Special session S4: CCETs Waste Management Guidelines Development
Chair: Dr. Hotta (IGES)
Expected date and time: 2 hours on Feb. 28, 2019

In order to assist the policy makers as well as implementers at national-level and city-level to select and implement appropriate waste management technologies for improving the waste management, CCET aims to develop a series of waste management guidelines on the targeted subjects related to the integrated MSWM, which include composting, Mechanical Biological Treatment (MBT), Anaerobic Digester (AD), Waste-to-Energy (Incineration). Expected natures of this series are (1) a user-friendly knowledge product by providing a clear, concise and inclusive points, which is easy to identify desirable options at a glance; (2) developed on “resource perspective” instead of “waste treatment perspective” based on 3R concept and waste hierarchy; (3) addressing both the physical (technical) elements as well as the ‘soft’ aspects (governance, public awareness, institutional and financial aspects); (4) based on good practices; and also (5) supported by a brief review of the related exiting works of literature and information.

**:**-**:** SP1-1 Opening remark: Challenges and Key Factors in Advancing Environmentally Sound Management of Wastes in Asia and the Pacific
Dr. Shunichi Honda, UNEP (15 mins)

**:**-**:** SP1-2 Introduction of the CCET and waste management guidelines activity
Mr. Kazunobu Onogawa, CCET (10 mins)

**:**-**:** SP1-3 Development of the framework of CCET Guideline Series on MSWM
Dr. Chen Liu, IGES (15 mins)

**:**-**:** SP1-3 Guideline Development on Mechanical Biological Treatment (MBT)
Dr. Tomonori Ishigaki, NIES (15 mins)

**:**-**:** SP1-4 Guideline Development on Anaerobic Digestion for MSWM
Dr. Andante Hadi Pandyaswargo, Waseda University (15 mins)

**:**-**:** SP1-5 Guideline Development on Waste-to-Energy from MSW incineration
Prof. Katsuya Kawamoto, Okayama University (15 mins)

**:**-**:** SP1-6 Discussion and dialogue (30 mins)

**:**-**:** SP1-7 Closing remark
Mr. Kazunobu Onogawa, CCET (5 mins)
Challenges and Key Factors in Advancing Environmentally Sound Management of Wastes in Asia and the Pacific

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ABSTRACT

All countries, regardless of their economy level, face challenges to fully implement the environmentally sound management of waste. Looking at Asia, compared to municipal solid waste generation in 2012, the region will likely generate about 6.4 time more waste (1.8 billion tonnes) in 2025, and thus will continue facing challenges including separate collection, storage, treatment, recycling and disposal appropriate for each situation and practice in each of the countries. However, municipalities need to consider these challenges as an opportunity to reframe waste management practices as part of their socio-economic development.

Keywords: environmentally sound management, socio-economic development, waste management strategy

Environmentally Sound Management of Waste for Socio-Economic Development

Environmentally sound waste management brings with it opportunities not only to develop and implement appropriate waste management but also create socio-economic benefits based on available options within national and municipal capacity. Waste management is one of our indispensable daily actions and should be integrated into the socio-economic system as a potential key national industry. Waste management practices depend on various factors, including technical availability, capacity of all players, national and local registrations and regulations, and people’s customs and behaviours. But it is technical expertise that provides the necessary guidance to all stakeholders on how to treat waste using environmentally sound management.

Technical expertise also needs to include practical factors to support waste management practitioners on a path towards socio-economic development. Because municipalities in Asia normally need to secure 10-30% of their city budget for waste management and due to the fact that they always face challenges in securing even the minimum budget for waste management, one of the important waste management strategies should leverage waste management practices as part of the socio-economic system.

Way Forward

Implementation of environmentally sound management of waste needs technical expertise applicable for municipalities. Furthermore, knowledge and technology transfer supports municipalities to develop appropriate waste management systems. An appropriate waste management system should provide an opportunity for waste management practitioners to contribute to socio-economic development as a key national industry.

ACKNOWLEDGEMENTS

United Nations Environment Programme would like to offer its appreciation to the Government of Japan for its generous contributions, and to the IGES Centre Collaborating with UNEP on Environmental Technologies for its kind collaboration.
Development of the Framework of CCET Guideline Series on Municipal Solid Waste Management

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ABSTRACT
In order to assist policymakers and implementers at the national and city level to select and implement appropriate waste management technologies for improving the waste management, CCET (IGES Centre Collaborating with UNEP on Environmental Technologies) aims to develop a series of waste management guidelines on the targeted subjects related to the integrated municipal solid waste management (IMSWM), which include composting, Mechanical Biological Treatment (MBT), Anaerobic Digester (AD), and Waste-to-Energy (Incineration). As the key concepts of this series, (1) it is a user-friendly knowledge product that provides clear, concise and inclusive points, which makes it easy to identify desirable options at a glance; (2) it has been developed from a “resource perspective” rather than a “waste treatment perspective” based on 3R concept and waste hierarchy; (3) it addresses both the physical (technical) elements (collection, disposal, recycling) as well as the ‘soft’ aspects (governance, public awareness and participation, institutional and financial aspects) toward social involvement; (4) it is supported by good practices; and also (5) it is supported by a brief review of the related existing works of literature and information. This paper describes the background, the main purpose, key concept, content and structure of this guideline series.

Keywords: IMSWM, MSWM guideline, resource perspective, 3R concept

BACKGROUND & PURPOSE
The issue of waste is considered as one of the key drivers for countries worldwide to achieve both the Paris Climate Agreement and the 2030 Development Agenda (SDGs). CCET takes on a role in providing technical assistance to national, sub-national and local governments in developing countries on the development and implementation of waste management strategies. During operation of CCET activities, it was found that waste management is more complex in developing countries, where dramatic urbanization has led to an increased volume and types of waste (including dangerous chemicals and metals, such as mercury, lead etc.), but where there is a lack of capacity for sustainable implementation of proper waste management, including legislation and policies for realistic long-term planning, limited collection and a lack of proper disposal, scavenging issue, poor funding, low public awareness, and so on. Furthermore, there is a lot of inappropriate technology and equipment introduced due to insufficient knowledge on sustainable waste management. There is an urgent need to provide proper knowledge to assist policymakers and implementers to have a clear and holistic view about each of the waste management technologies. The existing guidelines on Municipal Solid Waste (MSW) could be widely divided into two types: an integrated type such as the
“Integrated solid waste management for local governments” by ADB (Asian Development Bank, 2017; OECD, 2007; UNEP, 2013); another type focuses on one specific technology such as WtE, composting and so on. However there are barriers to both of these when trying to respond to the local needs. The former lacks the viewpoint of phase-by-phase implementation, while the latter lacks consistency among individual guidelines. The CCET guideline is a series which consists of key technology options that would play an important role as puzzle pieces in identifying appropriate technology mixture for addressing the unique challenges faced by the targeted governments. It is a well-shared understanding that there are no universally right or wrong answers for appropriate technology. Rather, solutions need to be developed locally and tailored specifically to local needs and conditions. Potential citizens and related stakeholders need to be involved in designing their own services which, in turn, need to be delivered by a diversity of types of service at a locally-affordable cost. CCET guideline series has a role as a knowledge-based support (similar to pieces of a puzzle) for CCET’s activities of strategies and action plan development (which makes up the whole picture of the puzzle), and this generates synergy with other activities as shown in Figure 1.

The main purpose of this guideline series aims to assist policymakers and implementers at the national and city levels to select and implement appropriate waste management technologies and related policies for improving waste management. In FY2018, CCET is focusing on the main intermediate treatment technology, which includes composting, Mechanical-Biological Treatment (MBT), Anaerobic Digester (AD), Waste-to-Energy (Incineration).

TARGET AUDIENCES
The main target audience for the guidelines is anyone who faces a SWM planning challenge, in particular, policymakers and implementers who can gain assistance using the guidelines for proper selection of appropriate technologies for better management of waste. Considering the main activities of CCET in FY2018, Asian developing countries, in particular, Myanmar, Cambodia, Maldives, India, Sri Lanka, Indonesia, and other South Asia are paid high attentions for the development of guidelines.

WASTE SCOPE
CCET guideline series mainly focuses on Municipal Solid Waste (MSW), which is conventionally understood as solid waste that is collected and disposed of by or for municipalities. It is worth noting that the definition and classification of MSW varies considerably among countries.
KEY CONCEPTS

Key concepts of this guideline series are as follows:

(1) It is a user-friendly knowledge product that provides clear, concise and inclusive points, which makes it easy to identify desirable options at a glance;

(2) It has been developed from a “resource perspective” rather than a “waste treatment perspective” based on 3R concept and waste hierarchy;

Waste policy is increasingly moving from “end-of-pipe waste management” to a “sustainable materials policy” with an agenda focused on recognising individual waste as a resource (Johansson and Corvellec, 2018). Considering the common needs of waste management such as saving resources, reducing pollution loads, prolonging existing landfill usage-time and less demand for new landfill sites, as well as creating economic opportunities and jobs, this new paradigm shift is not only for high-income countries, but is a more urgent issue for middle- and low-income countries. The main differences between “resource perspective” and “waste treatment perspective” is summarized in Figure 2.

Figure 2 Paradigm shift of waste management policy

(3) It addresses both the physical (technical) elements (collection, disposal, recycling) as well as the ‘soft’ aspects (governance, public awareness and participation, institutional and financial aspects) toward social involvement;

There have been numerous examples where ‘proven’ technologies in developed countries have failed in developing countries because sufficient attention was not paid to the ‘soft’ governance aspects. CCET guideline series are expected to address both the technical elements and the “soft” aspects. Based on the JICA’s guideline on WtE¹, a framework of key elements for planning (Figure 3; WtE as an example) and a pre-check list have been developed and expanded to all individual specific theme guideline.

¹ https://www.jstage.jst.go.jp/article/jsmcwcm/28/0/28_81/_pdf/-char/ja
(4) It is supported by good practices; and also

(5) It is supported by a brief review of the related existing works of literature and information.

Figure 3 Key elements for planning, construction and operation of WtE (Source: WtE guideline)

CONTENTS & STRUCTURE OF GUIDELINE

This guideline series was undertaken to identify and assess the technology available worldwide for treatment and disposal of MSW, and make a general assessment of the applicability of these technologies to various waste management. A brief outline is as follows: 1) Introduction, 2) Background and objectives, 3) Key elements for planning steps (see Figure 3), 4) Targeted MSW and main technology, 5) Environmental impact including GHGs emission/reduction, 6) Economic factor (cost & benefit), 7) Social factor such as citizen empowerment, participation, green jobs and so on, 8) Essential/Effective institution/policy/strategy, society and awareness building strategy and so on, 9) References lists for further reading, and 10) Good practices (at least three cases).

ACKNOWLEDGEMENTS

This research was supported by IGES Centre Collaborating with UNEP on Environmental Technologies (CCET) under its project component for deployment of guidelines on selected waste management topics (PCA2-2-1).

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Asian Development Bank, 2017. INTEGRATED WASTE MANAGEMENT FOR LOCAL GOVERNMENTS.


Guideline Development on Mechanical and Biological Treatment

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ABSTRACT

A technical guideline is now under development for mechanical biological treatment (MBT) aims at stakeholders involved in the planning of appropriate solid waste management in Asia. The guideline will give resource perspectives in terms of local and global sustainability as well as outline the basic function of waste treatment, which is essential for achieving the public health and welfare in urban areas. MBT is known as a pre-treatment method prior to landfilling to reduce the amount of waste to be disposed. MBT literally means the combination of microbial treatment and mechanical (physical) crushing and/or sorting processes. The major benefit of MBT is that it can be applied to mixed domestic solid waste without systematic segregation. It produces refuse-derived fuel or solid recovered fuel (SRF) as a separated fraction of high calorific value from the waste. Recyclable resources can also be recovered by the sorting process. The final debris generated from MBT is called as compost-like organics although it is substantially disposed of. Key considerations and a preliminary check list for implementing MBT are shown in Figure 1 and Table 1, respectively.

Key elements to check at the planning stage for selecting the appropriate technology

![Diagram of key elements for planning, construction and operation of MBT]

Figure 1 Key elements for planning, construction and operation of MBT

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1 This research was supported by IGES Centre Collaborating with UNEP on Environmental Technologies (CCET) under its project component for deployment of guidelines on selected waste management topics (PCA2-2-1).
<table>
<thead>
<tr>
<th>Classification</th>
<th>Importance</th>
<th>Item</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Social conditions</td>
<td>less important</td>
<td>(1) Target city population</td>
<td>The target population is less than 100,000 though it is applicable for more population.</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>(1') MSW discharge securing</td>
<td>Securing of MSW is essential. Future change of composition (reduction of plastics etc.) should be taken into consideration.</td>
</tr>
<tr>
<td></td>
<td>less important</td>
<td>(2) Social needs</td>
<td>Requirement of expanding the lifetime of disposal site is widely accepted. Policy promotion on renewable energy utilization is disseminated.</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>(3) Capacity of SRF users</td>
<td>Industrial furnace, waste incinerator, or SRF powerplant are required for stable trading of SRF.</td>
</tr>
<tr>
<td></td>
<td>Most Important</td>
<td>(4) Marketability of SRF</td>
<td>Price of SRF and other fuels, logistics, quality of SRF</td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(5) Development status of social</td>
<td>Administrative services of energy, waterworks and sewerage works are provided in the target city without problems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>infrastructure pertaining to</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>environmental sanitation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(6) Integration of environmental</td>
<td>Laws with regards to pollution prevention and environmental impact assessment (environmental laws etc.) have been developed and enacted in target countries and target areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and social considerations</td>
<td></td>
</tr>
<tr>
<td>2) Public awareness</td>
<td>Important</td>
<td>(1) Agreement of construction of facility</td>
<td>In addition to laws with regards to solid waste management, enforcement orders and rules have been developed.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>by residents</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(1) Development of laws, enforcement</td>
<td>Referable industrial standard (domestic or international) will enhance the utilization of SRF.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>orders and rules</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>(2) Quality standard for SRF</td>
<td>Construction site in which MBT facility can be built is available.</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>(3) Adequacy of construction site</td>
<td>Construction site in which MBT facility can be built is available.</td>
</tr>
<tr>
<td>3) Institutional aspect</td>
<td>Important</td>
<td>(1) Positioning of MBT in master plan</td>
<td>MBT has its position in the upper level plans (comprehensive plan, regional development strategy, etc.).</td>
</tr>
<tr>
<td></td>
<td>Most important</td>
<td>(2) Reduction of waste management cost</td>
<td>Reduction of Municipal budget for waste management by implementation of MBT is confirmed.</td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(3) Reduction of GHGs emission</td>
<td>Reduction of GHGs emission from waste sectorby implementation of MBT is confirmed.</td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(4) Renewable energy target</td>
<td>Composition of biomass in SRF is evaluated and contribution of renewable energy utilization is confirmed.</td>
</tr>
<tr>
<td>4) Governance capability</td>
<td>Important</td>
<td>(1) Securing of financial resources</td>
<td>Project cost (capital and operating cost) of MBT has to be secured. Own budget or ceratin subsidy or loan are prepared to bear the costs on operation (e.g. maintainace of equipment, fuels, electricity, tipping fee). Reliable investors is involved in the project.</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>(2) Tipping fee</td>
<td>Tipping fee is taken into account while the disposal of debris is outsourced. Future plan of disposal in the local goverment is getting along together with.</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>(3) Revenue by sales of SRF</td>
<td>Contract and agreement of condition of SRF with consumers is necessary.</td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(4) Project scheme</td>
<td>Project schemes (DB, DBO, BTO, etc.) are being discussed among stakeholders.</td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(5) Project risks</td>
<td>Major project risks are confirmed and the difference of responsibility division points according to project schemes are understood.</td>
</tr>
<tr>
<td>5) Financial aspect</td>
<td>Important</td>
<td>(1) Collecting basic data concerning</td>
<td>Basic data and information concerning waste (amount and composition of waste, collection frequency) have been obtained.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(2) Technical capacity of manufacturers</td>
<td>Reliable manufacturers are expected to participate in the project.</td>
</tr>
<tr>
<td></td>
<td>Important</td>
<td>(3) Proper disposal of residue</td>
<td>Proper disposal of MBT residue is possible.</td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(4) Environmental monitoring system</td>
<td>Laboratories for analysis of exhaust gas, wastewater, noise, vibration, odor, etc. exist and enable perform appropriate monitoring.</td>
</tr>
<tr>
<td></td>
<td>Recommended</td>
<td>(5) Securing of engineers and equipment</td>
<td>It is possible to secure engineers (personnel with skills equivalent to technical high school graduates). Arrangement of equipments (crusher, separators, etc) is confirmed.</td>
</tr>
</tbody>
</table>
Guideline Development on Anaerobic Digestion for MSWM

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ABSTRACT

Organic waste presents a significant portion of MSW compositions in many cities. The proper treatment of organic waste is therefore an important concern, particularly in low and middle-income countries. Biological treatment methods are widely accepted as a technical option to get the full advantage of organic waste as a resource. The most popular treatment options for the biological fraction of MSW are either aerobic treatment such as composting or anaerobic treatment such as fermentation or anaerobic digestion (AD). Considering the demand and some advantages of applying AD method in MSW, this paper aims to present a framework for the development of a guideline for policymakers and implementers to be able to anticipate and manage risks as well as planning related matters when they consider implementing AD technology for waste management. The guideline development is based on literature reviews, focus group discussions with practitioners and stakeholders, and some field visits. In the guideline, we present the key elements, technical planning steps, sustainability aspects, and case studies from various countries.

Keywords: anaerobic digestion (AD), biogas, municipal solid waste management (MSWM), technical guide, sustainability factors

INTRODUCTION

The composition of municipal solid waste (MSW) usually depends on the level of national income and the local urbanization level. It can be estimated that lower-income countries usually have a higher percentage of organic waste, amounting to as much as 60% of total waste generation (World Bank, 2018; UNEP/ISWA, 2015). These estimations also revealed that even in high-income countries, organic waste still accounts for the biggest individual fraction of MSW (approximately 30%) when compared to other types of waste such as plastics, paper, glass, metal and others. This implies that finding the most appropriate methods and technologies to manage organic waste is important regardless of the development and economic level of a country.

To take full advantage of the resource potential of organic waste, there are some biological treatment methods widely recognized and practiced, such as composting and AD. Considering its advantages in addressing both energy and material recovery (soil conditioner), the AD method is the main focus of this study. The AD process captures greenhouse gases (GHG) emitted by organic waste that would otherwise be
released into the atmosphere if waste is being landfilled. These will then generate biogas with a CH₄ concentration of 50 to 65% (which could be used in thermal or co-generation processes to produce thermal and electrical energy, or upgraded towards natural gas quality). AD-based energy contributes to the global efforts to avoid fossil fuels by providing clean and renewable energy. Depending on the process (dry or wet fermentation), AD produces slurry with a dry matter content of 6 to 20%. By dewatering the slurry, fertigation water and landscape conditioner can be produced. Despite the seemingly perfect solution of using AD to treat organic waste, both decision-makers and practitioners found it difficult to start or sustain AD plants using MSW. This study therefore aims to develop a simple guideline for policymakers and practitioners, especially in low and middle-income countries to build their decision-making capacity in applying AD into city or national waste management systems. The guideline covers key sustainable aspects, including geographical, social conditions, as well as institutional, governance, financial, and technical aspects in the planning and operation of the technology. It also presents some selected case studies from both lower- and upper-income countries and AD plants and projects of a variety of different sizes and scales.

MATERIALS AND METHODS
The study applies literature review, interviews, focus group discussions, case study analysis and field observations as key methods to collect relevant information on AD methods and its sustainability aspects such as technical, financial and other aspects that lead to the success or failure of AD plant planning for MSW. In the literature review, more than 50 studies on the subject of AD and its practices worldwide were reviewed using including scientific journals, private sector websites, and governmental reports. Among them, several case studies will be selected for in-depth analysis. This will be conducted in various forms such as interviews, written correspondences, focus group discussions and site visits.

RESULTS AND DISCUSSION
The findings so far highlight that the majority of successful AD plants in emerging countries are practiced on a smaller scale in rural areas. It is the large-scale plants in urban areas that are facing some challenges in sustaining their operations. These challenges include: 1) high initial investment, 2) fluctuations in feedstocks due to seasonal availability, 3) finding appropriate markets for the soil conditioner and fertigation water, and 4) feedstock impurity. Our findings revealed that some solutions could be: 1) green energy tariffs that could support the financial aspects of an AD projects, 2) high volume of digestate should be anticipated by securing market for soil conditioners and fertigation water, and 3) better waste separation at source and collection. These findings highlighted the importance of having proper preparation by the policymakers and practitioners before introducing AD into their waste management system.

OUTLINE OF THE GUIDELINE
Based on the preliminary findings, the following guideline outline was determined: 1) Introduction, 2) Background and objectives, 3) Key elements, 4) Technical planning, 5) Sustainability aspects, and 6) Case studies. In the Introduction part, the definition and importance of AD will be elaborated. In the Background
and objective part, the development of AD in various regions, especially in Asia will be presented as well as summarizing technical elements such as different types, feedstocks, scale, and use of outputs. In the Key elements part (Table 1), the “soft-elements” that need to be checked for decision-making are discussed. These include social conditions, institutional aspects, governance capacity, technical and financial aspects, and public awareness.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Conditions</td>
<td>Target city population, social needs, infrastructure, residence cooperation and awareness</td>
</tr>
<tr>
<td>Institutional aspects</td>
<td>Laws and regulations enforcement, administrative effectiveness, construction cite adequacy</td>
</tr>
<tr>
<td>Governance Capability</td>
<td>Government roles, capacity, and leadership</td>
</tr>
<tr>
<td>Financial aspects</td>
<td>Capital funds, tipping fee, revenues, financial risks</td>
</tr>
<tr>
<td>technical aspects</td>
<td>Local MSW basic data, technical capacity of manufacturing, implementing, operation, and maintenance</td>
</tr>
</tbody>
</table>

In the Technical planning part (Figure 1), basic technical planning steps for an AD project will be discussed. These include: 1) source of inputs, 2) calculation of biogas amount, 3) selection of technology, 4) size of digester, 5) size of engine, 6) site layout, 7) flow chart, 8) estimate of costs, 9) use of outputs (energy and liquid fertilizer), and 10) operation and monitoring. In the Sustainability aspects part, the social, environmental and economic effects of AD projects will be discussed. And finally, in the Case study part, good practices from different countries will be presented so that lessons could be learnt, and good strategies can be replicated. Some of the featured case studies are from Japan, Indonesia, and Germany (Table 2).

![Figure 1 Project technical planning flow recommendation for MSWM with AD](image-url)
CONCLUSION

This study responds to the critical issue in addressing the appropriate technology and treatment methods to manage the organic fraction of MSW especially utilizing the advantages of AD technology. A simple guideline covering the basic knowledge, most important success factors, and pitfalls is being developed through discussions among experts, literature reviews, and interviews with AD practitioners. The results will help to develop a more practical, appropriate and user-friendly guideline for policymakers and practitioners in developing countries including a flow chart for making decisions in planning, and important information about aspects affecting and resulting in implementation socially, environmentally, and economically. The guideline also elaborates factors that will influence the future of AD such as technology development, trends of national policies and agenda, and business and international collaboration opportunities.

ACKNOWLEDGEMENT

This research was supported by IGES Centre Collaborating with UNEP on Environmental Technologies (CCET) under its project component for deployment of guidelines on selected waste management topics (PCA2-2-1). Authors also thank AD project managers and experts contributing to this paper.

REFERENCES


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<table>
<thead>
<tr>
<th>Location</th>
<th>Feedstock</th>
<th>Capacity</th>
<th>Technology Specification</th>
<th>Output</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Java, West Nusa Tenggara, Central Java, Jogjakarta, West Java, Bali, East Nusa Tenggara, South Sulawesi, and Lampung, Indonesia</td>
<td>Animal farming / small-scale food industry organic waste</td>
<td>Small scale</td>
<td>Fixed Dome Biogas digester</td>
<td>Equivalent to daily rural household needs for lighting and cooking</td>
<td>The country-wide project is taking place mainly in the rural area where access to highly subsidized LPG tank is limited</td>
</tr>
<tr>
<td>Oki Town, Fukuoka, Japan</td>
<td>Kitchen waste, Human Waste, Septic Tank Sludge</td>
<td>Kitchen waste (3.8 TPD), Human Waste (7 TPD), Septic Tank Sludge (90.6 TPD)</td>
<td>Medium temperature (37°C) methane fermentation tank</td>
<td>Electricity (752 kWh per day)</td>
<td>Interlinked with local agricultural production using the effluent liquid mixture</td>
</tr>
<tr>
<td>Gütersloh City, Northrhine-Westfalia, Germany</td>
<td>Source-separated household organic waste</td>
<td>30,000 TPY</td>
<td>Dry Fermentation</td>
<td>approx. 5.7 million kWh / year</td>
<td>The attached composting plant uses park and garden waste in addition to the household waste</td>
</tr>
</tbody>
</table>
Guideline Development on Waste-to-Energy from MSW incineration

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ABSTRACT
Waste-to-energy (WtE) can be considered as a potential alternative source of energy and is a subject of very considerable interest in both developed and developing countries. In order to provide a guideline for introducing WtE from municipal solid waste (MSW) in Asian countries, investigations were carried out on the overall framework and factors and elements that should be taken up in the guideline. These were based on research into the recent situation of WtE at incineration plants in Japan and technically detailed knowledge obtained from past research in Japan. As a proposed framework, possible main factors are: 1) Confirmation of social conditions, 2) Institutional aspects, 3) Governance capability, 4) Necessity and presence of appropriate technology, 5) Financial aspects and 6) Public awareness & cooperation of residents. Following this, knowledge necessary for the guideline and specific numerical criteria are extracted from the ground data, which including 1) the population of target area of WtE must be at least 70,000 and preferably 100,000 and above. These numbers correspond to plants with capacities at about 50 and 70 ton/d, respectively; and, 2) the low heat value of MSW should be at least 4,500 kJ/kg or higher and preferably higher than 6,000 kJ/kg.

Keywords: MSW, incineration, energy recovery, Waste-to-energy, guideline

INTRODUCTION
Nowadays, it is strictly required to appropriately control and manage MSW in the context of achieving a sustainable society and in light of global population expansion and limited natural resources. Efforts should first be made to give the 3Rs priority, and following this, thermal treatment of MSW can efficiently reduce the amount and volume of waste, as well as recovering energy. The most practical and technological treatment is currently incineration, and this process for power generation and heat recovery is now attracting a great deal of attention from various countries. However, the amount of waste generated and the ways in which it is generated are different from country to country and also even within the same country due to the diversity of human life. Furthermore, many factors are involved in the implementation of energy recovery from waste other than waste property such as technology, legal systems and economic aspects. Therefore, a standard guideline is required to implement WtE effectively and successfully in every country.

In this study, a guideline is provided in order to respond to this situation. The current status of the subject is reviewed based on actual Japanese data, and various knowledge will be integrated in order to make a realistic directive map. The aim of this document is to provide a guide to introduce WtE and to indicate the standards based on reliable technical data and knowledge, and consideration of various factors.
INVESTIGATION METHODS

Guideline framework

Several guidelines, their drafts and concepts have been announced up to now in various forms and with various contents (Rand, T. et al., 2000; CWG 2016; Yamamoto, T., 2017). Many of them were created for the purpose of supporting decision-makers when introducing incineration facilities and WtE processes, and they succeeded in serving that purpose. However, in addition to a guideline for decision-makers who are not necessarily rich in expertise, it is also necessary to create a guideline based on advanced technical information and related knowledge. A new framework has been formulated based on the review of existing guidelines.

Technical data and information of MSW and WtE in Japan

To clarify technical matters of MSW incineration and WtE, a few detailed investigations were carried out looking at past research data in Japan (Kawamoto K., 2018). An investigation was conducted for seven gasification-melting incineration plants for MSW which were newly constructed in the first half of 2000s, which was when this system began to gain popularity. Data was collected based on actual operation data in each plant over two years. The survey was conducted on the change of input waste amount, output residue, and power generation data and so on. Another investigation was conducted on policy changes for plastic waste in household waste to be classed as combustibles in Tokyo’s 23 wards. Before and after this policy change, a quantitative assessment was conducted on the changes in the amount and composition of MSW, looking at operational data such as power generation and flue gas nature. Based on data from past surveys, findings for formulating a guideline were extracted.

RESULTS AND DISCUSSION

Framework for the guideline

Since there are many elements involved when introducing WtE, careful planning and thorough implementation procedures are required when building WtE facilities in specific areas in developing countries. From a survey on previous guidelines, possible main elements and detailed items are shown in Figure 1. The

Figure 1 Framework of possible elements to be included in guideline on WtE
main elements include 1) Confirmation of social conditions, 2) Institutional aspects, 3) Governance capability, 4) Necessity and presence of appropriate technology, 5) Financial aspects and 6) Public awareness & cooperation of residents. Next, more specific items for each element should be considered, and then it is necessary to clarify concrete and quantitative contents.

Technical data and information of MSW and WtE in Japan

Among many aspects concerning incineration facilities, profiles of changes in waste input volume and fly ash generation volume etc. are fundamental to finding out the material balance of a facility. In this respect, long-term data for seven facilities were obtained. From these results, it was shown that the maximum amounts of MSW input and amounts of treated materials nearly doubled. The low heat value of MSW also changed from 6,700 - 11,000 kJ/kg-MSW based on comprehensive measurements of actual MSW samples. Figure 2 shows the relationship between waste amounts processed per month and the amount of power generated for the same month. Figure 2 also shows almost similar trends in the data at seven different facilities. Based on actual data, the generated power per unit amount of MSW was calculated to be 250 kWh/ton-MSW. However, according to recent information obtained from facility visits and interviews, numbers over 300 kWh/ton-MSW have been observed in incineration plants in Japan. These actual values might be useful when deciding on criteria for formulating a WtE guideline.

Figure 2 Relationship obtained between waste amounts processed in seven facilities and power generation data (A – G indicate the facilities investigated.)

Looking at the situation nationwide in Japan, about 67% of MSW incineration facilities utilize heat for power generation and heat recovery. In 348 incineration facilities that make up about 32% of all facilities, electricity is generated and utilized including selling the power externally. However, average efficiency rate of power generation was only 12.6% at the end of fiscal year 2015. This is not a very high rate of efficiency and could be improved further. On the other hand, highly efficient power generation can be achieved at the brand new facilities constructed in recent years in Japan. For example, boiler steam conditions are 40 MPa in pressure and 400 °C in temperature using gas turbine generators, resulting in a power generation efficiency of around 20% (Kawamoto, K., 2018). From the investigation of Tokyo’s 23 wards, the low heat value of MSW was considerably affected by the ratio of plastic waste in MSW. However, there is no clear relationship between
this ratio and the power generation value. This was considered to be the main reason that there are many factors other than plastic waste in a complex plant system.

Guideline for WtE

Based on the research data and recent information, the knowledge necessary for a guideline and specific numerical criteria have been extracted, as follows:

A. Target city population in the classification of “Confirmation of social conditions”
   i. The population of target area of WtE must be at least 70,000 and preferably 100,000 or more. These numbers correspond to plant capacities with about 50 and 70 ton/d, respectively.

B. Collecting basic data concerning waste in “Necessity and presence of appropriate technology”
   i. The low heat value of MSW should be at least 4,500 kJ/kg or higher than 6,000 kJ/kg.
   ii. The moisture of MSW should be lower than 50 % (W/W), which determined by waste composition.
   iii. The steam condition of the boiler significantly affects the output of the power generator. It is desirable to design high temperature and high pressure. The typical value set in recent years is 400 ºC and 4 MPa.

Regarding other related technical matters, the assumed environmental impact from WtE plant can be minimized by the application of recent pollution control technologies.

This proposed description plan on the necessary elements should be further modified and improved future going forward.

CONCLUSION

This study aimed to propose a guideline for WtE based on quantitative indicators and information. Since the guideline will also be used by those with limited expert knowledge, it is necessary to make it easier to use. Therefore, it would be better to suggest a standard procedure in the future.

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