	12.4	6,767	6,557	357
Transportation cost	1,920	655	1,920	696	1,920
Total cost (in thousand USD per annum)	5,943	669	10,626	8,500	2,414
Revenue:					
Compost production (tonnes per annum)		706	0	46,976	0
Selling price (USD/tonne)		118	0	40	0
Electricity production per annum (in thousand kWh)		0	20,071	0	17,849
Selling price (USD/kWh)		0	0.11	0	0.11
Total revenue and tipping fee savings (in thousand USD per annum)		959	2,303	1,873	2,048
Revenue:cost ratio	0	1.4	0.217	0.220	0.8

Table 13. Comparison of cost-benefit results for the five scenarios

The revenue:cost ratio is estimated as

$$\mathbf{RCR} = R/C \tag{11}$$

where

RCR = Revenue:cost ratio

R = Total revenue (USD per tonne per year)

C = Total cost (USD per tonne per year)

The total cost and total revenue were estimated per annum, for which the assumed project life is 20 years. According to the estimates, the communal composting of Scenario 2 has the highest potential in terms of the benefit:cost ratio. The second-best option is the landfill gas to energy of Scenario 5. The third-best option is central composting (Scenario 4) followed closely by anaerobic digestion (Scenario 3). The baseline scenario of landfill use (Scenario 1) has the worst potential, as it does not yield any revenue from products.

5.1.7. Potential revenue from recycling of sorted recyclable waste

In addition to the economic evaluation for each of the scenarios, this study also estimates the potential revenue from sorted recyclable waste based on primary data on the quantity of recyclable waste from households and selling prices of recyclable materials obtained from field surveys. The potential revenue from these waste products is shown in Table 14.

Waste category	**Sub-category**	**Average selling price (USD per kg)**	**Average quantity sold per household (kg per month)**	**Revenue potential (USD per annum)**
Paper and cardboard				
	Newspapers	0.17	3.57	14,684,065
	Magazine	0.21	1.75	8,869,442
	Carton boxes	0.25	4.43	27,130,412
Plastic				
	Refuse plastic sacks	0.33	1.00	8,121,364
	Plastic bottles	0.27	1.75	11,617,372
Metal		0.45	1.04	11,529,765
Glass		0.23	1.36	7,668,986
Textiles	Used clothes and fabrics	1.04	1.00	25,319,547
Total			**15.90**	**114,940,952**

Table 14. Potential revenue from recycling of recyclable waste in Jakarta

5.2. Benefits from greenhouse gas emission reduction and co-products for each scenario

For each of the waste treatment scenarios, the economic analysis in this study accounts for the benefits from both greenhouse gas (GHG) emission reduction and co-products, such as compost and electricity generation. The costs and benefits deriving from such externalities are not usually taken into account; therefore, this study accounts for CO_2 as a GHG emission reduction benefit and for the co-products generated by each waste treatment method, whereas other benefits are neglected. The equation to which the economic analysis is applied is as follows:

$$\mathbf{NPV_{cost}} = I + OM + T\,(1 - (1 + r)^{-t} / r) \tag{12}$$

$$\mathbf{NPV_{revenue}} = (R_p + R_{ghg}) \times (1 - (1 + r)^{-t} / r) \tag{13}$$

$$\mathbf{NPV_{benefit}} = NPV_{revenue} - NPV_{cost} \tag{14}$$

where

I = the investment cost (USD)

OM = operation and maintenance cost (USD per annum),

T = transportation cost (USD per annum)

R_p = revenue of co-products (USD per annum),

Rghg = revenue from greenhouse gas reduction (USD per annum)

r = discount rate (based on Aye, 2006)

t = project life time.

Greenhouse gas (GHG) emission reductions were calculated in a previous study (Aprilia et al, 2011) in which the GHG emissions of each scenario were compared to the baseline scenario. The carbon price is USD 12 per tonne of CO_2 (UNFCCC, 2009). At the time of that study, the price of grid electricity was on average about IDR 860 per kWh, or USD 0.1 per kWh. A comparisons of the GHG savings externality for each of the waste treatment scenarios is presented in Table 15.

	Scenario 1 (Landfill)	Scenario 2 (Communal composting)	Scenario 3 (Anaerobic digestion)	Scenario 4 (Central composting)	Scenario 5 Landfill gas to energy
CO_2 savings (kg/tonne waste)	0	461,000	498,000	461,300	489,906
Carbon price (USD/tonne CO_2)	0	12			
Project life (year)	20				
Discount rate	6.37%				
NPV cost (USD/tonne)	75	373	4,302	878	876
NPV revenue (USD/tonne)	0	509	1,031	210	768
NPV benefit (USD/tonne)	0	136	-3,271	-668	-108
Revenue:cost ratio	0	1.37	0.24	0.24	0.88

Table 15. Comparison of the economic impact of the scenarios (in USD)

The assumption used for the anaerobic digestion scenario is that the residue is not composted but is placed in a landfill. Regarding the communal composting scenario, voluntary action is assumed. The CH_4 collection efficiency for the landfill gas to energy scenario is 60%.

Based on the economic analysis for each waste treatment scenario, communal composting (Scenario 2) has the highest potential, as it has the highest benefit to cost ratio. However, it should be noted that the communal composting that takes place in Jakarta employs voluntary labour with an average wage below the regular labour wage. The costs for the existing common communal composting sites are also relatively low because simple composting techniques are applied. The costs of construction, equipment, O&M, planning, design, and engineering (which accounts for the total investment cost) are seven up to sixty six times lower than with the other options.

Landfill use for electricity generation (scenario 5) does not generate positive benefit, since its cost per tonne treatment is higher than revenue; however it has better potential rather than anaerobic digestion and central composting scenario. The potential revenue from scenario 5 includes revenue from both GHG emission reductions through the CDM and electricity generation. The price of electricity that can be sold to the grid is currently USD 0.11 per kWh, whereas in 2006 it was USD 0.06/kWh. The implementation of this scenario should be accompanied by financial support by the government, particularly to cover the investment costs of equipment provision and land acquisition.

Centralised composting (scenario 4) is the third-preferred option followed by anaerobic digestion (scenario 3). Both of these scenarios show negative benefit and would need subsidy or financial support to achieve positive benefit. As waste in Jakarta is not sorted, centralised composting becomes labour-intensive, particularly for manually sorting the organic from inorganic waste. The type of machinery used for the centralised composting plant considered in this study is a conventional windrow, which is a manual non-mechanical composting process.

Anaerobic digestion is the least profitable as it requires the highest investment cost for construction and equipment, as well as O&M cost. The revenues obtained from the implementation of this scenario are from the GHG saving with CDM scheme and electricity generation that are sold to the grid, as the case for scenario 5. Scenario 1 has the least cost; however it does not generate any revenues.

All of the options proposed in this study, except for the Scenario 1, require at-source waste sorting by householders. This approach minimises the need for manual and automated sorting within waste treatment facilities and increases the effectiveness of the composting and digestion processes. If plastic and inorganic material is present in urban solid waste during anaerobic digestion or landfill gas to energy generation, the material causes the total amount of gas produced to decrease (Muthuswamy, S. et al., 1990).

6. Conclusions

This study employs socio-economic evaluation to measure household solid waste management scenarios. According to the estimation, communal composting has the highest potential with the highest benefit:cost ratio. Theoretically, composting can be performed at the communal level at temporary storage sites, at composting centres or at the landfill. The costs of processing and transport and the roles, perceptions, and responsibilities of households are arguably different. Despite the potential for communal composting, a high percentage of respondents indicated that there is no neighbourhood composting. Thus, the present composting rates are low compared to the composition of the waste.

There are several possible constraints impacting the further application and expansion of communal composting, such as

1. Land acquisition

The land being utilised for communal composting usually belongs to a specific entity that dedicated it as a public space, and the land came to be used for communal composting later. For instance, the communal composting that takes place in Rawajati Jakarta uses land that belongs to the Indonesian ground forces and is dedicated to communal composting at no cost. Further application of communal composting throughout other areas would imply the need for open space dedicated to composting. In addition, the limited availability of open space in Jakarta poses particular constraints on the siting of communal composting facilities.

2. Labour and wage systems

The current communal composting sites in Jakarta employ voluntary labour with a lower waging system. Further application of communal composting would require an appropriate waging system at or above the regional minimum wage. A subsequent issue regards the marketing of compost products and the extent to which compost sales would be able to cover operational costs, such as the provision of income for the labourers. The current practice is that most of the compost produced is used by the community. The tendency of urban residents not to conduct farming practices that require compost and the scarcity of land for farming raise the question of marketing issues such that the marketing of compost might have to be extended to neighbouring areas of Jakarta.

3. Capacity of composting facilities

The capacity of communal composting facilities is usually much smaller than that of industrialised composting sites, and increasing, their capacity would be a challenge, due to the limited compostable waste feedstock and the limited space for the communal composting facilities.

All of the options proposed in this study, except for the baseline scenario, suggest that at-source waste sorting by householders is necessary. However, the majority of people in Jakarta do not sort their waste, and household waste is a mix of biowaste, inorganic waste, hazardous waste, and bulky waste. Waste sorting tends to take place outside of the home by waste transporters and manual labours at temporary storage sites and waste treatment or disposal facilities.

Despite the current trend of not sorting waste, most of the respondents surveyed for this study agreed to consider waste sorting. The willingness to consider waste sorting by people who have not yet adopted it is more likely if benefits, information, and assistance are provided. Increased transparency from waste service providers and government regarding the modalities of waste treatment and final disposal is expected to increase public awareness and active participation in at-source waste sorting.

At-source waste sorting by householders can be successfully achieved through both voluntary measures and regulatory measures. The current approach to promoting at-source sorting is through voluntary measures, specifically, the introduction of incentives through revenue from sorted recyclables and revenue from home and communal composting.

Although several types of incentives are present, they are not sufficient to encourage the public to sort their waste. Thus, regulatory measures may have to be considered through the formulation of a regulatory framework to mandate sorting at households with the provision of disincentives or penalties for householders that do not properly sort their waste. A regulatory framework for waste sorting would essentially increase composting success rates. For the regulatory measures to prevail, concrete mechanisms would be required, such as the provision of information for proper sorting, trained waste collectors, varied waste collection schedules according to different types of waste, and the provision for purchase of standardised transparent plastic bags to enable checking by responsible officers.

Promoting at-source waste sorting is important; however, appropriate end-of-pipe technologies for the treatment of municipal solid waste are also required. This study identified feasible technologies with cost-efficiency assessments that can be considered for further implementation. Communal composting is found to have the highest potential with the highest benefit:cost ratio and the greatest greenhouse gas savings, but there are challenges, such as land availability, labour and waging systems, and the capacity of composting facilities. The second preferred option is landfill gas to energy scenario, followed by central composting and anaerobic digestion. However it should be noted that the operation of landfill gas to energy, central composting and anaerobic digestion require substantial financial support from the government, particularly to cover investment and O&M costs. The financial support is regarded as the costs for municipal waste treatment that is borne by the government of Jakarta. The imposed subsidy on electricity tariff results in the uncompetitive selling price of electricity from these scenarios. Therefore when it comes to the revenue analysis, scenario 3 and 5 may show better results if the electricity subsidy were lifted. Communal composting would still have high potential as the land acquisition cost very low due to the provisions by the government. If the low-cost land provision were retrieved, communal composting still have good potential since its O&M, construction, equipment and other cost are very low compared to the other scenarios.

Although people displayed a high degree of willingness to sort their household waste, proper monitoring will be required to ensure the success of sorting. Possible criteria that merit further study include social impact analysis and life cycle analysis to determine the environmental impacts of each waste management option. These complementary aspects would complete the analysis within an integrated framework.

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