Municipal Solid Waste Treatment Technologies and Carbon Finance

World Bank
Carbon Finance Unit

Thailand, Bangkok
January 24, 2008

Outline

- Municipal Solid Waste (MSW) characteristics
- Current MSW systems in East Asia region
- Low cost MSW technologies
- Advanced MSW treatment technologies
- Comparison of MSW treatment technologies & carbon financing
- Recommendations

Waste Generation Rate

Income Level	Generation Rate kg / capita / day	Waste Quantity* tons / day
Low	0.5	500
Middle	0.7	700
High	1.6	1,600

* Assumed population 1.0 million.

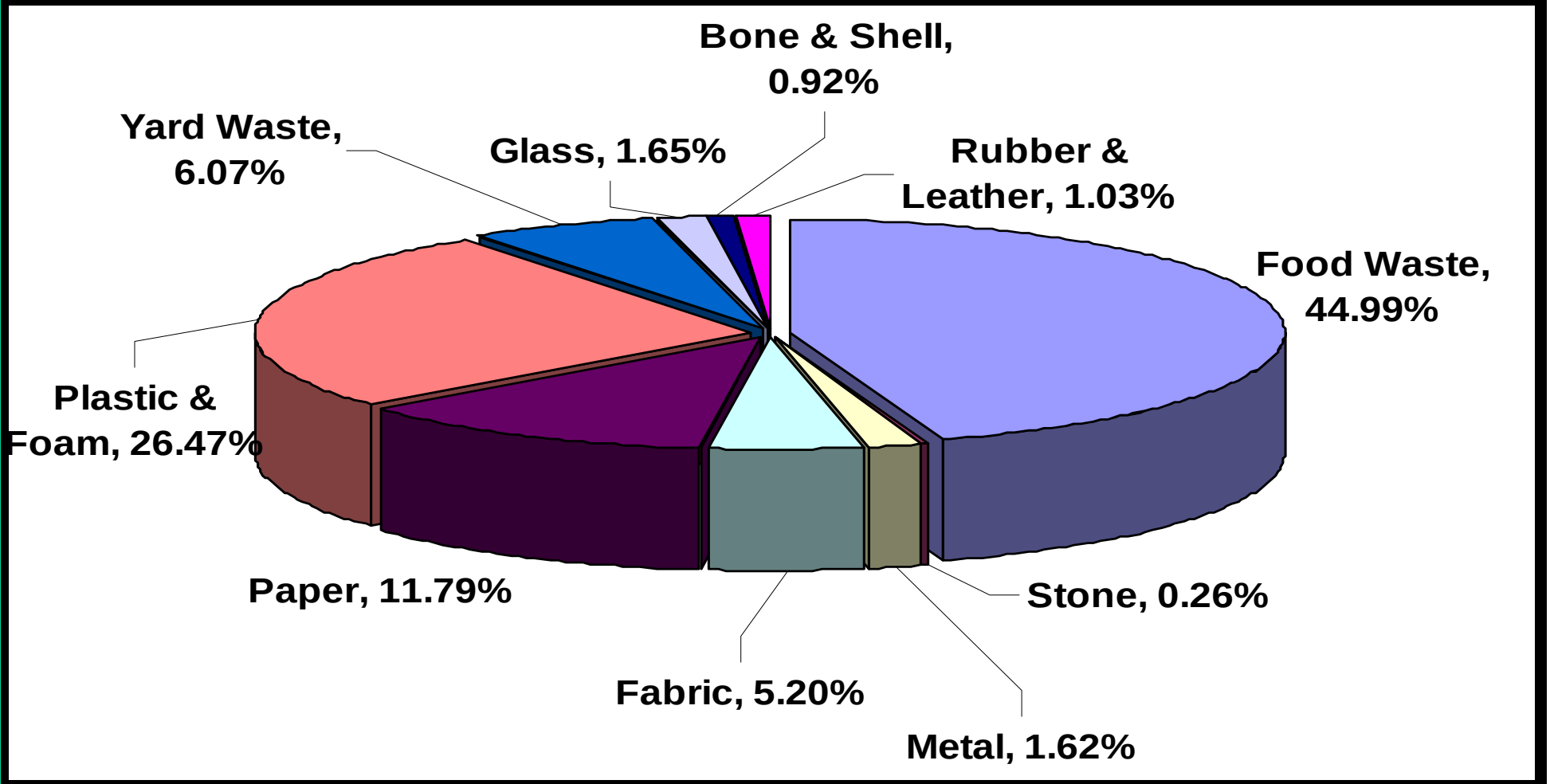
Composition & Moisture Content

	Income Level		
Material	**Low**	**Middle**	**High**
Food	40-85%	20-65%	20-50%
Paper	1-10%	15-40%	15-40%
Recyclables	4-25%	5-26%	11-43%
Fines	15-50%	15-50%	5-20%
Moisture	40-80%	40-60%	20-30%

- More biomass organics / moisture – beneficial to LFG and composting projects – not favorable for combustion and thermal technologies
- Moisture – higher precipitation more rapid decomposition - - IPCC: > 1,000 mm / yr.

Solid Waste Composition in Bangkok

2006 data



Solid Waste Composition in Bangkok (cont.)

- 8,000-9,000 t/d
- Half (44-60%) water by weight
- Half (49-61%) is organic[1]
- Third (33-45%) is combustible[2]

1 Food, yard and miscellaneous organic

2 Paper, plastic, rubber, leather, textiles

Current MSWM systems in East Asia region

- MSW collection rates: Singapore (90%), Bangkok, Jakarta and Kuala Lumpur (80 – 85%)
- MSW practices: recycling / recovery, landfilling / open dumping, composting and incineration.
- Composting and incineration plants installed are either not working or operating at low capacities for the following reasons:
  - High O&M costs
  - Poor maintenance and operation of facilities
  - Lack of expertise
  - Poor pre-treatment (for ex. incomplete separation of non-compostables, inhomogeneous waste feed to incinerator)
  - High cost of compost compared to commercial fertilizers
  - Local opposition to incineration is growing

Current MSW treatment systems in East Asia region

Country	Disposal / Treatment Methods (%)				
	Composting	Open dumping	Landfilling	Incineration	Others
Indonesia	15	60	10	2	13
Malaysia	10	50	30	5	5
Myanmar	5	80	10	-	5
Philippines	10	75	10	-	5
Singapore	-	-	30	70	-
Thailand	10	65	5	5	15
Vietnam	10	70	-	-	20

Low cost MSW treatment technologies

- Low cost and sound MSW disposal / treatment methods are:
  - Controlled landfills: has clay liner, leachate collection and treatment system, systematic layering and compaction of waste, regular covering, etc.)
  - Sanitary landfills: has geo-synthetic liner, leachate collection and treatment system, passive venting, proper operation)
  - Bio-reactor landfills: designed and operated as bio-reactor / anaerobic digestor. 15-25% less land requirement compared to sanitary landfills; maximization of LFG generation with time
  - Composting (windrow or passive)
  - In-vessel composting is not low cost technology, but well established and effective treatment process especially with MSW having high organic fraction (>40%), low land availability (small footprint), odor problems, problems siting of treatment facility

Landfill Design

LFG-to-Electricity (1 MW)

Durban, South Africa

Landfill Gas (LFG) Recovery System

Technology I: windrow

Technology II: Aerated Static Pile

Technology III: **In-Vessel**

Landfilling verses Low cost composting of different types of wastes (500 t/d)

	Sanitary Landfill	MSW [a]	Market/food[b]
Total ERs 2009 - 2014 (tCO2e)	175,000	350,000	600,000
Methane avoided (tons CO2e/ton MSW)	0.25	0.5	0.7
Capital Cost M US$	$1 M + cost of landfill	4-5	1-1.5
O&M cost US$ / yr.	70,000 – 100,000	100,000 – 200,000	50,000 - 100,000

a: 65% organic content (requires sorting, composting and screening processes)

b: 100% organic content (market / food waste)

Advanced MSW treatment technologies (AMSWTT)

AMSWTT also referred to as waste to energy (WTE) technologies require 5 components:

1. Front end MSW pre-processing: is used to prepare MSW for treatment by the AMSWTT and separate any recyclables
2. Conversion unit (reactor)
3. Gas and residue treatment plant (optional)
4. Energy recovery plant (optional): Energy / chemicals production system includes gas turbine, boiler, internal combustion engines for power production. Alternatively, ethanol or other organic chemicals can be produced
5. Emissions clean up

Pyrolysis

- Non-commercial has been proven technically at pilot scale but not commercial scale / financially
- Thermal degradation of organic materials through use of indirect, external source of heat
- Temperatures between 300 to 850^{o}C are maintained for several seconds in the absence of oxygen.
- Product is char, oil and syngas composed primarily of O_2, CO, CO_2, CH_4 and complex hydrocarbons.
- Syngas can be utilized for energy production or proportions can be condensed to produce oils and waxes
- Syngas typically has net calorific value (NCV) of 10 to 20 MJ/Nm

Gasification

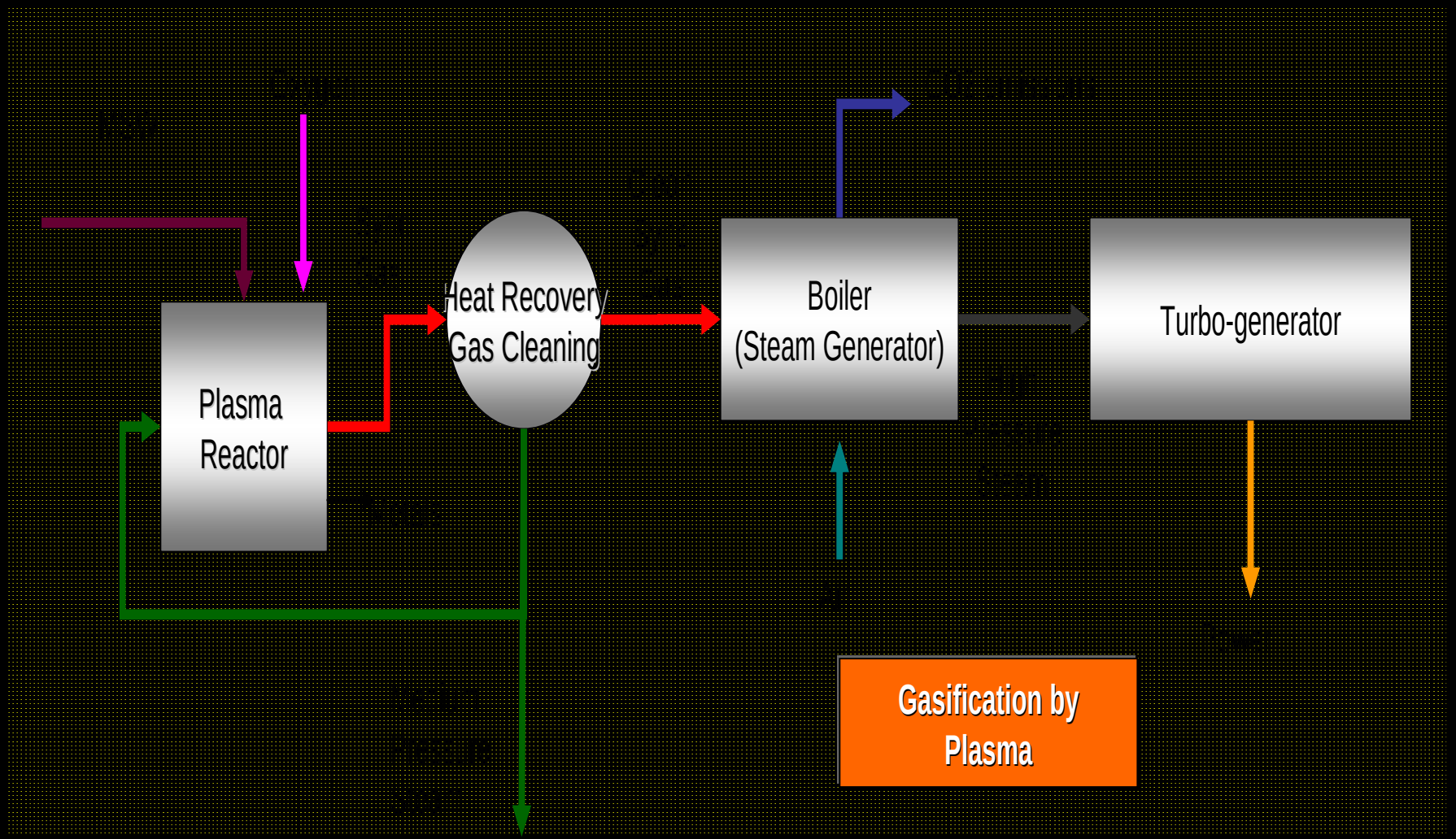
- Non-commercial has been proven technically (pilot scale) but not not commercial scale / financially
- Can be seen as between pyrolysis and combustion (incineration) as it involves partial oxidation.
- Exothermic process (some heat is required to initialize and sustain the gasification process).
- Oxygen is added but at low amounts not sufficient for full oxidation and full combustion.
- Temperatures are above 650^{o}C
- Main product is syngas, typically has NCV of 4 to 10 MJ/Nm^{3}
- Other product is solid residue of non-combustible materials (ash) which contains low level of carbon

Note: Natural gas has NCV of around 38 MJ/Nm^{3}

Plasma Gasification

- Non-commercial has been proven technically (pilot scale) but not not commercial scale / financially
- Use of electricity passed through graphite or carbon electrodes, with steam and/or oxygen / air injection to produce electrically conducting gas (plasma)
- Temperatures are above 3000^{o}C
- Organic materials are converted to syngas composed of H2, CO
- Inorganic materials are converted to solid slag
- Syngas can be utilized for energy production or proportions can be condensed to produce oils and waxes

Plasma gasification



Incineration

- Combustion of raw MSW, moisture less than 50%
- Sufficient amount of oxygen is required to fully oxidize the fuel
- Combustion temperatures are in excess of 850^{o}C
- Waste is converted into CO2 and water concern about toxics (dioxin, furans)
- Any non-combustible materials (inorganic such as metals, glass) remain as a solid, known as bottom ash (used as feedstock in cement and brick manufacturing)
- Fly ash APC (air pollution control residue) particulates, etc
- Needs high calorific value waste to keep combustion process going, otherwise requires high energy for maintaining high temperatures

Anaerobic digestion

- Well known technology for domestic sewage and organic wastes treatment, but not for MSW
- Biological conversion of biodegradable organic materials in the absence of oxygen at temperatures 55 to 75^{o}C (thermophilic digestion – most effective temperature range)
- Residue is stabilized organic matter that can be used as soil amendment after proper dewatering
- Digestion is used primarily to reduce quantity of sludge for disposal / reuse
- Methane gas generated used for electricity / energy generation or flared

Advanced MSW treatment technologies (cont.)

General characteristics of AMSWTT are:

- Well established technologies in industrial sector / domestic sewage (for anaerobic digestion), but not in the MSW sector. Exceptional case is incineration
- For MSW, the AMSWTT are at demonstration stage, have not been designed for large MSW volumes (largest installed capacity is 400 t/d pyrolysis plant in Japan)
- Very high capital, and O&M costs
- Require skilled engineers / operators
- Have not been designed to handle heterogeneous mixed MSW
- Not optimized in terms of overall energy and materials production

Comparison of AMSWTT

Technology	Plant capacity (tons/day)	Capital cost (M US$)	O&M cost (US$/ton)	Planning to commissioning (months)
Pyrolysis	70-270	16 - 90	80 - 150	12 - 30
Gasification	900	15 - 170	80 - 150	12 – 30
Incineration	1300	30 - 180	80 - 120	54 – 96
Plasma gasification	900	50 - 80	80 - 150	12 – 30
Anaerobic digestion	300	20 - 80	60 - 100	12 - 24
In vessel composting	500	50 – 80	30 - 60	9 – 15
Sanitary landfill	500	5 - 10	10 – 20	9 – 15
Bioreactor landfill	500	10 – 15	15 - 30	12 – 18

Recommendations

- Carry out detailed feasibility study using Municipal Solid Waste Decision Support Tool (MSW DST) or similar model for a city, for evaluation of technical, economical, environmental, siting / permitting and social aspects to come up with most efficient integrated MSW system
- AMSWTT should not be considered at this stage as these are under development, not proven to be cost effective with MSW in general and especially at large scale, require expensive upstream pre-treatment, high expertise, etc.
- Put appropriate source segregation programs, recycling centers, composting (in-vessel for cities with scarce land; market waste separate) and landfilling of rejected material (should not exceed 20-25% of total MSW generated)
- Include carbon finance revenues in a programmatic manner to address MSW on the city or country level to maximize CF revenues and at least pay for O&M costs

THANK YOU VERY MUCH

FOR MORE INFORMATION CONTACT

Neeraj Prasad, nprasad@worldbank.org
Ahmed Mostafa, amostafa1@worldbank.org
Nat Pinnoi, npinnoi@worldbank.org
Charles Peterson, cpeterson@worldbank.org

Useful References (1)

General Websites on CDM and JI:

- CFU website on CDM methodologies: Carbon Finance at the World Bank: Methodology (www.carbonfinance.org)
- Website of the UNFCCC: CDM: CDM-Home (http://cdm.unfccc.int/ and http://ji.unfccc.int/)
- Website on CDM (and JI) procedures (Ministry of the Environment Japan, Institute for Global Environmental Strategies): http://www.iges.or.jp/en/cdm/report01.html
- Website (UNEP, Risø Centre): CDM (and JI) pipeline overview

  http://cd4cdm.org/index.htm

Website on Waste Management

- World Bank website: www.worldbank.org/solidwaste

Useful References (2)

Websites useful for country information and data:

- National Communications (for Annex I and non-Annex I Countries) and National Emissions Inventories (Annex I countries): http://unfccc.int/national_reports/items/1408.php
- IPCC Methodology reports (e.g. National Guidelines for National GHG Inventories) : http://www.ipcc.ch/pub/guide.htm
- Website for energy statistics (International Energy Agency): http://www.iea.org/Textbase/stats/index.asp
- Website on Climate Analysis Indicators Tool (World Resources Institute): http://cait.wri.org/
- Website on emissions from oil and gas industry (US EPA Gasstar): http://www.epa.gov/gasstar/index.htm