HOUSEHOLD SOLID WASTE MANAGEMENT IN JAKARTA, INDONESIA: EVALUATION ON HUMAN BEHAVIOUR, ECONOMY, AND GHG EMISSIONS

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by

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Abstract

Household solid waste in Jakarta is largely landfilled without treatment and incineration does not take place. Methane is considered to be responsible for approximately 20% of the recent increase in global warming and landfills are a major source of methane. Bantar Gebang landfill that treats Jakarta waste would exceed the capacity by 2019, thus the need to design future solid waste management (SWM).

The goal of this study is to design the measures to promote the preferred SWM system based on the criteria of this study (economic and environment associated with GHG emission) to be implemented in Jakarta, Indonesia. Based on estimations, the amount GHG emissions are similar for the systems of anaerobic digestion, communal composting, and centralised composting. Thus the selection of waste management system can be chosen from other criteria such as economy.

Communal composting of organic waste and recovery of inorganic recyclable waste that generally exist as community-based waste management (CBWM) has the highest economic revenue with moderate GHG emission. For the case of Indonesia, CBWM of this kind is preferred because of the least cost, considering that the allocated funds for Cleansing Department are only 2.9% of the total Municipal Budget and waste levies are not imposed.

In light of these, CBWM scheme were probed from the perspective of human behaviours. Based on the study on communities that are successful and failed in CBWM, distinct properties that set apart the two groups were identified. In the successful cases, grassroot/informal CBWM was initiated prior to any top-down institutional/formal measures. Basic means for CBWM were also provided independently by communities. In addition, the successful cases were present in the homogenous middle-income communities that sort, racial heterogeneity, and presence of senior influencing CBWM leaders.

Based on the study on households, it suggests that for continuous operation of CBWM system, top-down institutional/formal measures are necessary but after the grassroot/informal initiation. The top-down institutional/formal measures are in the forms of readiness of waste market system to ensure the income from the sales of

recycled products and compost produced by the CBWM activities, regulations to prevent mixing of sorted waste, and the information provision to householders with regard to the implementation of CBWM system and sorting. Grassroot/informal middle-income community groups can become avenues to promote CBWM initiatives such as *arisan, PKK,* and *pengajian groups,* in addition to top-down institutional/formal community groupings established by the government.

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Abbreviations and Acronyms

3R	Reduce, Reuse, and Recycle
ADB	Asian Development Bank
BAT	Best Available Technologies
BAU	Business as usual
CBWM	Community-Based Waste Management
CER	Certified Emission Reduction
CH4	Methane
CO	Compostable
CO2	Carbon Dioxide
CO_2eq	CO_2 equivalent
DOC	Degradable Organic Carbon
EF	Emission Factor
ERRA	European Recovery and Recycling Association
GALFAD	Gasification, Landfill, Anaerobic Digestion
GHG	Greenhouse Gas
Gg	Gigagram
g	Gram
HWM	Household Waste Management
IDR	Indonesian Rupiah
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JBIC	Japan Bank for International Cooperation
JPY	Japanese Yen
kg	Kilogram
km	Kilometer
kWh	Kilowatt hour
LCI	Life Cycle Inventory
LFG	Landfill gas
MCF	Methane Correction Factor
MSW	Municipal Solid Waste
MTCE	Metric Tonne Carbon Equivalent
$MTCO_2e$	Metric Tonne Carbon Dioxide Equivalent
MWe	Mega Watt electric
N_2O	Nitrous Oxide
NCO	Non Compostable
NRE	Non-recyclable
O&M	Operation and Maintenance
OECD	Organisation for Economic Co-operation and Development
OX	Oxidation Factor
PDD	Project Design Document
RE	Recyclable
SMS	Sound material-cycle society
SWM	Solid Waste Management
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar
WTP	Willingness to Pay

CHAPTER 1: INTRODUCTION

1.1. General Background and Problem Description

Solid waste is the discarded materials that derived from various sources. Solid waste in the cities is often perceived as problems due to improper management such as open dumping or burning. In urban areas, municipal solid waste (MSW) requires proper management rather than sustaining the current landfilling system. In many developing countries, solid waste management (SWM) is not yet properly implemented. There are many systems and technologies for SWM; however the effective application depends on the specific characteristics of the waste generated.

The increasing quantity of wastes also escalates the problems that give burden to the environment. Waste is one of the sources of greenhouse gas emissions that contributes 1.4 Gton or 3% of the total CO_2 emissions (Stern, 2006). Thus, waste management and recycling measures have begun to take on international aspects. The current trend toward the establishment of an international sound material-cycle society (SMS) is centered on the 3Rs (Reduce, Reuse, and Recycle) (Yoshida, Shimamura, Aizawa, 2007).

To realise an international SMS, the 3R approaches should first be implemented in each individual country. The definition of SMS taken from the Japanese Fundamental Law to Establish a Sound Material-Cycle Society, which is as follows: “a society where the consumption of natural resources is minimized and the environmental load is reduced as much as possible, by restraining products, etc. from becoming wastes, etc., promoting appropriate recycling of products, etc., when they have become recyclable resources, and securing appropriate disposal of the recyclable resources not recycled” (Ministry of Environment Japan, 2000).

Household waste represents a large fraction of MSW. The management of SWM in developed countries has incorporated householders’ participation in at-source waste sorting prior to treatment by the municipal government. At-source sorting is one of the basic essential elements for effective SWM, which is carried out by the general public. In developing countries, sorting is not generally required, but in some communities there exist the autonomous community-based waste management (CBWM). The number of communities that take part in CBWM is increasing despite the challenges and it gives rise to the interest for undertaking studies in this issue.

It is used to be perceived that the social task of waste management has been to get rid of it. However, there is a current new economy of waste, in which there are three basic drivers of change that are turning waste and waste management into a dynamic, fast-changing, economic sector, which are: Growing concern about the hazards of waste disposal; broader environmental concerns, especially global warming and resource depletion; economic opportunities created by new waste regulations and technological innovation (Murray, 1999); the rising problems with regard to solid waste management have called upon each community members to participate in 3R. In the past, the paradigm and attitude of householders towards wastes with the term "not in my backyard" (NIMBY)[1] should be replaced with "now I must be involved" (NIMBI) (Mangkoedihardjo et al, 2007). It gives rise to the emerging importance to implement 3R practices from the households.

The research that is conducted in a developing country such as Indonesia is of importance due to the following reasons:

a) Studies and assessments of waste management systems have been conducted mainly in developed countries. However, such analyses are lacking for developing countries, such as Indonesia. The typical outcomes produced by assessments that result from research studies conducted in developed countries are not applicable and may well represent a different set of circumstances due to the differences in climate and operational systems, strong presence of informal sectors, and the fact that large portion of GHG emissions in Indonesia were derived from the waste sector.

b) The different socio-economy of developing countries' populace resulted in different waste characteristics and waste generation rate compared to developed countries.

c) There have been studies on CBWM, but there have not been any studies that identify the reasons behind the success and failures of implementation in the different communities. Given that there are two types of CBWM approaches (grassroot/informal initiation approach and top-down institutional/formal initiation approach), there have not been any studies that provided empirical evidence on the preferred sequence of the approach.

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[1] NIMBY means that local populations refuse to allow polluting facilities to be located nearby their residential areas due to the absence of protection mechanisms

d) The rising middle-income population in developing countries that leads to the increase of waste generation rate require proper management.

e) Indonesia has approximately 300 ethnic groups with over 700 languages and dialects spoken. These different ethnic groups live in various parts of the capital city, including Betawi people as the original ethnicity of Jakarta.

f) Indonesia's specialty is on the community behaviour. The top-down institutional/formal government-formed community grouping systems of neighborhood units/associations (RT/RW) to form the community-based initiatives, as well as grassroot/informal community neighborhood groupings that permeate Indonesian middle-income community groups exist, e.g.:

- *Arisan*, which is a rotating-credit associations in the form of microfinance that is common in Indonesian culture. It is conducted as social gatherings at fixed interval (e.g. monthly) in the homes of each member, or at public areas such as restaurants or cafés.
- *Pemberdayaan dan Kesejahteraan Keluarga or 'PKK'* is the women's group for family welfare. The groups usually exist within community units and clusters.
- *Pengajian* groups, which is Islamic prayer groups that meet at fixed interval in the homes of each member, mosques, or other public places. During the meetings, the Holy Qur'an recitation and discussions are conducted.

g) Indonesia is the most populated country in Southeast Asia and the fourth most populous nation in the world with over 238 million people (BPS Statistics Indonesia, 2011). With the growing population, proper waste management is one of the important areas that need attention.

h) By 2025, Indonesia is among the other five major emerging economies—Brazil, China, India, South Korea, and Russia— that will account for more than half of all global growth (World Bank, 2011). With the rising economic growth, consumption rates would rise that result in the increasing rate of waste production. Thus, proper waste management should become one of the main focuses in development. Any investment in proper waste management facilities should be taken in order to accommodate the future likeliness of the rise in waste production.

i) The allocated funds for Cleansing Department are only 2.9% of the total Municipal Budget and waste levies are not imposed. Thus financing expensive large-scale and sophisticated waste treatment facilities may not be feasible for Jakarta, therefore optimisation of CBWM was prioritised by the government, which calls upon this study to be conducted.

Indonesia has been encountering pressing problems with regard to the management of MSW. MSW is generally defined as wastes that are managed by municipalities or other local authorities. Typically MSW includes household waste; garden/yard and park waste; commercial/institutional and industrial waste (IPCC, 2006). The major urban areas in Indonesia produce nearly 10 million tons of waste annually, which increases 2-4 per cent annually (Ministry of Environment Indonesia, 2008). The main constituent of MSW in Jakarta is organic wastes with 74 percent (United Nations Environment Programme, 2002). With the total population of 246 million, Indonesia would generate 1.87 million ton/day of MSW in a total area of 1.89 million km2 (Chaerul, Tanaka, Shekdar, 2007). It is predicted that by 2019, the volume of waste in Jakarta will reach 7.8 thousand ton/day (Cleansing Department, 2010).

Household waste is the largest stream of MSW in Indonesia, followed by traditional markets. The most common methods for waste management are currently open dumping and burning in open spaces. In Jakarta, unsanitary landfilling still takes place, which is the opposite of sanitary landfilling. The characteristics of sanitary landfilling is anaerobic degradation, including conditions such as proper site management with no scavenging at the operational area; frequent surface covering; prevention of landfill fires, litter and scavenging animals, and gas control and extraction/recovery. To the contrary, unsanitary landfilling is characterised by aerobic degradation, which include characteristics such as presence of scavenging by people and animals; poor and light operational equipment, for instance bulldozers (being in widespread use) have in general a low area pressure, resulting in limited compaction effect, and frequent fires (IPCC, 2006).

The three-pronged approach to sustainability is applied for the evaluations, in order to apply waste management system that is sustainable from the perspectives of environment, economic, and human behaviour. The concept is adopted from the grand concept of “sustainable development”, which is "to meet the needs of the present without compromising the ability of future generations to meet their own needs."

(World Commission of Environment and Development, 1987). The interrelationship of the three approaches as utilised in this study is described in Fig.1.3.

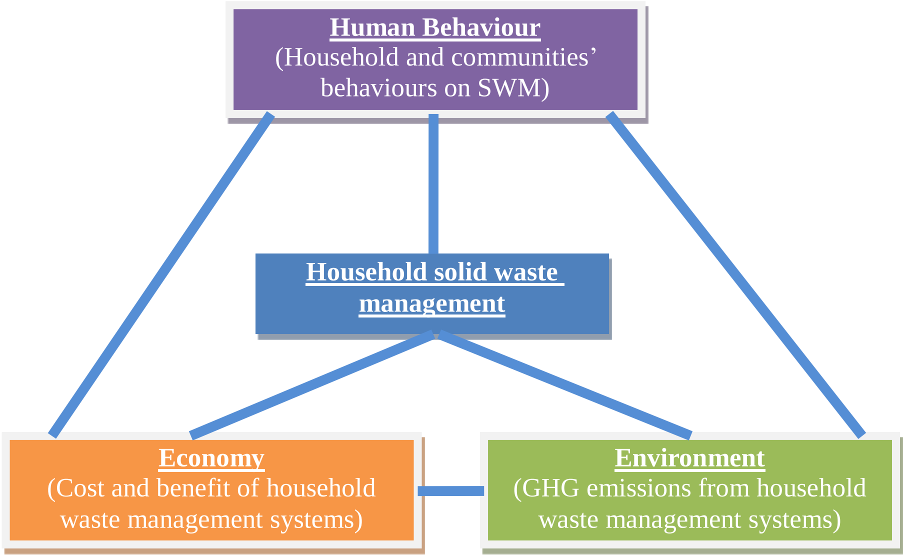


Fig. 1. 1 The approach to describe the interrelationship of economic, social, and environment to achieve sustainable household SWM

The criteria selected for economic evaluation is the cost and benefit of household SWM systems. This was selected because the allocated funds for Cleansing Department, including for waste treatment technologies purchase, are only 2.9% of the total municipal budget. Therefore economic cost and benefit are important to be estimated. The second criteria for environment evaluation are GHG emission estimations, because several SWM systems such as composting emit methane nitrous oxide as GHG emissions. Indonesia is touted as one of the top GHG emitting countries, while as the largest archipelagic state in the world; it is vulnerable to the negative impacts of climate change. The Government of Indonesia (GoI) has also expressed commitments in lowering the GHG emissions. According to the Ministry of Public Works (2013) that is responsible for national waste management, the national climate change mitigation actions are: "development and optimisation of community-based waste management (CBWM) and final disposal site." Emissions from the waste sector are relatively small compared to the other sectors, but it is the main contribution of methane (CH_4) and nitrous oxide (N_2O) emissions. GHG emissions from the Indonesian waste sector is ranged from 32 – 60 $MtCO_2e$, which ranks Indonesia as the sixth largest emitter in the waste sector (Kunzler, M., 2010). Thus the estimation of GHG emission from different waste management systems in Indonesia is required to identify the preferred system from the viewpoint of GHG emission.

In addition, the evaluation of waste in terms of GHG emission to estimate the emissions for each method of waste treatment and the potential GHG emission savings are also required for determining the potential future emission reduction projects in the waste sector. Indonesia has been touted as not yet been able to take advantage of the opportunities in the emission reduction projects. Indonesia has emissions reduction potential that can be developed as emission reduction projects, ranging from methane reduction through waste treatment to methane capture through biogas production.

Further to these multi-criteria evaluations, in order to realise the methods and policy, the aspect of human behaviour that composed of household and communities' behaviours in CBWM is also included.

1.2. Prior Studies

There had been many studies conducted in the field of waste management. This section presented previous studies that are of relevance with this thesis, i.e.:

SWM in developed countries

A number of studies and assessments of waste management systems have been extensively conducted in developed countries such as the UK (Parfitt, J.P., Lovett, A.A., Sunnenberg, G., 2001), Scotland (Collins, A., O'Doherty, R., Snell, M.C., 2006), USA (Staley, B.F., Barlaz, M.A., 2009; US EPA, 2010) and household waste surveys in Vietnam (Thanh, N.P., et al. (2010)) and at several cities in Japan such as Kawanishi city (2011); Kita city (2012); Kyoto city (s.a); Sendai city (2012); Sunigami city (2010); and Setagaya city (2012).

Developing countries and Indonesia

There have been studies to quantitatively and qualitatively examine the waste generated in developing countries (Troschinetz, A.M., Mihelcic, J.R., 2009; Dhokhikah, Y. 2012). Quantification and characterisation survey have also been conducted in Indonesia for general municipal solid waste, although not specifically on household waste (Chaerul, M., Tanaka, M., Shekdar, A., 2007; Helmy. M., Laksono, T.B.. Gardera, D., 2006) and studies in several cities in Indonesia (JICA, 2008). There has also been a survey conducted on municipal solid waste in Bandung (Damanhuri, E., Wahyu, I.M, Ramang, R., 2009) and Surabaya (Trihadiningrum, Y., 2006). There were some studies that analyse the municipal waste management in Indonesia that focused on traditional market waste (Aye and Widjaya, 2006). Another study compared between different systems for municipal solid waste management by analysing the material flows and environmental impacts (Trisyanti, D., 2004). Japan Bank for International Cooperation (JBIC, 2008) also produced a report for project preparation for municipal solid waste management project in Jakarta, whereas JICA (2003) conducted a project in Jakarta to increase the capacity of waste collection and transportation to the final disposal facility.

General overview on SWM in several major cities in Asia (Dhokhikah, Y. Trihadiningrum, Y., 2012); Indonesia (Chaerul, M., Tanaka, M., Shekdar, A., 2007), Bandung (Damanhuri, Wahyu, Ramang, Padmi, 2009), Surabaya (Trihadiningrum, 2006) and Semarang (Supriyadi, Kriwoken, Birley, 2002). The study on observation of inorganic waste dumped into the rivers and Jakarta Bay was conducted by Steinberg, (2007); status of waste management development in Indonesia (Meidiana, 2010); studies on scavengers for societal inclusion (Sembiring, Nitivattananon, 2008, 2010; Supriyadi, Kriwoken, Birley, 2002; Marshall, 2005). Studies on CBWM in Surabaya based on newspaper articles and interviews (Tahir, Yoshida, Harashina, 2014),; CBWM scenarios in Malang that concluded on three scenarios of participation rate in CBWM (Purba, Meidiana, Adrianto, 2014); the influence of CBWM system on people’s behavior and waste reduction in Semarang (Sekito et al, 2013).

Pasang et al (2007) explored about neighbourhood-based waste management for Jakarta’s context. Meidiana (2010) stated the ways to involve communities in reducing waste, i.e. through waste retribution and community initiatives in SWM. Kardono (2007) argued that CBWM becomes important in Indonesia because due to the low-cost and high-participation of people, which argument was not backed up empirically.

Human behaviour (households and communities)

Prior studies have linked household participation and behaviour to economic assessments with the concept of willingness to pay sorting in the European countries (e.g., Purcell et al, 2010; Bruvoll et al, 2002; and Berglund, 2006). Charuvichaipong and Sajor (2006) concluded that the failed public participation in waste separation project in Thailand was due to lack of participation, weak CSO, top-down institutional/formal approach, and the government-community relations. Mongkolnchaiarunya (2003) conducted the study on CBWM through recycling. A study by JICA (2003) concluded that external supports would not bring significant improvement without public participation in practicing at-source sorting and CBWM. Shekdar (2008) proposed an approach for SWM improvement in Asian countries that include public participation. Prior study had also been conducted on pilot program concerning source separation of household waste in China, which introduced a waste at-source separation method (Zhuang et al, 2008).

There were studies on community-based initiatives (other than CBWM) that concluded on the importance of finding a balance between top-down and bottom-up efforts (MacIntyre, 2003; Carrey and Braunack-Mayer, 2009), collaborative management through shared responsibilities (Suraji et al, 2014), and integrating participatory ‘bottom-up’ approaches with conventional ‘top-down’ systems (Frasera et al, 2006).

Ozinga (1999) introduced the term eco-altruism that implies doing something for the environment at the cost to oneself. Hopper et al (1991) confirmed that recycling behavior is consistent with Schwartz's altruism model. There were theories of human behaviour that may explain the reasons for humans to undertake such activity. One acclaimed theory is the theory of planned behaviour (Ajzen, 1991) provides a theoretical framework for systematically identifying the determinants of human behaviour related to household waste management. Prior research had been conducted by using this theory of planned behaviour as a baseline in understanding the household waste management attitudes and behaviour in the UK (Barr, S., 2007; Tonglet, M., Phillip, P.S., Read, A.D., 2004) and Malaysia (Latifa, S.A., Omara, M.S., Bidina, Y.H., Awang, Z., 2012).

There were criticisms towards the theory of planned behaviour, e.g. Conner & Armitage, 2006; Bentler and Speckart, 1979; Bagozzi, 1992; Eagly, A. H., Chaiken, S, 1993. Human behaviour can be regulated by an adequate manipulation of rewards and punishments (Singhirunnusorn, Donlakorn, Kaewhanin, 2012; Mannetti et al, 2004). Some studies found that the psychological variables related to social norm and peer pressure influences are useful for predicting human behaviour towards household waste management (Nixon and Saphores, 2009).

Economic and environment associated with GHG emission of SWM

In regards to the economic studies, there have been prior studies conducted (e.g., Bohma, Folzb, Kinnamanc, and Podolskyd, 2010; Aye and Widjaya, 2006; Sonneson, Bjorklund, Carlsson, and Dalemo, 2000; Reich, 2005). They have discussed and estimated the impact of economies in household waste management.

With regard to environment associated with GHG emission estimations, many studies had been conducted in European countries using IPCC approaches, but such studies have not been conducted in developing countries such as Indonesia, as of the time of this study. For example, Kennedy, C., et al. (2010) made inventories of GHG emissions from waste. Friedrich, E., Trois, C (2011) applied IPCC approaches to compare the emissions of GHGs from various waste management processes. Evaluation of GHG emissions in waste management had also been conducted in China (Zhao, W., Voetb, E., Zhanga, Y., Huppes, G., 2009); Turkey (Ozeler D., Yetis U., Demirer, G.N., 2006); Israel (Ayalon, O., Avnimelech Y., Shechter, M., 2001); Taiwan (Chen, T.C., Lin, C.F., 2008); Japan (Bogner, J., et al, 2008), and others.

In summary, prior studies on waste management systems were mainly conducted in developed countries. Studies on waste characterisation had been conducted in developing countries, but not specifically on household waste. Studies on GHG emission estimations from waste management systems were also mostly conducted in developed countries. There have also been studies on household participation and behaviour using several theories. The result of studies in developed countries is not applicable for developing countries due to the different socio-economy and waste characteristics.

Existing gaps in research field prior to this study

Based on the literature studies, there are existing drawbacks in the research field before this study, i.e.:

- Lack of literatures in developing countries' context (e.g. Marshall et al, 2013; Seadon, 2010)

- Lack of empirical studies in household SWM to identify participation in CBWM is preferred. (e.g.Troschinetz, A.M., Mihelcic, J.R., 2009; Dhokhikah, Y. 2012).
- Lack of empirical studies on conditions for successful implementation of the preferred SWM system. (e.g.Meidiana, 2010; Kardono, 2007; Pasang et al, 2007)
- No study to address the sequence of top-down institutional/formal approach and grassroot/informal approach in SWM (e.g. Charuvichaipong et al, 2006)
- No empirical evidence to identify the factors for the success and failure of CBWM

1.3. Goals and objectives

The goal of thesis is to design the measures to promote the preferred system to be implemented in Jakarta, Indonesia. Systems analysis was conducted to enable interdisciplinary evaluations (which relates to more than one branch of knowledge) for decision making in SWM, which would provide opportunities to develop better solid waste management strategies and policies, which is necessary for Indonesia.

To achieve the goals, the objectives of this thesis are:

1. To identify the preferred household SWM system based on the criteria of this study: economic and environment associated with GHG emission.
2. To identify the factors for successful CBWM implementation, identification of primary target communities for CBWM, and promotion measures by government to promote the implementation of the preferred SWM system.
3. To identify the preferred sequence of the top-down institutional/formal approach and grassroot/informal approach in the preferred SWM system.

There have been many studies on assessments of SWM options from the technical perspectives, but little attention have been paid to the householders and communities that partake in the implementation process of the SWM system. In this study however, evaluations against householders and communities to be involved in the implementation of the preferred SWM system were conducted.

The focus on household solid waste is selected for this study, because households in Indonesia generate the largest stream of waste. However there were only a limited number of existing studies that focused on household waste, because most studies focused on municipal waste. The difference is on the composition of waste generated by households from other sources such as commercial waste, hospital waste, or traditional market waste. Therefore systems evaluation is necessary, by taking into account evaluation on human behaviours, i.e. householders and communities as the waste generators and contributors of the household SWM system implementation.

Conventional studies on SWM disconnected technical aspects from human behaviour aspects. CBWM is not a new concept and there exist successful and failed cases of CBWM implementation. To the author’s knowledge to date, there are no studies that provided empirical evidence that may explain the factors behind the successes and failures of CBWM.

Systems thinking is one of the ways to cope with complexity, thus the first attempt to conquer the existing difficulties is to conduct a multi-criteria analysis to identify the preferred household SWM system based on the criteria of this study. The result suggests that communal composting is a preferred system for Jakarta, which generally exists within a CBWM framework.

Henceforth, studies to compare different groups of CBWM communities and householders were conducted to identify the distinct properties and barriers of CBWM implementation, and finally conclude on the factors for successful CBWM implementation, identification of primary target communities for CBWM, and promotion measures by government. In this thesis a basic framework for mainstreaming interdisciplinary analysis of household SWM system is introduced.

Despite CBWM to have existed through grassroot/informal initiation and top-down institutional/formal initiation, but there have been no studies that specifically addressed how the approach may affect the prospect to prevail the CBWM initiatives. With the hypothesis that CBWM is a preferred household SWM system, this study further aims to identify the factors for successful CBWM implementation, primary target communities for CBWM, and proposed promotion measures. Comparative studies with multiple target groups were conducted to identify the distinct properties and barriers among the different groups. It further aims to identify the preferred sequence of the top-down institutional/formal approach and grassroot / informal approach in CBWM implementation.

The government of Indonesia is only recently focusing on household waste management, as the new state regulation to address this issue that has recently been stipulated in October 2012. The regulation, namely the Government Regulation in 2012, is concerning the management of household waste and household-like waste. The Regulation is aimed to be the implementation of the Act in 2008. This state regulation would need to be translated into local regulation for Jakarta, which is still being devised. Thus, it is expected that this study would provide recommendation for the local policy and local strategic action plans.

1.4. Data Survey

To furnish the data requirement for conducting the economic and GHG emission estimation evaluations, waste survey at households were conducted. At present there is limited data regarding the household waste generation rate in Jakarta. There was however, the information provided by the Environment Center of Information (2001) that stated the average waste generation in Indonesia. This information is rather misleading because this is the amount of waste generated from all sources (households, industries, commercial, etc), thus it cannot be generalised that each person generate an average of 800 gram per day. This study estimated that the amount of household waste generation is 330 gram per capita per day or 1.32 kg per household per day.

Although there are regular household waste surveys conducted at cities in Japan and other developed nations, this practice is not yet common practice in Indonesia or Jakarta. There is a necessity for learning from Japan and other developed countries, regarding regular household waste surveys that are necessary in order to:

- maintain and check the effectiveness of certain waste management policy, for instance the policy on at-source waste minimisation
- stipulate future policies that correspond to the types of waste that are generated by households in certain period of time.

This study is the first study that provides detailed data of household waste, of which conducted survey was at the households for reasons of precision. Other existing surveys conducted in Indonesia are either a) composed of general municipal waste from sources that are not only households; or b) the surveys were conducted at the temporary storages or landfills, thus where the source of waste cannot be justified to be mainly from households.

Compared with previous studies, there are differences with this thesis as there were discourses that have not yet been addressed, such as:

1. This study introduced an interdisciplinary approach to the study on household SWM, with original data from primary survey for comparative evaluations against householders and communities to be involved in the implementation of the preferred SWM system. Conventional studies on SWM tend to disconnect technical aspects from human behaviour aspects; despite the general claim that public participation in SWM process in developing countries is of importance.
2. This thesis uses multi-comparative studies of different households and communities attempts to identify the distinct properties and barriers to implement the preferred household SWM from the perspective of end-users. This has not yet been addressed in prior studies. Several existing studies concluded that CBWM is necessary for SWM, but did not observe the householders and communities in profound manner.
3. This study uses participatory approach in waste survey for Indonesian householders to be involved in hands-on at-source sorting, which essentially changed people's behaviour who participated in the research.[2]
4. This study fills the gap in the existing studies that are lacking the focus on household waste in Indonesia, despite the fact that householders are the main generator of waste.
5. This thesis studied on both sorting and non-sorting group, as well as CBWM participants and non-participants, to identify the distinct properties and barriers. Prior study only focused in the failed waste sorting project (Charuvichaipong et al, 2006).

Further, the points of this thesis that can be applied and generalised to other areas or studies are:

1. proposal of waste management system evaluation formulae;
2. participatory waste survey;
3. method for evaluation of waste management system realisability based on questionnaires and interviews.

Jakarta contains special characteristic of the existence of ethnicities' diversity,

[2] Prior to survey, more than 80% do not usually conduct waste sorting at home. After the two-weeks exercise, 53% of these respondents stated willingness to sort.

where the indigeneous ethnicity of Betawi live alongside other ethnic groups in Jakarta. It can also be a common trait of other cities in Asian countries, although the indigeneous ethnicity in those other areas may have different characteristics from Betawi ethnicity.

1.5. Academic contribution of thesis

- Provided economic, environment and energy empirical evidence on CBWM as a preferred system for Jakarta, Indonesia, based on the criteria of this study (chapter 3 and 4)
- Integration of grassroot/informal approach and top-down institutional/formal approach as a sequence to promote the preferred household waste management system (chapter 5).
- Identified the factors for successful CBWM implementation to promote the preferred household SWM system (chapter 6)
- Research approach to bridge quantitative technical evaluations and qualitative human behavioural evaluations.
- Additionally, participatory approach of householders in waste survey by hands-on sorting eventually changed people’s behaviour. (From 80% non-sorting respondents, 53% stated willingness to sort after survey).

The outline of study and output are described in Fig.1.2. It explains about how the evaluations relate to one another, as well as the output of study, which are the factors, primary target communities, and promotion measures to implement preferred household SWM based on the criteria of this study.

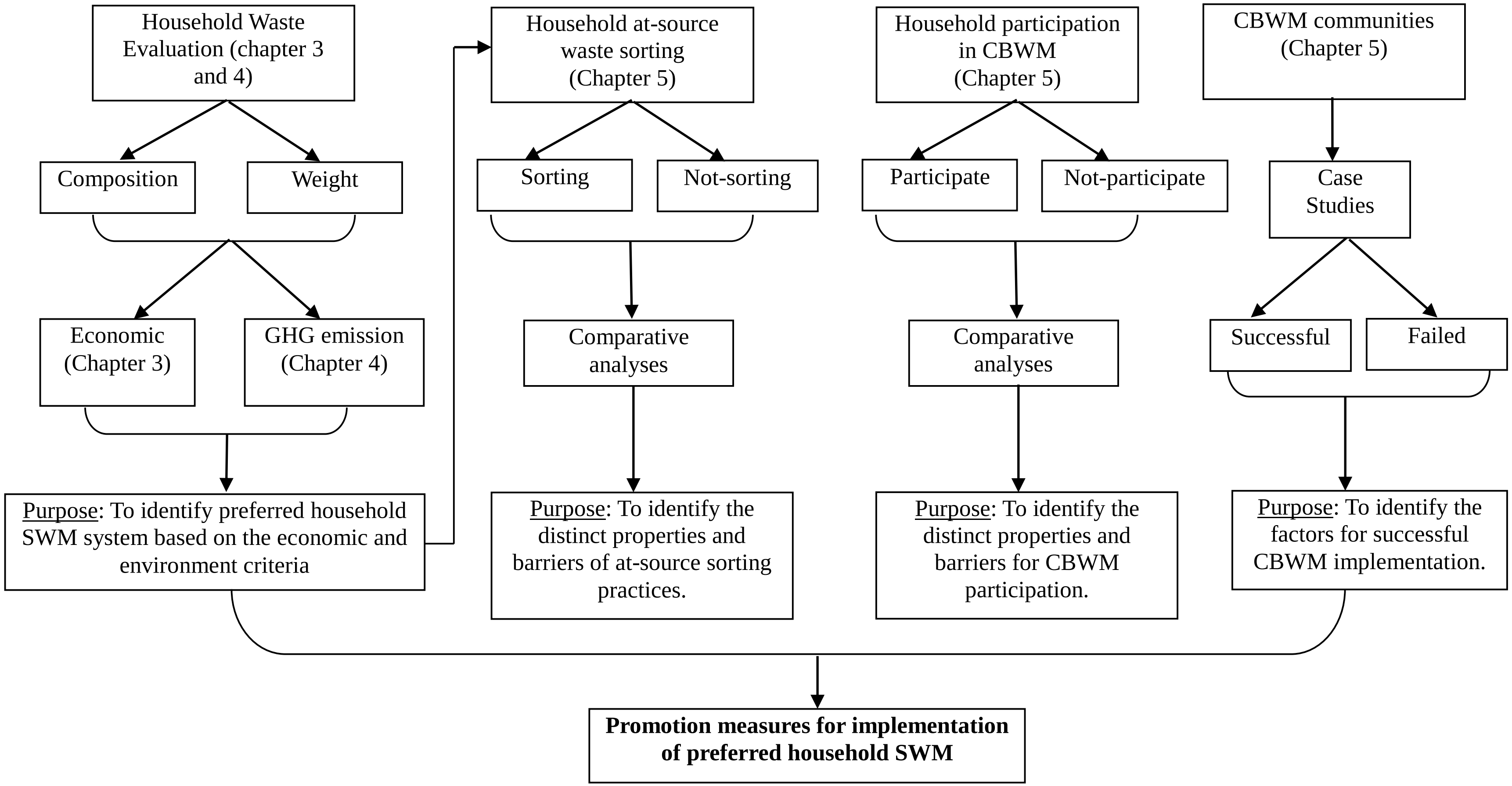


Fig. 1. 2 Outline of study and output

CHAPTER 2: COMMUNITIES AND COMMUNITY-BASED WASTE MANAGEMENT (CBWM) IN JAKARTA, INDONESIA

This chapter provides definitions and an overview about communities and CBWM in Jakarta. It also presents the review of policies on waste management in Indonesia.

2.1. Definitions

Community was defined as a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings (MacQueen et al, 2001). Rein (1997) defined a community as a group of people sharing common interest and set of values.

Anschütz (1996) stated a practical definition of community as a group of users of a service who live in the same area and have access to, and use, a certain service. It differs from a neighbourhood, which is defined as a geographical and/or administrative entity in which a community lives. Therefore communities are established autonomously by the community members, whereas neighbourhoods are administratively established by the government.

Community-based initiatives refer to operations that are limited to particular communities living in certain neighbourhoods. Anschütz further defined community-based waste management (CBWM) as the activities carried out by members of communities to clean up their neighbourhood and/or to earn an income from solid waste. Some examples are the collection of solid waste, the sale of recyclables, recycling and composting activities.

In the field of community studies, there are two main approaches in community-based activities, namely grassroot/informal initiation approach and top-down institutional/formal approach. In the field of waste management, ***grassroot/informal initiation approach*** refers to the activities that are initiated by the community members with autonomous resources. ***Top-down institutional/formal initiation approach*** refers to the activities that started by external support with provision of external resources to support the activities with expectations that the activities will prevail. Examples of grassroot / informal initiation of CBWM are those that are autonomously commenced by the members of neighbourhood units or clusters, whereas examples of top-down institutional/formal initiation approach of CBWM are pilot projects that are initiated and funded by the Ministry of Environment, universities, private sectors, donor agencies, etc.

The community-based initiatives can either be commenced autonomously by the community through grassroot / informal initiation approach, or by external top-down institutional/formal approach. External funding support currently exists, however it is these external institutions that selected which communities can have the support. The supports are in the forms of hardwares (sorting storages, land/space for waste storage, composter, etc); softwares (e.g. CBWM mechanism/system, information, knowledge, etc); and financing.

Panda (2007) defined bottom-up as an approach that emphasises local decision making, community participation and grassroots mobilisation/movements, whereas the top-down institutional/formal approach involves decision-making authorities such as government agencies. Macdonald (1995) stated that top-down institutional/formal approach uses external resources that plan, implement, and evaluate development programs. A set of strategies were outlined by Blanchard (1988) to operationalise the bottom-up approach, which included comprehensive community participation and localising financial access.

It was argued that the formalisation of ‘grassroot/informal approach’ through community involvement in environmental management projects has been driven by past failings of ‘top-down institutional/formal’ approach. This shift in emphasis still requires careful analysis of diverse case studies where there has been a move to involve communities in proposing and measuring sustainability indicators to analyse the extra benefits that the integration of top-down and bottom-up approaches achieve. Such a bottom-up approach matches the wider recognition of the need for active community participation in sustainable environmental management (Chambers, 1997, Pound et al., 2003, Fraser et al, 2006, Prabhu et al., 1999).

Taking into account existing definitions, this thesis defines **CBWM** as the waste management activities that are conducted by communities living within a certain neighborhood through grassroot/informal initiation approach, and/or top-down institutional/formal approach. Grassroot/informal CBWM is decided, managed, and organised autonomously by the communities. The community members would appoint a CBWM leader to be the decision makers and manager of the activities, together with several staff as part of the support system. The leader and staff are members of the communities. To the contrary, for top-down institutional/formal CBWM, the initiators are external actors that provide the funds and support. The external entity makes the decision for CBWM to be implemented in a certain location, appoints a leader in the community as the CBWM leader and manages the activities, as well as gives directions to organise the activities.

2.2. Community Based Waste Management (CBWM)

This section explains about the history and management of CBWM. The establishment of community participation mainly evolved to respond to the problems of maintenance of infrastructure and services in the 1980s and 1990s (Furedy, 1989; Anschütz, 1996).

In Indonesia, community-based activities became pervasive since the regional autonomy policy implemented by the government in 2001. With regional autonomy, the decision and policy making concerning regional development is decentralised. In other words, local governments have the authority to devise and implement policies. With regional autonomy, local governments are demanded to allow citizens to participate, including in waste management. The benefits of regional autonomy are that the local governments have understanding of local conditions, which would enable appropriate policy making. Local governments ideally have vested interest to preserve the environment, thus the decisions on waste management systems would be determined by taking into account the environment considerations in addition to economy.

CBWM are often established in developing countries with limited access to waste management services. But nowadays CBWM exists in urban areas as well. Several CBWM in Southeast Asian cities exist with the support from foreign governments. For instance in partnership with the Japan's Kitakyushu International Techno-cooperative Association, since 1990s the Surabaya municipality has started composting programme using 'Takakura method' by constructing compost houses to reduce organic waste (Kurniawan et al, 2013). In Vietnam, similar initiative was under the direction of JICA (Richardson, 2003).

There are many types of CBWM that use different types of waste treatment methods, e.g. biogasification, small-scale incineration, or composting. There are CBWM that employs both organic and inorganic waste management, and CBWM that either treats organic waste or inorganic waste collection.

As the term 3R becomes popular in the 1990s, Indonesians have adopted the principles to conduct CBWM. The first CBWM through ‘waste banking system’ was first established in 2008 in Jogjakarta. As of 2012, there are nearly 800 CBWM that were established in cities of Indonesia (BBC, 2012). In Jakarta, there are 94 areas that already operate CBWM. These areas can reduce waste of up to 485 ton per day, which is around 7% of the total waste generation (Cleansing Department, 2010b). CBWM implementation in Indonesia is challenging, due to the varied ethnicity and the socio-economic divergence. These issues are not yet explored in prior studies.

Standard management system of CBWM

Communities that conduct CBWM activities live within neighbourhoods, which are assigned administratively by the government. Jakarta was decided to be the focus of this study due to the following considerations:

1) Jakarta is an example of Asian city with increasing economic growth that results in the rapid growth in waste generation;

2) Currently most of the waste of Jakarta is disposed at Bantar Gebang landfill, which is planned to be closed in the next few years; and

3) Jakarta contains peculiar characteristic of diversity of ethnicities.

Jakarta province is divided into municipalities and regency, i.e. North Jakarta, Central Jakarta, East Jakarta, South Jakarta, West Jakarta, and Kepulauan Seribu regency (Seribu Island). Each municipality is subdivided into districts, which are split into wards, which are further divided into neighborhood clusters. In Indonesian language, the districts are called *Kecamatan* and the wards are called *Kelurahan*. The larger neighborhood clusters are called *Rukun Warga* (RW) and the smaller neighborhood units are called *Rukun Tetangga* (RT). See Fig.2.1 for the administration of Jakarta.

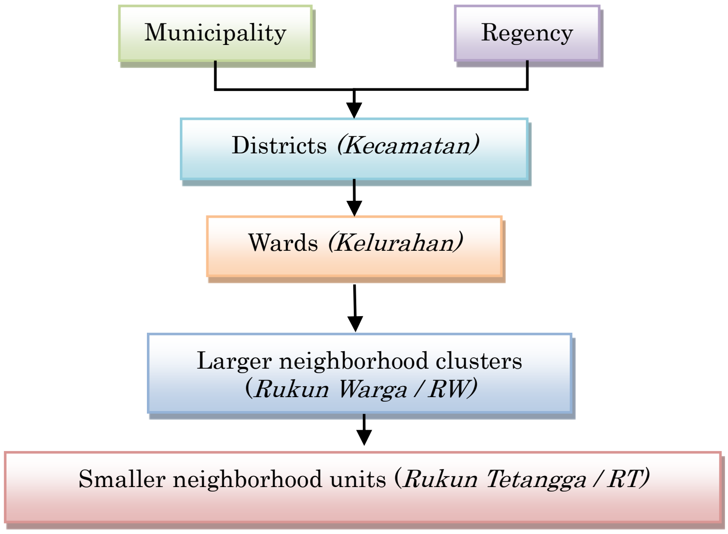


Fig. 2. 1 Local administrations in Indonesia

Based on field observation and discussion with the main actors of waste management in the community level, the typical management flow of CBWM waste management in Indonesia is presented in Fig.2.2.

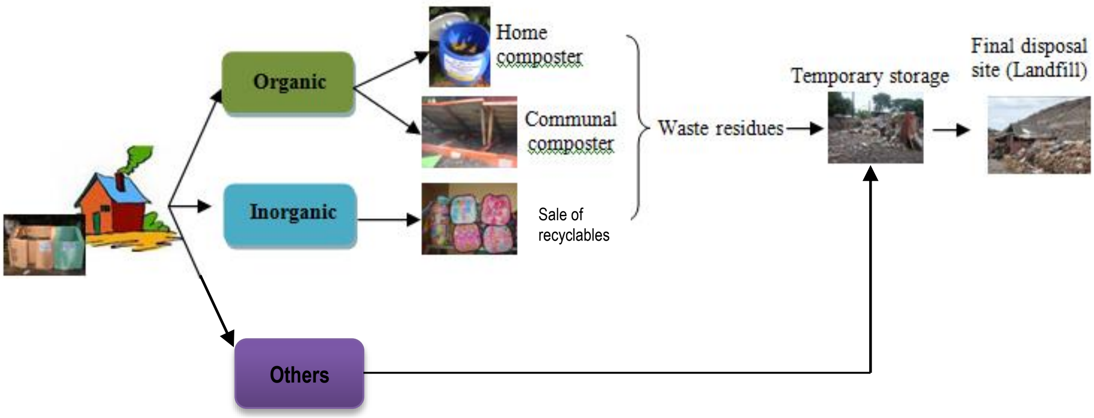


Fig. 2. 2 Household waste management flow in CBWM

For grassroot/informal CBWM, the system is designed and organised by the community, with the CBWM leaders as the decision makers and managers. The daily operations are managed by CBWM leaders with the help of subordinates, who are also the member of the communities. Activities include communal composting and sale of recyclables from householders to scrap dealers. The householders who are CBWM members are required to sort the waste at-source and to bring recyclables to the collection points. The waste transporters are employed and are not the members of the communities.

For top-down institutional/formal CBWM, external institutions that provide initial support design the system and authorise the CBWM leaders − who are originally members of the communities, to manage the daily operations. The CBWM leaders are responsible to recruit waste transporters and householders to take part in the CBWM.

Fig. 2.2 explains about three streams of waste from households, namely a) organic, b) inorganic, and c) others/scrap. These three types of waste are sorted at-source by the householders that participate in the CBWM. The organic waste is being composted by communal composter. Inorganic recyclable wastes are sold collectively. The other types of waste such as scrap, hazardous and chemical wastes are transported to the temporary storages and later disposed in the landfill. The rest-waste from composting and unsellable inorganic waste are transported to the temporary storages, which are later be transported and disposed at the landfill.

2.3. Waste Management Policies

Further to the implementation of regional autonomy policy, the government devised specific policies that encourage communities as potential to be involved. Regarding the policies on waste management, it is indicated that waste must be minimised and sorted at source. With regard to sorting and CBWM, because the initiatives are still voluntary, therefore not many communities adopt. The major regulation concerning household waste was enacted in 2012 during the course of study. Financing of SWM relies on the Regional Budgets and for Jakarta, the allocated funds for Cleansing Department is merely 2.9% of the total Budget.

This section presents about policies related to waste management in Indonesia. For CBWM to be implemented, householders and community participation are required. Citizen participation is an increasingly important factor in planning and development policies following the legislation for decentralisation in Indonesia. The capacity of citizens to plan and deliver services have immediate relevance as the country moves to a decentralised planning model following the two key pieces of legislation underlying this shift are Acts in 1999 and implemented in 2001. The enactment of these laws has changed Indonesia from a highly centralised state with governance, planning, and fiscal management partially `de-concentrated' to provincial government offices, to a decentralised state with autonomous power over these responsibilities delegated to lower levels of government. From a policy perspective, successful decentralisation rests on the assumption that householders as community members through their participation in civil society organizations will undertake many planning and service-delivery functions that are used to be the responsibility of various levels of government (Beard, 2005).

The same notion of decentralisation applies to MSW management in Indonesia, in which the laws that are devised by the state government are to be followed by regional regulations as guidelines for the technical implementation. Currently, the implementation of MSW management in Indonesia is not based on any specific guidelines or requires any regulations compliance since the policy formulation is still at inception. The follow up of the laws that should be translated into regional policies are still underway, which are expected to provide effective baseline for devising regional policy.

According to a Government Regulation in 2001, the regional government has the main authority to manage the wastes in their respective jurisdiction area (Jakarta Regional Government, 2010). The master plan of waste management in Jakarta is mainly based on two major laws: Law in 2008 and the Medium Term Development Plan Jakarta Province year 2007 – 2012.

In 2006, The Minister of Public Works issued a regulation was devised that addressed communities as potential to be involved in the waste management; however it has not been systematically developed. Under this regulation, there are several policies that were devised; such as the minimization of wastes optimally from the source and improvement of active roles of the society and private sectors as waste management partners. Further to this, the President of Republic of Indonesia enacted a law on Waste Management in 2008. According to the law, waste generation must be minimized at the source to reduce the burden of waste transport and treatment. The law also highlighted the importance of community in undertaking measures for waste reduction to minimize the burden of management and treatment. However, as these initiatives are still voluntary, not many communities are willing to apply the initiative.

The Government Regulation enacted in 2012 that serves as the regulation for implementation of waste management was issued following the Law in 2008 on waste management. It was released during the course of PhD study. The regulation is concerning the management of household waste and household-like waste. However the local policy is not yet made that specifically regulate the waste management at municipal level.

The financing of SWM largely relies on the Regional Budgets and based on the Regional Budget of Jakarta in 2010, the allocated funds for Cleansing Department is 2.9% of the total Budget (Jakarta Provincial Government, 2010).

Major urban centres in Indonesia produce nearly 10 million tons of waste annually that increases 2-4 per cent annually. It is predicted that by 2019, the volume of waste in Jakarta will exceed the design capacity of Bantar Gebang landfill (Cleansing Department, 2010). Bantar Gebang landfill is the main location for disposal of waste generated by Jakarta residents. It has been opened since 1980s to be the disposal site of around 6,000 tonnes of waste per day. However in 2015 a rift happened between the Bekasi members of parliament and the Jakarta governor, which resulted in the threat for closure of Bantar Gebang landfill. This political occurance, in addition to technical factors, resulted in the importance for Jakarta government to prepare for new waste management strategies due to the foreseeable closure of landfill.

Indonesia has large new and clean energy potential from waste methane extraction, which includes 50 gigawatt of biomass (Ministry of Energy and Mineral Resources, 2008). With regard to energy from waste, currently the government has generated 2 megawatt of energy, which is targeted at 26 megawatt by 2013 (Suara Pembaruan, 2010). Organic municipal waste is identified as one of the potential source of biomass energy. The types of wastes produced in Indonesia are mainly consists of organic matter (65%). The major sources for MSW are residential localities (Chaerul, 2006). Considering these facts, the waste in the landfill is mostly consists of household organic wastes that produce methane, therefore potential for energy generation.

To support the development of new and renewable energy, the government has issued several key regulations, consisting of Presidential Decree in 2006 on the National Energy Policy, Law in 2009 on Electrification, Law in 2007 on Energy, Law in 1985 on electricity, Government Regulations in 2005 and 2006 regarding the supply and usage of electricity, and Blueprint of National Energy Management 2005-2025. The government allocates IDR 144 billion (ca. US$ 16 million) for energy subsidies out of the total IDR 1,13 trillion (ca. US$ 125 million) of National Budget in 2010 (Government of Indonesia, 2010).

The current overall development of clean and renewable energy is regulated by the Presidential Decree in 2006 on National Energy Policy. This decree states that the contribution of new and renewable energy in the 2025 national primary energy mix is estimated at 17%, consisting of 5% biofuel, 5% geothermal power, biomass, nuclear, hydro, and wind, and also liquefied coal at 2%. The government will take measures to add the capacity of biomass of 180 MW by 2020 (Ministry of Energy and Mineral Resources, 2008). The specific regulations regarding the management of waste to energy is not yet in place (IEA, 2008). Jakarta municipal government is currently targeting 26 megawatt of energy generation from waste by 2013.

2.4. Conclusion

There are many alternatives to waste management, and one of the systems is community-based waste management (CBWM). There are currently top-down institutional/formal initiation approach and grassroot/informal initiation approach to implement CBWM. The system for grassroot/informal CBWM is designed and the activities are organised by the community members, with the CBWM leaders as the decision makers and managers. The daily operations are managed by CBWM leaders with the help of subordinates, who are also the member of the communities. The householders who are CBWM members are required to sort the waste at-source and to bring recyclables to the collection points. The waste transporters are employed and are not the members of the communities.

To the contrary, for top-down institutional/formal CBWM, external institutions that provide initial support would design the system and subsequently authorise the CBWM leaders, who are originally members of the communities, to manage the daily operations. The CBWM leaders are also responsible to recruit waste transporters and encourage householders to take part in the CBWM.

Prior studies suggest that grassroot/informal initiation approach is driven due to past failures of top-down institutional/formal approach. In terms of CBWM, this thesis will propose integration and present evidence for the preferred approach sequence as presented in chapter 5.

With regard to the existing waste management policies, there is a lack of clear policies to identify the preferred waste management system. The lack of blueprint in waste management system would have the possibility for conflict of feedstock for waste treatment facilities. For example, composting and anaerobic digestion systems both require organic waste as feedstock. Composting would result in compost as co-product; whereas anaerobic digestion would result in electricity as the co-product. However with the government's ambitious target of generating energy from waste, the amount of organic waste as feedstock needs to be estimated.

The implementation of waste management systems other than the business-as-usual landfilling would require at-sources sorting to ensure proper treatment. The state government regulation has stated the importance for households to sort, however this policy is not yet enforced through translation into local policies. Additionally, as Indonesian households are not yet accustomed to sorting, it is prerequisite to not only focus on policies but also awareness raising and education to enable proper at-source sorting.

CHAPTER 3: ECONOMIC EVALUATION OF HOUSEHOLD SOLID WASTE MANAGEMENT IN JAKARTA, INDONESIA

3.1. 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. The implication of these demographic changes is that the urban population will increase by 70% from 108 million in 2006 to 187 million over the next 25 years (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).

3.2. Aim of Study

This chapter aims to identify the preferred household SWM from the perspective of economy, through estimation of the economic cost and benefit, which was performed against the background of five predetermined MSW management systems. The non-BAU systems proposed by this study comprises of 75% of waste treated by systems and 25% of rest-waste are landfilled.

3.3. Systems for household solid waste management

Waste management systems 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 emission reductions project might involve, for example, landfill with gas collection (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 systems. The systems 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 system– 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).

Prior to defining the systems, field observations were conducted. The following flow chart for the waste management system in Jakarta is based on these observations:

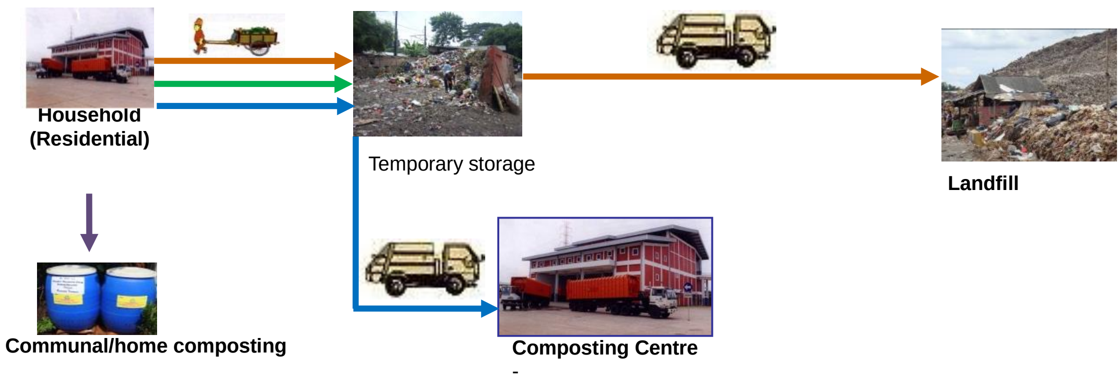


Fig. 3. 1 Flow chart of the household solid waste management system in Jakarta

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.

3.4. System boundaries

Understanding the system boundary of this study is essential in order to understand the result of evaluations. This would also enable other researchers to properly use this research approach for other studies.

The system boundaries for the economic and environment associated with GHG emission evaluations in this study are presented in Fig.3.2, which applies to chapter 3 and 4, respectively. The boundaries of the economic and GHG emission evaluations extend from the waste discharged from household, to transportation, waste treatment, co-products derived from waste, and transportation of co-products.

The cost estimations include the transportation costs (including energy and labour), waste treatment cost (including materials, labour costs), and revenues from co-products. The estimated GHG emissions are CH_4, N_2O, and CO_2. The estimated emissions were from the process of waste transportation to waste treatment facilities, emissions from waste treatment processes, and the avoided emissions from co-products.

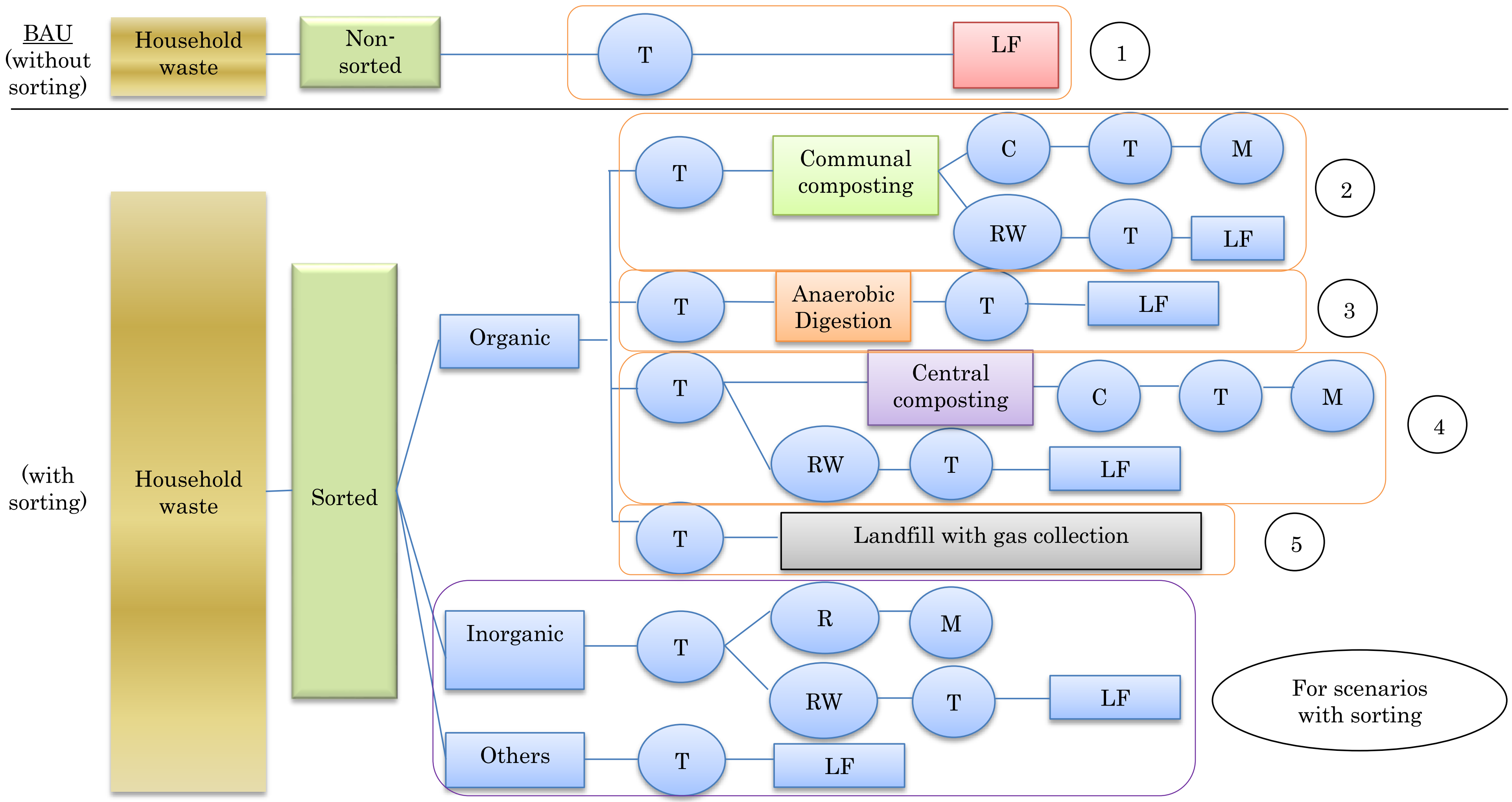
Discussions beyond the system boundary of this study include scavengers and recycling. The issue of scavengers is not included because the existing informal scavenging do not use safety measures, which jeopardised lives and health. Their roles can be shifted to other occupations within the system, e.g. as waste transporters or waste treatment operators, with the proper training. The issue of recycling technologies cost benefit and GHG emission is also not included in this study, because the technologies vary widely depending on the type of waste to be recycled.

3.5. Methodology

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 systems 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 with gas collection 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.

3.6. Sampling of respondents

A combination of stratified random sampling, cluster sampling, and proportionate random sampling methods was used to select the respondents. The sample used in this study was based on population demographics in Jakarta. The survey was designed to identify the features of waste collection, waste disposal systems and waste flows. The survey was conducted in central Jakarta, north Jakarta, west Jakarta, south Jakarta, and east Jakarta, which are the five municipalities of Jakarta.



(T: Transportation. LF: Landfill. RW: Rest Waste. C: Compost. R: Recyclables. M: Market)

Fig. 3. 2 System Boundaries of Evaluations on Economy and Environment Associated with GHG Emissions

For each of the system other than landfilling, in addition to the economic evaluation (in chapter 3) and GHG emission estimations (in chapter 4) of organic waste treatments; potential revenues and avoided emissions from sorted inorganic recyclables, and transportation of rest waste, were included in the estimations.

The appropriate size for the sample was determined with the help of a statistical formula for estimating proportions in a large population (Dennison et al., 1996 and Mc. Call, C.H. Jr., 1982). The households were divided according to 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).[3] The population numbers, which were previously divided according to 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 set at 100 respondents for each sub-district and income level combination.

3.7. Economic analysis

The economic analysis of the five systems distinguished here consists 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.The cost incurred is assumed to be the cost for the government.

3.7.1. Potential revenue from recycling of sorted recyclable waste

In addition to the economic evaluation for each of the systems, this study also estimates the potential revenue from sorted recyclable waste based on primary data on

[3]According to BPS Statistics Indonesia (2009), the percentage of the population of Jakarta with low, middle, and high income is 60%, 30%, and 10%, respectively. The annual average income of the low-income group is US$ 2,284, or IDR 20.6 million. The annual average income of the middle-income group is US$ 5,356, or IDR 48.2 million, and the annual average income of the high-income group is US$ 14,198, or IDR 127.8 million.

Table 3. 1 Potential revenue from recycling of recyclable waste in Jakarta (per 1,000 tonne of waste)

Waste category	Sub-category	Average selling price (US$ per kg)	Average quantity sold per household (kg per month)	Percentage	Fractions from 1000 tonne recyclables (tonne)	Potential revenues* (USD)
Paper and cardboard						
	Newspapers	0.17	3.57	22%	224.4	28,431
	Magazine	0.21	1.75	11%	110.1	17,173
	Carton boxes	0.25	4.43	28%	278.8	52,529
Plastic						
	Refuse plastic sacks	0.33	1.00	6%	62.9	15,724
	Plastic bottles	0.27	1.75	11%	110.1	22,493
Metal		0.45	1.04	7%	65.5	22,324
Glass		0.23	1.36	8%	84.8	14,755
Textiles	Used clothes and fabrics	1.04	1.00	6%	62.5	48,713
Total			15.90	100%	1,000	222,143

Assumption: 75% recyclables sold

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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 3.1.

Fig.3.3 depicts the potential revenue from sub-categories of sorted recyclable waste with the assumption that 75% of recyclables are recovered and sold, whereas 25% are disposed at the landfill. This figure shows that the potential revenue is the greatest for carton boxes followed by textiles, newspapers, and plastic bottles.

The field observations revealed that there are a vast number of carton boxes that are sold by householders to scrap dealers, waste buyers, and/or scavengers. The types of carton boxes sold include milk boxes, disposable food boxes, instant noodle containers, and goods containers. People in Jakarta tend not to have subscriptions to newspapers or magazines. Instead, they prefer to purchase individual copies, read the newspaper in the office, and watch the news on television or through internet.

If the total number of households in Jakarta is taken into account, the potential revenue from sorted recyclable inorganic waste is as presented in fig. 3.3.

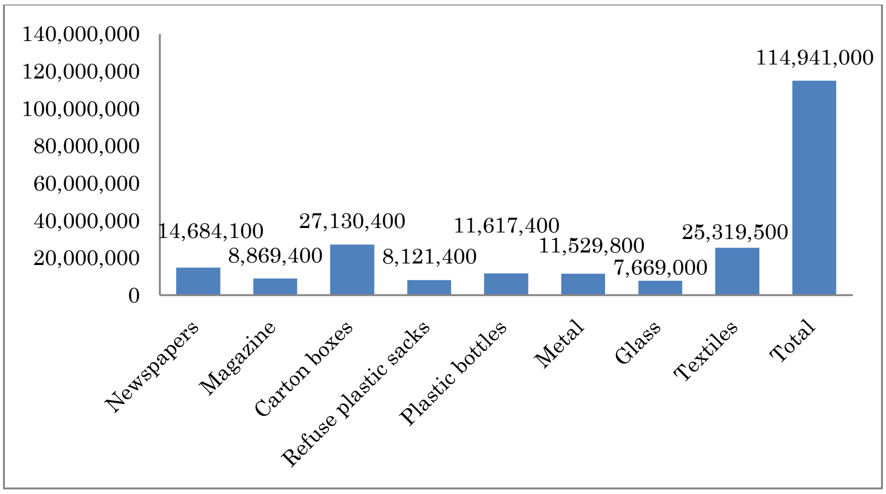

Fig. 3. 3 Potential revenue from sorted recyclable waste (US$ per annum)

This estimation revealed that the potential revenue from implementing waste sorting to recover recyclable waste amounts to nearly US$ 115 million per annum for the whole municipality of Jakarta.

3.7.2. Financial cost-benefit analysis of the waste management systems

The costs were estimated as follows:

$\mathbf{C_{ET}} = C_L + C_C + C_E + C_P + C_{OM} + C_T$, [1]

where C_{ET}= estimated total cost, C_L= cost of land acquisition, Cc = 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

$\mathbf{R_{compost}} = S_{compost} \times P_{compost}$ [2]

$\mathbf{R_{electricity}} = S_{electricity} \times P_{electricity}$ [3]

$\mathbf{R_{product}} = R_{compost} + R_{electricity}$ [4]

where

$R_{compost}$ = Revenue from compost (US$ per annum)
$S_{compost}$ = Selling price of compost (per tonne)
$P_{compost}$ = Production of compost (tonnes per annum)
$R_{electricity}$ = Revenue from electricity (US$ per annum)
$S_{electricity}$ = Selling price of electricity (US$ per kWh)
$P_{electricity}$ = Production of electricity (US$ 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:

$$\mathbf{p} = \frac{y}{(1+r)^t} \quad [5]$$

where
p = Value for the present year (2011)
y = Value for year i (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

3.6.1.1. System 1

The information on the quantity of waste disposed in the landfill is taken from a reference document, and the investment costs for System 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 system.

3.7.1.2. System 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 US$ 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 (US$ 127 per annum), the costs of fermentation chemicals (US$ 28 per annum), the purchase of additives, such as bran and molasses (US$ 14 per annum), packaging costs (US$ 11,294 per tonne per annum), and maintenance of the facility (US$ 85 per annum). The average production of compost is 706 tonnes per annum with an average revenue of US$ 118 per tonne.

3.7.1.3. System 3

The costs and benefits of System 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 GWh per annum and a selling price of US$ 0.10 per kWh.

3.7.1.4. System 4

The costs and benefits were estimated based on the data from JBIC (2008). The centralised composting in System 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 US$ 47,000 per tonne per annum with an average selling price of US$ 39 per tonne of compost.

3.7.1.5. System 5

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

3.7.1.6. Transportation

Fuel consumption costs are added into the cost estimate for each system. 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 US$ 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 (US$ per annum). The data were obtained from surveys with the waste transporters.

The total transportation cost is estimated as

$$\mathbf{C_T} = \Sigma\,(F_{con}\,.\,F_i) + (W_H\,.\,H_T\,/\,H_S) + (W_T\,.\,T_T)\;, \qquad [6]$$

where

C_T = Cost of transportation

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

F_i = Cost of fuel i (US$ per litre)

W_H = Wage for transporting waste from households to temporary storage (US$ 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 (US$ 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 US$ 1,115 per person per annum, whereas the average wage for transporting waste from temporary storage to waste treatment or disposal facilities is US$ 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:

$$\mathbf{C_T} = C_i / Q_i \qquad [7]$$

The total revenue per tonne of waste is estimated as

$$\mathbf{R_T} = R_i / Q_i \qquad [8]$$

where
C_T = Total cost per tonne of waste (US$ per annum)
C_i = Total cost per tonne of waste treated per system i (US$ per annum)
R_T = Total revenue per tonne of waste (US$ per annum)
R_i = Total revenue from system i (US$ per annum)
Q_i = Quantity of waste treated per system i (tonne per annum)

Table 3.2 elaborates on the parameters for each treatment method that are used for the economic estimations of this study.

Table 3. 2 Parameters for each treatment method

Treatment methods	Parameters	Values	Unit	References
Common parameters:	✓ Cost of construction labour	15% of investment cost		Ray, 1998; Tyagi et al, 2009; Sbioinformatics, 2002
	✓ Cost of O&M labour	15% of total physical O&M cost		
	✓ Electricity selling price	860	IDR per kWh	UNFCCC, 2009
	✓ System lifetime	10	years	Assumption
	✓ Annual rate	6.5%		Aye et al, 2006
	✓ Carbon price	12	USD per tonne of CO_2	UNFCCC, 2009
	✓ CH4 collection efficiency for landfill with gas collection	60%		Gikoko, 2009
	✓ Tipping fee for landfill	103,000	IDR per tonne	PT Godang Tua

	✓ Energy generated from organic waste Digesting 1 tonne of food waste can generate about 300 kWh of energy	300	kWh/tonne	NNFCC, 2009
Transportation	Distance to Landfill and Anaerobic Digestion sites from: Central Jakarta North Jakarta West Jakarta South Jakarta East Jakarta Distance to Composting Centre Cakung-Cilincing from: Central Jakarta North Jakarta West Jakarta South Jakarta East Jakarta Distance from Composting Centre to Landfill Distance from Composting Center to Market (PT Holcim) Distance to market of inorganic waste (Bekasi and Tangerang Waste amount per vehicle: Central Jakarta North Jakarta West Jakarta South Jakarta East Jakarta	 36.5 35.8 44.9 33 16.9 15.5 16 28.3 26.2 23.1 19.2 27.5 38.55 3.35 3.34 3.34 2.48 2.85	 km km km km km km km km km km km km km Tonne /vehicle Tonne /vehicle Tonne /vehicle Tonne /vehicle Tonne /vehicle	 map map map map map map map map map map map map map JBIC, 2008 JBIC, 2008 JBIC, 2008 JBIC, 2008 JBIC, 2008

The total cost and total revenue were estimated per 1,000 tonne of organic waste, for which the assumed system lifetime is 10 years. The investment cost of each system includes the cost of land acquisition, which was the actual cost of land acquisition in each area where the system takes place. The estimation of the investment costs of landfilling were adopted from the actual costs (PT Godang Tua, 2011), whereas the O&M cost were adopted from Aye et al (2006). The costs and benefits for communal composting options were estimated from local data gathered via interview with relevant stakeholders where the O&M include waste shredder fuel consumption, fermentation chemicals, additives (bran and molasses), packaging, and maintenance of facility. The costs estimations for central composting and anaerobic digestionwere adopted from JBIC (2008). The O&M of anaerobic digestion include maintenance of digester, combined heat and power (CHP) systems, and decanter centrifuge[4] to separate the digestate. The costs estimations for landfill with gas collection were adopted from actual costs (PT Gikoko Kogyo, 2009). GHG emission reductions were calculated in the preceding chapter in which the GHG emissions of each system were compared to the baseline system. At the time of that study, the price of grid electricity was on average about IDR 860 per kWh, or US$ 0.1 per kWh.

For each of the waste treatment systems, the economic analysis in this study accounts for the benefits from both greenhouse gas (GHG) emission reduction and co-products, such as electricity (for anaerobic digestion and landfill with gas collection systems); carbon credit (for all systems that have potential CO_2 savings, which does not include landfilling); and compost (for communal and central composting). The CO_2 savings were estimated in chapter 4 (see Table 4.6. GHG savings of systems compared to baseline landfilling system). The costs and benefits deriving from 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:

$$\mathbf{NPV_{cost}} = I + OM\,(1 - (1 + r)^{-t} / r) + T\,(1 - (1 + r)^{-t} / r) \quad [9]$$

$$\mathbf{NPV_{revenue}} = (R_p + R_{ghg}) \times (1 - (1 + r)^{-t} / r) \quad [10]$$

$$\mathbf{NPV_{benefit}} = NPV_{revenue} - NPV_{cost} \quad [11]$$

where

I = the investment cost (US$)

OM = operation and maintenance cost (US$ per annum),

T = transportation cost (US$ per annum)

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

Rghg = revenue from greenhouse gas reduction (US$ per annum)

r = annual rate (%)

t = project life time.

[4]Decanter is vessel to hold the decantation of a liquid which may contain sediment.

The cost and revenues for each system per 1,000 tonne waste are presented in Table 3.3.

Table 3. 3 Estimations of cost and revenue for each system per 1,000 tonne waste

	Scenario 1 / baseline (Landfill)	**Scenario 2 (Communal composting)**	**Scenario 3 (Anaerobic digestion)**	**Scenario 4 (Central composting)**	**Scenario 5 Landfill gas to Energy**
Investment cost					
Land acquisition	30,882	435,510	267,069	515,088	35,028
Construction	862,890	11,765	1,480,364	359,082	978,711
Equipment	5,003	882.4	643,052	552,848	312,987
Planning, design and engineering	151,161	22.1	261,996	331,932	31,971
Wage of construction labour	185,283	79,560	290,782	373,770	137,372
Wage of O&M labour	37,826	9,296	1,015,100	983,623	31,315
Physical O&M cost	217,117	52,676	5,752,233	5,573,863	1,061,696
Transportation	1,098	928.7	1,098	696,141	1,098
Revenue:					
Compost production	0	1	0	129	0
Selling price	0	117,647	0	39,862	0
Electricity production	0	0	300,000	0	180,000
Selling price (USD/kWh)	0	0	0.11	0	0.11
CO2 savings (tonne CO_2/1000 tonne waste)	0	460,982	497,362	460,766	409,308
Carbon price (US$/tonne CO_2)	0	12	12	12	12
Sales of inorganic recyclables (US$/1000 tonne waste)	0	222,143	222,143	222,143	222,143

Further, the estimations are conducted based on further the assumptions that:

- ✓ For landfill system, 100% of waste is unsorted and landfilled. For the other systems, sorting takes place where 75% of organic waste is treated and 25% are landfilled;
- ✓ 75% of of inorganic recyclables are sold whereas 25% are landfilled.
- ✓ The waste fractions from the total 1,000 tonne waste: 59% organic waste, 21% inorganic, 20% other waste (based on findings of waste survey for this study)
- ✓ For communal composting system, it is assumed that transportation to market is neglected because the composts are purchased by the community members within the neigborhood.
- ✓ The anaerobic digestion system is located within the landfill compound
- ✓ The cost incurred is for government, the revenue is for government and community members that can be allotted through profit sharing.

Based on the economic analysis, among all of the proposed systems, communal composting has the highest revenue ($4.6x10^6$ US$ per 1,000 tonne of waste). Landfill gas for electricity generation has the second highest revenue ($1.5x10^6$ US$ per 1,000 tonne of waste). The potential revenue from landfill with gas collection includes revenue from both GHG emission reductions projects and electricity generation. Other systems generated economic loss or negative revenue, such as central composting. 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 system are from the GHG saving through emission reductions projects and electricity generation that are sold to the grid. Landfilling system performs better than anaerobic digestion, however it does not generate any benefits.

All of the systems proposed in this study, except for landfilling system, 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 with gas collection, the material causes the total amount of gas produced to decrease (Muthuswamy, S. et al., 1990).

Table 3. 4 Cost and revenue evaluations (US$ per 1,000 tonne of waste)

	Organic waste				Inorganic recyclable waste			Other waste	**Total revenue**
	Cost of treatment	Transport to market	Transport to landfill	Revenue from compost or electricity	Transport cost to market	Transport cost to landfill	Revenue from recyclables	Transport to landfill	
Landfill (unsorted)	15x10^{5}	0	1.1x10^{3}	0	0	0	0	0	-1.5x10^{6}
Communal composting	3.7x10^{5}	0	0.6x10^{2}	5.2x10^{6}	0	2.8x10^{2}	3.4x10^{4}	0.8x10^{2}	4.6x10^{6}
Anaerobic digestion	4.3x10^{5}	0	0.9x10^{2}	1.7x10^{6}	1.2x10^{3}	2.8x10^{2}	3.4x10^{4}	1.3x10^{2}	-6.9x10^{6}
Central composting	4.1x10^{5}	1.9x10^{3}	1.3 x10^{2}	6.5x10^{6}	1.2x10^{3}	2.8x10^{2}	3.4x10^{4}	1.8x10^{2}	-1.8x10^{6}
Landfill with gas collection	1.1x10^{5}	0	2.7x10^{2}	3.7x10^{6}	1.2x10^{3}	2.8x10^{2}	3.4x10^{4}	0	1.5x10^{6}

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3.8. Discussion

Communal composting has the highest revenue, followed by landfill with gas collection system. It should be noted that the operation of landfill with gas collection, 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 subsidy on electricity tariff results in the uncompetitive selling price of electricity from these systems. Therefore when it comes to the revenue analysis, anaerobic digestion and landfill with gas collection systems 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 systems.

This result has slight difference from a study by Aye et al (2006) on traditional market waste that concluded composting in a centralised plant was found to be more economically beneficial than small-scale composting, followed by anaerobic digestion. This is because the nature of the small-scale composting for traditional market is unlike CBWM in residential areas with lower labour cost due to the voluntary nature.

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 observed constraints impacting 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 systems proposed in this study, except for the baseline system, 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 organic waste, 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.

Given the high potential revenue from the recovery of sorted recyclable inorganic waste in Jakarta of nearly US$ 115 million per year, proper sorting and management is required to prevent the loss of valuable materials at the landfill. Such a programme would also reduce the amount of waste disposed of at the landfill. Promoting at-source waste sorting is important; however, appropriate end-of-pipe technologies for the treatment of municipal solid waste are also required.

3.9. Conclusions

This study employs economic evaluation to measure household solid waste management systems. There are potential revenues from the selling of electricity, compost, and carbon credits through emission reductions projects, which were taken into account in the evaluation. Communal composting has the highest economic potential followed by landfill with gas collection system. Other systems such as central composting and anaerobic digestion would require substantial financial support from the government, particularly to cover investment and O&M costs. Although communal composting may seem as the most beneficial from the perspective of economy, there are several constraints in terms of land acquisition for composting facilities, labour and waging systems of composting operators, and the limited capacity of composting facilities.

This study suggests that the business-as-usual landfilling does not generate any benefit but have less cost than anaerobic digestion. Nevertheless, it is important to move beyond landfilling due to hygiene issue, land constraints, leachate, odours and public health issues. Thus for the implementation of improved waste management system moving from landfilling system, it would require sorting, either at-source or automated with sorting equipment at the waste treatment facilities. Sorting would have the potential to generate revenues from the recovery of sorted recyclable waste in Jakarta with nearly US$ 115 million per year. This untapped opportunity would be a fringe benefit for having improved waste management system and sorting that avoids recyclable materials to be disposed at the landfills.

CHAPTER 4: CHARACTERISTICS OF HOUSEHOLD SOLID WASTE MANAGEMENT AND ESTIMATION OF GREENHOUSE GAS EMISSIONS FOR WASTE MANAGEMENT SYSTEMS IN JAKARTA, INDONESIA

4.1. Introduction

Jakarta employs a major landfill, located at Bantar Gebang in the suburban town of Bekasi. The landfill only absorbs ca. 6,000 tonnes per day. Although it has been designed as a 'sanitary landfill', it is operated primarily on unsanitary landfill or open-dumping principles. The method of open dumping is a major source of environmental pollution. It has become increasingly difficult to identify new sites for disposal owing to public opposition, the cost of land, and the lack of appropriate land areas (Shekdar, 2009). Another pressing problem for waste management in Jakarta is overcapacity. The Bantar Gebang landfill operates over its design capacity of 4,500 tonnes/day (Pasang et al., 2007). However, it has been predicted that the volume of waste in Jakarta will reach 7,800 tonnes/day by 2019 (Cleansing Department, 2010).

Jakarta city contains the municipalities of East, South, North, West, and Central Jakarta and has an estimated 2,030,000 households (BPS Statistics Indonesia, 2009). The city's total area is 662 km^2, and its population density reaches 14,000/km^2. Jakarta is therefore categorised as the most densely populated region in Indonesia (Jakarta in Figures, 2009). The Jakarta municipal government, through its Cleansing Department, is responsible for Jakarta's solid waste disposal. However, it can only collect 91.5 percent of the city's garbage owing to its limited infrastructure and logistics. Currently, 94 areas in Jakarta follow the so-called '3R programme' (reduce, reuse, recycle) for waste management. Data furnished by the Cleansing Department (2010) indicate that these areas can reduce waste by as much as 485 tonnes per day, or approximately 7 percent of the total amount of waste generated.

Household waste is the largest fractions of municipal solid waste. The sources of municipal solid wastes in Jakarta are as follows (Cleansing Department, 2010): Households (52.97%); Commercial sectors (27.35%); Industrial sectors (8.96%); Schools (5.32%); Traditional markets (4%); Others (1.4%).

Waste reduction at-source is preferred to avoid waste generation, whereas recycling is useful for conserving resources and for preventing materials from entering the waste stream. However, the local governments in some Indonesian cities have not previously considered waste sorting as an aspect of waste disposal. A previous study by Supriyadi et al. (2000) identified several factors that contribute to the public's resistance to at-source waste sorting. These factors include: (i) the perceived low contribution of recycling towaste reduction; (ii) problems associated with collection; and (iii) relatively inexpensive landfills. Waste sorting at the moment is mostly performed by unorganised scavengers whopick up recyclable waste from household waste bins orat a temporary-storage facility. Other research has suggested that community-based waste management (CBWM) practices have demonstrated the possibility of active involvement of the community in reducing waste generation through various schemes.

Initiatives on proper municipal solid waste management and the promotion of at-source waste sorting have been quite successful in cities of the developed countries. In the developing countries, these types of initiatives are also emerging as an essential component of non-end-of-pipe and long-term solutions to the burgeoning solid waste problem. Studies by Charuvichaipong et al. (2005) identified the general assumption that waste sorting and proper waste management can only be applied in the developing countries through projects with financial supports from donors. Such projects may omit thorough consideration of the country's particular socio-political circumstances and traditions and of the specific characteristics of the waste produced. In some cities or regions, this may be the case if community waste management initiatives through 3R are financially supported by the private sector or international bodies. However, there are also instances of successful independent community initiatives in Jakarta that have used waste sorting as part of their autonomous CBWM.

4.2. Purpose of Study

The aims of this study are as follows:

1) To identify the preferred household SWM system from the perspective of environment associated with GHG emissions.

2) To compare the emissions from the systems and GHG emission savings compared with the baseline system of landfilling

3) To identify the potential GHG savings from the use of recycled materials instead of virgin materials that reduce the energy demands and non-energy GHG emissions associated with manufacturing.

This study hypothesed that “compared to the other systems, anaerobic digestion system emits the least GHG emission, followed by communal composting.”

4.3. Previous Studies

Waste management has to be designed in accordance with waste characteristics and quantities, and it must be compatible with prevailing operating conditions (Shekdar, 2009). Because waste management decisions are often made locally without concurrent quantification of GHG mitigation, the importance of the waste sector for reducing global GHG emissions has been underestimated. Flexible strategies and financial incentives can expand waste management systems to achieve GHG mitigation goals in the context of integrated waste management, local technology decisions are a function of many competing variables, including waste quantity and characteristics, cost and financing issues, infrastructure requirements including available land area, collection and transport considerations, and regulatory constraints (Bogner, J., 2007).

There are initiatives such as clean development mechanism (CDM) and attempts to reduce GHG emissions. Current projects in landfill with gas collection in Indonesia had taken the route to be part of the CDM mechanism by which the CO_2 emission that can be saved through emission reductions projects. To date emission reductions projects have been largely confined to schemes that control emission from landfill, but projects that avoid landfilling are beginning to be submitted (Barton, J.R., Issaias, I., Stentiford, E.I, 2007). This study therefore strives to identify the GHG emissions and potential emission savings or carbon reductions for several waste management systems compared to the baseline system of landfilling. The estimated GHG emissions will be taken into account to estimate the potential revenues that can be generated from the GHG emission savings from the implementation of waste management systems.

When it comes to deciding the policies and strategies on waste management, there are many aspects to be considered, such as the environmental aspects of the surrounding areas, i.e. hygiene issues of the cities, odour issues, and scenery issues. These are priorities to be considered when it comes to devising waste management policy systems. This study only addresses limited parts in terms of the environmental evaluation, namely GHG emission.

The aim of this study as presented by this chapter is to present findings based on the investigation of the detailed characteristics and quantities of waste. The estimation of GHG emissions for each waste management system is one of the factors considered for determining proper solid waste management system. The original aspect of this research is that the estimates of GHG emissions obtained by the study are based on novel primary data collected from field surveys conducted in households solely for the purpose of the research. Comparisons of waste management systems for Indonesia based on estimates of GHG emissions have not previously been conducted in Indonesia, although GHG emissions are directly proportional to the acceleration of climate change. The previous lack of attention to this topic is attributable in part to the tendency of developing countries to be concerned primarily with other aspects of the problem, such as cost, when they consider waste management systems.

Waste characterization studies are also used to assist in planning, policy development, and infrastructure sizing decisions for various facets of an integrated solid waste management programmes (California Integrated Waste Management Board, 1999). A number of studies and assessments of waste management systems have been extensively conducted in developed countries such as the UK (Parfitt, J.P., Lovett, A.A., Sunnenberg, G., 2001), Scotland (Collins, A., O'Doherty, R., Snell, M.C., 2006), USA (Staley, B.F., Barlaz, M.A., 2009; US EPA, 2010) and household waste surveys in Vietnam (Thanh, N.P., et al. (2010)) and at several cities in Japan such as Kawanishi city (2011); Kita city (2012); Kyoto city (s.a); Sendai city (2012); Sunigami city (2010);and Setagaya city (2012). There have also been studies to quantitatively and qualitatively examine the waste generated in developing countries. (Troschinetz, A.M., Mihelcic, J.R., 2009; Dhokhikah, Y.2012).

Quantification and characterisation survey have also been conducted in Indonesia for general municipal solid waste, although not specifically on household waste (Chaerul, M., Tanaka, M., Shekdar, A., 2007; Helmy. M., Laksono, T.B.. Gardera, D., 2006) and studies in several cities in Indonesia (JICA, 2008). There has also been a survey conducted on municipal solid waste in Bandung (Damanhuri, E., Wahyu, I.M, Ramang, R., 2009) and Surabaya (Trihadiningrum, Y., 2006). There were some studies that analyse the municipal waste management in Indonesia that focused on traditional waste (Aye, L., Widjaya, E.R, 2006). Another study compared between different systems for municipal solid waste management, using ORWARE simulations as the tool to analyze the material flows and environmental impacts (Trisyanti, D., 2004). It should be noted that the findings from these studies are incomparable to this study as the source of waste is not specifically from households.

There have been vast amount of prior studies that analyse household waste management in the developed countries. However such analyses that particularly focus on household waste management as the largest stream from which municipal solid waste derived are still lacking for developing countries with tropical climates, such as Indonesia. The general characteristics of tropical country include the year-round warm temperatures (all months have mean temperatures above 18°C or 64°F) and abundant rainfall (typical annual average exceeds 150 cm [59"] (Lyndon State College Atmospheric Sciences, s.a). Indonesia falls into the category of tropical country as the average temperature in Indonesia is 27.7 °C (82 °F). On average, there are 130 days annually on which occurs precipitation (rain, frozen rain/hail, or snow) with greater than 0.1 mm (Climatemps, 2012).The types of wastes produced in Indonesia are typical to those of developing and tropical countries, which mainly (65%) consist of compostable organic matter. The moisture content is also very high, typically in the range of 55-75 wt% (K. Maniatis, s. Vanhille, a. Martawijaya, 1987).

The difference between developing countries and developed countries is the different motivational factors for GHG accounting and reporting. Developing countries do not have a mandatory obligation to report GHG and there are less data and information for waste management in general and in particular for the quantification of greenhouse gases (Friedrich, E., Trois, C., 2011). The typical outcomes produced by assessments that result from research studies conducted in developed countries are not applicable and may well represent a different set of circumstances owing to the differences in climate and operational systems as well as the strong presence of informal sectors in waste management. As indicated above, household waste is the largest source of municipal solid waste. It is therefore necessary to analyse the disposal systems for household waste.

This study assesses the potential systems for the management of household waste handling in Indonesia by evaluating the emissions of GHGs associated with these systems. The estimates of GHG emissions in this study are based on the IPCC (2006) approaches. Of the six main GHGs that contribute to climate change and that are covered by the Kyoto Protocol, three types of gases that are associated with waste management and disposal are CH_4, N_2O, and CO_2. CH_4 and N_2O have a global warming potential 21 and 296 times greater than CO_2, respectively. Therefore, waste management systems 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 'greenhouse gases' (especially the former) and 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, D.A., et al., 1990), and landfills are thought to be a major source of methane.

4.4. Characteristics of household waste

4.4.1. *Material and methods*

One of the important elements of this study is to provide detailed information on waste composition to calculate estimates of GHG emissions. Detailed information on the composition of household waste is necessary to furnish the data required for these calculations. In this study, data on waste generation were collected by conducting a household waste survey. The methodology on which this survey was based is described in Thanh, N.P., et al. (2010); the target householdswere provided with colored transparent plastic bags of two kindsfor waste disposal. Households were requested to keep and separate their waste into "biodegradable wastes" and "non-biodegradable wastes". Biodegradable wastes and non-biodegradable wastes were collected, respectively, every day and every week.

In this study, the difference with the methodology used by Thanh, N.P., et al is that three types of different-coloured plastic waste bags were distributed to respondents to allow efficient waste sorting. The waste was measured by *weight,* not volume. This is because the wastes that are collected from temporary storages to treatment and disposal sites are delivered by using compactor trucks, thus minimise the volume. The waste was weighed on a scale measuring a minimum of one gram and the maximum capacity of each plastic bag was 20 kilograms. The waste was recorded as wet weight. Householders were requested to separate their waste as “organic waste”, “inorganic waste”, and “garden waste”. Organic wastes were stored in the orange plastic bags and were surveyed every day, whereas inorganic waste and garden waste were kept inside transparent and yellow plastic bags respectively, and were surveyed once every three days.The two-week survey was conducted from 27 February through 10 March 2011.

Fig. 4. 1 The different plastic bags for waste separation

A number of detailed waste classification schemes had been devised, for example by Warren Spring Laboratory UK (1994) that had analysed household waste using a 33-category classification. The European Recovery and Recycling Association (ERRA) had also proposed a hierarchical classification system, of which a simplified version of this classification was used as the basis for the LCI model by McDougall (2001).

As the estimation of GHG emissions employs IPCC (2006) approach, the survey for this research also used the IPCC waste categorisation with 11 categories of waste that comprise of 31 subcategories. The IPCC waste categorization is selected as it is an approach that is accepted internationally and the waste categorisation in line with the IPCC approach would facilitate the imputation of data figures.

Fig. 4. 2 Weighing the collected sorted waste

According to IPCC, waste composition is one of the main factors that influence the emissions from solid waste treatment; therefore waste composition survey is prerequisite.

4.4.2. 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.4.3 shows a map of Jakarta City and the locations of the target areas corresponding to the five municipalities. The survey was conducted in different locations throughout Jakarta because it is expected that the outcomes of survey from the five municipalities would serve as a representation of Jakarta as a whole.

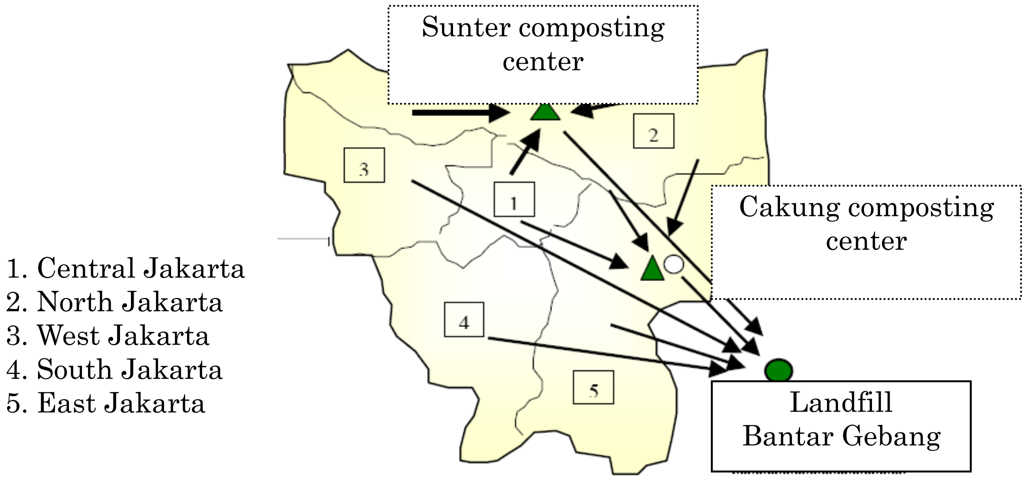


Fig. 4. 3 Waste Collection and Disposal Flow (JBIC, 2008)

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.[5]

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.

[5] 1 USD = 9,000 IDR

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):

$$n = \pi (1 - \pi) Z^2/\epsilon^2 \qquad [1]$$

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

$$k = \frac{N}{n} \qquad [2]$$

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. The decision regarding the number of respondents were taken by considerations of available limited funding and time for undertaking the survey.

4.4.3. Results

4.4.3.1 Waste generation rate and composition

Fig.4.4 shows the composition of the waste generated by households in Jakarta per category per year.

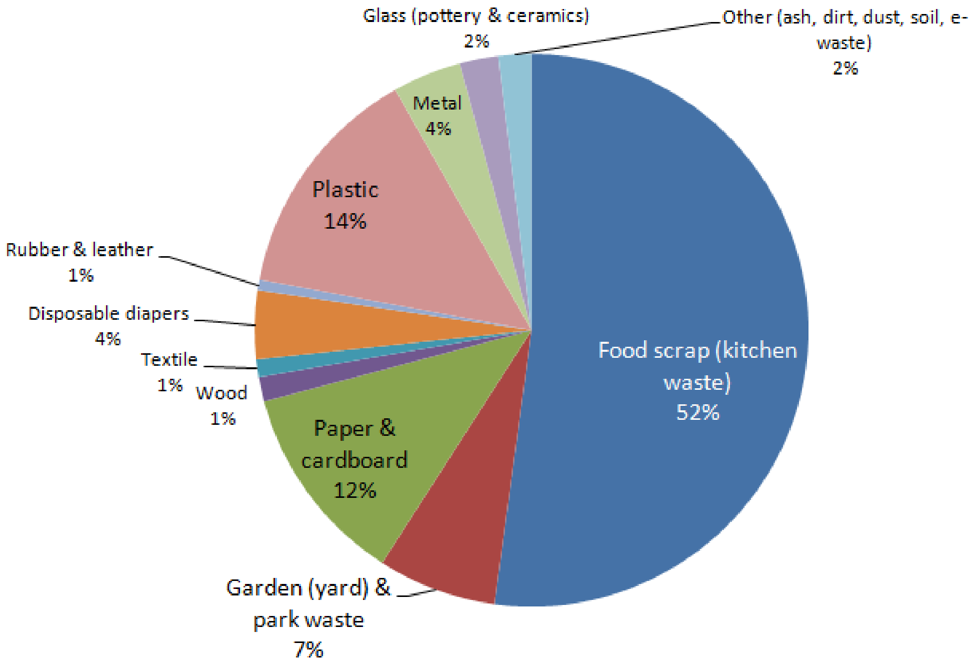


Fig. 4. 4 Composition of waste per category per year

The waste survey results indicate that kitchen waste represents greater than 50% of the total. This component of the waste can potentially be composted. Plastic (14%) is the second largest component, followed by paper and cardboard (12%), garden waste (7%), metal (4%), disposable diapers (4%), glass (2%), others (2%), rubber and leather (1%), textile (1%) and wood (1%).

This study also examines the detailed composition of household waste based on the IPCC (2006) characterisation. The average household solid waste generation in Jakarta was 1.32 kg per household per day, or 0.33 kg per capita per day given an average of 4 residents per household. The average amounts and percentage representation of the household waste according to the different waste categories are shown in Table 4.1.

The waste generation rate based on income levels are described in figure 4.5. Based on Fig.4.5 it shows that the average waste generation of high income groups are the highest with 1.67 kg/household/day (0.42 kg/capita/day), followed by the middle income groups with 1.42 kg/household/day (0.35 kg/capita/day).

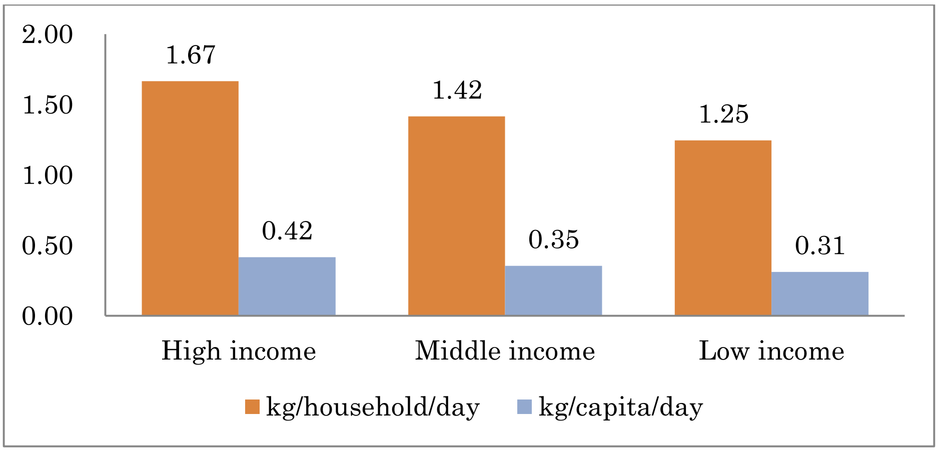


Fig. 4. 5 Waste generation rate per income level

The low income groups generate less waste with 1.25 kg/household/day (0.35 kg/capita/day). It should be noted however, that although the low income groups generate the least amount of waste, the percentage of low-income groups that reside in Jakarta is highest with 60% of all population, aside of the 10% of high income and 30% of middle income groups (BPS Statistics Indonesia, 2009).

As mentioned on the preceding section, there are existing waste surveys conducted bythe Ministry of Environment (2009), in the city of Bandung (Damanhuri, E., Wahyu, I.M, Ramang, R., 2009) and Surabaya (Trihadiningrum, Y., 2006). The study conducted in Bandung is for municipal solid waste, whereas the study in Surabaya was for household waste. The outcome of waste survey in Surabaya leads to the estimated municipal solid waste generation rate of 0.24 kg/capita.day. The average value of waste generation rate of the high income group that was higher than the other income groups (0.27 kg/capita/day), whereas the middle income group and the low income group generated 0.25 kg/capita/day and 0.19 kg/capita/day, respectively.

Although there had been prior waste surveys taken place in Indonesia, the approach and method used for undertaking these surveys were different from this study. This includes the household waste survey conducted in Surabaya. In the previous studies, the measurement and characterisation of waste as the activities of waste survey were conducted at the temporary storages and final disposal sites. However it is a known fact that the wastes that end up at the temporary storage and final disposal site are not specifically from households, but from other sources such as commercial sectors, schools, etc. Thus the results do not reflect the exact composition of waste from households. The detailed composition of waste from household is important to determine the estimated fraction of waste that can be composted, recycled, and for energy generation. Therefore to the author's knowledge, this study is the first survey of household waste in Indonesia that was conducted at households, which results in the better accuracy compared to the other existing waste surveys.

5.4.3.2 Potential for saving materials from disposal in the landfill

A number of waste classification categories are available, such as Warren Spring Laboratory UK (1994) and ERRA (1993), however the waste classification potentials were identified by Thanh, N.P., et al (2010b) with specification of waste based on compostability and recyclability. The latter classification with specification of waste based on compostability and recyclability is selected for this study. The "recycling potential" of waste materials is indicated by a classification that includes compostable, non-compostable, recyclable, and non-recyclable materials. The results for these categories are given in Table 4.1.

Table 4. 1 Waste categories, sub-categories and recycling potential

Waste category	Sub-categories	Kg/household/year	Percentage (%)	Recycling potential [a]
Food scraps (kitchen waste)	N/A	1,260	52	CO
Garden waste	N/A	167.6	7	CO
Paper & cardboard	Newspapers	64.7	2.7	RE
	Magazine	26.0	1.1	RE
	Other paper	79.2	3.3	NRE
	Card packaging	82.2	3.4	NRE
	Other card	32.5	1	NRE
Wood	N/A	34.7	1	NCO
Textile	N/A	24.8	0.9	NRE
Disposable diapers	N/A	96.9	4	NRE
Rubber & leather	N/A	14.9	0.6	NRE
Plastic	Refuse sacks	82.0	3.4	RE

Waste category	Sub-categories	Kg/household/year	Percentage (%)	Recycling potential [a]
	Other plastic film	4.7	0.2	NRE
	Clear plastic beverage bottles	57.8	2.4	RE
	Other plastic bottles	28.0	1.2	RE
	Food packaging	98.1	4	RE
	Other dense plastic	63.2	2.6	NRE
Metal	Steel beverage cans	16.8	0.7	RE
	Steel food cans	12.8	0.5	RE
	Batteries	6.0	0.3	NRE
	Other steel cans	3.2	0.1	RE
	Other ferrous metal	6.1	0.3	RE
	Aluminum beverage cans	40.9	1.7	RE
	Aluminum foil	6.6	0.3	RE
	Other non-ferrous metal	4.5	0.2	RE
Glass (pottery & ceramics)	Brown glass bottles	18.5	0.8	RE
	Green glass bottles	3.4	0.1	RE
	Clear glass bottles	27.2	1.1	RE
	Clear glass jars	4.7	0.2	RE
	Other glass	1.7	0.07	NRE
Other (ash, dirt, dust, soil, e-waste	N/A	46.4	1.9	NRE
Total		2,416	[b]	

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

[b] Percentages may not sum to 100 because figures were rounded up.

According to the above findings, household waste in Jakarta includes large amounts of compostables and recyclables. Compostable material accounts for 59 percent of all waste. Its composting potential is therefore high. An additional 21 percent of all waste is categorised as recyclable. The remaining 20 percent of household waste may be discarded in the landfill because it is non-compostable or non-recyclable. 17.7% of the total waste is NRE and 1% is NCO. 44% of the total inorganic waste is NRE.

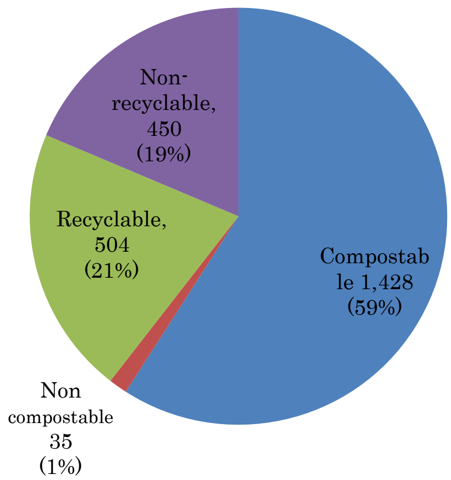


Fig. 4. 6 Potential for saving materials from the landfill through waste sorting

In comparison with other countries, data on waste generation are presented with the basis of socio-economic standing. For this purpose, the regional data are obtained from the developed nations as designated by the International Monetary Fund (2005) and availability of data. USA, Europe and Japan are selected to represent the developed nations. Fig.4.7 illustrates the difference of waste composition between developing countries and developed countries. The data on Jakarta waste generation is based on the finding of this study and represent developing countries in Asian region. The data on waste generated in Eastern Africa was selected among other regions featured by IPCC (2006) and is described here to represent the developing countries. The waste composition data from some developing countries featured in IPCC (2006) are incomplete and the fractions of waste for some countries did not add up to 100%. Thus the complete data available of developing countries among others is Eastern Africa, thus the selection of this country to represent developing countries. Meanwhile, USA (US EPA, 2010), Japan (Crume, R., Crume, Y., 2011;United Nations Environment Programme, 2006), and Europe (IPCC, 2006) serve to represent the developed countries.

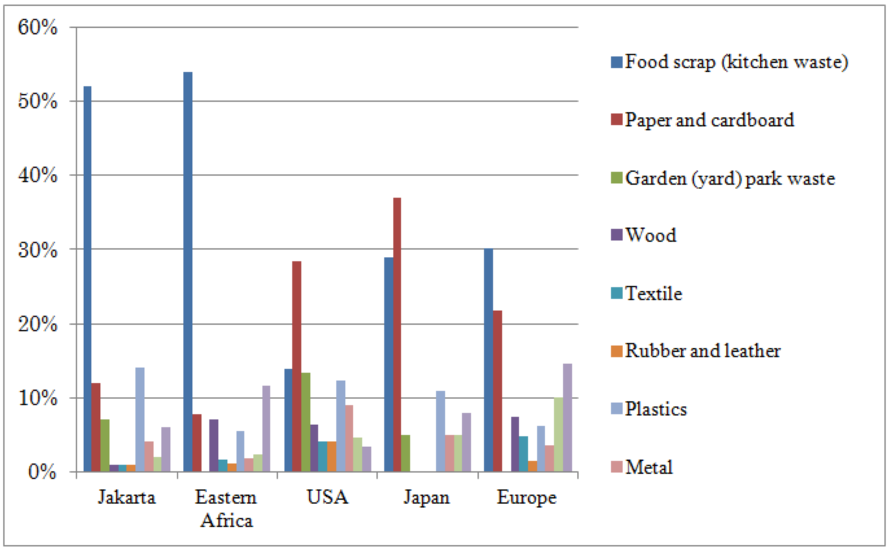


Fig. 4. 7 Comparison of waste fraction and categories

The data presented in Fig.4.7 all referred to general municipal solid waste, except for Jakarta and Japan. Waste composition comparisons between countries are often problematic due to inconsistencies in reporting. For example, reporting may address household wastes or alternatively the broader category of municipal wastes, weight or alternatively volume of waste (Crume et al, 2011). Also in Fig.4.7 the data from Japan did not present the waste categories of wood, textile, and rubber and leather. It is likely that wood is categorised as garden (yard) waste, whereas textile, rubber and leather are under the category of 'others'.

Despite these inconsistencies, developed countries generally have a similar mix of paper, plastics, metals, and glass, and organic matter in their household municipal wastes (Crume et al, 2011). Some argues that high-income households generate more inorganic material from packaging waste, whereas low-income households produce more organic material due to preparing food from base ingredients (Wells, 1994; Troschinetz, A.M., Mihelcic, J.R., 2009).

Based on the comparison as presented in Fig.4.7, developing countries tend to produce more organic waste, namely food scrap (kitchen waste) whereas developed countries produce less. Meanwhile, a prominent feature of difference between the waste generated in developed countries is the high amount of recyclables such as paper and cardboard compared to developing countries. This could be due to the high consumption of packaged goods, which lead to the waste of packaging made of paper and cardboard. In the case of household waste in Jakarta, less paper is generated due to two reasons: 1) the lower consumption of packaged goods; and 2) the general householders in Jakarta tend not to have subscriptions to newspapers or magazines that would eventually result in the generation of paper waste.

4.5. Comparison of GHG emissions for different systems

As previously stated, an objective of this study is to evaluate the GHG emissions from each waste management process system. The evaluation of GHG emission is indeed very complex; however this study attempts to evaluate the GHG emission within the system boundaries, which are estimated from the treatment methods to final disposal of wastes. However the energy driven from the biogas treatment either for thermal or electricity back to the facilities is not included due to the confidential nature of the data that could not be revealed by the waste treatment operator. Before these systems were defined, field observations were conducted. These observations produced the following flow chart for the waste management system in Jakarta:

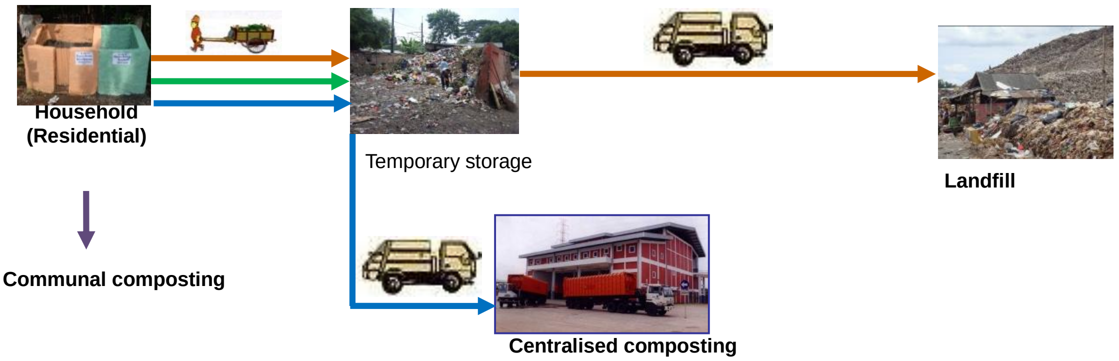


Fig. 4. 8 Flow chart for the household solid waste management system in Jakarta

Temporary storage is established to reduce the hauling distances for collection trucks, thus lowering transportation costs. It can be categorized as depot, which is an area that is also used to store hand carts to transfer the waste to the garbage trucks; waste handcarts base that is usually located on the side of the road; transship site; and waste collection point made of concrete. There are 1,478 temporary storages available in Jakarta (Cleansing Department, 2006). On the temporary storage, the wastes are transferred to waste trucks, which are operated by manual labour or shovel loader. The wastes are then transported to the composting centres or landfill. There is no intermediate treatment at these transfer stations; however transport efficiency to the disposal site is increased (Pasang, 2007).The system boundary of waste treatment in this study is as presented in Chapter 3, which comprised of the treatment methods to final disposal of wastes. The GHG emissions from waste treatment are difficult to be estimated and very complex in nature. It includes the methane gas that is captured and the transportation of waste to treatment facilities and final diposal, but not the GHG emissions and energy driven from the captured methane for thermal or electricity back to the facilities. This is due to the confidential nature of data that could not be revealed by the waste treatment operator. The waste management systems are presented in Fig.4.9.

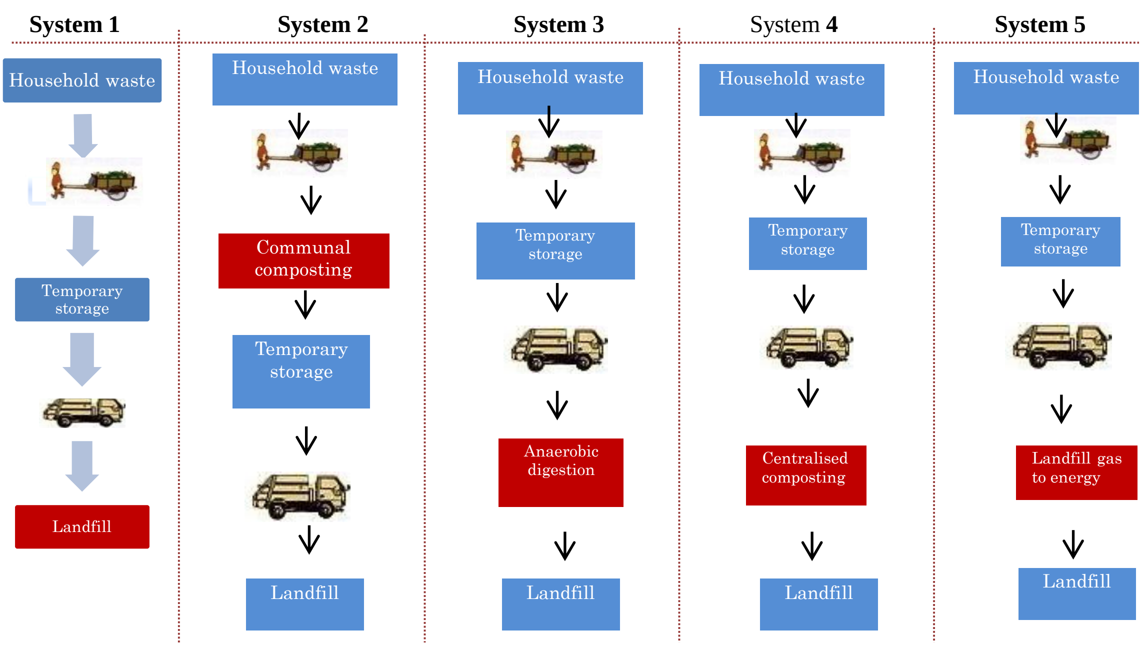


Fig. 4. 9 Household solid waste management systems

The boundaries of the GHG emission evaluations extend from the waste discharged from household, to transportation, waste treatment, and avoided emissions from co-products.

The GHG emissions estimated are CH_4, N_2O, and CO_2; from waste transportation to waste treatment facilities, emissions from waste treatment processes, and avoided emissions from co-products. The estimations include the emissions from transportation, waste treatment, and avoided emissions from co-products.

Discussions beyond the system boundary of this study include scavengers, recycling, residual waste treatment, and transportation of co-products to consumers.The electricity used for waste treatment is not estimated in this study because the data required for such estimation could not be obtained through primary surveys with stakeholders due to the confidential nature of such information.

Table 4. 2 Parameters for each treatment method

Treatment methods	Parameters	Values	Unit	References
Landfilling	Methane Correction Factors (MCF)	0.6	- -	IPCC, 2006
	Fraction of degradable organic carbon dissimilated (DOC_F)	0.6	- Gg/year	idem
	CH_4 fraction in landfill gas (F)	0.5	Fraction	idem
	Recovered CH_4(R)	0		idem
	Oxidation factor (OX)	0		idem
	Electricity consumption	6.38	MWh/Gg	Dote et al, 1999
	Diesel consumption	0.763	kL/Gg	idem
Composting	Emission Factor (EF)	4	GgCH4/kg waste	IPCC, 2006
	Total amount of CH4 recovered in inventory year (R)	0 50%	GgCH4	idem Johnson, G.V. et al,
	Nitrogen fertilizer response	40%	-	2003
	Percentage of compost produced from total amount of waste treated	13.4	-	Dept. of Environment, Community &Local
	N_2O emission from chemical fertilizer production		kg-N2O/kg-N	Government, 2012 Kramer, K.J et al, 1999
	Electricity	50	MWh/Gg	Sakai et al, 2005
	Diesel	0.30	kL/Gg	Advanced Scientific Technology & Management, 2010
Anaerobic Digestion	Emission Factor (EF)	1	GgCH4/kg waste	IPCC, 2006
	Recovered CH_4 (R)	0	Gg/year	Idem
	Electricity consumption for digestion	357.5	MWh/Gg total solids	Advanced Scientific Technology &

	Electricity consumption for waste water treatment	32.54	MWh/Gg-waste water	Management, 2010 Idem
Landfill with gas collection	Landfill gas collection rate Low heating value (LHV) CH_4 Gas engine efficiency MCF GHG emission unit by fossil fuel consumption for electricity production	60% 50.26 37% 0.8 0.841	- GJ/t - - t-CO_2/MWh	Gikoko Kogyo, 2009 IPCC, 2006 Advanced Scientific Technology and Management, 2010 IPCC, 2006 World Energy Council, 2010
Common parameters: ● Energy conversion factor ● Global warming potential ● DOC Content ● Emission ● Moisture content (% wet-waste) ● Nitrogen (%-dry-waste) ● Diesel	✓ Conversion factor for primary energy ✓ Conversion factor for secondary energy ✓ GWP $_{CH_4}$ ✓ GWP $_{N_2O}$ ✓ Food ✓ Paper ✓ Wood ✓ Textile GHG emission from electricity production ✓ Food ✓ Paper ✓ Wood ✓ Textile ✓ Food ✓ Paper ✓ Wood ✓ Textile	9.36 3.6 23 296 15% 40% 43% 24% 0.841 60% 10% 15% 20% 3.09 0.23 0.84 2.92 0.30	GJ/MWh MJ/kWh - - - - - - t-CO_2eq/MWh - - - - - - - - kL/kg waste	World Energy Council, 2010 McDougall et al, 2009; IPCC, 2006 IPCC, 2006 idem idem idem idem IPCC, 2006 idem idem idem idem idem idem IPCC, 2006 idem idem idem Advanced Scientific Technology & Management, 2010
Transportation	Distance to Landfill and Anaerobic Digestion sites from: Central Jakarta North Jakarta West Jakarta South Jakarta East Jakarta Distance to Composting Centre Cakung-Cilincing from: Central Jakarta North Jakarta West Jakarta	 36.5 35.8 44.9 33 16.9 15.5 16 28.3	km km	map map

	South Jakarta	26.2		
	East Jakarta	23.1		
	Distance to Landfill from Composting Centre	19.2	km	map
	Diesel fuel efficiency	0.328	L/km	Mc Dougall et al,
	Amount of waste per		Tonne /vehicle	2009
	vehicle:	3.35		JBIC, 2008
	Central Jakarta	3.34		
	North Jakarta	3.34		
	West Jakarta	2.48		
	South Jakarta	2.85		
	East Jakarta	38.14	MJ/L	
	Fuel heating value (diesel)			Mc Dougall et al,
	GHG Emission coefficient:	72.1	g/MJ	2009
	CO_2	0.003	g/MJ	
	CH_4	0.002	g/MJ	Mc Dougall et al,
	N_2O			2009
	Emission from			idem
	transportation			idem
	CO_2	1,650,779	kg/year	IPCC, 2008
	CH_4	69	kg/year	idem
	N_2O	46	kg/year	idem

4.5.1. Systems Constructed

This study compares five systems (see Fig.4.8) for handling waste from households in Jakarta. The current operation of landfill use (open dumping) was included in the baseline business-as-usual (BAU) system for comparison. As the incineration of waste is largely not feasible in non-OECD countries, due to cost and frequently unsuitable waste composition (UNEP, 2002), incineration is not included in the systems in this study.

The assumption used in this study is that the majority of the organic waste (75%) is treated with the waste treatment method or technology characteristic of the particular system (i.e. landfill, communal composting, anaerobic digestion, centralised composting, and landfill with gas collection). The rest of the organic waste that cannot be treated is disposed of in the landfill. The fraction of inorganic waste is disposed of in the landfill. Scavengers, part of the informal sector, play a role in sorting waste and extracting usable materials, such as metal and paper.

For the GHG emission estimation for recycling, it is done through the estimation of emissions saved due to the use of recycled materials instead of virgin materials reduces the energy demands and non-energy GHG emissions associated with manufacturing. The reduction in GHG emissions is the result from the use of recycled materials instead of virgin materials (Chen et al., 2008). However there are further considerations on the estimation of GHG emissions from recycling, namely the technology used in recycling, which determine the amount of GHG emission generated from it. Therefore the system boundary of this study does not include recycling of inorganic waste, but instead estimated the potential savings of GHG emissions from the use of recycled materials instead of virgin materials.

4.5.2. Methods

As previously stated, this study aims to estimate the GHG emissions from different systems of waste treatment. To reach the objectives, the IPCC approach for estimating the GHG emissions from landfill waste is employed.

The IPCC Guidelines for National Greenhouse Gas Inventories that covers the topic of waste offers methodological guidance for the estimation of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from the following categories:

- Solid waste disposal
- Biological treatment of solid waste

As the case for anaerobic digestion, the assumptions on the waste treated by composting is that the moisture content is 60%. The emission factors for dry waste are estimated from those for wet waste assuming moisture content of 60% in wet waste.

4.5.2.1. Landfill

The IPCC guidelines present formulae for the calculation of the estimated emissions of CH_4 from landfills. The first-order decay (FOD) method is used for these calculations. In this research, the GHG emissions are estimated for one year, and the primary data obtained from the field survey are used to obtain the estimated GHG emissions. The GHG emissions from the landfill waste are determined from the equation

$$CH_4 Landfill = (\sum MSW_i \times DOC_i) \times MCF \times DOCF \times F) - R \times (1 - OX) \times 16/12 \qquad [3]$$

where MSWi is the total MSW generated in the inventory year, DOCi is the degradable organic carbon, MCF is the methane correction factor in year x (fraction), DOCF is the fraction of degradable organic carbon dissimilated, F is the CH_4 fraction in landfill gas, R is the amount of CH_4 recovered, and OX is the oxidation factor (fraction).

4.5.2.2. Communal Composting and Centralised Composting

According to IPCC (2006), composting is an aerobic process, and a large fraction of the degradable organic carbon (DOC) in the waste material is converted into carbon dioxide (CO_2). CH_4 is formed in anaerobic sections of the compost, but it is oxidised to a large extent in the aerobic sections of the compost. The estimated CH_4 released into the atmosphere ranges from less than 1 percent to a few per cent of the initial carbon content in the material. Composting can also produce emissions of N_2O. The range of the estimated emissions varies from less than 0.5 percent to 5 percent of the initial nitrogen content of the material.

This research covers two types of composting processes, namely communal composting and centralised composting. The communal composting is usually performed following the collection of sorted organic waste. The waste is treated with a communal composter. Centralised composting is performed at a central composting facility. This facility receives the waste from the surrounding area. The sources of the waste are not necessarily close to the facility. The collected waste is transported by garbage trucks. The collection and transportation of the waste are coordinated by the Cleansing Department. The primary difference between communal composting and centralised composting, as discussed in this research, is the transportation of waste from the residential areas to the composting facility and the subsequent transportation of the residual waste from the composting facility to the landfill. The CO_2 emissions generated by waste transportation were incorporated in the analyses.

The amounts of organic waste for each waste category are shown in Table 4.3.

Table 4. 3 Organic waste

Categories	**MSWi (Gg)**
Paper/cardboard	113.7
Food:	587.1
Textiles	9.7
Wood	12.6
Garden waste	58.3
Disposable diapers	40.7
Rubber & leather	5.4
Total	**827.4**

The GHG estimates based on the above categories are used for the calculation of total GHG emissions in the following formulae:

$$CH_4 emissions = \sum_i (M_i \times EF_i) \times 10^{-3} - R \quad [4]$$

$$N_2O emissions = \sum_i (M_i \times EF_i) \times 10^{-3} \quad [5]$$

where Mi is the mass of organic waste treated by composting (Gg), EFi is the emission factor for composting, and R is the total amount of CH_4 recovered during the inventory year.

The avoided emission from chemical fertilizer production is estimated through the nitrogen emissions from chemical fertilizers, as follows:

$GHG_{avoid} = N_2O_{content}$ x %-compost x Mi

where GHG_{avoid} is the avoided GHG emission, $N_2O_{content}$ is the nitrogen content in waste, %-compost is the percentage of compost produced from total amount of waste treated, which is assumed at 40% (Department of the Environment, Community and Local Government, 2012), and Mi is the amount of waste type I composted.

The nitrogen content in waste is determined with the following formulae:

$$N_2O_{content} = \sum_i (M_i \times N_{wet} xNFR / 100) \quad [6]$$

where $N_2O$is the Nitrogen content in waste (Gg-N/Gg waste), Mi is the amount of waste type i composted (Gg), N_{wet} is the percentage of nitrogen in wet waste, NFR is the nitrogen fertilizer response. The NFR is at 50% (Johnson, G.V. et al, 2003).

To determine the percentage of Nitrogen in *wet* waste the following formulae is used:

N_{wet} = %-dry x (100 - %-wet) / 100 [7]

where N_{wet} is the percentage of N_2O, %-dry is the percentage of moisture content in dry-waste, %-wet is the percentage of moisture content in wet waste.

The avoided GHG emission from chemical fertilizer does not include the transportation of fertilizer to the consumers nor the fossil fuel consumption during the fertilizer production processes.

4.5.2.3. Anaerobic Digestion

The anaerobic digestion of organic waste accelerates the natural decomposition of organic material without oxygen by maintaining the temperature, moisture content and pH close to their optimum values (IPCC, 2006). Anaerobic digestion is defined as the anaerobic decomposition of organic wastes to produce biogas (methane and carbon dioxide) and biosolids (digestate). An anaerobic digestion system may reduce GHG emissions because it captures the methane from waste that might otherwise be released into the atmosphere as a potent greenhouse gas. The technology may contribute to the development of clean energy because the captured methane can be used as an energy source to generate electricity (Bracmort, K., 2010). It is a waste management technology practised by both developing and developed countries (E. Friedrich et al., 2011).

Emissions of CH_4 from such facilities due to unintentional leakages during process disturbances or other unexpected events will generally be between 0 and 10 percent of the amount of CH_4 generated. In the absence of further information, 5 percent was used as a default value for the CH_4 emissions. Where technical standards for biogas plants ensure that unintentional CH_4 emissions are flared, CH_4 emissions are likely to be close to zero. N_2O emissions from the process are assumed to be negligible; however, the data on these emissions are very scarce.

In Indonesia, anaerobic-digestion technology is primarily found in pilot demonstration projects and in experimental research on the treatment of agricultural waste and waste from animal husbandry. Many biogas-technology research activities are performed by research centres and universities in Indonesia. The raw materials used for biogas production are agricultural wastes, ranging from animal manures to a diverse selection of crop residues. However, the number of biogas digesters installed has not increased significantly, owing to the high capital costs required. In addition, kerosene has been relatively inexpensive, owing to government subsidies for commercial energy (Ishizuka et al., 1995).

The GHG emissions from anaerobic digestion and composting are obtained from the following formulae:

$$CH_4 emissions = \sum_i (M_i \times EF_i) \times 10^{-3} - R \qquad [8]$$

$$N_2Oemissions = \sum_i (M_i \times EF_i) \times 10^{-3} \quad [9]$$

where Mi is the mass of organic waste treated by anaerobic digestion (Gg), EF is the emission factor for anaerobic digestion, and R is the total amount of CH_4 recovered during the inventory year.

The analyses of composting and of anaerobic digestion use the same formulae for the calculations of GHG emissions. However, the emission factors for the two types of waste treatment have very different values. The CH_4 and N_2O emission factors for composting are 4 g CH_4/kg waste treated and 0.3 g N_2O/kg waste treated, respectively. However, the CH_4 emission factor for anaerobic digestion is 1, and the N_2O emission factor is very small and can be assumed negligible. The global warming potential for a 100-year time horizon is 23 for CH_4 relative to CO_2, whereas the corresponding value for N_2O relative to CO_2 is 296.

The anaerobic digestion is assumed to have the gas collection efficiency of 60% (UK Department of Energy & Climate Change, 2013; US EPA, 2010). The GHG emissions that are captured by taking into account the gas collection efficiency can be calculated with the following formulae:

$$GHG\ emission = CH_{4\ i} x\ Cef_i\ x\ q \quad [10]$$

where $CH_{4\ i}$ s the amount of methane generated from the fraction of waste treated with method i (which is anaerobic digestion), Cef_i is the gas collection efficiency of method i and q is 44/12 or the conversion from MTCE to $MTCO_2e$.

The avoided GHG emission (GHG emission reduction) from energy recovery was estimated as follows:

$$GHG_{emission} = E_{produced}\ x\ GHG_{electricity}\ x\ LFG_{coll}\ x CH_{4cont} \quad [11]$$

where $E_{produced}$ is the electricity produced and $GHG_{electricity}$ is the GHG emission unit on fossil fuel consumption for electricity production, which is assumed at 0.841 t-CO2/MWh (World Energy Council, 2010), LFG_{coll} is the landfill gas collection rate that is set at 90%, and CH_{4cont} is the methane content in the landfill gas that is set at 60% (Bastian, L., Yano, J., Hirai, Y., Sakai, S., 2013).

Whilst the produced electricity was estimated with the following formulae:

$$E_{produced} = EM_{CH4} \times LFG_{coll} \times CF / (1-CH4_{coll}) \times GE_{eff} / C \quad [12]$$

where $E_{produced}$ is the produced electricity, EM_{CH4} is the CH4 emission, LFG_{coll} is the LFG collection rate, which is assumed at 90%, CF is the conversion factor for secondary energy that is set at 3.6 MJ/kWh (IPCC, 2006), GE_{eff} is the gas engine efficiency that is set at 37% (Advanced Scientific Technology and Management et al, 2010), and C is conversion factor for secondary energy that is set at 3.6 MJ/kWH (IPCC, 2006).

To estimate the emission of CH4 the following formulae was used:

$$EM_{CH4} = \Sigma M_i \times DOC \times MCF \times (1-OX) \times F/12 \times 16 \times (1-LFG_{coll}) \quad [13]$$

where M_i is the amount of waste type i treated, DOC is the Degradable Organic Carbon, MCF is Methane Correction Factor, OX is Oxidation Factor, F is the CH_4 fraction in landfill gas set at 0.5 (IPCC, 2006), and LFG_{coll} is the LFG collection rate that is set at 90%.

4.5.2.4. Landfill with gas collection

Taking into consideration the system of landfill gas generation to energy, there are assumptions that were taken by previous studies on the methane gas collection efficiency. US EPA (1998) and Wanichpongpan, W., Gheewala, S.H (2007) assumed a collection system with a gas collection efficiency of 75%; Mendesa,M.R., Aramaki, T., Hanaki, K (2004) assumed that 50% of the landfill gas is collected so in other words, 50% of the methane gas is released to the atmosphere; Jaramillo, P., Scottmatthews, H (2005) assumed collection efficiency of 85%. This study used the assumption that 60% methane is assumed as gas collection efficiency (Gikoko, 2009).The GHG emission savings from methane capture can be calculated with the following formulae:

$$GHG\ emission = CH_{4\ Landfill} \times Cef_i \times q \quad [14]$$

where $CH_{4\ Landfill}$ is the amount of methane generated from the landfill, Cef_i is the gas collection efficiency of treatment i (which is landfill with gas collection) andq is 44/12 or the conversion from MTCE to $MTCO_2e$.

The avoided GHG emission (GHG emission reduction) from energy recovery was also estimated as follows:

$$GHG_{emission} = E_{produced}\ x\ GHG_{electricity}\ x\ LFG_{coll}\ x CH_{4cont} \qquad [15]$$

where $E_{produced}$ is the electricity produced and $GHG_{electricity}$ is the GHG emission unit on fossil fuel consumption for electricity production, which is assumed at 0.841 t-CO2/MWh (World Energy Council, 2010), LFG_{coll} is the landfill gas collection rate that is set at 60% (Gikoko Kogyo, 2008), and CH_{4cont} is the methane content in the landfill gas that is set at 60% (Bastian, L., Yano, J., Hirai, Y., Sakai, S., 2013).

Whilst the produced electricity was estimated with the following formulae:

$$E_{produced} = EM_{CH4}\ x\ LFG_{coll}\ x\ CF / (1-LFG_{coll})\ x\ GE_{eff} / C \qquad [16]$$

where $E_{produced}$ is the produced electricity, EM_{CH4} is the CH4 emission, LFG_{coll} is the LFG collection rate, which is set at 60%, CF is the conversion factor for secondary energy that is set at 3.6 MJ/kWh (IPCC, 2006), GE_{eff} is the gas engine efficiency that is set at 37% (Advanced Scientific Technology and Management et al, 2010), and C is conversion factor for secondary energy that is set at 3.6 MJ/kWH (IPCC, 2006).

To estimate the emission of CH4 the following formulae was used:

$$EM_{CH4} = \Sigma M_i\ x\ DOC\ x\ MCF\ x\ (1-OX)\ xF/12x16x(1-LFG_{coll}) \qquad [17]$$

where M_i is the amount of waste type i treated, DOC is the Degradable Organic Carbon, MCF is Methane Correction Factor, OX is Oxidation Factor, F is the CH_4 fraction in landfill gas set at 0.5 (IPCC, 2006), and LFG_{coll} is the LFG collection rate.

4.5.2.5. Transportation

The GHG emissions from waste transportation result primarily from the CO_2 generated by the transport vehicles' fuel consumption. The amount of emissions varies with the distance from the residential area to the waste disposal or treatment sites, the fuel efficiency, the fuel type, the load, and the number of trips. The GHG generated from the transportation of waste to the solid waste disposal or treatment sites is estimated as follows (Chen T.C., et al., 2008):

$$E_t = F_{ic} \times H_i \times C_{ig} \times GWP_g \qquad [18]$$

where Et is the GHG carbon equivalence from collection and transportation of waste per year, Fic is the amount of fuel i consumed (L/year, i: fuel type such as diesel or petrol), Hi is the fuel heating value of fuel i (GJ/L), Cig is the GHGs emission coefficient (g/MJ, g: GHG type, such as CO_2, CH_4 or N_2O), and GWPg is the Global Warming Potential value of greenhouse gas g.

The total fuel consumption is determined by fuel efficiency (L/km), the distance from each area of the city to the solid waste disposal or treatment sites, the waste load (tonnes per vehicle) based on JBIC (2008), the total waste transported per year, and the total trips per year. The field observations conducted in this study indicated that the household wastes that are placed in the storage units in front of the houses are subsequently taken to a nearby temporary storage facility by waste transport operators using handcarts. The household wastes are taken by waste trucks from the temporary storage facilities to the landfill or to composting centres.

4.5.2.6. Recycling

GHG emission reductions potential from recycling is briefly examined despite beyond the scope of the system boundary. Recycling yields savings in GHG emissions because the use of recycled materials instead of virgin materials reduces the energy demands and non-energy GHG emissions associated with manufacturing (Chen et al., 2008). Nevertheless, no GHG emission reduction credits for recycling because there is little certainty that materials diverted for recycling will actually be processed (Mohareb, E.A., MacLean, H.L., Kennedy, C.A., 2011).

This research estimates the reduction in GHG emissions that would result from the use of recycled materials instead of virgin materials. This analysis uses the IPCC recycling categories, the quantities measured by the field survey, and the EPA (2006) values for GHG emission reductions. In this research, potential GHG emission savings fromrecycling of inorganic recyclable materials are estimated. The formula to estimate the reduction in GHG emissions resulting from using recycled materials in place of virgin materials is adopted from Friedrich, E., et al. (2011) and Chen T.C, et al. (2008):

$$GHG_{emissions} = \sum (M_i \times R_r \times EF \times q) \qquad [19]$$

where Mi is the average generation of waste per household per year (tonnes), Rr is the recycling rate or the rate of material recycling, EF is the emission factor, and q is 44/12 or the conversion from MTCE to $MTCO_2e$.

4.6. Results

The GHG emissions from waste are primarily determined by the types and quantity of waste generated by households. The estimates of GHG emissions should be calculated separately for each waste category because the amounts of GHGs derived or produced from each type of waste and from each mode of treatment will vary. This study examines both the physical composition of waste and the GHGs emitted from the treatment of waste. An analysis of this kind requires detailed statistical data on the waste generated by householders. Data of this type are still not available from a standard source for Jakarta and Indonesia. For this reason, a field survey to determine the rate and quantities of waste generation was conducted as a component of this study.

4.6.1. Potential GHG emission savings from using inorganic recycled materials

The emission factors of inorganic recyclable materials were determined based on EPA (2006). The emission factors by EPA has the unit of $MTCO_2E$/short ton of material recovered. 1 short ton equals to 0.907 therefore adjustment through calculations were conducted to equate the unit to $MTCO_2e$/tonne.

The detailed table is summarised in Table 4.4.

Table 4. 4 Reduction in GHG emissions from using inorganic recycled materials instead of virgin materials

Materials	Waste recycled (average tonne/household/year)	GHG Reductions ($MTCO_2e$/tonne of material recovered) [a]	Emissions (tonne CO_2e)[d]
Plastics:			
Refuse sacks	0.02	-1.36	-0.03
Other plastic film	0.00	-1.36	0.00
Clear plastic bottles	0.01	-1.38	-0.01
Other plastic bottles	0.01	-1.36	-0.01
Food packaging	0.02	-1.36	-0.03
Other dense plastic	0.01	-1.25	-0.01
Metal:			
Steel beverage cans	0.00	-1.63	0.00
Steel food cans	0.00	-1.63	0.00
Other steel cans	0.00	-1.63	0.00

Other ferrous metal[b]	0.00	-4.90	0.00
Aluminum beverage cans	0.01	-12.34	-0.12
Aluminum foil			
Other non-ferrous metal[c]	0.00	-4.90	0.00
Glass (pottery&ceramics):	0.00	-4.47	0.00
Brown glass bottles	0.00	-0.25	0.00
Green glass bottles	0.00	-0.25	0.00
Clear glass bottles	0.01	-0.25	0.00
Clear glass jars	0.00	-0.25	0.00
Other glass	0.00	-0.25	0.00
Total	0.09	N/A	-0.22

[a] *EPA, 2006*

[b] *Ferrous metal: materials that contain iron, e.g. carbon steel and stainless steel.*

[c] *Non ferrous metal: materials such as aluminum, brass, copper, titanium.*

[d] *Values of emissions are presented in negative due to GHG savings*

N/A : Not Applicable

The estimations are based on the assumption that all of the sorted and recovered inorganic recyclable materials were recycled. Based on the estimations as presented in Table 4.5, the recycled inorganic waste has the potential of saving 0.22 tonne CO_2eq per household per year. Considering the number of households in Jakarta, which is 2,030,341 households, with the assumption of 80% recycling of all recyclable materials, the potential savings amount to 357.3 x 10^3 tonne CO_2eq per year, which is more than amount of total emissions from all systems other than landfilling.

4.6.2 GHG emission evaluations of the waste management systems

The parameters and assumptions used for the estimations were as presented in preceding chapter 3.6. It is assumed that for organic waste, 75% treated with system, 25% landfilled. The restwaste from composting is 25% of total waste composted and it is landfilled. For inorganic waste, the recovery rate of recyclables is 75% and the rest is landfilled. For communal composting option, the transport of compost is negligible because the consumers are residents within the neighbourhood. Table 4.5 shows the total emissions for each system per 1,000 tonne of original waste.

According to the estimation, landfilling as the baseline system emits the highest amount of GHG with 7.0 x10^6 kg CO2eq per 1,000 tonne of treated waste. Conversely, anaerobic digestion performs best in terms of GHG emission with -4.6 x10^5 per 1,000 tonne of treated waste.

Table 4. 5 GHG emissions for each system (kg CO2eq per 1,000 tonne waste treated)

System	Organic waste					
	GHG from treatment	Rest waste landfilling	Emission from energy consumption	Transport of compost from treatment plant to market	Transport of rest waste from treatment plant to landfill	Avoided emission from chemical fertilizer production or energy recovery
Landfill (unsorted)	6.9x10^{6}	0	30.1x10^{3}	0	30.4x10^{3}	0
Communal composting	5.7x10^{5}	43.5x10^{4}	64.3x10^{3}	0	7.6x10^{3}	-20.1x10^{3}
Anaerobic digestion	5.5x10^{2}	43.5x10^{4}	58.2x10^{4}	0	0.5x10^{2}	-2.2x10^{6}
Central composting	5.7x10^{5}	43.5x10^{4}	48.2x10^{3}	5.6x10^{3}	7.6x10^{3}	-20.1x10^{3}
Landfill with gas collection	2.9x10^{6}	43.5x10^{4}	30.1x10^{3}	0	0	-1.0x10^{6}

System	Inorganic recyclable waste			Other waste	Total emission	Emission savings compared to baseline
	Avoided emission from recyclables	Transport emission of rest waste from temporary storage to landfill	Transport emission from temporary storage to market	Transport emission to landfill		
Landfill (unsorted)	0	0	0	0	7.0 x10^{6}	0
Communal composting	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	8.5x10^{3}	2.9 x10^{5}	6.7 x10^{6}
Anaerobic digestion	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	0.5x10^{2}	-4.6 x10^{5}	7.5 x10^{6}
Central composting	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	5.7x10^{3}	2.7 x10^{5}	6.8 x10^{6}
Landfill with gas collection	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	0	1.6 x10^{6}	5.4 x10^{6}

Communal composting and central composting have similar amount of GHG emission with the slight difference on the emission from transportation. The total emissions for communal and central composting are 2.9x10^{5} and 2.7x10^{5} kg CO2eq per 1,000 tonne of treated waste, respectively. Landfill with gas collection involves methane extraction for energy generation from organic waste.

This system has total emission of 1.6 x10^6 kg CO2eq per 1,000 tonne of treated waste. Compared with the baseline system; the anaerobic digestion, communal composting, and central composting generated similar emission savings of 7.5 x 10^6 kg, 6.8 x 10^6, and 6.7 x 10^6 kg CO2eq per 1,000 tonne of treated waste, respectively.

4.7. Discussion

Anaerobic digestion has the highest potential for GHG emission savings, followed by communal composting and central composting. The three systems have similar amount of emissions. Overall, the GHG emission from transportation is insignificant compared to the emission from waste treatment processes.

This finding corroborates to prior study by Aye, L., Widjaya, E.R. (2006) on the GHG effect of traditional waste management systems. Based on that study, biogas from anaerobic digestion has the lowest level of GHG emission, followed by small-scale composting and centralised composting. Landfill with gas collection system presents the highest greenhouse impact among the alternatives considered, but less greenhouse effect than landfilling. Additionally, according to another study that used organic waste research model (ORWARE) for LCA evaluation, anaerobic digestion result in the lowest environmental impact compared to composting and incineration (Sonesson, U., Bjorklund, A., Carlsson, M., Dalemo, M., 2000). Another study also suggests that biological treatment of waste such as composting has been touted as the most appropriate treatment for MSW generated in Indonesia (Chaerul, M., Tanaka, M., Shekdar, A., 2007).

This study suggests that at-source waste sorting by householders would be required for the systems other than the baseline system. This approach minimises the need for manual and automated sorting within the centralised facilities and increases the effectiveness of the composting and digestion processes. If plastic and inorganic material is present in urban solid wastes during anaerobic digestion, it causes the total gas production to decrease (Muthuswamy, S. et al., 1990).

The end-uses of each system are outside of the system boundary of this research, but general observations were undertaken and presented herewith. The end-users of the home compost are the householders themselves, whereas the communal compost is not only being sold or used by the community, but also sold to other communities or private companies. The compost produced by the composting centers is being sold to various business corporations that have agreed to purchase in large volumes. Concerning the anaerobic digestion, taking the case of applications in other countries, the energy generated from it can be sold to the grid.

4.8. Limitations of study

This study has provided information about the waste composition and weight generated from households as well as the estimation of the GHG emissions derived from each treatment method; however there are several limitations of study. The GHG emissions from waste treatment are difficult to be estimated and very complex in nature.

The small number of respondents restricts the findings to be generalised to the total population of Jakarta. Interpretation of results in a wider context should be done carefully, because there are possible factors that may affect the amount of waste generated, such as the seasons and timing. Waste generated from households in different seasons (i.e. dry and rainy seasons) may generate different results. Major events that coincidentally take place during surveys also would affect the results, for instance the waste generated during the holiday seasons, religious celebrations and other major public events would be different from normal days. Further research that take into account the different seasons and months can be conducted to identify the more precise average year-round generation of waste.

Devising policy for appropriate waste management system would not only take into account the GHG emissions but other factors should be considered, namely the environmental aspects of the surrounding areas of the waste treatment facility, hygiene, public health issues, etc. These other priorities when it comes to devising waste management policy should be considered in addition to the limited parts of evaluation addressed in this study.

In terms of the estimations of GHG emissions, this study estimated the emissions from the waste treatment process and transportation. For composting and anaerobic digestion, the emissions would depend on factors such as method/technology, temperature, water content, and supply of oxygen during the process (Chen, T.C., Lin, C.F., 2008). This would essentially affect the wide range of emission and would need further scrutiny. Similarly, the overall quantification of GHG emission from anaerobic digestion has a high degree of uncertainty associated with it and Møller et al. (2009) identified the key parameters influencing emissions from anaerobic digestion, namely the substitution of energy or natural gas by biogas; nitrous oxide emissions from digestate in soil; fugitive methane emissions at the plant; unburned methane during combustion; carbon bound in soils and fertilizer substitution. Some of these parameters are hard to quantify in developed countries, but even more so in developing countries, and even if case specific data is available, a certain degree of uncertainty will still persist (Møller et al., 2009; Friedrich, E., Trois, C., 2011).

This study also estimates the potential GHG reduction from the use of recycled materials instead of virgin materials. The actual GHG emissions from conducting such recycling depend mostly on the method/technology used. As recycling is outside the boundary of research, this study only address the potential savings from the use of recycled materials therefore further research on the GHG emissions from recycling would be recommended.

4.9. Conclusions

Household waste in Indonesia is the largest fraction of municipal solid waste. Household waste and other types of waste have different characteristics. This study proposes several systems for household solid waste management and determines the estimated amounts of GHG emissions for each system.

This study suggests that anaerobic digestion has the highest potential for GHG emission savings, followed by communal and central composting. However the amount of emissions is similar for these three systems. Therefore, the selection of waste management system can be chosen from other criteria such as economic.

The waste survey suggests that the average household solid waste generation in Jakarta was 0.33 kg per capita per day. Kitchen waste represents greater than 50% of the total. This component of the waste can potentially be composted. Plastic is the second largest component, followed by paper and cardboard. While kitchen waste is valuable as feedstock to compost, plastic, paper and cardboard have potential to be recycled. Meanwhile, the presence of hazardous waste is low.

Among the top fractions of inorganic waste from households, nearly all are recyclable, except dense plastic that are unrecyclable scraps. Other wastes, such as food packaging, refuse plastic sacks, clear plastic beverage bottles/PET bottles, and aluminum beverage cans, can be recycled and would therefore have significant economic values in scrap dealing. Household waste in Jakarta includes large amounts of compostables and recyclables. Compostable material accounts for 59 percent of all waste. Its "recycling potential" is therefore high. An additional 21 percent of all waste is categorised as recyclable. The remaining 20 percent of household waste may be discarded in the landfill because it is non-compostable or non-recyclable. Although there are valuable resources present in household waste, the majority of respondents dispose the recyclable wastes together with other types of waste, including organic waste.

In comparison with other countries on the basis of socio-economic standing, developing countries tend to produce more organic waste, namely food scrap (kitchen waste) whereas developed countries produce less of this waste category. The reason for this could be because people living in developing countries have lower income compared to people in the developed countries, thus they produce more organic material due to preparing food from base ingredients, whereas people from developed countries generate more inorganic waste from packaged food items (Wells, 1994; Troschinetz, A.M., Mihelcic, J.R., 2009). Another prominent feature of difference between the waste generated in developed countries is the high amount of recyclables such as paper and cardboard compared to developing countries. This could also be due to the high consumption of packaged goods, which lead to the waste of packaging made of paper and cardboard. In the case of household waste in Jakarta, less paper is generated due to: 1) the lower consumption of packaged goods; and 2) the general householders in Jakarta tend not to have subscriptions to newspapers or magazines that would eventually result in the generation of paper waste.

4.10. Multi-criteria evaluation

From the result of evaluations of economic and GHG emission estimation, a multicriteria evaluation is presented as Table 4.6 and Fig.4.10

Table 4. 6 Multicriteria evaluation of economic and GHG emission estimations

	Landfill	**Communal composting**	**Anaerobic digestion**	**Communal composting**	**Landfill with gas collection**
Revenue (USD)	-2,982,523	4,570,510	-6,857,712	-1,769,997	1,526,614
GHG emission savings (kg CO_2eq per 1,000 tonne waste treated)	0	6.7 x10^6	7.5 x10^6	6.8 x10^6	5.4 x10^6

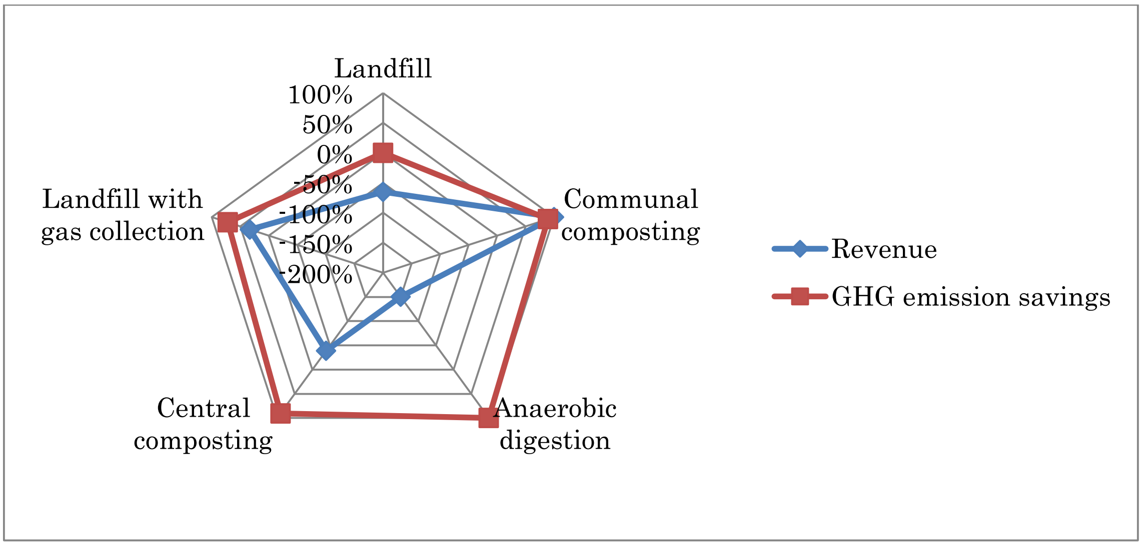


Fig. 4. 10 Multicriteria evaluation of economic and GHG emission estimations

According to the multicriteria evaluation, communal composting has the highest economic revenue, with moderate GHG emission. Anaerobic digestion performs best in GHG emission saving but has the lowest economic revenue. The GHG emissions are similar for anaerobic digestion, communal composting, and centralised composting. Therefore the selection of waste management system can be chosen from other criteria such as economy.

For the case of Indonesia, communal composting is preferred due to the economic consideration. Moreover, the allocated funds for Cleansing Department are only 2.9% of the total Municipal Budget and waste levies are not imposed. Thus, financing expensive large-scale and sophisticated waste treatment facilities such as anaerobic digestion is not preferable for Jakarta from the economic point of view.

Based on these result, the proceeding Chapter 5 will discuss about communal composting and inorganic waste recovery that generally exist as community-based waste management (CBWM) system. The study would focus on human behaviour, where distinct properties that set apart the two groups of successful and failed CBWM communities are identified, as well as the two groups of householders who sort and do not sort.

CHAPTER 5: EVALUATION OF HUMAN BEHAVIOUR IN THE MANAGEMENT OF HOUSEHOLD WASTE

5.1. Introduction

According to the economic and environment associated with GHG emission estimations in preceding chapter 3 and 4, multi-criteria evaluation will later be presented in chapter 6. Communal composting has the highest revenue with moderate GHG emission. Thus for the case of Indonesia, communal composting is desirable due to the high revenue. The allocated funds for Cleansing Department are only 2.9% of the total Municipal Budget and waste levies are not imposed.

Communal composting usually exists through community-based waste management (CBWM) mechanism. 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 scavengers) 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 studies on human behaviour, which 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. Human behaviour study also provides information regarding social (non)acceptance rates, and they can be used to determine expected levels of public acceptance towards a given policy or programme. It could highlight aspects and dynamics that govern the system in which households and informal scavengers 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 human behaviour in waste management, have not been discussed in-depth in the solid waste management literature, which is dominated by technical science and supply-side thinking..

In chapter 2 the definitions of community and CBWM had been described. Community is defined as a group of people who have a sense of common purpose(s) and/or interest(s) for which they assume mutual responsibility; who acknowledge their interconnectedness; who respect the individual differences among members; and who commit themselves to the well-being of each other and the integrity and well-being of the group (Wood, G.S., Judikis, J.C., 2002). Communities can be separated into categories on the basis of their fundamental differences, and the five kinds of communities are namely: 1) nuclear; 2) tribal; 3) collaborative; 4) geopolitical; and 5) life. The categories for each type of communities are described on Table 1 that includes descriptors for each category. Indonesian people in particular have an underlying ethic (*gotong royong*), which is a tradition to encourage development strategies based on collective solidarity and reciprocity (Cameron, 2000).

Community-based waste management (CBWM) has been touted as an alternative approach to SWM in developing countries. Tahir et al (2007) argued that provides waste service in areas where public/private services are limited. Colona and Fawcett (2006) noted several reasons that could hamper the success of CBWM, which related to the appropriate technology, financing, participation of community members, managerial capacity, and support of local municipalities. Nevertheless CBWM is usually small-scale (Van de Klundert et al, 1995), whereas recently the new government administration through the Ministry of Public Works (2013) decided CBWM as one of the two main climate mitigation actions in the waste sector. The government will carry out development and optimisation of CBWM for expansion. The question remains whether CBWM can be expanded in such large scale and top-down manner; and this thesis explored avenues for identify ing the factors for successful CBWM implementation based on specific traits found in the surveys and interviews.

5.2. Purpose of Chapter and Previous Studies

This chapter aims to identify the distinct properties and barriers of householders and communities in terms of sorting and CBWM participation. Therefore the study is conducted by means of surveys and in-depth interviews for comparative studies of:

1) The cases of successful and failed CBWM communities
2) The distinct properties and barriers for at-source sorting from the group of householders who sort and the group who do not sort.
3) The distinct properties and barriers of CBWM participation from the group of householders who participate and the group of householders who do not participate.

There are two general approaches of CBWM in Indonesia, namely grassroot/informal initiation approach and top-down institutional/formal initiation approach. Top-down institutional/formal CBWM is commenced and supported by government or private sector's corporate social responsibility (CSR). Grassroot/informal initiation of CBWM is independently commenced by the communities. This thesis also aims to identify the preferred sequence of the top-down institutional/formal approach and grassroot/informal approach for prevailing CBWM. CBWM usually started either by external institution or autonomously.

There are many factors that may contribute to the success and failure of CBWM. However, this study focuses on the discussion of the grassroot/informal approach and top-down institutional/formal approach of CBWM. Grassroot/informal initiation approach implies that the CBWM is commenced by the community, whereas top-down institutional/formal approach of CBWM is commenced by external institutions.

There were many prior studies on community and community-based waste management initiatives, however no prior studies have indicated the validity of hypothesis whether the commencement of CBWM through top-down institutional/formal initation or grassroot/informal initiation approach may result in the success or failure of CBWM. Prior studies such as Charuvichaipong and Sajor (2006) concluded that the failed public participation in waste separation project in Thailand was due to lack of participation, weak CSO, top-down institutional/formal initation approach, and the government-community relations.

A study by JICA (2013) concluded that external supports would not bring significant improvement without practice of at-source sorting and CBWM. Shekdar

(2008) proposed an approach for SWM improvement in Asian countries that include public participation. Pasang et al (2007) argued that neighbourhood-based waste management strategy is a promising solution for Jakarta, because it is more applicable and suitable for Jakarta's context. Meidiana (2010) stated the ways to involve communities in reducing waste, i.e. through waste retribution and community initiatives in SWM. Kardono (2007) argued that CBWM becomes important in Indonesia because due to the low-cost and high-participation of people, whose claim was not empirically supported. Prior study had also been conducted on pilot program concerning source separation of household waste in China, which introduced a waste at-source separation method (Zhuang et al, 2008).

In Indonesia, there is a significant socio-economic discrepancy. Indonesian society is characterised by a high degree of inequality with regard to income distribution (Indonesia Investments, 2013). In addition to the top-down institutional/formal initiation and government-formed community grouping systems of neighborhood units/associations (RT/RW) to form the community-based initiatives; grassroot/informal community neighborhood groupings permeate Indonesian middle-income community groups such as *arisan* (rotating-credit associations), *PKK* (women's family welfare group), and *pengajian* groups (Islamic worship group).

Colon et al (2006) conducted case studies of two South Indian cities, at higher and middle-income communities. The scheme in a middle-class area of Chennai suffered from diseconomies of scale and lack of social integration, making it less viable in the medium to long term. Both schemes in the high and middle-income communities suffered from a lack of community involvement, motivation and political support. Henry et al (2006) argued that community involvement through neighbourhood groups of people from middle and higher income groups and business individuals can provide the needed solution in mobilization of community-based efforts.

Alesina et al (1999) argued that the propensity to participate in social activities is influenced by individual characteristics, but it also depends on the composition and degree of heterogeneity of the community. Theoritically more heterogeneity of the population leads to less social interaction. The study concluded that participation in social activites is significantly lower in racially or ethnically fragmented localites.

Altruism generally defined as unselfish acts that come from within, for the welfare of others. Ozinga (1999) introduced the term eco-altruism that implies doing something for the environment at the cost to oneself. Hopper et al (1991) confirmed that recycling behavior is consistent with Schwartz's altruism model, according to which behavior is influenced by social norms, personal norms, and awareness of consequences. A block-leader program, in which residents encouraged their neighbors to recycle, influenced altruistic norms and increased recycling behavior. According to Charuvichaipong et al (2006), it is often assumed that waste separation at source can be had simply through a donor-driven project. A case study of failed public participation in waste separation project in Hatyai City in southern Thailand was conducted. They argued that the factors for the lack of participation are due to weakness of civil society organization, top-down institutional/formal approach, and the relations between government and community.

Sharholy et al (2008) argued that the lack of resources such as financing, infrastructure, and leadership, are the main barriers in CBWM. Tahir et al (2009) found that bottom-up CBWM with limited support from external agents, relied on resources provided by the community members. Meanwhile, top-down institutional/formal CBWM supported by private sectors has the challenge of dependence to the external support.

Prior studies have linked household participation and behaviour with the concept of willingness to pay for others to sort in the European countries (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 systems and systems to be realised. There are a number of papers with the discourse on household waste management (e.g. Sterner and Bartelings, 1999; Oberlin, 2011, Pasang et al, 2007; Dennison et al, 1996).

Correlation between stakeholder involvement and sustainability existed, as supported by the fact that the only three factors driven by all three dimensions (social, environmental, economic) of sustainability, namely: waste collection and segregation, municipal solid waste management plan, and local recycled-material market. These were the three that required the greatest collaboration with other factors (Troschinetz A.M., James R. Mihelcic, 2009). It has also been concluded that a systematic effort for sustainable SWM systems is necessary to improve various factors, including public participation and awareness of the solid waste management systems (Shekdar, 2009)

There have also been several studies on waste management in Indonesia and cities of Indonesia including Jakarta. Improper waste management as part of the general overview of Jakarta's environmental problems became apparent as inorganic waste were let into the rivers and ended up in the Jakarta Bay (Steinberg, F., 2007). General overview on solid waste management in had been studied in several major cities in Asia (Dhokhikah, Y. Trihadiningrum, Y., 2012), Indonesia (Chaerul, M., Tanaka, M., Shekdar, A., 2007), and in specific cities such as Bandung (Damanhuri, Wahyu, Ramang, Padmi, 2009), Surabaya (Trihadiningrum, 2006) and Semarang (Supriyadi, Kriwoken, Birley, 2002).

Meidiana (2010) published the result of literature review on the status of waste management development in Indonesia. There have also been some studies on scavengers as the informal sectors working on waste with the attempt to provide an overall picture and conceptual approach for societal inclusion (Sembiring, Nitivattananon, 2008, 2010; Supriyadi, Kriwoken, Birley, 2002; Marshall, 2005). There are arguments that signified the roles of scavengers for waste reduction, however the roles of households are also no less important.

Beard (2007) pointed out the contribution of households for the provision of waste management services, among otherservices. In Indonesia, household contributions to those efforts are significant because the state has implemented decentralization policies that transfer the power from central government to local governments.

JICA (2003) conducted a project in Jakarta to increase the capacity of waste collection and transportation to the final disposal facility, which increased the service level of solid waste management in Jakarta city. The project evaluation concluded that technical and financial supports from foreign donors will not bring a significant improvement without public participation in practicing sorted collection, implementing the 3Rs (Reduce, Reuse, and Recycle) strategy as well as paying garbage fee collection and disposal. Therefore campaigns and education on 3Rs programmes were deemed important to be implemented.

To our knowledge, there have not yet been any studies in Indonesia that address the issue of sorting and composting based on questionnaire surveys with households at the time of this study. Yet this is important in order to understand the reasons and barriers in doing so. Because if the system of other than landfilling is to be properly implemented, at-source sorting will be prerequisite, hence householders' stance in terms of sorting is required to be understood. Thus this study is conducted to address these issues.

This study makes use of socio-experimental research in which householders were involved in hands-on sorting and then surveyed on their willingness to sort if it were required in the future. The experience of having to sort the waste helped respondents to understand the technicality of sorting and strengthen the validity of response regarding their willingness based on the experience from taking part in this study as respondents. The result of study as presented at this section will be beneficial for drawing the conclusion, which is to identify the current behavior of sorting and the willingness to sort or pay others to sort the waste.

There are theories of human behaviour that may explain the reasons for humans to undertake such activity. One acclaimed theory is the theory of planned behaviour (Ajzen, 1991) provides a theoretical framework for systematically identifying the determinants of human behaviour related to household waste management. The theory postulates three conceptually independent determinants of intention. The first is the attitude toward the behavior and refers to the degree to which a person has a favorable or unfavorable evaluation or appraisal of the behavior in question. The second predictor is a social factor termed subjective norm; it refers to the perceived social pressure to perform or not to perform the behavior. The third antecedent of intention is the degree of perceived behavioral control which refers to the perceived ease or difficulty of performing the behavior and it is assumed to reflect past experience as well as anticipated impediments and obstacles.

Ajzen (1991) argued that the principle of aggregation does not explain behavioral variability across situations, nor does it permit prediction of a specific behavior in a given situation. It was meant to demonstrate that general attitudes and personality traits are implicated in human behavior, but that their influence can be discerned only by looking at broad, aggregated, valid samples of behavior. Their influence on specific actions in specific situations is greatly attenuated by the presence of other, more immediate factors. Indeed, it may be argued that broad attitudes and personality traits have an impact on specific behaviors only indirectly by influencing some of the factors that are more closely linked to the behavior in question.

There are however several criticism towards the theory of planned behaviour. The majority of research on the TPB employs self-report measures, which may be biased or confounded by social desirability (Conner & Armitage, 2006). In a study by Bentler and Speckart (1979) it was determined that factors other than intentions were more important in predicting behavior. The variables outlined in models such as the theory of planned behaviour are necessary, but not sufficient determinants of behavior (Bagozzi, 1992). Eagly, A. H., Chaiken, S. (1993) criticised the theory for not clarifying the exact nature of the relations between intention and behavior.

In terms of householders' behaviour in waste management, there is a theoretical basis to include past behavior in this study. Some researchers argued that household waste management is unique from other environmental behavior because it is repetitive in nature (Boldero, 1995) and hence may be considered as a habit. Therefore, past behavior should be an important variable in predicting both intention and actual behavior.

Human behaviour can be regulated by an adequate manipulation of rewards and punishments (Singhirunnusorn, Donlakorn, Kaewhanin, 2012; Mannetti et al, 2004). Some studies found that the psychological variables related to social norm and peer pressure influences are useful for predicting human behaviour towards household waste management (Nixon and Saphores, 2009). Prior research had been conducted by using this theory of planned behaviour as a baseline in understanding the household waste management attitudes and behaviour in the UK (Barr, S., 2007; Tonglet, M., Phillip, P.S., Read, A.D., 2004) and Malaysia (Latifa, S.A., Omara, M.S., Bidina, Y.H., Awang, Z., 2012).

There have been recent studies on CBWM, such as CBWM in Surabaya (Tahir, Yoshida, Harashina, 2014), which looked at the specific Green and Clean programme. The study was based on newspaper articles and 15 interviews with stakeholders. Another study is on CBWM scenarios in Malang, which concluded on three scenarios of participation rate in CBWM (Purba, Meidiana, Adrianto, 2014). The influence of CBWM system on people's behavior and waste reduction in Semarang was studied by

Sekito et al (2013), which concluded that CBWM reduces improper waste disposal behavior.

McKenzie-Mohr (2011; 2000) proposed a notion of community-based social marketing, which is effective at bringing about behaviour change. In determining behaviour change, barriers must be identified. Therefore differences must be identified between individuals who engage in the activity and those who do not, though focus groups, observational studies, and survey research. Barriers can be internal (e.g. lacking skills) or external (e.g. absence of programme), and behavior-specific barriers.

This thesis therefore takes a different approach from prior studies, which usually be focused on either the failed CBWM or the successful CBWM. Hence this study compare the properties of communities and community members (householders) in both the failed and successful CBWM. It identifies the underlying factors for householders who already conduct sorting, composting, and participate in CBWM and those who do not; through mixed methods of 100 household surveys, in-depth interviews with CBWM leaders and government.

This study also takes into account discussion on ethnicities that have not yet been addressed in prior studies, wherein Indonesia consists of many cultures from different ethnicities and tribes. There are approximately 300 ethnic groups consisting of Javanese, Sundanese, Madurese, Malays, Betawi, etc, with over 700 languages and dialects spoken, such as Acehnese, Batak, Sundanese, Javanese, etc (Embassy of Indonesia, 2008). Although the national language of Bahasa Indonesia is widely used to communicate, nevertheless dialects are preferred modes of communication within certain ethnic groups.

According to Earley et al (2006), the greatest cultural difference in intercultural communication is the degree of directness of speech acts. Hall (1976) discovered that a speech act can vary across cultures depending on whether the culture is a high-context culture or a low-context culture. Cultures are either high or low context depending on the degree to which meaning comes from the settings or from the words exchanged. In high-context cultures, meanings are implicit. Information is provided through gestures, use of space, and indirect. On the contrary, in low-context cultures, speech is explicit and meanings are direct and taken literally.

Within the context of Indonesia, throughout the different tribes, ethnicities and cultures, there are a variety of low and high context respectively. For instance, Javanese are more sensitive people and their language is more high-context than any other Indonesians who come from other areas in Indonesia. Javanese people tend not to be straight-forward in terms of conveying their messages (Center for Intercultural Learning, 2009).

In this chapter, we inventorise the potential factors of householders' behaviour in sorting and CBWM, which were translated into questions in the household questionnaires. After the first preliminary interview with the successful CBWM community, we observed the candidates of important factors for the success and failure of CBWM as the hypothesis. From there, we translated the hypothesis into questions for householders and the interviews with the successful and failed CBWM communities.

5.3. Methodology

This section explains about the methodology used to determine the samples, data analyses, and interviews with CBWM communities. The aim of this chapter is to identify the distinct properties and barriers of householders and communities in sorting and CBWM. Therefore, in-depth interviews with CBWM leaders at the successful and failed CBWM locations and questionnaire surveys to householders were conducted.

The process for designing the questionnaire is presented in fig. 5.1. The interview questions were designed based on the inventory of possible factors for successful and failed CBWM as observed in the preliminary interview with several waste stakeholders and institutions working on waste management issues. There were candidates of factors that were selected and neglected based on the result extracted from preliminary open-ended interviews, for instance issues on scavengers, public health conditions and slums surrounding the landfill site, and recycling.

Further to the literature studies, we formulated a list of potential factors for the success and failure of CBWM. The first open-ended interviews were conducted to obtain the overview of waste management and CBWM, where a number of stakeholders were interviewed, i.e. the government agencies responsible in waste management, such as Cleansing Department and Ministry of Public Works; international agencies working on waste management projects namely UNEP Osaka and JICA Jakarta; and the leader and subordinates of the successful CBWM.

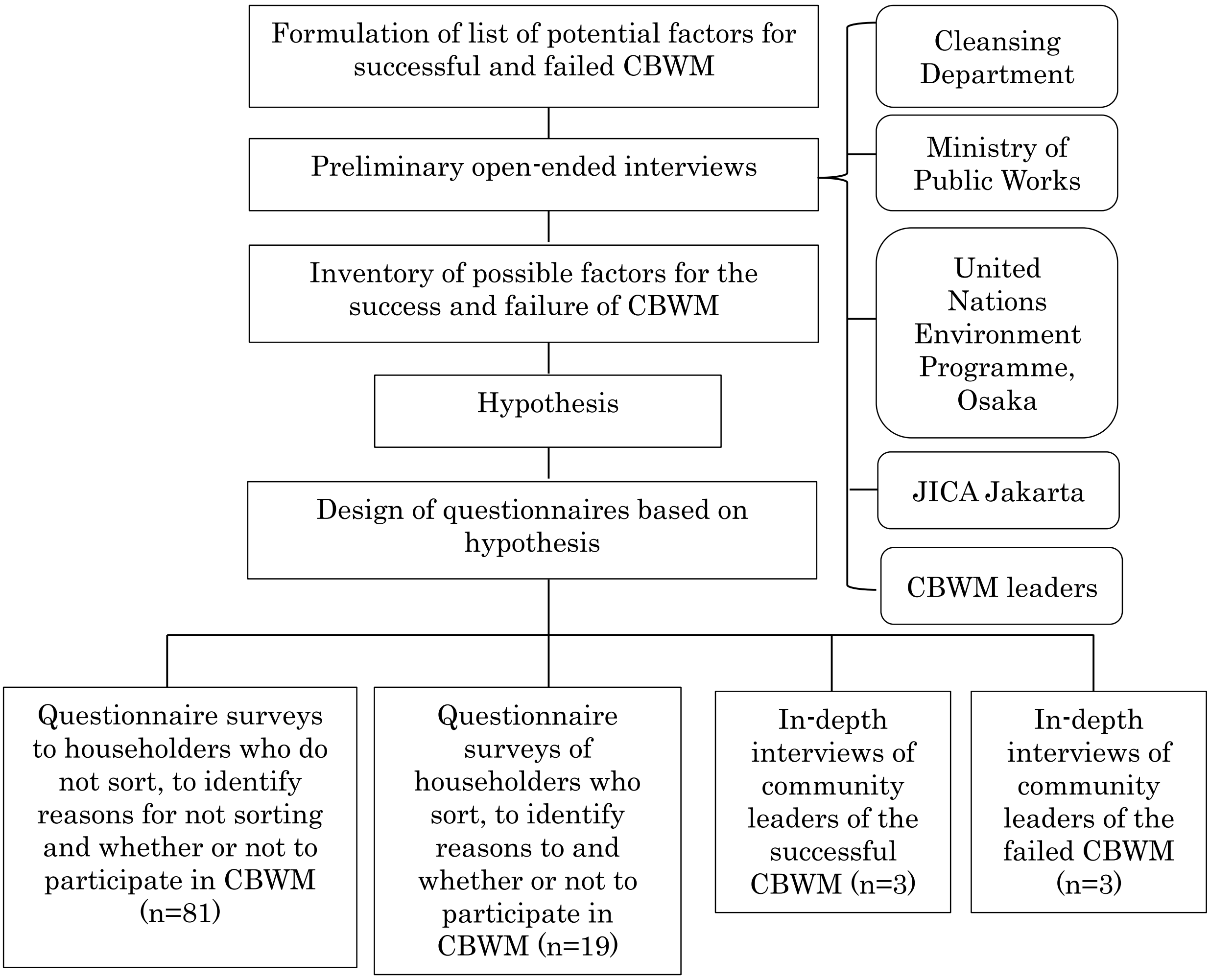


Fig. 5. 1 Householders' questionnaire and CBWM leaders' interview designs

Subsequently, we inventorised the hypothesised factors for the successs and failure of CBWM based on the first interviews. After that the questionnaires were designed based on the hypothesis, which consist of household questionnaire surveys and community leaders' in-depth interviews.

5.3.1. Method on CBWM case studies

Qualitative research comprised of in-depth interviews with CBWM leaders as respondents, at areas with three successful and three failed cases of CBWM implementation as identified by Cleansing Department. Six communities were selected for this study to represent the successful and failed CBWM communities, due to constraints regarding time, labour, and financial resources. Therefore these six community leaders were selected as the priority of communities whose leaders agreed to be interviewed for this study.

The three successful case studies of CBWM are: 1) Kompleks Zeni TNI AD Kalibata, Jl. Zeni AD RT 006 RW 03, Kelurahan Rawajati Pancoran with Mr. Suwarso as the key informant; 2) Jl. Sultan Agung no 20 Guntur Jakarta Selatan with Mrs. Yeni Mulyani Hidayat as the key informant; 3) Jl. Benting Indah I No 15 Semper Barat, Cilincing, Jakarta Utara, with Mr. Nanang Suwardi as the key informant.

The three failed case studies of CBWM are: 1) Jalan Cipedak Raya RT 04 RW 09, kelurahan Srengseng Sawah, kecamatan Jagakarsa, with Ms. Yuyun Komalasari as the key informant; 2) Jl. Anggrek No. 1, Karet Kuningan, with Ms. Sri Wahyuningsih as the key informant; 3) Jalan Perintis no 11/12 Kelurahan Karet, Jakarta Selatan, with Mr. Sublime Prasetiandi as the key informant.

The respondents to the interview were invited to 1-hour in-depth interview held at their places of residents or in a room at the community-centre office building. Six respondents were able to participate, three respondents hat represent the successful case of CBWM, and another three respondents that represent the failed CBWM.

5.3.2. Method on householders research

5.3.2.1. Sampling methods

To investigate the householders' behaviour in at-source sorting, direct questionnaire surveys were conducted in the period of two weeks from 27 February through 10 March 2011. Parts of the questionnaire were constructed with reference to previous studies (Bruvoll et al., 2002; Berglund, 2006), particularly on the questions regarding personal motives. These questions were complemented with issues beyond personal motives, such as willingness 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 questionnaire was prepared according to the Likert Scale in order to measure the strength of the respondents' opinion on the household waste management issues under consideration. The questionnaire included several statement systems such as strongly disagree, partly disagree, disagree, neutral, agree, partly agree, and strongly agree.

A combination of stratified random sampling, cluster sampling, and proportionate random sampling methods was used to select the respondents. The sample used in this study was based on population demographics in Jakarta. The survey was conducted in central Jakarta, north Jakarta, west Jakarta, south Jakarta, and east Jakarta, which are the five municipalities of Jakarta. The respondents that have not yet conduct sorting and those who already conduct sorting were surveyed. The set of questions for these two groups were diverged, in order to identify the variables that affect their current state of sorting practices.

Table 5. 1 Sample size and number of respondents

Municipality	Number of households [a]	Percentage	Number of Respondents [b]			Subtotal
			Low income	Medium income	High income	
East Jakarta	600,131	30%	18	9	3	30
South Jakarta	406,020	20%	12	6	2	20
North Jakarta	347,751	17%	10	5	2	17
West Jakarta	438,963	22%	13	7	2	22
Central Jakarta	237,476	12%	7	3	1	11
Total	2,030,341	100%	60	30	10	100

[a] BPS Statistics Indonesia, 2009

[b] Based on income groupings, BPS Statistics Indonesia, 2009

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.

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 income levels, and samples were taken within each region. The appropriate size for the sample was determined by a statistical formula for estimating proportions in a large population (Dennison et al., 1996 and Mc. Call, C.H. Jr., 1982). The population numbers, which were previously divided according to 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 set at 100 respondents for each sub-district and income level combination, also in consideration of the limited resources for this research.

Parts of the questionnaire that intend to probe more on the behavioural issues were prepared following the Likert scale to obtain simplified feedback from the respondents. The Likert scale involves the use of intensity questions/statements to measure the strength of a respondent’s opinion on a topic or issue. A numerical value is assigned to each potential choice and a mean figure for all the responses is computed at the end of the evaluation or survey. There are debates about how many choices should be offered. An odd number of choices allow people to be undecided. An even number forces people to make a choice, whether or not it reflects their true position. Some respondents may not like taking extreme choices as this may make them appear as if they are totally sure when they realize that there are always valid opposing views to many questions. They may also prefer to be thought of as moderate rather than extremist. They are therefore much less likely to choose the extreme systems. This is a good argument to offer seven choices rather than five. It is also possible to note people who do not make extreme choices and 'stretch' their scores, although this can be a somewhat questionable activity (Likert, 1932).

5.3.2.2. Data analysis

A combination of stratified random sampling, cluster sampling, and proportionate random sampling methods was used to select the respondents. The sample used in this study was based on population demographics in Jakarta. The survey was designed to identify the features of waste collection, waste disposal systems and waste flows. The survey was conducted in Central Jakarta, North Jakarta, West Jakarta, South Jakarta, and East Jakarta, which are the five municipalities of Jakarta.

5.4. Results

5.4.1. Result of case studies on the successful and failed CBWM

Based on the in-depth interviews with the CBWM leaders, there were remarkably different properties between the successful and failed CBWM as presented in Table 5.2.

Table 5. 2 Distinct properties between successful and failed CBWM case studies

	Successful CBWM	Failed CBWM
cs1. Attributes	a) At-source sorting b) Homogeneous middle-income c) Racially heterogeneous d) Commenced autonomously through grassroot/informal initiation approach	a) No at-source sorting b) Heteregeneous income levels c) Racially homogeneous d) Commenced by external support through top-down institutional/formal initiation approach
cs2. Benefits and supports	a) Independence from external assistance b) Full support and recognitions exists from all stakeholders within the community..	a) Dependence on external assistance to sustain operation. b) Lack of support and recognition from relevant stakeholders
cs3. Leadership	a) Strong influencing capacities b) Seniority	a) Weak influencing capacities b) Juniority
cs4. Means	a) Assigned land for CBWM activities and waste storage b) Ownership and use of sorting bins by all CBWM community members c) Justified CBWM mechanism, d) Clear distribution of work of CBWM actors e) Established design of waste collection, treatment & waste transactions flows	a) Unsecured land for CBWM activities and storage b) Sorting bins are not used by community members c) Unjustified CBWM mechanism, d) Unclear distribution of work e) Unestablished design of waste collection, treatment & waste transactions flows

Note: The result is arranged in numbering points starting with the code 'cs' to abbreviate 'case study' for the purpose of cross-referencing the conclusion in chapter 6.

cs1. Attributes

The distinct properties of community members' personal attributes in the successful and failed CBWM case studies are the status of sorting, income level, racial properties, and the nature of initiative commencement. In all of the successful CBWM cases, the communities are composed of homogeneous middle-income community members with heterogeneous ethnicities, where the CBWM were commenced as grassroot/informal initiation with presence of at-source sorting. The failed CBWM shows the opposite; where the communities were composed of heterogeneous income of community members with homogeneous ethnicities where local Betawi is the major ethnicity. CBWM were commenced by external institutions with top-down institutional/formal initiation approach, with no or lack of presence of at-source sorting.

cs1a) Sorting status

At the successful case of CBWM, sorting by householders as CBWM members is conducted at-source, which eased the burden of CBWM administrators at the collection points. There are several households that were still learning to properly sort and some wastes were still mixed. The CBWM initiative has generated revenue from the profit margin gained from selling inorganic recyclables and compost from organic waste to hire employees that help ensuring the waste to be sorted properly.

Conversely at the failed CBWM case, householders do not sort their waste at-source, thus the CBWM leaders encountered difficulties in conducting manual waste separation at the waste collection point. There had been extensive instigation by CBWM leaders for the community members to properly sort waste and explanation on how to sort, but the community refutes.

cs1b) Income level

In the failed CBWM cases, there were heterogeneous income groups, which lead to intense disparity between the low-income group and the high-income group. The low income groups had difficulties on meeting their daily needs that refrain them from being active in CBWM, whereas the high incomers view that waste management is a'defile task' that should be carried out by other people (of lower strata). As for the successful CBWM cases, the economic status of residents were homogeneous with the majority of middle-incomers.

cs1c) Racial properties

In the successful case of CBWM, the community composes of heteregenous ethnicities where large fractions are non-local ethnicities (non-Betawi people). In the failed case of CBWM, the community is mainly comprised of local people. The majority of community members that reside in the successful CBWM sites are of Javanese descents and other tribes than the local tribe of Betawi. The CBWM leaders were also originally from Jogjakarta, Central Java.

To the contrary, in the failed CBWM cases, a large fraction of the residents are homogenous local ethnicity (Betawi descents). The lack of conformity was likely due to status quo, namely resistance to change, as well as not being used to manage garbage, and not willing to be part of the initiative.

cs1d) Nature of initiative commencement

The successful CBWM cases commenced the activities autonomously through grassroot/informal initiation approach. It was only afterwards that the initiative gained attention from external stakeholders. To the contrary, the failed CBWM cases were commenced by external institutions with top-down institutional/formal initiation approach. The initiators conducted efforts to put together the team consisting of the community members, while providing them trainings and other supports.

cs2. Benefits and Supports

The benefits and support from external source were in the form of funding and basic means for CBWM. In all of the successful cases, the communities autonomously provide the basic CBWM means and infrastructures; whereas the in the failed cases the communities is dependent on external support.

cs2a) Reliance on external assistance

At the successful cases, the CBWM infrastructures and means were provided autonomously by the community members. For the case of Rawajati, the community were bestowed a land space for CBWM activities. The land is located under extra high voltage aerial line (wiring) of 500 kV that is intended to distribute electrical energy from the power centers located in remote areas to the load centers so that electrical energy can be transmitted. For that reason, the land was vacant as there are safety restrictions that prohibit the land to be used for housing. Thus it was decided that the land is to be dedicated for CBWM activities.The CBWM community was provided with external supports after the community demonstrates success of CBWM implementation. They were in the forms of seed money and other assistance such as waste shredding equipment from the Jakarta Cleansing Department; waste filter, sieving equipment and green house from the Department of Agriculture.

Inversely, the failed CBWM cases are dependent on external assistance from the beginning for the provision of infrastructures for CBWM and means to sort. It notably has no available sufficient land specifically dedicated for waste storage space and CBWM activities. The unavailability of land for CBWM is one of the major causes for the initiative to collapse.

cs2b) Support and recognitions

The success of CBWM is due to the active participation of community members and the CBWM leaders. In addition, the staff members at the neighborhood cluster (*RW*) and ward office (*kelurahan*) also offer support and encourage the initiative to be up-scaled to the ward level. These moral supports contribute to the sense of belonging on the CBWM activities.

The success was appreciated through awards, for the case of Rawajati, such as the acclamation as the “Best community cluster in Jakarta province for greenery and cleanliness” in 2004; appointed as the Agro-tourism Ward by the Department of Tourism in 2005; award as “CBWM Best Practice of Jakarta” in 2013 - which lead to the CBWM to be up-scaled to cover the whole ward. The CBWM members were rapidly increasing in 2013 after the CBWM received intense exposure as a best practice.There were a number of large-scale private companies that express interests to support the CBWM activities but the CBWM leaders refuse the support in order to retainimpartiality.

Regarding the failed case, the initiators of the pilot projects provided initial support such as waste shredding equipment and communal composter; while the Cleansing Department provided training on compost-making. It was noted during the interview that there were lack or no support from the community members, neighbourhood cluster association, neighbourhood unit, and ward. The community members was lacking in participation and dedication to undertake and promote the CBWM.

cs3. Leadership

Leaders of CBWM communities are the members of the communities that are appointed by the other members. In the successful cases, all of the leaders proved influencing capacities and they have seniority compared to the average age group majority of the CBWM members. To the contrary, all of the CBWM leaders interviewed in the failed cases showed less influencing capacities and are more junior compared to the average age group majority of the CBWM members.

cs3a) Influencing capacities

In the successful CBWM case, Rawajati is an army residential area in which military personnel and retirees reside. The hierarchy indeed exists and the power of CBWM leaders depends on the capacity to influence and acceptance from community members. The level of position in the army is one of the main factors that determine influencing capacities. The current CBWM leader is a retired major in the army and well-respected in the community. He has the power of influence the community members to participate in CBWM, particularly but not limited to those who are or used to be with the army. The CBWM leaders at the failed case are regular civilians who had lack of capacity to influence the community members and were less proactive. In the other successful cases, the CBWM leaders are also great influencers in the community as they are heads of the neighborhood associations who are well-respected.

cs3b) Seniority/juniority

Hierarchical power based upon seniority is still much instilled in the Indonesian culture. In the case of successful CBWM, the leaders were more senior than most of the rest of the community members. The leaders were retirees aged over 60. The seniority deemed to have more power and authority to motivate the communities to shift behaviour. As for the failed CBWM case, the leaders were more junior compared to a large portion of the existing community members. The leaders were aged between 35 – 40 years old, whereas there are large portion of the community members who were senior citizens.

5.4.2. Result of study on householders

5.4.2.1. 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.

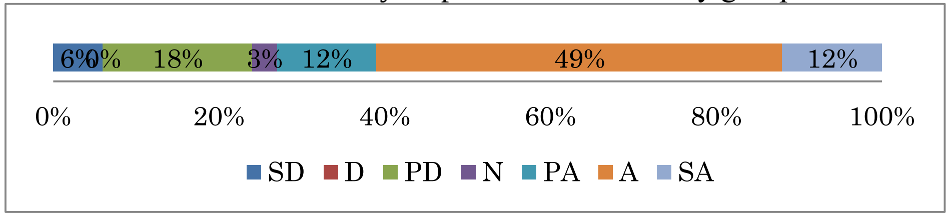
Regarding income level, 38% earned between IDR 651,000 and 1,290,000 per month, 26% earned between IDR 1,290,000 and 5,000,000 per month, 17% earned between IDR 5,001,000 and 10,000,000 per month, 8% earned between IDR 10,001,000 and 15,000,000 per month, 7% earned IDR 0 – 650,000 per month, and 4% earned more than IDR 15,001,000 per month.

Reasons to and not to sort

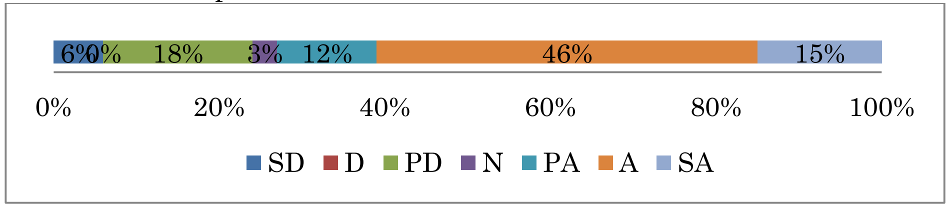
Further, this study compared the group of respondents who sort and the group of respondents who do not sort in order to identify the reasons for doing and not doing so. The result is presented in below figures.

Reasons for Sorting

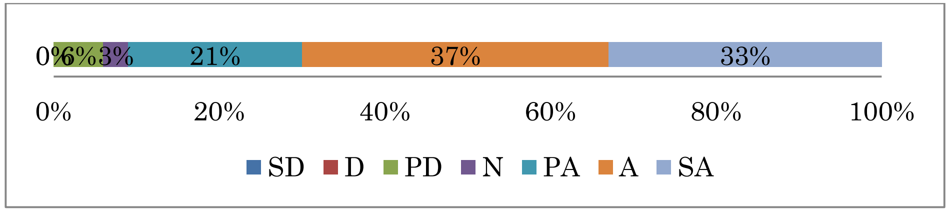
1a. It is recommended by respondents’community group



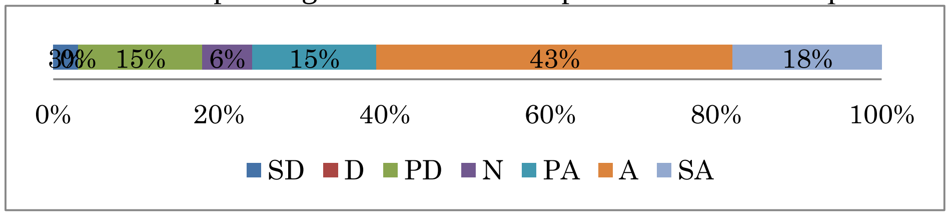
1b. To get additional income by selling recyclable/reusable materials to scrap dealers



1c. To contribute to a better environment

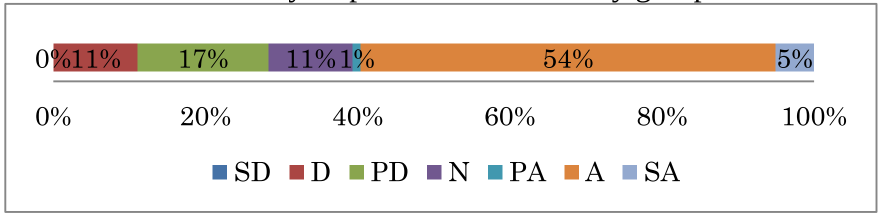


1d. To compost organic waste with respondents’ home composter

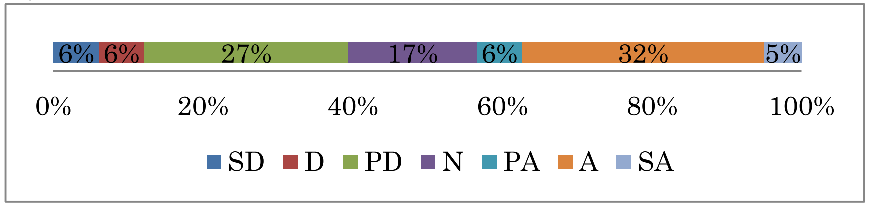


Reasons for Not Sorting

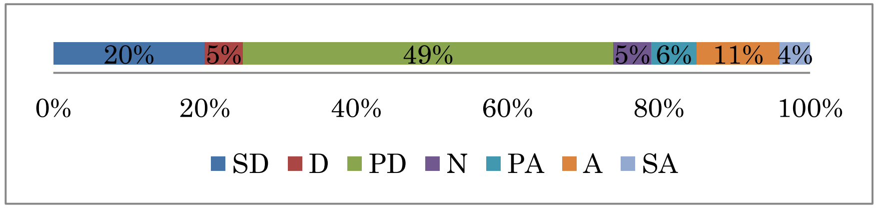
6a. It is not endorsed by respondents’ community group



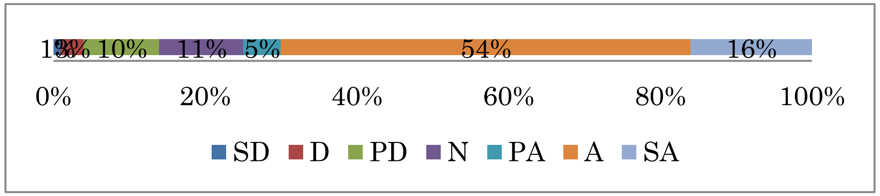
6b. There are no or lack of financial benefits from selling recyclable/reusable materials to scrap dealers



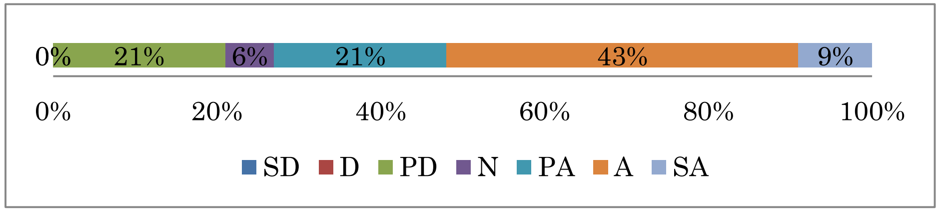
6c. Respondents do not think sorting contribute to a better environment



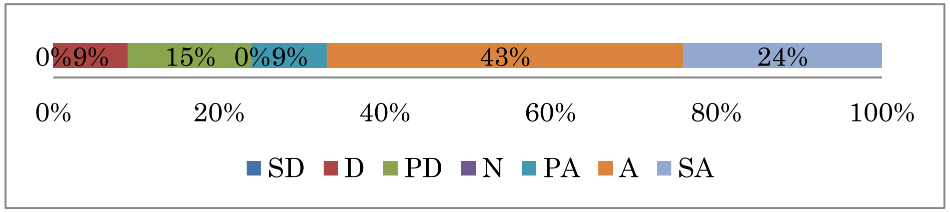
6d. Respondents do not use home composters



1e. To treat sorted waste through CBWM

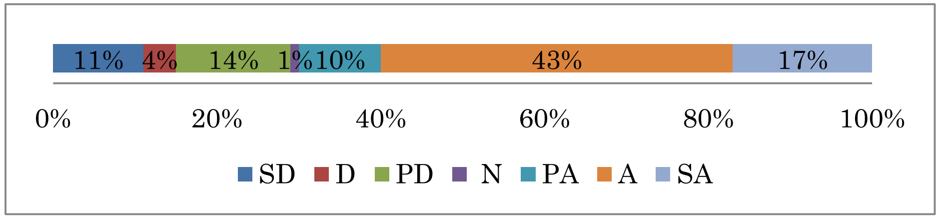


1f. Sorting is a pleasant activity in itself that brings satisfaction

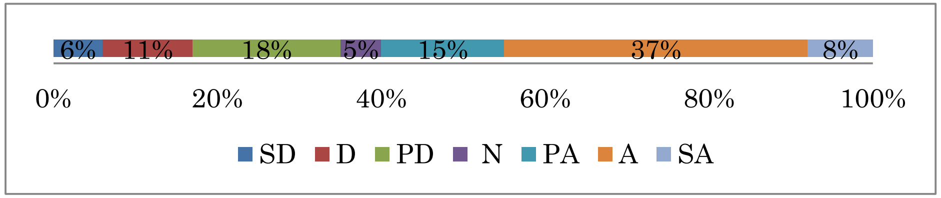


Difficulties in sorting (for sorting respondents)

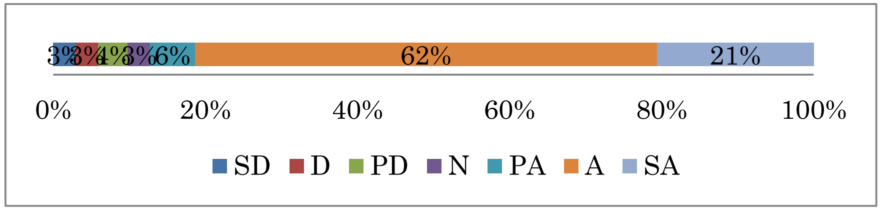
2a. Insufficient economic incentives/benefits



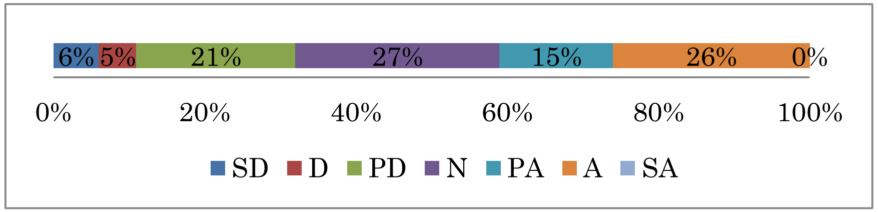
2b. Mechanism for treatment of sorted waste is not yet established



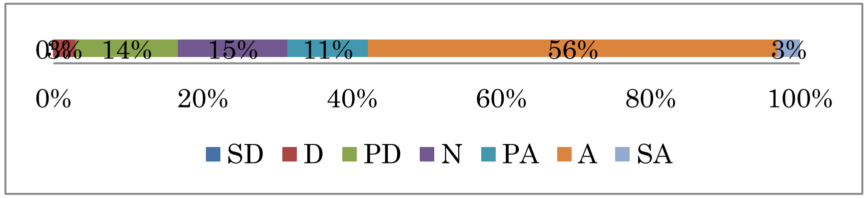
6e. There is no CBWM system to treat the sorted waste



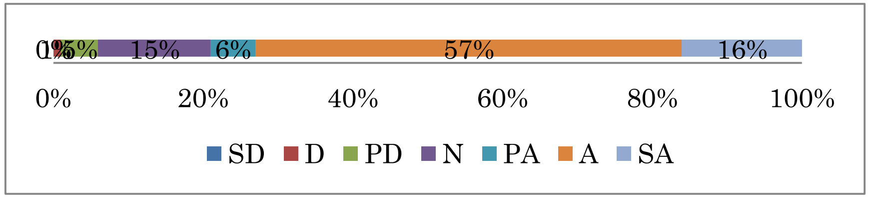
6f. Sorting waste is not a pleasant activity



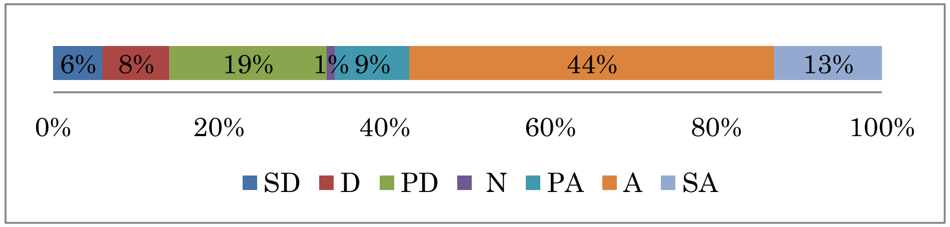
6g. Economic incentives/benefits to sort waste is insufficient



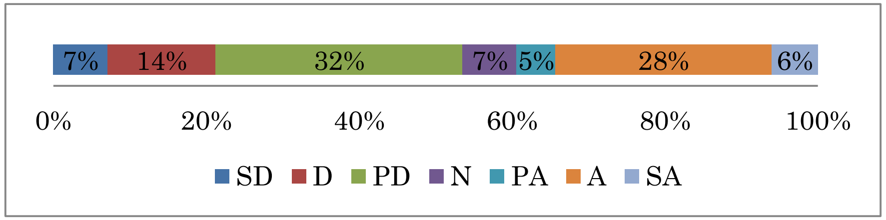
6h. Mechanism for treatment of sorted waste is not yet established



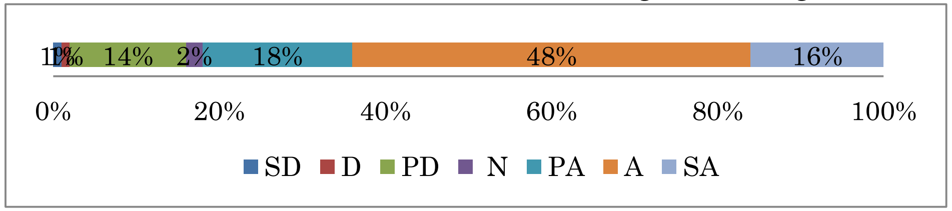
2c. Respondents do not know how to properly sort waste



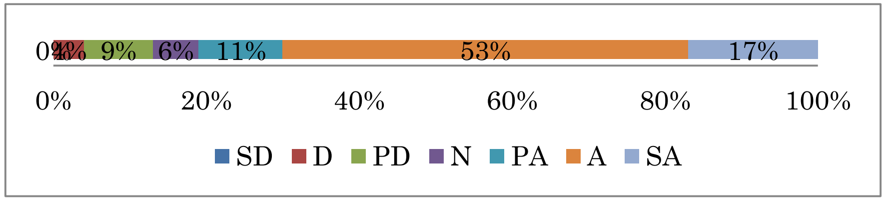
6i. Respondents do not know how to properly sort waste



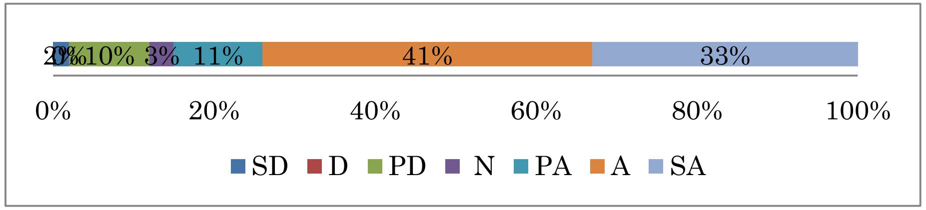
2d. There is a lack of information on the advantages of sorting



6j.There is a lack of information on the advantages of sorting



2e. There is no assurance that the waste transporter will not mix the sorted waste at the temporary storage.



6k. There is no assurance that waste transporters will not mix the sorted waste in the temporary storage.

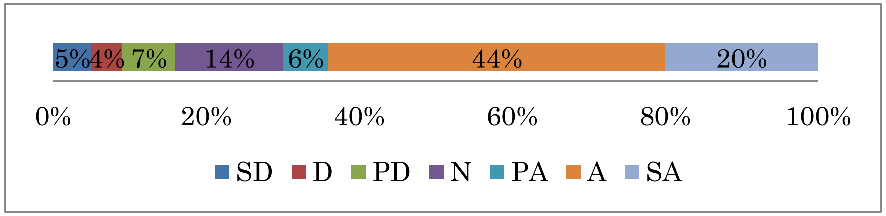


Fig. 5. 2 Reasons to and not to sort

There is a high degree of agreement among respondents who practice sorting that the reason for sorting is to contribute to a better environment (91%). This finding corroborates with the finding of a prior study in Norway, of which environmental considerations represent the most obvious reason for sorting at the source. In their survey, 97% of respondents who sort at the source entirely or partly agreed that they did this partly because they wanted to contribute to a better environment.

For the non-sorting group, another reason for not sorting is because there is no CBWM mechanism to treat the sorted waste (89%), whereas the sorting group agreed that the reason for sorting is to treat the sorted waste through CBWM (73%) and home composting (76%). The non-sorting group also identified the unestablished mechanism for treatment of sorted waste as the reason for not to sort (79%).

The sorting group also agreed on other reasons, such as recommendation from community groups (73%), to get additional income from selling recyclables (73%), and because it is a pleasant activity that brings satisfaction (76%). Incentives for sorting are also of importance for the two groups (both 70%).

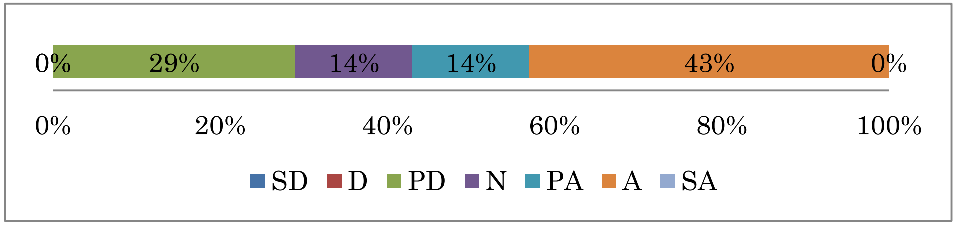
When asked about difficulties in sorting, 82% of the sorting group identified the lack of information on sorting advantages and 85% identified the inexistent assurance for waste transporters to not mix the sorted waste at temporary storages. High agreement was also stated by non-sorting group with regard to the lack of information on sorting advantages (81%) and no assurance for not mixing sorted waste (70%).

Reasons to CBWM participation and non-participation

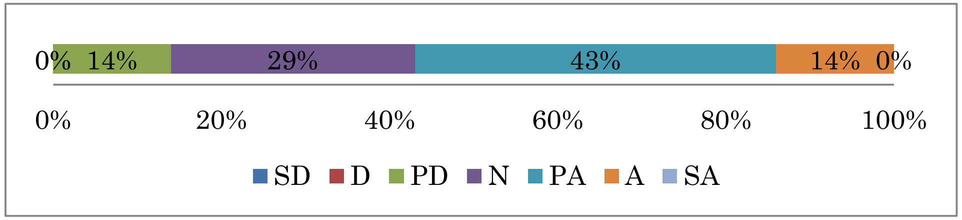
Further, the respondents were grouped into 2 groups; the first group consist of those participating in CBWM and the second consist of those who do not participate in CBWM, to identify the reasons to participate (and not to participate) in CBWM.

Reasons to Participate in CBWM

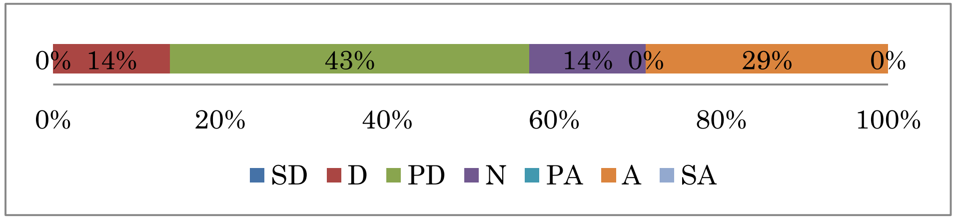
9a. It is recommended by respondents' community group



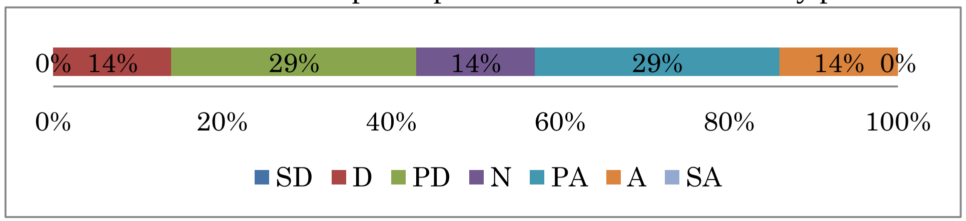
9b. Respondents think CBWM contribute to a better environment



9c. CBWM is a pleasant activity

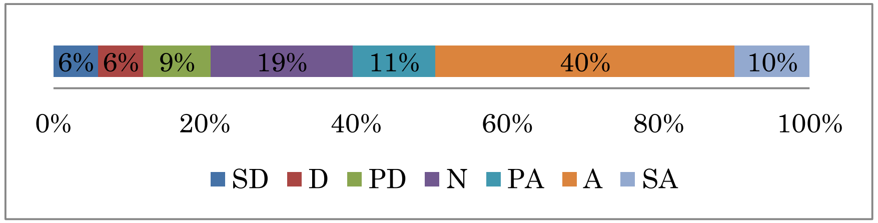


9d. Incentives/benefits to participate in CBWM is sufficiently provided

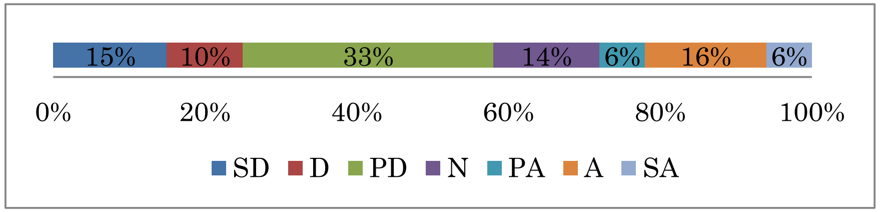


Reasons to Not Participate in CBWM

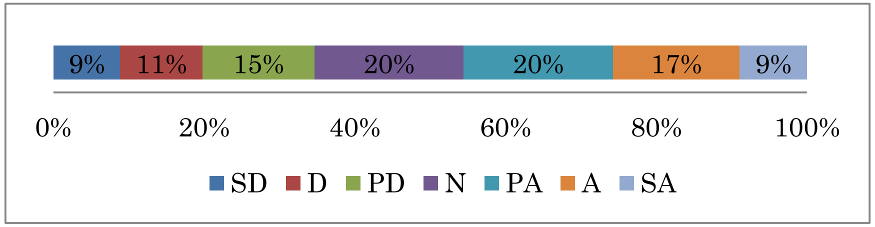
7a. It is not recommended by respondent's community group



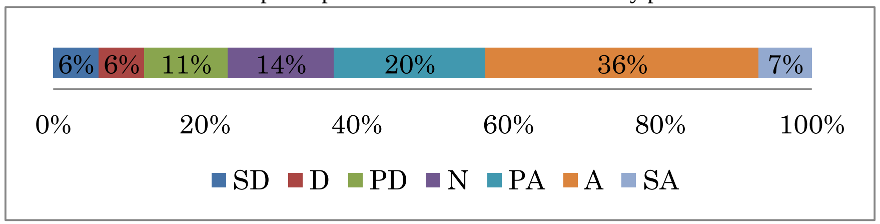
7b. Respondents do not think CBWM contribute to a better environment



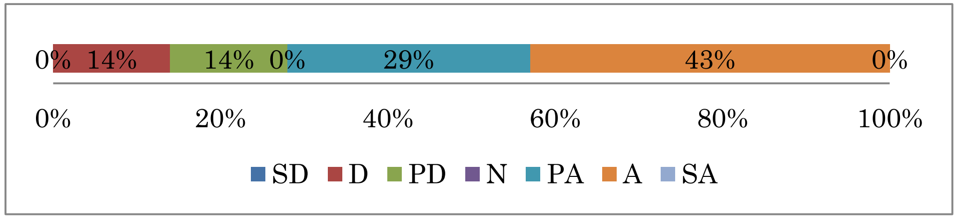
7c. CBWM is not a pleasant activity



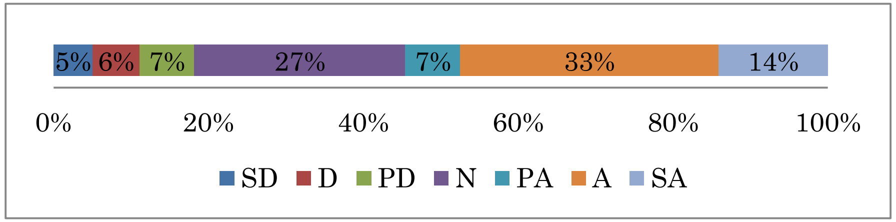
7d. Incentives/benefits to participate in CBWM is not sufficiently provided



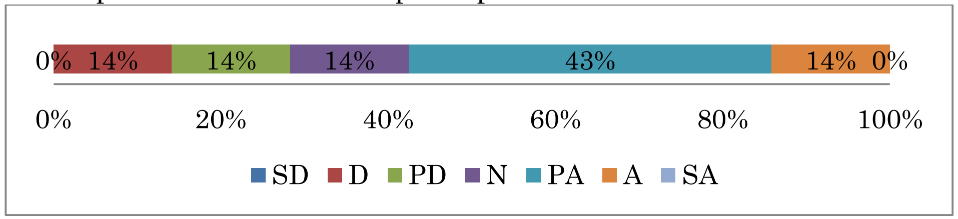
9e. Mechanism for proper CBWM is already established



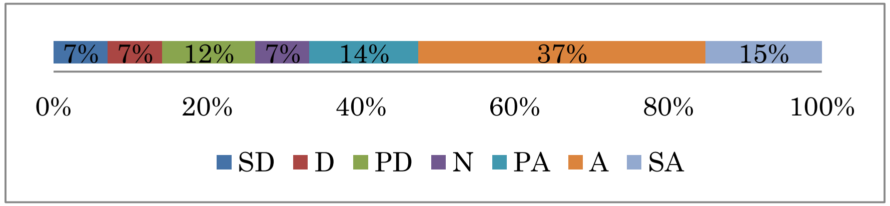
7e. Mechanism for proper CBWM is not yet established



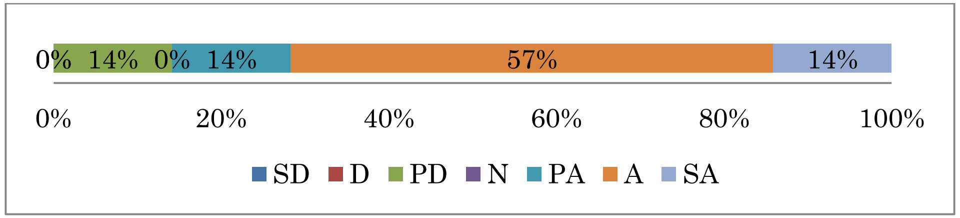
9f. Respondents know how to participate in the CBWM



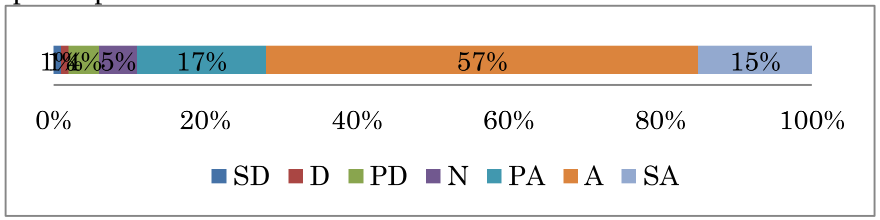
7f. Respondents do not know how to participate in the CBWM



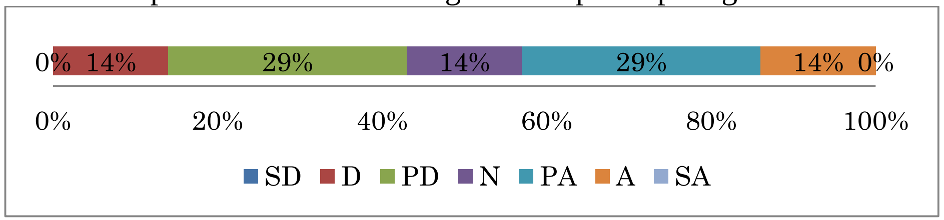
9g. There are sufficient information on advantages of CBWM participation



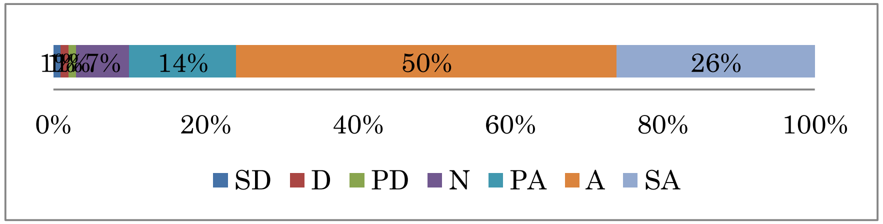
7g. There are lack of information on advantages of CBWM participation



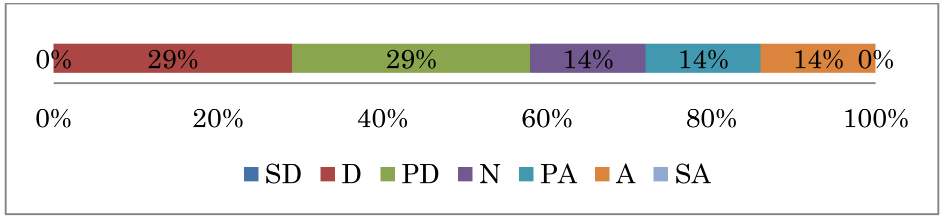
9h. There is provision of free sorting bins for participating in CBWM



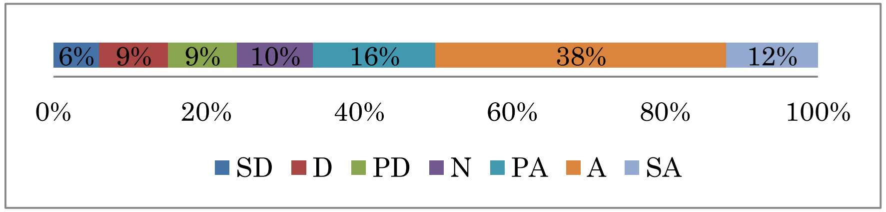
7h. There is no provision of free sorting bins for CBWM



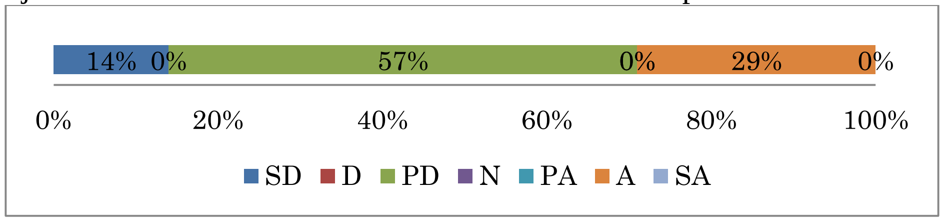
9i. There is information about benefits of CBWM to the environment



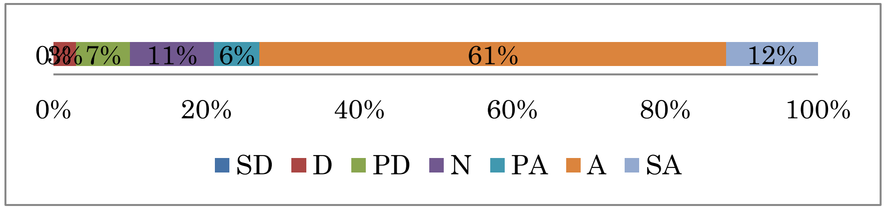
7i. There is no information about benefits of CBWM to the environment



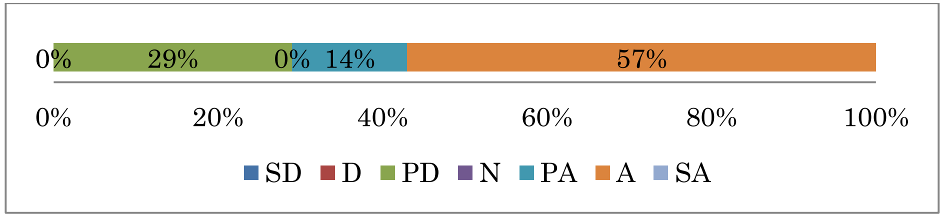
9j. There is information about benefits of CBWM to public health



7j. There is no information about benefits of CBWM to public health



9k. There is information about how the sorted waste will be treated by CBWM activities



7k. There is no information about how the sorted waste will be treated by CBWM activities

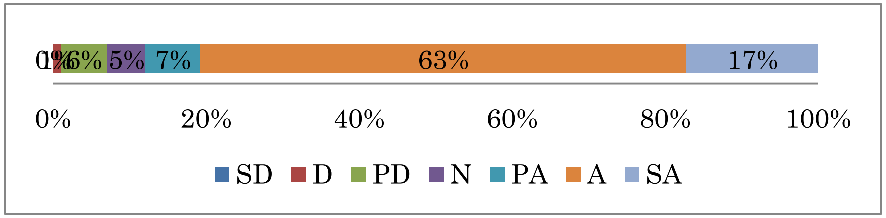


Fig. 5. 3 Reasons to and not to participate in CBWM

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There are CBWM facilities 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 that is used for composting organic waste. A shredding machine is usually also available at the facility. Organic waste is collected by manual labourers who transport it to the composting facility. Inorganic recyclable wastes are also collected per type and CBWM participants may receive money incentive, which amount is determined based on the quantity (in kg) and price of waste per type.

Of all the respondents surveyed in this study, 88% claimed that there are no CBWM in their area of residence. Among the respondents who indicated that CBWM are available, only 7% claimed to be actively involved. The participation rate and awareness of such activities are still quite low. This finding corroborates to the outcome of a prior study in Canada, in which participation rate of CBWM communal composting is only 17% (Taylor, S., Todd, P., 1995).

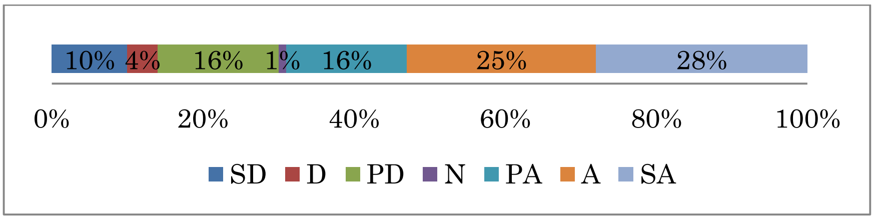
Based on the survey, there are reasons where both groups have high agreement on. First, information on advantages of CBWM participation is deemed as an important reason (85% of CBWM participants and 89% of the non-CBWM participants). Secondly, information on how the sorted will be treated through CBWM is also of importance (71% of CBWM participants and 87% of non-participants).

There are however differences of agreement level in the reasoning among the two groups. According to the responses from CBWM participants, established mechanism for proper CBWM if of importance (72%), whilst the non-participants deemed it to be of less importance (54%). The group of non-participants agreed that no provision of free waste sorting bins is the reason for them not so participate in CBWM, whereas the CBWM participants' agreement rate is 43%. The inexistence of information about on benefits of CBWM to public health also becomes the reason not to participate in CBWM (79%), whilst the CBWM participants did not identify it as the reason to participate (29%).

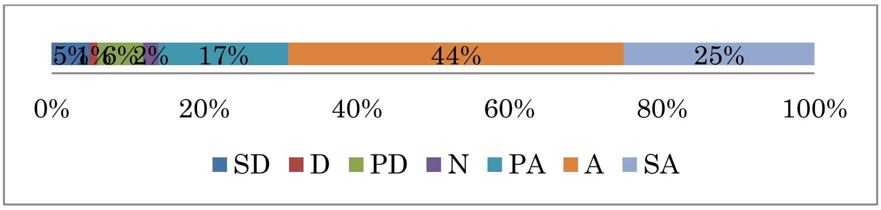
5.4.3. Perceptions of roles within the waste management system

The perceptions of all respondents regarding waste management systems were studied and presented below.

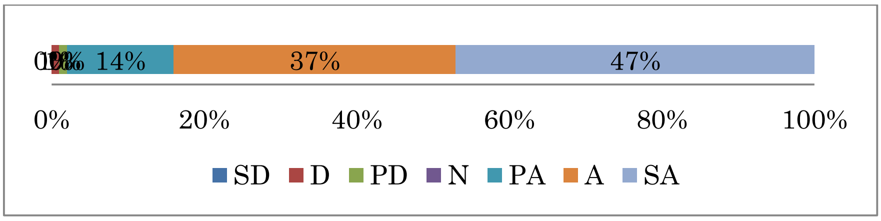
a. Municipal government is responsible for waste management as respondents pay a waste levy/fee to them.



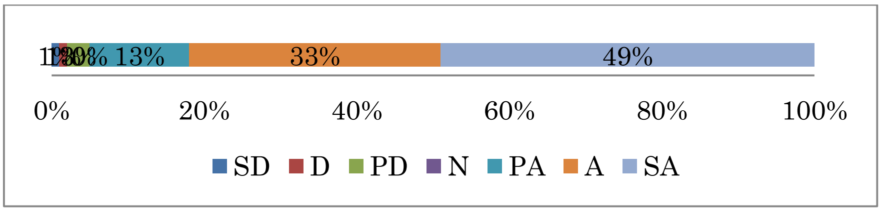
b. Commercial services should be involved to manage the waste properly, even if increased market-rate fees are a consequence.



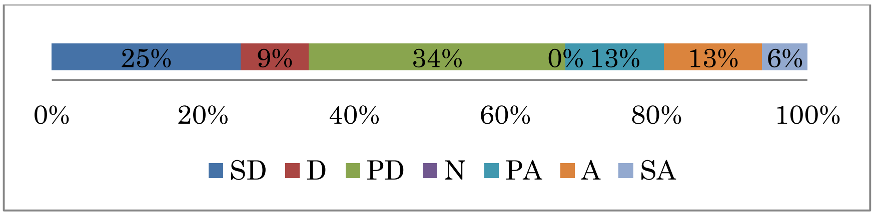
c. Waste management is a shared responsibility to which the respondents, as citizens, also held responsible.



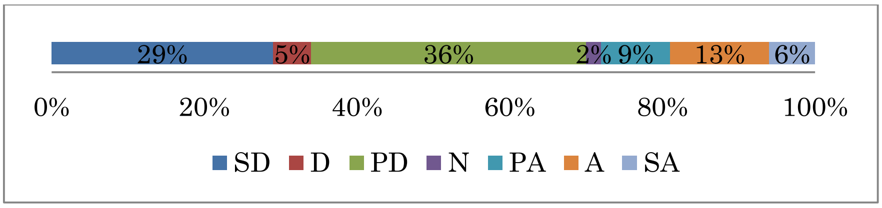
d. Government and waste providers are fully responsible and must provide better waste management service.



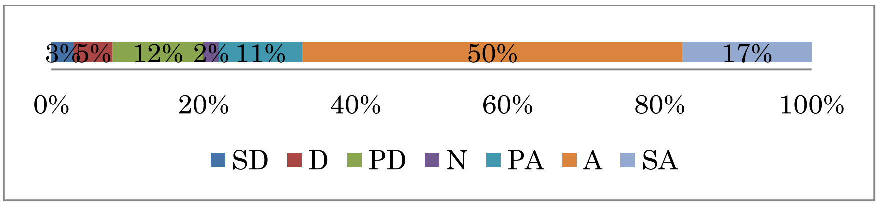
e. If household waste sorting is required, women should be the ones who conduct it.



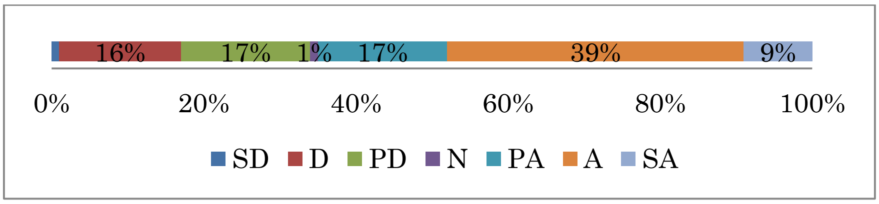
f. Maids are the ones responsible for managing my household waste



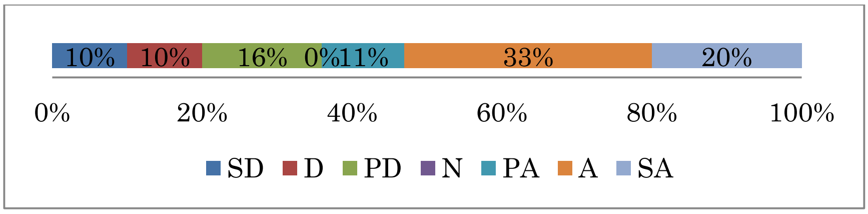
g. There is a lack of regular waste collection services



h. There is pollution/littering not properly managed in respondents' residential area



i. There is waste that is scattered as a result of careless collection



j. Respondents trust that the waste is managed, treated, and disposed of properly by waste providers.

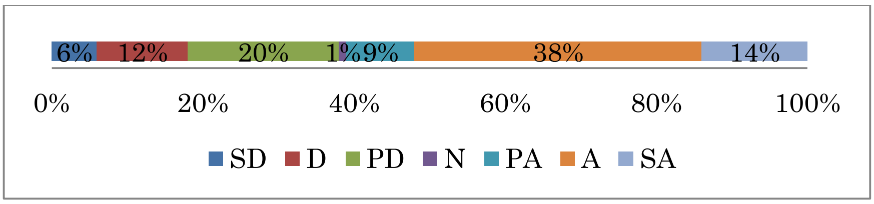


Fig. 5. 4 Perceptions of respondents on current existing SWM system

The survey for this study revealed that there is a high degree of agreement (86%) that commercial services should be involved in managing waste, despite the consequences of increased fees. There has yet any specific regulation in Indonesia that regulates the private operators working on waste management. ADB (2011) presented the recommendation based on a study of waste management in South Asian country, that one of the key issues to be addressed at the state and local levels is the avoidance of levying royalties (an additional fee on the private operator) as a source of additional revenue; if royalties are required by the municipality, they should not exceed 2% of the income from the compost plant, or in lieu of cash transaction, they should be in the form of compost, which may be used by the local government for its parks and other greenery.

Based on prior studies, payment for waste management services or facilities is very important to the success of the private sectors' participation in waste management program. The willingness to or not to pay waste levy for waste management services could have direct impact (positive or negative) on the reliability and success of any solid waste management strategy (Longe, E.O., Longe, O.O., Ukpebor, E.F., 2009; Epp, D.J., Mauger, P.C., 1989; Rahman, M., Salequzzaman, Md., Bahar, M., Uddin, N., Islam, A., al Hrun, A.Y., 2005). The question therefore has to do with the economics of household waste management especially in a developing economy. Unwillingness to pay could lead to illicit burning and dumping, thus Fullerton and Kinnaman (1995) argued that household collection should be subsidized in order to prevent such external environmental costs resulting from illegal dumping.

Majority of respondents agree that waste management is a shared responsibility to which they should be held responsible as citizens (98%). By contrast, respondents also agree that government and waste providers are fully responsible and must provide better service (SI= 95%). This contrasting opinion on the responsibility also distinguished in a prior study on the perception on waste management charges. The majority of respondents based their beliefs on the perception that government should pay for waste management; the next most commonly given reason was a belief among respondents that they themselves should pay for waste services because it is their responsibility to do so (Purcell, M., Magette, W.L., 2010).

It was observed that the respondents generally disagree that if household waste sorting is required, women should be the ones who conduct it. Thus it implies that women are not perceived as the ones whom are responsible for household waste management and disposal. This finding differs to the outcome of prior studies in China (Chung, S.S., Poon, C.S., 1999, 2001) and Britain (Martin, M., Williams, I.D., Clark, M., 2006), of which there are tendencies for women to be responsible for household waste management.

As there is the tendency to hire maids to support household chores and errands of families in developing countries (Afroz, R., Masud, M.M., 2011), this study probed on whether the respondents perceive maids are the ones responsible for managing household waste. The response was that the respondents were generally disagree that household waste is managed by maids.

5.4.4. 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).

Table 5. 3 Willingness to pay (n=100)

	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%

If government authorities were to require at-source waste sorting, the majority of the respondents (57%) claimed that they will sort their own waste. However, 42% agreed to pay others to sort their waste an average of 16.5 thousand IDR (approximately US$ 1.87) per month.

This figure seems low considering the minimum regional wage of Jakarta. Therefore another means of determining WTP is to estimate the labour cost per hour of sorting.[6] The minimum regional wage in Jakarta is 2.2 million IDR (approximately US$ 248) per month. This wage corresponds to USS$ 1.6 per hour, assuming a 20-day work month and an 8-hour workday.

5.4.1.5. Inorganic and hazardous waste generation rate and composition

Household waste contains hazardous materials such as used motor oil, pesticides and solvent and paint residues in used cans and bottles. Contaminants such as heavy metals also occur; they are found in small quantities in a range of household waste items but are mainly concentrated into a few items such as used batteries, discarded light bulbs and tubes and mercury thermometers. If mixed MSW composting is to be carried out, the operator must be aware that high heavy metals levels (from batteries, etc) may prevent the resulting compost being sold as it would be likely to exceed the legally permissible heavy metal limits (McDougall FR, White PR, Franke M, Hindle P, 2009).

IPCC categorized the following waste types as inorganic waste: plastic, metal, glass (pottery and ceramics), and other (electronic waste/e-waste, ash, dirt, dust, soil). Household waste could contain hazardous and toxic waste such as expired drugs, dried

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

cells, broken class, syringes and thus constitute serious environmental and health hazards (Delgado et al., 2007). Bulky waste refers to large-size waste such as drawers and furniture (Wada, Y., Okumoto, T., Wada, N., 2009). In terms of the disposal of hazardous and bulky waste items in Jakarta, 91% of all respondents dispose of hazardous waste together with other household waste, whereas 63% dispose of bulky waste together with other household waste. The modes of disposal for inorganic bulky waste, hazardous, and toxic waste items, are presented in Table 5.4.

Table 5. 4 Disposal of bulky and hazardous waste items

	Percentage of total respondents
Method of bulky waste disposal	
Dispose of bulky waste together with other household waste	63%
Transport bulky waste directly to temporary storage	9%
Transport bulky waste to community/collective bulky waste disposal	5%
Sell bulky waste to scrap dealer	4%
Other	19%
Method of hazardous waste (e.g., batteries, harmful chemicals) disposal	
Transport the hazardous waste to the communal waste pool station	4%
Dispose of together with other household waste	91%
Transport to battery/chemical disposal station at malls	1%
Others	4%

The methods of bulky and hazardous waste disposal as per municipality are presented in Fig.5.5 and 5.6 accordingly.

According to Fig.5.6, the majority of hazardous waste in all municipalities are disposed with other wastes. There are however, small percentage of other methods of disposal, such as burning, burying, and dispose in the river banks.

According to Fig.5.5, a large portion of bulky wastes are disposed with other wastes. However in East Jakarta and Central Jakarta, some respondents disposed the bulky waste with other methods, such as open burning and give away the bulky materials that are usable (e.g. furniture) to others.

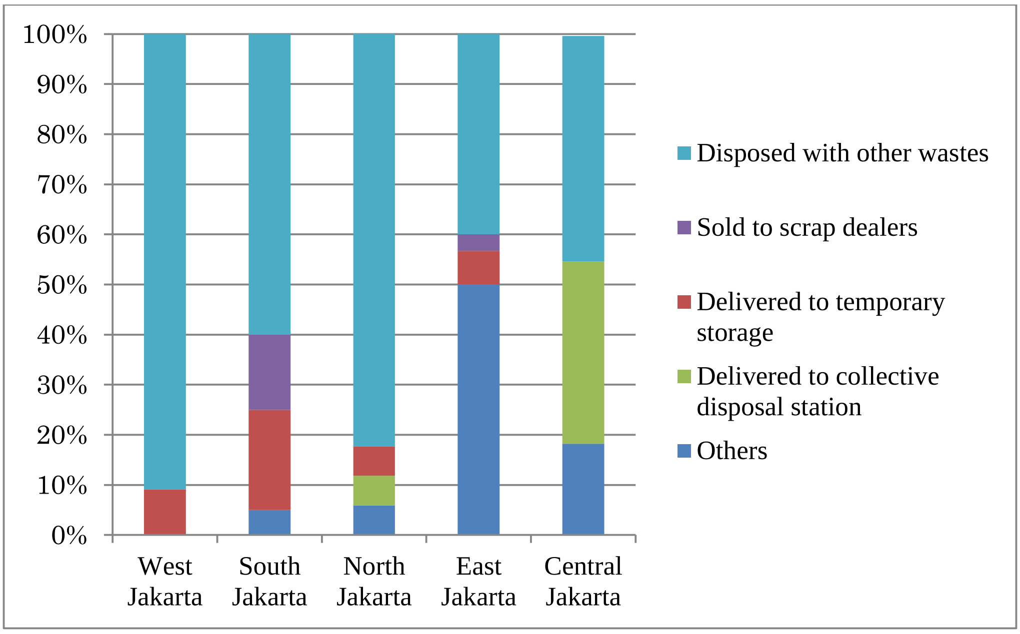


Fig. 5. 5 Method of bulky waste disposal by respondents per municipality

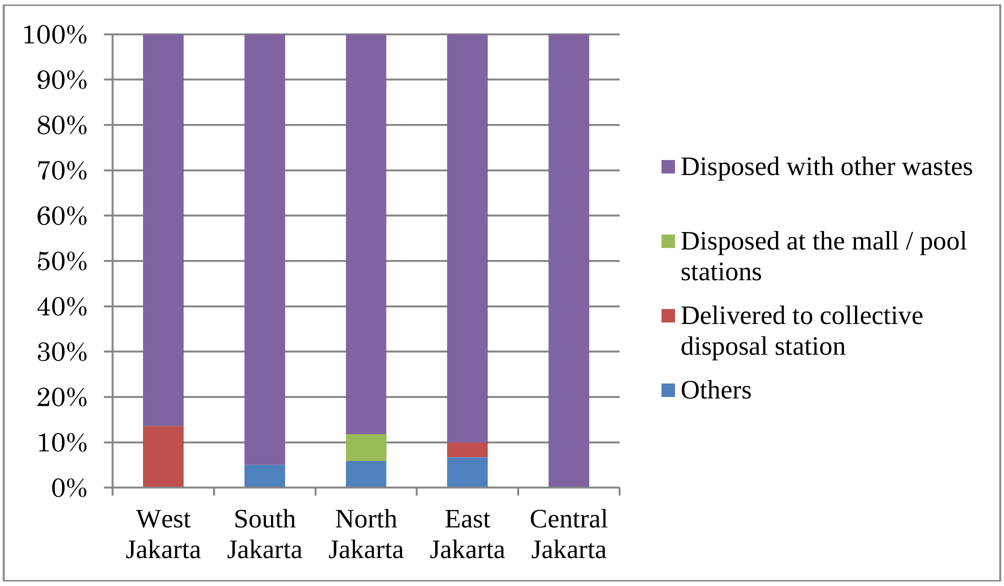


Fig. 5. 6 Method of hazardous waste disposal by respondents per municipality

5.5. Discussion

The findings from the study on CBWM communities suggest that there were distinct traits for successful CBWM that sets them apart from the failed case. Specific community members' personal attributes in conducting at-source sorting is one of the key determinants for successful CBWM. Prior studies (e.g. Henry et al,2006; Baud et al, 2001; Kapepula et al, 2007) mentioned briefly about sorting for general MSW. However this study further supports the notion that at-source sorting is very crucial for the success of CBWM.

The successful CBWM cases takes place in homogeneous middle-income communities with racial heterogeneity, whereas the failed cases have heterogeneous income levels with racial homogeneity. With regard to the homogenous middle-income group, the finding corroborates Arcand and Fafchamps (2012) who find that on average, the more fortunate members are more likely to take part in community-based organisations. Membership is directly related to socio economic status, where people with lower incomes are less likely to participate in voluntary associations. Arcand and Fafchamps did not address high-income groups, but in my study it suggests that those groups are unlikely to participate compared to the middle-income groups. In regards to the heterogeneous ethnicities, it refutes prior study findings (Alesina, 2000) wherein for a wide range of community activities, they find that participation is lower in more unequal or ethnically fragmented localities. This also opposed the findings from Muller and Vothknecht (2013) who suggested that the willingness to become involved in certain local groups decreases with the relative engagement of people from other ethnic groups.

The successful cases of CBWM started through grassroot/informal initiation, whereas the failed ones started as a top down pilot project by external supports. It verifies JICA (2003) that external supports would not bring significant improvement without public participation in practicing at-source sorting and CBWM.

Subsequently, this study found that the successful cases of CBWM were independent from external assistance. However, despite the non-reliance on external support, CBWM requires full support from all stakeholders within the community, namely the participation of community members and CBWM leaders. In addition, the support from staff members at the neighborhood cluster (RW) and ward office (kelurahan) were also prerequisite in providing CBWM coordination. Recognitions also lead to awareness and more households to participate in CBWM.

Leadership capacities of CBWM leaders also play an important role in the successful CBWM case. Specific traits in successful CBWM leadership are strong capacities to influence and seniority of the leaders. This corroborates prior studies by Chrislip et al (1994) that civic leaders may bring together diverse community members in efforts that lead to real, measurable change in the lives of communities. Cook (1975) also suggested that unsupported leaders often become discouraged and drop activities that are potentially beneficial to community residents.

Additional to the above-mentioned properties of communities, there were also autonomous provision of basic means in the successful case studies that were absent in the failed cases, i.e:

a) Assigned land for CBWM activities and waste storage
b) Ownership and use of sorting bins by all CBWM community members
c) Justified CBWM mechanism,
d) Clear distribution of work of CBWM actors
e) Established design of waste collection, treatment & waste transactions flows

Subsequently, the householders were probed on the reasons to sort and not to sort, in order to identify on the distinct properties and barriers in sorting.

Table 5. 5 Reasons to (and not to) sort

Group 1: Householders that conduct at-source sorting ***(Main reasons to sort)***	**Group 2: Householders that do not conduct at-source sorting** ***(Main reasons not to sort)***
Commonality:	
To treat the sorted waste through CBWM (1e)	There is no CBWM system to treat the sorted waste (6e)
Common barriers in sorting:	
Insufficient incentives to sort waste (2a and 6g)	
No assurance for waste transporters not to mix the sorted waste at temporary storages (2e and 6k)	
Lack of information on sorting advantages (2d and 6j)	

Both groups stated that the existence or non existence of CBWM system is the main reason for them to sort or not sort. This corresponds to the findings of Cook (1975) who stated that citizens will voluntarily participate in a community activity when they see positive benefits to be gained and have an appropriate organizational structure available to them for expressing their interests.

The importance of incentives as noted in this study corroborates to prior research by Chung and Poon (1994; 1999) in which they concluded that people were generally willing to separate materials for purposes that would generate financial incentives. It also supports Pasang et al (2007) argument that sorting practices and CBWM in Jakarta have ceased to operate due to inexistence of economic incentives, among others.

The group that conduct sorting stated the following additional reasons to sort, which differs from the group who do not sort:

- To contribute to a better environment (1c)
- Sorting recommendation from community groups (1a)
- To get additional income from selling recyclables (1b)
- Sorting is a pleasant activity that brings satisfaction (1f)

Further this study probes on the main reasons for the group of householders who participate in CBWM and the group of householders who do not participate in CBWM are presented in Table 5.6.

Table 5. 6 Reasons to (and not to) participate in CBWM

Group 1: Householders that participate in CBWM ***(Main reasons to participate in CBWM)***	**Group 2: Householders that do not participate in CBWM** ***(Main reasons not to participate in CBWM)***
Commonality:	
There is sufficient information on advantages of CBWM participation (9g)	There is lack of information on advantages of CBWM participation (7g)
There is information on how the sorted will be treated through CBWM (9k)	There is no information on how the sorted will be treated through CBWM (9k and 7k)

This finding suggests that the availability of information on advantages of CBWM participation and how the sorted waste will be treated through CBWM are the main reasons that determine whether or not householders would participate in CBWM. Information is an important factor for community participation, as also stated by Bede (2010) that people are reluctant to participate in community activity when they do not have enough education or information to act responsibly.

The group that participate in CBWM stated that established mechanism for proper CBWM is also a reason to participate (9e), which differs from the non-participating group.

Meanwhile, the group of CBWM non-participants stated the following additional reasons, which differs from the other participants group:

- No provision of free waste sorting bins is the reason for them not so participate in CBWM (7h).
- No information about on benefits of CBWM to public health (7j).

5.6. Limitations of Study

There are several limitations of study; firstly, the small sample size of respondents restricts the findings to be generalised to the total population of Jakarta. Interpretation of results in a wider context should be done carefully, because the measures of behaviour were measured on a self-report basis. Such measurement for behavioural research is common; however there is a possibility of discrepancies of opinions that are reflected in the responses from the actual practice.

Environmental issues and awareness are currently being discussed and mainstreamed in the society. This to some extent may have affects the opinions of respondents when responding to the survey, in the attempt to appear as environmentally-conscious individuals.

5.7. Conclusions

Many studies have been conducted on community-based (CB) and CBWM initiatives; however no prior studies gave empirical evidence on the preferred sequence of the top-down institutional/formal approach and grassroot/informal approach.[7]

This thesis contributes to knowledge for the unanswered question of the preferred sequence of top-down institutional/formal approach and grassroot/informal approach for prevailing CBWM initiatives. It is generally understood that many examples cannot verify causality, but it can increase validity of hypothesis. This study

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7 e.g. Charuvichaipong, 2006; Shekdar, 2008; MacIntyre, 2003; Suraji et al, 2014; Evan et al, 2006; Pasang et al, 2007; Meidiana, 2010; Kardono, 2007; Zhuang, 2008; JICA, 2013; Carrey and Braunack-Mayer, 2009, Frasera et al, 2006, etc

found a hypothesis that can be applied to the six CBWM communities, where grassroot/informal initiation must first become the starting point prior to any top-down institutional/formal measures, so long as the CBWM initiatives are voluntary, not regulatory.

This argument is based on the result of comparative studies, of which in all successful cases of CBWM communities under study indicated that their initiatives started firstly through grassroot/informal initiation, with presence of at-source sorting practices within the communities, and independent provision of basic means such as land for CBWM activities and sorting storages.

According this study, we found a hypothesis that grassroot/informal initiation is more likely to be established in homogeneous middle-income communities with high willingness to sort and heterogenous ethnicities. Other important factors are the high motivations of the CBWM leaders and members. After the foundation is established and progressing, top-down interventions (such as government support or private sectors' CSR) could take place to strengthen the pillars, i.e. through provision of additional means, CBWM design guidance, information, and incentives. In addition to the top-down institutional/formal initiation and government-formed community grouping systems of neighborhood units/associations (RT/RW) to form the CBWM initiatives; grassroot/informal community neighborhood groupings permeate Indonesian middle-income community groups such as *arisan* (rotating-credit associations), *PKK* (women's family welfare group), and *pengajian groups* (Islamic worship group). These can be avenues for effective means of entry points to promote CBWM initiatives. This is also because this study found the hypothesis that CBWM prevails in middle-income communities.

CHAPTER 6: CONCLUSION

The goal of thesis is to design the measures to promote the preferred household solid waste management (SWM) system to be implemented in Jakarta, Indonesia. To achieve the goals, the objectives of this thesis are:

1. To identify the preferred household SWM system based on the criteria of this study: economic and environment associated with greenhouse gases (GHG) emission.
2. To identify the factors for successful community-based waste management (CBWM) implementation, identification of primary target communities for CBWM, and promotion measures by government to promote the implementation of the preferred SWM system.
3. To identify the preferred sequence of the top-down institutional/formal approach and grassroot/informal approach in the preferred SWM system.

According to the multi-criteria evaluation based on the results of Chapter 3 and 4, communal composting has the highest economic revenue, with moderate GHG emission. Anaerobic digestion performs best in GHG emission saving but has the lowest economic revenue. The GHG emissions are similar for anaerobic digestion, communal composting, and centralised composting. Therefore the selection of waste management system can be chosen from other criteria such as economy.

For the case of Indonesia, CBWM that is composed of communal composting for organic waste and collective recovery of inorganic recyclable waste - is preferred, due to conomic consideration. Moreover, the allocated funds for Cleansing Department are only 2.9% of the total Municipal Budget and waste levies are not imposed. Thus, financing expensive large-scale and sophisticated waste treatment facilities such as anaerobic digestion is not preferable for Jakarta from the economic point of view.

Further to this, communal composting and inorganic waste recovery that generally exist as community-based waste management (CBWM) system were discussed in Chapter 5. Based on the findings, successful CBWM were established in communities which members are mostly middle-income people, have presence of at-source sorting practices; have homogenous income group and heterogeneous ethnicity where indigenous ethnicity of Betawi is a minority. Sorting practices are determined by existence of CBWM system and incentives in sorting. The main reasons to determine householders' participation in CBWM are provision of information on advantages of CBWM participation and how the sorted waste will be treated by CBWM. After the initiative is commenced autonomously, external top-down support could take place to sustain the activities, i.e. through provision of additional means, CBWM design guidance, information, and incentives.

This study have increased the validity of hypothesis that so long as the CBWM initiatives are voluntary, successful CBWM is derived from autonomous establishment through grassroot/informal initiation approach. In addition, grassroot/informal community groupings such as *arisan* (rotating-credit associations), *PKK* (women's family welfare group), and *pengajian* groups (Islamic worship group), which permeate Indonesian middle-income community groups can become avenues to promote CBWM as it tends to prevail in middle-income communities.

In order to streamline the conclusion, the outline of this thesis is presented in Fig.6.1. There are five household waste management options that are covered in this study; namely landfilling, communal composting, anaerobic digestion, central composting, and landfill with gas collection. Incineration option is not included in this study because the method is not suitable for treatment of organic waste, while based on the composition survey; household waste in Jakarta mostly consists of organic waste fractions. In addition according to UNEP (2002), incineration is a largely unfeasible option in non-OECD countries due to the high cost and often unsuitable waste composition.

The general conclusion is that communal composting is the preferred household SWM system for the case of Jakarta based on the criterias set in this study. Communal composting exists within the framework of community-based waste management (CBWM) that requires sorting and householders' participation. This study presented the factors for householders to be more likely to conduct sorting and for communities to be successful in CBWM implementation.

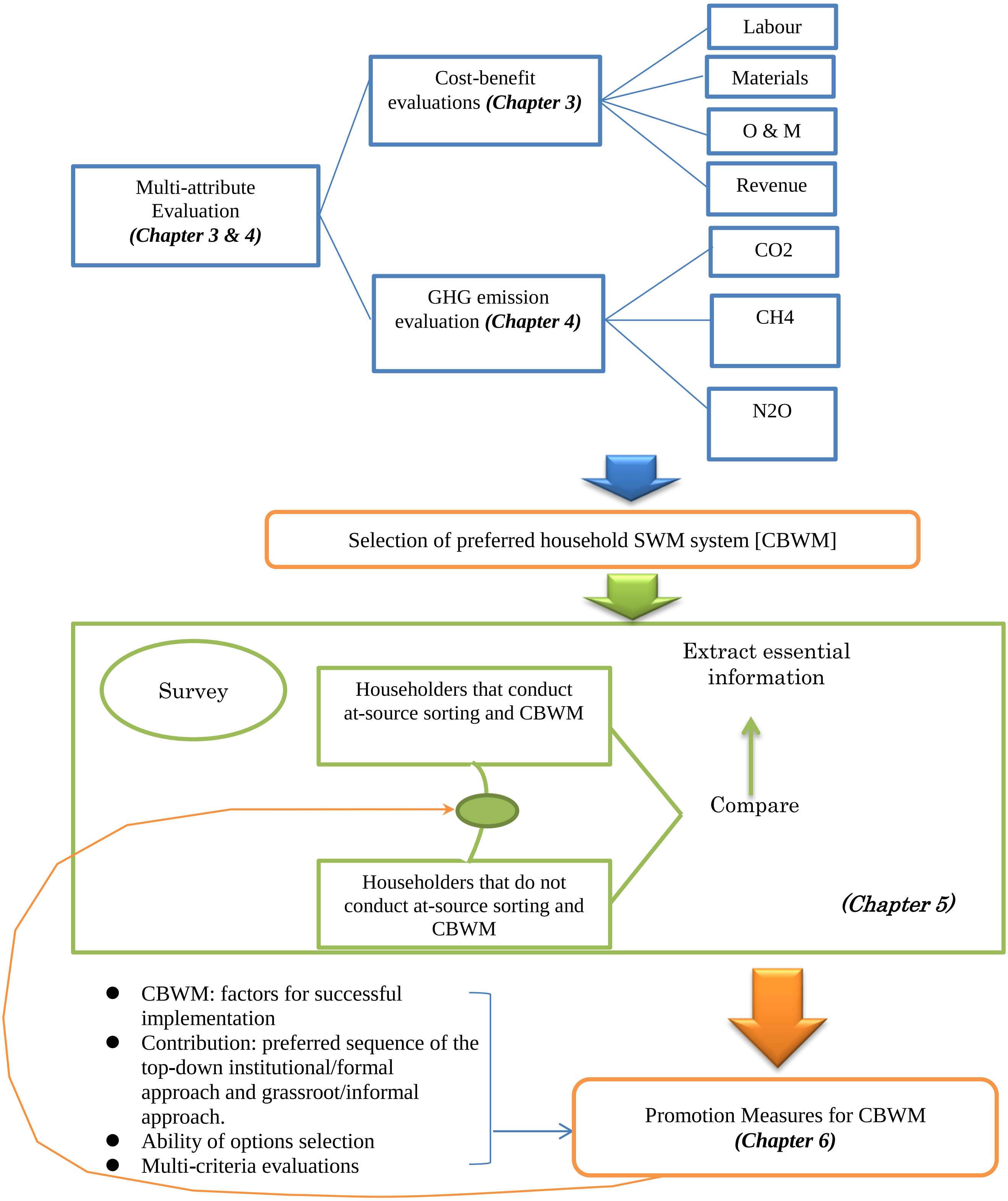


Fig. 6. 1 Outline of Thesis

The objectives and conclusions of the main chapters are as follows:

1) Chapter 3: Economic Evaluation of Household Solid Waste Management in Jakarta, Indonesia

For the economic evaluation, this study introduced an approach where not only the cost and benefit from SWM system from organic waste were estimated, but also the cost and benefit from the recovery of inorganic recyclable waste, including transportation costs to deliver the co-products.

a) Objectives: To identify the economic performance of each SWM system through estimation of the economic cost:benefit, taking into account the benefits from compost, electricity, and carbon credit sales.

Conclusions:

1. Communal composting has the highest economic revenue, followed by landfill with gas collection system. The other systems generated economic loss or negative revenue, such as central composting. 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.
2. 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 system are from the GHG saving through emission reductions projects and electricity generation that are sold to the grid. Landfilling system performs better than anaerobic digestion, however it does not generate any benefits and there are issues regarding hygiene, land constraints, leachate, odours and public health concerns.
3. The operation of 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 subsidy on electricity tariff results in the uncompetitive selling price of electricity from these systems. Therefore when it comes to the revenue analysis, anaerobic digestion and landfill with gas collection systems 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 systems.

4. In principle, 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.
5. CBWM scheme that comprised of communal composting for organic waste and collective sales of inorganic waste is a desirable system from economic perspective.

b) Objective: to identify the potential revenue from the recovery of sorted recyclable inorganic waste.

Conclusion: Sorting would have the potential to generate revenues from the recovery of sorted recyclable waste in Jakarta with estimation of nearly US$ 115 million per year.

2) Chapter 4: Characteristics of Household Solid Waste Management and Estimation of Greenhouse Gas Emissions For Waste Management Systems in Jakarta, Indonesia

a) Objectives: To identify the solid waste generation rate for each type of waste to estimate the GHG emissions.

Conclusions:

1. The average household solid waste generation in Jakarta was 1.32 kg per household per day based on the survey. Kitchen waste represents greater than 50% of the total. This component of the waste can potentially be composted. Plastic (14%) is the second largest component, followed by paper and cardboard (12%), garden waste (7%), metal (4%), disposable diapers (4%), glass (2%), others (2%), rubber and leather (1%), textile (1%) and wood (1%).
2. Among the top fractions of inorganic waste from households, nearly all are recyclable, except dense plastic that are unrecyclable scraps. Other wastes, such as

food packaging (18%), refuse plastic sacks (15%), clear plastic beverage bottles/PET bottles (11%) and aluminum beverage cans (8%), can be recycled and would therefore have significant economic values in scrap dealing. According to the findings, household waste in Jakarta includes large amounts of compostables and recyclables. Compostable material accounts for 59 percent of all waste. Its "recycling potential" is therefore high. An additional 21 percent of all waste is categorised as recyclable. The remaining 20 percent of household waste may be discarded in the landfill because it is non-compostable or non-recyclable. Although there are valuable resources present in household waste, the majority of respondents dispose the recyclable wastes together with other types of waste, including organic waste.

b) Objectives: To identify the environment impacts associated with GHG emission through the emission estimation on each of the waste management system.

Conclusions:

1. Anaerobic digestion performs best in terms of GHG emission with emission savings of $7.5x10^6$ kg CO_2eq per 1,000 tonne of treated waste compared to the baseline system of landfilling.
2. Communal composting and central composting have the second lowest emission with similar amount of GHG emission, which slight difference is due to the emission from transportation. The total emission savings for communal and central composting are $6.7x10^6$ and $6.8x10^6$ kg CO_2eq per 1,000 tonne of treated waste, respectively. Compared with the baseline system, these two systems yields 76% reduction of GHG emissions.
3. Landfill with gas collection involves methane extraction for energy generation from organic waste. With the assumption of 60% gas collection efficiency, this system has emission savings of $5.4x10^6$ kg CO_2eq per 1,000 tonne of treated waste compared with baseline system.
4. Landfilling as the baseline system emits the highest amount of GHG with $7.0x10^6$ kg CO2eq per 1,000 tonne of treated waste.
5. This study suggests that anaerobic digestion has the highest potential for GHG emission savings, followed by communal and central composting. However the

amount of emissions is similar for these three systems. Therefore, the selection of waste management system can be chosen from other criteria such as economic.

c) Objectives: to identify the potential GHG savings from the use of recycled materials instead of virgin materials.

Conclusions:

1. Recycled inorganic waste has the potential of saving 0.22 tonne CO_2eq per household per year from the use of recycled materials instead of virgin materials.
2. Considering the number of households in Jakarta, with the assumption of 80% recycling of all recyclable materials, the potential savings is 357.3×10^3 tonne CO_2eq per year.
3. The GHG emission-saving potential is the greatest for food or kitchen waste (810×10^3 tonne CO_2eq per year), followed by paper and cardboard (251×10^3 tonne CO_2eq per year), garden waste (64×10^3 tonne CO_2eq per year) and textiles (21×10^3 tonne CO_2eq per year).

Table 6. 1 GHG emissions for each system (kg CO2eq per 1,000 tonne waste)

System	Organic waste					
	GHG from treatment	Rest waste landfilling	Emission from energy consumption	Transport of compost from treatment plant to market	Transport of rest waste from treatment plant to landfill	Avoided emission from chemical fertilizer production or energy recovery
Landfill (unsorted)	69x10^{6}	0	30.1x10^{3}	0	30.4x10^{3}	0
Communal composting	5.7x10^{5}	43.5x10^{4}	64.3x10^{3}	0	7.6x10^{3}	-20.1x10^{3}
Anaerobic digestion	5.5x10^{2}	43.5x10^{4}	58.2x10^{4}	0	0.5x10^{2}	-2.2x10^{6}
Central composting	29x10^{6}	43.5x10^{4}	48.2x10^{3}	5.6x10^{3}	7.6x10^{3}	-20.1x10^{3}
Landfill with gas collection	29x10^{6}	43.5x10^{4}	30.1x10^{3}	0	0	-1.0x10^{-6}

System	Inorganic recyclable waste			Other waste	**Total emission**	**Emission savings compared to baseline**
	Avoided emission from recyclables	Transport emission of rest waste from temporary storage to landfill	Transport emission from temporary storage to market	Transport emission to landfill		
Landfill (unsorted)	0	0	0	0	7.0 x10^{6}	0
Communal composting	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	8.5x10^{3}	2.9 x10^{5}	6.7 x10^{6}
Anaerobic digestion	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	0.5x10^{2}	-4.6 x10^{5}	7.5 x10^{6}
Central composting	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	5.7x10^{3}	2.7 x10^{5}	6.8 x10^{6}
Landfill with gas collection	1.0x10^{6}	5.9x10^{3}	1.9x10^{3}	0	1.6 x10^{6}	5.4 x10^{6}

From the result of evaluations of economic and GHG emission estimation, a multicriteria evaluation is presented as Table 6.2 and Fig.6.2.

Table 6. 2 Multicriteria evaluation of economic and GHG emission estimations

	Landfill	**Communal composting**	**Anaerobic digestion**	**Communal composting**	**Landfill with gas collection**
Revenue (USD)	-2,982,523	4,570,510	-6,857,712	-1,769,997	1,526,614
GHG emission savings (kg CO_2eq per 1,000 tonne waste treated)	0	6.7 x10^6	7.5 x10^6	6.8 x10^6	5.4 x10^6

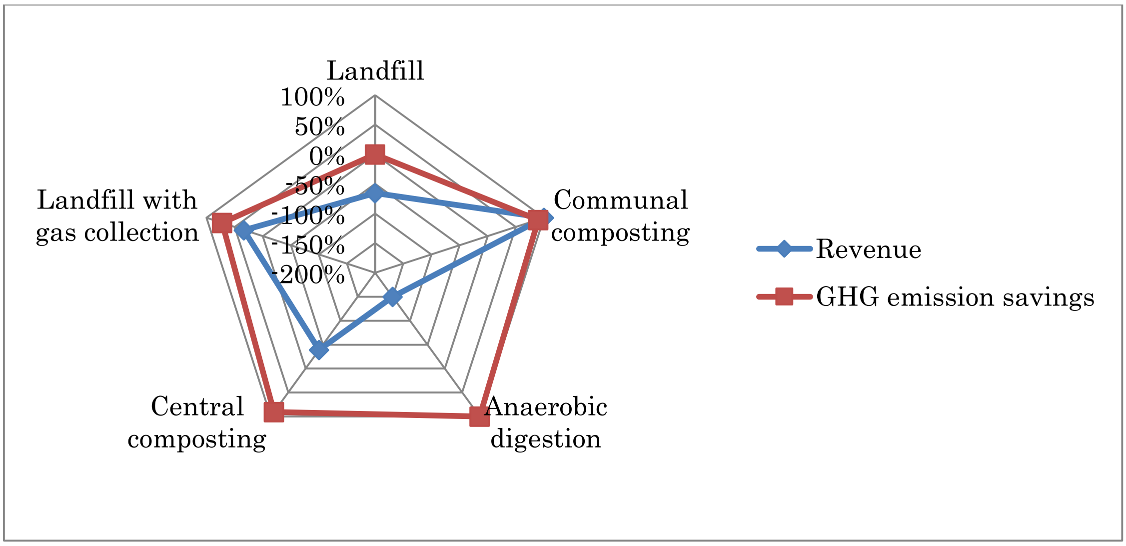


Fig. 6. 2 Multicriteria evaluation of economic and GHG emission estimations

According to the multicriteria evaluation, communal composting has the highest economic revenue, with moderate GHG emission. Anaerobic digestion performs best in GHG emission saving but has the lowest economic revenue. The GHG emissions are similar for anaerobic digestion, communal composting, and centralised composting. Therefore the selection of waste management system can be chosen from other criteria such as economy.

For the case of Indonesia, communal composting is preferred due to the economic consideration. Moreover, the allocated funds for Cleansing Department are only 2.9% of the total Municipal Budget and waste levies are not imposed. Thus, financing expensive large-scale and sophisticated waste treatment facilities such as anaerobic digestion is not preferrable for Jakarta from the economic point of view.

3) Chapter 5: Evaluation of Human Behaviour in the Management of Household Waste

This part of thesis used a new approach of study to identify householders and CBWM communities' behaviours, in order to identify the distinct properties and barriers, to eventually conclude on the factors for successful CBWM and promotion measures for CBWM implementation.

- Objectives: to identify the factors to promote the implementation of the preferred household SWM system through identification of distinct properties and barriers.

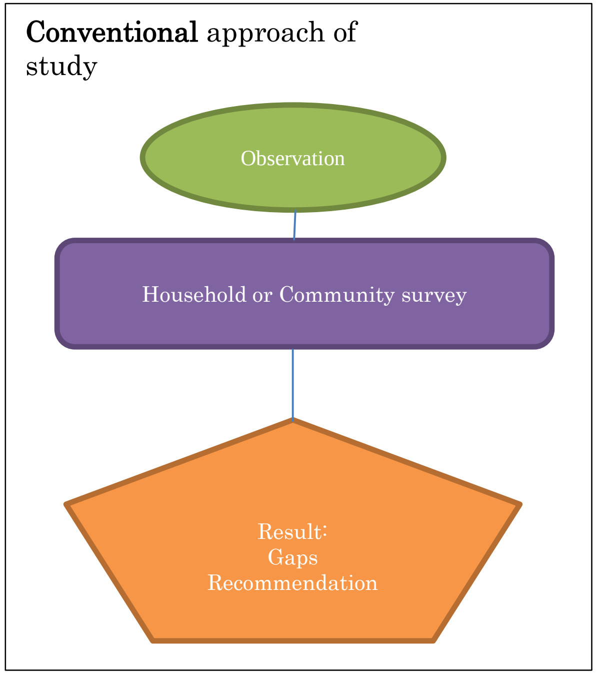
1) The case studies of successful and failed CBWM

Conclusion: There were distinct traits for successful CBWM cases that set apart from the failed cases. Specific community members' personal attributes, which is the *presence of at-source sorting practices* is one of the key determinants for successful CBWM. Subsequently, this study found that the successful cases of CBWM were *autonomously commenced by community members, have influencing senior CBWM leaders, and autonomous provision of basic means for CBWM activities*.

2) Reasons to sort for the group of householders who conduct at-source sorting and the reasons not to sort for the group of householders who do not sort.

The *existence of CBWM system* determines the reason to conduct sorting. Inversely, the inexistence of CBWM system is the reason not to sort. Both groups indicated the significance of *incentives in sorting* that drived their sorting behaviour.

The group that conduct sorting stated the following additional reasons to sort, which level of agreement is different from the group who do not sort. The sorting group highly agree, whereas non-sorting group do not have high agreement on the following reasons: a) To contribute to a better environment, b) sorting recommendation from community groups; c) to get additional income from selling recyclables; and d) sorting is a pleasant activity that brings satisfaction.



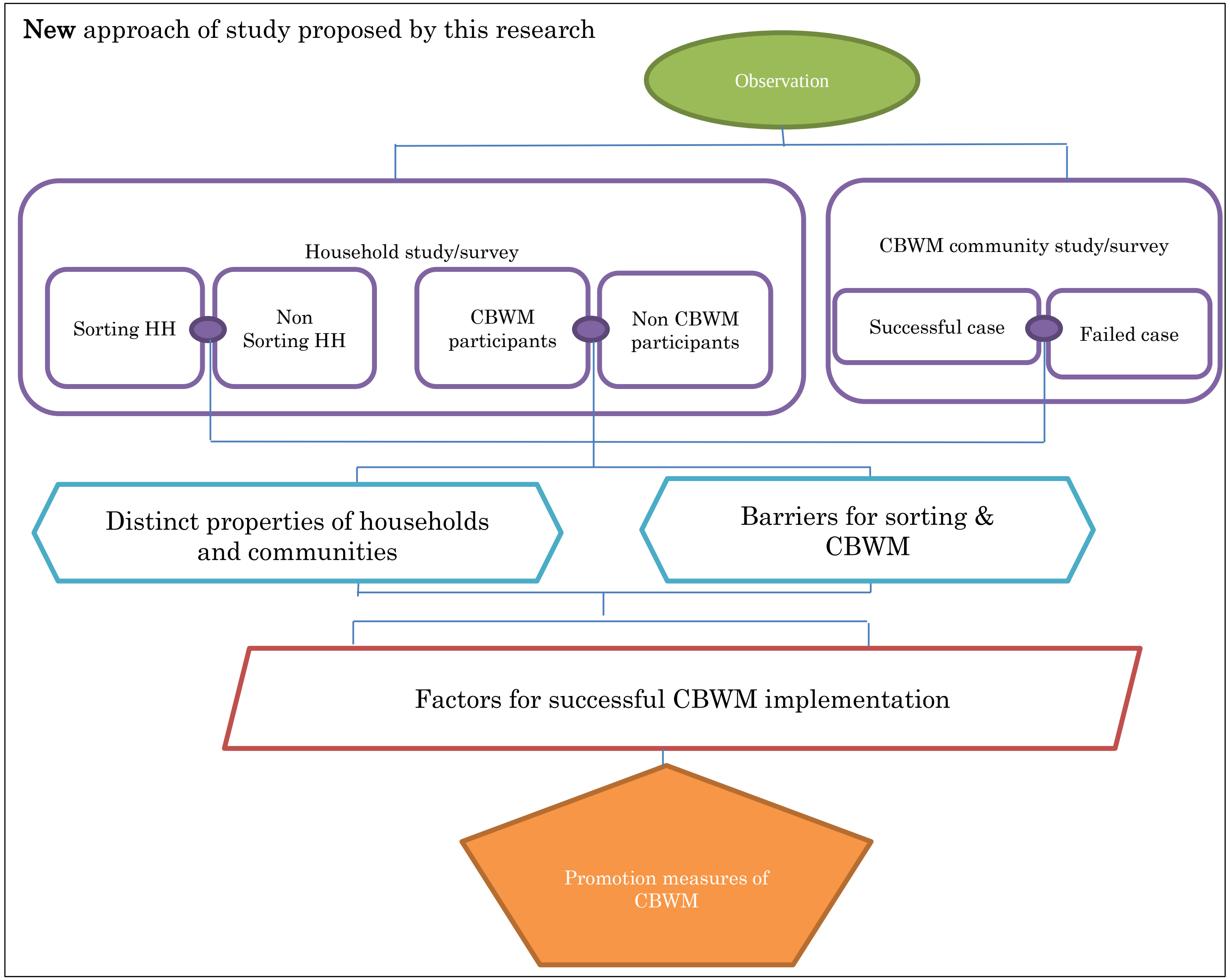


Fig. 6. 3 Conventional vs New Approach of Study

3) The group of householders who participate in CBWM and the group of householders who do not participate in CBWM

Both groups agreed that the *availability of information on advantages of CBWM participation* and *how the sorted waste will be treated through CBWM* are the main reasons that determine whether or not householders would participate in CBWM. The group that participate in CBWM stated that established mechanism for proper CBWM is also a reason to participate. Meanwhile, the group of CBWM non-participants stated the reasons for not participating, namely no provision of free waste sorting containers and no information about on benefits of CBWM to public health.

Overall Conclusions

Based on the study we found the hypothesis for Jakarta about the successful CBWM to be established in communities which members are mostly middle-income people, have presence of at-source sorting; have homogenous income group and heterogeneous ethnicity where indigenous ethnicity of Betawi is a minority. After the initiative is commenced autonomously, external top-down institutional/formal support can be presented to sustain the activities, i.e. through provision of additional means, CBWM design guidance, information, and incentives.

This study have increased the validity of hypothesis that so long as the CBWM initiatives are voluntary, successful CBWM is derived from autonomous establishment through grassroot/informal initiation approach. In addition, grassroot/informal community groupings such as *arisan* (rotating-credit associations), *PKK* (women's family welfare group), and *pengajian* groups (Islamic worship group), which permeate Indonesian middle-income community groups, can become avenues to promote CBWM as they prevail in middle-income communities.

This thesis contributes to answer the question of the preferred sequence of top-down institutional/formal approach and grassroot/informal approach for prevailing CBWM initiatives. This study has increased the validity of hypothesis that so long as the CBWM initiatives are voluntary, successful CBWM is derived from autonomous commencement with grassroot/informal initiation approach. This argument is based on the result of study, where all of the successful CBWM cases were conducted through grassroot/informal initiation and do not rely on external support, whereas all of the failed CBWM cases were commenced by external institutions such as government.

As the support from external institutions exist, hence ideally these supports are obtained after CBWM is established, for continuing the activities after the initiation. These support ideally be provided based on the performance from the autonomous commencement. Without evidence of good performance, external support cannot be obtained.

The promotion measures of CBWM are presented as Fig.6.4, which suggests that there are primary target communities for CBWM that have success potential, namely communities with existing at-source sorting practices, grassroot/informal initiation, and autonomous provision of basic means for CBWM. Top-down support through government interventions may subsequently exist, namely through regulations and information provisions. Issues to be regulated are incentives to sort through regulating standardised market pricing and proper mechanism to prevent mixing the collected sorted waste. The information required are on the advantages of sorting, CBWM participation, and how the sorted waste will be treated through CBWM.

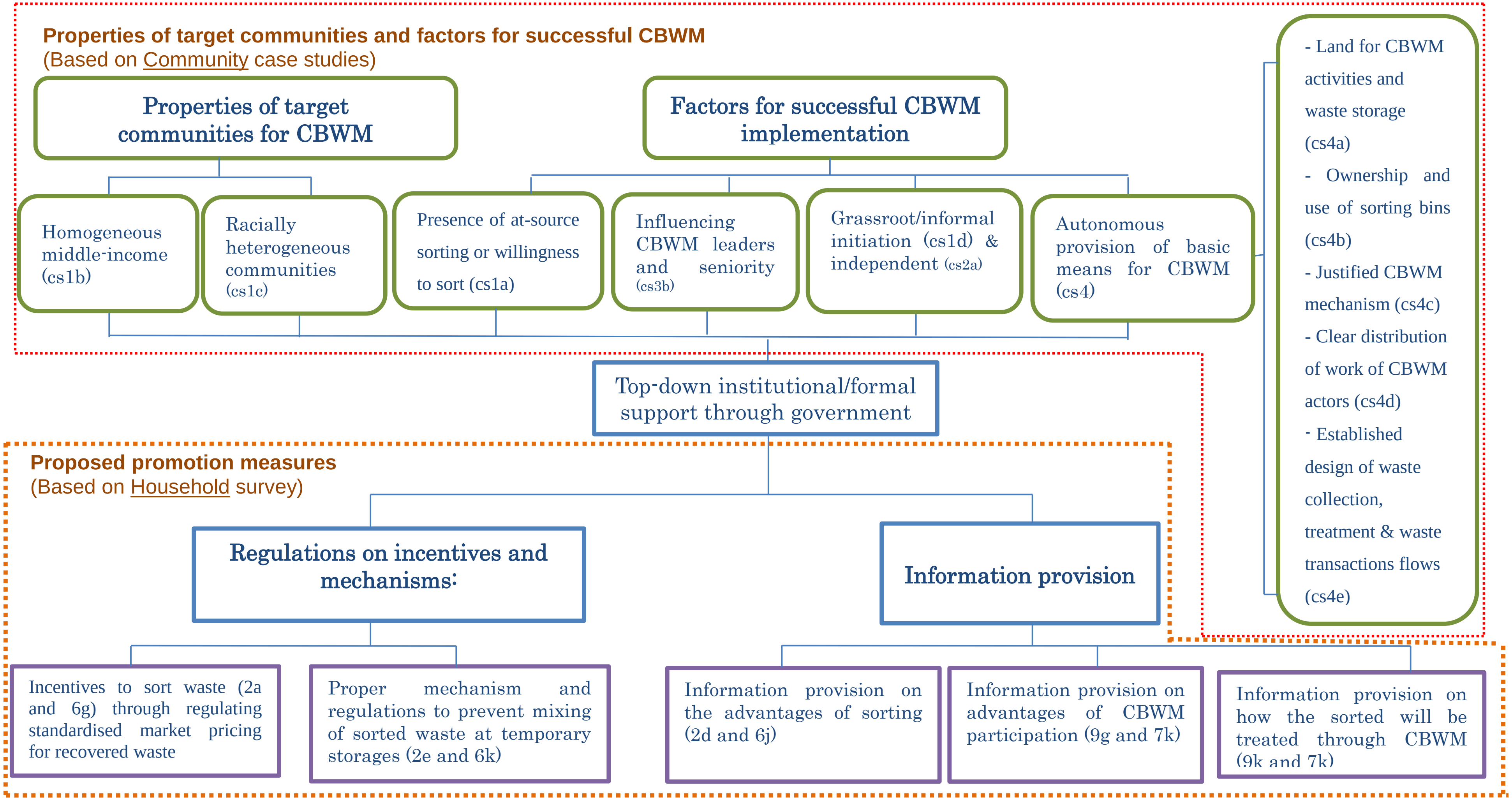


Fig. 6. 4 Promotion measures of CBWM

Further Studies

This study serves as the basis for the attempts to evaluate the entire household solid waste management in Indonesia, with the case study of Jakarta. The community-based framework for deciding policy measures for promoting community-based waste management as presented in this thesis may be applied to other sectors. For example, voluntary community-based organic agriculture, community-based environmental preservation, community-based ecotourism, etc.

The current SWM system of landfilling is unpreferred due to the environmental issues such as hygiene issues, odour issues (smell), land use issues, and scenery issues. The wastes in Indonesia are presently managed through landfilling (40.1%); composting and recycling (1.6%); open burning (35.5%); others (15.3%) (BPS Statistics Indonesia, 2001). Awareness of people upon proper waste management is also of importance. There are several ways to increase the public awareness, such as the provision of awareness raising campaigns and environmental education. Those mentioned in the antecedent sections are the priorities to be considered when it comes to devising waste management policy systems. However this study only addresses limited parts of the whole waste management system, namely household and community behaviours on the preferred household SWM based on the criteria of this study.

Possible criteria that merit further study would include the following:

1. Thorough social impact analysis to determine the impacts of each of the options.
2. Social acceptability analysis to identify the level of public acceptance on each of the options.
3. Social experimental research that aims to thoroughly observe the behaviour of householders in terms of the application of waste sorting.
4. Studies on the reduction of waste that changes the composition of waste generation.
5. Feasibility studies and analysis of other possible waste management technologies
6. Studies on recycling technologies to observe about the availability and feasibility.
7. Extended life cycle analysis to determine the environmental impacts of each waste management options.

These complementary aspects would complete the analysis within an integrated framework.

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Appendix

Ethnography of CBWM case studies

Successful case 1: Kompleks Zeni TNI AD Kalibata, Jl. Zeni AD RT 006 RW 03, Kelurahan Rawajati Pancoran

The respondent is the CBWM leader Mr. Suwarso, a 64-year old retiree who served at the ground forces army. Ten neighborhood units within one neighborhood clusters in which 686 households reside at Rawajati ward are involved in the community-based waste management scheme. The management of waste treatment and disposal from households in Rawajati are conducted by the neighbourhood unit (RT). At-source sorting has already taken place. The CBWM activities uses land that belongs to the Indonesian ground forces and is dedicated to communal composting at no cost. The CBWM commenced through grassroot/informal initiation. It was only after a few years that the initiative gained attention from government and private sectors. The majority of CBWM participants have homogeneous middle-income. The majority of people who are not active are the high-income groups. The age of CBWM leader is older than the average age of active participants between 45-55+ years old.

The community is mainly composed of heterogeneous non-indigeneous ethnicity, because it is a residential area for migrated military personnel army soldiers and army retirees. The majority of community members are a mix of Central Javanese descents, Sundanese, Batak, and many other tribes than the local tribe of Betawi. The CBWM leader is a Central Javanese who originally came from Jogjakarta. The variations of tribes are due to the fact that the military personnel were recruited from all over Indonesia thus they were mostly non-locals. Betawi people are minority and they rarely participate in CBWM.

The hierarchy within this community exists and the power of CBWM leaders depends on the capacity to influence and acceptance from community members. The level of position in the army is one of the main factors that determine influencing capacities. The current CBWM leader is a retired major in the army and well-respected in the community. He has the power of influence the community members to participate in CBWM, particularly but not limited to those who are or used to be with the army.

The CBWM started first by a group of community members who were concerned by the state of environment in the area. The idea for conducting CBWM was then being discussed in the neighbourhood cluster meeting, where subsequently a leader was appointed. There were one main leader with two subordinates, all of whom are part of the community members and local residents of where the CBWM is conducted. The management is carried out by the community under the leader’s supervision. All of the stakeholders involved in the CBWM are community members, except for waste transporters, who were recruited and were not local residents of the area.

The CBWM leaders, who takes the role of importance, are more senior than most of the rest of the community members. The seniority deemed to have more power and authority to motivate the communities to shift behaviour. The leaders are initially part of community members, who were then appointed to manage the CBWM activities.

The materials for CBWM such as land and waste sorting storages were provided autonomously by the community members. The community were bestowed a land space for CBWM activities. The land is located under extra high voltage aerial line (wiring) of 500 kV that is intended to distribute electrical energy from the power centers located in remote areas to the load centers so that electrical energy can be transmitted. For that reason, the land was vacant as there are safety restrictions that prohibit the land to be used for housing. Thus it was decided that the land is to be dedicated for CBWM activities. The operation and management (O&M) is also carried out by the community members, under the guidance and direction of the CBWM leaders.

After the community demonstrates success of CBWM implementation, the community was offered with external supports. They were in the forms of seed money and other assistance such as waste shredding equipment from the Jakarta Cleansing Department; waste filter, sieving equipment and green house from the Department of Agriculture.

The success of CBWM is due to the active participation of community members and the CBWM leaders. In addition, the staff members at the neighborhood cluster (RW) and ward office (kelurahan) also support the activities after it demonstrates a success. The success was appreciated through awards, such as the acclamation as the “Best community cluster (RW) in Jakarta province for greenery and cleanliness” in

2004; appointed as the Agro-tourism Village by the Department of Tourism in 2005; award as "CBWM Best Practice of Jakarta" in 2013 - which lead to the CBWM to be up-scaled to cover the whole ward. The CBWM members were rapidly increasing in 2013 after the CBWM received intense exposure as a best practice. There were a number of large-scale private companies that express interests to support the CBWM activities but the CBWM leaders refuse the support in order to retain impartiality.

Successful case 2: Jl. Sultan Agung No. 20 Guntur, South Jakarta

The respondent is the CBWM leader Mrs. Yeni Mulyani Hidayat, a 45 years old housewife with a bachelor's degree in banking. The CBWM served 3 neighbourhood clusters (RW) with 24 neighbourhood units (RT). The income levels for people who actively participate in waste banks are homogeneous middle-income group. The majority of people who are not active are the high-income groups. The age of CBWM leader is older than the average age of active participants between 35-44 years old.

The CBWM activities were commenced as activities initiated by the communities (grassroot/informal initiation). A leader was then appointed among the neighbourhood cluster's community members. The households already conducted proper at-source sorting. Initially the CBWM leader was an active leader of women's welfare group (PKK) of the community. In 2000, the focus was on the waste management. The women's welfare group started to be interested in collecting plastic bottles. From there on, they discussed about the formation of CBWM. They made use of Mrs. Yeni's land for CBWM activities. To establish it, they used a month of preparation time. Later, the CBWM initiative was proposed to the mayor of Jakarta, and on September 14, 2012 it was formalized.

The management for CBWM is carried out by the community under the leader's directions. All of the stakeholders involved in the CBWM are community members, except for waste transporters, who were recruited and were not local residents of the area. The activities also include handicraft production from inorganic wastes, which involved housewives and students.

The CBWM leader, who takes the role of importance, is more senior than the majority of community members. The seniority allows her to show authority to influence the communities to shift behaviour to sort and participate in CBWM. The CBWM leader is a Sundanese who was originally from Cianjur, West Java. The majority of the ethnicity of the community members is high-income Indonesian Chinese. They are however, the most inactive ethnic group in the CBWM, other than the Betawi people. The majority of ethnicities most active in CBWM are Sundanese, Central Javanese, and Indonesian-based Indian people. The community has a racial heterogeneity.

The leader strongly agreed that she is motivated to lead the community in order to contribute to a better environment and because it is a fun activity that gives her satisfaction. The advantages as a leader are that it increases her income, and to her it gives personal satisfaction. She claimed to be able to meet new people, new experiences and to go around the country and travel abroad to share experiences of CBWM. Since the establishment in 2012, the number of households that are active in CBWM is increasing. The leader aggressively influenced the community members and do not hesitate to visit residents directly in their homes.

After the initiative is successfully established from the grassroot, it started to gain attention, where the government institution PT. PLN (State Electricity Company) provided assistance to the CBWM. The support was through provision of wheel bins (handcarts), recycling equipment, renovation of the CBWM facility, means for involvement on various exhibitions, and networking. The government support has increased the level of public participation because the people feel appreciated. However there is no assistance from private companies, but the CBWM leader was requested to provide assistance in the form of trainings to private companies, such as PT. King Koil, Bank Mandiri and PT. WIKA.

There is currently no support for increasing awareness regarding CBWM (e.g training / training) provided by the government. Thus the leader suggests that the government should provide an operational standard or mechanism for all CBWM in Indonesia so that they will be more systemised.

Successful case 3: Jalan Benting Indah I No 15, Semper Barat, Cilincing, Jakarta Utara

The respondent is the CBWM leader Mr. Nanang Suwardi, a 51-year old high school graduate, who is also the head of neighbourhood cluster (RW). The ward consists of 17 neighbourhood clusters (RW), which comprises of 108 neighbourhood units (RT). There are more than 16 neighbourhood units that are served by the CBWM, with approximately 1,000 households being active participants.

The majority of people who are active in CBWM are homogenous middle-income groups, whereas the low-income groups are the most inactive. Most of the active participants are housewives and students. In this community, most inorganic recyclables are provided by kindergartens that are taught to carry wastes from homes to be collected at CBWM.

The CBWM was initiated in by the community members through grassroot/informal initiation and was established in 2008. The initiative was initiated by the CBWM leader who also served as the head of neighbourhood cluster. It was based on a concern at that time due to the lack of cleanliness in the neighbourhood. He provided 60 trash bins and distributed them to the community members. He wanted to change people's mindset that waste can also have economic value. Afterwards he gave away organic and inorganic waste sorting sacks.

The materials for CBWM were provided autonomously by the community members. The operations and maintenance are conducted under the directions of the CBWM leaders. Since the CBWM leader is also the head of neighbourhood cluster, he has subordinates to help with the implementation of activities. The leader is the decision maker who takes the role of importance for the management.

At-source sorting is taking place at households that participate in CBWM from then on. After 3 months, with the help of 'Karang Taruna' (community youth group), he recruited 78 people to become participants. The initial programme was to provide interest-free loans only by provision of wastes. Subsequently they established programme that allows participants to pre-paid electricity credits with the waste they collected.

On January 10, 2010, this CBWM was formalised and the leader received many awards from the government. Due to the success, the mayor of North Jakarta issued an official letter, which stated that all wards should have at least 1 CBWM and if there is a ward that does not have CBWM would lead the termination of the head of ward.

The CBWM leader is a Sundanese who was originally from Cirebon. In the community, the major ethnicity is Central Javanese and they are the most of active participants other than Sundanese, Manado, Bugis, Madura, Batak.

The leader utilised personal approach to influence participation from children to adults. He provided information through community women's group (*PKK*) and monthly meetings of neighbourhood clusters and units. The role of leaders is very important to influence public participation.

The reason for the leader to lead is the motivation to contribute to better environment, instead of for obtaining additional income. Other than that, the leader considers CBWM as an activity that brings personal satisfaction. The CBWM activities take place in a vacant space. After the grassroot/informal initiation of CBWM is established, the government provided support through the provision of communal composter. The private company PT Astra also provided support such as CBWM facility building and uniforms for CBWM operators. However the government and private sectors have not provided support for awareness raising on CBWM. Instead, the CBWM leader was requested to provide trainings to the governments and corporates. There was a significant increase of participation in 2010-2012 because the initiative was still new and it was being covered by the media.

Failed case 1: Jalan Cipedak Raya RT 04 RW 09, kelurahan Srengseng Sawah, kecamatan Jagakarsa, South Jakarta

The respondent is the CBWM leader Mrs. Yuyun Komalasari, a 41-year old high school graduate, who is a housewife and a committee of the women's welfare group (PKK). The CBWM ceased operation within 1 year after it was being established. There were a variety of reasons, such as the householders do not sort their waste at-source, thus the CBWM leaders were facing difficulties in conducting manual waste separation at the waste collection point. There were only 9 participants and there was no space available to store sorted waste.

The government of Jakarta appointed Srengseng Sawah ward as the Betawi Cultural Village. Therefore most of the community members were homogeneous Betawi people, with minority of Javanese and Sundancese ethnicities.

The community has heterogeneous income groups, which lead to intense disparity between the low-income group and the high-income group. The low income groups had difficulties on meeting their daily needs that refrain them from being active in CBWM, whereas the high incomers view that waste management is a ‘defile task’ that should be carried out by other people (of lower strata). As for the successful CBWM cases, the economic status of residents were homogeneous with the majority of middle-incomers.

The CBWM were initiated as top-down pilot projects by the University of Indonesia. The initiator conducted efforts to put together the team consist of the community members, while providing them trainings and other supports.

The materials for CBWM activities were provided through external assistance since the beginning of activities. The University of Indonesia provided initial support such as waste shredding equipment and communal composter; while the Cleansing Department provided training on compost-making. However the community did not have available land specifically dedicated for waste storage space and CBWM activities, which became one of the causes for the initiative to fail.

The CBWM leader is of Central Javanese ethnicity, who resides in a community which majority of people is Betawi descents. The leader was appointed by the University of Indonesia as she was the focal point of the project. Although she was responsible for the operations and management, organization, and management, but her efforts to influence participation in CBWM was not welcomed by the community members.

The CBWM leader was a regular community member who had lack of capacity to influence the community members. The CBWM leader was junior compared to the large portion of the existing community members who were mostly senior citizens.

It was noted during the interview that there were lack of support from the community members, neighbourhood cluster association, neighbourhood unit, and ward. The participation rate of the community members was low.

Failed case 2: Jl. Anggrek 10, Karet Kuningan, Setiabudi, South Jakarta

The respondent is the CBWM leader Mrs. Sri Wahyuningsih, a 47-year old high school graduate, wife of the head of neighbourhood cluster. There are 73 households in one neighbourhood unit, and from the first establishment until the termination of CBWM there were only 8 households active.

This CBWM was initiated by the government through Cleansing Department. The CBWM in this community started with the former Jakarta governor's visit to the neighbourhood cluster in 2011. From then on, there came an appeal for each ward to establish CBWM. It is later being realised and the CBWM was formed. However it ceased operation within less than 1 year because of the low participation level, no support to the CBWM leader, and lack of motivation for public to participate.

The community received external support from the beginning of activities. The types of support were waste sorting storages, training on CBWM, and sewing machines to make handcrafts from inorganic waste. The community failed to autonomously provide the basic means for CBWM such as land space for CBWM activities, waste weighing scales, and basic operational costs.

The majority of CBWM participants are homogenous middle-income groups. High-income groups are the most inactive in the CBWM. Most of the occupational groups of active participants are housewives.

The CBWM leader self-assessed her influencing capacities to be insufficient, which failed her attempts to influence her fellow community members to participate in CBWM. She attempted to recruit CBWM participants during the monthly credit-rotating association (*arisan*) meetings.

The CBWM leader has a Betawi ethnicity. Karet Kuningan is an area in Jakarta that is a cultural territory for Betawi ethnicity where other ethnicities were minorities. There were no residents of Betawi ethnicity who participated in CBWM other than the CBWM leader. The CBWM leader was not formally appointed. He agreed that the reason to be the leader is to earn extra income and because CBWM gives him satisfaction. He strongly agreed on the point to contribute to a better environment.

Failed case 3: Jalan Perintis no 11, Kelurahan Karet, Jakarta Selatan

The respondent is the CBWM leader Mr. Sublime Prasetiandi, 43 year old diploma graduate who works for the government, which is South Jakarta city council. There are 3 neighbourhood clusters and 18 neighborhood units in this ward, where 50 households live within 1 neighborhood units. There are approximately 3,000 people living in the ward. However there were only 30 households were active in the CBWM.

The CBWM was started by a forum under the Ministry of Environment. After further discussion with the Ministry of Environment, the CBWM was established and supported by the Ministry who appointed Cleansing Department as a supervisor. Subsequently, a CBWM leader was appointed by Cleansing Department as a focal point of the activity. Basic CBWM means were provided by these government institutions, i.e. waste sorting storages, communal composter, training on CBWM, seed money in the amount of IDR 500,000 – 1 million, digital weighing scale, sewing machine, and a depot to store sorted waste.

The majority of people who participated in the CBWM were middle-income groups, whereas the low-income groups were most inactive. The occupational group of participants was housewives and members of the women's welfare group (*PKK*). The most inactive occupational group was private sector employees. In this ward there are heterogeneous income groups, ranging from low, middle, to high income groups.

The CBWM leader is of Betawi ethnicity. This ward is an area of cultural territory for Betawi community despite a recent upsurge of Central Javanese ethnicity who reside in the area. The majority of ethnicity within the community members who were active in the CBWM were homogeneous Betawi-Javanese ethnicity.

The CBWM leader was formally appointed by the Ministry of Environment. One of the main reasons for the leader to be the CBWM leader is to contribute to a better environment. He did not think of financial benefit as a reason. There was a difficulty encountered when the CBWM leader could no longer lead the activities due to lack of successor.

The waste bank activities ceased its operation after less than 1 year running. The major causes of failure were the low public participation level and no support to the CBWM leader.

List of Publications

Chapter 2: Communities and Community-Based Waste Management in Jakarta, Indonesia

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Chapter 3: Economic evaluation of household solid waste management (SWM) in Jakarta, Indonesia

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Chapter 4: Characteristics of household solid waste management and environment impacts associated with greenhouse gas emissions from waste management systems

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