IGES Policy Report-2011-06

A GUIDE FOR TECHNOLOGY SELECTION AND IMPLEMENTATION OF URBAN ORGANIC WASTE UTILISATION PROJECTS IN CAMBODIA

Sustainable Consumption and Production Group, Institute for Global Environmental Strategies (IGES)

APN CAPaBLE

COMPED

IGES Institute for Global Environmental Strategies

IGES Policy Report-2011-06

A GUIDE FOR TECHNOLOGY SELECTION AND IMPLEMENTATION OF URBAN ORGANIC WASTE UTILISATION PROJECTS IN CAMBODIA

Leading authors

Dr. Janya SANG-ARUN,
Sustainable Consumption and Production Group,
Institute for Global Environmental Strategies -IGES

Mr. Chau Kim Heng,
Cambodian Education and Waste Management Organization - COMPED

Contributors

• Mr. Uch Rithy, Cambodian Education and Waste Management Organization - COMPED
• Mr. Sam Phalla, Cambodian Education and Waste Management Organization - COMPED

Reviewers

- Dr. Magnus Bengtsson, Institute for Global Environmental Strategies - IGES
- Mr. Surya Chandak, United Nations Environment Programme, International Environmental Technology Centre - UNEP. IETC
- Dr. Samanthi Nirmala Madanayaka Menikpura, Institute for Global Environmental Strategies - IGES
- Dr. Chrin Sokha, Mininstry of Environment, Cambodia
- Mr. Sarun Sambo, Mininstry of Environment, Cambodia
- Mr. Touch Sovanna, Ministry of Industry, Mines and Energy, Cambodia
- Mr. Chan Saman, Municipality of Phnom Penh
- Mr. Thiv Kimseth, Municipality of Phnom Penh
- Ms. Kim Vatanak Thida, Municipality of Phnom Penh
- Mr. Sao Kunchun, Municipality of Phnom Penh
- Mr. Leng Simen, Waste Management Department, Phnom Penh
- Mr. Kham Kim Sure, Environmental Department, Phnom Penh
- Mr. Ny Sona, Department of Public Works and Transportation, Phnom Penh
- Mr. Mam Sithy, Municipality of Phnom Penh
- Mr. Khum Keang, Municipality of Phnom Penh
- Ms. Dauk Vannak, Municipality of Phnom Penh
- Mr. Lay Sovann, Agriculture Department, Phnom Penh
- Mr. Cheay Youb, Environmental Department, Battambang Province
- Mr. Va Moeun, Mlup Baitang Organisation

Supporting Organisations

Asia Pacific Network for Global Change Research - APN
Ministry of Environment, Japan - MOEJ
Ministry of Environment, Cambodia - MOEC

Institute for Global Environmental Strategies (IGES)
2108-11 Kamiyamaguchi, Hayama, Kanagawa, 240-0115, Japan
Tel: +81-46-855-3720 **Fax:** +81-46-855-3709
E-mail: iges@iges.or.jp **URL:** http://www.iges.or.jp

A guide for technology selection and implementation of urban organic waste utilisation projects in Cambodia

The Institute for Global Environmental Strategies (IGES) is an international research institute conducting practical and innovative research for realising sustainable development in the Asia-Pacific region.

The Sustainable Consumption and Production (SCP) Group aims to contribute towards sustainable patterns of consumption and production in Asia, with a focus mainly on low and middle income countries in the region. Special attention is given to the flows of materials through society, activities by consumers and producers, and the environmental impacts associated with material flows. The group's research is based on life-cycle thinking and explores how different actors, institutions and policies can influence society's utilisation of natural resources in a more sustainable direction.

ISBN: 978-4-88788-083-2

Printed in Japan

Foreword

Environmental sustainability is the key tool to support the socio-economic development of Cambodia with the crucial functions to maintain the balance between natural resources and human needs. Therefore, it is necessary to take environmental protection into account consistent with the socio-economic development. The Royal Government of Cambodia under the ideal leadership of Samdech Akka Moha Sena Padei Techo Hun Sen, Prime Minister of the Kingdome of Cambodia, in the context of environment, has adopted several legislations, for example, the Law on Environmental Protection and Natural Resources Management, Law on Natural Protected Areas, Law on Biosafety, and the four related sub-decrees as well, emphasizing its support and commitment to protect and manage the environment and natural resources in a sustainable manner.

Currently, environment integration is being raised and applied within sectoral development. In this connection, several directives, standards, technical guidelines, etc., have been developed to effectively implement such environmental legislations as above. A Guide for Technology Selection and Implementation of Organic Waste Utilisation Projects in Cambodia is a crucial document to guide stakeholders to draw attention to possible use of organic waste prior to disposal based on the 3R initiatives, including the sound management of solid waste by appropriate technologies.

The Ministry of Environment of Cambodia firmly supports this important document, and expects that it will be comprehensively disseminated and implemented at national and sub-national levels in order to share the accomplishment of the Goal No. 7 of the Millennium Development Goals, 'To Ensure Environmental Sustainability' in parallel with the socio-economic development in the Kingdom of Cambodia.

The Ministry of Environment finally would like to highly evaluate the cooperation between IGES, COMPED and APN, and deeply thanks these organisations which have participated in protecting and maintaining our green environment and human health, especially the reduction of causes and effects of climate change.

Phnom Penh, Date: 27 December 2011

Secretary of State, Ministry of Environment

Foreword

The Institute for Global Environmental Strategies (IGES) is an international research institute conducting practical and innovative research for realising sustainable development in the Asia-Pacific region. During 2009-2011, IGES received funding from the Asia-Pacific Network for Global Change Research (APN) through the APN CAPaABLE Programme for the project *Promoting Sustainable Use of Waste Biomass in Cambodia, Lao People's Democratic Republic and Thailand: Combining Food Security, Bio-energy and Climate Protection Benefits*. This multilateral, collaborative project aims to promote the use of climate-friendly technology for waste biomass conversion for food and energy production in Cambodia, Lao PDR and Thailand.

In the three studied countries, the problem of managing urban organic waste is more severe than agricultural waste management, while the situation and progress on solid waste management varies significantly. The idea of country-specific publications to facilitate the implementation of urban organic waste utilisation technology was thus born. Through these publications, it was envisioned that experiences and lessons learnt in Thailand, which is more advanced in waste biomass utilisation, could be shared with and transferred to neighbouring countries in the form of South-South cooperation.

In this report, the authors describe and analyse the current situation of urban organic waste management in Cambodia through field surveys and interviews with local stakeholders, including national and local governments, the private sector, and non-governmental organisations. In addition, the authors introduce various organic waste utilisation technologies that are successfully implemented in neighbouring and other developing Asian countries. In the latter part of the report, reflecting on the local situation and the lessons learnt from other countries, the authors analyse whether these technologies would be applicable in Cambodia. They emphasise that careful selection of technology and proper implementation is required to ensure successful adoption by local governments in Cambodia, and they provide a practical guide for technology selection and proper implementation in the latter part of this report.

I congratulate the authors for completing this challenging assignment and believe that the findings will have value for policy makers and practitioners responsible for organic waste management, not only in Cambodia, but also in other countries at a similar stage of economic development and facing similar waste management challenges.

Hideyuki Mori

President
Institute for Global Environmental Strategies

Preface

In recent years, Cambodia has enjoyed relatively high rates of economic growth, but at the same time rapid population growth and urbanisation, driven by rural people searching for employment, are placing great pressure on its urban infrastructure and services. Lifestyles are also changing, with serious implications for waste generation and management. Organic waste, which was previously used to feed animals kept around homes and some of which was naturally composted around trees, is now commonly disposed along or in water bodies, or on vacant lots in the cities. This waste becomes a food source for disease carriers such as houseflies and rodents, is an eyesore and generates foul odours.

The laws and regulations of the Ministry of Environment task local governments with the responsibility of managing dumpsites, though they can contract private companies for waste collection, transport and disposal. The main problems for the government in solid waste management are a lack of budget, insufficient human resources and most importantly a lack of public engagement.

Most waste disposal sites in Cambodia, as in most developing Asian countries, are substandard and not sustainable from the perspective of environmental management. The waste is dumped in landfills without separation at source, meaning that organic waste, recyclable waste and other forms of waste are mixed. Organic waste is of particular concern as it contributes to global warming through the emission of methane, a gas with a global-warming potential over 21 times greater than carbon dioxide.

The major aim of this guide is to assist local city and provincial authorities in making wise decisions on the selection and implementation of organic waste management techniques that will not only contribute to better waste management, but will also provide co-benefits in the form of food and energy security and climate protection. This guide is also expected to contribute to Cambodia's national strategic plans for the 3Rs (reduce, reuse, recycle), climate change mitigation, poverty reduction, as well as food and energy security.

I would like to thank the provincial/city authorities who are currently working on solid waste management and hope that this publication would help them in their decision-making on organic waste management.

Mr. Chau Kim Heng

Director
Cambodian Education and Waste Management Organization

Acknowledgement

The authors owe a debt of gratitude to the Asia-Pacific Network for Global Change Research (APN) for funding the development of *A Guide for technology selection and implementation of urban organic waste utilisation projects in Cambodia* through the APN CAPaBLE Programme in FY2009 and FY2010. We are also grateful to the Ministry of Environment, Japan for providing the necessary financial support to translate and print the report.

The authors would like to thank Dr. Magnus Bengtsson (IGES) and Mr. Surya Chandak (UNEP.IETC) for their substantial comments on the drafts of the report. We would also like to express our gratitude to the Ministry of Environment, Cambodia, the Phnom Penh Municipality and all reviewers for their valuable comments on this publication.

This publication was originally written in English. Mr. Chau Kim Heng has translated it into Khmer to enable use by local governments and others in Cambodia. He apologises for any unclear terms in the Khmer text or any errors in the translation.

We welcome feedback and comments on this guide, which can be sent to the addresses below.

26 October 2011

The authors

For feedback and comments
In English
Dr. Janya Sang-Arun (sang-arun@iges.or.jp or janyasan@gmail.com)

In Khmer and English
Mr. Chau Kim Heng (heng@comped-cam.org)

Executive Summary

Cambodia, a least developing country, faces rapid urbanisation as people move into the towns for work and a better life. With changing consumer preferences accompanying urbanisation, solid waste generation is increasing but the local governments do not have enough budget and capacity to collect and treat it in an environmentally sound manner. Open dumping and burning are the common practices for disposing of waste. They degrade the environment and pose risks to human health (especially to waste pickers and residents in the vicinity of the disposal site), as well as release greenhouse gases into the atmosphere. Improved waste management can contribute not only to healthier living conditions, it can also contribute to employment generation for non-skilled and skilled labourers as well as to the global effort to mitigate climate change.

The Institute for Global Environmental Strategies (IGES) realised that Cambodia needs international support to overcome its solid waste management problems. Together with the Cambodian Education and Waste Management Organisation (COMPED), IGES is proposing that the use of urban organic waste be explored within the context of sustainable development. We argue that sustainable organic waste management can contribute to the national agenda for food and energy security, framed within sustainable consumption and production systems and a 'low carbon society'.

Under the scope of this project, we aim to improve the capacity of local governments to: understand their solid waste management problem and its links with climate change; and provide guidance on how they can utilise urban organic waste as a resource for achieving national food and energy security, using available technology that exists in Cambodia and neighbouring countries, particularly Thailand, as well as drawing on lessons from experiences in other developing Asian countries. Technology selection can be difficult, as what is considered the best technology may not always be the most appropriate in the developing world. We thus analyse each technology in terms of the local conditions in Cambodia and provide guidance on technology selection and implementation.

To make this report useful and pragmatic for local governments and policy makers, we conducted detailed analysis of waste management in four major cities in Cambodia (Phnom Penh, Battambang, Siem Reap, Kampong Cham) through field observations, stakeholder interviews and review of secondary data sources. In addition, we conducted a preliminary

analysis of waste composition in the studied cities to estimate the significance of organic waste management to climate change and food and energy security.

From our field studies we found that the private sector plays an important role in waste collection, and in some cities waste disposal, because the local governments cannot secure sufficient budget for this activity. The collection was limited to areas where residents could pay for the service and this resulted in lower than 50% coverage in most cities, except for Phnom Penh where the fee is included in the electric bills. Most of the collected waste is disposed at the designated dump sites, most of which are located in flood prone areas and do not have gas recovery systems. Waste separation at source is not practiced, except for the separation of some recyclable materials that can be sold by households. Therefore, the utilisation of urban organic waste is very low. There are only two small composting facilities at landfill sites in operation in the entire country: one in Phnom Penh (currently closed due to changes of the landfill site and local government policy) and another in Battambang. A small amount of food waste is collected for animal feed.

Biodegradation of organic waste under anaerobic conditions can generate methane, a highly potent greenhouse gas. We estimated the total methane emissions from landfill of urban organic waste in the four major cities, which had a total population of 1.7 million in 2008. We found that the emissions were as much as 360,000 tonnes CO_2 equivalent (assuming disposal in unmanaged deep landfills). Urban populations and waste generation per capita are increasing due to urban development and economic growth. More waste will be disposed in landfills, and as long as government capacity to invest in methane capture remains highly constrained, methane emissions from landfills will continue to increase. In this context, the landfill of urban organic waste should be avoided and efforts made to utilise this waste as a resource to overcome the budget constraints facing solid waste management.

In this guide, we introduce a range of technologies for utilising urban organic waste. We provide guidance on animal feed, composting, anaerobic digestion, mechanical biological treatment (MBT), sanitary landfill and incineration. We also emphasize the importance of waste reduction and point out that this can be achieved through better resource efficiency. As this guide aims to facilitate technology selection and successful implementation of urban organic waste utilisation projects, we provide not only basic information of each technology, but also describe the advantages and disadvantages of each technology (resource efficiency, climate benefits, investment and operation costs, personnel requirement and so on) and provide examples of actual implementation in Cambodia, its neighbouring countries (e.g. Thailand) and other developing Asian countries (e.g. India) where appropriate.

Reflecting Cambodia's socio-economic conditions and the capacities of local governments, we recommend small-medium scale composting and anaerobic digestion for urban organic waste utilisation. Composting can produce soil improvement materials and thus increase crop productivity. Anaerobic digestion can generate soil improvement products and energy, and thus can contribute to both national food and energy security. As the investment required for anaerobic digestion is higher than that for composting, local governments need to consider the costs and benefits of technology adoption in the context of their needs and their available resources. This guide aims to support such decisions. It identifies a number of issues which should be considered at the design phase of waste management projects in order to reduce the risk of failures after implementation, including key factors for selection of appropriate technology and a practical guide for successful implementation.

Table of Contents

List of Tables

List of Figures

1.
Introduction

1. Introduction

Cambodia is a low lying country located in the massive watershed of the Mekong River (Fig. 1.1). The country covers an area of 181,035 km^2, with a population of 14.7 million as of July 2011 (Table 1.1). The ratio of urban population is 20% with an annual growth rate of 3.2% in 2010. The socio-economic development in this country is gradually increasing. In 2008, the national GDP per capita was USD739, which increased from USD287 in 2000.

Figure 1.1 Cambodia map

Table 1.1 Basic information on Cambodia

Information	Statistics
Area (km^2)	181,035
No. of provinces	24
Population (in July 2011)*	14,701,717
Female (%)	51.5
Population growth rate (%)	1.6
Urban population (%) (2007)	20.9
Urban population growth rate (%)	4.6
GDP per capita (in 2008)	USD739

Source: UNdata, 2010; *CIA, 2011

Based on a 2004 survey by the Ministry of Planning of Cambodia, poverty incidence is 35%. In addition, 20% of Cambodians are living below the food poverty line (Ministry of Planning, 2006). Therefore, food insecurity and malnutrition are priorities in the national agenda for socio-economic development.

Approximately 75% of Cambodians are engaged in agriculture. Rice production is the major agricultural activity, but its land productivity is very low compared to other countries in the region such as Thailand and Viet Nam. To increase crop yield, the Department of Agronomy and Agricultural Land Improvement (DAALI) is promoting making and using compost for soil fertility improvement. In addition, the Royal Government of Cambodia is promoting organic farming to ensure food security, socio-economic development and environmental protection (MAFF, 2006).

Energy insecurity in Cambodia is a national concern. Electricity supply relies mainly on imports from neighbouring countries (32% from Thailand, 67% Viet Nam and 1% Laos) and small scale electricity generation by private power producers, called Rural Electricity Enterprises (REE) (Jona, 2011). Due to these conditions, the price of electricity in Cambodia is the highest in the region. In 2010 only 29% of Cambodians had continuous access to electricity supplied by public grid (Jona, 2011). Common energy sources in Cambodia are 90% firewood for cooking and 80% kerosene for lighting. However, it is predicted that energy demand on average in Cambodia will increase by 19% per year while in Phnom Penh the electricity demand growth rate is expected to be as high as 25% (Jona, 2011).

Urban waste in Cambodia is being generated at an increasing rate as a result of economic development and urbanisation. However, reliable data on waste generation is rare. Our site observations found that organic waste generated throughout the chain of food production, distribution and preparation accounts for much larger volumes than other types of waste. This organic waste generates greenhouse gases (mainly methane) when disposed in landfills, a common practice of waste disposal in Cambodia.

The Institute for Global Environmental Strategies (IGES) realised that Cambodia needs international support to overcome its solid waste management problems. Together with the Cambodian Education and Waste Management Organisation (COMPED), IGES is proposing that the use of urban organic waste be explored within the context of sustainable development, which can contribute to the national agenda for food and energy security and climate change mitigation policies.

Therefore, this decision tool and implementation guide is aimed to promote the utilisation of such organic waste in Cambodia. The guide explains the current situation of solid waste management and the impacts of improper organic waste management on the local environment as well as on the global climate. Later on, examples of appropriate technology for urban organic waste utilisation are introduced alongside essential information for decision-making of local governments, such as technical and social advantages and disadvantages, and investment, operation and maintenance costs. A set of recommendations on how to select the most appropriate technology suitable for local circumstances are provided. Finally, suggestions are made on how local governments can implement projects successfully.

2.
Current Urban Organic Waste Management and Policies in Cambodia

2. Current urban organic waste management and policies in Cambodia

2.1 Legislation and national policy on solid waste management

2.1.1 Legislation and regulation

The government of Cambodia notified the sub-decree No. 36 on solid waste management in April 1999. This sub-decree is the fundamental law of solid waste management. It applies to all activities related to disposal, storage, collection, transport, recycling, dumping of household and hazardous waste.

Based on this sub-decree, the Ministry of Environment (MOE) shall establish guidelines on disposal, collection, transport, storage, recycling, minimising and dumping of household waste in provinces and cities in order to ensure the proper management of household waste (Ministry of Environment, 1999).

According to this sub-decree, the authorities of the provinces and cities shall establish the waste management plans in their province and the city for short, medium and long terms. In addition, they are responsible for collection, transport, storage, recycling, minimising and disposal of waste.

As a supplement to the sub-decree on solid waste management, Ministry of Environment (MOE) and Ministry of Interior (MOI) issued a ministerial declaration (Prakas) no. 80 in 2003 (Inter-ministerial MOI/MOE, 2003). The objectives of this declaration are to improve the responsibility of an authority and involve institutions for efficient implementation of solid waste management in provinces and cities of the Kingdom of Cambodia, in order to protect human health, environmental quality, scenery and biodiversity. The declaration clearly stated that disposal of waste in public spaces, streets and canals is illegal. In addition, local governments are required to provide sufficient waste bins, arrange "forbidden" signs and educate the residents on proper waste management, establish temporary waste stock, and clean and dispose the generated solid waste in their administrative area regularly.

Unfortunately, the detailed regulations, standards and guidelines, which have to be established based on the above sub-decree and declaration, are not yet complete due to lack of personnel capacities and budget constraints.

Beginning in 2010, the Municipality of Phnom Penh (MPP) has been implementing a pilot project to fine people for discarded waste in the public parks. Once people are familiar with the concept and practice, the MPP will extend the coverage area of such regulations.

2.1.2 *Integration of 3R strategy in solid waste management*

In 2008, the Ministry of Environment (MOE), with support from the United Nation Environment Programme (UNEP), drafted a strategy on the 3Rs (reduce, reuse, recycle: Appendix I) for sustainable solid waste management in the Kingdom of Cambodia.

The Cambodian national 3R strategy aims to establish an efficient solid waste management system through increased waste collection service, promote waste separation for recycling, enhance organic waste composting, and improve disposal sites. By 2015, the government plans to compost 20% of organic waste from all sectors. By 2020, the government plans to increase composting of organic waste from households by 40% and from business centres by 50%.

The 3R concept is very new to Cambodian national and local officials. Therefore, the Government of Cambodia plans to i) establish the 3R policies and regulations for waste management at national and local levels based on the existing environmental legal instruments and related statues, ii) organise capacity building programmes for government officials, iii) implement pilot scale projects in the selected urban area, iv) disseminate knowledge and implicate the 3R policies and regulations in public and private sectors, and v) integrate the 3R initiatives into the national policy development.

2.2 Current urban organic waste management

The data on quantity and composition of municipal solid waste in Cambodia is not systematically collected. It is mostly interpreted from the data of Phnom Penh and in some cases data from a few major cities are included. For instance, the Ministry of Environment has reported that waste generation in Cambodia is approximately 520,000 tons/year[1] (Sokha, 2008). In 2009, we interviewed waste collection companies and the local government officials in four major cities of Cambodia: Phnom Penh, Battambang, Siem Reap and Kampong Cham. It was found that the assumption of waste generation in these cities is 1,465 tons/day or 534,725 tons/year which is slightly higher than the data of national solid waste generation (Table 2.1). Therefore, it is construed that the quantity of waste generation in Cambodia is underestimated. Consequently, environmental problems which are related to improper waste management would be higher than the expectations.

As shown in Table 2.1, waste generation rate in Phnom Penh is higher than other small cities. Phnom Penh is more modernised and crowded than other cities in Cambodia. In 2009, COMPED investigated waste composition at the disposal sites in Phnom Penh, Kampong Cham, Battambang, and Siem Reap (Fig. 2.1). It was found that food waste generation in more urbanised cities is higher than in less urbanised cities (Table 2.2). In fact, according to the composition of the generated waste, food waste amounted to 70% in Phnom Penh, 71% in Battambang, 54% in Siem Reap, and 60%

1 1 ton = 1,000 kilograms

Table 2.1 Municipal solid waste in major cities of Cambodia in 2009

City	Area (km^2)	Population (persons)*	Waste generation (tons/day) **	Per capita waste generation (kg/person/day)	Waste collection (tons/day) **	Residents pay for waste collection service (%)**
Phnom Penh	290	1,325,681	1,200	0.91	1,005	80
Battambang	140	143,656	100	0.70	51	<20
Siem Reap	473	174,265	115	0.66	115	N/A
Kampong Cham	162	63,771	50	0.78	35	10%
			Sum = 1,465	Average = 0.86	Sum = 1,206	

* Population census 2008
** Interviewed with waste collection company and local governments

Table 2.2 Waste compositions in four major cities in Cambodia

City	Waste composition at disposal site (%)							
	Food	Paper	Plastic	Metals	Textile	Glass	Wood and dry matter	Others
Phnom Penh	70	5	6	2	3	2	6	6
Battambang	71	2	10	3	2	4	6	2
Siem Reap	54	6	11	1	3	3	11	11
Kampong Cham	60	5	12	1	1	2	3	16
Average	64	4	10	2	2	3	6	9

Figure 2.1 Waste composition analyses at Kampong Cham

in Kampong Cham.

The traditional waste management practices at household level are throwing away food waste at their backyard and using it as a feed for household pets but these actions are difficult to practice due to limited space. In addition, a significant amount of food waste is being generated from hotels and restaurants in large cities. Therefore, waste generation particularly food waste delivered to disposal sites is higher than smaller cities.

2.2.1 *Waste collection service*

Due to the limitation of budget and personnel, the local authorities transferred their responsibility on waste collection and disposal to contracted private companies without monetary compensation. Therefore, waste collection service is based on the waste fee that private companies collect from the residents. Many of the contracted waste collection companies failed to recover the cost of waste collection because the residents are not willing to pay for the service. Residents who refused to pay for the waste collection service have their waste dumped in a public space, such as in front of neighbourhood house and private land. Often, the waste is then burned.

The waste collection companies are unable to collect a sufficient amount of service fees from the residents. Thus they have limited their services to densely populated and high income areas (Fig. 2.2) where most residents paid for waste collection service. In general, the coverage of waste collection service in urban Cambodia is lower than 50%, except in Phnom Penh where waste collection service covered 84% (Table 2.1).

Collection of the service fee is successful, to some extent, in Phnom Penh due to the cooperation of the contracted waste collection company (CINTRI) with the Electric Department of Phnom Penh City (Electric du Kambodge). The waste fee is included in the electric bills. However, around 20% of residents who have no access to electricity do not pay for waste collection service.

Waste collection in Siem Reap is also handled by a private company. A strategy for collecting the waste fee is door-to-door service. The Environmental Department of Siem Reap notified and enforced a local regulation to associate waste collection service. Also, if the residents are not satisfied with the waste collection service, they can inform the Environmental Department of Siem Reap directly.

The fee for waste collection service is based on economic condition of residents, not on quantity of waste generated. For instance, the service charge for each general household is 5,000 Riel (USD1.25 per month), but the charge is more expensive for each large house owner (USD 2.5) and business enterprise (USD 5-50) such as restaurants, jewellery shops and hotels. This policy aimed to make it payable by residents, but there is no incentive for waste reduction.

2.2.2 *Waste disposal*

Generally, the waste collected by the

Figure 2.2 Waste Collection in Cambodia's Cities

private company is simply dumped in the disposal sites without considering the basic management practices such as compaction and covering with soil layer. Often, the disposal site generates foul odours and outbreaks of houseflies. Residents in the vicinity of the landfill site are exposed to health risks caused by houseflies and vermin. Sometime, burning is practiced to reduce the volume of waste. Such practices could release smog and other carcinogens.

Due to its geographical feature, the most of the disposal sites in Cambodia are located in flood prone areas. Leachate[2] is produced during the degradation process of waste which percolates and contaminates with groundwater table and surface waste in the surrounding paddy fields. The residents closer to the disposal sites are exposed to hazardous substances and pathogens.

The most advanced landfill was constructed in Dang Kor, Phnom Penh in 2009 (Fig. 2.3). This disposal site has a compaction and leachate drainage system, even though housefly outbreak is a serious problem that has threatened the living conditions of the residents in the vicinity of the landfill.

Figure 2.3 New disposal site at Dangkor, the Phnom Penh Municipality

In some cities, the waste disposal sites are owned by local governments, but some are owned by contracted private companies. In cases where the local government owns the disposal facility, private companies must pay the disposal fee. Due to budget constraints, there is not much difference in the quality of management of the disposal sites whether owned by local governments or private companies.

Despite an increasing waste generation rate in Cambodia, there is a very little improvement of financial and institutional capacities development in local governments or contracted private sectors for enhancing the situation of waste disposal sites. The price of land is rapidly increasing. Therefore transport distances between the disposal sites and the downtown area tend to increase anytime a new disposal site is established. Consequently, the cost for waste transportation increases, but residents are still not really willing to pay. If these shortcomings continue, the standard of solid waste management in Cambodia will worsen. Consequently, environmental impacts from improper solid waste management would increase and these negative effects will badly influence human health and income generation from tourism.

2.2.3 *Waste separation at the generation source*

In 2009, there was no mainstream waste separation at the generation source practiced in Cambodia. Separation of recyclable waste was practiced on a voluntary basis due to an

2 Leachate is water that has percolated from waste. Normally, it is highly polluted.

indirect influence caused by increasing the economic value of sellable waste.

Waste pickers play a dominant role in separating sellable waste that is dropped in waste bins and at disposal sites. For instance, more than 2,000 waste pickers that are working at both the downtown and the disposal site of Phnom Penh, help reduce waste buried in landfill.

Food waste that has no value in the recycling market occupies the landfill – making it difficult to separate sellable materials, emitting foul smell and toxic gases to human health, making it a place full of resident vermin and disease carriers, and polluting the soil and water environment.

2.2.4 *Current organic waste utilisation*

Generally, the utilisation of urban organic waste in Cambodia is very low. Organic waste is utilised for two purposes: animal feed and composting. However, only a low percentage of food waste from restaurants is collected for animal feed. Also, only a few composting facilities are operated by NGOs.

With respect to animal feed, some farmers claim that direct feeding of food waste is not favourable in comparison to instant feed in terms of growth rate. There is also a concern on animal health due to the poor quality of food waste. Therefore, it is necessary to process food waste to a suitable standard for animal feed.

For the composting facility, Cambodian Education and Waste Management Organization (COMPED) established a windrow composting facility at the old disposal site of Phnom Penh (Fig. 2.4). A new composting plant was constructed in Battambang by COMPED in 2009 and it has been operating since April 2010. Some household composting is promoted by the Community Sanitation and Recycling Organization (CSARO).

The composting plant at MPP received 5 tons/day (1,800 tons/yr) of organic waste from a market which accounts for 0.4% of Municipal Solid Waste (MSW) or 0.7% of food waste generated in this city (see Appendix II for technical details). The composting activity of this project declined when the local government of Phnom Penh closed the old disposal site and started

Figure 2.4 Composting by COMPED at Phnom Penh Municipality

to use the new one in 2009. This facility was terminated by the operator due to uncertainty over local government policy that is likely to begin supporting energy production (rather than compost) from waste.

2.3 Impacts of improper organic waste management and climate change

Biodegradation of organic waste under anaerobic condition (e.g. in a landfill) can generate greenhouse gases (GHG). Methane is the most serious GHG emitted from the waste sector, since its global warming potential is more than 20 times higher than carbon dioxide[3]. Methane generation per kilogram of organic waste varies depending on the extent of absence of oxygen and the type of organic waste. For example, one kilogram of food waste can release 0.42 $KgCO_2eq$ when it is dumped into an unmanaged shallow landfill (<5 m depth) but the emissions can be as high as 1.05 $KgCO_2eq$ if the same amount of waste is disposed on a deep compact landfill (>5 m depth) (Sang-Arun and Bengtsson, 2009).

Cambodia has low capacity to invest in landfill gas capture; therefore, most of the methane from landfills and dump sites is released directly to the atmosphere. As shown in Table 2.1, it is estimated that methane emissions from landfill of organic waste in major cities in Cambodia in 2008 was approximately 360,000 tons CO_2eq (assuming disposal in unmanaged deep landfills). Currently, urban population and waste generation per capita of Cambodian are increasing due to urban development and economic growth. In addition, there is also an increase of waste collection service and disposal by landfill. Therefore, the potential methane emissions from landfills are set to increase.

2.4 Overall discussion

Improving urban organic waste management in Cambodia requires efforts from both national and local governments. The national government should establish an enabling legal framework and develop guidelines for solid waste management suitable for the country. Budget allocation from both national and local governments should be made to ensure resources for solid waste management. Local governments should implement policy and follow regulations established by the national government.

The involvement of the private sector for waste collection and in some cities for disposal is a good initiative to reduce the workload of local governments and create business opportunities for the contracted private companies. However, local governments should support the contracted private companies to ensure efficient waste collection service and improved disposal system, by providing awareness raising campaign to residents. The local governments should encourage residents to reduce waste generation, discard waste in proper containers, drop waste at the collection points on given schedules, and pay for waste collection and disposal services.

[3] Scientists reported global warming potential (GWP) of methane over carbon dioxide in different level. However, the value that adopted for national GHG inventory report to the IPCC is 21.

Disposal of urban organic waste at disposal sites should be avoided as this waste could contribute to soil, water and air pollution, cause an odour nuisance, spread vermin and insects, cause a disease outbreak, and also reduce the quality of other recyclable wastes. In order to avoid environmental impacts from landfill of organic waste, organic waste should be separated for effective utilisation, for instance, by means of animal feed, soil amendment materials and alternative energy.

3.
Urban organic waste utilisation technologies

3. Urban organic waste utilisation technologies

There are many technologies being developed for utilising urban organic waste. It is very difficult for local governments and project developers to select the most suitable technologies without knowing the advantages and disadvantages of such technologies.

This guide introduces some technologies that are implemented for urban organic waste treatment in the region[4]. Technology that is suitable for the current situation of Cambodia is discussed and examples of some waste utilisation techniques are presented as choices for selection.

3.1 Waste reduction

Waste reduction is the most fundamental strategy to achieve sustainable waste management. Therefore, waste management authorities should make efforts to reduce the amount of waste generated. This practice could avoid waste generation at all stage of waste management. Waste reduction has benefits on saving resources and reducing costs for waste collection and treatment. The significance of waste reduction in developed countries is now well recognised (e.g., OECD, 2000). There is less scope for waste reduction in most developing countries as their per capita waste generation rate is still at relatively low levels. In these countries, however, there are a growing number of people, especially in urban areas, who generate as much waste as people in industrialised countries. Significant waste reduction requires active participation from large numbers of households by changing their consumption patterns and daily habits.

3.2 Animal feed

The use of food waste for animal feed has been practised for as long as humans have kept domestic animals. This practice is still common in rural areas, but mostly very limited in large cities. In Cambodia, food waste collection for animal feed is practiced by some farmers as it reduces the cost of the feed (Fig. 3.1). Sometimes, the growth rate of animals raised by food waste is slower than that of those using instant feeds. Also, there is a concern about animal health risk. Therefore, the use of food waste for animal feed is limited, and the addition of high

4 Some parts of the summary of waste treatment technology was written by Bengtsson et al., 2008, Urban organic waste from hazards to resource. In Second IGES White Paper Climate Change Policies in the Asia-Pacific: Re-uniting climate change and sustainable development. IGES.

Figure 3.1 Food waste collection for animal feed

nutrient feed is required in order to increase nutrient balance and competitiveness with instant feeds.

3.3 Composting

Composting is a technique to enhance the degradation of organic matter under aerobic condition. This technique generates carbon dioxide, water and humus-like products (compost). Major factors influencing composting process are the ratio of carbon and nitrogen in the waste, as well as temperature, oxygen, moisture and microorganisms. Moisture content should be maintained at 40-60%. Therefore, composting is not appropriate for liquid waste, otherwise dry matter must be added.

Composting can reduce the volume of the waste, generally by 30-50%. The residual product, compost, is pathogen free. It is applicable for improving soil structure and for adding nutrients to soil. Most types of soil can benefit from adding compost, especially sandy and clay soils, which lack organic matter. Compost helps to improve the water-holding capacity of the soil. The use of compost can also reduce expenses for chemical fertiliser.

Composting has been practiced for a long time in rural areas. In general, composting is technically uncomplicated and may be an economically realistic alternative for many municipalities in Cambodia. It can be applied at various scales, from individual households to large centralised facilities. However, there are some risks and disadvantages of composting; bad smells can occur and vector-borne diseases can spread if the composting process is poorly managed.

Under well-managed conditions, composting does not generate methane. Some emissions may occur if the substrate is not sufficiently aerated or becomes too wet. Small emissions of nitrous oxide (N_2O) may occur if vermin-composting is employed (Hobson et al., 2005). Nevertheless several environmental agencies have concluded that when composting is done properly, it generates very small amounts of GHGs (e.g. MFE, 2002).

3.4 Anaerobic digestion

Anaerobic digestion is well recognised for the treatment of agricultural waste, organic industrial waste and sewage sludge. Only in recent years it has been used for municipal solid waste management. The degradation process occurs under an oxygen-free environment and generates gases with a high proportion of methane.

Methane that is captured from the anaerobic digester is used as an alternative energy for cooking, lighting, generating electricity and fueling vehicles. The use of biogas can save labour for gathering fuel wood, make cooking more pleasant, decrease the health risk that is induced by the smoke of fuel wood and charcoal, avoid deforestation, reduce greenhouse gas emissions, and improve the sanitary conditions of households and cities. In addition, discharge from the anaerobic digester can be used for soil amendment.

Some leakage of methane from digestion tanks and gas powered combustion engines may occur. Studies in developed countries found that emissions from digesters at farms are in the range of 3.4 to 8.4%, and a fugitive loss in gas powered engines is 3.5% on average (Reeh and Møller, no date). However, it is reasonable to assume that average losses in developing countries will be higher.

Anaerobic digestion has many advantages over composting in terms of products, types of waste inputs and environmental impacts. This technology is available to treat both solid and liquid waste such as food waste, vegetable and fruit residue, and kitchen wastewater. It generates fewer odours and requires less space than composting. However, the investment for anaerobic digestion is higher than composting.

3.5 Mechanical biological treatment (MBT)

MBT is a group of hybrid methods where unsorted waste undergoes pre-treatment prior to landfill or incineration. There are many possible designs, but a common MBT pre-treatment system includes (i) mechanical treatment to homogenise the waste and separating valuable materials such as metals, glass and plastics and (ii) biological treatment where the organic fraction is decomposed. The biological process can include either anaerobic (generating biogas) or aerobic (composting) treatments.

MBT is an alternative to enhance resource recovery from unsorted waste. It can significantly reduce the volume of the waste and lower the leakage and gas emissions from landfills (Visvanathan et al., 2005). Therefore, it can extend the lifetime of the landfill (approximately 50%), reduce environmental impacts, and avoid public nuisance (e.g. odours and flies) and health hazards. However, it requires labour, infrastructure, hard machinery, energy and working space for mechanical and biological processes.

Decomposed organic matter that contains low heavy metals can be applied for soil amendment. Separation of recyclable materials and refuse-derived fuel (RDF) from MBT can create income for the facility. RDF from MBT can be used as an energy source for heavy industries or converted to liquid fuels. The RDF that can be used for thermal technology must contain less than 10% of polyvinyl chlorine (PVC). Inert waste after the MBT process can be easily disposed of in landfills or incinerators.

Some MBT systems have been installed in China and Thailand through financial and technical assistance from Germany. In most of these cases, the technology is simplified with more manual separation and only aerobic treatment (composting). In Thailand, Phitsanulok Municipality employed a passive aerated windrow composting technique for biological process (Fig. 3.2). The composting process takes 5-9 months allowing degradation of most of organic matter. Decomposed organic matter contains high heavy metal contamination; therefore it is used as a cover material for the

Figure 3.2 **Mechanical biological treatment prior to landfill in Phitsanulok Thailand (Photo: Suthi Hantrakul)**

new composting pile. Plastic is converted to liquid fuels. Non-value inert waste is buried in landfills. By implementing the MBT, the lifetime of the landfill of this municipality is tripled, with an increased lifetime from 16 years to 44 years (Phitsanulok Municipality, 2005).

Cambodia can extract lesson learnt from the Phitsanulok Municipality where the waste delivered to landfill is approximately 80 tons/day. Current landfill operations in Cambodia entail waste being simply dumped and thousands of waste pickers earn from the recyclable waste. The MBT system that enhances income generation for the poor people is preferable than a sanitary landfill. In addition, once separation of hazardous waste is practiced, the compost from MBT can be used for soil improvement.

3.6 Sanitary landfill

Sanitary landfill is a disposal site that has proper siting, design, operation and long term environmental impact control (Johannessen and Boyer, 1999). Basically, the sanitary landfill site should have an effective liner to prevent underground water contamination, effective leachate treatment infrastructure that reduce contamination into the environment, incorporate a full set of measures to control greenhouse gas emissions, apply a compaction measure for waste and use soil cover daily, and implement plans for closure and aftercare when landfill is closed.

Many recyclable materials such as metals, glass, paper, plastic are buried in landfill. Although landfill mining is applicable, but it can be practiced safely only after the landfill is closed for years. Mining of landfill when the biological degradation process is ongoing may induce health risks due to environmental hazards (e.g., inhalation of methane and toxic gases like NO_X, SO_X, NH_3, contamination of leachate and toxic substance).

Capture of methane for energy use is an alternative to reduce climate impact from landfills (Fig. 3.3). Landfill gas consists of 40-60% methane and it has 50% fuel equivalent of natural gas (SCS Engineers, 1994). The sale of electricity generated from landfill gas can earn up to USD1-2

Figure 3.3 **Sanitary landfill with gas recovery system in Thailand (Photo: Komsilp Wangyao)**

per ton of waste (Ewall, 2008). However, landfills that installed the landfill gas collection system covering all areas within one year after the waste is deposited can achieve 60-85% collection efficiency (with 75% in average) (EPA, 2010). In developing countries, the collection system is not well installed due to budget constraints, so landfill gas recovery is very low, with a large percentage of methane leaking to the atmosphere. Therefore, in developing countries, this initiative is economically attractive under high fossil fuel costs, government support, charging of environmental impact, and carbon credit trading (e.g. Clean Development Mechanism, CDM).

Currently, landfills in Cambodia are 'semi-controlled dumps': no lining, no compaction, and no soil cover. The most advance landfill is a new disposal site in Phnom Penh Municipality. This system is, more or less, considered as'semi-engineered landfill': liner and leachate treatment system existed, no soil cover and no landfill gas management. Therefore, it would be very difficult for local governments in Cambodia constructing and managing sanitary landfill without international aid.

3.7 Incineration

Incineration is a waste treatment technology for destroying waste under controlled burning at high temperatures. It can effectively eliminate the hygiene hazards associated with organic waste as well as drastically decreasing the volume of waste. Methane generation is completely avoided and the process can also generate electricity and heat which can replace energy from fossil fuels. However, the incineration process can produce fossil based carbon dioxide from plastic burning, carbon monoxide, dioxins, heavy metals and other harmful substances.

Incineration of municipal solid waste is widespread in industrialised countries (Fig. 3.4). However, only few developing countries are successfully incinerating municipal solid waste. Waste in developing countries typically has a high moisture content and low calorific value compared to that in developed countries. Therefore, extra fuel, typically coal, needs to be added (Solenthaler and Bunge, 2005). As a consequence, the recoverable energy is low and the cost is high. The investment costs for incineration plants are high compared to other options, and the technology used is advanced which requires highly skilled personnel for operation and maintenance. In many cities, incineration has met strong opposition because of emission of highly toxic dioxins and other pollutants. It is possible to reduce these emissions to very low levels by advanced flue gas treatment, but this makes the investment costs for incineration plants significantly higher.

Figure 3.4 An incineration plant in Japan

3.8 Evaluation of organic waste treatment technologies

Organic waste utilisation and treatment technologies (Fig. 3.5) can be divided into two levels:

i) Household and community level – waste reduction, animal feed, composting, and anaerobic digestion,

ii) Municipality level:

a. Unsorted waste – open dumping, sanitary landfill, MBT, incineration

b. Segregated organic waste – composting, anaerobic digestion

Promotion of waste utilisation and treatment at household and community levels could reduce the expenses for waste collection, transportation and disposal. It could also avoid conflicts between local authorities and residents on implementation of waste disposal facility. However, budget allocation for mainstream education, training, and implementation is required.

Table 3.1 describes advantages of technologies versus indicators on environmental impacts, greenhouse gas emissions, utilisation and job creation. Waste reduction could reduce costs for the whole system of waste collection, transportation and disposal; however it requires active cooperation from citizens. Waste reduction is an economic incentive for individual households, but it does not recreate jobs for low-income and non-skilled labourers.

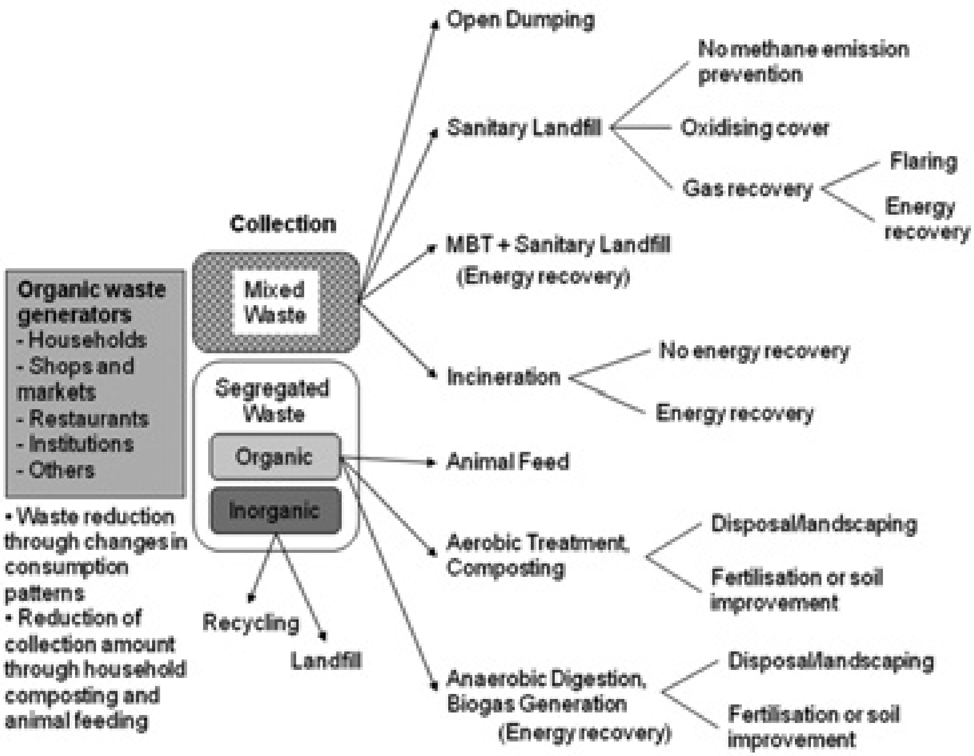

Figure 3.5 Waste utilisation and treatment technologies (Bengtsson et al, 2008)

Table 3.1 Advantages of waste utilisation and treatment technologies

Technology	Reducing authority expense for waste collection	Reducing authority expense for waste disposal	Reducing household expenses	Applicable with budget less than 100,000 US$	Avoiding GHG emissions from landfill and incineration	Avoiding GHG emissions from non-waste sectors	Avoiding environmental impacts induced by open dumping and open burning	Avoiding environmental impacts induced by landfill	Avoiding environmental impacts induced by incineration	Recovery of nutrients (contribute to food security)	Recovery of energy	Recovery of valuable materials	Creating jobs	Existence of in-country expertise
Waste reduction	○	○	○	○	○	○	○	○	○	×	×	×	×	×
Animal feed	○	○	△	○	○	○	○	○	○	○	×	×	○	○
Composting	△	△	△	△	○	○	○	○	○	○	×	×	○	○
Anaerobic digestion	△	△	△	△	○	○	○	○	○	○	○	×	○	△
MBT	×	×	×	×	○	△	○	○	○	△	△	○	○	×
Sanitary landfill	×	×	×	×	△	△	○	△	○	×	△	△	○	△
Incineration	×	×	×	×	△	×	○	○	△	×	△	×	○	×

Remarks: ○ is advantage, △ is likely advantage or may be advantage, depends on specific condition, × is disadvantage

Collection of good quality food waste for animal feed could be practiced by individuals households and animal farms. This practice could reduce waste delivery to the waste stream and thus reduce costs for waste management. There is a limitation with regards to the quality of food waste which impacts on an animal's health and its growth rate compared to instant feed.

For unsorted waste, MBT prior to landfill or incineration is more favourable than delivering fresh waste to sanitary landfill and incineration. MBT could avoid GHG emissions, enhance recovery valuable materials, and improve waste characteristics for efficient incineration and safe landfill disposal.

In developing countries, using waste as animal feed is practiced by residents and farm owners. Local authorities handle or allocate budgets for other treatment options. Table 3.2 compares the requirements for implementation of anaerobic digestion, composting, MBT, and sanitary landfill. Each technology has advantages as well as disadvantages. Composting is an attractive

Table 3.2 Comparison of composting, anaerobic digestion, mechanical biological treatment, sanitary landfill and incineration

Factors	Composting	Anaerobic digestion	MBT	Sanitary landfill	Incineration
Capital investment per ton of waste	Very low-low	Medium	Low	Low	High
Operation cost per ton of waste	Low-medium	Medium	Medium	Low	High
Land requirement	Medium	Low	High	Very high	Low
Labour inputs	Medium-high	Low	Medium-high	Low	Low
Personnel skill	Low-medium	Medium-high	Medium-high	Low-medium	Medium-high
Energy use	Low-medium	Low-medium	Medium	Low	Medium-high
Scale	Household-large	Household-large	Medium-large	Medium-large	Medium-large
Time requirement to treat the waste safely	1-12 weeks	3-4 weeks	5-9 months	>2-100 yrs	1 day
Maintenance skill	Low-high	Medium-high	Low	Low	Very high
GHG emissions	Low	Very low	Low	Medium-high	Low

Note : This estimation referred to small-medium scale of composting and anaerobic digestion with simple technology that possible to implement in Cambodia. The MBT and sanitary landfill is generally implemented for centralised of medium-large scale, therefore the table is reflecting its general facility.

technology for developing Asian countries in terms of the investment and the flexibility of scale. Implementation of MBT and sanitary landfill are generally practiced on a large scale, and so require high capital investment which Cambodia may need to seek by applying for international aid.

Table 3.3 presents capital investment for solid waste treatment projects found in Thailand and Cambodia. This cost estimation does not include expense for land because many local authorities did not purchase for the land. Incineration is too costly or unfeasible for high moisture and low calorific value waste. Anaerobic digestion for energy recovery in medium to large scale is also expensive, but it is attractive for cities where electricity costs are high. In-vessel composting is more costly than sanitary landfill construction. Windrow composting is the cheapest option.

Landfill gas recovery and the use of oxidising landfill covers have important roles to play for reducing future GHG emissions from old landfills and landfills that are currently in operation. However, constructing new landfills for untreated organic waste, even if equipped with gas recovery systems, should consider the following concerns: (i) GHG emissions will still be relatively high, (ii) valuable nutrients will be lost or mixed with pollutants, (iii) the land could be used more productively for other purposes, and (iv) the risk of water contamination cannot be

Table 3.3 Example of capital investment for solid waste treatment projects

Solid waste treatments	Waste input (ton/day)	Capital investment* (million US$)	Capital investment for capacity of one ton of waste input per day (US$)	Area (ha)
Incineration				
- Phuket, Thailand	280	24.63	88,000	
- Samui, Thailand	140	15.66	112,000	
Anaerobic digestion				
- Rayong, Thailand	60	4.53	75,500	
- Koh Chang, Thailand	30	1.77	58,900	
Sanitary landfill (no gas recovery)				
- Samutprakarn, Thailand	85	2.06	24,100	16.5 ha (15 yrs)
- Phnom Penh, Cambodia	1,200	NA	NA	31 ha
Mechanical biological treatment				
- Phitsanulok, Thailand	80	1.60 (including landfill site)	20,000	10 ha (approx. 24 yrs)
Composting				
- In-vessel, Bangkok, Thailand	1,000	27.97	28,000	
- Windrow, Phnom Penh, Cambodia	5	0.065	13,000	

Note: *This cost is for construction only, not including land purchase or rent.

eliminated particularly in flood prone area of Cambodia.

From a sustainability perspective, implementations of composting and anaerobic digestion projects are favourable. Technologies for these options range from manual to automated systems and also vary from household to large scale. Therefore, they have more feasibility of implementation than MBT, sanitary landfill and incineration in terms of scale. Commonly, composting is cheaper and simpler than anaerobic digestion, but it has disadvantages with regards to energy recovery. Anaerobic digestion is technically more complicated than composting and the process needs to be operated by professional staff in order to function well. Composting is a labour intensive method and therefore generates more jobs. Low investment requirements make composting especially suitable for projects with limited funding. Together with its low-tech nature and the possibility of introducing it on a very small scale, composting is a highly suitable option for community-driven waste management initiatives.

Examples of composting and anaerobic digestion techniques are described below.

A) Composting techniques

Composting can be practiced from the very small scale at household level (<1 kg waste per day) to a large scale at municipality or sub-regional level (>1,000 tons waste per day). At the household level, composting can simply be practiced in the backyard (Fig. 3.6). At community level, a community composting facility can be implemented in a public space and operated by community volunteers (Fig. 3.7). Residents who do not have space for cultivation or gardening can participate in the composting programme by separating waste for community or centralized composting. The produced compost is used for gardening, vegetable growing and farming by the household themselves. Excess production of compost can be distributed around the neighborhood or can be sold at the market.

Figure 3.6 A windrow composting under a banana bush in Cambodia

There are many composting techniques. Each technique requires different labour input, skills, investment, and time for maturity. Examples of composting techniques are Takakura home method (THM), static pile windrow composting, passive aerated windrow, forced aerated windrow, in-vessel composting, and vermin-composting (using earthworms). Table 3.4 compares advantages and disadvantages of some composting techniques. Considering budget and personnel constraints, THM, static pile windrow, and passive aerated windrow are appropriate for Cambodia.

Figure 3.7 A household and community static pile windrow composting in Thailand

i) Takakura home method (THM)

THM was developed by Mr. Koji Takakura, JPEC Company, Japan. This composting technique is suitable for individual household level in urban areas. It is well adopted in Surabaya, Indonesia and then replicated in many cities in developing Asian countries.

THM takes one to two weeks for fermentation and another two weeks for maturity. Basically, this technique uses local available effective microorganism to enhance fermentation as so called "seed compost". Equipment required includes a breathable container, a cardboard or porous material for inner lining of container, a shredder and a cover sheet (Fig. 3.8). Fine chopped of waste enhanced rapid degradation of the waste, thus the time requirement for composting is shorten.

ii) Static pile windrow composting

Windrow composting is the simplest composting technique and widely practice in developing countries. Investment cost is lower than other types of composting. However, it requires constant labor inputs for turning the compost piles and watering.

Figure 3.8 Takakura home composting in Bangkok, Thailand (Photo: Toshizo Maeda)

Table 3.4 Advantage and disadvantage of some composting techniques

Input requirement	Composting techniques					
	Takakura Home Method	Windrow	Passive aerated windrow	Forced aerated static pile	In-vessel	Vermin-composting
Capital investment per ton of waste	Medium	Very low	Low	High	Very high	Medium
Operation cost per ton of waste	Low	Low	Very low	High	Very high	Medium
Land requirement per ton of waste	High	High	High	High	Low	High
Labor input	Medium	High	Very low	Very low	Low	Low
Personnel skill	Trained	Trained	Trained	Trained	Well trained on machine's operation	Trained
Energy use	No	Low	No	Medium	High	No
Time	1-3 weeks	12 weeks	12 weeks	12 weeks	1-2 days	0.15 ton waste per 1 ton earthworm per day
Maintenance requirement	Low	Low	Low	Medium	High	Medium
GHG emissions	CH_4 when ventilation is not sufficient	CH_4 when ventilation is not sufficient CO_2 from machinery use for turning the pile	CH_4 when ventilation is not sufficient	CO_2 from energy use	CO_2 from energy use	NO_X

The size of composting pile is normally found in elongate shape with 1-2 m wide and 1-3 m high (Fig. 3.9). The duration of composting is about 3 months, but it may take more time if the aeration and moisture is not well maintained.

iii) Passive aerated windrow composting
Passive aerated windrow is similar to static pile windrow method; however aeration is available through the porous pipe that made from bamboo or plastic tube (Fig. 3.10). This composting technique can reduce labour power requirement for turning the composting piles. Well mixed of composting material is required before developing the composting piles. It is also important to avoid compaction of material, thus aeration can flow smoothly.

iv) Forced aerated windrow composting
Forced aeration composting is developed from the passive aerated windrow. An electric pump is required to ensure good aeration of the composting pile (Fig. 3.11). The investment cost is increased, while labor input is reduced. This technology is, somehow, not suitable for Cambodia where energy is expensive.

v) In-vessel composting
In-vessel composting is referred to composting that practicing in enclosed system which allows a high degree

Figure 3.9 Static pile windrow composting in Cambodia

Figure 3.10 Passive aerated windrow composting in Cambodia

Figure 3.11 Forced aerated static pile composting in Thailand

of process control compared with windrow composting (Fig. 3.12). This technique allows processing of large quantity of waste in a limited space. High investment and skillful personnel is required to implement and operate this composting system. Therefore, it may not be suitable for Cambodia where budget is a major constraint and energy is expensive.

vi) Vermicomposting

This composting technique is widely promoted in India. Implementation of this technique in Cambodia and neighboring countries are still in laboratory and pilot scales. Therefore, suitability of this technique for Cambodia is questioned. Furthermore, some scientist claimed that vermicomposting may contribute nitrogen oxide to the atmosphere. The global warming potent of this gas is 290-310 times higher than carbon dioxide.

Vermicomposting is carried out by using earthworms (e.g. tiger worms (*Eisenia foetida*), red worms (*Lumbricus rubellus*), and Pheretima peguana (a Thai local specie) (Fig. 3.13). These earthworms can reproduce very fast, thus the speed of converting waste to compost can be speeded up over time as the number of worm increases.

Figure 3.12 In-vessel composting in Thailand

Figure 3.13 Pilot plants of vermicomposting in Cambodia (left) and Thailand (right)

Currently, Cambodia has two urban composting facilities operated by COMPED and CSARO (community scale). Cambodia can increase the number of urban composting plants in the country by utilising experience and lesson learnt from the existing composting plants. In each city, composting technology may be varied depending on the interest of local stakeholders, quantity of organic waste, land availability and budget. In any case, residents need to participate in organic waste separation at the generation source to ensure the quality of compost and sustain sufficient deliveries of organic waste to the composting plant.

B) Anaerobic digestion techniques

Anaerobic digestion is an organic waste degradation process without oxygen. This process generates biogas which contained 50-60% methane. An anaerobic digestion process that has 10-15% of dry matter is called 'wet digestion' and that which has 24-40% of dry matter is called 'dry digestion' (see Appendix IV for a dry digestion process). The dry digestion has advantage over the wet digestion as it does not required washing process and so wastewater discharge is lower (Luning et al., 2004). The dry digestion process can save water use and provide higher digestion efficiency than wet digestion process (Jiang et al., 2007). However, the wet anaerobic digestion process is found commonly in India and Thailand because it could treat liquid waste from the kitchen.

In India, two famous anaerobic digestion developers use cow dung (Biotech) and sugar (Appropriate Rural Technology Institute, ARTI) as the starter of the process. After the system is well adopted, there is no need to add more cow dung or sugar. ARTI mentioned that efficiency of digester initiated by one kilogram of sugar is equaled to 40 kilograms of cow dung; therefore the size of digester using sugar is very much smaller than that using cow dung. In addition, the system using sugar can generate biogas within 24 hours. Therefore, it is available to install in urban area where space is limited. However, a pilot test is required to check whether it is technically efficiency and economically viable for Cambodian circumstances.

Based on experience of Biotech, food waste can produce gas quicker than animal dung, thus the size of digester can be reduced. Organic waste mixture can be fed to the system once a day, thus avoiding discard of kitchen waste to the waste stream and improve sanitary condition of the building. A result of household interviews in India showed that biogas can replace 30-50% of liquid petroleum gas (LPG) for cooking. The discharge from the wet digestion process is directly used for fertilizing backyard gardening (Fig. 3.14), thus increases vegetable production for household consumption.

Large scale anaerobic digestion is successfully implemented in developed countries. However, this system requires skillful personnel and incurs high costs for construction and operation. Amongst developing countries, India is the most successful in promoting biogas generation from food waste in small and medium scale. The technology is

Figure 3.14 Direct use of discharge from anaerobic digestion tank for cultivation in India

somewhat similar to the project of biogas generation using manure. Therefore, the current biogas project in Cambodia may be modified to treat urban organic waste.

Small scale anaerobic digestion is suitable for Cambodia where the government has limited budget allocation for solid waste management. However, large scale anaerobic digestion would be applicable once budget is secured for both construction and long-term operation and as long as waste separation at the generation source is well practiced.

Currently, many biogas system developers try to make biogas systems simpler to use on a household scale. This guide introduces two types of digester that are commonly found in developing Asia countries: floating drum and fixing dome digesters. Table 3.4 presents differentiation comparison between floating drum and fixing dome digesters

i) Floating drum digester

This system is well practiced in India. It can be prepared by using two drums with slightly different diameters (Fig. 3.15). The material use should have a high resistance to erosion. The bigger drum is set on the ground and functions as a waste collector. The smaller one is turned upside down into the bigger one and functions as gas collector. The upper drum will gradually rise up when gas is generated, thus no need to install a measure gauge. Other equipment requirements are a waste feeder and

Figure 3.15 Floating drum digester tanks used in India

an effluent discharge system.

ii) Fixing dome digester
This system is common practiced in many countries including China and Cambodia (see figure in Appendix III). Normally, this type of system is built in the ground and the structure is made of masonry, thus its lifetime is longer than the floating drum. Also, leakage of biogas is lower than the floating drum. Biogas that occurred in the digester will put pressure on the effluent discharge from the digester system.

Table 3.5 Comparison between floating drum and fixing dome digesters

Factors	Floating drum	Fixing dome
Capital investment per ton of waste	Lower	Higher
Operation cost per ton of waste	Not much different	
Land requirement	Not much different	
Labour input	Not much different	
Personnel skill	Not much different	
Energy use	Not much different	
Time	Not much different	
Maintenance requirement	Not much different	
Lifetime	Shorter	Longer
Mobility	Possible	Not possible

4.
A guide for selection of urban organic waste utilisation technology

4. A guide for selection of urban organic waste utilisation technology

The major obstacles of waste management in Cambodia are budget and personnel constraints, therefore high capital investment and complicated technology are not appropriate. When selecting technology, other factors such as geography, waste characteristics and social awareness should be considered. Table 4.1 presents the limitations on technology and local circumstances. Geographical limitations may cause risk of flooding, so sanitary landfill is not an appropriate technology for Cambodia, unless flood control measures and ground lying can be taken into account to prevent contamination of toxic substances with surface and underground water resources. Incineration is suitable in terms of topography but it is not viable due to budget constraints and waste characteristics. MBT could avoid risk of water resource contamination compare to direct landfill of untreated municipal solid waste. MBT could even extend the lifetime of the landfill. However, initial investment of MBT is higher than sanitary landfill, but it is cheaper in a long term. Anaerobic digestion is preferable as it could provide both energy and soil improvement benefits.

Fig. 4.1 shows appropriate organic waste

Table 4.1 Limitation on municipal solid waste management in Cambodia

Factors	Limitation	Appropriate solid waste management options
Budget	- lack of budget - most local governments do not allocate budget for waste management	- Low cost technology such as windrow composting, household anaerobic digestion, MBT and sanitary landfill
Personnel	- lack of high skilled personnel	- Low technological input technology such as windrow composting and MBT
Geography	- lowland and risk to flooding - most disposal sites are located in paddy fields	- Technology that would not be affected seriously from flooding such as composting, anaerobic digestion, MBT, and incineration.
Waste characteristic	- high biodegradable - high moisture content	- Non-thermal technology such as composting, anaerobic digestion, MBT
Social awareness	- Very low especially on sanitary issue: e.g. some residents use wastewater from the canals for bathing and washing cloths	- Technology for unsorted waste such as MBT and sanitary landfill

treatment and potential use of their products for different types of waste. Animal feed, composting and anaerobic digestion are aligning with the Cambodian national agenda on socio-economic development and environmental protection. However, waste separation at the source (household level) is required to ensure the quality of waste input, operation system, and the product's quality. If waste separation at the generation source fails, other options such as MBT and sanitary landfill with gas recovery system should be considered.

Fig. 4.2 describes the hierarchy for urban organic waste management in Cambodia. Even though the rate of waste generation in Cambodia is low, reduction of the over-demand of food and post harvest losses leading to waste still need to be highlighted as a fundamental way to achieve sustainable waste management in a long term. Very high quality leftover food, vegetables and fruits should be used for human consumption and the rest for animal feed. These techniques do not require investment by the government, but it can be practiced by individual residents and enterprises. However, these techniques may not applicable for a large scale waste management facility due to issues of health risk.

For the waste that being collected by the collection service, composting of organic waste is highly recommended because a few pilot projects have implemented this, with help from local experts, and with the advantage that the investment is lower than other technologies. Anaerobic digestion is also recommended, if local government could secure funding and could utilise the

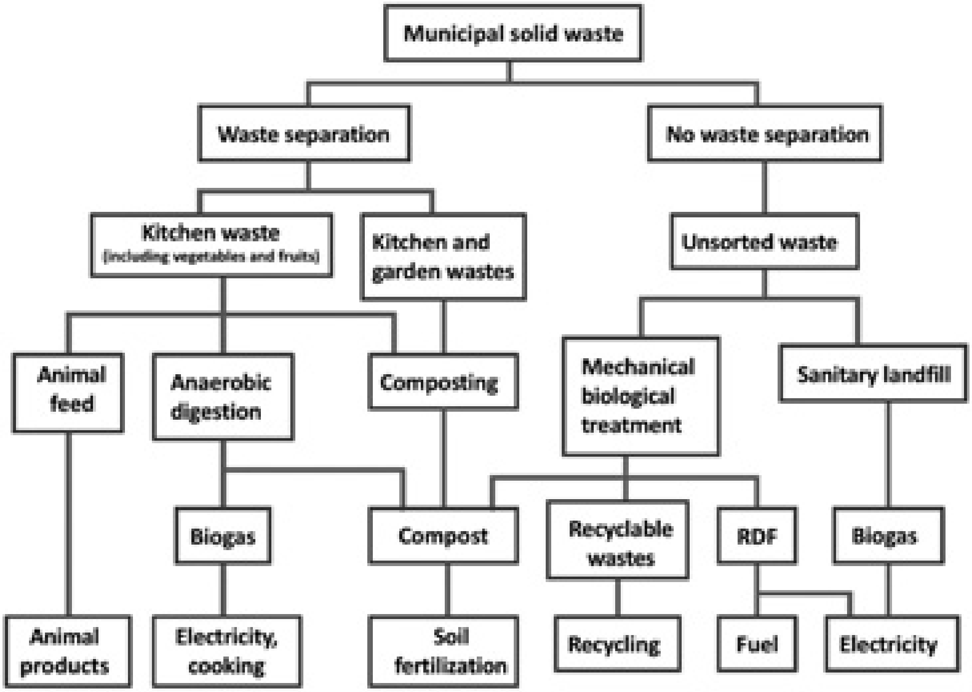

Figure 4.1 Some of the potential technologies for organic waste utilisation

current experience on the national biogas project. Both technologies are available from households to cities. Use of the compost and discharge from anaerobic digestion for food production requires a quality control process to avoid contamination of toxic substances into the food chain.

A recent study by Barton et al. (2008) suggested that composting should be the first option for replacing open dumping in developing countries. However, this does not imply that composting is the best treatment option for all kinds of organic waste in all cities.

For unsorted waste, MBT is better than sanitary landfill which does not promote resource efficiency and income generation for resource-poor people. However, landfill gas recovery from old dumpsites is recommended to avoid methane emissions into the atmosphere. It can also generate electricity and income for landfill owners.

The technologies described above are not necessarily competing options. Based on local conditions, local authorities and relevant stakeholders need to combine options into an integrated system that can efficiently treat the waste generated in the municipality. Influencing factors to be considered include the quantity, characteristics and composition of the waste, the economic conditions, past experience with technologies, households' willingness to segregate their waste at the generation source, the availability of nongovernmental organisations (NGO) or community groups with waste issues, land availability, and the demand for organic waste products. In addition, it is worth noting that all systems

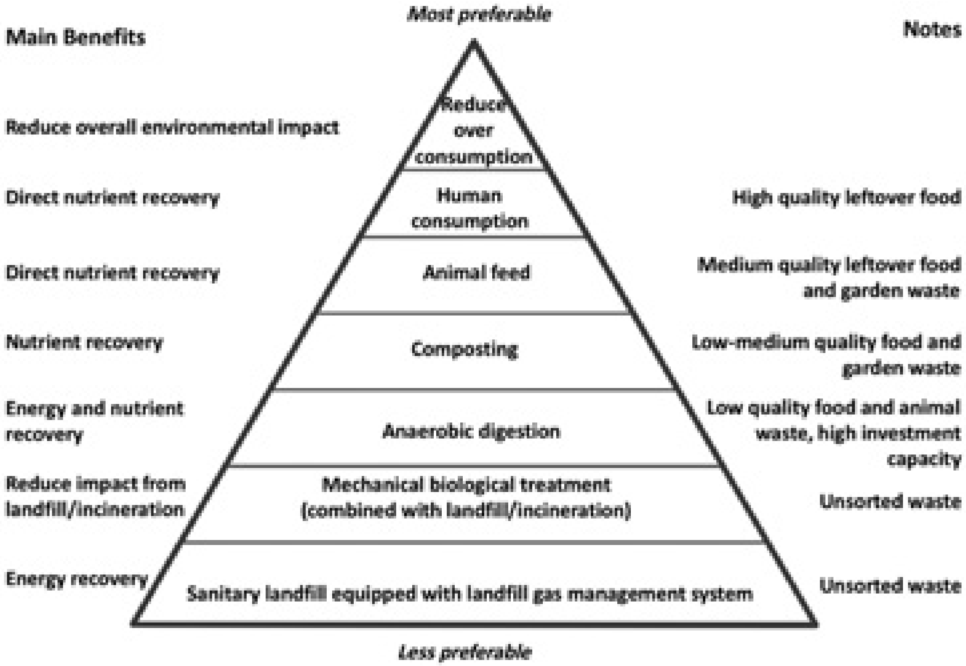

Figure 4.2 Recommended hierarchy for urban organic waste management in Cambodia

have to adapt over time in response to changing conditions.

Although composting and anaerobic digestion area recommended as suitable options for organic waste utilisation in Cambodia, local authorities should consider various aspects to select the most applicable technology, such as quantity and characteristics of waste, and social interest. The following are guidelines for the selection of technology.

4.1 Checking quantity and sources of organic waste

First of all, the local government should know the quantity and source of organic waste in the city. This data can be used for selecting the scale of the project and the types of technology for organic waste utilisation.

Except for Phnom Penh, waste in cities of Cambodia is less than 150 tons/day, of which approximately 64% is food waste. Food waste separation is practiced by some restaurants and households, however mainstream waste separation at the generation source programme has not yet been established. Therefore, the project should not aim to handle the entire amount of food waste in the cities, but start with a selected waste generation source that could contribute large amount of waste input to the waste utilisation facility.

Based on the experience of composting project in Surabaya, Indonesia, it is recommended that the local authorities start with a few large organic waste generators such as food markets and restaurants and also a few selected communities. Once the project implementers are experienced, the activity could be extended to other parts of the cities.

4.2 Observing demand of products and users

Demand of products and users are keys to successful project implementation in both the short and long terms, especially where the project must be self-sustaining because the Government of Cambodia cannot provide long-term subsidies. Residents or implementers will maintain their efforts to operate the facility, if they can sell the products or can use it by themselves.

Considering the benefits of biomass utilisation technology, anaerobic digestion has an advantage over composting as it can generate methane for energy use and also soil amendment materials. It is possible for residents to use biogas, but a specific gas stove and light bulb may be required. Electricity generation from biogas is also possible, but the economic returns for the plant need to be analysed. The price of electricity generated by biogas should not be higher than the current electricity price, otherwise subsidies from the government would be required. Furthermore, biogas is not suited for transportation due to its bulky volume. If the implementer would like to produce electricity, a medium scale anaerobic digestion should be selected and implemented in an area that has high organic waste such as restaurant, hotel or food market.

4.3 Selecting simple technology

Among the introduced technologies,

composting is simpler than anaerobic digestion. However, it does not mean that anaerobic digestion is not appropriate for Cambodia. There are various specific techniques for both composting and anaerobic digestion, from a simple technique whereby residents can build and operate the facility by themselves in their own homes, to a complicated one that requires design, construction and operation by experts.

Simple composting techniques that allow residents to construct and operate by themselves include static pile windrow, passive aerated windrow, and Takakura home composting techniques. For anaerobic digestion, local residents would be able to operate wet digestion in fixing dome and floating drum digesters, but technical supports from experts may be required for design and installation.

4.4 Choosing cheaper technology: low investment and operation costs

Budget constraint is a crucial issue in Cambodia. Local governments have only a limited budget for solid waste management. Constructing a large scale facility is very much dependent on international aid. Further, there is no warrantee how local governments can operate such an advanced facility in the long run and how local governments can maintain the facility and equipment if it breaks down.

Considering the financial barrier, composting is more appropriate than anaerobic digestion. Residents can practice household composting for their own use. A community composting scale can be promoted to enhance waste separation at the generation source for high densely residential areas. A centralised composting plant can be operated by local governments, waste collection companies or NGOs.

Compost can be used for cultivation and can increase crop productivity of farmlands. In some cities, such as Kradang-Nga sub-district, Thailand, compost is distributed freely to residents involved in waste separation at the generation source. In Dhaka city, Bangladesh, compost is sold to a fertiliser company which produces fortified compost, with the system being supported by gathering waste collection fees and selling the product.

Anaerobic digestion requires technical support for installation. A basic digester with 1 cubic meter made from local materials may cost USD100. However, this method means that residents can have both energy and soil improvement material.

4.5 Considering capacity of personnel

A small-scale project and simple technology requires lower skills from personnel compared to a large-scale project. Therefore, it is possible for local residents to operate the facility with a short-term training programme.

Cambodia has local experts in composting of urban organic waste and anaerobic digestion of animal manure. Lesson learnt and expertise in these fields could contribute to the successful implementation of urban organic waste utilisation projects.

4.6 Selecting type of project: decentralised or centralised

A decentralised waste management project helps reduce the responsibility of local authority on investing and operating large-scale waste treatment plants. It also extends the lifetime of final disposal site, reduces the cost for collection and transportation, and helps improve interaction between residents in communities. This activity is suitable for developing Asian countries like Cambodia where investment and personnel capacity is not so high and organic waste separation at the generation source is not well practiced. However, local government efforts for mainstreaming education, public awareness raising and interaction with residents are required. Often, residents lose interest in practicing decentralised waste management in households and community after the end of the project due to lack of incentives. Therefore, institutional setting, mode of operation, utilisation and marketing of products, as well as follow-up activity should be arranged to sustain the project activity.

A centralised waste management project requires high investment and operation costs, skillful personnel, large numbers of workers, and a large quantity of waste input compared to a single decentralised project. Often, local authorities in developing countries fail to operate large scale waste management projects mainly due to a shortage of budget for rejuvenation once the system fails, and also due to a lack of skilful engineers to carry out maintenance, as well as a lack of consistency supplying waste to the system.

A combination of both decentralised and centralised facilities is recommended for Cambodia, to enhance resource recovery, create job opportunities for residents particularly for lower income groups, reduce environmental impacts from direct landfill of organic waste, and also increases life quality of residents.

4.7 Starting from small scale and planning to scale-up

Most cities in Cambodia have no experience in organic waste utilisation. It is recommended that local governments should start from small-scale activity and then scale up after gaining more experience and after the project is well recognised by residents.

For residents that have land space for gardening, a household scale composting or anaerobic digestion can be introduced. For high density residential area, a centralised facility for composting or anaerobic digestion should be established. In this case, food waste separation and a collection system must be practiced to ensure quality and quantity of waste input to the facility. A plan for product use and distribution should be arranged to secure the operational costs of the facility.

In case of composting in Phnom Penh, it is somehow considering a small-scale centralised project. Approximately, 5 tons/day of waste from the food market is collected and delivered to the composting facility located adjacent to the disposal site. The facility has been operating for several years run by an NGO (COMPED). Compost is also well accepted by residents, thus the NGO could sell compost to cover the operational costs of the facility.

This successful case clearly shows the importance of an operational scheme in sustainability that does not receive subsidies from governments, apart from the provision of land.

4.8 Selecting technology with less environmental impact

In the current situation in Cambodia, solid waste management does not yet meet environmental standards due to budget constraints and lack of skilled personnel. Obvious problems of the current disposal site in Cambodia are foul odours and housefly outbreak. Contamination of toxic substances in underground water and leachate contamination is out of sight, so people are not aware of the long-term impacts on soil and water quality. Therefore, an improvement of the waste disposal system is required.

Anaerobic digestion and composting could reduce the foul odours and housefly outbreak. However, anaerobic digestion is more efficient than composting as it is operated under a close digester. In addition, potential GHG emissions from anaerobic digestion are lower than composting. In any case, composting techniques can contribute less GHG emissions compared to landfill, except for vermin-composting.

4.9 Responding to national policy and legislation

National policy and legislation framework are key tools enforcing local authorities to improve solid waste management and increase resource utilisation. The strategy on the 3Rs for waste management in the Kingdom of Cambodia is drafted under a project supported by UNEP in 2008. Recently, the 3R initiative has been integrated into the Environmental Strategic Plan 2009-2013 (MOE, 2009).

Projects that contribute to national agenda and policy have high potential to receive subsidies from either national or international supports (grant, technical support, capacity building, etc).

An integrated approach for organic waste management between decentralised composting and anaerobic digestion combined with large scale MBT would allow efficient resource recovery and would lead to successful 3R's implementation in Cambodia.

4.10 Conducting a public hearing and multi-stakeholder consultation

Sometime, the best technology in term of environmental aspect may not be selected. Also, the technology that is selected by experts may not be accepted by residents. Therefore, it is highly recommended that once the local government makes a final list of preferable technology, a public hearing or questionnaire survey should be conducted to gathering residents' opinions and matching interest of multi-stakeholders prior to technology selection. Otherwise, local authorities may face social resistance when starting the implementation which often happens in other countries such as Thailand and the Philippines.

5.
A guide for implementation of urban organic waste utilisation projects in Cambodia

5. A guide for implementation of urban organic waste utilisation projects in Cambodia

After the local governments select the most suitable technology for their cities, it is recommended that implementation preparation should involve local stakeholders including residents, private sectors and NGOs so as to enhance public cooperation for successful implementation.

Local governments should arrange the following activities to achieve successful implementation of the waste utilisation project: setting institutional framework, mainstreaming education and capacity building, arranging a public hearing and democratic discussion, promoting waste separation at the generation source, improving waste collection system, selecting a proper site for project implementation, planning for site operation, identifying how to use or sell products, monitoring and evaluating effectiveness of the project and modifying them if necessary. Dissemination of project progress and outcome to the public is also essential to enhance public awareness and encourage further cooperation.

5.1 Setting an institutional framework

Local governments in Cambodia do not have enough budget and personnel to handle solid waste management. Therefore, involvement of private sectors and NGOs on organic waste utilisation is essential. However, local governments should set up a monitoring system and public relation personnel to follow up and ensure efficient operation by private sectors and NGOs. Designated personnel should be trained with lessons learnt from other countries.

Local regulation and notification should be prepared and announced to the public. Incentives and disincentives strategies should be set, such as reduction of the waste fee for households that implement household composting or anaerobic digestion.

Budget setting is also required. Currently, local governments are facing many problems in setting a budget for waste management. Discussion and negotiation with the private sector would be an alternative to increasing the budget available for local governments. Even though duties on waste collection and waste disposal are handled by contracted private companies, the local governments still need a budget for capacity building (for local government officials), awareness raising (for residents) and monitoring and evaluation (for services of the contracted private companies). Otherwise, the local governments could not control the quality of work that is carried out by the designated private company.

5.2 Providing public education and capacity building

It seems that residents in Cambodia are not aware of the health risks which are closely associated with the environmental impacts of waste management. Some farmers use wastewater drained from the urban area for vegetable cultivation and bathe in the wastewater canal. There is also no resistance to landfill siting and no claim about landfill impacts to local governments. This situation makes local governments and private sectors that are involved in waste management feel comfortable in designing and operating the facility. On the other hand, residents that are not aware of environmental impacts are likely not to cooperate in the waste management policy of the local authorities. Most people are not willing to pay waste fees. They leave waste along the road side, dumped on empty ground, and discard it elsewhere in the town. Open burning is regularly practiced by the residents and some cities look like 'a smoky town'.

Improvement of waste management in Cambodia cannot be achieved without awareness of residents. Public education through an illuminating campaign is essential. Cooperation is recommended with private companies (particularly with large waste generators and the waste collection and disposal companies), environmental NGOs, education institutes and schools. Training and demonstration programmes are important to enhance proper waste separation at the generation source. A technical training project is required if household composting or anaerobic digestion is introduced.

5.3 Conducting a public hearing and democratic discussion

A public hearing is a process that the local governments arrange to convey project information to the residents and interested stakeholders. After essential project information is provided, residents and stakeholders can clarify project details with the governments, ask questions, propose additional activities or points of concern, and agree or disagree with the project. However the reasons for agreement or disagreement must be explained. Public hearings may be organised a few times until most residents can agree upon the project contents.

The date of the public hearing should be announced in advance to residents. The government should also distribute project information to residents allowing them to study and discuss about the project contents before the public hearing is held.

A public hearing may delay the process of project implementation; therefore many local governments may not like this process. Some residents may support the project but some may oppose it, so it is very hard for the local government to conclude their decision-making. Some adjustment may be required to match with residents' requests. However, once the project is agreed and supported by residents, there is only a low risk of project failure due to social resistance.

5.4 Promoting waste separation at the generation source

Once composting or anaerobic digestion is selected, the local governments must encourage residents to separate waste at the generation source and establish organic waste collection system to ensure quality and quantity of waste input to the facility. Economic incentives such as reduction of the waste collection fee may be applied to enhance waste separation at the generation source. Certification for environmental volunteers may be introduced for groups of people who are not convinced by decreasing the waste collection fee.

Informal waste separation, to some extent, is already practiced in Cambodia such as separation of food waste for animal feed and separation of sellable waste for sale. Recently, formal waste separation at the generation source has been initiated in a pilot area of Phnom Penh. Residents are not yet familiar with the practice of waste separation. However, a mainstream programme of waste separation at the generation source has not yet been established. Consequently, the formal waste collection service is not designed for collecting the sorted waste.

If centralised composting or anaerobic digestion is selected, the local government should promote organic waste separation at the generation source to ensure quality and quantity of waste input to the facility. In addition, separation of organic waste can enhance efficient separation of other sellable waste.

At the beginning, waste separation at food markets and restaurants should be promoted because it can contribute to a substantial reduction of organic waste dumped into landfill. In addition, these sources have a massive volume of waste thus make it easier for collection compared with households that generate smaller amounts of food waste.

5.5 Improving waste collection service system

When waste separation at the generation source is introduced, the waste collection system should be reviewed and modified to associate the waste separation practice. A designated schedule for organic waste collection should be arranged. For making decisions on the schedule of organic waste collection, policy-makers must consider the number of vehicles that are available for this activity. If collection vehicles and personnel are limited, involvement of the community in door-to-door waste collection and delivery of the collected waste to transfer points is recommended.

In-depth discussions should be conducted on the role and benefits that can be shared among stakeholders, such as local governments, waste collection company, community leaders and organic waste utilisation facility operator, and agreement should be reached among these stakeholders.

In developed countries, depending on the climate, the local governments assign a different day of the week for collecting different kinds of waste on a designated day. Collection of organic waste is more frequent than other waste, for example, two or three days a week. For other types of waste, the frequency is just once a week or twice a month.

Cambodia could develop a similar programme to the one in developed countries mentioned above, but there needs to be an adjustment to fit with Cambodian conditions. Categories of waste would be diversified based on the local situation. At the beginning, Cambodia may start with separation of organic waste for utilisation and non-organic waste for landfill. Collection of organic waste should be on a daily basis due to the tropical climate.

5.6 Selecting a proper site

Household scale: For household organic waste treatment, composting and an anaerobic digester can be installed on empty land located where the owner feels convenient to operate it without adverse effects to the quality of life.

Community and centralised projects: The community and centralised projects are required larger area of implementation. Therefore, the following criteria should be considered.

- Size
- Ownership
- Current land use system
- Land use in boundary
- Distance from residential area
- Risk of flooding
- Accessibility
- Cost of transportation
- Complexity of natural resources and biodiversity
- Landscape, amenity and visual impacts
- Environmental impact: foul odour, dust, flies
- Distance from users of products

5.7 Arranging mode of operation

The local governments should clearly indicate the conditions for sharing roles between the division-in-charge of solid waste management and the contracted organisation, particularly if the local government is unable to operate all project activities by itself.

Household and community project: Continuous monitoring and technical advice are important to sustain project activity. For instance, in Thailand, many households stopped operating the composting facilities when local government officials did not visit their activities for several months.

Centralised projects: Often, local governments in Cambodia cannot operate the facilities by themselves. Involvement of private sectors and NGOs are recommended. In this case, agreement between the local government and the contracted organisation is essential for quality control and ensure smooth implementation. At the least, the following topics should be discussed and agreed between the Parties.

- Investment: e.g. Who will pay for the capital, operation and maintenance costs?
- Public education and outreach activity: e.g. Who will take responsibility? Where is the budget source? What are the possible ways of disseminating knowledge?
- Waste collection activity: e.g. How many times a week?
- Marketing and use of products: e.g. Who is the owner of product? How to distribute?

- Benefits sharing: e.g. How to share benefits?
- Business report: e.g. How often should the implementers report the achievements of the project to the local government?
- Monitoring and evaluation: e.g. How to monitor the environmental impacts from the project?

5.8 Planning for utilisation and marketing of products

Utilisation and marketing of the product is the key to project sustainability. It is recommended that the implementer identify appropriate ways to use and sell the products. Also, the implementer should survey the attitude of residents and users on products from the waste utilisation project. In addition, the implementer should identify potential major buyers and ask for their cooperation.

5.9 Monitoring, evaluation, modification and dissemination of project activities and outcome to the public

Monitoring and evaluation of the project activity should be carried out from time to time, to identify obstacles and opportunities to improve the project efficiency. In particular, the following issues should be concerned and observed.

- Resident's awareness
- Quality of waste separation at the generation source
- Improvement of the efficiencies of waste collection and recovery rate
- Quality of facility operation
- Difficulties of project operation
- Opportunities of improvement
- Economic and natural impacts
- Local effects of project on waste quality, air quality and soil quality

6. Conclusion

With increasing waste generation, the local governments need to improve their urban organic waste management by shifting from open dumping and burning to more environmentally and climate friendly manner options. More than 60% of urban solid waste in Cambodia is organic. It can be utilised for animal feed, soil amendment, and energy.

Despite the high potential for its use, urban organic waste utilisation in Cambodia is limited. The major obstacles are lack of skilled personnel and budgets of the local governments. Therefore, the typical approach to solid waste management in Cambodia is to contract private companies to provide waste collection services and to sometimes manage the dumpsites. Undoubtedly, these practices induce human health risks and emit greenhouse gases into the atmosphere.

There are many ways that organic waste can be used and technologies to support this use. Sorted organic waste can be used for animal feed, compost, and to generate biogas through anaerobic digestion. Unsorted organic waste can be used to produce RDF through mechanical biological treatment (MBT), which also reduces waste volume and emissions, as well as electricity from sanitary landfills with gas recovery systems, and incineration. Small-medium scale composting and anaerobic digestion for urban organic waste utilisation are appropriate technologies for Cambodia, given its socio-economic conditions and the capacities of local governments. Composting can produce soil improvement materials and thus increase crop productivity. Anaerobic digestion can generate soil improvement products and energy, and thus can contribute to both national food and energy security. As the investment required for anaerobic digestion is higher than that for composting, local governments need to consider the costs and benefits of technology adoption in the context of their needs and their available resources.

For local governments to decide which waste utilisation technology is the most appropriate for them is challenging. This guide facilitates their decision making by providing step-by-step advice for technology selection and successful implementation. The guide does not promote any specific technology; rather it encourages local governments to carefully consider the advantages and disadvantages of alternative technologies with respect to local conditions, human resources and finances. Better management of organic waste in Cambodia will contribute to human health and improved living conditions, as well as national food and energy security goals, and can be a central element of Cambodia's climate change action plan.

References

Barton, J.R., I. Issaias and E.I. Stentiford (2008) Carbon – Making the right choice for waste management in developing countries. Waste Management 28: 690-698.

Bengtsson, M., J. Sang-Arun, J., O. Tsydenova, T. Maeda (2008) Urban organic waste from hazards to resource. In IGES White Paper II, Climate Change Policies in the Asia-Pacific: Re-uniting climate change and sustainable development. IGES. P.133-157.

CIA (2011) The World Factbook: Cambodia. Available online at https://www.cia.gov/library/publications/the-world-factbook/geos/cb.html (accessed on 26 October 2011).

EPA [United States Environmental Protection Agency] (2010) LFG energy project development handbook: Chapter 2 Landfill gas modeling. 7P.

Ewall, M. (2008) Fact sheet: landfill gas. Available online at Energy Justice dot net.

Hobson, A.M., J. Frederickson, N.B. Dise (2005) CH_4 and N_2O from mechanically turned windrow and vermicomposting systems following in-vessel pre-treatment. Waste management: 25(4): 345-352.

Inter-ministerial MOI/MOE (2003) The declaration (Prakas) No. 80 of the Ministry of Interior and the Ministry of Environment on garbage solid waste management in provinces-cities of the Kingdom of Cambodia.

Jiang, J., J. Sui, S. Wu, Y. Yang, L. Wang (2007) Prospects of anaerobic digestion technology in China. Tsinghua Science and Technology 12(4): 435-440.

Johannessen, L.M. and G. Boyer (1999) Observations of solid waste landfills in developing countries: Africa, Asia, and Latin America. World Bank, 41P.

Jona, V. (2011) Cambodia energy status and its development. Presentation at the 2011 Cambodia outlook conference: a partnership of CDRI and ANZ Royal Bank, held in Phnom Penh on 16 March 2011. 20P.

Luning, L., E.H.M. van Zundert, A.J.F. Brinkmann (2004) Comparison of dry and wet digestion for solid waste. In Wilderer, P. and R. Moletta (editors) Anaerobic Digestion of Solid Wastes: Selected Proceedings of the 3rd IWA International Symposium on Anaerobic Digestion of Solid Waste, Held at Garching, Munich, Germany, 11-13 September 2004.

MAFF [Ministry of Agriculture, Forestry

and Fisheries, Cambodia] (2006) Third National Report to Convention on Combat Desertification. United Nations Convention to Combat Desertification (UNCCD). 89P.

MFE [Ministry for the Environment] (2002) Assessment of greenhouse gas emissions from waste disposal as a result of implementation of the proposed New Zealand Waste Strategy: Reference No. 19518.

Ministry of Environment (1999) Sub-degree on solid waste management, April, 1999.

Ministry of Planning (2006) A poverty profile of Cambodia 2004. 147P.

MOE (2009) Environmental strategic plan 2009-2013.

OECD (2000) OECD Reference Manual on Strategic Waste Prevention, ENV/EPOC/PPC(2000)/5/FINAL, OECD, Paris.

Phitsanulok Municipality (2005) Phitsanulok model for solid waste management. Phitsanulok, 282P. (in Thai).

Reeh and Møller. (undated) Evaluation of different biological waste treatment strategies. http://orgprints.org/1924

Sang-Arun, J. and M. Bengtsson (2009) Improved organic waste management: climate benefits through the 3Rs in developing Asian countries. IGES-WMR Working Paper 2009-001. 52P.

SCS Engineers (1994) Implementation guide for landfill gas recovery projects in the northeast. 40P.

Sokha, C. (2009) The formation of 3R strategy of the Kingdom of Cambodia. Presentation. Inaugural meeting of the regional 3R forum in Asia, 11-12 November 2009, Tokyo.

Solenthaler, B. and R. Bunge (2005) Waste Incineration in China. Rapperswil: Institute für angewandte Umwelttechnik (www.umtec.ch).

UNdata (2010) World Statistics Pocket Book: Cambodia.

Visvanathan, C., J. Tränkler, C. Chiemchaisri (2005) Mechanical-biological pre-treatment of municipal solid waste in Asia. International Symposium MBT 2005 www.wasteconsult.de.

Appendix I

Summary draft of the formation of the 3Rs for waste management in Cambodia

Appendix I
Summary draft of the formation of the 3Rs for waste management in Cambodia

1. National challenges and opportunities to deal with 3Rs initiatives

- Domestic waste is not separated at the generation source
- Low standard landfill is dominant
- Contamination of hazardous waste in urban waste
- Irregular collection of domestic wastes, thus a large quantity of waste is left uncollected
- Lack of capacity (both budget and personnel)
- Limited education and dissemination programmes
- Less public participation in waste management
- Poverty is a crucial issue
- No pilot project on the 3Rs has been implemented
- Waste fee does not reflect waste generation
- Lack of data.

2. Opportunities

- Existing environmental law and sub-decrees
- Informal recycling business
- High possibility to raise awareness of private sector working on waste related business
- Private sector is interested in the 3R programme.

3. Targets

- Improve waste collection service to cover 50% of municipal solid waste by 2015 and 60% by 2020
- Enhance waste separation at the generation source up to 10-20% at households and 30-40% at business area by 2015 and increase to 50% and 70%, respectively, by 2020
- Compost 20% of urban organic waste and promote use of compost by 2015 and increase the target to 40% of household organic waste and 50% of organic waste generated at markets and business centres by 2020.

Appendix II

COMPED Composting Project at Stung Meanchey Dumpsite

Appendix II
COMPED Composting Project at Stung Meanchey Dumpsite

Stung Meanchey dumpsite was used during 1965 – 2009. The size of this dumpsite is 6.8 ha, and it received up to 1,000 tons of waste per day. Biomass makes up 65-70% of the waste from Phnom Penh. Therefore, COMPED proposed to compost municipal solid waste because it could provide the following benefits:

- Reducing the waste amount to be disposed of and to increase the lifetime of landfill
- Reducing the amount of landfill leachate, thus avoid environmental contamination
- Avoiding methane generation under anaerobic condition of landfill
- Enhancing separation of waste biomass for compost, thus increasing the separation of potential of recyclable materials
- Improving soil quality for cultivation through use of compost
- Reducing use of chemical fertiliser, thus reducing environmental impact from agrochemical
- Upgrading waste pickers to be workers in composting plant, and so helping increase their quality of life and securing their income.

a. Composting plant

COMPED operated a composting plant on 2,000 m^2 of the Stung Meanchey Dumpsite (Fig. II-1) with financial support from the Ministry of Agriculture, Nature Conservation and Environment of the Federal State of Thuringia (TMLNU), Germany which provided USD65,000 for capital investment. The Phnom Penh Municipality supported the project by allowing COMPED to construct the composting plant at the dumpsite without charging a rental fee.

The Composting technique is a static pile windrow method. The composting pile is turned from time to time to enhance

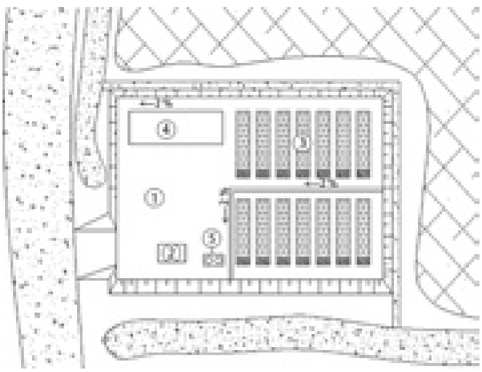

Figure II.1 Sketch map of COMPED Composting plant at Stung Meanchey

aeration of the composting pile as well as to separate non-degradable materials. Information of COMPED composting plant is as follows:

- Composting plant is located near the entrance of Stung Meanchey Dumpsite, Phnom Penh. Easy to deliver input materials to composting plant and transport by-product (e.g. plastics) to dumpsite.
- Ground layer of the composting plant is compacted to prevent leachate percolation.

The composting plant consists of access road, pre-treatment area including sorting place, composting pile area, post-treatment area including sieving and packing, product storage area, leachate collection system, water supply system, rest area for workers, and accommodation for workers.

b. Composting process

i) Input materials
Approximately 5 tons/day of waste from Doeumkor Market is transferred to COMPED composting plant. The waste consists of 76% biomass waste (e.g. vegetables, fruits, sugarcane, maize, coconut shell).

ii) Pre-treatment
- Separating non-biodegradable waste by manual
- Reducing waste size
- Mixing wet and dry materials together

iii) Composting pile
Piling mixed waste with the size of 3-5 m wide and 1.2-3 m high. The length is sometimes longer than 5 m (Fig. II-2).

iv) Fermentation
During composting, microorganisms in the composting pile digest biomass waste and release heat. Sometimes the temperature of the composting pile rises up to 70 °C with a water content of 65%. The composting pile must be remixed for aeration and adjustments must be made to the water content. If moisture content is low, irrigation is required. Inorganic waste must be separated during remixing of the composting pile.

Generally, it takes four months to complete the composting process, and sometimes up to six months for hard residues such as sugarcane skin and coconut shell. The temperature in the completed composting pile is drop to the level of air temperature.

Figure II.2 Heap formulation

Figure II.3 Sieving of composted waste

v) Sieving
Sieving is important for compost quality control (Fig. II-3). Large size materials, plastic, glass and metal must be separated from compost.

c. Compost quality produced by COMPED

Urban compost produced at COMPED composting site consists of 1.32% of nitrogen (N), 1.72% of phosphorus (P), 2.24% of potassium (K), 0.86% of magnesium (Mg) and has a pH value of 7.0-7.5.

d. Problem and solution

- Quality of waste input: Waste delivered to the composting site is mixed with non-biodegradable materials. Thus, separation of inorganic materials is required throughout the composting process such as during mixing of waste, piling of waste, turning of composting pile and sieving at the end of the process. Separation of non-biodegradable materials is a time-consuming and high labour input process, but is necessary to ensure compost quality.
- Infrastructure of composting plant: Due to budget constraints, the composting area is not covered with a roof, which causes delays to the composting process in the rainy season and means that valuable nutrients are leached out. It is necessary to turn the composting pile more often in the rainy season, whereas irrigation is frequently required during the dry season.

Appendix III

Biogas generation from manure project in Cambodia

Appendix III
Biogas generation from manure project in Cambodia

Biogas generation from manure is promoted by the National Biodigester Programme (NBP). NBP is a joint programme between the Cambodia Ministry of Agriculture Forestry and Fisheries (MAFF) and the Netherlands Development Organisation (SNV).

a) Energy background of Cambodia

- Estimated 34% of population in Cambodia, located mainly in rural areas, living on less than USD1 per day.
- More than 90% of energy for cooking is supplied by charcoal and firewood. The daily firewood consumption per household is estimated to be between 6.0 and 7.6 kilograms. Cost of charcoal varied by place (USD0.15 - USD0.30 per kilogram on average, USD1 = 4000 Riel).
- Only 9% of rural households have access to national grid electricity.
- More than 50% of rural households in Cambodia using lead acid batteries for electricity.
- More than 1,000 rural electricity enterprises (REEs) providing electricity through mini-grids powered by diesel generators.
- The high reliance on firewood resulted in health impact from indoor air pollution, poverty (e.g. time wasted for gathering firewood, medical expenses), and environmental degradation (e.g. deforestation, land exhaustion).
- Using mini-grids powered by diesel generators contributing greenhouse gas emissions.

b) Potential of biodigester plant

- About 25% of the rural population in Cambodia has a technical potential to install a biodigester with a minimum daily input of 20 kilograms manure and/or night soil.
- Biogas plants provide multiple benefits at the household, local, national and global levels. These benefits have a clear impact on gender, health, poverty, employment and environment.
- For farmers, a biogas plant provides clean cooking energy, reducing the burden and time required for wood collection, cooking and cleaning of pots, and decreasing health impacts from smoke inhalation, especially for women. In addition, gas lamps may provide more comfort for family's activities and child's education. Solid residues and slurry from the biogas tank can be applied for soil fertilisation thus improve food security and reduce cost for chemical fertiliser of the household.

- On a national scale, a substantial numbers of biogas systems will help reduce deforestation, increase agricultural production, raise employment, and substitute imports of fossil fuels and fertilisers.

c) **Benefits of using household biodigester plant** (http://www.nbp.org.kh/)

i) Economic benefits
- Saving energy expenditures; saving cost for 6-9 kilograms of firewood and 0.2 litres of kerosene per household per day.
- Saving time that is required for firewood collection.
- Increasing crop productivity by using by-product from biogas tank.
- Reducing expense for chemical fertiliser.
- Reducing environmental impact and land degradation that caused by using of chemical fertiliser.
- Reducing health expenditures caused by smoke-borne diseases.
- Creating job for biogas digester implementing workers and distributors.
- Increasing opportunity for business development.
- Minimising livestock health problems.
- Decreasing risk of house burnt caused by ignorance of fire.

ii) Health benefits
- Reducing smoke-borne diseases (e.g. dizziness, headache, eye-burning, respiratory tract infection, nausea).
- Improving household sanitation.
- Avoiding contagious disease carried by houseflies.

iii) Environmental benefits
- Preserving forest.
- Reducing greenhouse gas emissions.
- Decreasing land degradation that accelerated by chemical fertilisers.
- Eliminating smell nuisance from manure.
- Reducing water pollution that caused by discharged from pig farm.

iv) Social benefits
- Saving more time for leisure and social activities.
- Improving social status of family in the community.
- Reducing workload especially for women and children who normally work for firewood collection and cooking
- Creating more opportunity to work and study at night time.
- Providing opportunity for children particularly girls to study in schools because the family requires less labour input for firewood collection.

d) **Farmer's friendly biodigester plant of NBP**

NBP is promoting Deenbandhu fixed dome, which developed in India using manure and human excreta. This model is modified to match with local condition of Cambodia and called "Farmer's Friendly Biodigester Plant".

The different between Deenbandhu fixed dome (Figure III-1) and Farmer's Friendly Biodigester Plant (Figure III-2) (NBP News, third publication, January 2007) are:

- Storage capacity of modified plant is scale down to 50% of the original one.

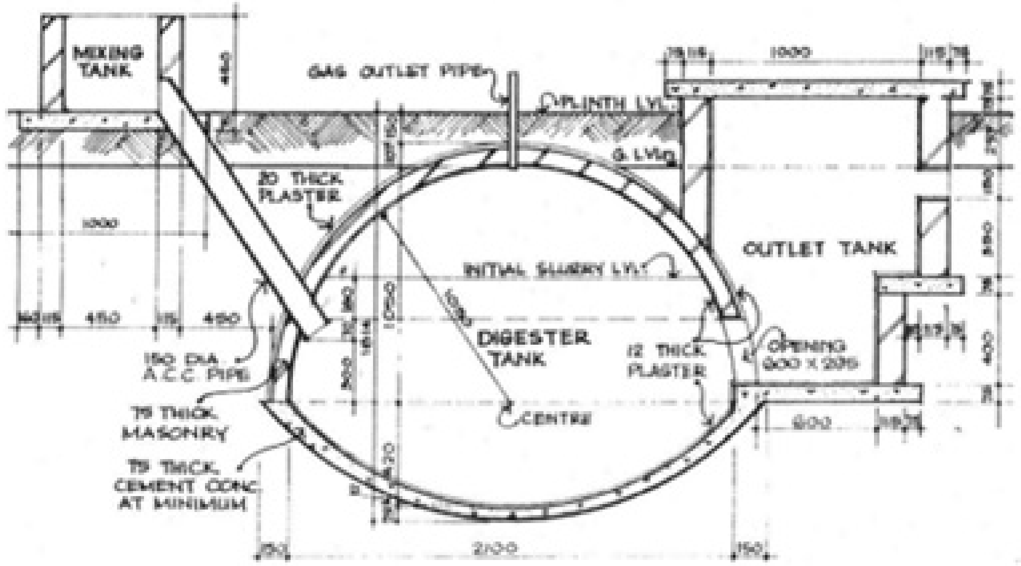

Figure III-1 Deenbandhu fixed dome, India

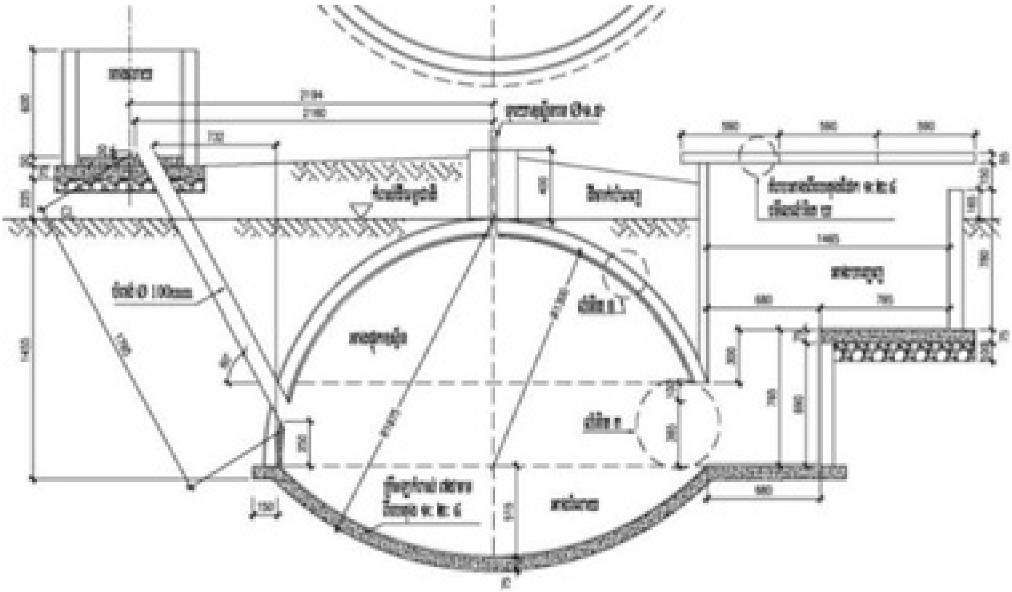

Figure III-2 Farmer's Friendly Biodigester Plant modified by NBP

- Hydraulic retention time is up to 40 days depend on climate condition in Cambodia.
- Location and size of outlet are modified to simplify the flow out of digester by gas pressure and gravity.
- Simplified the manhole that makes it more convenient for maintenance.
- Using cement-acrylic emulsion for gas storage dome.
- Inlet is modified in order to reduce construction cost.

- Wall construction based on material available in Cambodian market.
- Reducing plaster layer of the tank to reduce cost for construction.

Important parts of Farmer's Friendly Biodigester Plant (Figure III-3) are:
(1) Mixing tank (2) Inlet pipe
(3) Digestion tank (4) Gas storage/dome
(5) Manhole (6) Outlet tank
(7) Gas outlet pipe

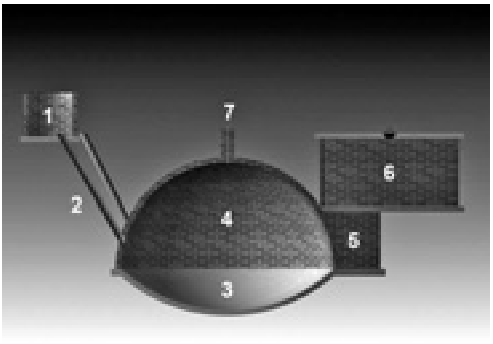

Figure III-3 Important parts of Farmer's Friendly Biodigester Plant

The cost of implementation of this biodigester is varied from USD400 – 900 (Table III-1).

e) Optimal condition for biogas production:

1) Anaerobic condition
Digester tank should be completely close to enhance absence of oxygen. In aerobic condition, most methanogenic bacteria are inactive and thus it is not possible for them to generate methane gas. In many places digesters are buried in the earth to ensure anaerobic condition.

Table III.1 Cost of biodigester plant installation in Cambodia

Cost (USD)	Size (m^3)				
	4	6	8	10	15
Construction materials and labour fee	375	437	502	572	845
Guarantee	10	15	20	25	35
Participation fee	15	15	15	15	15
Total cost	400	467	537	612	895

2) Temperature
Optimal temperature for digestion is 35 °C. Mechanism of methanogenic bacteria is slower in cold conditions, resulting in low methane gas generation.

3) Quality of input material
In order to feed the digester properly, the following points have to be considered:
- Collect fresh dung that has no dry straw or other materials.
- Do not use dried or very old cattle dung/swine manure to feed the plant.
- Remove the unwanted materials, such as remained fodder, soil and stones, before mixing the dung/ manure with water or adding it to the maturation pond.
- Adjust ratio of manure and water with 1:1 for cattle dung and 1:2 for swine manure
- It is better not to feed the biodigester when the gas is being used.
- Do not wash the inlet tank with soap or detergent. Do not use much water to clean it.
- It is recommended to feed a new

plant with the digested slurry (50-60 kilograms) from existing biodigester nearby, if available.

Benefits of good quality input materials are:
- Enabling the digester to function efficiently with maximum biogas production.
- Reducing risk of failure in biogas generation.
- Gaining a good reputation for neighbourhoods and enhancing replication of biogas technology.
- Reducing by-product of the digestion tank.

4) Starter of digestion plant
After the biodigester plant is installed, an appropriate quantity of starter is required (Table III-2) to initiate biogas generation. It is better to use at least 70% cattle manure. The starter should be added up to the outlet bottom line within 2-3 days. In general, biogas is produced after one week. In order to release the air from the digester plant, the main gas tap and tap connecting to gas stove have to be opened during feeding.

5) Daily feeding
Daily feeding is recommended as shown in Table III-3.

Table III-2 Starter requirement for different size of biogas digestion tank

Digester size (m^3)	Amount of manure (Kg)	Water (litre)
4	1,500	1,500
6	2,300	2,300
8	3,000	3,000
10	3,800	3,800
15	6,000	6,000

Table III-3 Daily manure feeding for biogas digestion plant

Digester size (m^3)	Amount of manure (Kg)	Water (litre)
4	20-40	20-40
6	40-60	40-60
8	60-80	60-80
10	80-100	80-100
15	120-150	120-150

Appendix IV

BEKON Biogas technology for dry digestion in batch system

Appendix IV
BEKON Biogas technology for dry digestion in batch system

Introduction

The BEKON dry digestion technology can generate methane from organic waste with no requirement of water input. Biogas can be used for heating or generating electricity. The high quality compost, which resulted from the process of dry digestion, can be used as a valuable fertiliser for agriculture and horticulture.

Process description of BEKON Biogas Technology (Fig. IV-1 and Fig. IV-2)

The BEKON dry digestion is a single-stage batch process for biogas generation. The system consists of eight chambers (6 m high, 5.5 m wide, 28 m long). Capacity of each chamber is 400 tons. This system costs approximately 4.5 million Euro.

Organic matter is inoculated with starting substrate before feeding into the digester (under anaerobic condition). Percolating

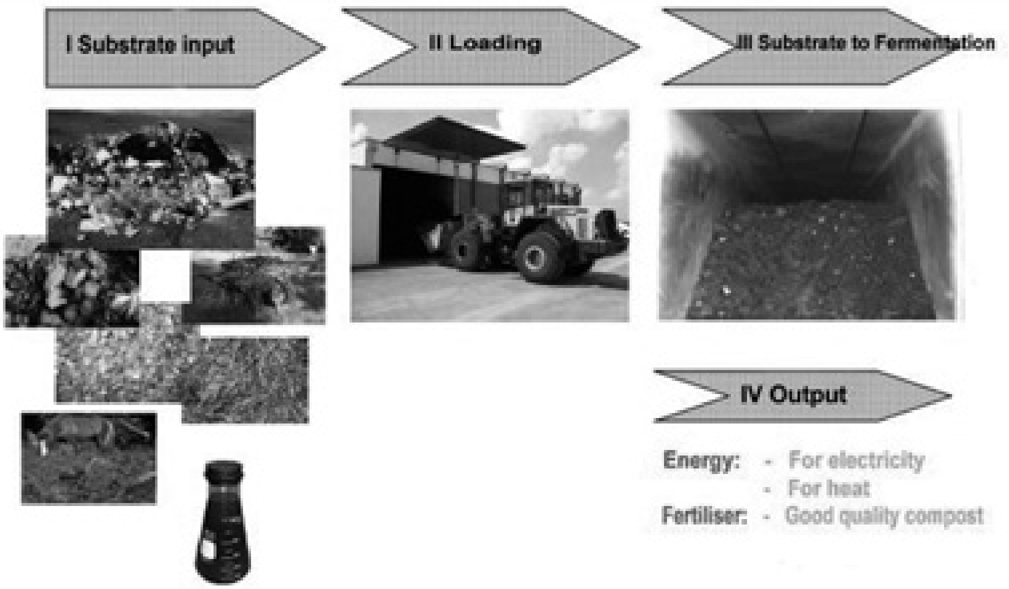

Figure IV-1 Overview of dry digestion process

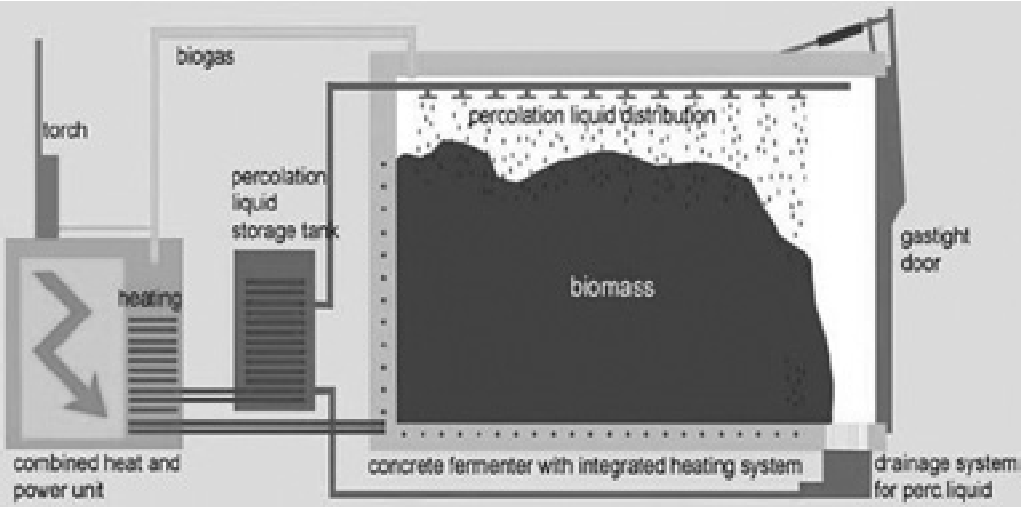

Figure IV-2 Processing scheme of dry digestion

discharge from the digester is circulated into the digester, thus accelerating the digestion process and reducing by-products. No stirring is required for this digestion system. The temperature of the digester is controlled by a built-in floor heating system in the digester and a heat exchanger in the tank which acts as a reservoir for the percolating discharge. The whole digestion process is completed within one chamber. To obtain a higher yield, after 28 days, half of the feedstock needs to be removed from the chambers and refilled with a new load of waste.

Low energy consumption for processing

During the fermentation process, no further mixing, pumping or stirring is necessary inside the digester. Therefore, BEKON dry fermentation technology requires only a low energy input for processing, in contrast with a large-scale wet digestion which requires higher energy input for operation.

High gas yield and excellent quality

Gas yield from dry digestion of organic waste is similar to that achieve under wet digestion system. However, the quality is better because the gas generated under the dry digestion system consists of low sulfur.

Compact design with safety reserves

The digesters are made of gas-tight concrete and can be filled and emptied with a wheel loader or a front-end loader. The digesters are elongated and garage shaped, with a large gate at one end. After the biomass has been introduced, the gates are closed and shut gas-tight. The system is equipped with an especially developed safety device, preventing an explosive atmosphere when the digester is opened for emptying and refilling.

Heat and power generation

The biogas is dehydrated in a gas-processing chamber, where gas quality and volume are measured. Then the gas is pumped, through a gas-regulating device, to a combined heat and power unit. A specific designed biogas engine in the co-generation unit generates 1 MWh of electricity. Some of the excess heat is used to maintain optimum temperature in the digesters, but most is available for other uses.

Figure IV.3 A BEKON dry digestion plant

Other possibilities for the utilisation of biogas (not specific for Cambodia)

Biogas can be utilised as a natural gas substitute in gas driven vehicles, or for feeding into the natural gas supply network. Specific quality standards for biogas as a substitute for natural gas have to be formulated by the operators of the gas supply network. In a few EU countries such strategies have already been successfully tested. In areas where the installation of a natural gas network is too expensive the installation of a local biogas supply network could become economically viable.

Further utilisation of the digested organic waste

Once the fermentation process is completed, the digesters are emptied and the digested matter can either undergo further composting or be spread directly onto fields. The highly valuable compost can be utilised as a quality fertiliser by farmers, municipalities and in private and commercial gardening operations after being digested for 28 days in each chamber.

ISBN 978-4-88788-083-2

Cambodian Education and Waste Management Organization (COMPED)
#34BE0, Street 376, Boeng Kengkang III, Chamkar Man, Phnom Penh, Cambodia
Tel: +855-23 222 963 E-mail: comped@comped-cam.org URL: http://www.comped-cam.org

Institute for Global Environmental Strategies (IGES)
2108-11 Kamiyamaguchi, Hayama, Kanagawa, 240- 0115 Japan
Tel: +81-46-855-3700 Fax: +81-46-855-3709 E-mail: iges@iges.or.jp URL: http://www.iges.or.jp

An eco-friendly waterless printing method was used which does not yield harmful waste water.
VOC free ink was used to print this report.