TOWARD SUSTAINABLE MUNICIPAL ORGANIC WASTE MANAGEMENT IN SOUTH ASIA

A Guidebook for Policy Makers and Practitioners

ADB

Australian Government
Aid Program

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Contents

Tables, Figures, and Boxes

Tables

Figures

Boxes

Foreword

This report was produced under the Australian Agency for International Development-supported regional technical assistance for the Development Partnership Program for South Asia.[1] The primary objective of the technical assistance project was to facilitate knowledge transfer to policy makers and city managers throughout South Asia by identifying, documenting, and disseminating good practices and innovative operational approaches for improving the management of municipal organic (biodegradable) waste. It reflects literature review and field research conducted during 2009–2011, and summarizes key findings of three national workshops held in Nepal (2–3 April 2010), Sri Lanka (6 April 2010), and India (15 May 2010), and a regional workshop in Bangladesh (2–3 August 2010). Workshops encouraged exchanges among the region's key public and private sector players—policy makers, practitioners, technical experts—and spanned the urban, agriculture, and energy sectors. The aim of this project is to convert these discussions into new initiatives that improve service delivery and positively impact the quality of life in the region's urban areas. The report is presented as a practical guide to identify existing challenges and approaches. It will be disseminated both in hard copy and through ADB's website and promoted to policy makers and practitioners in coordination with ADB's resident mission offices.

This report is organized into three chapters covering the key aspects of municipal organic waste management in South Asia, including financial, institutional, strategic planning, private sector involvement, community initiatives, and economic and environmental benefits. These are complemented by findings of workshops supported under the regional technical assistance, as well as case studies.

- Chapter 1 provides a sector overview of organic waste and describes the key drivers for change. It highlights the immense resource recovery potential in South Asia, and shares current experience and key issues for scaling up sector performance.
- Chapter 2 provides a practical guide for municipal officials and operators interested in establishing an organic waste management system. The chapter is presented as a tool kit resource and outlines the various technological options, criteria for selecting the right technology, and guidance for engaging in public–private partnerships; and provides planning and operational guidelines to support effective operations.
- Chapter 3 outlines the key policy, regulatory, and institutional issues for providing an environment conducive to organic waste management in South Asia. It highlights the need for intergovernmental coordination, quality standards, fiscal measures, monitoring systems, and market-based instruments for supporting the sector.

[1] Asian Development Bank. 2006. *Technical Assistance for the Development Partnership Program for South Asia*. Manila. The South Asian countries included in this study are Bangladesh, India, Nepal, and Sri Lanka. These countries are the largest in the region by population and area. However, the recommendations made in this report are generally applicable to other countries within the South Asia region, such as Bhutan and the Maldives.

Preface

The massive scale of urbanization in South Asia is expected to create a surge in demand for solid waste services. India's urban population alone could soar to 590 million by 2030 with solid waste generation expected to rise nearly five times in that period.[2] An enormous opportunity exists to improve upon the "business-as-usual" approach of uncollected waste and open dumping witnessed throughout the region and to convert this waste into value-added resources, such as alternative fuels and agricultural fertilizers. As approximately 70% of the region's municipal waste stream is currently organic (biodegradable) waste, methods such as composting, anaerobic digestion, and conversion to refuse-derived fuels offer a more sustainable course of action.

This report aims to align South Asian cities with Strategy 2020—the long-term strategic framework of the Asian Development Bank (ADB)—for environmentally sustainable growth and livable cities. It provides a useful management resource, identifying key issues and pointing policy makers, city managers, and practitioners to improved waste treatment technologies.

Waste management, climate change, and food and energy security are crucial issues for South Asia, and provide great opportunities for sustainable urban development. ADB has been working to support waste management and promote the "reduce, reuse, recycle" (3R) approach in the Asia and Pacific region through public and private participation at the policy and project levels. ADB will continue to work with country stakeholders to identify innovations that promote good waste management practices and sustainable urban growth in South Asia.

[2] McKinsey Global Institute. 2010. *India's Urban Awakening: Building Inclusive Cities, Sustaining Economic Growth*. London: McKinsey & Company.

Acknowledgments

This report was developed from the findings of the Australian Agency for International Development–supported regional technical assistance for the Development Partnership Program for South Asia. The report was prepared by Ron H. Slangen, urban development specialist, Urban Development and Water Division, South Asia Department (SARD), ADB, who also supervised the project. Country assessment reports and national and regional workshops were prepared by a team of solid waste experts from Bangladesh, India, Nepal, Sri Lanka, and Australia. The team included Muhammed Alamgir (Bangladesh), Angus Campbell (Australia), Iftekhar Enayetullah (Bangladesh), Enamul Haque (Bangladesh), N.B Mazumdar (India), Samarakkody Rhan Priyantha (Sri Lanka), A.H.Md. Maqsood Sinha (Bangladesh), and Bhushan Taladhar (Nepal). Significant contributions to the final report were made by Iftekhar Enayetullah and Angus Campbell. ADB is grateful for the excellent cooperation, support, and technical information provided by the team, as well as all workshop participants who provided useful information on current trends, practices, and future directions of the sector.

The report benefited from the overall guidance provided by M. Teresa Kho, director, Urban Development and Water Division, SARD. The project also benefited from the valuable technical guidance of Sekhar Bonu, director, Regional Cooperation and Operations Coordination Division, SARD; Jiwan Acharya, climate change specialist, Sustainable Infrastructure Division, Regional and Sustainable Development Department (RSDD); Jingmin Huang, urban development specialist, Urban and Social Sectors Division, East Asia Department; Vijay Joshi, environmental specialist, Environment and Safeguards Division, RSDD; Atsushi Kaneko, senior urban development specialist, India Resident Mission; Norio Saito, senior urban development specialist, Urban Development and Water Division, SARD; Manoj Sharma, urban development specialist, Urban Development and Water Division, SARD; and Andante Pandyaswargo, intern, Urban Development and Water Division, SARD.

Abbreviations

3R	–	reduce, reuse, recycle
ADB	–	Asian Development Bank
APCF	–	Asia Pacific Carbon Fund
BOO	–	build–own–operate
BOOT	–	build–operate–own–transfer
C:N	–	carbon–nitrogen (ratio)
CBO	–	community-based organization
CDM	–	Clean Development Mechanism
CER	–	certified emission reduction
GHG	–	greenhouse gas
GNP	–	gross national product
IPNS	–	Integrated Plant Nutrient System
m^3	–	cubic meter
MOA	–	Ministry of Agriculture
MOE	–	Ministry of Energy
MSW	–	municipal solid waste
MW	–	megawatt
NGO	–	nongovernment organization
NPK	–	nitrogen, phosphorous, and potassium
PPP	–	public–private partnership
RDF	–	refuse-derived fuel
Rs	–	rupee
tpd	–	ton per day
US EPA	–	United States Environmental Protection Agency

Executive Summary

Great untapped potential exists in South Asia to scale up innovative approaches in managing the large fraction of municipal organic (biodegradable) waste within the region's solid waste streams. On average, 70% of solid waste generated throughout the region is biodegradable organic mass with high moisture content. Left to itself, this organic waste is digested through an anaerobic process leading to the emission of harmful methane gas which not only adds to global warming and associated climate change, but also leads to increased public and environmental health risks. Alternative treatment methods such as composting, anaerobic digestion, and refuse-derived fuels (RDF) offer a more sustainable course of action than the "business-as-usual" approach of open dumping and unsanitary landfilling. These approaches also produce value-added resources, including organic fertilizer and renewable energy, while generating environmental and economic benefits.

It is estimated that the region has the potential to produce around 8 million tons of compost worth an estimated $709 million, or alternatively, an estimated 3,340 million kilowatt-hours/year of electricity (from biogas) with a market value of around $701 million/year. Additional carbon financing could generate up to $218 million/year from reduced greenhouse gas emissions. Furthermore, diverting this waste from landfills would save around 27.88 million cubic meters of landfill volume, with associated cost savings at the municipal level.

According to the South Asian Association for Regional Cooperation (SAARC) Dhaka Recommendation on Waste Management (October 2004), countries agreed that incineration as well as unproven technologies such as plasma should not be considered as an option for the treatment of the region's municipal solid waste (MSW) because of the low calorific value and high environmental pollution potential. SAARC countries agreed to promote community-based source segregation of waste with separate collection and resource recovery systems. The SAARC declaration also stated that to attract foreign investment in waste management projects, financing opportunities under the Clean Development Mechanism should be harnessed.

The weak performance in source segregation and collection of waste throughout the region are the primary constraints to the sector. Other key issues identified by workshop participants under the regional technical assistance project include:

- an unequal playing field for organic products to compete with highly subsidized chemical fertilizers and nonrenewable energy sources;
- municipalities' poor financial standing to invest in organic recycling;
- low municipal capacity to operate and maintain such facilities and to engage private sector partners;
- low community awareness;

- scarcity of government land to provide for organic waste management; and
- weak regulatory and enforcement systems, coupled with poor monitoring capabilities to ensure high standards of compost.

Key recommendations for scaling up organic waste management in the region are as follows:

Policy and Institutional

- Chemical fertilizers are typically sold at a subsidized price, so in the medium to long term such subsidies should be reduced to create a more level playing field for compost. A co-marketing policy for compost with chemical fertilizers would also make compost more competitive in the agricultural market.
- Compost quality standards should be stringent and enforced to protect public health and safety, and to increase confidence and demand among farmers. Standards should be coupled with registration and certification by an independent regulatory body in order to raise industry standards. A quality control system needs to be put in place for producers, and producers should have their compost regularly tested at accredited laboratories. The results should be sent to agriculture agencies prior to marketing.
- Feed-in tariffs would facilitate the sale of biogas and fuel briquettes as alternative energy sources.
- Carbon financing is an important mechanism to support the financial sustainability of projects.
- Intergovernmental coordination between urban, agriculture, and energy departments is critical for formulating clear and targeted policies.
- National guidelines are required for the siting and operation of composting facilities. Facility guidelines should complement compost quality standards by requiring compliance with compost product standards, rather than duplicating or redefining requirements.

Municipal Level

- Increase collection to 100% with a focus on source segregation. This can be done initially on a pilot basis to serve as a demonstration activity for scaling up.
- Charge collection fees to households that supply mixed waste but exempt those that segregate waste (i.e., the polluter pays principle).
- Capacity building of the local government staff is essential, especially regarding planning, tendering, technology, waste management system design, supervision, and monitoring. Creating centers of excellence within countries would help support improved capacity development.
- Incorporation of land for waste processing and disposal in the land use plans at the district and state levels for each individual municipality or at regional level is essential.
- Community awareness programs can significantly improve segregation of waste at source. Public awareness generation is a powerful tool for driving the system in a sustainable manner and a critical part of any waste management program.

- Regardless of the treatment system, a municipality needs to complement treatment with a good collection and transport system and a sanitary landfill for the disposal of rejects.

Operational Considerations

- A successful MSW composting plant must be designed with strict attention to the finished compost. Product specifications will determine requirements for both the incoming refuse and the physical and biological processes employed. Low contaminant levels are essential if MSW composting is to live up to its potential and recycle organic wastes. Source segregation is the key to improved performance.
- Technology selection should match the local context to ensure adequate operational capacity and markets for selling waste by-products.
- Small-scale projects that generate biogas from sorted organic waste are best suited for the region, as they require less investment, are easier to operate, and are a better fit to the types and volumes of municipal waste.

Private Sector Participation

- Private sector participation can significantly reduce costs and enhance service delivery. Solid and organic waste management can be improved by leveraging the expertise of the private sector through public–private partnerships.
- Concessions and incentives need to be deliberated upon, such as (i) tax assignment and grants for segregation, (ii) advertisement rights for segregation at collection centers, (iii) unit cost payment for collection and transport, (iv) making land available for disposal, (v) buy-back and basket approaches to composting, (vi) tax holidays and other incentives, and (vii) carbon credits.

Marketing

- Proper quality control and pricing are the key factors for scaling up compost marketing efforts. Unless compost meets the quality requirements of farmers and is affordable, it will not be bought and used.
- Engaging fertilizer companies to market the compost is most effective, as these companies have an existing network of distribution channels up to the village level.
- Before the initiation of any RDF or biogas project, a detailed survey must be undertaken by the project proponent to analyze the potential market. RDF markets exist in industrial towns where a concentration of cement kilns and boilers can utilize fuel briquettes for energy production and reduce transport costs.

Chapter 1

Sector Overview: Municipal Organic Waste Management

Issues and Technologies

It is estimated that 5.2 million tons of solid waste are generated daily worldwide, of which 3.8 million tons are from developing countries.[1] Table 1 compares solid waste generation among various countries throughout Asia. As waste generation increases significantly, it results in greater demand for both waste collection and innovative treatment options. The goal of municipal solid waste (MSW) management—which deals principally with household waste but includes commercial waste generated in municipal areas—is to treat the waste in an environmentally and socially acceptable manner, with appropriate clean technologies. Failure to achieve this goal results in serious local, regional, and global public and environmental health problems, including air pollution, soil and groundwater contamination, and emissions of greenhouse gases (GHGs).

The three main MSW treatment options are landfilling, composting, and incineration. Table 2 shows a comparison of waste treatment options for different countries, including those in South Asia. All waste disposal options eventually decompose organic materials into simpler carbon molecules, such as carbon dioxide and methane.

In industrialized countries with rich experience in waste management, incineration is recognized as the single most effective method for MSW treatment, as it reduces waste volume by 90% and eliminates methane emissions.[2] Incineration yields heat, which is captured through waste-to-energy facilities to produce electricity. However, there are a number of key differences in the waste characteristics of industrialized countries and less developed countries (Table 3). The waste in developing countries, particularly in South Asia, is characterized by a significantly higher density and moisture, mainly organic waste with low caloric values (700–1,000 kilocalories). In South Asia, this is particularly relevant, given the large number of people with vegetarian diets, estimated to be 42% of the Indian population.[3] Given these physical and

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1 Cointreau, S. 2007. *The Growing Complexities and Challenges of Solid Waste Management in Developing Countries*. Washington, DC.

2 Rand, T., J. Haukohl, and U. Marxen. 2000. *Municipal Solid Waste Incineration—A Decision Maker's Guide*. Washington, DC: World Bank.

3 Food and Agriculture Organization of the United Nations. 2001. *Project on Livestock Industrialization, Trade and Social–Health–Environment Impacts in Developing Countries*. Rome.

Table 1 Waste Generation and Projection Comparisons throughout Asia

Country	Current					2025				
	GNP per Capita 1995 (%)	1995 Population		Urban Waste Generation		Predicted GNP per Capita[a]	Predicted Population		Predicted Urban Waste Generation	
		Total (million)	Urban (% of total)	Generation Rate (kg/capita/day)	Total Waste (ton/day)		Total (million)	Urban (% of total)	Municipal Solid Waste (kg/capita/day)	Total (ton/day)
Low-Income Countries										
Bangladesh	240	119.8	18.3	0.49	10,742	440	193.1	40.0	0.6	47,064
PRC	620	1,200.2	30.3	0.79	287,292	1,500	1,526.1	54.5	0.9	748,552
India	340	929.4	26.8	0.46	114,576	600	1,392.1	45.2	0.7	440,460
Lao PDR	350	4.9	21.7	0.69	734	850	9.7	44.5	0.8	3,453
Mongolia	310	2.5	60.9	0.60	914	560	3.8	76.5	0.9	2,616
Myanmar	240	46.5	26.2	0.45	5,482	580	75.6	47.3	0.6	21,455
Nepal	200	21.5	13.7	0.50	1,473	360	40.7	34.3	0.6	8,376
Sri Lanka	700	18.1	22.4	0.89	3,608	1,300	25.0	42.6	1.0	10,650
Viet Nam	240	73.5	20.8	0.55	8,408	580	118.2	39.0	0.7	32,269
Middle-Income Countries										
Indonesia	980	193.3	35.4	0.76	52,005	2,400	275.6	60.7	1.0	167,289
Malaysia	3,890	20.1	53.7	0.81	8,743	9,440	31.6	72.7	1.4	32,162
Philippines	1,050	68.6	54.2	0.52	19,334	2,500	104.5	74.3	0.8	62,115
Thailand	2,740	58.2	20.0	1.10	12,804	6,700	73.6	39.1	1.5	43,166
High-Income Countries										
Japan	39,600	125.2	77.6	1.47	142,818	53,500	121.6	84.9	1.3	134,210
Korea, Republic of	9,700	44.9	81.3	1.59	58,041	17,600	54.4	93.7	1.4	71,362
Singapore	26,730	3.0	100.0	1.10	3,300	36,000	3.4	100.0	1.1	3,740

GNP = gross national product, kg = kilogram, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

[a] Assumed GNP country waste generation rates are based on weighted averages from different cities within the country.

Source: World Bank. 1999. *What a Waste: Solid Waste Management in Asia*. Washington, DC.

Table 2 **Comparison of Waste Treatment Practices** (%)

Country (Year)	Untreated	Sanitary Landfill	Composting[a] and Recycling	Incineration
Bangladesh (2001)	88	10	2	0
PRC (2006)	48	43	2	8
European Union[b]	0	45	36	19
Hong Kong, China (2007)	0	55	45	0
India (2001)	60	15	10	5
Japan (2005)	0	8	19	73
Nepal (2001)	70	10	5	0
Singapore (2007)	0	10	0	90
Sri Lanka (2001)	85	0	5	0
United States (2007)	0	54	34	13

PRC = People's Republic of China.

[a] For Bangladesh, India, Nepal, and Sri Lanka, the figures reflect only composting activities. Recycling in these countries is done by the informal sector, and it is found that around 15%–20% of total waste, in India for example, could be recycled.

[b] Average of 15 European Union countries.

Sources: ADB. 2005. Country reports for Bangladesh, India, Nepal, and Sri Lanka. Unpublished documents under RETA 6337: Development Partnership Program for South Asia; ADB and United Nations Economic and Social Commission for Asia and the Pacific. 2000. *State of the Environment in Asia and the Pacific 2000*. New York: United Nations; and Zhu, D., et al. 2008. *Improving Municipal Solid Waste Management in India: A Sourcebook for Policy Makers and Practitioners*. Washington, DC: World Bank.

chemical characteristics of waste in the region, incineration—which is ideal for dry matter with high caloric value—is not a suitable option. In 1987, for example, a 300 tons/day (tpd) incineration plant was established in Timarpur, Delhi. The project, which was expected to produce 3.75 megawatts (MW), failed, and ultimately shut down in 1990 due to the high volume of refuse with low caloric value. Although this is an older case, there have been few efforts to develop incineration since then. Until the caloric value of waste improves, or the technology and processes for incineration advance, the biological treatment and recycling of this bulk organic fraction at a lower cost makes these methods a more suitable option for developing municipal economies in South Asia. Moreover, in 2004, the South Asian Association for Regional Cooperation (SAARC) Dhaka Recommendation on Waste Management (October 2004) agreed that incineration, as well as unproven technologies such as plasma, should not be considered as an option for the treatment of their MSW of low caloric value and high environmental pollution potential. SAARC countries agreed to encourage nongovernment organizations (NGOs) and private companies to establish community-based segregation at source, separate collection, and resource recovery from wastes with particular focus on composting.

Municipal Solid Waste Management in South Asia

Current and future waste treatment in the South Asia region is greatly affected not only by population growth and consumption patterns, but also by (i) the policies, regulations, and incentives provided by governments; (ii) applicable funding from private and public sectors; and (iii) community social awareness.

Table 3 Waste Collection Typologies by Gross Domestic Product per Capita

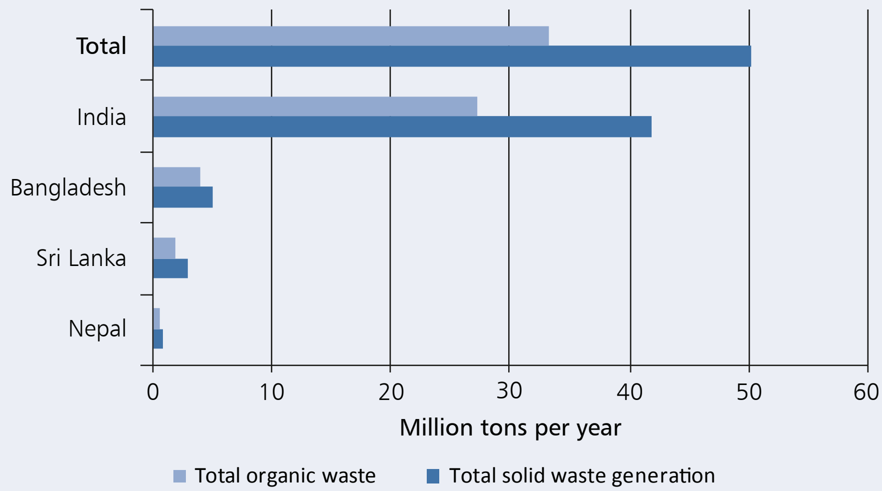
Particulars	Low-Income Countries	Middle-Income Countries	High-Income Countries
GDP ($/capita/year)	< $55,000	$5,000–$15,000	> $15,000
Average consumption of paper and cardboard (kg/capita/year)	20	20–70	130–300
Municipal waste (kg/capita/year)	150–250	250–550	350–750
Formal collection rate of municipal waste	< 70%	70%–95%	> 95%
Statutory waste management framework	No or weak national environmental strategy, little application of the statutory framework, absence of statistics	National environmental strategy, Ministry of the Environment, statutory framework but insufficient application, little statistics	National environmental strategy, Ministry of the Environment, statutory framework set up and applied, statistics
Informal collection	Highly developed, substantial volume capture, tendency to organize in cooperatives or associations	Developed and in process of institutionalization	Quasi-nonexistent
Municipal waste composition (% weight basis) Organic or fermentable Paper and cardboard Plastics Metals Glass Moisture content (%) Caloric value (kcal/kg dry basis)	 50–80 4–15 5–12 1–5 1–5 50–80 800–1,100	 20–65 15–40 7–15 1–5 1–5 40–60 1,100–1,300	 20–40 15–50 10–15 5–8 5–8 20–30 1,500–2,700
Waste treatment	Uncontrolled landfills > 50% Informal recycling 15%	Landfill sites > 90%, start of selective collection, organized recycling 5% coexistent informal recycling	Selective collection, incineration, recycling > 20%
Informal recycling	Highly developed, substantial volume capture, tendency to organize in cooperatives or associations	Developed and in process of institutionalization	Quasi-nonexistent

< = less than, > = more than, GDP = gross domestic product, kcal = kilocalorie, kg = kilogram.

Source: United Nations Environment Programme. 2011. *Waste: Investing in Energy and Resource Efficiency*. Nairobi.

The organic matter within MSW streams in the region averages around 70%. Figure 1 illustrates the ratio of organic to total solid waste by mass within the region. The total municipal waste generation amounts to 50 million tons/year, out of which 33 million tons/year are organic waste (Table 4). The high volume of organic waste in the region is an important consideration for developing appropriate management plans and treatment options.

Figure 1 **Organic Waste Composition of Solid Waste in South Asia, 2005–2010**



Sources: Bangladesh: Waste Concern. 2005. *Urban Solid Waste Management Scenario of Bangladesh: Problems and Prospects*. Dhaka; India: Government of India, Department of Economic Affairs, Ministry of Finance. 2009. *Position Paper on Solid Waste Management Sector in India*. Delhi; Nepal: Solid Waste Management and Resource Mobilization Center. 2004. *A Diagnostic Report on State of Solid Waste Management in Municipalities of Kathmandu*; Sri Lanka: Government of Sri Lanka, Ministry of Environment and Natural Resources. 2005. *Database of Municipal Solid Waste in Sri Lanka*. Colombo. More recent data is not readily available.

Table 4 **Organic Waste Generation in South Asian Countries**

Country	Solid Waste Generation Rate (million tons/yr)	Waste Generation per Capita (kg/day)	Organic Matter (%)	Total Organic Waste (million tons/yr)
Bangladesh	4.9	0.41	78	3.8
India	42.0	0.40	65	27.3
Nepal	0.7	0.36	74	0.5
Sri Lanka	2.8	0.53	65	1.8
Total	**50.4**	**1.70**	**66**	**33.4**

kg = kilogram, yr = year.

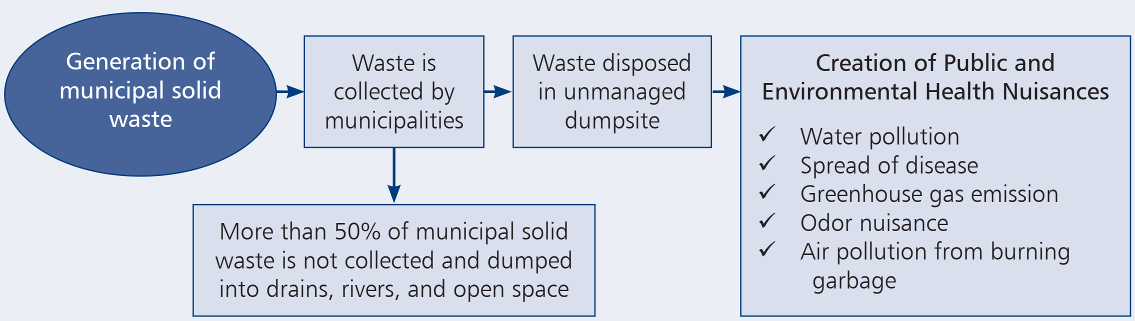
Sources: Bangladesh: Waste Concern. 2005. *Urban Solid Waste Management Scenario of Bangladesh: Problems and Prospects*. Dhaka; India: Government of India, Department of Economic Affairs, Ministry of Finance. 2005. *Position Paper on Solid Waste Management Sector in India*. Delhi; Nepal: Solid Waste Management and Resource Mobilization Center. 2004. *A Diagnostic Report on State of Solid Waste Management in Municipalities of Kathmandu*; Sri Lanka: Government of Sri Lanka, Ministry of Environment and Natural Resources. 2005. *Database of Municipal Solid Waste in Sri Lanka*. Colombo; More recent data is not readily available.

The most prevalent existing treatment option throughout the region is landfilling, as it remains the cheapest and easiest way to dispose of waste. However, most landfills are not scientifically engineered and are poorly maintained, effectively turning into open, unsanitary dumpsites. Collection rates in the region are typically low, at 50%–60%, with the uncollected waste dumped into drains, rivers, and open spaces, causing severe public and environmental health problems. For example, the bubonic plague outbreak in Surat, India, in 1994 led to the subsequent streamlining of solid waste collection and transport systems, leading to increased public pressure to improve solid waste management throughout the country. The government subsequently passed rules on solid waste management, which were notified in 2000.[4]

The practice of landfilling also requires large tracts of land, not only for the actual disposal site, but also for the surrounding no-development buffer, which is recommended by India's *Municipal Solid Waste (Management Handling) Rules, 2000*.[5] Moreover, landfill costs range between $5/ton and $25/ton for low-income countries and between $15/ton and $30/ton for middle-income countries. Given the large area requirements for landfilling, growing population pressure, and increasing costs and land values, municipal officials are constrained to find land of reasonable proximity and price (if private land is to be acquired) for waste management. This is particularly relevant in Bangladesh—one of the world's most densely populated countries. Figure 2 illustrates the typical waste management scenario throughout the region.

Because of the high levels of organic matter within the region's waste streams, diverting this waste into resource recovery systems presents a sizeable untapped potential for extending the life of landfills, creating economic and environmental benefits, and ultimately reducing the pressure on municipalities to manage the ever increasing complexity of waste systems.

Figure 2 **Typical Scenario of Solid Waste Management in South Asia**



Source: Authors.

[4] Government of India. Ministry of Environment and Forests. 2002. *Agenda 21: An Assessment*. Delhi.

[5] Government of India. 2000. *Municipal Solid Wastes (Management and Handling) Rules, 2000*. Delhi.

Resource Recovery Potential from Municipal Organic Waste

By recycling organic waste into compost, the region would have the potential to produce around 8 million tons of compost worth about $710 million. Alternatively, if the entire 33.4 million tons of organic waste were used to produce electricity from biogas, the potential is estimated at 1,670 million cubic meters (m^3) of biogas and 3,340 million kilowatt-hours (kWh)/year of electricity (Table 5). If 3,340 million kWh is converted into per day generation, the amount of electricity that may be generated is estimated at 9,150 megawatt-hours, which has a market value of $701 million/year (Table 6).

Table 5 Estimated Organic Waste Resource Recovery in South Asia

Country	Organic Waste Generation Rate (million tons/yr)	Compost (million tons/yr)	Biogas (million m^3/yr)	Biogas to Electricity (million kWh/yr)	RDF (million tons/yr)
Bangladesh	3.8	0.95	190	380	0.15
India	27.3	6.82	1,365	2,730	1.09
Nepal	0.5	0.13	25	50	0.02
Sri Lanka	1.8	0.45	90	180	0.07
Total	**33.4**	**8.35**	**1,670**	**3,340**	**1.33**

kWh = kilowatt-hour, m^3 = cubic meter, RDF= refuse-derived fuel, yr = year.

Note: Conversion rate per ton of organic waste to compost is 25%, biogas is 50 m^3/ton, electricity generation rate is 2 kWh/m^3 of biogas, and RDF is 4% of waste (paper, rags, wood, and plastic except PVC).

Sources: Bangladesh: Waste Concern. 2005. *Urban Solid Waste Management Scenario of Bangladesh: Problems and Prospects.* Dhaka; India: Government of India, Department of Economic Affairs, Ministry of Finance. 2009. *Position Paper on Solid Waste Management Sector in India*. Delhi; Nepal: Solid Waste Management and Resource Mobilization Center. 2004. *A Diagnostic Report on State of Solid Waste Management in Municipalities of Kathmandu*; Sri Lanka: Government of Sri Lanka, Ministry of Environment and Natural Resources. 2005. *Database of Municipal Solid Waste in Sri Lanka*. Colombo.

Table 6 Estimated Value of Organic Recycled Material in South Asia ($ million)

Country	Compost	Biogas to Electricity	RDF	Potential Value of Carbon Credits
Bangladesh	80.75	79.8	7.5	24.83
India	579.7	573.3	54.5	177.45
Nepal	10.6	10.5	1.0	3.38
Sri Lanka	38.2	37.8	3.5	11.83
Total	**709.25**	**701.4**	**66.5**	**217.49**

RDF = refuse-derived fuel.

Note: Compost value assumed at $85/ton, electricity price at $0.21/kilowatt-hour, and RDF at $50/ton and certified emissions reductions at $10/ton. For compost, prices are estimated based on the lower price in 2011 of compost sold in Bangladesh. For electricity, the price is based on the Government of Bangladesh's payment to independent power producers. For RDF, the price is assumed to be half of the coal price in Bangladesh. These rates were compared to the other countries and found to be conservative estimates. The current 2011 price of certified emissions reductions is about $16.38/ton; however, for conservative estimation, a price of $10/ton is used.

Source: Authors.

The total potential market value of products from recycling of organic waste is estimated at around $985 million/year. Apart from this income-earning potential, improved organic waste management would save around 27.88 million m^3 of landfill volume, with cost savings felt at the local level.[6]

Drivers for Change

Apart from the resource-recovery and revenue-earning potential as indicated above, the following are the major drivers for scaling up organic waste management in the region:

Food Security

Management of soil organic matter is a major issue in the region to address soil fertility. "Soil fatigue," or the depletion of organic matter in soil from decades of intensive cultivation and imbalanced fertilizer use, is common throughout the region. In Bangladesh, it is estimated that 83% of cultivated land has low organic matter content due to increased cropping intensity.[7] Biodegradable municipal organic waste, when converted to compost, becomes an important soil amendment, increasing organic matter and key nutrients in soils. Research demonstrates that where there is a shortage of nutrients in soils, particularly nitrogen, compost application can result in higher productivity.[8]

Governments across the region also spend millions of dollars each year on the purchase of inorganic fertilizers, which are sold at a subsidized rate to farmers for the production of subsistence crops such as rice and pulses (legumes). For urea and other chemical fertilizers farmers are charged only about 50% of the actual cost to the government. In Sri Lanka, the central government spends around $400 million/year subsidizing fertilizer for rice production alone, and it has determined that the use of quality composts from urban organic wastes can reduce fertilizer use in rice production by 25%. The Government of India estimates that it would need about 301 million tons of food grains by 2025 to feed the country's 1.4 billion population. This would create a demand of 35 million tons of chemical fertilizers, in addition to about 10 million tons from organic manure and biofertilizers. The available organic manure in India from all sources is about 270 million–300 million tons, which would provide only 5 million–6 million tons of nitrogen, phosphorus, and potassium (NPK) nutrients.[9] A concern exists over the imbalanced NPK ratio critical for soil health. There is an enormous demand for increased production of compost from municipal organic waste to serve as an important soil amendment to support improved soil health, agricultural productivity, and food security.[10]

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[6] In the region, landfill density is found to be 1.2 tons/m^3. Total organic waste is 33.46 million tons/year. As such, land volume required is 33.46/1.2 = 27.88 million m^3.

[7] Jahiruddin, M., and M.A. Satter. 2010. *Agricultural Research Priority: Vision 2030 and Beyond—Subsector: Land and Soil Resource Management*. Dhaka: Bangladesh Agricultural Research Council.

[8] United States Environmental Protection Agency (US EPA). 2006. *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*. 3rd Edition. Washington, DC.

[9] Government of India. 2005. *Report of the Inter-Ministerial Task Force on Integrated Plant Nutrient Management Using City Compost*. Delhi.

[10] While compost offers NPK, as well as a wide range of other necessary plant nutrients and trace elements, these nutrients are generally present in much lower concentrations than synthetic fertilizers and will vary considerably based

Data from long-term experiments in India have shown that combined application of organic and chemical fertilizers produces higher crop yield and higher-quality produce than when each is applied alone.[11] However, the Indian Council of Agricultural Research, throughout its All India Coordinated Long Term Fertility Project, identified that the chemical fertilizers that helped the country achieve self-sufficiency in food are becoming less effective. An important indicator is the response ratio (the unit weight of food produced per unit weight of fertilizer application), which is declining sharply.

The Government of India Inter-Ministerial Task Force on Integrated Plant Nutrient Management Using City Compost (2005) identified that returning organic carbon and nutrients from urban solid wastes to the soil is essential for sustaining the production of subsistence crops required to feed the country's growing population. The Indian Council for Agricultural Research indicates that India is still short of organic manure to practice integrated plant nutrient management on a large scale, and that the supplies could be augmented to a great extent, especially in peri-urban areas, by recycling and composting biodegradable organic city waste (Box 1).

Box 1 **Integrated Plant Nutrient Management**

Integrated plant nutrient management is an approach that seeks to increase agricultural production and safeguard the environment for future generations. It is a strategy that incorporates both organic and inorganic plant nutrients to attain higher crop productivity, prevent soil degradation, and thereby help meet future food supply needs. It relies on nutrient application and conservation, new technologies to increase nutrient availability to plants, and the dissemination of knowledge between farmers and researchers. Techniques to conserve and add nutrients to the soil through the application of organic or inorganic fertilizers can help to maintain and increase the nutrient reserves of the soil.

Source: Gruhn, P., F. Goletti, and M. Yudelman. 2000. *Integrated Nutrient Management, Soil Fertility, and Sustainable Agriculture: Current Issues and Future Challenges*. 2020 Vision Brief 67. Washington, DC: International Food Policy Research Institute.

The benefits of compost application are that it[12]

- contains a number of essential plant nutrients (e.g., NPK);[13]
- contains macro- and micronutrients often absent in synthetic fertilizers;
- releases nutrients slowly—over months or years, unlike synthetic fertilizers, helping to bind clusters of soil particles, called aggregates, which provide good soil structure containing tiny air channels and pores that hold air, moisture, and nutrients;
- helps the enriched soil retain fertilizers better with less runoff to pollute waterways;
- helps sandy soil retain water and nutrients;

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on the content of the raw ingredients included in the compost. Combining municipal compost with sewerage sludge can increase the total nutrient content of compost.

11 Government of India, *Report of the Inter-Ministerial Task Force*.

12 US EPA. Wastes—Resource Conservation—Reduce, Reuse, Recycle—Composting. www.epa.gov/epawaste/conserve/rrr/composting/basic.htm

13 Although the nutrient content of compost is low compared to synthetic fertilizer products, compost is usually applied at greater rates, and therefore nutrient contribution can be significant.

- buffers the soil, neutralizing both acid and alkaline soils, bringing pH levels to the optimum range for nutrient availability to plants;
- loosens tightly bound particles in clay or silt soil so roots can spread, water can drain, and air can penetrate;
- alters soil structure, making it less likely to erode;
- brings and feeds diverse life in the soil—bacteria, fungi, insects, and worms that support healthy plant growth;
- contains bacteria that break down organics into plant-available nutrients, and some bacteria that convert nitrogen from the air into a plant-available nutrient;
- may suppress diseases and harmful pests that could overrun poor, lifeless soil;
- increases soil nutrient–holding capacity, reducing the need for commercial fertilizers;[14] and
- reduces agricultural nonpoint source pollution of watercourses caused by chemical fertilizers.

A number of public health and safety risks arising from municipal waste–generated compost and measures to protect food systems are described later in this report.

Global Warming

The indiscriminate dumping of organic wastes into landfills or open dump sites results in the generation of large quantities of methane, a GHG with 21 times greater global warming impact than carbon dioxide. Organic waste management efforts can avert landfill methane generation and reduce direct emissions.[15] Consequently, these activities are eligible for carbon financing under the Kyoto Protocol Clean Development Mechanism (CDM) on the basis of reduction in methane emissions. This is discussed in more detail on page 73.

Moreover, research suggests that aerobic composting, when managed properly, results in carbon sequestration in soils, thereby facilitating greater adaptation to climate change. Because compost use increases soil water retention, moister soil gives a number of ancillary benefits, including reduced irrigation costs and reduced energy required for pumping water. Compost therefore plays an important role in adaptation strategies that will be necessary as existing climate zones shift with climate change and some areas become more arid.[16]

Land Scarcity

In India, per capita land availability decreased from 0.48 hectares (ha) in 1951 to 0.17 ha in 1985, and further declined to 0.10 ha in 2005. As organic matter is the largest component by weight of the total municipal waste generated, diversion of organic wastes from dumpsites and

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[14] Haering, K., and G. Evanylo. 2005. *Composting and Compost Use for Water Quality*. Department of Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg, VA.

[15] The US EPA created the Waste Reduction Model to help solid waste planners track GHG emission reductions from several different waste management practices. http://epa.gov/climatechange/wycd/waste/calculators/Warm_home.html

[16] US EPA, *Solid Waste Management and Greenhouse Gases*.

landfills will significantly extend the working life of such sites, reducing the need and expense of establishing additional solid waste disposal sites in the future.

Public Health Risks

The risks to water quality and human health from current unsanitary (i.e., open dumping) solid waste disposal practices across the region are significant, as evident in the 1994 Surat, India plague outbreak. An important benefit of scaling up organic waste management is that leachate management will be easier with less organic waste. High levels of biochemical oxygen demand are typically detected in waterways receiving leachate from landfills with anaerobic conditions. The improved environmental conditions surrounding landfills, including soil, air, and water quality, as a result of diverting the organic waste fraction from landfills would reduce the health risks to surrounding communities.

Inadequate Municipal Finances

Many local governments allocate around 20%–40% of their annual budgets for collection, transport, and disposal of municipal waste, but few recover the actual costs. Often, municipal levies barely cover the costs of collection and transport, leaving little to no financial resources for the safe disposal of waste. Naturally, the lack of space for dumping causes tipping fees to climb, and the longer distances trucks must travel, coupled with increased fuel costs, contributes to the strain on municipal budgets.

Throughout the region, municipal financing is also dominated by one tax source—property tax—that contributes nearly two-thirds of total revenue receipts. However, its potential is not exploited properly. Proper and regular assessment is not done, and most of the municipalities are not even correctly equipped to assess. Therefore, solid and organic waste management can be improved by leveraging the expertise of the private sector through public–private partnerships (PPPs), as discussed in Chapter 2.

Experience of Municipal Organic Waste Management in South Asia

Table 7 summarizes the technology currently used in South Asian cities to recycle and reuse municipal organic waste. Among the organic waste-recycling technologies, composting is the most common in the region. Bangladesh, India, and Sri Lanka all have formal quality standards for compost products which producers are required to meet. Nepal currently has no standard. A brief overview of country experience in organic waste management is presented in Appendix 1.

Key Issues in Scaling Up Organic Waste Management

Based on the review of South Asian experience, the following issues surfaced as impediments to scaling up organic waste management in the region:

Table 7 **Technology Used in South Asia to Recycle and Recover Organic Waste**

Management Option	Composting	Anaerobic Digestion (biogas)	Refuse-Derived Fuel[a]
Suitable type of organic matter	Food, vegetables, fruits, and plant residues	Food, vegetables, and fruits	Paper, plant residues, wood waste
Required waste quality	Medium (low heavy metal)	Medium (low heavy metal)	Low (no dioxin-emitting waste)
Project scale	Household to large	Household to large	Household to large
Investment	Low to medium and high	Medium to high	Low to medium
Examples of practicing countries	All countries	India, Nepal, and Sri Lanka (limited scale)	India and Nepal (limited scale)

[a] The refuse-derived fuel (RDF) process is essentially a method that enriches the organic content of municipal solid waste through removal of inorganic materials and moisture. The caloric value of RDF pellets can be around 4,000 kilocalories/kilogram, depending upon the percentage of organic matter in the waste, additives, and binder materials used in the process.

Source: Sang-Arun, J., and M. Bengtsson. 2009. *Improved Organic Waste Management: Climate Benefits through the 3Rs in Developing Asian Countries.* Hayama, Japan: Institute for Global Environmental Strategies. http://enviroscope.iges.or.jp/modules/envirolib/view.php?docid=2636

Mixed waste. This is undoubtedly the key constraint to improved sector performance. Recycling of mixed municipal waste has led to production of inferior-quality compost, which in turn gives rise to higher operational costs and marketing problems. Composting and biogas projects using mixed waste inputs often fail. An additional disadvantage of bringing mixed waste to a compost plant is that the volume of reject materials would be large, and these would have to be transported and disposed of appropriately, resulting in additional costs.

Quality and processing standards. Quality standards and registration of the compost by the Ministry of Agriculture, as well as its promotion by the public sector, are vital for scaling up efforts. However, the key issue for promoting the use of compost in agricultural soils is the methods of production, which must ensure that the compost is of suitable quality for safe and beneficial reuse and reliable performance in agricultural production. To protect human health, compost production must ensure that organic waste materials are effectively sanitized with heat to destroy human pathogens (disease organisms). Such heat-based pasteurization of organic waste materials is also required to destroy plant pathogens and weed seeds in order to manage the biosecurity risks to the agricultural economy and ensure that compost products are not a vector for the spread of crop diseases or weeds. Compost piles should reach a minimum temperature of 55°C, thereby causing the thermal death of pathogens and plant propagules.

Additionally, compost quality standards are required to ensure the absence of phytotoxic compounds (compounds toxic to plant growth) and other elements associated with immature composts which can be detrimental to plant growth. Standards must ensure that such risks are addressed, and that compost products can be safely used and will deliver reliable agronomic performance.

Community awareness. A greater effort is needed to increase the level of awareness of local communities and encourage source segregation of waste. Segregation of recyclable waste at source is not conscientiously practiced by households, shops, and establishments throughout the region. Farmers must also be trained on the benefits of municipal organic waste, and to shift their full reliance away from chemical fertilizers.

Technological issues. The selection of appropriate technology depends on the physical and chemical composition of the waste, its moisture content, the prevailing climate conditions, and the type of waste collection method used (mixed or sorted). Mechanization is not required for small- (less than 20 tons per day [tpd]) and medium-scale projects (less than 100 tpd). Anaerobic digestion plants and RDF are capital-intensive, and require well-trained operators, resulting in a more expensive organic waste management option. Throughout the region, this option should be carefully weighed against other less expensive options, and matched to fit the municipalities' management and technical capacity. Industrial towns are suitable locations for RDF as there is a concentration of cement kilns and industrial boilers. Combined systems can also be considered if costs, capacity, and improved segregation of waste permit.

Environmental issues. The location of the compost plants and open composting without shed and buffer areas also affect the project's viability. Odor problems have been observed in plants where anaerobic conditions prevail, and when the composting is undertaken in an open yard. Formal environmental clearance from the government is also an important issue for establishing plants.

Financing issues. A level playing field must be created to support the organic waste sector. Chemical fertilizer subsidies by governments distort the market for organic compost. Chemical fertilizers are typically sold at a subsidized price, so in the medium to long term, such subsidies should be reduced, rather than providing the same level of subsidies to organic composts. Providing subsidies to organic waste operators could also be considered to help municipalities and the private sector in implementing such projects. However, direct subsidy of capital costs (plant and machinery) does not always deliver the desired results. Since chemical fertilizers and nonrenewable energy are heavily subsidized, some incentive should be offered for the purchase of compost and renewable energy by consumers. Also, in the case of compost, as it is transported in bulk for direct selling to farmers, a transport subsidy may be extended, as is sometimes offered to fertilizer companies. The private sector should be considered for back-ended capital subsidy of the plant costs (compost, biogas, or RDF) if the municipality owns the plant, and an interest subsidy could be extended for the entire loan repayment period at a favorable discount rate. Moreover, a promotional subsidy could help raise awareness and promote the use of compost and biogas among the broader consumer market, particularly farmers. This type of financial assistance is critical for the successful scaling up of support for organic waste management. Regardless of the financial assistance strategy selected by the government (reduced subsidies to chemical fertilizers or increased subsidies to compost operators), a careful assessment of opportunity costs (less land required for landfill, lower transport costs, lower operation costs of landfill, improved local environment, etc.) should be done to convince decision makers who manage scarce government budgets.

Management issues. Selection of the correct management model for the operation of compost and other recycling plants is also an important factor for the project's sustainability. Experience throughout the region illustrates that municipally operated and owned projects have not been successful. In Sri Lanka, a major cause of failure of composting projects operated by local authorities is the lack of an institutional mechanism to support and train local authorities in operation and maintenance, even when the capital costs were funded by donors. In India, it was also observed that local officials did not have adequate knowledge of composting and management of such systems. Agencies such as the All India Institute of Local Self Government could be involved in such training. Capacity building should also be coupled with incentive programs, including financial incentives such as collection fees for nonrecyclable waste or noncompliance with source segregation rules.

Public–private partnership. PPP agreements designed without considering factors such as price escalation, changes in fuel prices, quality of waste, tipping fee, and lack of penalty clauses have led to problems during the implementation of PPP projects in India and Sri Lanka. In Bangladesh, concession agreements must clearly mention collection of organic waste with a focus on market waste, not mixed household waste, until household waste segregation is improved.

Clean Development Mechanism. CDM financing is happening in India and Bangladesh for waste composting and RDF projects. Lack of information among municipal officials and high transaction costs are clear obstacles. Programmatic CDM opportunities can be further explored to address these issues. There is an opportunity for more waste-based CDM projects in the region to help bridge the financing difficulties faced by municipalities and operators.

Intergovernmental coordination. Coordination among various ministries, including environment, local government, agriculture, energy, and finance, is crucial for the promotion of organic waste recycling.

Marketing. The wrong marketing strategy for compost is also a major bottleneck for developing good practices in the region. For waste-to-energy projects, the lack of proper price structures on biogas-to-electricity or RDF-to-electricity ventures is a significant barrier for investment from the private sector.

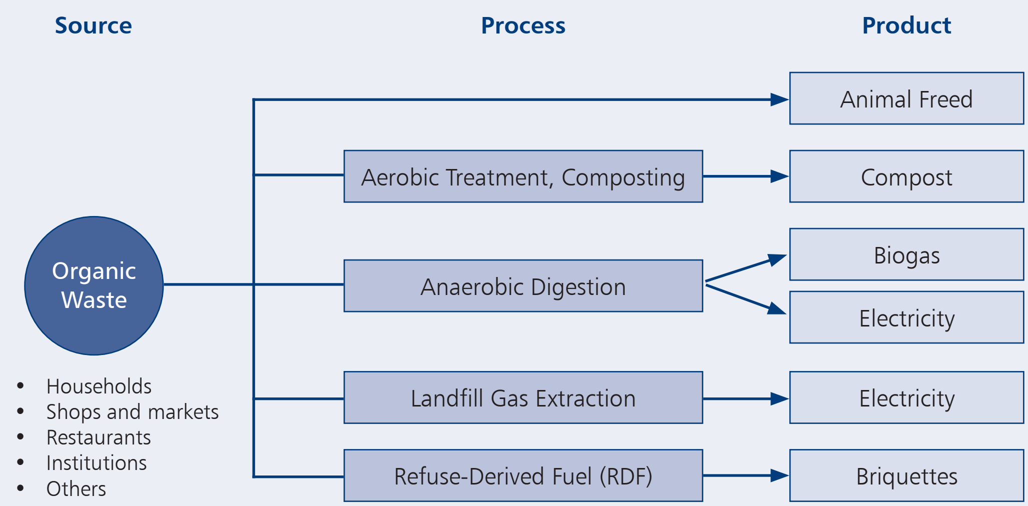
Capacity building. Lack of training of municipal employees and the staff of nongovernment organizations on proper operation and maintenance of compost, biogas, and RDF plants is an impediment to developing such projects. There is a need for training and capacity building on organic waste management for stakeholders.

Chapter 2
Tool Kit for Municipalities and Operators

Analysis of Technology Options for Organic Waste Recycling

Figure 3 shows the various treatment methods and value-added products generated from municipal organic waste treatment. This process is made difficult in most cases throughout the region as mixed waste is collected, managed, and treated without source segregation. Source segregation of waste (discussed later in the report) is critical; however, if mixed waste is collected (currently the norm), hand sorting of mixed household waste is possible for small-scale plants with a capacity of 3–5 tons per day (tpd), while in medium- and large-scale plants processing daily waste volumes of greater than 50 tpd, mechanization is recommended, resulting in increased production costs, and consequently higher compost prices. Determining

Figure 3 **Waste-Recycling Options for Organic Waste**



Note: RDF also takes in take plastic, rubber, and other high-caloric organic materials.

Source: Authors.

waste treatment technology therefore highly depends on collection and pretreatment options. The following section describes in more detail the different options and technologies for organic waste recycling.

Aerobic Composting

Composting is an aerobic process (requiring oxygen) where microorganisms decompose organic materials under controlled conditions. This process reduces the waste volume by up to one-third. Based on experience in Bangladesh, the compost conversion ratio from municipal waste varies between 15% and 25%, depending upon the type of waste composted, the technology used, and the composition of the waste. It takes 2–4 months to produce the final compost product. Composting can be applied on various scales, from individual households to large centralized facilities with the capacity for several hundred tons of waste per day. Composting is based on microbial degradation of food, vegetables, fruits, leaves, grasses, and crop residues (Table 8). This is a traditional practice for agricultural waste, and is also applicable to municipal organic waste. The composting of municipal solid waste (MSW) is practiced in South Asian countries. However, the average amount of waste currently composted in the region varies from 2% to 10% of total municipal waste. The production of compost is not intended to replace chemical fertilizers altogether; rather, it is simply intended to act as a soil amendment, which can improve overall soil health and agricultural sustainability.

Table 8 Common Inputs for Aerobic Composting

• Fruits and vegetables	• Houseplants
• Animal manure	• Leaves
• Cardboard	• Nut shells
• Paper	• Sawdust
• Shredded newspaper	• Tea bags
• Hair and fur	• Wood chips
• Coffee grounds and filters	• Wool rags
• Cotton rags	• Yard trimmings
• Dryer and vacuum cleaner lint	• Hay and straw
• Eggshells	• Grass clippings
• Fire ashes	

Source: United States Environmental Protection Agency. Basic Information. Wastes—Resource Conservation—Reduce, Reuse, Recycle—Composting. http://www.epa.gov/osw/conserve/rrr/composting/basic.htm

The main factors influencing the composting process, and which need to be carefully managed, are listed and explained below. Table 9 provides basic mitigation measures to help manage the compost process.

- **Carbon and nitrogen content.** These elements are essential for growth and cell division of the microorganisms. Microorganisms can only degrade the organic carbon present in the waste if they have enough nitrogen for growth. Lack of nitrogen or a high carbon–nitrogen (C:N) ratio inhibit the composting process. The ideal C:N ratio to start composting ranges between 25:1 and 40:1 (i.e., 25–40 parts carbon to 1 part nitrogen in terms of dry weight). This allows rapid and efficient degradation of the organic material. It is generally advisable to start a mixing ratio with one part "green" and one part "brown" waste.[17] Depending on process performance, adjustments may have to be made for every new compost pile. The right balance is something learned by experience, but a rough guide is to use equal amounts by volume of green and brown waste.

- **Oxygen.** To allow aerobic microorganisms to be active in the compost pile, sufficient oxygen should be maintained in the system. The size of the pile is an important factor for the oxygen content in the compost. Air can be introduced into the pile by turning the material frequently, or by allowing air to penetrate through active or passive ventilation. In active ventilation, air is blown or drawn through the compost pile. Passive ventilation takes advantage of natural air diffusion through the pile, which can be enhanced by ventilation structures such as perforated pipes, triangular bamboo racks, or openings in the walls of compost bins. If the oxygen supply in the pile is limited, anaerobic microorganisms proliferate. These species should be avoided during the composting process, as they produce odors and methane.
- **Moisture.** It is important to maintain an adequate moisture content in the pile to support microbial activity. The ideal moisture content throughout the pile should be 40%–60% by weight. Moisture can be best controlled if the compost piles are covered by a roof to protect them from direct sun and excessive rain. If composting is conducted outdoors, the piles should be as steep as possible and covered with canvas, composting fleece, or gunny bags. The cover protects the pile from both excessive evaporation and excessive water infiltration. An optimum moisture level is reached if the composting material feels damp to the touch (i.e., if a few drops of liquid can be squeezed from a handful of material).
- **Size and structure.** The surface area of the organic material exposed to microorganisms is another factor determining the composting rate. Shredded and chipped waste material, or any material otherwise reduced in size, is degraded more rapidly—an important factor when processing wood and other materials that degrade slowly. Particles that are too fine should be avoided as they reduce permeability and thus restrict air circulation in the compost pile.
- **Temperature.** In aerobic decomposition, heat is generated as a result of microbial activity. With adequate levels of oxygen, moisture, carbon, and nitrogen, compost piles can heat up to temperatures in excess of 65°C. The temperature should be maintained at 55°C or higher for 15 days or longer, with a minimum of 3 days between turnings to ensure sanitization or pasteurization of potential plant or human pathogens in the waste material, as well as weed seeds and insect larvae.

Samples of the compost should be tested in a laboratory for bacterial and heavy metal content, especially if the source is from mixed MSW. Odors also need to be controlled. The public should be informed of the operation, and have a means to address any complaints about animals or bad odors. Other concerns might include zoning and siting requirements.

A number of composting techniques exist (Table 10). Some composting techniques are manually operated, while others aerate the decomposing waste mechanically. Other techniques rely on microorganisms that exist naturally, the addition of worms through a process known as

[17] "Green waste" is biodegradable waste including domestic and commercial food waste. "Brown Waste" is any biodegradable waste that is predominantly carbon based, such as dry leaves, paper, sawdust, and cardboard. Green waste is high in nitrogen, whereas brown waste is primarily high in carbon.

Table 9 Troubleshooting during Composting

Situation	Possible Solutions
1. Raw material composition	
Large amounts of sand and stones	• Improve public awareness to reduce inert materials in waste • Adapt collection vehicle (mesh floor) to reduce sand content • Remove organics from the mixed waste instead of removing the residues from the organic waste (inverse selection) • Prescreen waste at site with fine mesh size
Large amounts of household hazardous waste	• Improve public awareness to initiate source segregation • Provide separate collection for hazardous materials
2. Composting parameters	
Nitrogen deficiency (high C:N ratio)	• Add manure or urea
Carbon deficiency (low C:N ratio)	• Add wood chips, dry leaves, or sawdust
Too high temperature during thermophilic phase (> 70°C)	• Turn pile • Water pile if necessary
Too low temperature during thermophilic phase (< 30°C)	• Check moisture content, if necessary add water • Check C:N ratio
High moisture content (> 70%)	• Turn pile, spread out pile before reforming, and leave to dry • Add sawdust or wood chips to absorb moisture
Low moisture content (< 40%)	• Spread waste and sprinkle with sufficient water
Odor development (anaerobic conditions)	• Insufficient oxygen, turn the pile more often • Add coarse material like wood chips to increase surface area • Avoid meat and fish leftovers for composting
3. Climatic influences	
Hot and humid climate or high rainfall season	• Protect waste from getting soaked, use roofed area for composting and maturing • Alternatively, cover piles with tarpaulin or composting fleece
Hot and arid climate or extended dry season	• Use roof to protect compost from direct sunlight • Alternatively, cover with tarpaulin or composting fleece to avoid excess evaporation • Water more frequently, collect rainwater to store for use in dry season if possible
Frequent strong winds	• Check moisture more frequently as evaporation will be increased
4. Vectors	
Excessive flies, insects	• Cover heap with 2-inch layer of coarse compost • Make sure to receive fresh organic waste (not older than 2 days)
Rodents and other animals	• Protect piles with barrier and fencing (fine-meshed chicken wire) • Cover with compost fleece held down by stones
5. Unidentified problems	
Compost heap smells	• Anaerobic heap probably due to high moisture content, lack of oxygen, or too little coarse material • If waste is very sticky and compact, add wood chips while turning • If heap is too wet, turn and let dry out before repiling

C:N = carbon–nitrogen.

Source: Enayetullah, I., et al. 2006. *Decentralised Composting for Cities of Low- and Middle-Income Countries: A Users' Manual*. Dhaka: Waste Concern and Zurich: Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

Table 10 Technological Options for Aerobic Composting

Aerobic Composting Technology	Description	Application	Types of Waste and Waste Generators	Climate or Seasonal Considerations	Requirements	Results	Environmental Considerations
Vermicomposting	Worms are placed in bins with organic matter in order to break it down into a high-value compost called castings. Worm bins are easy to construct (they are also commercially available) and can be adapted to accommodate small volumes of food scraps.	Vermicomposting can be ideal for apartment dwellers or small offices that want to derive some of the benefits of composting and reduce solid waste. It is frequently used in schools to teach children conservation and recycling.	Food scraps, paper, and plants are the main wastes used.	The optimal temperatures for vermicomposting range from 55°F (13°C) to 77°F (24°C). In hot, arid areas, the bin should be placed in the shade.	Worms, worm bedding (e.g., shredded newspaper, cardboard), and a bin to contain the worms and organic matter are required. Maintenance procedures include preparing bedding, burying garbage, and separating worms from their castings.	One pound (453 grams) of mature worms (approximately 800–1,000 worms) can eat up to half a pound of organic material per day. It typically takes 3–4 months for the worms to produce harvestable castings, which can be used as potting soil. Vermicomposting also produces compost or worm "tea," a high-quality liquid fertilizer for house plants or gardens.	This is a simple technology with few environmental nuisances.
Aerated (turned) windrow composting	Organic waste is formed into rows of long piles called "windrows" and aerated by turning the pile periodically by either manual	This method is suited for large quantities, such as that generated by entire communities and collected by local governments, and high volume	This method can accommodate large volumes of diverse wastes, including yard trimmings, grease, liquids, and animal by-products	In a warm, humid, or arid climate, windrows are sometimes covered or placed under a shelter to prevent water from	Windrow composting often requires large tracts of land, sturdy equipment, a continual supply of labor to maintain	This method will yield significant amounts of compost, which might require assistance to market the end product. Alternatively,	The public should be informed of the operation and have a method to address any complaints about pests or bad odors.

continued on next page

Table 10 *continued*

Aerobic Composting Technology	Description	Application	Types of Waste and Waste Generators	Climate or Seasonal Considerations	Requirements	Results	Environmental Considerations
	or mechanical means. The ideal pile height of 4–8 feet (ft) (1.2–2.4 meters) allows for a pile large enough to generate sufficient heat and maintain temperatures, yet small enough to allow oxygen to flow to the windrow's core. The ideal pile width is 14–16 ft (4.3–4.9 m).	food-processing businesses (e.g., restaurants, cafeterias, and packing plants).	(such as fish and poultry wastes), but only with frequent turning and careful monitoring.	evaporating. In rainy seasons, the shape of the pile can be adjusted so that water runs off the top of the pile rather than being absorbed into the pile. Windrow composting can also work in cold climates. Often the outside of the pile might freeze, but in its core, a windrow can reach 140°F (60°C).	and operate the facility, and patience to experiment with various materials, mixtures, and turning frequencies.	local governments can make the compost available to residents for at little or no cost.	Other concerns might include zoning and siting requirements.
Aerated static pile composting	Organic waste is mixed together in one large pile instead of rows. To aerate the pile, layers of loosely piled bulking agents (e.g., wood chips or shredded newspaper) are added so that air can pass from the bottom to	Aerated static piles work for larger-quantity generators of municipal solid waste (e.g., food scraps or paper products), which might include local governments.	Aerated static piles are suitable for a relatively homogenous mix of organic waste. This method, however, does not work well for composting animal by-products or grease from food processing industries.	Like windrow composting, in a warm, humid, or arid climate, aerated static piles are sometimes covered or placed under a shelter to prevent water from evaporating. In the cold, the core of the pile	This method typically requires equipment such as blowers, pipes, sensors, and fans, which might involve significant costs and technical assistance. A controlled supply of air enables construction of large piles,	This method produces compost relatively quickly—within 2–4 months.	Since there is no physical turning, this method requires careful monitoring to ensure that the outside of the pile heats up as much as the core. One way to alleviate bad odors is to apply a thick layer of finished compost over

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Table 10 *continued*

Aerobic Composting Technology	Description	Application	Types of Waste and Waste Generators	Climate or Seasonal Considerations	Requirements	Results	Environmental Considerations
	the top of the pile. The piles also can be placed over a network of pipes that delivers air into or out of the pile. Air blowers might be activated by a timer or a temperature sensor.			will retain its warm temperature, but aeration might be more difficult in the cold because this method involves passive air flowing rather than active turning. Some aerated static piles are placed indoors with proper ventilation.	which require less land than the windrow method.		the pile, which can help maintain high temperatures throughout the pile. Another way to deal with odor, provided that the air blower draws air out of the pile, is to filter this air through a biofilter made from finished compost. If land is a constraint, forced aeration can be considered.
In-vessel composting	Organic materials are fed into a drum, silo, concrete-lined trench, or similar equipment where the environmental conditions—including temperature, moisture, and	Some in-vessel composters can fit into a school or restaurant kitchen, while others can be as large as a school bus to accommodate large food-processing plants.	In addition, it can accommodate virtually any type of organic waste (e.g., meat, animal manure, biosolids, and food scraps).	In-vessel composting can be used year-round in virtually any climate because the environment is carefully controlled, often by electronic means. This method can	In-vessel composters are expensive and might require technical assistance to operate properly, but this method uses much less land and manual labor	Conversion of organic material into compost can take as little as a few weeks. Once the compost comes out of the vessel, however, it still requires a few more weeks or months for the microbial activity	In-vessel composting produces very little odor and minimal leachate.

continued on next page

Table 10 *continued*

Aerobic Composting Technology	Description	Application	Types of Waste and Waste Generators	Climate or Seasonal Considerations	Requirements	Results	Environmental Considerations
	aeration—are closely controlled. The apparatus usually has a mechanism to turn or agitate the material for proper aeration. In-vessel composters vary in size and capacity and can process large amounts of waste without taking up as much space as the windrow method.			even be used in extremely cold weather if the equipment is insulated or the processing takes place indoors.	than windrow composting.	to stabilize and the pile to cool.	

Source: United States Environmental Protection Agency. Science/Technology—Understanding the Composting Process. Wastes—Resource Conservation—Reduce, Reuse, Recycle—Composting. http://www.epa.gov/osw/conserve/rrr/composting/science.htm vermicomposting, or even the application of specialized microbes to speed up decomposition—a process known as inoculation. In general, composting is a technically simple and cost-effective alternative to landfills.

Under ideal conditions, composting does not generate methane, but under real conditions there is a risk of some emissions caused by anaerobic decomposition. This risk is high if the composting process is poorly managed, especially if the substrate is not sufficiently aerated or becomes too wet.

The following subsections discuss the appropriate scales and costs of composting operations using municipal organic waste as inputs. These categories represent the different management models in the region.

Backyard composting in recycled 200-liter plastic barrels with perforations is sufficient for a household of four persons. This approach is feasible for households with a high level of composting awareness, a garden for placing the barrel, and a use for the compost produced. The cost of a barrel can be recovered within a 4-year time period from compost sales generated from the barrel. The cost of the plastic barrel with lid is around $100, and biodegradable waste degrades in 2 months. This type of composting can be found in both high-income areas and slums throughout the region. Since waste generation is low in slum and squatter settlements, a specially designed 200-liter perforated barrel is sufficient for a group of six households, and is usually placed on a raised base with a concrete ring. Slum dwellers using compost barrels are trained and motivated to dispose of their kitchen waste in the barrels. Waste decomposes aerobically into compost over a period of 2–4 months. Small-scale, decentralized backyard composting systems are used throughout the region, but they are not considered a solution to be replicated on a large scale (Box 2).

Community-based systems are frequently box-composting systems or vermicomposting systems. These schemes are usually small-scale (less than 1,000 households) and are integrated with a residential waste collection service. Therefore, inputs are either sorted at the source or after collection, depending on the degree of initiative of residents. This composting scheme can be seen in Bangladesh, India, Nepal, and Sri Lanka, and can recycle organic waste up to a maximum of 5 tons per day (tpd). Excluding the land cost, up-front investment required for this type of plant ranges from $10,000/ton to $15,000/ton.

Company and institutional composting operations often have similar technological approaches to community-based schemes, but vary according to the quantity of waste being processed. However, as there is often space on company premises, composting can usually be practiced without affecting workplace practices or local residents. This type of composting is being practiced in a few institutions in Bangladesh, India, and Nepal. Excluding the land price, investment required for this type of plant ranges from $10,000/ton to $15,000/ton.

Medium-scale private sector–composting enterprises handle around 5–50 tons/day of organic waste. They mostly use the windrow or box methods of composting, and treat pure, biodegradable market waste that they collect themselves from the source of waste generation. This type of composting can be found in Bangladesh, Nepal, and Sri Lanka. Excluding the land cost, investment required for this type of plant ranges from $15,000/ton to $20,000/ton.

Box 2 Successful Small-Scale Composting Initiatives in India

One successful example of backyard composting is in Chennai, India, where nongovernment organization ExNoRa is promoting source segregation of waste into dry and wet categories. Households compost their waste in compost bins in their backyards, or by vermicomposting. Compost is sold in the neighborhood for 20 Indian rupees (Rs) ($0.45) per kilogram, which reflects the fact that target users are from middle- and high-income areas.

In Mumbai the municipal corporation is supporting neighborhood schemes called Advanced Locality Management (ALM). This involves technical as well as organizational support from the municipality. ALMs are involved in waste collection and street sweeping. Of 670 ALMs in Mumbai, 284 have incorporated vermicomposting. The municipal target is to have one vermicomposting scheme per ward. Compost produced within the locality is used by the residents, and the surplus is sold.

Another example of decentralized composting in India is from Lucknow, where local nongovernment organization Muskan Jyoti Samiti was authorized by the city to collect waste from 30,000 households. It charges between Rs15 ($0.34) and Rs30 ($0.68) per household per month as a waste collection fee. It has employed 900 rag pickers this purpose. Rag pickers are not paid a salary but have 100% right over the recyclables they collect. On average they earn up to Rs1,500 ($34.00) per month from selling recyclables. The city authorities gave 65 acres of land at no cost for the construction of compost pits for vermicomposting, and a cycle van for the collection of waste. The project became operational in 2000 and was financially stable within 2 years. The project recycles around 25–40 tons of waste per day. The sale of compost and fees generated from waste collection make this project viable.

Source: Authors.

Large-scale public–private composting schemes treat around 50–300 tpd of organic waste or more. These types of schemes use windrow and static pile methods, with forced aeration. These plants are frequently semi-mechanized and built on a concession agreement with the municipal authorities, or in many cases owned and operated by the municipality. They usually process mixed waste. Segregation of waste occurs at the plant; however, some plants take only market vegetable wastes, which provide a natural source of segregated organic wastes. The waste is either collected by the private company operating the compost plant, or supplied by the municipality (Box 3). Excluding the land, investment required for this type of plant ranges from $20,000/ton to $30,000/ton, depending on the degree of mechanization. Table 11 shows the types of costs and line items associated with a composting plant in India processing mixed waste. A cost reduction up to 30%–40% can be expected if waste is segregated.

Anaerobic Digestion

Biogas is generated using anaerobic digestion systems, which in turn produce a valuable, renewable energy source. Organic waste treated with an anaerobic digester yields 2–4 times as much methane in 3 weeks than 1 ton of waste in a landfill in 6–7 years.[18] This treatment method has been used for many years to treat agricultural waste, organic industrial waste, and sewage sludge, but only in recent years has it been used for municipal organic waste. Anaerobic digestion of municipal solid waste (MSW) is practiced in several countries. While anaerobic digestion has been successful in Europe owing to excellent upstream source segregation of

[18] Unnikrishnan, S., and A. Singh. 2010. Energy recovery in solid waste management through CDM in India and other countries. *Resources Conservation and Recycling*. 54. pp. 630–640.

Box 3 Experience of Large-Scale Compost Plant in Ahmedabad, India

In Ahmedabad, Gujarat state, private company Excel entered into a 15-year agreement in 1997 with the Ahmedabad City Corporation to process 500 tons of mixed municipal waste into compost. The plant began operation in 2000. It is the largest and oldest-surviving compost plant in India. As per the public–private partnership contract, the city provided 10 hectares of land at a nominal rent of 1 Indian rupee (Rs) ($0.02) per square meter per year at the landfill. The company agreed to take 500 tons of waste without any tipping fee from the municipality. Excel pays 2.5% in royalties on the sale of compost for the entire lease period. However, it was discovered during operations that Excel could not accept 500 tons of waste per day because the waste was mixed. The cost of production was Rs4,200/ton ($95/ton), but due to the inferior quality of the compost, they marketed it at Rs2,250/ton ($51/ton). Excel requested a tipping fee of Rs220/ton ($5/ton) as a reimbursement cost for segregating the mixed municipal waste at the plant. However, the municipality did not agree, since it was not mentioned in the contract document. Since the plant was in an open dumpsite and rainwater fed straight into the plant, additional costs were required for maintenance. In addition to these issues with the city corporation, Excel wanted to market the product by themselves. Considering the bulk volume requiring large storage facilities and the low price, they had to limit the area for sales to within 200 kilometers. As a result of the mixed waste and open composting, Excel treated only 70 tons of waste per day, instead of 500 tons. The city started to provide separated waste from hotels, parks, and households from doorstep collection, which led to an overall improvement in quality and a better price for the compost. For example, during 2007–2008, 2,378 tons of compost were sold, amounting to Rs3,894,000 ($88,500). During 2009–2010, 6,324 tons were sold, amounting to Rs11,114,900 ($252,611). Thus, with the additional steps taken by the city, the sale of compost increased by 3,946 tons, with company revenues of Rs7,220,900 ($16,411) and additional city revenues of Rs180,526 ($4,102) (from royalties)—a 91% improvement.

Source: Authors.

waste, the technology has not been so successful in many Asian cities where segregation of waste at source is poor. Moreover, the rate of implementation is hindered by the high up-front investment, maintenance costs, and technical skills requirements. Anaerobic digestion plants (and RDF facilities, as described below) are capital-intensive and require well-trained operators, resulting in an extremely expensive organic waste management option. Throughout the region, this option should be carefully weighed against other less-expensive ones, and matched to fit municipalities' management and technical capacity. Such plants are highly specialized and require technical collaboration with firms (mostly international) that have patented technologies.

The sustainability of an anaerobic digestion plant relies heavily on a homogenous organic waste stream that is mostly free from inert materials (stones, bricks, and metals). As a rule of thumb, a city with a population of 1 million generating an average of 0.4 kilograms (kg) per capita of waste a day containing 60% organic matter, could power a 2-megawatt (MW) capacity anaerobic digester. This could supply energy for its own operation (20% of the electricity generated) and the balance could be exported to the grid. Therefore, small-scale projects that generate biogas from sorted organic waste are best suited for the region, as they require less investment, are easier to operate, and are a better fit to the types and volumes of municipal waste.

Examples of sources include vegetable markets and food waste from hotels, hospitals, and university dormitories. There is also potential for using slaughterhouse waste for the production of industrial-scale biogas. In Kerala, India, nongovernment organization (NGO) Biotech has developed biogas digesters for managing food waste and other organic waste from more than 20,000 households, 220 institutions, and 19 municipal sites. The digesters are prefabricated

Table 11 **Sample Cost Estimates for a Composting Plant, 2005–2006**

Infrastructure Required	Population[a]		
	Under 50,000	Up to 100,000	Up to 200,000
Disposal site including landfill area (acre)[b]	20+15	25+20	30+25
Compound wall or barbed wire fencing	Cost depends on materials used		
Internal and peripheral roads	Rs200,000	Rs300,000	Rs500,000
Greenbelt along the boundary	Rs50,000	Rs75,000	Rs150,000
Weigh bridge	Rs500,000	Rs500,000	Rs750,000
Control room as office and laboratory	Rs300,000	Rs400,000	Rs500,000
Concrete yard with drains: Area (cubic meter) Cost	 6,000 Rs4,500,000	 12,000 Rs8,000,000	 18,000 Rs12,000,000
Shed for processing machinery with space for storing and bagging	Rs1,500,000	Rs2,500,000	Rs4,000,000
Processing machinery (such as rotary screens with conveyor belts)	Rs3,000,000	Rs5,000,000	Rs8,000,000
Processing equipment	Rs1,000,000 (1 tractor with accessories)	Rs2,500,000 (1 medium payloader and 1 tractor with accessories)	Rs6,500,000 (1 heavy-duty payloader, 2 medium payloaders, and 1 tipper)
Vehicle shed	Rs50,000	Rs50,000	Rs100,000
Leachate tank Capacity (liter) Cost	 20,000 Rs50,000	 35,000 Rs100,000	 50,000 Rs200,000
Water supply (excluding bore well cost) and lighting	Rs100,000	Rs150,000	Rs200,000
Generator with panel board: Capacity (horsepower) Cost	 25 Rs600,000	 50 Rs750,000	 100 Rs850,000
Total	**Rs11,800,000**	**Rs20,325,000**	**Rs33,750,000**

Rs = Indian rupee.

Note: Estimates given are for treating unsegregated municipal solid waste. A reduction can be expected up to 30%–40% if waste is segregated. Case based on Karnataka Compost Development Corporation. ($1 = Rs44)

[a] Although 25 tons per day (tpd) of waste are expected to be generated for a population of 50,000, provision is made to treat garbage up to 50 tpd (up to 100,000 people). Similarly, for a population of up to 100,000, provision is made to treat up to 100 tpd; and for a population of up to 200,000, provision is made to treat up to 200 tpd.

[b] Value of site is not included.

Source: Zhu, D., et al. 2008. *Improving Municipal Solid Waste Management in India: A Sourcebook for Policy Makers and Practitioners*. Washington, DC: World Bank.

from ferro-cement and gas collectors are made from fiberglass-reinforced plastic which can be installed quickly and easily on the site and have no electric or moving parts. Biogas is produced from the decomposition of the organic matter in anaerobic conditions, and the gas is used directly for cooking, producing household savings of about 50% when replacing liquefied petroleum gas. The main feedstock for the plants is food waste, but human or cow dung needs to be used initially to provide a culture of suitable bacteria to get the digestion process started.

Refuse-Derived Fuel

RDF is a fuel made of dehydrated combustible waste converted into fluff, and then into pellets, briquettes, or logs. RDF consists largely of the combustible components of municipal waste, such as plastics and biodegradable waste. RDF-processing facilities are normally located near a source of MSW. RDF pellets can be used as an alternative fuel in combustion engines and boilers to generate electricity in combination with other traditional fuels, such as coal, biomass, or tire scraps. The waste used to make RDF may contain both plastic and organic waste, but it should not contain incombustibles such as glass and metals. Combustible organic materials with high-caloric value organic waste can be converted into usable fuel briquettes. Examples of such materials are paper, textiles, sawdust, wood, and plant residues. Separated plastics, excluding PVC, can also be used in the production of RDF to increase the caloric value. RDF can be used as an alternative to fuelwood, coal, and kerosene, and can be promoted to reduce the use of fuelwood. This is particularly important in countries such as Nepal where there is an acute shortage of fuelwood. RDF can be used to generate electricity with an industrial boiler or cement kiln, or it can be added to a coal-fired power plant. Adequate management and technical capacity is required to operate and maintain such facilities, and it is critical to ensure adequate occupational and environmental safety measures are taken during the design and operation stages. There are two RDF facilities in Delhi, India, which are registered for Clean Development Mechanism (CDM), and another nonregistered RDF plant producing 225–450 tpd of RDF, indicating that the technology is growing in popularity in the South Asian context. There are several RDF plants in India in Bangalore, Guntur, Hyderabad, and Mumbai of 50–700 tpd capacity, and more are being constructed in Delhi.

Landfill Gas Extraction

Generally, over half of the waste dumped in landfills in South Asian countries is organic waste that converts to methane gas under anaerobic conditions. Landfilling is the least desired option for managing organic wastes, as most landfills within the region are nonengineered open dumpsites. However, recently efforts have been made to develop engineered landfills with methane gas capture systems throughout the region.

Methane gas production depends on the waste composition, weather conditions, and landfill management. For methane gas extraction, the amount of waste dumped should generally be greater than 1 million tons in a site with a depth of more than 10 meters. The landfill gas can be recovered using a network of perforated gas-collection pipes; the gas can be used for power generation.

The production of methane gas starts in a landfill site within a few months of waste disposal, and lasts for about 10 years or more, depending on the composition of waste, its availability, and moisture content. Generally, the depth of the methane gas well is 80% of the height of the landfill.

Technology Selection: How to Choose the Right Organic Waste Treatment System

The selection of the right technology for organic waste management is important for local governments and operators throughout the region. In most cases, technologies are prescribed without any consideration of the local context, and as a result the projects often fail. Municipal officials may also be attracted to the technology that is successfully used in industrial countries, without evaluating its applicability to the local context. Experience shows that more mechanization is required for larger processing plants. Cities can use a combination of technologies such as composting to tackle their vegetable and food waste, biogas digesters for fish and meat waste, and RDF for dry organic waste of high caloric value. More advanced waste treatment systems in Europe use a combined mechanical biological treatment system which is currently nonexistent in South Asia, as it comes at a higher cost and strictly relies on segregated waste, which is more common in Europe. The key criteria to be considered before selecting the type of organic waste treatment system are as follows:

Population size and waste volume. Based on population size and the daily waste volumes, a city can decide the scale of organic waste-recycling facilities. Larger cities with high waste volumes can consider more mechanical systems, as their higher operational costs may be recovered through increased revenues from the sale of compost, higher tipping fees, and carbon financing. Efforts should be made to find cost-effective solutions.

Waste composition. The physical composition and chemical characteristics of the municipal waste will enable local government officials and private operators to decide which organic waste technology will be most suitable for a particular city. As indicated earlier, a significant portion of waste in the region is biodegradable organic waste, while the rest consists of inorganic recyclables and miscellaneous inert matter. Ratios vary from city to city, with more industrial and economically developed cities possibly containing more hazardous or construction waste material.

Availability of land. The type of technology selected to cater to the amount of waste volumes will be a factor in determining the amount of land required. However, land scarcity is a major issue throughout the region. Local officials are typically constrained to find available land for waste disposal, which requires large areas typically situated 500 meters from communities. Municipal authorities can play an important role in making suitable land available for current and future waste management disposal and treatment through improved land use planning and regulation.

Availability of workers and capacity. An abundance of unskilled workers makes labor intensive technology more attractive for South Asian cities. In smaller cities, mechanized approaches should be avoided to minimize investment and operational costs. The health and safety of the workers must be considered, and personal protective equipment (e.g., hard hats, closed shoes, reflective wear, gloves, and masks) and occupational health and safety plans must be basic requirements in all facilities. Facilities should also promote the employment of women, create daycare facilities, and provide healthy meals for workers. These attributes are common in many privately run operations, including in Bangladesh.

Existing policies linked to waste management. Policies conducive to promoting public, private, and community partnerships that also encourage waste reduction, recycling, and reuse are helpful. For example, without proper policy guidelines, source segregation of waste is difficult. Private investment in waste management and the recycling sector should be encouraged with up-front capital subsidies, incentives, and tax breaks, or reduced subsidies on chemical fertilizers or nonrenewable energy sources to create a level playing field for the organic waste product market.

Marketing of product. Financial sustainability of facilities relies on a dependable consumer market for selling organic end products (e.g., compost, biogas, and fuel briquettes). For example, a compost or biogas plant that does not generate constant revenues from compost or electricity sales will not last. Table 12 summarizes some of the key criteria for selecting the right technology.

Table 12 **Criteria for Selection of Appropriate Technology**

Technical Criteria	Financial Criteria	Managerial Criteria
• Experience with technology under South Asian conditions • Scale of operation • Required land, water, and power • Locally available spare parts • Process aesthetics • Environmental impact	• Investment cost • Operation cost • Financing mechanisms • Market for end product (demand, price)	• Labor requirement • Skills for operation and maintenance • Skills for monitoring and management

Source: Zhu, D., et al. 2008. *Improving Municipal Solid Waste Management in India: A Sourcebook for Policy Makers and Practitioners*. Washington, DC: World Bank.

Greenhouse gas reduction. It is estimated that direct emissions reductions from improved municipal organic waste management are 20%–98% for composting and 60%–100% for anaerobic digestion when compared to landfilling.[19] Also, the use of RDF technology for registering such projects for carbon financing through the CDM is on the rise in India.

Tables 13 provides a technology selection matrix for different sized towns and cities, and Table 14 lists technology selection indicators which should be carefully considered by local government officials prior to the selection of any MSW management technology for their cities.

Private Sector Participation in Organic Waste Management

Various organizational and fiscal constraints have made municipalities ill-equipped to effectively manage MSW and consider organic waste recycling. Engaging the private sector in MSW

[19] Sang-Arun, J., and M. Bengtsson. 2009. *Improved Organic Waste Management: Climate Benefits Through 3Rs in developing Asian Countries*. Hayama, Japan: Institute for Global Environmental Strategies.

Table 13 Technology Selection Matrix for Different Sized Towns and Cities

Technology	Small-Scale Waste Generation (less than 5 tpd)	Medium-Scale Waste Generation (less than 50 tpd)	Large-Scale Waste Generation (more than 50 tpd)	Comments
Composting	Suitable for • backyard composting, • community-based systems, and • company and institutional composting.	Suitable for • backyard composting, • community-based systems, • company and institutional composting, and • medium-scale private sector composting.	Suitable for • medium-scale private sector composting, and • large-scale private-composting schemes with and without the Clean Development Mechanism.	Source-separated organic waste required. It should not be mixed with any kind of toxic or hazardous elements. Waste with high organic matter, high moisture content, and low caloric value can be suitable for composting.
Anaerobic digestion (biogas)	Suitable: Anaerobic digestion facility may be placed along with a small compost plant to utilize fish and meat waste.	Suitable: Anaerobic digestion facility may be placed along with a compost plant to utilize fish and meat waste and food waste from hospitals, hotels, and dormitories.	Potentially suitable: Medium industrial anaerobic digestion facility to be established to utilize fish, meat, and slaughterhouse waste, however, experience is limited. Food waste from large hotels, vegetable market, and hospital could be used.	Waste should be either source-separated or sorted and pretreated manually to gain relatively pure organic content before feeding into the digester. Contaminated combustibles can be made into refuse-derived fuel and the digestate, which is the by-product of anaerobic digestion, can be used for soil conditioning.
Refuse-derived fuel	Not suitable: Small facility is not financially viable because the amount of raw material is not sufficient to run the plant in a cost-effective manner.	Suitable: Enough dry organic raw materials and markets for refuse-derived fuel are available.	Potentially suitable: The calorific content of waste content is suitable and there is a market for the product. The product can also be used as additional fuel in coal-fired power plants.	The advantage of refuse-derived fuel is it can take mixed waste inputs (except inert matter). Therefore, these systems can accept plastics and organic waste inputs.

tpd = ton per day.

Source: Authors.

Table 14 **Technology Selection Indicator Matrix**

Indicator	Existing Situation in South Asian Cities	Technology		
		Composting	Anaerobic Digestion (Biogas)	Refuse-Derived Fuel
Composition of waste	Organic fraction high (average around 70%)	Highly suitable: Source segregation program can improve the quality of the product. In case source segregation is not done properly, it is recommended to use vegetable market waste and wet organic waste from hotels and restaurants.	Suitable: Source segregation of waste can improve biogas production. Homogenous waste such as manure, slaughterhouse waste, and food waste from hotels, hospitals, and student dormitories are suitable.	Potentially suitable: It is not economically attractive to use fresh organic waste. It would only be suitable for dry soiled plastic, fabrics, paper, and wood waste.
Quality of waste	Mostly mixed waste	Medium quality (low heavy metal) required. Source-separated waste would be highly desirable.	Medium quality (low heavy metal) required. Source segregation of waste required.	Low quality (no dioxin-emitting waste) required. PVC with chlorine should be controlled to avoid emission of highly toxic gases (dioxin and furan).
Availability of raw material	Densely populated large cities have abundance of organic raw material.	Available	Available Segregation and grinding needed	Available Drying of organic waste needed
Moisture content (% wet weight at point of generation)	70%–80%	Suitable	Suitable	Not suitable for refuse-derived fuel Needs secondary drying
Caloric value	800–1,000 kcal/kg	Suitable	Suitable	Wet organic waste not suitable (only dry organic matter with higher caloric value is suitable)
Land requirement	Land constraint because of high population	150–200 m^2/ton (for static pile) 300 m^2/ton (for windrow method	400–500 m^2/ton (includes space for drying of slurry)	125 m^2/ton
Investment cost (excludes land cost)	Low cost is preferable; cannot afford costly solution.	$100–$30,000/ ton	$350–$500/m^3 of digester size (with electricity generation option) or $23,333–$33,300/ton of waste input (dry matter)	$75,000–$100,000/ton of design capacity

continued on next page

Table 14 *continued*

Indicator	Existing Situation in South Asian Cities	Technology		
		Composting	Anaerobic Digestion (Biogas)	Refuse-Derived Fuel
Operation cost	Should not be high. Low operational costs are preferable.	Low to medium	High	High
Skilled workers	Simple labor-intensive technology preferred. Abundance of unskilled labor exists.	Requires trained workers	Requires trained workers	Requires trained workers
Marketing of output	Must have a market for the end product.	Requires proper marketing strategy	Difficult to sell (gas or electricity) commercially if there is no feed-in tariff set by the government. However, for small-scale plants, both biogas and electricity can be used for the producer's internal use.	Need proper marketing strategy. Refuse-derived fuel is an alternative for coal, furnace oil, or diesel. Without government promotion of the product, marketing may be a problem.
Opportunity of income from carbon trading	Desirable. It makes the project attractive with additional income from carbon emission trading.	High	High	High
Technology	Easy to understand and suitable for the economy and climate.	Simple	Comparatively simple	Simple
Capacity of the project or facility	Can be small, medium, and large in scale.	Household to large scale	Household to large scale	Medium to large scale

kcal/kg =kilocalories per kilogram, m^2 = square meter, m^3 = cubic meter, tpd = ton per day.

Source: Authors.

management can (i) bring in private finance for modernizing the local waste system, (ii) increase efficiencies of the waste collection and treatment process, (iii) enable cost savings and raise productivity, and (iv) improve the quality of services. Municipalities must change their role from that of a service provider to that of a services facilitator, simplify bureaucratic processes within the traditional solid waste management system, and enable performance-based private sector participation. Mainstreaming private sector participation can improve effectiveness and efficiencies and ensure value for money of public interventions.

Public–private partnerships (PPPs) take various forms. Service contracts require the private partner to provide a clearly defined service to the local government. In the case of a management contract, the private partner is responsible for core activities such as operation and maintenance. In some cases, services are leased, where the private partner is fully responsible for operation and maintenance and the public partner is responsible for new investments. Single or multiple private players may be involved, depending on the type of waste management solution. An example of a successful PPP arrangement in Bangladesh is provided in Box 4.

Box 4 **Successful Private Sector Experience in Dhaka, Bangladesh**

Waste Concern is a private compost operator based in Dhaka, Bangladesh, and a recognized leader in the organic waste management sector throughout Asia. The company submitted a waste-composting project for Clean Development Mechanism registration for approval to their designated national authority in March 2006, and the project was approved in July 2006 as a registered Clean Development Mechanism project. Verification of certified emission reductions (CERs) was in June 2011, and issuance of the first CERs from the United Nations Framework Convention on Climate Change is expected by the third quarter of 2011. Subsequently, a 15-year concession agreement was signed with Dhaka City Corporation in 2007. The delay in signing the public–private partnership contract was due to the lack of Government of Bangladesh guidelines on such partnerships for the waste sector, which were subsequently issued in 2010. The project started operation in the fourth quarter of 2008. This is the first concession agreement in solid waste recycling in Bangladesh. Under this project, Waste Concern can collect up to 700 tons/day (tpd) of organic waste (not mixed, only vegetable waste), incrementally starting from 100 tpd. Land for composting is arranged by Waste Concern along with collection of organic waste. No waste collection fee or tipping charge is provided to Waste Concern by the municipality. If Waste Concern fails to collect waste, there is a penalty clause of 250 taka (Tk)/ton ($3.50/ton). All the vegetable markets are under the jurisdiction of Waste Concern for the collection of waste. However, for the first plant with a capacity of 100 tpd, Dhaka City Corporation has allowed Waste Concern to collect waste from six vegetable markets of Dhaka, and daily monitoring of the amount of waste collected is undertaken by the municipality. This project is a joint venture between Waste Concern from Bangladesh, World Wide Recycling, Entrepreneurial Development Bank of the Netherlands (FMO), and High Tide Investments of the Netherlands. The project uses aerobic composting in a shed with forced aeration.

The compost produced by Waste Concern has been approved and certified by the central government. It took 18 months for Waste Concern to obtain the registration and approval from the government. Advanced Chemical Industries (ACI), the largest fertilizer marketing company in Bangladesh, purchases all the compost from the factory gate at a price of Tk6,000/ton ($85/ton) for a 40-kilogram bag, and Tk10,750/ton ($150/ton) for a 5-kilogram bag. ACI then distributes it through its own network in villages as far as 500 kilometers from the plant. The production cost per ton of compost, including the waste collection cost, is Tk4,500/ton ($63/ton). Apart from sale of compost, the project earns 25%–30% extra revenue from the sale of carbon credits. There is no marketing problem for Waste Concern. ACI is the sole distributor for the compost. The process used for composting is forced aeration using the box method. The entire composting operation is done with overhead cover and a leachate collection system. The first plant has a 100 tpd capacity and is located in Bulta, near Dhaka. Waste Concern will start the construction of its second plant with a capacity of 250 tpd close to the site of the first plant. The project is financed by FMO, High Tide Investments of the Netherlands, and Dutch Bangla Bank of Bangladesh.

Source: Authors.

Key Considerations in Public–Private Partnerships

The overall objective of involving the private sector is to achieve improved solid waste management services, especially in treatment and recycling. Municipalities in the region usually provide a contract to the private sector for collection of waste and street sweeping, mostly by means of a lump-sum payment or, in many instances, on a per ton basis in cities with weigh bridges at their landfill sites. It is a common tradition in Bangladesh, India, and Nepal to have private waste collection contractors, both primary and secondary.

Engaging the private sector and forging partnerships to treat and recycle organic waste involves investment. Depending on the type of technology, a design capacity of $10,000–$100,000/ton is required in addition to the land cost. The partnership will only work well when risks and benefits are clearly discussed, understood, and shared by all parties, and potential sources of conflict are resolved in advance. The following issues must be considered to facilitate private sector participation in organic waste recycling:

Municipal laws. There must be enabling clauses in the municipal law to engage the private sector through PPP. These laws provide clear rules and guidelines for private investment in public waste services. Ordinances requiring source segregation are standard practice in cities throughout the world.

Quality and quantity of waste. The performance of organic waste-recycling projects depends on the quality and quantity of waste. Most compost and waste-to-energy projects using waste-to-energy technology fail to yield desired results due to faulty processing and the low quantity of mixed waste. This issue must be addressed in PPP contracts, along with equitable risk sharing, since both the quality and quantity of waste vary from season to season, ultimately affecting cash flow.

Cost recovery. Cost recovery has the potential to shift the costs of waste management—including administrative, capital, and operational costs—to households, allowing for more appropriate sharing of costs following the polluter pays principle. Cost-recovery measures can include (i) administrative charges and fees covering the establishment and maintenance of registration; (ii) authorization or permitting systems; and (iii) user charges and fees for publicly provided waste collection, treatment, and disposal services. However, the government must have legislation in place to enable the private sector to be paid for every ton of waste recycled by the municipality. In case the private sector has to collect and recycle waste and recover the cost through fees imposed on residents, legislation must allow the private sector to recover this fee in conjunction with other service charges, such as water supply or electricity. In Toronto, Canada, waste-collection fees are linked with the water bill. Adjustment of payment to reflect inflation is an issue requiring consideration, and must be addressed in the PPP contract. However, it is also important that any taxes imposed on households do not result in increased illegal dumping, and should instead encourage the “reduce, reuse, recycle” (3R) approach. At the household level, waste-collection fees based on weight or volume for brown waste (waste to be landfilled), in tandem with free collection for recyclables, including organic matter, are widely used as incentives for practicing 3R. This type of policy usually coexists with investments in either curbside collection or community deposit sites for recyclables.

Restriction of contract duration. If the rules surrounding the time limit of a contract are unsuitable for waste recycling, they will need to be modified. Organic waste-recycling plants usually have a long payback period. As such, the contract for build–own–operate (BOO) or build–own–operate–transfer (BOOT) operations should be for at least 15 years, and preferably more than 20 years.

Taxes and custom duties. When the private sector provides public services such as waste collection and recycling, it must be given special tax privileges. An example of an important tax privilege would be the cancellation of import duties for required machinery.

Lease of municipal land. Modifications in legislation may be required to enable local governments to allow long-term lease of land to the private sector (both local and international companies).

Registration. Agencies and ministries that deal with registration, permits, and licenses should be identified to implement PPP projects for MSW or organic waste treatment. The most effective process is a "one-stop" approval. Many projects are delayed for years due to delays in obtaining permits and licenses to operate. Lengthy approval periods and tendencies not to honor the agreement subsequent to signing create many problems and should be avoided.

Environmental standards. Partnership documents and contracts are required to keep abreast of current and future environmental standards. These should specify the performance required by the private sector. Examples include leachate water treatment, buffer zones around the recycling plant, use of rainwater instead of fresh water, and odor control.

Transparency and public disclosure of information. Organic waste-recycling facilities can generate public opposition. Such opposition may be fueled by nondisclosure and lack of information. Each organic waste project must be transparent, ensuring that appropriate environmental and financial information is made readily available to the public.

Product marketing. In many countries, including Bangladesh, there is a requirement for compost registration for marketing purposes. This process usually has two stages: a field trial of compost and a laboratory analysis. It may take 1–2 years to obtain the permit to market the compost. In such an event, the local authority should buy the compost from the plants and use it for city greening programs in parks, landscaping, and road median plantations, instead of buying animal manure. However, in such situations, the local authority should pay the market price to the compost plant operators until registration is approved and the operator can sell it in the market. Without income from the sale of compost, the plant's cash flow will be affected. This issue must be considered during PPP contract negotiations. RDF briquettes have a limited number of users, unless the developer uses them in his or her own plant furnaces or sells them to brick kilns. Marketing of products must be carefully reviewed in the PPP contract.

Technology identification. Selection of technology without considering the waste characteristics of the region has led to the failure of some projects. A biomethanation project in Lucknow, India, was unable to produce the desired results because the waste was not segregated and had a high plastic content. Careful selection of technology based on local waste characterization and management should be practiced for PPP projects.

Independent monitoring. Independent performance monitoring must form part of the contract, with detailed schedules for performance measurement linked to a strong set of incentives for improving service as well as penalties for nonperformance.

Table 15 shows the options available for PPP for large-scale organic recycling projects, processing more than 50 tpd of waste.

Table 15 **Public–Private Partnership Options for Large-Scale Projects**

Option	General Features	Benefits for City	Operation and Maintenance	Capital Investment	Contract Duration
Build–own–operate	Private sector builds compost, biogas, or refuse-derived fuel facility, and owns and operates it. Private sector charges a tipping fee to recover its costs. Land for the plant is provided by the private sector. The public sector will assign a certain amount of waste to be recycled by the private sector.	Besides creating competition in the market, the city transfers the responsibility of investment and management in a cost-effective manner. There is limited risk to the city.	Private	Private	20–30 years
Build–own–operate–transfer	This is the same as build–own–operate with an additional clause for transfer of assets to the public partner. The public sector provides land for the plants on lease.	Benefits include obtaining private sector investment with operational and management risks being shouldered by the private partner, while assets are transferred to the public sector.	Private	Private	20–30 years
Lease	The private sector is fully responsible for operation and maintenance issues, and the public partner is responsible for new investment. However, it is very important that the private sector involved in operation and maintenance is also involved in the design of the plant. The public sector may provide a tipping fee for managing the waste.	Benefits include improved services along with financial benefits for the city (since part of the revenue from the facility will also go to the municipality). It is similar to a management contract since the facility belongs to the city.	Shared	Public	15–20 years

Source: Zhu, D., et al. 2008. *Improving Municipal Solid Waste Management in India: A Sourcebook for Policy Makers and Practitioners*. Washington, DC: World Bank.

How to Select a Private Sector Partner

The transparent selection of the right private sector partner for the city is very important for the success of organic waste management projects. For BOO and BOOT projects, the city should first select a technology before selecting a private sector partner. It is not advisable to initiate the bidding process without a clear technology in mind.

The selection of a private sector partner is a two-stage process, beginning with advertising for expressions of interest, followed by detailed requests for proposals. The selection of a private sector partner will require proper evaluation of the candidate in terms of (i) experience in managing similar commercial plants, (ii) technical labor availability, (iii) financial condition of the private sector company, (iv) provision of an in-house laboratory facility to check different environmental parameters, and (v) a marketing strategy for the products. It is important for the PPP operator to have sufficient experience of designing and operating successful waste treatment plants of a similar size. The firm with the technical experience should be the majority shareholder in a joint venture.

For selection of a private partner for the lease agreement, the city can invite bids from the private sector from candidates with experience in design, operation, and maintenance of such facilities. A consideration for selection can be whether the private sector is able to recover the costs of operation and maintenance from revenue generated by the plant itself, such as sale of compost and carbon credits. Another important consideration is whether the private sector company requires subsidies from the city for operation and maintenance, in addition to the tipping fee provided by the local government. Such subsidies include those for capital investment, transport of compost, interest payments, utilities (water and electricity), and promotion and marketing fees.

Planning and Operational Guidelines

Proper operation of an organic waste-recycling facility depends on (i) identification of environmental legislation and land use regulations, (ii) proper design of recycling plant and selection of appropriate machinery, (iii) promotion of source segregation of waste, (iv) marketing of products, and (v) operational issues linked with organic waste-recycling facilities.

Identification of Environmental Legislation and Land Use Regulations

Since national regulations vary significantly, they need to be examined on a case-by-case basis. Prior to starting a composting, biogas, or RDF project, the laws and regulations governing the project need to be examined thoroughly by the municipality and operator to avoid delays or even subsequent cancellation of the project. If necessary, the prospective private sector partner should seek advice from a legal expert, the environmental agency, or municipal authority on the following:

- **Environmental laws and policies.** Determine the existence of environmental legislation supporting or prohibiting waste recycling and reuse. It is important to obtain environmental clearance certificates before any construction.

- **Solid waste management rules.** Determine the existence of government rules supporting or prohibiting waste recycling and reuse. Identify whether source segregation of waste is promoted, and whether a tipping fee is allowed.
- **Land use regulations and urban planning strategies.** Determine the existence of regulations on the construction and operation of waste treatment plants. In some cases, the establishment of such plants in residential areas, wetlands, and agricultural land is prohibited. It is vital that the project proponent for any organic waste-recycling facility obtains land use clearance from the environmental and/or planning authority.
- **Agricultural laws.** Determine whether sale of compost is regulated and/or subsidized in any way (e.g., through quality certificates, reuse limitations, or pollution control). India's Ministry of Agriculture requires a basket or co-marketing scheme for chemical fertilizers and compost.
- **Trade laws and regulations.** It may be a requirement to register the compost with the agriculture department prior to marketing. In many countries, it takes time to register compost before it can be marketed.
- **Fiscal regulations.** Determine whether there are any tax breaks for operating a waste-recycling plant, as well as concessionary import duties for machinery.
- **Feed-in tariff.** Determine whether the country allows a feed-in tariff for biogas or electricity generated from organic waste. Feed-in tariffs offer a guaranteed power purchase agreement for electricity generated from a renewable energy source. These purchase agreements are generally framed within long-term (15–25 years) contracts.

Recommendations for Compost Plant Design and Equipment Selection

An organic waste-recycling plant comprises an operation area and a green buffer zone. The buffer zone, formed by a belt of bushes and trees surrounding the operation area, improves the visual appearance of any recycling plant. It also buffers odor during windy periods. The plant's design capacity should be based on the organic waste to be processed per hour and the number of shifts to be operated per day. The design of the plant should be modular so that as the waste-processing capacity increases, additional operational areas can be easily added. Since land is a constraint for compost plants, the box method with static pile and forced aeration, which requires less area compared to the windrow method of composting, may be considered (Table 16).

The operation area of a recycling plant should be divided into different zones. A composting plant should contain space for waste unloading and sorting, composting, maturing, and sieving and bagging of the compost. Space is also required for storage of compost and recyclables, and storage and treatment of wastewater. These zones must be arranged to ensure efficient workflow of the composting process.

Additional space should be allocated for storage for machinery, an office, a dining area, first aid supplies, toilet and bathing facilities for the workers, and a day-care center (for a plant processing more than 100 tpd of waste). It should be noted that the final setup of the site is strongly dependent on local conditions.

Since the region experiences 4–5 months of monsoon, the operation area should be protected with a roof in order to operate the plant year-round. This will also help avoid odor problems and

Table 16 Design Specifications for a Compost Facility of 100 Tons per Day

Facilities	Space Required (m^2)	Roof Required
Composting area		
Sorting area	530	Yes
Storage of rejects	35	Yes
Storage of recyclables	35	Yes
Composting pad	3,075	Yes
Maturation area	3,533	Yes
Screening and bagging area	1,000	Yes
Compost storage area	1,000	Yes
Subtotal composting area	**8,750**	
Facilities		
Office	300	Yes
Sanitary facilities	50	Yes
Tool shed	40	Yes
Water supply point	15	No
Additional space requirement		
Vehicle parking area	300	No
Green buffer zone (trees and bushes)	200	No
Total area	**9,685**	

m^2 = square meter.

Note: This excludes circulation area and ramp for waste reception. Circulation area can take up to 40% additional space.

Source: Based on compost plant designed by Waste Concern.

leachate from fresh waste. At least 50%–55% of the plant area should be covered in compost plants. There is a need for a leachate collection tank in compost and RDF plants. Leachate may be recycled. Moreover, for biogas plants, it is essential to have a drying bed for slurry. The compost, biogas, and RDF site should have separate storm water drainage and leachate collection systems. There are always risks of rodents and ground and surface water pollution from waste treatment and recycling plants, therefore compost plants should have a concrete floor. Moreover, compost plants must have a boundary wall and green space in front to act as buffer.

In addition, the following additional features may also be considered for the organic recycling facility:

Water supply and rainwater harvesting. A reliable onsite water supply is a basic infrastructural requirement in a composting, biogas, and RDF site. Water is needed for hygienic purposes and for watering the compost heaps, and may be provided by a standpipe in the operational area. For biogas plants, there is huge demand to add water to waste as feedstock. An additional water storage tank is, however, advisable if the water supply is not continuous.

A further useful feature is a rainwater harvesting system. The roof of the composting shed and other facilities can be specially designed to collect rainwater. During the rainy season, water can be collected in a tank for use during water shortages in the dry season. The storage volume depends on the length of the dry season and the daily water demand. Rainwater can be used for the composting process, for cleaning and washing of the composting plant, and for watering the green belt.

Organic farming demonstration site. If sufficient land and staff are available, a small plot inside the composting plant can be used as a demonstration unit for organic farming, or as a nursery for potted plants. The core idea is to encourage the owner of the composting plant to keep the facility as "clean and green" as possible. A clean, hygienic, and pleasant environment near a composting plant can combat negative perceptions of waste treatment, and the use of compost can be directly demonstrated to visitors.

Wastewater reuse system. A significant amount of wastewater is generated during the facility's cleaning and composting processes. Onsite-generated wastewater can be reused for new compost piles to maintain the moisture balance and enhance the decomposition process. Wastewater from the drainage system can be collected in a small covered storage tank below ground level. By mixing this wastewater with fresh water, or water from the pipes or rainwater tank, water may be conserved.

Energy-efficient lighting system. If the compost plant is connected to the electricity grid, an energy-efficient lighting system should be fitted to reduce operational costs in the long run.

Machinery for plant. For small and medium-sized towns, it would be appropriate to utilize manual, labor-intensive methods with personal protective equipment instead of mechanization (Table 17). However, for large-scale compost plants dealing with more than 100 tons per day (tpd), semi-mechanization is mandatory. For the transfer of waste inside the plant, a wheel loader is a must, along with a mechanical screener and bagging machines. Caterpillar front-wheel loaders are expensive; this cost can be lowered if the loaders are attached to a tractor. When the windrow method of composting is used, a mechanical turner for aeration of compost is very advantageous, since it reduces the concrete floor area required during turning of waste. Reduction in the concrete area can reduce the capital cost for civil works.

Promotion of Source Segregation

The supply of source-segregated waste increases the recovery and reduces the cost of compost and/or biogas production. However, source segregation is not common practice throughout the region, and represents a critical area for improvement. It can be facilitated if households agree to segregate waste, placing biodegradable (or "wet") waste into a separate containers, as is the practice in developed countries with established organic waste management programs. Implementation of source segregation requires long-term preparation (community awareness and behavior change initiatives) and vehicle modification (two compartments in the container). The following section highlights some good practices to promote source segregation in the South Asian context.

Municipal ordinances. Municipalities around the world have already made source segregation and enforcement integral parts of their local laws (Box 5). Penalty clauses for households that

Table 17 Typical Equipment Used at a Compost Plant

• Sorting table (if required) • Mechanical screener • Buckets • Shovels • Rakes (long or short handle) • Watering pots and pipes • Thermometer • Moisture meter • Oxygen meter • Sieving drum or machine • Bags (woven plastic bags, size depends on the market requirements)	• Equipment for sealing bags • Front-wheel loader (for large-scale compost plants) • Mechanical turners (if windrow composting is used) • Blowers (if the static pile composting method is used) • Brooms (for large-scale plants, a mechanical floor-cleaning machine is required) • Baskets • Uniforms, gloves, boots, and face masks • Bagging machine

Source: Authors.

Box 5 Sample Municipal Ordinance Requiring Source Segregation—Quezon City, Philippines

Quezon City, Philippines. City Ordinance No. SP-1707, S-2006, effective June 2011, requires the segregation at source of all household, institutional, industrial, and commercial wastes into wet and biodegradable, and dry or nonbiodegradable. Section 10 of Republic Act 9003, known as the Ecological Solid Waste Management Act of 2000, stipulates that segregation and collection of solid waste will be conducted at the *barangay* (village or district) level. The city government shall conduct a 2-week dry run upon the effectivity date so that the residents can familiarize themselves with the types of wastes to be segregated and the schedule of collection. An estimated 300 information, education, and communication campaigners of the city-contracted haulers will also be simultaneously deployed in all barangays within the city to explain in detail the implementation procedures. After the dry-run period, the city government, with the assistance of *barangay* officials, will strictly implement the no segregation, no collection policy. All *barangays* will implement segregation of biodegradable and nonbiodegradeable wastes in each household and door-to-door dedicated collection of segregated wastes. Collection schedules will be Monday–Wednesday–Friday, with Monday and Friday collection for biodegradables and Wednesday collection for nonbiodegradables.

Source: Local Government of Quezon City. 2011. http://www.quezoncity.gov.ph/

do not segregate organics from other waste are common and waste is simply not collected if it is not segregated. The success of San Francisco, California's waste segregation program is due to the strict implementation of the city's Environmental Code which requires source segregation. Few cities in South Asia have similar rules and systems for segregating organic wastes with a separate collection system to produce useful recycled organic products. However, there are some initiatives within the region to promote source segregation (Box 6).

Distribution of separate bins. San Francisco's recycling and garbage law requires every household and business to use three different bins for discards: blue for recyclables (e.g., cans,

Box 6 Signs of Improvement in Promoting Source Segregation in South Asia

India's *Solid Waste (Management and Handling) Rules, 2000* require segregated waste storage, collection, and transport along with appropriate plant design for segregated waste. In Bangladesh, the government approved a national reduce, reuse, recycle policy in December 2010 along with the drafting of municipal solid waste rules, which make it mandatory to separate waste into three categories: dry, wet, and hazardous. The Government of Bangladesh financed a massive awareness campaign to promote source segregation of waste and distributed free bins to segregate waste in Dhaka and Chittagong. In Sri Lanka, the national waste strategy recommends source segregation of waste. In Nagpur, India, door-to-door collection of waste with community cooperation has led to savings of some 50 million Indian rupees ($1 million) in the municipality's solid waste services. A nongovernment organization was involved to boost the involvement of the community. The initiative provided livelihoods for 1,600 people from the most deprived segment of society. The effort also boosted the financial credibility of the organization, increasing its budget by at least 30 times.

Source: Authors.

bottles, paper, and plastic containers); green for compostables (e.g., food scraps, leaves, and dirty paper napkins); and black for trash (e.g., plastic bags). In South Asia, a two-bin system (wet and dry waste) could be more applicable at the household level, combining recyclables and other trash as dry waste. Bins should be distributed for free, or at a nominal cost, and segregation must be strictly enforced to avoid misuse of bins for other storage purposes.

Financial incentives. European experience shows that in many cities, source segregation could only be successfully implemented with accompanying measures, such as an incentive tax (collection fees) according to the polluter pays principle. Households pay collection fees for nonrecyclables, but organic wastes and recyclables are collected at no cost to the domestic generator. Such accompanying measures require enforcement of existing solid waste management laws and regulations, and depend greatly on the political environment and the environmental awareness of the general public. Hence, expectations of success should be realistic, as the scheme is dependent on the awareness of households and their voluntary participation. Other financial incentives include municipalities providing additional budget to specific wards within the city that achieve segregation at source, as is done in Coimbatore City Municipal Corporation in India.

Awareness building. Any source segregation program needs to be implemented alongside an awareness building campaign. There should be extensive coordination between central, state, provincial, and local governments, NGOs, and schools for implementation and awareness building on source segregation. The success of San Francisco's source segregation program was achieved due to the intense awareness programs undertaken by the city's Department of Environment at the school level. The program educated 80% of the schoolchildren on garbage and segregation and how to dispose of it. Educating students on the importance of waste segregation extended awareness to households. In South Asia, awareness activities should focus on women, children, and household helpers, who typically have responsibility for waste disposal at the household level. The following three activities will raise the awareness of the community: (i) prepare and distribute leaflets to households describing the benefits of source segregation and providing guidelines to help residents differentiate between inorganic and organic waste; (ii) affix posters with basic information to the collection trucks; and (iii) organize an open-house event, inviting the community to the composting, biogas, or RDF plant. Explain onsite why source segregation greatly enhances the operation of the composting plant.

Municipalities can apply the following simple seven-step sample program for promoting waste segregation at the household level as practiced in Waste Concern's source segregation programs in Bangladesh, Sri Lanka, and Viet Nam.

Step 1: Community needs assessment
Before initiating the project, a brief questionnaire survey is conducted to assess community needs and their level of awareness of and interest in the project.

Step 2: Focus group discussion with community leaders and residents' associations
Focus group discussions are undertaken as a part of a pre-campaign survey. Members of the welfare association and representatives of the waste collection company are present in the meeting. The main objectives of the discussions are to (i) assess the present attitude of the residents toward using communication tools for waste segregation at source, and (ii) identify effective communication tools for conducting a media campaign to increase residents' awareness regarding household waste management.

Step 3: Community awareness and participation fair
To promote source segregation and build residents' awareness of proper waste management, activities can be introduced at cultural fairs or local community events. Small stalls can be colorfully designed to demonstrate and build awareness of proper waste management and source segregation. Toward this end, items such as educational stickers, banners, flyers, hand fans, and black and white leaflets can be distributed to residents.

Step 4: Modification of primary waste collection vehicles
One of the important steps in the source segregation program is to have a waste collection vehicle with two chambers or storage areas to separately collect the dry and wet waste. It is useless if households separate their wastes and then observe the separated waste being mixed during primary transport. The program suggests that the waste collection company use an existing rickshaw van with one chamber for wet waste, and a plastic bag to collect the dry recyclable waste. This is a low-cost solution to collect source-separated dry and wet waste.

Step 5: Training of waste collectors and household help
Before the start of waste collection, a training program is organized for the waste collectors as well as household helpers who are directly involved in the segregation of waste at the household level. Training is organized in partnership with the resident association and the waste collection company. The trainers discuss (i) how to separate waste, (ii) the benefits of source segregation, and (iii) the motivation of household workers to separate dry and wet waste.

Step 6: Project launching
A launching ceremony can include local residents and schoolchildren, as well as media representatives. During this event, a multimedia presentation can be delivered based on the survey undertaken previously. Waste management scenarios in the communities, along with the waste segregation process and impacts, are highlighted. After the inauguration program, a yellow colored bin for "dry" (inorganic) waste, made of recycled plastic, along with t-shirts and leaflets, can be distributed among the participants. As part of the program, resident associations and community groups are involved by asking them to distribute bins door-to-door and taking signatures of the representatives of each household.

Step 7: Monitoring source segregation
For monitoring purposes and to maintain community awareness, community groups or clubs can be formed in coordination with resident associations to oversee the entire household segregation activity. It takes approximately 6 months for awareness raising within the local community.

Marketing of Organic Products

The marketing of products from an organic waste-recycling facility is vital for the long-term sustainability of the facility. This section describes the key issues linked with marketing products generated by composting, biogas, and RDF facilities.

Compost marketing

Compost is a marketable, value-added commodity. Many composting plants have failed to deliver tangible results due to marketing problems. Marketing of compost depends on

- the quality of the compost and its compliance with standards,
- the packaging and branding of the product,
- availability of a consistent supply of compost during cropping seasons,
- the distribution and sales mechanism, and
- communication and promotion of the product.

In addition, the following external factors are vital:

- the company should adhere to government-issued compost standards and obtain certification;
- the department of agriculture should promote Integrated Plant Nutrient Systems, demonstration farming, and extension; and
- the company should negotiate buy-back at a fixed price by municipalities or agriculture departments.

Product quality is the most important factor in ensuring customer satisfaction and continued sales. Compost quality can be classified into visible and invisible criteria (Table 18).

Clearly, visible criteria are easier to control during production than invisible criteria. In order to convince the customer about invisible criteria, governmental product certification through a registration number and results from a government-approved laboratory are important.

Table 18 **Visible and Invisible Criteria for Compost**

Visible Criteria Assessed by Customers	Invisible Criteria Assessed by Laboratory Analysis
• Color	• Nutrient content (NPK)
• Smell	• Suitability for plants (pH, salt content)
• Foreign materials (plastic, glass, wire, nails)	• Heavy metal content
• Degree of maturing assessed by color, smell, and moisture content	• Presence of pathogens

NPK = nitrogen, phosphorous, and potassium.

Source: Rouse J., S. Rothenberger, and C. Zurbrügg. 2008. *Marketing Compost: A Guide for Compost Producers in Low- and Middle-Income Countries*. Zurich: Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

Since 2008, Bangladesh's Department of Agricultural Extension has provided licenses to companies producing compost, as well as to approved compost brands. One key criterion for compost registration in Bangladesh is that the compost producer must have a quality control laboratory for batch analysis, and the results must be sent to the Department of Agricultural Extension prior to marketing. Registration and certification of compost by the government have resulted in increased customer demand for government-certified compost. In addition to in-house laboratories, a system of independent sampling, independent laboratories, and strong penalties for noncompliance is required. For producers at the community level, a quality control system needs to be put in place so that compost is regularly tested at accredited laboratories. There are numerous cases where high-quality black soil was reportedly sold as compost. The credibility of quality compost among farmers needs to be much improved and very strict quality control by independent regulatory agencies is required to increase demand for compost in the agricultural market.

It is also important to market the compost in bags and display the product's brand name prominently. In Bangladesh, compost is usually sold in 40 kg bags to farmers, and 5 kg bags for horticulture. It is always advantageous to sell compost in bags rather than in bulk. Packaging can be used to promote the company's product, display the logo, and provide production information.

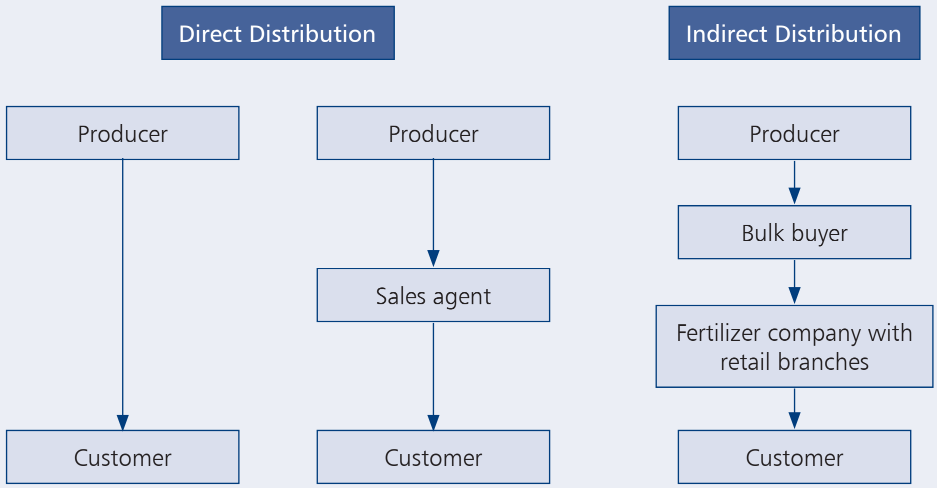
A sales and distribution mechanism has a notable impact on compost marketing. There are three options for marketing compost (Figure 4):

- **Direct distribution**. Producer sells directly to customer. This kind of marketing is sustainable for small-scale community-based compost plants.
- **Semi-direct distribution.** Producer engages a sales agent to market the product.
- **Indirect distribution.** Producer engages a bulk buyer, such as a specialized fertilizer company with retail branches.

Since compost is an agricultural product and compost plants are located in urban areas, away from customers that are located mostly in rural areas, the direct marketing of compost to rural customers is very difficult. Transport and storage costs also increase the price of compost. Experiences in Bangladesh, India, Nepal, and Sri Lanka have shown that when large-scale compost plants employ a direct sales approach to market the product, it inevitably fails. Farmers prefer to deal with specialized fertilizer companies with local retail branches that offer them credit instead of having to pay cash. Farmers then pay back the fertilizer companies after harvesting their crop. Box 7 provides an example of a successful partnership between a compost producer and a fertilizer marketing company in Bangladesh. Box 8 highlights the advantages of awareness raising for the Integrated Plant Nutrient System (IPNS), and Box 9 highlights the importance of compost registration for certification as a good practice. Except for Bangladesh, no country in South Asia registers or approves compost through laboratory analysis and field trials.

Engaging fertilizer companies to market the compost through indirect distribution has a number of advantages. Fertilizer companies (i) already have their existing networks and distribution channels up to the village level, (ii) have their own storage and transport facilities, (iii) sell compost in their retail shops with chemical fertilizer, and (iv) provide credit and undertake promotional work through their retail shops.

Figure 4 **Compost Sales and Distribution Models**



Source: Rouse J., S. Rothenberger, and C. Zurbrügg. 2008. *Marketing Compost: A Guide for Compost Producers in Low and Middle-Income Countries*. Switzerland: Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

Box 7 **Use of Fertilizer Marketing Company for Sales of Compost in Bangladesh by Waste Concern**

Waste Concern is Bangladesh's largest compost manufacturer having a production capacity of 15,000 tons/year. By 2012, Waste Concern will attain a capacity of 50,000 tons/year. Since 2000, the company has marketed and distributed their product throughout Bangladesh by engaging the country's biggest fertilizer marketing company, Advanced Chemical Industries (ACI). ACI purchases bagged compost from Waste Concern's plant, then transports and distributes it through its own established network. ACI also undertakes several other marketing activities such as promotional branding (leaflets, posters, stickers, television advertisements); brand awareness and technology transfer (farmers' meetings and demonstration farming); product launching with agricultural officials and agro-scientists; and seminars and meetings with the Department of Agricultural Extension. This approach has enabled Waste Concern to market the compost without any problems. Waste Concern sells their compost to ACI for 6,000 taka/ton ($88/ton), while ACI sells it to the farmers at 9,000 taka/ton ($130/ton), which includes transport, storage, and promotional costs.

Source: Waste Concern.

Biogas marketing

Biogas plants produce biogas, electricity, and slurry. In the case of household or institution-level biogas or biogas-to-electricity plants, the producer is usually the user, therefore the marketing of products is not an issue. However, large-scale biogas or biogas-to-electricity projects should not be undertaken without first identifying a buyer. For countries like Bangladesh, Nepal, and Sri Lanka, where there is no rate fixed by the government for waste-generated biogas or electricity from waste (considered renewable energy), a sales agreement will take

Box 8 Integrated Plant Nutrient Systems: The Way Forward for Promoting Compost

The most important aspect in marketing is communicating the right message. Compost is not an alternative to chemical fertilizers. Rather, when compost is used in conjunction with chemical fertilizers, it provides a higher yield (at least 25%–30% higher in the case of rice and vegetables in Bangladesh). The use of compost also results in a 30% reduction in the use of chemical fertilizer. The requirement for irrigation is also reduced by 35%, since compost has high moisture-holding capacity while simultaneously acting as a medium for climate change adaptation by improving the quality of soil and increasing the soil's organic matter content. In Bangladesh, the government is officially promoting the use of both chemical fertilizers and compost as part of their Integrated Plant Nutrient System to improve soil quality and crop production. A similar approach is followed in Sri Lanka. In India, the Ministry of Agriculture promotes a basket approach or co-marketing of both chemical fertilizers and compost to farmers. Promotion of the Integrated Plant Nutrient System needs a large quantity of quality, certified compost. The use of compost and chemicals should be jointly promoted, rather than promoting compost alone.

Source: Authors.

time, and the price will remain uncertain. Until and unless these issues are addressed, investment in large-scale biogas and biogas-to-electricity projects should be carefully considered from all angles. Moreover, marketing, sales, and distribution of its liquid product, slurry, are difficult.

Refuse-derived fuel marketing

The main output from an RDF plant is fuel briquettes, which can be used as an alternative to fuelwood and coal. RDF can be used for (i) co-combustion in coal fired boilers, (ii) co-incineration in cement kilns, (iii) co-gasification with coal or biomass, (iv) combustion in brick kilns as an alternative to coal, and (v) co-combustion in coal-fired power plants.

However, before initiating an RDF project, a detailed survey must be undertaken by the project proponent to analyze the potential market. Usually, RDF has lower caloric value than coal and requires auxiliary fuels such as biomass or tire scraps to increase its energy potential. In many cases, co-combustion may be required. In the absence of an assured market for fuel briquettes and government approval for use of RDF as fuel, it is not advisable to implement such projects. Industrial towns, with their higher concentration of consumers, including factories with industrial boilers and cement kilns, offer suitable locations for RDF facilities.

Operational Issues in Organic Waste Management

The operation of composting, biogas, and RDF plants requires a level of technical knowledge, as well as process control and management capacity. In the absence of such knowledge and skills, problems will arise related to odor and leachate, among others. Some common operational issues are as follows:

Odors are created in the plants if the compost operation is not undertaken properly, particularly if anaerobic conditions prevail within the compost piles. This situation can be avoided by turning piles at regular intervals, or using the forced aeration method (if the static pile composting

Box 9 Registration and Certification of Compost

Apart from marketing difficulties, there are certain regulatory concerns that greatly influence the marketing of compost. One such issue is standards for compost and certification by the country's agriculture department. Bangladesh, India, and Sri Lanka have national standards for compost and other organic fertilizer. To market compost commercially in Bangladesh, the compost manufacturer must obtain licenses for the product, its brand name, and for compost production. Approval for licensing is a two-stage process. First, the compost produced by the manufacturer is tested in three government laboratories. Subsequent to compliance with the national standards, the compost is sent for a field trial on crops for two agricultural seasons. The field trial is undertaken using the Integrated Plant Nutrient System. If field trial results demonstrate that use of the compost lowers the need for chemical fertilizer and increases yields, the compost and its brand name will be approved. After this stage, the Department of Agricultural Extension issues a license to the compost manufacturer.

In Bangladesh, the process for product and manufacturer registration takes approximately 1–2 years. Although the entire process is lengthy, the final government approval of the product indirectly assists in marketing the compost. The Government of Bangladesh is promoting the use of compost as part of its Integrated Plant Nutrient System program, and field-level agricultural extension officers are encouraging farmers to use registered, government-approved compost. As a regulatory requirement, the compost producer has to send monthly production data and compost quality data to the Department of Agricultural Extension. Moreover, the department also randomly undertakes quality control tests on the compost for laboratory analysis to ensure compliance. If major deviations from the approved standard are detected, then the government may cancel the license to market compost. The Ministry of Agriculture instructs fertilizer shops all over the county to market only government-approved compost.

Source: Waste Concern.

method is used). Balancing the C:N ratio and following good housekeeping rules by regularly cleaning plants results in minimal odor. Odor is not a major concern in biogas and RDF plants.

Leachate production and chemical composition will depend on whether inputs include mixed waste or homogenous organic materials. It is very important that operators planning to manage their leachate in any way other than disposal have it tested so that they are aware of its contents. However, excess water must be stored and treated before discharge. The evaporation of excess leachate water is one treatment method. This is viable for large-scale compost plants. Leachate that is free of elements of potential concern can be considered a valuable resource and reused in a variety of applications. It can be applied directly to plants as a source of liquid nutrients, or used to re-wet material still in the active composting stage. In the RDF plants, dust and leachate management are issues to be considered. However, most of these problems can be minimized by following basic housekeeping rules as part of an operational manual.

Occupational safety is important for workers and operators. Plants should distribute personal protective equipment and provide training on occupational health and safety to all workers. The plant operator must have a health and safety manual. Protective equipment such as uniforms, gloves, boots, and face masks must be provided to all plant workers, who must be trained to use them while working. Moreover, separate toilet and bath facilities must be provided for male and female workers. It is also very important for large-scale plant operators to have fire-fighting equipment, and for their staff to have emergency and fire training.

Capacity building of local government and operational facility staff is very important. Operating any organic waste-recycling facility requires a certain level of managerial skill and a businesslike approach. From the operational side of a compost plant, one needs to ensure an adequate and consistent supply of raw materials (clean organic waste), and effective processing of the raw material into high-quality compost. This must be successfully undertaken without creating odor or leachate contamination problems. A subsequent aspect involves marketing compost to users (farmers) who usually reside in rural areas, far away from the compost plant. As such, the plant operator must possess technical and business skills, without which it becomes difficult to sustain medium- to large-scale compost plants.

Most compost plants in South Asia are unable to deliver the desired results mainly due to poor managerial practices and an incorrect management model. Compost plants are generally owned by the municipality and often operated by municipal staff, where very few technically sound professionals are involved in the day-to-day operation of plants and very few possess a practical business plan to market the product. Marketing of compost requires a different approach, since fertilizer marketing in the region operates on credit. Municipal staff may not have business or marketing skills. Most of the plant operators themselves prefer to market to farmers, without understanding the marketing and distribution chain. Failure to produce high-quality compost and effectively market the product are linked with management problems.

Conversely, compost plants owned by private sector companies are found to be functioning far better than municipal-operated ones. However, compost plants have to compete with chemical fertilizer plants on a non-level playing field, where the latter receive incentive subsidies from the government. It is recommended to reduce subsidies with chemical fertilizers to create a level playing field.

Municipal budgets for compost plants owned by the municipality need to be maintained. Although they are built by the central government with the aid of a grant or donor support, their operational costs must be borne by the municipality. Compost projects usually have a 5–7-year payback period for the capital investment. The political will of the city is very important for allocating resources (both human and financial) to ensure that the plants are operational. City authorities should look into the environmental benefits as well as savings in landfill costs provided by composting.

Tipping fees for one privately operated landfill in India ranged from $5/ton to $12/ton. When the environmental and financial benefits of recovered landfill areas are accounted for, all compost plants seem viable. This argument can be used to encourage cities to provide either a tipping fee to plants operated by the private sector to ensure the facility’s viability, or a budget from its own resources if operated by the municipality.

Chapter 3

Enabling Framework for Scaling Up Operations

Management of organic waste is best addressed as part of a comprehensive government approach, including solid waste management, environmental protection, renewable energy, food security, and private sector development. An enabling framework created by central, provincial, state, and local governments, the private sector, and civil society provides the necessary basis for sustainable organic waste management. This section highlights the necessary features and activities required to create a positive enabling environment and can be used as a checklist for decision makers at various levels of government.

Institutional Roles and Responsibilities

Central Government

The following are key strategic, policy, and regulatory issues to be addressed at the central government level:

- improving inter-ministerial and interdepartmental coordination;
- introducing strategies, policies, rules, and standards to protect public health and promote high-quality organic products, such as compost and biogas;
- promoting Integrated Plant Nutrient System (IPNS) to encourage the use of organic compost fertilizers;
- promoting renewable energy, such as biogas and refuse-derived fuel (RDF);
- building awareness for behavior change, including segregation of waste;
- setting pricing and government subsidies for organic waste commodities and services (e.g., compost and biogas) to encourage growth of the sector and promote good industry practices;
- introducing tariff guidelines for renewable energy;
- requiring co-marketing of compost and chemical fertilizer to create a more level playing field for organic fertilizers;
- establishing guidelines for public–private partnership (PPP) to create an enabling environment to encourage private sector participation; and

- establishing or strengthening national training institutes for capacity building and centers of excellence to facilitate technology transfer to local governments.

Table 19 outlines the various activities and associated institutions commonly involved in organic waste management throughout South Asia. Table 20 shows the status of implementation of such activities in Bangladesh, India, Nepal, and Sri Lanka, and that none of these countries has all the enabling features to fully scale up organic waste-recycling projects. The following is a general description of key ministries and their roles in regulating and promoting organic waste management. Note that this is a general description of institutions within the region, and different countries' ministries have different names and responsibilities. The report does not suggest the transfer of roles and responsibilities from one ministry to another, rather it highlights the key roles typical of these institutional bodies in South Asia.

Ministry of Environment. In general, the Ministry of Environment is a nodal ministry responsible for preparing and enforcing a country's municipal solid waste (MSW) management rules. These rules require (i) source segregation of waste into dry and wet waste, (ii) standards for composting, (iii) anaerobic digestion and waste-to-energy projects, and (iv) guidelines for involving the private sector in waste management. Promotion of "reduce, reuse, recycle" (3R) approach; site selection criteria for recycling plants; and applicable environmental standards are typically articulated by the Ministry of Environment. For large-scale organic waste-recycling plants, an environmental impact assessment would also be overseen by the environment agency. The Ministry of Environment and Forests or the government's pollution control agency (in India, this is the Central or State Pollution Control Board) should also monitor local government performance for compliance with such rules and environmental regulations.

Ministry of Agriculture. The Ministry of Agriculture (MOA) is the nodal ministry for developing and enforcing compost standards for soil application and registration and certification of compost.[20] Apart from the targeted specifications to be achieved, the MOA monitors (i) methods of analysis of organic fertilizers, (ii) various forms of application for obtaining a certificate of manufacture as well as forms for issuing the certificate of manufacture, and (iii) forms for different activities relating to analysis of organic fertilizers. The order lays down the specifications in terms of physical and chemical parameters, including heavy metals. In India, certification is required from the state agriculture department, rather than the ministry.

Further tasks include the application of compost to IPNS. Comprehensive awareness of IPNS is important, as is providing subsidies to promote compost along with chemical fertilizers. Demonstration farming of IPNS is also vital, along with a directive to all fertilizer companies to market government-approved compost brands. Recommended activities for the MOA to support the municipal organic waste management sector include:

- providing financial subsidies to organic compost, as is done for chemical fertilizers, to allow market opportunities;
- requiring fertilizer companies and distributors to co-market municipal organic compost with chemical fertilizers through a basket approach;
- fixing safe thresholds for applying organic fertilizers to different crops, which should be set forth in fertilizer guidelines issued by the MOA;

[20] India also has a Ministry of Fertilizer and Chemicals.

Table 19 Roles and Responsibilities of Relevant Ministries in Organic Waste Management

Ministry or Organization	Coordination Committee	Strategy, Policy, Rules, and Standards	Promotion of Source Segregation of Waste	Feed-In Tariff for Waste to Biogas or Electricity	Tipping Fee for Organic Waste-Recycling Plant Operators	Provision of Land for Establishment of Organic Waste-Recycling Plants	Standard for Compost and Slurry, Promotion of IPNS, and Co-marketing of Compost with Chemical Fertilizers	Promotion of Use of RDF	Guideline on PPP	Incentives on Compost, Biogas, and RDF	Capacity Building of Stake-holders
MOA	X	X					X				X
MOE	X	X		X		X		X			X
MOEF	X	X	X								X
MOF	X								X	X	
MOI	X		X								X
MOUD/MOLG	X	X	X		X	X		X	X		
ULBs	X	X	X		X	X				X	X

IPNS = Integrated Plant Nutrient System, MOA = Ministry of Agriculture, MOE = Ministry of Energy, MOEF = Ministry of Environment and Forests, MOF = Ministry of Finance, MOI = Ministry of Information, MOLG = Ministry of Local Government, MOUD = Ministry of Urban Development, PPP = public–private partnership, RDF = refuse-derived fuel, ULB = urban local body.

Source: Waste Concern.

Table 20 **Status of Enabling Activities in Bangladesh, India, Nepal, and Sri Lanka**

Country	Coordination Committee	Strategy, Policy, Rules, and Standards	Promotion of Source Segregation	Feed-In Tariff for Waste to Biogas or Electricity	Tipping Fee Paid to Operator for Organic Waste Recycling	Provision of Free Government Land for Establishing Organic Waste-Recycling Plants	Standard for Compost and Slurry, Promotion of IPNS, and Co-marketing of Compost with Chemical Fertilizers	Promoting RDF	PPP Guidelines	Capacity Building Institutes on Organic Waste Management
Bangladesh	Proposed	Rules under preparation	Pilot Project started	No	No	In some cases	Enforced	No	Yes	In some cases
India	Proposed	Yes	Partial	Yes	No	Yes	Yes, not enforced	Yes	Yes	Yes
Nepal	No	No	No	No	No	No	No	No	No	No
Sri Lanka	Yes	Yes	No	No	No	Yes	Yes, not enforced	No	No	Yes

IPNS = Integrated Plant Nutrient System, PPP = public–private partnership, RDF = refuse-derived fuel.

Source: Asian Development Bank. 2006. *Technical Assistance for the Development Partnership Program for South Asia*. Manila.

- issuing government certification of organic compost;
- monitoring sales of government-approved compost at the local distributor level;
- demonstration farming to clearly illustrate the agricultural benefits of compost application to crops (e.g., higher yields); and
- training farmers in applying balanced doses of organic and chemical fertilizers through government agricultural extension networks.

In 2005, Bangladesh revised its fertilizer application guidelines to include organic compost fertilizer application for different crops in conjunction with the use of chemical fertilizer. Since 2008, the Department of Agricultural Extension has actively marketed compost. In 2003, the Government of India constituted the Inter-Ministerial Task Force for Integrated Plant Nutrient Management using City Compost, which recommended that co-marketing of compost with chemical fertilizer in a basket approach (e.g., 3–4 bags of compost with 6–7 bags of chemical fertilizer) should be made mandatory for widespread marketing of compost. This should be applicable to chemical fertilizer companies as well as their storage agents or dealers.

Ministry of Urban Development and Ministry of Local Government. Urban local bodies receive broad policy support from these ministries. The tasks of these ministries include (i) provision of directions and guidelines to implement 3R projects related to organic waste management; (ii) effective allocation of funds to local government bodies to implement composting, anaerobic digestion, and RDF projects; and (iii) the preparation and distribution of guidelines on PPP related to the organic waste sector.

Ministry of Finance. This ministry is a key player in deciding the levels of financial support and subsidy from the central government to develop organic waste recycling within each country. Fiscal incentives include (i) tax holidays for up to 10 years for all waste treatment and recycling plants, (ii) lifting of import (custom) or excise duties on relevant equipment, and (iii) lifting value-added or sales tax on purchases of related machinery.

Ministry of Energy. The Ministry of Energy (MOE) is a key player in promoting the development of renewable energy within each country. For example, the MOE would be instrumental in linking biogas plants producing electricity to the national grid. The MOE can also catalyze financing for renewable energy investments through, for instance, promoting feed-in tariffs as a policy mechanism to accelerate investment in renewable energy technologies. Through a feed-in tariff system, biogas plants are awarded a lower per kilowatt-hour price, while technologies like solar power are currently given a higher price, reflecting their higher costs.

Ministry of Information. The Ministry of Information plays an important role in promoting source segregation of waste via awareness campaigns in the national media. It can raise awareness of the positive impacts of compost application to crops, along with promoting the use of RDF or biogas. Apart from telecasting or broadcasting in the media, the ministry can also instruct the print media to provide factual information regarding source segregation, as well as encouraging the use of organic waste products as part of corporate social responsibility.

Inter-ministerial coordination committees. It is clear that organic waste management falls under the purview of several ministries, line agencies, and departments. An inter-ministerial coordination committee would facilitate communication and collaboration between these various bodies. In Bangladesh, the government is considering establishing a National Solid Waste Management Board to coordinate the activities of different ministries related to solid waste management. In Sri Lanka's Western Province, such a coordination committee already exists. Nepal recently approved the Solid Waste Management Act (2011), and the existing Solid Waste Management and Resource Mobilization Center established under its Solid Waste (Management and Resource Mobilization) Act (1987) will be transformed into the Solid Waste Management Technical Support Center, although it requires further capacity to realize its mandate. In India, the Inter-Ministerial Task Force on Integrated Plant Nutrient Management using City Compost recommended the establishment of a coordination cell in the Ministry of Urban Development at the central level, and in urban development departments at the state level to expedite the implementation of all urban solid waste management activities. The task force further recommends that such a coordinating cell be responsible for the release of subsidies granted by the Ministry of Agriculture, and that all concerned officials in the coordinating cell be well trained in technical matters related to compost plant operations and marketing.

State and Local Governments

Solid waste management also falls under the purview of state and local governments. However, it is important to note that municipal authorities have the overall responsibility for day-to-day solid waste management. The following are key issues to be addressed at the state and local levels (Tables 19 and 20):

- mandating of a nodal department or division to oversee all aspects of MSW management, including organic components;
- paying of tipping fees to operators to promote private sector participation;
- ensuring land use policies reserve adequate and suitable land for organic waste management, as suitable sites should be at least 500 meters from the nearest habitation and no-development zones should be enforced by local governments;
- collecting and managing data on waste composition and generation;
- providing land at concessional rate and subsidy for setting up processing plants;
- creating community awareness;
- engaging the private sector;
- selecting correct technology;
- rationalizing municipal taxes to ensure adequate funds available for supporting investments in human and capital resources for supporting solid and organic waste management;
- introducing fiscal benefits for urban waste management projects, e.g., exemption of excise duties, value-added tax, and service tax, which would be important for attracting private capital and expertise;
- providing government support for certain commodities and services directly or indirectly related to waste management, such as preferential use of city waste-based compost in municipal gardens and parks and government premises, and preferential purchase of electricity generated from waste;
- avoiding levying royalties (an additional fee on the private operator) as a source of additional revenue; if royalties are required by the municipality, they should not exceed 2% of the income from the compost plant, or in lieu of cash transaction, they should be

in the form of compost, which may be used by the local government for its parks and other greenery;

- updating or adopting by-laws which promote private sector participation and include source segregation of waste;
- providing land, access road, power, and water connection, followed by supply at concessionary rates;
- providing agreed quantity of garbage—preferably segregated—for private operators;
- engaging local stakeholder groups, including nongovernment organizations (NGOs), neighborhood associations, and self-help groups for promoting primary collection; and
- joining together of small and medium-sized cities and peri-urban areas to build a common (regional) facility.

Civil Society and Nongovernment Organizations

Improving waste management services takes a concerted effort by both city managers and civil society and requires active citizen participation. However, the scale of the challenge for local governments to provide these services throughout the region often results in the strong involvement of NGOs and community-based organizations (CBOs). NGOs and CBOs are critical partners in helping raise community awareness, change personal behavior, and increase participation in source segregation and recycling efforts. Chapter 3 of this report discussed ways to engage communities to promote source segregation where NGO and CBO partnerships are critical in informing, educating, and communicating important messages to communities. Local stakeholder committees involving community leaders can ensure wide representation of local ward representatives and community members, particularly women, who are critical to behavior change at the household level. A strong stakeholder committee ensures maximum participation of civil society and NGOs.

Compost Quality Standards

In the South Asian context, the explicit policy intent is for compost to be manufactured from MSW for application in food production systems in order to sustain soil health and productivity to feed a large and growing population. However, throughout South Asia, the two biggest challenges to the success of compost operations are poor quality and low marketability of compost products. Compost from mixed MSW can become contaminated with chemical, biological, and physical contaminants that pose risks to both public and environmental health.

Quality standards are an important step to address these issues. These are published documents that provide specifications and procedures to ensure that organic products and processing systems are safe, reliable, and consistently perform as intended. This approach fosters confidence among the government, farmers, and consumers as it provides an objective assessment of compost quality. Commercial investors in compost infrastructure are also advised to conduct such testing for the purpose of managing commercial risk and liability.

Formal compost standards were developed and adopted in Bangladesh in 2008, in India in 2006 (revised in 2009), and in Sri Lanka in 2003. Nepal currently has no published standard.

The standards are commonly developed and issued by the national ministries of agriculture. Published compost standards for the region are

- Sri Lanka Standards Institution. 2003. *SLS 1246: 2003—Specification for Compost from Municipal Solid Waste and Agricultural Waste*. Colombo, Sri Lanka.
- National Fertilizer Standardization Committee. 2008. *Organic Fertilizer Standard*. Ministry of Agriculture, Dhaka, Bangladesh.
- Ministry of Agriculture. 2009. *Fertilizer (Control) Third Amendment Order, 2009*. Department of Agriculture and Cooperation, Government of India, Delhi. (This amended 2009 edition supersedes the original 2006 edition.)

Different grades of compost can be produced for community or commercial use. Composting can produce a range of compost products, each with different benefits, and all of very high quality depending on the processing method and operational quality. Because compost is formulated, rather than treated simply as a by-product, it can be used to satisfy end markets in residential, municipal, or agriculture sectors, as well as the stringent requirements of government standards. Nonconforming compost may be used for lawns, forests, nurseries, social forestry, and other venues. The lowest grade of compost can be used as cover material for sanitary landfill and revegetation of degraded lands and mining overburdens, where it provides a suitable substrate for the growth of vegetation. It can also be used on roadsides and in social forestry schemes.

Key Considerations for Quality Standards

To effectively manage risks and ensure agronomic benefit, compost standards must address the following issues:

- Define the usable raw materials, and those that are excluded from use according to compost production standards. This requirement is fundamental to framing the scope of risk to be addressed by the standard.
- Define the chemical, physical, and biological parameters and associated threshold or range limits for agronomic properties to enable informed, beneficial, and reliable use in agricultural production systems.
- Define and document standard test methods and reporting protocols against which compliance with the standard can be objectively assessed, ensuring that product claims can be verified.
- Define and document sampling methods to best ensure that compost samples for analysis are representative of the compost product actually being sold for use.
- Define and document the requirements for auditing to demonstrate that the fundamental requirements and risk management practices of the composting process are being implemented.
- Document standard terms and definitions for the sector to enable a common language to be used consistently by central and local government, the waste and recycling industry, compost manufacturers, fertilizer and compost distributors, farmers, agricultural researchers, and academics. This should include a clear definition of compost and key quality parameters for composts.

- Specify required physical, chemical, and biological labeling requirements and user information to ensure informed selection and safe and beneficial use of compost products.

Lessons Learned from International Standards

The compost standards for Bangladesh, India, and Sri Lanka were compared with the standards of Australia and the United Kingdom. Lessons learned from this exercise for enhancing compost standards within the South Asian context are as follows:

- The standards should include all relevant tests for the spectrum of possible contaminants within mixed municipal waste systems, including persistent organic pollutants and heavy metals.
- The processing requirements to achieve effective pasteurization should be specified.
- A particle size specification should be permitted that meets the requirements of farmers.
- Moisture content requirements for finished composts should be reviewed, with a view to permitting moisture content of up to 35%–40%, which allows composts to remain biologically active for the entire composting process, and enables reliable assessment of compost products via analytical testing.
- Defined, proven, and cost-effective laboratory tests are available to assess phytotoxicity (the degree of toxic effect of a compound on plant growth) and should be included in all compost standards.

Constraints Faced by Compost Manufacturers and Regulators in South Asia

Compost manufacturers in the region find that it is not easy to achieve the minimum organic carbon and other plant nutrient values in terms of nitrogen, phosphorus, and potassium (NPK) from mixed municipal garbage. They would also like to see restrictions on use of biodegradable waste of industrial origin, which is a source of possible contamination. As compost cannot compete with NPK values of chemical fertilizers, it is suggested to use and market it as a soil amendment.

Regulators in the region highlighted the lack of dependable laboratories for frequent and affordable analytical tests as a constraint to their activities. Some of the tests, particularly for heavy metals, require sophisticated equipment which may be scarce. They also cited a lack of capacity and staffing to adequately monitor and enforce compost standards. It is suggested that in addition to in-house laboratories, a system of independent sampling, independent laboratories, and strong penalties for noncompliance is required.

Capacity Building, Training, and Education

The capacity of governments to initiate and regulate organic waste programs is inadequate throughout the region. Training is required for operators, regulators, and planners within both government and the private sector to ensure safe and sustainable organic waste operations. Hand-holding by state and central government, in addition to expert institutions, is needed to strengthen capacity. The private sector can fill many of these gaps for improved service delivery; however, in order to create equal partnerships for effective and successful operations, government employees at the local and state levels will require formal capacity development in the key areas of (i) statutory compliance and monitoring, (ii) planning, (iii) financial management (budgeting and accounting), (iv) preparation of bidding documents, (v) technical operation and maintenance, (vi) effective human resource management, and (vii) community health and occupational safety. Training should take place at an operational compost or biogas facility with an established system of production that complies with applicable operating guidelines and compost product standards. Further capacity development is needed for improved regulatory monitoring and laboratory testing of compost quality to ensure compliance with government standards.

It is recommended that agricultural research councils throughout the region set up a wing for training, and engage research institutes and universities. Private research and development organizations can provide necessary technology support. Fabrication of a prototype compost plant with a capacity of 10–100 tons per day (tpd) can be demonstrated at public or private institutes, along with training on operation and maintenance of such plants. The Ministry of Agriculture, Department of Agriculture, and Agricultural Research Council could earmark funds for research, development programs, and projects by the government or private research institutes. However, it is recommended that these capacity building programs are coordinated with the ministries of local government or urban development, environment, and forests.

The departments of agricultural engineering of agricultural universities and colleges should take up research projects for the improvement of plant machinery and equipment on a priority basis. These should be financed by the government.

The perception of municipal organic waste as a soil amendment needs to be improved. Awareness needs to be created among farmers on the use and benefits of organic manure, both as a stand-alone product and as a supplement to chemical fertilizer in an IPNS. Farmers need to be exposed to the benefits of integrated nutrient management through field demonstrations. This can be introduced as an extension activity of the Ministry of Agriculture, as well as of the agriculture departments of the agricultural universities.

Scientists of agriculture research institutes and agricultural universities could study the roles of organic fertilizer, compost, and bio-slurry as soil conditioners leading to better absorption and holding of nutrients from chemical fertilizers. Such research will demonstrate a reduction in the chances and extent of percolation of nitrates and other chemicals into groundwater. The research, methodology, and results need to be transparently publicized for the benefit of farmers. Box 10 highlights a recycling training center in Bangladesh.

Fiscal Measures and Market-based Instruments

Despite their favorable environmental and social benefits, organic waste management projects have a payback period of at least 7 years. It is therefore essential that governments promote a combination of fiscal incentives and market-based instruments to promote private sector investments in organic waste-recycling projects.

Box 10 Recycling Training Center in Bangladesh

In order to promote organic waste recycling in Bangladesh, a recycling training center was established in 2005 in Dhaka, supported by the Ministry of Environment and Forests and the United Nations Development Programme. The training center offers tailor-made programs to municipal officials, nongovernment organizations, and the private sector regarding (i) the design, operation, and maintenance of compost and biogas plants; (ii) eco-sanitation; (iii) rainwater harvesting; (iv) biodiesel production; and (v) emission reductions through waste recycling. The training center also offers hands-on training to staff members for operation and maintenance of organic waste-recycling plants. This training center offers both theoretical and practical training. Since 2009, the training center has been supported by the United Nations Economic and Social Commission for Asia and the Pacific, and training programs are organized for municipal officials, municipal engineers, nongovernment organizations, and community-based organizations from countries in Asia and the Pacific.

Source: Authors.

Governments may adopt the following measures to promote private sector investments in this sector:

- tax holidays to provide incentives for private investment, including exemption from value-added tax on products such as compost and RDF;
- exemption from customs duty on the import of capital machinery;
- subsidy on the capital cost of the project;
- payment of tipping fees to private operator for collecting organic wastes;
- concessionary rates for utilities such as electricity, diesel, and water;
- concessionary rates for bank loans with low interest rates (soft loans);
- subsidy on compost, similar to that for chemical fertilizers;
- promotion of products such as compost, biogas, and RDF by the government;
- provision of land on long-term lease from the government;
- fixing of a feed-in tariff for electricity generated from biogas;
- mandatory sale of compost along with chemical fertilizer at the dealers, or co-marketing of compost with chemical fertilizers; and
- no royalties imposed by the local government on private operators.

Tax holidays. Entrepreneurs setting up a compost plant as part of a joint venture or within the private sector should be considered for a tax holiday for 10–12 years, and should be allowed an exemption on customs duty, excise duty, value-added tax, sales tax, and other local taxes on equipment, machinery, processing plant, and others. This exemption should also include products such as compost and RDF to promote private sector participation in the production of compost from municipal waste, biogas, biogas-to-electricity, and RDF.

Capital subsidies. Entrepreneurs should be considered for a capital subsidy up to 50% of the plant cost (if the municipality owns the plant, as in the case of build–operate–own–transfer [BOOT]), and 30% of plant cost (if owned by private sector, as in the case of build–operate–own [BOO]). Moreover, for any project financed by banks, lower interest rates should be fixed by the government, along with a long loan term.

Two financing patterns were suggested by the Government of India Inter-Ministerial on Integrated Plant Nutrient Management using City Compost for administering capital subsidies for setting up compost plants. First, where a local body owns the compost plant, there is a 50% grant subsidy, 15% equity (local body), and 35% debt from a financial intermediary. Second, where a joint venture between the urban local body and a private company exists, a 30% grant subsidy, 30% equity (15% each partner, including land), and 40% debt from a financial intermediary is applied.

Tipping fees. A private sector entity operating organic waste-recycling facilities such as compost, biogas, or RDF plants should not be asked to pay royalties to the city. Alternatively, tipping fees should be paid by the city for each ton of waste processed by the entrepreneur, since waste recycling reduces the landfilling cost. The payment of tipping fees to private operators is the norm in Europe and North America.

Concessionary rates for utilities. The entrepreneur should be supplied with electricity, diesel, and water at the same rates provided to the agriculture sector or at a concessional rate, whichever is less.

Long-term lease of land. One of the major barriers for implementation of organic waste-processing plants is the lack of available land. Entrepreneurs should be provided with land at existing dumpsites on a long-term lease, free of cost, for setting up compost, biogas, or RDF plants. The private sector (in case of BOO) or municipality (in case of joint venture such as BOOT) should be allowed to take out loans from commercial banks and others by jointly mortgaging the land, if required.

Creating parity with chemical fertilizers. Although governments throughout the region promote compost use, governments are providing unequal subsidies to chemical fertilizer companies to the detriment of organic fertilizer and compost manufacturers. The use of compost has multiple environmental and economic benefits, including greenhouse gas emission reduction and higher yield when used in conjunction with chemical fertilizer, and thus warrants increased government subsidy. It is recommended to reduce subsidies to the fertilizer companies to support greater access of compost to the agricultural market.

Co-marketing compost with chemical fertilizers. Fertilizer companies can adopt a "basket approach," entailing the co-marketing of compost with chemical fertilizers. For larger-scale compost plants, the use of fertilizer marketing companies for distribution and sale of compost provides a great advantage. A suggested ratio is two bags of chemical fertilizer to one bag of certified registered compost.

The Government of India Inter-Ministerial Task Force for Integrated Plant Nutrient Management using City Compost recommends co-marketing of compost from city garbage with chemical fertilizers in an indicative ratio of 3–4:6–7 (i.e., 3–4 bags of compost with 6–7 bags of chemical fertilizer).

Government promotion and awareness raising. A national campaign to generate awareness of the utility of compost and organic fertilizer needs to be launched through electronic and print media in local languages. The message should encourage the use of compost and organic fertilizer on its own and as a supplement to chemical fertilizers. This can also be incorporated in the extension activity of the Ministry of Agriculture and agriculture departments. Similarly, a media campaign can be undertaken to encourage source segregation of waste, the key activity for successful organic waste management. Moreover, the Ministry of Energy can encourage the use of RDF for certain types of industries, promote generation of electricity from biogas, and provide special rates for such electricity. The Government of India Inter-Ministerial Task Force for Integrated Plant Nutrient Management using City Compost encourages a promotional subsidy to popularize the use of compost.

The Way Forward

The assessment of municipal organic waste in South Asia shows that diverting this large amount of waste into resource recovery systems presents a huge untapped potential for extending the life of landfills, creating economic and environmental benefits, and ultimately reducing the pressure on municipalities to manage their waste. Mobilizing both the government and the private sector requires a number of enabling conditions to realize this potential. Priority actions defined for each country at the regional workshop in Dhaka, Bangladesh, on 2–3 August 2010 provide a road map for moving ahead (Appendix 2). Additional resources for further study are available in Appendix 3.

Mixed waste processing is undoubtedly the key constraint inhibiting sector performance. Governments need to make a greater effort and commitment to increase outreach and community awareness programs to encourage source segregation of waste. Awareness building should be coupled with increased budgetary allocations to the sector and stringent implementation of existing laws with stronger enforcement. However, the role of incentives should not be understated as public awareness programs alone may not suffice to lead to behavioral change by communities. Appropriate mechanisms, such as charging collection fees to households that produce mixed waste and exempting from such fees those that segregate waste, may be considered. Quality standards and registration of compost by the government as well as its promotion by the public sector are also vital for scaling up efforts.

Policy makers need to understand that the organic waste management is not a lucrative business given the current challenges associated with mixed waste streams, and that the private sector will not be automatically attracted to the sector to make major investments unless improvements in waste segregation are made. However, neither the national nor local governments in South Asia can afford to provide large subsidies for this work. Therefore, they should create a level playing field to support the organic waste sector. Chemical fertilizer subsidies by governments distort the market for organic compost. Any decisions made by local or national governments to support waste resource recovery requires full consideration of the opportunity costs (e.g., less land required for landfills, lower transport costs, lower operation costs of landfills, and less reliance on chemical fertilizers) and overall social and environmental benefits. Additional efforts are needed to collect high-quality data for improved analysis at the local and national levels to enable policy makers to make informed decisions.

Private sector participation can significantly reduce costs and enhance service delivery. Solid and organic waste management can be improved by leveraging the expertise of the private sector through public–private partnership (PPP) concessions, and incentives need to be carefully deliberated. When designing PPP agreements, municipalities should consider a number of factors including price escalation, changes in fuel price, quality of waste, tipping fees, and penalty clauses, and include the collection of household segregated waste.

Organic waste management projects qualify for carbon financing on account of their clear ability to reduce greenhous gas emissions. The organic waste management projects that qualify for carbon finance projects are composting, anaerobic digestion, refuse-derived fuel, and landfill gas recovery and electricity generation. Indeed there is an opportunity for more waste-based Clean Development Mechanism (CDM) projects in the region to help bridge the financing issues faced by municipalities and operators. Programmatic CDM opportunities can be explored to address these issues. Carbon finance has developed a complete range of financial systems, including a carbon trading "currency," direct investment, bank loans, carbon credits trading, carbon options, and other derivatives. Appendix 4 provides a brief overview of financial resources available from ADB to support carbon-financing initiatives.

Improved sector performance will require close coordination and strong political commitment to help realize the full potential of the organic waste sector's economic and environmental benefits.

Appendix 1
Country Experience in Organic Waste Management

Experience of Organic Waste Management in India

Organic waste management in India started in the 1970s with large-scale, municipal-owned, and operated compost plants based on the design of European countries. However, these plants could not operate due to their high operation and maintenance costs, as well as the low quality of compost due to mixed waste. The plants were subsequently forced to shut down, as the low-quality compost was difficult to market and sell. Since early 2000, the Government of India has made a number of efforts to improve the situation, especially with the enforcement of the government's Municipal Solid Waste Management Handling Rules, resulting in an increased awareness of organic waste management throughout the country.

The Supreme Court of India, through a 2003 court hearing, also took up the matter of municipal compost, and recommended that the government shift its subsidies from synthetic fertilizers alone to the combined use of synthetic fertilizers with city compost that conforms to the standards specified in the Municipal Solid Waste Handling Rules.[1] The Inter-Ministerial Taskforce on Integrated Plant Nutrient Management Using City Compost (2005) points out that unless compost meets the quality requirements of farmers and is affordable, it will not be bought and used in agriculture. The task force also identifies that proper quality control and pricing are the key factors.

The Indian Council of Agricultural Research drafted recommendations for compost quality standards in 2004. These were subsequently subject to detailed examination by the technical subgroup over a 2-year period, in association with preparation of the Inter-Ministerial Taskforce on Integrated Plant Nutrient Management Using City Compost (2005). The recommendations formed the basis of the first edition (2006) of the formal national compost standard for India (Ministry of Agriculture, 2009) which was issued as the Fertilizer Control Order. The work of the technical subgroup assumes mixed municipal solid waste (MSW) of Indian characteristics.[2] Registration of compost is being considered.

The Ministry of Agriculture introduced integrated and balanced use of chemical fertilizer in its Eighth Five-Year Plan, 1992–1997. Under this plan, the ministry supported local bodies and the

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[1] Civil Writ Petition No. 888 of 1996 in the matter of Mrs. Almitra Patel and Others vs. Union of India on 14 January 2003.

[2] Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation. 2009. *Fertilizer (Control) Third Amendment Order, 2009*. Delhi. This amended 2009 edition supersedes the original 2006 edition.

private sector in setting up facilities that convert MSW into compost. The grant was available for up to one-third of the project's cost for compost units with a capacity of less than 50 tons per day (tpd) or more than 100 tpd. A total of 30 facilities were constructed. However, most of the plants supported under this program are either not working to optimum capacity or are not functioning at all due to their use of mixed waste and/or the low quantity of waste inputs and poor management.

The Ministry of Fertilizers took up the recommendations of the Inter-Ministerial Task Force on Integrated Plant Nutrient Management by requiring fertilizer companies to implement a co-marketing scheme for compost from municipal organic waste with chemical fertilizers as a "basket approach," with an indicative ratio of 3–4:6–7 (3–4 bags of compost with 6–7 bags of fertilizer). The Ministry of Urban Development also issued instructions for implementation of the task force.

The Ministry of Environment and Forests also provides financial assistance through subsidies of up to 50% of the capital cost to set up pilot demonstration plants for MSW composting.

The Ministry of Non-conventional Energy has another scheme to support waste-to-energy projects. There is a support facility for up to 1,000,000 Indian rupees (Rs) (about $22,000) per project as project development assistance. Moreover, MSW-to-refuse-derived fuel projects will receive an incentive of Rs15 million/megawatt (MW) ($340,000/MW); biomethanation will receive Rs20 million/MW ($455,000/MW); and biogas generation for thermal application will get Rs10 million/MW ($227,000/MW).

Although these incentives promote waste-to-energy projects by supporting the capital cost of the projects, major issues such as source segregation of waste (which is very important for composting and anaerobic digestion), short-term contracts, buy-back of electricity from the project, and power purchase agreements were key challenges. Experience in India shows that sustainable composting requires the financial and organizational support of government and/or the private sector.

Experience of Organic Waste Management in Sri Lanka

The Government of Sri Lanka has made recent efforts to promote recycling of organic waste through the production and use of compost throughout the country. Since 2007, the Ministry of Agriculture Development and Agrarian Services promoted the production of organic and biofertilizer through an integrated plant nutrient system (IPNS) and fertilizer production using locally available raw materials.

In support of these efforts, the government initiated a national campaign to increase domestic food production, including compost production, under a national program called "Let Us Cultivate and Uplift the Country." Approximately 500 million Sri Lanka rupees (SLRs) (about $4.5 million) were allocated in 2008 and SLRs750 million ($6.8 million) in 2009 to promote awareness regarding quality compost production, farm demonstrations of IPNS technology, and improvement in compost quality. The country was the first in the region to issue compost quality standards in 2003.[3]

[3] Sri Lanka Standards Institution. 2003. *SLS 1246: 2003–Specification for Compost from Municipal Solid Waste and Agricultural Waste*. Colombo, Sri Lanka.

The Ministry of Environment and Natural Resources launched a national program called "Pilisaru"[4] in 2008, which aimed to provide technical and financial assistance to construct and operate compost plants in different municipalities. Under this project, the Government of Sri Lanka undertook a country-wide study for identification of compost projects to be established under the project. Fourteen large-scale compost plants (25–30 tpd) are planned, while 41 smaller-scale composting plants (up to 5 tpd) are under construction with a cost of SLRs93 million (about $0.8 million). Apart from providing designing and financial support, the Pilisaru program is also providing training to municipal staff in the operation and maintenance of such plants.

The Ministry of Local Government and Provincial Councils established the National Solid Waste Management Support Center. The main function of this center is to provide support to the nine provinces and to collaborate with the Ministry of Environment, the Ministry of Planning, the Central Environment Authority, and the Waste Management Authority of the Western Province, as well as international donors. During 2007–2009, the center distributed 30,000 compost bins to local government bodies. The center is also providing technical support for compost plant construction and operation, in some cases jointly with the Central Environment Authority and Pilisaru program.

Organic waste recycling through composting has gained momentum through the Pilisaru program, which provides grants to the municipalities and designs large-, medium-, and small-scale compost plants. Operation, maintenance, and marketing of the compost plants remain with the municipalities, requiring them to allocate adequate budget for this purpose. Past experiences have illustrated that municipally operated compost plants work well when the mayor has strong political commitment.

Experience of Organic Waste Management in Nepal

Organic waste management in Nepal started in 1986 when development partners collaborated to establish a 30 tpd capacity compost plant in Teku, Kathmandu, and a 6 tpd capacity compost plant in Bhaktapur. The compost plant in Teku used a windrow-composting system with a mechanical screening and turning system. The entire composting operation was done in an open yard without overhead covering, and there was no drainage system to collect leachate. The composting area had a concrete platform. This plant was operated by the local municipality and processed mixed waste. The plant operated until 1990, when the local residents raised complaints and forced the local authorities to close the plant due to odor problems.

In Nepal, incentives for compost production and regulatory standards are at the developing stage. Nepal recently approved the Solid Waste Management Act (2011). The act seeks household waste segregation, recognition of waste management as one of the most urgent state services, public–private partnership (PPP) for waste management, treatment of hazardous waste by producers themselves, and environment protection, among others. In 2010, Kathmandu City bid out its waste management on a build–operate–transfer (BOT) basis to the private sector with a maximum concession period of 30 years. The BOT contract used the Build, Operate, Own and Transfer (BOOT) Act, 2063 as its legal basis; however, there are currently no guidelines for private sector participation in the country.

[4] "Pilisaru refers to the conversion of the condition of a thing from useless state to use full state." Source: Central Environment Authority. Pilisaru Programme. http://www.cea.lk/Pilisaru_Programme.php

There are more than 200,000 biogas plants in Nepal. Most of these are household plants with 4–10 cubic meter (m^3) capacity, which use dung and toilet waste as feed materials. More recently, community and institutional biogas plants with capacities of up to 100 m^3 that use vegetable waste and wastewater as feedstock have also been constructed.

Experience of Organic Waste Management in Bangladesh

Organic waste management in Bangladesh began in 1992 with a pilot project to generate biogas from MSW. To promote organic waste recycling, the Government of Bangladesh, through its Ministry of Finance, allowed fertilizer plants, including compost facilities, a tax holiday of 5–7 years. There is also no value-added tax imposed on sales of compost.

The government's position on compost as an organic fertilizer has been a two-pronged approach of promotion and regulation. To ensure compost quality and facilitate marketing of compost to the agriculture sector, the government enacted a new regulation in 2008, which allows only certified and registered compost approved by the government to be marketed commercially. The registration of compost is a two-stage process, where after complying with standards of compost through laboratory analysis, a field trial is undertaken on different crops. Subsequent to the field trial, if the compost yields a higher crop through IPNS, then the compost is approved by the government and cleared for marketing. The compost must also meet the government compost quality standard.[5] As a result of these new rules, many compost plants face problems in marketing their product, since it takes around 1.5–2.0 years to receive the registration from the government. Unregistered compost cannot be sold commercially in Bangladesh markets, and the Department of Agricultural Extension encourages farmers to use only registered compost approved by the government. Fertilizer dealers all the over the country have also been instructed to market only registered compost.

A number of ministries, including the Ministry of Environment and Forests, the Ministry of Agriculture, the Ministry of Local Government, and the Ministry of Finance, each promote recycling of organic waste. The recycling of waste is also highlighted in the recently issued PPP guidelines issued by the Prime Minister's office as a priority area of PPP.

The Government of Bangladesh approved the National 3R Strategy in 2010, which made source segregation mandatory and gave directives to municipalities to pursue organic waste-recycling projects through composting, refuse-derived fuel, and biogas via PPPs (Box 2). It makes clear that medium- to large-scale organic waste-recycling projects will be implemented and managed by the private sector. Moreover, the strategy makes recommendations concerning issues such as tipping fees and access to municipal land for recycling projects. Despite the approval of these two regulations, they have yet to be implemented.

[5] Government of Bangladesh, National Fertilizer Standardization Committee. 2008. *Organic Fertilizer Standard*. Dhaka.

Appendix 2
Priority Actions by Country for Scaling Up Organic Waste Management

Findings of the Regional Workshop
(Dhaka, Bangladesh, 2–3 August 2010)

No.	Priority Action	Responsibility	Timeframe (Short-, Medium-, Long-Term)
Priority Actions for Bangladesh			
1.	To create awareness among citizens so that segregation of waste should be done at source	Local government division, Ministry of Environment, and Ministry of Education	Long-term
2.	Rules and regulations for marketing of compost should be easier	Government of Bangladesh	Short-term
3.	PPP should be encouraged for sustainable operations of waste management and facilities	Government of Bangladesh and municipalities	Long-term
Priority Actions for India			
1.	Allocation of land for waste processing facilities with buffer-zoning development plans	Urban local bodies, state governments, and Ministry of Urban Development	Medium-term
2.	Integrated designing for compost, RDF, and SLF, along with capacity building of urban local bodies	Ministry of Urban Development, Ministry of Agriculture, Ministry of Environment, and Ministry of New and Renewable Energy Sources	Short-term
3.	Co-marketing, co-warehousing, basket approach of compost with extension services, and community participation	Ministry of Fertilizer and Ministry of Agriculture	Short-term
Priority Actions for Nepal			
1.	Specific policy for scaling up organic waste should be introduced	Ministry of Local Development	Long-term

continued on next page

Findings of the Regional Workshop *continued*

No.	Priority Action	Responsibility	Timeframe (Short-, Medium-, Long-Term)
2.	Pilot projects on segregation and recycling of organic waste	SWMRMC and municipalities	Medium-term
3.	Explore programmatic CDM on waste composting	SWMRMC and municipalities	Short-term
Priority Actions for Sri Lanka			
1.	Popularizing household bins, review of existing standards, and onsite training on composting.	Local authority, national government, and central and provincial governments	Short-term
2.	Programmatic CDM, medium-scale compost projects, incentive schemes for composting, identify lands, and strengthen provincial councils capacity	Central government, provincial council, local level, and national government	Medium-term
3.	Promoting large-scale facilities and acquisition of land for composting.	National government	Long-term

CDM = Clean Development Mechanism, PPP = public–private partnership, RDF = refuse-derived fuel, SLF = sanitary landfill site, SWMRMC = Solid Waste Management Resource Mobilization Center.

Source: Development Partnership Program for South Asia regional workshop findings, 2–3 August 2010, Dhaka, Bangladesh.

Appendix 3
Additional Resources

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Appendix 4
Carbon Financing for Organic Waste Management

What is the Clean Development Mechanism?

The Clean Development Mechanism (CDM) allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to 1 ton of carbon dioxide. These CERs can be traded and sold, and used by industrialized countries to meet part of their emission reduction targets under the Kyoto Protocol. The mechanism is an innovative market-based instrument which provides investors with a means for promoting sustainable development in developing countries while curbing greenhouse gas (GHG) emissions beyond the business-as-usual level, and offers opportunities for government and private sector investment. Another distinctive feature of the CDM is the "bottom–up" approach to project development involving public and stakeholder scrutiny.

The CDM enables developing country entrepreneurs and others to receive investment funds for undertaking projects that reduce GHG emissions. Two aspects are important in the CDM:

- the project proponent must prove that the GHG emission reduction would not have occurred in the absence of the project, and
- the project must promote sustainable development.

As of June 2011, the South Asia region had 14 CDM projects using organic waste which were registered or requesting registration with the United Nations Framework Convention on Climate Change (UNFCCC). Of the 14 projects, 12 were from India and 2 were from Bangladesh. Of these projects, 10 were for composting, 2 were for refuse-derived fuels (RDF), and 2 were for landfill gas extraction.[1]

[1] UNFCCC. http://www.unfccc.int

Available ADB Carbon Funds

ADB provides the following funds to support carbon-financing initiatives:

ADB Asia Pacific Carbon Fund. The Asia Pacific Carbon Fund (APCF) is a trust fund established and managed by ADB on behalf of fund participants.[2] The APCF provides up-front cofinancing to CDM projects in ADB's developing member countries for future delivery of CERs. The APCF focuses on CDM projects with strong development impacts, and aims to carry out action on climate change with the principles of sustainable development. The APCF is currently involved in over 45 CDM projects across Asia and the Pacific. These carbon reduction projects include wind, solar, hydro, biogas, biomass, waste management, energy efficiency, and coal mine methane utilization.

ADB Future Carbon Fund. Responding to a post-2012 scenario where the current regulatory framework based on the Kyoto Protocol's first commitment period expires, this ADB fund stimulates new investments in clean energy projects even before a new international agreement is reached. Many regions, countries, and organizations now have, or are developing their own mandatory or voluntary commitments to reduce GHG emissions. Participants in the fund may include both public and private sector entities in ADB's member countries. It is a public–private partnership between ADB, governments, and companies who have decided to act before a new international agreement is reached.

Post-2012 Situation. The current regulatory framework, based on the Kyoto Protocol's first commitment period expires on 31 December 2012, hampering the trading in post-2012 carbon credits. This would affect the level of interest in developing new clean energy projects and other climate change initiatives in developing countries. Without long-term price incentives for reducing GHG emissions, investment trends could quickly return to business as usual. The post-2012 situation includes a number of proposals being worked out including Nationally Appropriate Mitigation Actions and sectoral CDM that may cover this sector in the new regime where financial assistance from developed countries to developing countries to reduce emissions will continue.

Recommendations for Clean Development Mechanism Projects

Evaluation of approved CDM methodologies and the documentation and data from registered large-scale CDM projects suggest a number of generalized but nonetheless clear conclusions for such CDM projects:

- The greater the level of contamination of biodegradable organic materials with nonbiodegradable materials, the lower the quantity of compost produced per ton of total material received and per dollar of capital investment expenditure. This necessarily equates to lower revenues from compost sales, and to lower CER revenue per ton of facility processing capacity, as the leakage of organic material to the reject residual waste stream is greater. This equates to a lower rate of return on capital investment.

[2] ADB. Climate Change—Financing. http://beta.adb.org/themes/climate-change/financing

- The processing of source-segregated organics will deliver greater emissions reduction and CERs per ton of material handled and processed. This equates also to greater rate of return on capital investment, as total tonnage per dollar of capital investment is limited. In other words, the greater the level of contamination of biodegradable organic materials with nonbiodegradable materials, the lower the CER revenue per ton of facility processing capacity.
- Manual-processing methods deliver greater potential emissions reduction and CERs per ton of material handled and processed (as laborers do not directly consume diesel fuel or electricity), and programmatic CDM now offers a cost-effective method for registering multiple decentralized small-scale facilities as activities under a single CDM registration.
- The 2,000 ton/week plus or minus 20% organic waste-processing capacity is a reasonable estimate for the tonnage threshold of 60 kilotons of emissions reductions per year that defines small-scale projects. This will depend on the type of waste processed and the baseline scenario variables.
- The CDM registration process does not provide any assurance of achieving actual emissions reductions. It is the responsibility of the project proponents to ensure that CDM methods, technologies, and monitoring mechanisms perform as required to deliver actual and verifiable emissions reductions.
- The CDM registration process validates only that (i) the proposal (project design document) conforms to the requirements of the approved methodology, (ii) baseline emissions from current disposal practices are valid, (iii) the project is not financially viable without CDM revenue, and (iv) the monitoring plan provides data to enable calculation of actual emissions reductions (if the plan is followed). Risk of project nonperformance is borne 100% by the project partners. The project partners are exposed financially to the extent to which the chosen composting technology and methods fail to perform and result in a lesser quantity of actual emissions reductions being achieved than originally projected in the project design document, and correspondingly lower level of revenue from the sale of CERs being realized.
- Forced aeration composting technologies provide greater control over the process, and (if well designed) will provide assurance of maintaining adequate oxygen levels required to achieve actual emissions reductions, particularly during the initial stages of the composting cycle.
- Regions that are subject to high rainfall, especially during monsoonal periods, will receive materials with significantly higher moisture content during wet periods, and unless covered, will struggle to maintain adequate oxygen levels in compost piles. Covered or roofed areas are required to manage the moisture content of piles and to enable screening; they are commonly referred to as “monsoon covers.”
- Co-location of the processing facility near to or at an existing waste dumpsite may reduce project risk by simplifying the required environmental impact assessment, reducing the risk of detrimental impact on the local community, and may simplify the emissions reduction calculations and monitoring requirements. Such co-location may also increase potential emissions reductions by minimizing emissions (and costs) associated with the transport and disposal of residual waste to landfill. This may be particularly relevant for processing facilities that accept mixed waste.
- CDM revenues should aim to pay down capital investment and repay CDM project establishment costs within the first crediting period (7 or 10 years).

Toward Sustainable Municipal Organic Waste Management in South Asia
A Guidebook for Policy Makers and Practitioners

The massive scale of urbanization in South Asia is expected to create a surge in demand for solid waste services. An enormous opportunity exists to improve upon the "business-as-usual" approach of uncollected waste and open dumping witnessed throughout the region and to convert this waste into value-added resources, such as alternative fuels and agricultural fertilizers. As approximately 70% of the region's municipal waste stream is currently organic (biodegradable) waste, methods such as composting, anaerobic digestion, and conversion to refuse-derived fuels offer a more sustainable course of action. This report aims to align South Asian cities with ADB's Strategy 2020 for environmentally sustainable growth and livable cities. It provides a useful management resource, identifying key issues and pointing policy makers, city managers, and practitioners to improved waste treatment technologies.

About the Asian Development Bank

ADB's vision is an Asia and Pacific region free of poverty. Its mission is to help its developing member countries reduce poverty and improve the quality of life of their people. Despite the region's many successes, it remains home to two-thirds of the world's poor: 1.8 billion people who live on less than $2 a day, with 903 million struggling on less than $1.25 a day. ADB is committed to reducing poverty through inclusive economic growth, environmentally sustainable growth, and regional integration.

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