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Annex 1: Waste Collection and Transport Calculations

ASSUMPTIONS

Assumptions used for the calculation of the collection and transport equipment.

Density of residual fraction / paper (tn/m^3)	0.18
Density of recyclables fraction (tn/m^3)	0.12
Density of biodegradable waste fraction (tn/m^3)	0.30
Density after compaction in waste truck (tn/m3)	0.5
Average collection truck speed in urban areas (km/h)	15
Average hauling truck speed (km/h)	40
Bins capacity for residual waste and recyclable material (lt)	660
Bins capacity for organic material (lt)	120
Bin fullness (%)	80
Waste collection trucks capacity for residual waste and recyclable material (m3)	7
Waste collection trucks capacity for organic material (m3)	6
Truck fullness (%)	85%
Standby allowance for trucks	25%
TS containers capacity (m3)	20
Density after compaction in transfer stations	0.65
Time for unloading of waste collection truck in TS/Disposal Facility (min)	20
Unloading time for hauling truck in treatment facility (hr)	30
Drivers working hours (h/d) - productive time	6

RESIDUAL WASTE COLLECTION AND TRANSPORT

Transfer stations (TS)

Description	Unit	TS1
Distance from Transf. Station to facility (vice versa)	km	28.4
Waste amount	tn/yr	26,986.12
Average weight in containers	tn/cont	13.0
Necessary routes (5wd/week)	routes/yr	2,076
	routes/day	8
Duration of 1 route	hr	1.4
Necessary trucks	number	2
Necessary containers	number	3
Total distance travelled	km/yr	58,954
Total hours of travel	hr/yr	1,965

Residual Waste Collection

	Cluster 1	Cluster 2
Total Population	71,565	113,492
Mixed waste (in t/yr)	26,986	42,797
Mixed waste (in kg/d)	73,935	117,251
Average production (m^3/d) Density 180 kg/m^3	411	651
Average weekly volume	2,875	4,560
Effective working hours/shift	7.5	7.5
Number of shifts	1	1
Needed working days/ year	312	312
Collection Bins		
Collection frequency / wk	3	3
Needed bin volume (in m^3)	958	1,520
Number of 660lt bins (80% full)	1,815	2,879
Served population per bin	120	120
Bins no.	596	946
Necessary number of Bins 660 lt	1,815	2,879
Collection Trucks		
Average pay load, t	5.0	5.0
Utilization of capacity	85%	85%
Average utilized payload, t	4.3	4.3
Average distance to disposal site/ TS, km	8.58	13.88
Average speed when travelling, km/h	40	40
Average time to and from disposal site/TS, h	0.43	0.69

Average time at disposal site/TS, h	0.50	0.50
Total time traveling/trip, h	0.93	1.19
Time for emptying one container, min	2	2
Time to drive to next container, min	1	1
Average weight loaded, t/bin	0.095	0.095
Loading efficiency/hour, t/h	1.9	1.9
Time for loading a truck totally, h	2.24	2.24
Total time per first trip, h	3.16	3.43
Standby allowance, 20%, h	0.6	0.7
Total time for 1 trip, h	3.8	4.1
Remaining time for second trip	3.7	3.4
Maximum number of possible trips per day	1.0	1.0
Average load collected/day	4.25	4.25
Compaction trucks required	21.0	33.0

RECYCLABLE MATERIALS SOURCE SEPARATION CALCULATIONS

	Cluster 1	Cluster 2
Total Population	71,565	113,492
Recyclable materials (in t/yr)	5,446	8,637
Recyclable materials (in kg/d)	14,921	23,663
Average daily production (m^3/d) density 120 kg/m^3	124.3	197.2
Average weekly volume	870.4	1,380.3
Containers		
Collection frequency / wk	1	1
Needed bin volume (in m^3)	870	1,380
Number of 660lt bins (80% full)	1,648	2,614
Served population per bin	200	200
Bins no.	358	567
Necessary number of Bins 660 lt	1,648	2,614
Collection Trucks		
Average pay load, t	5.0	5.0
Utilization of capacity	85%	85%
Average utilized payload, t	4.3	4.3
Effective working hours/shift	7.5	7.5
Average distance in urban area, km	2	2
Average distance to MRF, km	16.28	15.98
Average speed when travelling, km/h	40	40
Average time to and from MRF, h	0.91	0.90
Average time on disposal MRF, h	0.50	0.50
Total time traveling/trip, h	1.41	1.40
Time for emptying one container, min	2	2
Time to drive to next container	1	1
Bins capacity (lt)	660	660
Average weight loaded, t/ "dry bin"	0.063	0.063
Loading efficiency/hour, t/h	1.3	1.3
Loading time for loading a truck totally, h	3.35	3.35
Total time per first trip	4.77	4.75
Buffer time, h	0.5	0.5
Total time driving/loading/unloading, h	5.3	5.3
Standby allowance, 25%, h	1.3	1.3
Total time for 1 trip, h	6.6	6.6
Remaining time for second trip	0.9	0.9
Maximum number of possible trips per day	1.1	1.1
Selected trips per day	1	1
Average load collected t/day	4.25	4.25
Trucks req'd per cluster	4.11	6.51
Trucks req'd	11	

ORGANIC FRACTION SOURCE SEPARATION CALCULATIONS

	Cluster 1	Cluster 2
Total Population	71,565	113,492
Organic material (in t/yr)	1,780	2,824
Organic material (in kg/d)	4,878	7,736
Average daily production (m^3/d) density 300 kg/m^3	16.3	25.8
Average weekly volume	113.8	180.5
Effective working hours/shift	7.5	7.5
Number of shifts	1	1
Containers		
Collection frequency / wk	3	3
Needed bin volume (in m^3)	38	60
Number of 120lt bins (80% full)	395	627
Targeted population	2,863	4,540
Served households per bin	10	10
Bins no.	72	113
Necessary number of Bins 120 lt	395	627
Collection Trucks		
Average pay load, t	3.0	3.0
Utilization of capacity	85%	85%
Average utilized payload, t	2.55	2.55
Effective working hours/shift	7.5	7.5
Average distance in urban area, km	2	2
Average distance to disposal site/ TS, km	16.28	15.98
Average speed when travelling, km/h	40.0	40.0
Average time to and from Facility, h	0.91	0.90
Average time on disposal Facility h	0.50	0.50
Total time traveling/trip, h	1.41	1.40
Time for emptying one container, min	2	2
Time to drive to next container	2	2
Bins capacity (lt)	120	120
Average weight loaded, t/bin	0.029	0.029
Loading efficiency/hour, t/h	0.4	0.4
Loading time for loading a truck totally, h	5.90	5.90
Total time per first trip	7.32	7.30
Buffer time, h	0.5	0.5
Total time driving/loading/unloading, h	7.8	7.8
Standbuy allowance, 25%, h	2.0	2.0
Total time for 1 trip, h	9.8	9.8
Remaining time for second trip	0.0	0.0
Maximum number of possible trips per day	1.0	1.0

Average load collected t/day	2.55	2.55
Trucks req'd	2.24	3.55
Trucks req’d	6	

Annex 2: Alternative Waste Treatment Technologies Assessment Methodology

Department of Environment
and Conservation (NSW)

Alternative Waste Treatment Technologies

Assessment Methodology and Handbook

Version 1.0

OUR ENVIRONMENT
it's a living thing

Alternative Waste
Treatment Technologie

APPENDIX A
PERFORMANCE CRITERIA

Financial performance criteria

Technology cost

This criterion refers to the cost incurred by the technology purchaser for the waste treatment technology. Two options for representing this cost are discussed below. You can apply either, provided that you apply the same option for each alternative.

Option 1: Net input cost per tonne. Net cost per tonne input is equivalent to the gate fee that would be charged to the waste supplier by a proponent for the receival of collected material. It represents the net costs of processing, taking into account both the costs incurred by the proponent in treatment and the revenue from recovered resources. Gate fee is usually expressed on a $/tonne basis.

To determine a gate fee, whole-of-facility costs need to be accounted for, including capital costs, operating costs, and revenue. A sample cost calculation template that can be used as a guide for proponents to determine cost per tonne (gate fee) is provided overleaf.

Option 2: Whole-of-life costs. Most facilities for the treatment of municipal wastes are established under a contractual arrangement between one or more councils and a technology provider. Because of the large capital investment required, contracts are usually established over long periods (up to 20 years) to ensure that the project is economically viable.

Whole-of-life project costs represent the costs incurred by a technology purchaser over the life of the project (usually the contract period). Whole-of-life costs are usually calculated following the receipt of tenders for a project. They are usually not calculated at earlier stages of a project (e.g. at the 'expression of interest' stage).

In simple terms, whole-of-life costs can be calculated by multiplying input tonnage by the applicable gate fee summed over each year of the project life. In the calculation, it is important to account for the way a technology provider has factored in changes to variables that will affect the economics of a project over its life, which in turn affect the gate fee. These are sometimes referred to as 'rise and fall' provisions.

During long contractual periods, considerable changes can, and do, take place. For example, in the Sydney Metropolitan Area, charges for the disposal of 1 tonne of municipal solid waste at a licensed Class 1 landfill have increased from in the order of $20/tonne in 1990 to $85/tonne in 2003. This has been due to increased levies and allowance for post-closure environmental management.

Other variables that do influence, or have the potential to influence, the economics of alternative treatment technologies are:

- market prices for recovered resources
- government policies with respect to the recovery of energy from waste
- government incentives for green energy (e.g. renewable energy scheme)
- trading of emission reduction units
- government commitments to reduce greenhouse gas emissions
- changes in environmental standards and regulations
- labour costs
- fuel costs.

The impact on the gate fee of changes to the above variables is often linked to an appropriate indicator or index (e.g. the Consumer Price Index, market price for fuel, labour award rates). Assumptions related to each index are then made and the whole-of-life costs calculated.

In calculating whole-of-life costs it is important to ensure that the life of the project is consistently applied in the assessment of each alternative (e.g., 20 years).

Cost calculation template:
Alternative Waste Treatment Technology

Cost calculation

Input quantity at gate: tonnes/year

Cost item

1 Capital costs	Capital cost	Depreciation period (years)	Interest rate (%)	Annual costs	Cost per tonne
Site preparation (including earthworks, infrastructure and services)					
Buildings					
Major equipment (i.e. processing equipment)					
Ancillary equipment (i.e. monitoring equipment, mobile equipment, screens, tools)					
			Subtotal		

2 Maintenance, repair & insurance costs	% of capital costs	Annual costs	Cost per tonne
Major equipment			
Ancillary equipment			
Subtotal			

3 Ongoing costs	No.	Unit	Rate	Unit	Annual costs	Cost per tonne
Staff labour		h/y		$/h		
Fuel		L/y		$/L		
Power		kWh/y		$/kWh		
Water		kL/y		$/kL		
Waste water		kL/y		$/kL		
Processing additives		kg/y		$/kg		
Landfill disposal		t/y		$/t		
Statutory levies		t/y		$/t		
Lease of land	annual rent ($/y)					
				Subtotal		

4 Revenue	No.	Unit	Rate	Unit	Annual revenue	Revenue per tonne
Sale of recovered recyclables (glass, plastics, metals)		t/y		$/t		
Sale of processed organic material (if any)		t/y		$/t		
Sale of electricity (if any)		kWh/y		$/kWh		
Renewable energy certificates (if any)		kWh/y		$/kWh		
Emission reduction units		t CO_2/y		$/t CO_2		
				Subtotal		
				Total cost		

Note: Capital costs can be annualised by using the following equation:

$$AC = \frac{C \times (i\% \times (1 + i\%)^{DP})}{((1 + i\%)^{DP} - 1)}$$

where:

AC = Annualised capital cost ($/y)
C = Capital cost ($)
i% = Interest rate (%)
DP = Depreciation period (years)

Financial capacity

This criterion is a measure of the financial capacity of proponents to be able to provide the required waste treatment services. The importance of this criterion and the extent of information required usually depends on the stage of the process. Information that can be sourced from proponents or consortia to help assess their financial capacity can comprise one or more of the following:

- trading accounts
- independently certified profit and loss accounts and balance sheets
- taxation returns
- annual returns lodged at the Australian Securities Commission
- directors' statements
- auditors' reports
- the extent of bank overdraft facilities available, including associated security
- details of other financial resources available
- assurances from financial institutions and other creditors
- credit ratings (e.g. Standard and Poors); and
- bank account balances.

Financial assessment criterion: financial capacity

Description	Score
Proponent has demonstrated very strong capacity to meet likely financial commitments related to a facility employing the technology. There is a very low expectation of credit risk. This capacity is not significantly vulnerable to foreseeable events.	5
Proponent has demonstrated strong capacity to meet likely financial commitments related to a facility employing the technology. There is a low expectation of credit risk. This capacity is unlikely to be vulnerable to foreseeable events.	4
Proponent has demonstrated some capacity to meet likely financial commitments related to a facility employing the technology. The expectation of credit risk is uncertain. This capacity may be vulnerable to foreseeable events.	3
There is some uncertainty whether the proponent has the capacity to meet likely financial commitments related to a facility employing the technology. There is some expectation of credit risk. This capacity is likely to be vulnerable to foreseeable events.	2
There is considerable uncertainty as to whether the proponent has the capacity to meet its financial commitments related to a facility employing the technology. There is a considerable expectation of credit risk. The capacity is vulnerable to foreseeable events.	1

Environmental performance criteria

The assessment methodology provides the user with two different ways of conducting the environmental assessment:

- use of streamlined life cycle assessment (LCA) based on pollutant emissions and resource loads, or
- use of an ordinal ranking system of comparative environmental performance against each criterion.

The environmental performance criteria for the assessment of alternative waste treatment technologies are:

- global warming potential
- air emissions
- water emissions
- resource conservation.

A description of the determination of environmental criteria by using a streamlined method of LCA is provided below. To develop the relevant technology-specific life cycle data, the *Protocol for the Collection and Input of Environmental Data*, developed as part of this project, can be used (refer Appendix C).

There are three main steps to conducting LCA[3]. These are:

1. Goal and scope definition
2. Life cycle inventory analysis (LCI analysis)
3. Life cycle impact assessment (LCIA)

To undertake streamlined LCA of an alternative waste treatment technology as part of this handbook, only the *life cycle impact assessment* step is required (step 3). The other two steps (steps 1 and 2) have been completed as part of the development of this handbook and the accompanying software.

1. Goal and scope definition

The goal of the LCA is the environmental performance assessment of technology alternatives for the treatment of 1 tonne of waste (for the purpose of decision support). The assumed composition of the '1 tonne of waste' must be identical for each alternative considered, or otherwise the assessment will be invalid.

The system boundary for each alternative is from the point of waste receival (i.e. the facility's gate), through all treatment technology unit processes up to and including the final management of all residuals (either to landfill, via sewage treatment to land or sea, or through the stages of recovery). By-product recovery is included and, as such, the extraction, transport and refining of by-product substitutes (such as coal-fired electricity) are included in the emission credits.

2. Life cycle inventory analysis

Life cycle inventory analysis (LCI analysis) is a quantitative description of all of the flows across the boundary: either into or out of the 'system'. Further details are provided in the Protocol for the Collection and Input of Environmental Data (see Appendix C).

3. Life cycle impact assessment

A streamlined approach to LCA is used to aggregate the life cycle inventory data into environmental performance scores. A discussion of each criterion and the derivation of associated performance scores is provided below.

Global warming potential: determination by streamlined LCA

Global warming potential is expressed as CO_2 equivalents (tonnes). To derive 'global warming potential', the user must enter net emissions of carbon dioxide, methane and nitrous oxide in the life cycle inventory for each alternative waste treatment technology. The data are entered as tonnes of net emitted pollutant per tonne of input waste.

Entered life cycle inventory data are then converted to CO_2 equivalents (tonnes) by using equivalence factors, as outlined in the table below.

[3] The International Standards Organisation defines a fourth LCA step of *Interpretation.* However, in this handbook, this stage is conducted as part of the broader multi-criteria assessment technique.

Greenhouse gas equivalence factors

Greenhouse gas	Global warming potential (CO_2 equivalence factor)
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
Source: The Australian Greenhouse Office, Greenhouse Gap Program.	

In the methodology, the calculated CO_2 equivalents (tonnes) are then benchmarked against that for conventional landfilling for each alternative waste treatment technology.

Air emissions: determination by streamlined LCA

Air emissions are ranked to provide a relative comparison of the potential harm of the emission from each technology system being assessed. This initial comparison is not a full air assessment that involves sampling and modelling of air emissions. However, it does provide an important indication of the relative air emission benefits and disbenefits of a particular waste treatment technology against the other technologies being considered.

Each candidate technology is ranked by determining the volume of air required to dilute pollutant loads from the processing of 1 tonne of waste to meet ambient air quality goals. (The category is divided into toxic and general pollutants.) This volume is termed the 'critical volume'.

In the assessment methodology, air pollutant emissions are determined for each alternative waste treatment technology and entered by the user in a life cycle inventory. The data are entered as grams of emitted pollutant per tonne of input solid waste. The air critical volume is calculated as the sum of the critical volumes for each of the pollutants included in the analysis.

To demonstrate how critical volumes are derived, an example is provided in the table below for three hypothetical pollutants:

Example calculation of air critical volume based on three pollutants

Pollutant	Quantity emitted (g/t input)	Regulatory standard (mg/m^3)	Critical volume calculation
Pollutant A	50	1000	1000 x 50 / 1000 = 50 m^3/t input
Pollutant B	10	200	10 x 1000 / 200 = 5 m^3/t input
Pollutant C	5	300	5 x 1000 / 300 = 17 m^3/t input
Sum of critical volumes			72 m^3/t input

The calculated air critical volume is then benchmarked against that for conventional landfilling for each alternative waste treatment technology.

The air pollutants included in the life cycle impact assessment, together with the concentrations used to derive critical volumes as sourced from applicable regulatory standards, are shown in the table below.

Note that the ambient concentrations in the table are not stack or emission limits and are based upon the EPA's *Approved Methods and Guidance for Modelling and Assessment of Air pollutants in NSW.* The levels have various averaging periods, depending upon their associated impacts. For example, substances that have odour effects have relatively short averaging periods (e.g. 1 second for hydrogen sulfide (H_2S). In contrast, substances with chronic effects on health or vegetation may have longer periods (e.g. 90 days, 30 days, 7 days and 24 hours for hydrogen fluoride).

Comparing pollutants according to different averaging times can give an incorrect indication of the relative harm of different air pollutants. Therefore, the ambient criteria used for the critical air volume calculations have been standardised by using identical averaging times according to the adjustment factors used. Applying the adjustment factors to the ground level concentrations, an averaging period of 1 hour has been applied as the basis for 'normalising' critical volume concentrations.

Note that all future proposals will be required to meet the emission limits of the Clean Air (Plant and Equipment) Regulation 1997, and any development will be assessed by using the EPA's *Approved Methods and Guidance for Modelling and Assessment of Air Pollutants in NSW*.

Air pollutants and critical volume concentrations

Pollutant	Averaging period	Ambient concentration (mg/m^3)	Factor [1)]	Applicable standard for concentration	Critical volume concentration (mg/m^3)
Inorganic chemicals (metals and others)					
Hydrogen chloride (HCl)	3 min	0.3	0.55	Ground level concentration criteria (Table 3.3 of EPA 2001)	0.16484
Hydrogen fluoride (HF)	24 h	0.0029	2.50	Impact assessment criteria, 24-h averaging period (Table 3.2 of EPA 2001)	0.00725
Sulfur dioxide (SO_2)	1 h	0.57	1.0	Impact assessment criteria, 1-h averaging period (Table 3.1 of EPA 2001)	0.57000
Hydrogen sulfide (H_2S)	1 s	0.00138	0.43	Ground level concentration criteria. Population of affected community: Urban ($\geq \approx$ 2000) (Table 3.4 of EPA 2001)	0.00060
Nitrogen dioxide (NO_2)	1 h	0.246	1.0	Impact assessment criteria, 1-h averaging period (Table 3.1 of EPA 2001)	0.24600
Lead (Pb)	Annual	0.0005	12.50	Impact assessment criteria, annual averaging period (Table 3.1 of EPA 2001)	0.00625
Chromium (Cr)	3 min	0.017	0.55	Ground level concentration criteria (Table 3.3 of EPA 2001)	0.00934
Mercury (inorganic) (Hg)	3 min	0.0017	0.55	Ground level concentration criteria (Table 3.3 of EPA 2001)	0.00093
Organic chemicals					
Benzene	3 min	0.1	0.55	Ground level concentration criteria (Table 3.3 of EPA 2001)	0.05495
Chloroform	3 min	1.59	0.55	Ground level concentration criteria (Table 3.3 of EPA 2001)	0.87363
Dioxins (PCDD; polychlorinated dibenzo-dioxins)	24 h	4.56×10^{-10}	2.50	No value provided in EPA 2001. Value shown was derived from air emission limit values for PCDD and SO_2 in Council of the European Union (2000), and impact assessment criteria for SO_2, 24-h averaging period in EPA 2001	1.14E-09
Vinyl chloride	3 min	0.1	0.55	Ground level concentration criteria (Table 3.3 of EPA 2001)	0.05495

Sources:

Council of the European Union (2000), *Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste*, Annex V

EPA (2001), *Approved Methods and Guidance for the Modelling and Assessment of Air Pollutants in NSW (as at May 2002)*, **www.epa.nsw.gov.au/air/amgmaap-03.htm**

NEPS (as of February 20000) *National Ambient Air Quality National Environmental Protection Measure*, June 1988, **www.nepc.gov.au** (Lead data only).

1) *Averaging periods factors derived from following sources:*

1 second: Modelling and Assessment of Air Pollutants in NSW (EPA, August 2001)

3 minutes: EPA specific feedback to Model, 22 November 2002

1hour, 24 hours, Annual: United States EPA-454/R-92–019

Water emissions: determination by streamlined LCA

As for air emissions, water emissions are expressed as the volume of water required to dilute pollutant loads from the processing of 1 tonne of waste to meet relevant ambient water quality goals. (The category is also divided into toxic and general pollutants.) Ambient water quality goals have been used for comparative purposes and are not regulatory standards for discharge.

Water emissions are determined for each alternative waste treatment technology and entered by the user in the life cycle inventory. Critical volumes are then determined by using the same procedure as for air emissions, and each alternative waste technology is benchmarked against conventional landfilling.

The water pollutants included in the life cycle impact assessment, together with the concentrations used to derive critical volumes, as sourced from ANZECC/ARMCANZ (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, are shown in the table below.

Water pollutants and critical volume concentrations

Pollutant	Concentration (mg/L)	Applicable standard
Inorganic chemicals (metals and others)		
Ammonia	0.9	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
Arsenic (as V)	0.013	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
Cadmium	0.0002	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
Chromium (Cr VI)	0.001	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
Mercury (inorganic)	0.00006	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
Nickel	0.011	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
Nitrate	0.7	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
Organic chemicals		
Phenol	0.320	Trigger value for typical slightly to moderately disturbed freshwater systems (Table 3.4.1, ANZECC 2000)
ANZECC/ARMCANZ (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1, The Guidelines*, Australian and New Zealand Environment and Conservation Council / Agriculture and Resource Management Council of Australia and New Zealand **www.ea.gov.au/water/quality/nwqms/volume1.html**		

Resource conservation: determination by streamlined LCA

Resource conservation is expressed in 'ecodollars' and is based on environmental economic valuations[4] of the land-use and resource-scarcity/depletion effects of resource use. Resource conservation is calculated from the balance across the entire 'system', including both resource inputs and resource credits arising from recovery of resources.

Resources incorporated by the assessment are bauxite, coal, crude oil, iron (ore), lignite, limestone, NaCl, natural gas, sand, timber and compost (including any avoided degradation by salinity, water loss and acidification).

Global warming potential: determination by comparative ordinal ranking

Recently, technology providers have sought to quantify the greenhouse gas emissions from their technologies in order to claim greenhouse gas credits from the reduction in emissions when compared with conventional landfilling. Greenhouse gas credits are a potential source of income to facilities through emerging carbon-trading programs and (formerly) through the issue of Renewable Energy Certificates.

Of the greenhouse gases, those that contribute to global warming include carbon dioxide, methane, nitrous oxide and sulfur hexafluoride.

In the assessment of comparative emissions from a range of alternative waste treatment technologies, the following sources are usually included:

- transport of products to market
- fuel consumption
- emissions from landfilling of residues
- emissions from combustion
- emissions related to electricity consumption
- recovery of energy from waste (credit)
- recovery of recyclables (credit).

Ordinal scoring of global warming impacts for the purpose of comparative assessment of alternative waste treatment technologies is presented below. Scores are allocated with respect to the current management practice of the waste stream under consideration.

[4] Sources:
Nolan-ITU (2001a), *Independent Assessment of Kerbside Recycling in Australia*, National Packaging Covenant Council, and Nolan-ITU (2001b), *Organic Waste Economic Values Analysis*, Department of Industry and Trade and South Australian Environment Protection Agency (confidential report)

Environmental assessment criterion: global warming potential

Description	Score
Beneficial	5
Moderately beneficial	4
Negligible	3
Moderately detrimental	2
Detrimental	1

Air and water emissions: determination by comparative ordinal ranking

To assess air and water emissions in the absence of quantitative pollutant emission data, we have adopted a risk-based assessment procedure based on the methodology outlined in the Standards Australia and Standards New Zealand publication *Risk Management AS/NZS 4360:1999*. During its assessment of alternative waste treatment technologies, the Inquiry panel adopted this methodology in assessing the *Risk of Air Emissions* and *Risk of Water Emissions* (NSW Government 2000). An outline of the methodology is presented below.

Objectives. The objectives of the risk-based assessment approach are to:

- separate minor acceptable risks from major risks
- provide data to help evaluate and treat risks.

Risk analysis involves consideration of the sources of risk, the consequences of risk, and the likelihood that those consequences may occur.

Approach. In the risk-based assessment approach, the first step usually involves identifying the controls in place to manage risk (namely management, technical systems and procedures) and assessing their strengths and weaknesses.

In the context of alternative waste treatment technologies, the technology type (e.g. biological, thermal) influences the nature of the pollutants emitted (the pollutant emission profile) and hence their potential for environmental impact. Apart from technology type, the extent of the environmental controls provided is also used as an indicator of the risk of adverse emissions. When you are presented with a number of alternatives requiring comparative assessment, both these factors need to be taken into account.

The second step in the risk-based assessment approach examines both the *consequences* of adverse emissions, should they occur, and the *likelihood* of adverse emissions in the context of the controls provided. A qualitative description of each is provided in the following tables.

Qualitative measures of consequence or impact of adverse emissions

Descriptor	Detailed description
Insignificant	Emissions characterised as being insignificant in volume and/or toxicity. Negligible environmental impact.
Low	Emissions characterised as having minor consequence because of low volume and/or toxicity of pollutants released.
Moderate	Emissions characterised as having moderate consequence.
High	Emissions characterised as having major consequence because of large volume and/or high toxicity of pollutants released.
Extreme	Emissions characterised as having extreme consequence because of large volume and high toxicity of pollutants released.

Qualitative measures of likelihood of adverse emissions

Descriptor	Detailed description
Almost certain	Is expected to occur in most circumstances
Likely	Will probably occur in most circumstances
Possible	Could occur
Unlikely	Could occur at some time but not expected
Rare	Occurs only in exceptional circumstances

Finally, risks are assigned by combining their likelihood and consequence. For the purpose of this handbook, a matrix has been developed that assigns an ordinal rank against the emission, taking account of likelihood and consequence. The matrix is presented in the table below.

Qualitative risk analysis matrix and associated ordinal scores for assessment of air and water emissions

Probability of failure	Insignificant	Low	Moderate	High	Severe
Almost certain	3	2	2	1	1
Likely	3	3	2	2	1
Moderate	4	3	3	2	2
Unlikely	4	4	3	3	2
Rare	5	4	4	3	3

Consequence of failure

Further information on the risk-based assessment approach can be found in the Standards Australia (and Standards New Zealand) publications *Risk Management, AS/NZS 4360:1999* and *Environmental Risk Management – Principles and Process, HB 203:2000.*

Resource conservation: determination by comparative ordinal ranking

Resource conservation is achieved by alternative waste treatment technologies through recovery of resources – such as energy, compost, packaging materials (e.g. food and beverage containers), paper and cardboard – from the input waste. Such resources achieve significant environmental benefits as they substitute for, or lessen the need to extract, virgin materials. The greatest environmental benefits arise for products that are derived from highly industrial, resource-intensive processes (e.g. production of aluminium from bauxite).

Under the *Waste Avoidance and Resource Recovery Act 2001,* resource conservation is of primary importance in the consideration of resource management options. The hierarchy developed under the Act is:

(i) avoidance of unnecessary resource consumption

(ii) resource recovery (including reuse, reprocessing, recycling and energy recovery)

(iii) disposal.

Using the ordinal scoring system approach, the assessment of resource conservation is based on the following:

Environmental assessment criterion: resource conservation

Description	Score
High potential savings in terms of materials and/or energy	5
Moderate potential savings in terms of materials and/or energy	4
Small or neutral savings in terms of materials and/or energy	3
Moderate potential loss in terms of resource materials and/or energy	2
High potential loss in terms of resource materials and/or energy	1

Technical performance criteria

Flexibility in feedstock quality

Alternative waste treatment technologies differ significantly in their capacity to handle variations in the composition or quality of the waste delivered for processing (the feedstock material). Variations in the composition of domestic waste, and in its moisture content, can occur from load to load and from day to day, as well as over longer time periods. The key evaluation factors used in this assessment are:

- capacity of the technology to handle variations in feedstock quality for the intended waste streams, with or without additional pre-treatment means
- technology limitations on moisture content
- requirements for additives to adjust feedstock properties to suit process conditions, and potential effects on cost efficiency.

Technical assessment criterion: flexibility in feedstock quality

Description	Score
Technology has extensive flexibility in handling variations in the quality of the intended waste streams; no pre-treatment is required.	5
Technology has high flexibility, with some requirement for blending.	4
Technology has some flexibility, with minor limitations on moisture content and some requirement for additional pre-treatment, such as size reduction.	3
Technology has low flexibility; requires extensive pre-treatment and/or additives to adjust feedstock properties.	2
Technology has no flexibility; requires a homogeneous and consistent feedstock.	1

Modularity of the system

This assessment recognises that technologies differ in their capacity to expand or contract to cater for variations in the quantities of waste to be processed. Some technologies are based on units of large processing capacity that, when operated at or close to the design processing capacity, achieve lower operating costs than for multiple units of lower capacity. Such technologies, however, can cater for any increases in waste quantities only in very large increments. Similarly, any decreases in waste quantities result in inefficiencies in operations that are reflected in higher unit operating costs. Other technologies are based on units of lower capacity, and such modular systems are much more flexible in catering for changes in waste quantities. Increasing modularity can, however, result in comparatively higher capital and operating costs.

A separate issue is the flexibility of the technology to deal with changes to input quantities over short periods of time. This is more an issue of individual facility layout (i.e. in providing a sufficiently sized bunker to store waste), and is generally assessed at the tender stage.

Technical assessment criterion: system modularity

Description	Score
Very high modularity; capacity is readily increased or reduced by adding or removing processing units; each unit provides 20% or less of total capacity for a typical plant.	5
High modularity; each unit provides about 30% of total capacity for a typical plant.	4
Average modularity; each unit provides about 50% of total capacity for a typical plant.	3
Poor modularity; each unit provides more than 50% of total capacity for a typical plant.	2
No modularity; typical plant comprises one operating unit.	1

Process control

This assessment compares the extent to which the process can be controlled to cater for variations in waste input quality and quantity; to manage the decomposition process and environmental emissions; and to manage the output product quality.

Technical assessment criterion: process control

Description	Score
Very high control over process and/or output quality of products; well proven over numerous reference plants.	5
High control over process and/or quality of products; evidence that any operational difficulties have been overcome.	4
Moderate control over process and/or quality of products; some minor difficulties still evident but being overcome.	3
Poor control over process and/or quality of products; difficulties still to be resolved.	2
No control over process.	1

Staff requirements

This assessment takes into consideration the number of staff required to operate the technology and the level of technical expertise required. At all processing facilities personnel are required for managing material acceptance (and rejection) and material transport, and for process supervision and maintenance. The more complex technologies require more highly trained personnel for process control, risk management and product marketing. This evaluation covers the estimated number of staff required and the technical skills they will need.

Technical assessment criterion: staff requirements

Description	Score
A relatively small number of staff is required to operate the technology; the technical skills required from staff are relatively low and readily available locally.	5
A moderate number of staff is required; moderate technical skills are required and readily available locally, or staff could be readily trained.	4
A moderate number of staff is required; considerable technical skills are required, and staff training needs are ongoing.	3
A high number of staff is required; high technical skills are required and staff training needs are ongoing.	2
A high number of staff is required; very high-level skills are required, therefore skilled staff need to be imported from outside the local area.	1

Proven technology / reference facilities

This assessment takes into account the degree to which a technology is proven, as measured by the number and operating histories of commercial-scale facilities utilising the technology around the world (i.e. reference facilities). It also includes the degree to which a proponent has demonstrated a commitment to continuous improvement, including incorporation of best practice elements arising from technical developments and innovation. This criterion is generally given a high weighting in the assessment process.

Technical assessment criterion: proven technology /reference facilities

Description	Score
The technology is employed in more than five reference facilities, each with a successful operating history of more than 5 years.	5
The technology is employed at three or more reference facilities, each with a successful operating history of more than 2 years.	4
The technology is employed at one or more reference facilities, each with a successful operating history of at least 1 year.	3
The technology is being demonstrated at a commercial scale at one or more reference facilities, with an operating history of less than 1 year.	2
The technology has not yet been demonstrated at a commercial scale.	1

Efficiency of waste reduction

This assessment considers the effectiveness of the technology in reducing the amount and the pollution potential of the 'rejects' that remain for disposal.

Technical assessment criterion: efficiency of waste reduction

Description	Score
Residue requiring disposal is less than 20% of waste input on a mass basis, and can be disposed of to a standard landfill.	5
Residue requiring disposal is between 20% and 30% of waste input and can be disposed of to a standard landfill.	4
Residue requiring disposal is between 30% and 50% of waste input and presents a lower pollution potential than untreated waste.	3
Residue requiring disposal is between 50% and 75% of waste input; and presents a lower pollution potential than untreated waste.	2
No change to amount or pollution potential of the waste.	1

Operational reliability

The operational reliability of a technology is influenced by the facility concept, particularly in the design of the interaction of process stages and the performance of the selected equipment. This assessment takes into account these design-related factors (particularly the effects of equipment breakdowns on operational reliability) and the known operational experience of the technologies. One aspect of known operational experience is the concept of ‘availability’ (i.e. a measure of the actual operating time over a year for a facility) against the scheduled operating time.

Note that the technical and financial management skills of service companies that might offer the technologies to councils or regions are not included in this generic assessment. Such an evaluation would need to be conducted as part of a more detailed tender assessment process, together with other important operational issues such as contingency provisions and opportunities for incorporating technology advances in the facility.

Technical assessment criterion: operational reliability

Description	Score
Technology has high operational reliability; facility design provides for redundancy of key processes and reference facility data demonstrate high availability over more than 2 years of operation.	5
Technology has good operational reliability; facility design provides for some redundancy and reference facility data demonstrate good availability over more than 1 year of operation.	4
Technology has moderate operational reliability; facility design provides for some redundancy but operational experience is insufficient to demonstrate availability.	3
Technology has poor operational reliability; facility design provides no redundancy and either operational experience is insufficient to demonstrate availability or availability is poor.	2
No operational experience available for the technology.	1

Alignment with resource recovery strategy

This assessment compares the degree to which the various alternative waste treatment technologies fit within the context of the integrated resource recovery strategy, which has been developed for the local area or region under consideration. Factors to be considered here include compatibility with:

- strategy objectives (e.g. with respect to resource recovery)
- institutional arrangements (e.g. roles and responsibilities of parties involved, and risk allocation)
- resource allocation (including existing available staff, infrastructure, and funding considerations from the perspective of the technology purchaser)
- existing and planned implementation programs under the strategy (e.g. streaming of wastes, market development).

Technical assessment criterion: alignment with resource recovery strategy

Description	Score
Technology aligns very well with resource recovery strategy. Technology will significantly help to meet overall strategy objectives, falls within proposed institutional arrangements, and is highly compatible with existing and planned implementation programs.	5
Technology aligns well with resource recovery strategy. Technology will help to meet strategy objectives, falls within proposed institutional arrangements, and is compatible with existing and planned implementation programs.	4
Technology aligns with resource recovery strategy. Technology falls within proposed institutional arrangements, and is generally compatible with existing and planned implementation programs.	3
Technology does not align well with resource recovery strategy. Technology will not help to meet overall strategy objectives, and is not compatible with proposed institutional arrangements and/or existing and planned implementation programs.	2
Technology aligns poorly with resource recovery strategy. Technology will hinder the meeting of overall strategy objectives, and it conflicts with proposed institutional arrangements and/or existing and planned implementation programs.	1

Social performance criteria

Individual and family impacts

Individual and family impacts include the degree of ***public perception*** of risk to health, safety and/or amenity from a waste treatment technology; concerns about the displacement or relocation potential of the waste treatment technology; and the potential of the technology to affect public trust in political and social institutions.

(Note: All of the above will be dependent on a wide range of factors, including community awareness levels, past historical experiences, the nature of community institutions and the socio-demographic profile. Public perception is not static and can vary according to the stage of a development process. Hence, a user of the methodology may need to make assumptions based on his/her knowledge of local community aspects, as well as on the past track record of the technology. Alternatively, the user may wish to more accurately gauge community perceptions by using a variety of research tools.)

Social assessment criterion: individual and family impacts

Description	Score
No evidence of community perception of risk to health, safety and/or amenity; negligible consequences.	5
Some evidence of community perception of risk to health, safety and/or amenity, including sporadic representations from groups and individuals; low consequences.	4
Moderate evidence of community perception of risk to health, safety and/or amenity, including regular representations from groups and individuals; moderate consequences.	3
Significant evidence of community perception of risk to health, safety, and/or amenity, including regular representations from groups and/or individuals and development of local activism/opposition; high consequences.	2
Highly significant evidence of community perception of risk to health, safety and amenity, including numerous representations from groups and individuals, media reports, local activism, and community-initiated meetings; extensive consequences.	1

Residential amenity

Residential amenity is a measure of the potential impacts of waste treatment technologies on residential amenity in terms of noise, odour, dust, visual and aesthetic profile and traffic-related impacts. Primary consideration should be given to residents living adjacent to and near the potential facility.

Social assessment criterion: residential amenity

Description	Score
No or limited discernible impact; negligible consequences.	5
Impacts localised to area adjacent to application point; impacts can be mitigated and/or managed; low consequences.	4
Impacts across several residential areas; impacts can be mitigated and/or managed; moderate consequences.	3
Impacts localised to area adjacent to application point; impacts difficult to mitigate and/or manage; high consequences.	2
Impacts across several residential areas; impacts difficult to mitigate and/or manage; extensive consequences.	1

Employment

The employment criterion covers implications for direct and indirect job creation or loss in both the short and longer terms; it also includes impacts on the types of other commercial activity conducted near the waste treatment technology facility.

Social assessment criterion: employment

Description	Score
Potential to create long-term facility-specific and local employment opportunities (over 50 in total).	5
Potential to create long-term facility-specific and local employment opportunities (over 25 in total).	4
Potential to create some long-term facility-specific employment opportunities and short-term local employment opportunity in development phase.	3
Neutral employment opportunities from the facility itself; potential to create short-term local employment opportunities in development phase.	2
Potential to reduce local employment opportunities.	1

Natural and cultural heritage impacts

This criterion covers the impacts of the waste technology on sites or locales with natural, ecological, cultural, historical and/or archaeological significance or status. For the purpose of this criteria assessment, consideration should be restricted to examining any impacts that may be inherent to the technology, rather than focussing on the individual location or site.

Social assessment criterion: natural and cultural heritage impacts

Description	Score
No or limited discernible impact inherent to the technology itself; negligible consequences.	5
Impacts limited to specific site and/or aspect of significance; most impacts can be mitigated and/or managed; low consequences.	4
Impacts across several sites and/or aspects of significance; most impacts can be mitigated and/or managed; moderate consequences.	3
Impacts limited to specific site and/or aspect of significance; most impacts difficult to mitigate and/or manage; high consequences.	2
Impacts across several sites and/or aspects of significance; most impacts difficult to mitigate and/or manage; extensive consequences.	1

Occupational health and safety

This criterion covers the proponent's track record in OH & S and the degree to which OH & S issues have been addressed in the technology's design and operating procedures; it also includes compliance with legislative provisions.

Social assessment criterion: occupational health and safety

Description	Score
Proponent has exemplary track record in OH & S, including external recognition / accreditation of design and/or management elements.	5
Proponent has evidence of exceeding compliance with applicable OH & S provisions in terms of either design and/or management elements.	4
Proponent has evidence of compliance with all applicable OH & S provisions.	3
Proponent has no clear approach to OH & S issues.	2
Proponent has a negative track record in OH & S, including numerous claims.	1

Labour relations

This criterion covers the proponent's track record in labour relations and the degree to which labour relations issues are addressed in management and operational procedures; compliance with legislative provisions; and the proponent's level of commitment to cultural and gender diversity in the workforce.

Social assessment criterion: labour relations

Description	Score
Proponent has an exemplary track record in labour relations, including external recognition of practices.	5
Proponent has evidence of exceeding compliance with applicable labour relations provisions.	4
Proponent has evidence of compliance with all applicable labour relations provisions.	3
Proponent has no clear approach to labour relations.	2
Proponent has a negative track record in labour relations, including extensive workplace stoppages and industrial disputes.	1

Community relations

This covers the proponent's level of commitment to community relations in the development and ongoing operation of a waste treatment technology. Community relations can include consultation with local community and stakeholders, community education programs, provision of site-based educational facilities, public reporting commitments, public accessibility and open days, and support for community liaison and monitoring committee structures.

Social assessment criterion: community relations

Description	Score
Proponent is willing to commit to a community relations program (including evidence of potential human and capital resources); proponent has a track record in community relations.	5
Proponent is willing to commit to a community relations program (including evidence of potential human and capital resources); proponent has no track record in community relations.	4
Proponent is willing to commit to a community relations program in principle.	3
Proponent is willing to consider a community relations program.	2
Proponent has no clear position in terms of a community relations program.	1

Annex 3: Policy note on small scale incinerators

EUROPEAN UNION EXTERNAL ACTIONS

Technical support to upgrading the solid waste management capacities in Lebanon

"Contract number: ENPI/2017/389-095"

Policy Note on small scale incinerators

August 2018

This project is funded by the European Union

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IDOM
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1. EXECUTIVE SUMMARY

This report is part of the EU funded project "*Technical support to upgrading the solid waste management capacities in Lebanon – ENPI/2017/389-095".*

There has been recent growing interest in Lebanon in the option of waste incineration as a solution to the national municipal waste problem, including the use of small scale as well as larger incinerators. Because of the many environmental, health, technical, economic, financial, legal and other considerations associated with waste incineration, this Policy Note has been prepared to inform decision-making on this subject.

This document provides an overview of the issues which need to be considered in implementing municipal solid waste incineration (MSWI). The general issues apply to all municipal waste incineration, but there are some specific issues which apply to small incinerators. It draws from international guidelines produced to help address the problems of implementing waste to energy (WtE) projects outside of well-established waste management systems.

Main findings

The main findings are:

- A basic requirement for successful implementation of MSWI is the existence of an advanced waste management system which is based on the separate collection and treatment of different source separated waste streams and where MSW is already being disposed in controlled and well-operated landfills.
- Another basic requirement, necessary to ensure that the environmental emissions will not be harmful and the operations will be safe, is that the input waste stream should be free of hazardous and healthcare waste, specific industrial waste streams etc. This is a basic condition that is not yet met in Lebanon, most of the times waste collection involves all the different waste streams in a single collection scheme.
- Incineration is a lower order, high cost option in the waste management hierarchy and can be an option for MSW residue but should not compete with reuse and recycling.
- Small incinerators employ similar technologies as large and have similar success factors and problems.
- Incineration requires suitable feedstock: Materials with high organic, moisture and unsegregated inert content, are unsuitable for incineration. Material of inconsistent calorific value and volume reliability is unsuitable for power generation.

- The supply of combustible MSW should at least amount to 100,000 t / year. (Can be smaller in isolated areas but no smaller than 50,000t/year).
- The lower calorific value (LCV) must be, on average, at least 7 MJ/kg and never fall below 6 MJ/kg. This is really questionable in Lebanon, based on the high moisture content of the waste.
- Incineration generates highly toxic substances which are harmful to human health and the environment unless managed by proper emissions control technology. A serious challenge is the safe disposal of hazardous flying ash to a hazardous waste landfill. If a facility is not available locally, as it is the case in Lebanon, the flying ash must be exported to other countries with proper facilities at a high cost).
- Environmental monitoring of the operations requires high-level scientific support and laboratories supported with high-tech equipment capable to sample and measure pollutants like dioxins, furans and PAHs. In the case of Lebanon, such laboratories are not still in place and this poses an extra challenge and difficulty for incineration.
- Small, unregulated incinerators without emissions controls and skilled operation pose a high environmental and public health risk.
- A specific regulatory framework needs to be in place and enforced, especially to prevent harmful emissions.
- Skilled staff are needed for operation and maintenance, including for regulation and management.
- Incineration is a high capital and operating cost option for waste disposal and constitutes a substantial financial risk. Energy sales can partly cover operating costs but not capital costs.
- There needs to access to finance, including foreign currency for imported equipment and parts.
- The community should be able and willing to pay for the increased treatment cost for example via management charges, tipping fees, tax based subsidies or high electricity feed-in tariffs.
- The community planning system should be stable and able to make appropriate long term planning decisions.

Conclusions

The main conclusions from the review are that, based on extensive experience, MSW incineration is generally only considered suitable in mature waste management systems, where waste collection is working properly, where the calorific value has a certain minimum level and where the required tipping fees are affordable and the necessary regulatory, financial and other arrangements are in place. These considerations apply to small as well as larger plant.

When considering the introduction of MSWI technologies, decision makers should consider the following aspects:

- The development of MSWM systems should follow the waste hierarchy based on careful quantification and evaluation of the waste stream and building on an efficient MSWM systems
- MSWI must fulfil high emission standards with a comprehensive legal framework applying internationally recognized standards
- MSWI requires careful analysis of costs and revenues and significant financial resources which must be secured, as well as legal security for private sector investors

Based on the review, some initial conclusions can be drawn on the readiness of Lebanon for MSW incineration in general and on proposals for small and very small incinerators.

- The required conditions are not presently in place for the effective and safe implementation of MSW incineration. The main reason is that incinerators are effective only when they are working in a proper supportive ecosystem that ensures the quality and the quantity of the feedstock, addresses the institutional, financial and environmental challenges and integrates them in the waste supply chain. This supportive ecosystem does not exist in Lebanon.
- Accordingly, the construction of incinerators without the proper supporting ecosystem might present environmental, health and economic risks as well potentially undermining the implementation of an effective waste management strategy.
- Small plants are not viable for energy production (the lower limit is 50,000 t/year; above 150,000 t/year is more economical).

- Very small plants (e.g. 5,000t/year) are an expensive option for volume reduction, and in the absence of high levels of environmental control, present a high risk to the environment and public health.

A review of pyrolysis and gasification confirmed that they are not suitable for mixed MSW and they are not commercially viable.

Recommendations

The following recommendations are made:

- Proposals for incinerators, large or small, should be shelved until a detailed, independent assessment is made of their longer-term role, if any, in the national waste management strategy, including conformance to the waste hierarchy. Standalone interim proposals should not be easily approved because of their impact on the overall waste management system.
- No incinerator projects should be approved until appropriate environmental regulatory and management controls and conditions are in place; this includes establishing a specific regulatory framework and subjecting all proposals to environmental assessment as well as permitting.
- Having implemented effective legal, regulatory and related institutional changes, all proposals should be subject to independent and detailed economic and financial evaluation, including examination of suppliers' claims on costs and performance, training and maintenance obligations.

2. INTRODUCTION

2.1. Background

Recognizing the growing volumes and problems of municipal solid waste in Lebanon, and the need for better management now and in the future, several Waste Management Master Plans are presently being developed with EU assistance. These Master Plans propose a strategic approach to waste management at national and local levels based on the well-established hierarchy of waste management: reduce, reuse, recycle and, where no other options are available, disposal to landfill. The Master Plans propose waste management options as part of a transition to a more sustainable, circular economy, where materials are recovered as valuable resources rather than part of a linear flow to waste.

There has been recent growing interest in Lebanon in the option of waste incineration as a solution to the national municipal waste problem, including the use of small scale as well as larger incinerators. Because of the many environmental, health, technical, economic, financial, legal and other considerations associated with waste incineration, as well as implications for integrated waste management, this Policy Note has been prepared to inform decision-making on this subject.

2.2. Purpose and scope

This Policy Note provides an overview of the issues which need to be considered in implementing municipal solid waste incineration (MSWI). The general issues apply to all municipal waste incinerators, but there are some specific issues which apply to small incinerators.

This document has been prepared from a review of decision-making guidelines and other literature in this area, especially in implementation outside of mature economies. This literature is based on extensive international experience on the conditions which are necessary for successful implementation of MSWI projects, and the risks of failure where these conditions are not present. It does not constitute a feasibility study for waste incineration nationally in Lebanon or for any specific locality but provides some recommendations on what needs to happen for incineration to be successfully implemented.

Supporting information is provided in the Annexes: Concepts in waste as fuel in Annex 2, the technology concepts and components of a MSWI incineration plant in Annex 3.

As an additional note, a review of pyrolysis and gasification is provided in Annex 3.3. These technologies do not presently a scalable or viable solution for general MSW.

2.3. The Lebanese context in brief

Before detailing the challenges of incinerators, it is necessary to present in brief the Lebanese context of waste management. For that, the concept of Integrated Sustainable Waste Management as presented by a recent UNEP – ISWA report re will be used[1].

Integrated Sustainable Waste Management (further ISWM) planning is a dynamic tool including aspects that range from policy-making and institutional development to technical design of integrated solutions for the handling and disposal of waste. The concept of ISWM differs a lot from the conventional approach towards waste management by seeking stakeholder participation, covering waste prevention and resource recovery, including interactions with other systems and promoting an integration of different habitat scales (city, neighborhood, household). ISWM does not cope with waste management as just a technical issue, but also recognizes the political and social factor as the most important.

ISWM consists of three dimensions: The Stakeholders, the Waste System Elements and the Aspects of the SWM system, each of which is of crucial importance and must be taken carefully into consideration during the Planning Process.

1st Dimension-Stakeholders

ISWM is, first and foremost, about participation of stakeholders. A stakeholder is a person or organization that has a stake, an interest in - in this case- waste management. Stakeholders, by definition, have different roles and interests in relation to waste management; the challenge of the ISWM process is to get them to agree to co-operate for a common purpose, that of improving the waste system.

In Lebanon, there are very weak or sometimes non-existing practices and procedures for stakeholders' involvement and consultation. There is also a lack of trust against the state's interventions in waste management which is mostly based on previous failures to address or prevent the different waste crises that have been evolved in the country the last 15 years. The combination of both the previous (lack of consultation practices and lack of trust) creates a very big problem regarding the incinerators, as such serious, costly and long-term investments will

[1] D. C. Wilson, L. Rodic, P. Modak, R. Soos, A. Carpintero, C. Velis, M. Iyer and O. Simonett, "Global Waste Management Outlook," United Nations, Environment Program and International Solid Waste Association, Osaka and Wien, 2015.

never be viable without the social acceptance and support that results from proper stakeholders' interactions and consultation practices[2].

2nd Dimension-Waste System Elements

Waste system elements refer to how solid waste is handled and where it ends up. Particularly this last has important environmental implications and for this reason a number of national environmental ministries have taken the idea of a waste management hierarchy as an operational policy guideline. The waste hierarchy is also a cornerstone of the ISWM approach and gives priority to waste prevention, minimization, recycling and other forms of recovery of materials.

In Lebanon, considering a systemic view and the perspective of incinerators, there are four particular problems that should be addressed:

- Waste collection involves multiple waste streams, including healthcare waste, construction – demolition waste, small hazardous waste, industrial waste etc. that should not be driven to municipal waste incinerators both because of the operational problems that they will create and the environmental emissions that are associated with those streams.
- Waste composition presents a high organic fraction, sometimes between 55-60%, resulting in high moisture and low calorific value that can't sustain incineration without either the addition of costly external fuel or the removal of 15% of the organic fraction by pre-treatment[3].
- There is no national plan and specific targets about source separation and other resource recovery activities. Consequently, there is no clear idea of the impacts of recycling to the calorific value of the waste and no plan that documents their co-existence in the way this is done in many EU countries.
- There is no hazardous waste management system and no hazardous waste landfill that can receive the flying ash, and there is no proper solution outlined for the management of the huge quantities of the bottom ash.

3rd Dimension – Aspects

The third dimension of ISWM refers to sustainability aspects. These aspects can be defined as principles, or lenses, through which the existing waste system can be assessed and with which a

[2] Elias Azzi, Waste Management Systems in Lebanon, The benefits of a waste crisis for improvement of practices, KTH Royal Institute of Technology, Stockholm 2017

[3] CDR, SWM in Lebanon, Phase 1 Report, prepared by Ramboll, December 2012

new or expanded system can be planned. In order the new or the expanded system to be sustainable, it needs to consider all the technical, environmental, health, financial-economic, socio-cultural, institutional, legal and political aspects

Technical aspects concern the observable practical implementation and maintenance of all of the waste elements: what equipment and facilities are in use or planned; how they are designed; what they are designed to do; whether they work in practice; and how clean the city is on a consistent basis. In this aspect, the introduction of the high-tech incinerators that require high-skilled personnel to run them in the Lebanese landscape involves serious risks, as the rest of the waste management system is obviously low-tech and low-skilled. Technically speaking, a high-tech incinerator in Lebanon seems like having a Ferrari obliged to offer transportation services in Hamra during rush – hours: not certainly the best option and for sure not the most cost-effective one.

Environmental aspects focus on the effects of waste management on land, water and air; on the need for conservation of nonrenewable resources; pollution control and public health concerns. Health aspects have to do with the fact that WM is closely related with the protection of human health, since inappropriate, inefficient or non-existing WM poses a severe danger for society. From this point of view, Lebanon lacks both an advanced regulatory framework and the enforcement mechanisms to deal with the pollution posed by industries and waste management facilities[4]. In addition, in the case of incineration, it also lacks the required infrastructure in laboratories and equipment to ensure the sound and continuous monitoring of the environmental impacts.

Financial-economic aspects pertain to budgeting and cost accounting within the waste management system and in relation to the local, regional, national and international economy. Some specific issues are: privatization; cost recovery and cost reduction; the impact of environmental services on economic activities; the commodities marketplace and how the recycling infrastructures connect to it; efficiency of municipal solid waste management systems; macroeconomic dimensions of resource use and conservation; and income generation. From this point of view, the whole financial system around waste management is very weak, cost recovery is very low, tariff systems are not in place and accountability is a serious challenge for all the levels

[4] UN- Habitat, Wasteless Lebanon, Integrated Waste Management Policy Paper, December 2015

of the governance, from national to local. The operations of most of the facilities is based on governmental subsidies and the pollution pays principle is not applied[5].

Institutional and policy – legal aspects relate to the political and social structures which control and implement waste management: the distribution of functions and responsibilities; the organizational structures, procedures and methods implicated; the available institutional capacities; and the actors such as the private sector who could become involved. Planning is often considered the principal activity in relation with institutional and organizational aspects. Policy/legal/political aspects address the boundary conditions in which the waste management system exists: setting goals and priorities; determination of roles and jurisdiction; the existing or planned legal and regulatory framework; and the basic decision making processes. From this point of view, the weakest link of the existing waste management systems in Lebanon is the institutional development, which is characterized by lack of specific assigned roles and responsibilities from national to local level, lack of clarity in jurisdiction, weak planning and regulatory framework, and an incomplete, fragmented and sometimes misleading decentralization effort[6]. Such a framework is absolutely required to move towards a better waste management in the country, with or without incinerators. Especially for incinerators, there is a need for new regulations that will arrange the pricing of the electricity (and/or the heat) generated, the environmental monitoring parameters, the way they will be measured and the points of measurements, the framework for the management of the bottom ash, as well as the management of the hazardous flying ash.

[5] Chamieh, N., Abiad, M. G., Doumani, F. and Karine Abdelnour-Thome, March 2016. *Economic Instruments to Create Incentives for Recycling in Lebanon*. Prepared for the Lebanon Ministry of Environment through the European Union Support to Reforms – Environmental Governance (StREG) Project. GFA Consulting Group GmbH / Umweltbundesamt / Mott Mac Donald.

[6] Harb, M. and Atallah, S., 2015. Lebanon: A fragmented and incomplete decentralisation, in Local Governments and Public Goods: Assessing decentralisation in the Arab world. Chapter 5. Lebanon Centre for Policy Studies.

3. MSWI: BENEFITS AND CHALLENGES

MSWI has been successful in mature waste management systems but not elsewhere.

Small incinerators employ similar technologies as large and have similar success factors and problems

MSWI has been successfully been implemented in high-income countries because it offers several advantages over other waste handling methods:

Table 1: MSWI benefits

- The most efficient way of reducing the volume of the waste and thus the demand for landfilling.
- Incinerators can be situated close to urban areas, reducing the need for transportation.
- If the energy of the waste is recovered for power and/or heat or steam production, MSW can act as a substitute to fossil fuels.
- Can be environmentally beneficial compared to landfilling. In a landfill, organic materials eventually decompose and create greenhouse gases such as carbon dioxide and methane. Methane is a greenhouse gas which is 23 times more powerful than carbon dioxide produced when MSW is incinerated.
- MSW incineration bottom ash can generally be disposed of safely in construction work as aggregate – thus substituting virgin aggregates and further reducing the demand for landfills[7].

Globally, there are over 1200 MSWI plants in operation across more than 40 countries and is strongly developing in emerging countries along with a growing economy and the implementation of waste regulation[8]. Small scale incinerators are not uncommon, where small scale is generally defined as < 100,000 tonnes a year[9]. When the volume of waste, transportation costs or public opposition rule out large-scale mass-burn WtE, small-scale technologies can offer smaller communities in rural, semi-urban or remote areas an alternative to landfill. < 50,000 tonnes is generally regarded as the lowest level for economic energy production from MSWI although technically possible at lower levels[10].

Although superficially attractive as a solution to waste, especially when promoted by technology suppliers, international experience is that incineration is difficult to implement

[7] Waste Materials and By-Products in Concrete Springer Science & Business Media, Nov 13, 2007 – *Technology & Engineering*, Chapter 8

[8] A. Mavropoulos, D. Wilson, C. Velis, J. Cooper and B. Appelqvist, "Globalization and Waste Management. Phase 1: Concepts and Facts," International Solid Waste Association, Wien, 2012.

[9] International Solid Waste Association (ISWA), August 2013. ISWA Guidelines: Waste to Energy in Low and Middle Income Countries.

[10] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, May 2017 *Waste-to-Energy Options in Municipal Solid Waste Management. A Guide for Decision Makers in Developing and Emerging Countries.*

successfully outside of mature waste management and regulation systems. There are many challenges associated with incineration[11]. Some of them are listed in Table 2. These and others will be further discussed in this document.

Table 2: MSWI challenges

- Capital investment and operating costs are high.
- Incineration generates highly toxic substances which must be treated in expensive pollution control processes, including disposal of hazardous wastes (see Section 4.4) which significantly adds to costs.
- A resulting increase in waste treatment cost may incentivize waste generators to seek alternatives to incineration, which is good if the alternative is for recycling, but not if it ends up in uncontrolled dumping
- There is a minimum requirement for lower calorific value of waste. In low to middle income countries it may be a challenge to achieve this because of high levels of organic and inert waste.
- Skilled staff are required for the operation and maintenance of the furnace, boiler, turbine/generator and the flue gas cleaning system
- There can be a public opposition against WtE. This can influence the political process when planning an MSW facility.
- Implementing an MSW incineration facility in a poorly developed waste management system and without proper planning can lead to environmental and economic failure[12]. The key risks are varying waste amounts delivered, too low calorific value, poor financial support, inappropriate choice of technology and inadequate regulatory and institutional framework

While small scale incinerators often experience less opposition than large plants, they have similar problems. They also lack economies of scale and are even more expensive. The technologies are the same as for large plant but new small-scale designs present problems related to the attempt to avoid environmental standards.

WtE incineration has a poor success record outside of mature economies. There are some persistent myths fostered by suppliers and others with a vested interest, sometimes by inexperience salesmen unaware of different conditions outside of developing countries, sometimes the result of dishonest, even fraudulent, claims to make a sale[13]. WtE is often promoted as a simple solution which will solve all a city's waste problems, and which can be self-funding through energy sales, meeting a large part of a city's energy demand. None of these myths is true. Often the lack of guarantees and lack of long term maintenance had led to high

[11] An Independent Engineering Evaluation of Waste-to-Energy Technologies, *http://www.renewableenergyworld.com/articles/2014/01/an-independent-engineering- evaluation-of-waste-to-energy-technologies.html*

[12] GIZ, "Guideline, Application of Waste-to-Energy in Vietnam," 2015.

[13] OMSAR, Technical support to upgrading the solid waste management capacities in Lebanon ENPI/2017/389-095, Screening Tool for Waste Management Proposals, 2017.

rates of equipment failure as well as poor performance, technically, environmentally and economically. For good reason, WTE projects in developing and emerging economies is seen by investors as high risk.

The problems and risks has led ISWA, GIZ and other organizations to develop guidelines for decision-makers. The key lessons from these guidelines are drawn together in this Policy Note which summarizes the issues to be considered in the Lebanon context.

4. CONSIDERATIONS IN FEASIBILITY ASSESSMENT AND DECISION- MAKING

4.1. Overall level of waste management

A basic requirement for successful implementation of MSWI is the existence of an advanced waste management system which is based on the separate collection and treatment of different source separated waste streams.
Incineration is a lower order, high cost option in the waste management hierarchy and can be an option for MSW residue but should not compete with reuse and recycling.

MSWI should only be considered as part of an integrated waste strategy based on established principles of sustainability and good waste management practice. Stand-alone incineration projects do not have a good track record of technical and economic success, especially outside of mature economies. From sustainable development[14] and waste management principles[15], and good practice experience the following are some of the key strategic considerations (Table 3):

Table 3: Strategic considerations

- Achievement of UN sustainable development goals aims to maximize sustainable use of resources and transition to a circular economy. In this, waste management should follow the hierarchy of reduce (the most cost effective solution), reuse and recycle. Disposal to landfill is a last resort option in the waste hierarchy.
- Incineration is lower order disposal option for combustible residue which cannot be recycled or reused and where its high cost can be justified by high volumes (in large cities) and high landfill costs, including transport. It is not an alternative to reuse and recycling,
- MSWI can operate alongside reuse and recycling in an integrated and well regulated market, where it does not compete with or interfere with these activities in its demand for combustible feedstock.
- Well planned, managed and regulated MSW systems are needed to ensure quality and reliability of feedstock (see 4.2) as well as control of emissions and safe disposal of residues.

4.2. Waste composition and calorific value

Incineration requires suitable feedstock: Materials with high organic, moisture and unsegregated inert content, are unsuitable for incineration. Material of inconsistent calorific value and volume reliability is unsuitable for power generation

Waste as fuel is summarized in Annex 2. A crucial issue is the quality and reliability of feedstock. In high income, mature economies with high levels of packaging waste, material calorific values are sufficient for self-sustaining combustion. In lower to middle income countries relatively high

[14] Application of the Sustainability Assessment of Technologies Methodology: Guidance Manual, Nov 2012 http://www.unep.org/ietc/InformationResources/Publications/SustainabilityAssessmentofTechnologyManual/tabid/106701/Default.aspx

[15] A. Mavropoulos, A. Karkazi, A. Mentzis "Drivers and Barriers for the application of waste-to-energy technologies in Greece", Proceedings of 1st Biomass and Waste to Energy Symposium, Venice, 2006

volumes or organic waste as well as lack of segregation of other material (e.g. inerts, glass, street-sweepings) make materials unsuitable for incineration[16]. In the absence of proper regulation, a stand-alone incineration project can divert combustible materials from reuse and recycling, impacting on formal and informal recyclers. Other issues are listed in Table 4.

Table 4: Considerations in waste as fuel

- Separation of MSW at the source in households is the best precondition for recycling and also for MSWI. Hazardous & bulky mineral waste should be collected and treated separately.
- If MSW is regularly mixed with hazardous and mineral fractions the suitability of incineration must be assessed frequently. Measures to improve waste separation at source should be initiated (e.g. separate collection and treatment of construction & demolition waste and batteries).
- Autothermic combustion (self-sustaining combustion without additional fuels) of MSW must be ensured throughout the year for incineration. Co-firing of oil, gas or other fuels is expensive and should be applied only to start up the combustion process or in emergency.
- For incineration, calorific value is one indicator to decide if MSW is suitable for the process. A high mineral content from construction and demolition waste, glass or ash, a high metal content or a high humidity from organic waste reduce the calorific value. Calorific values > 8 MJ/kg indicates that all combustion technologies are suitable options for MSWI projects.
- Drying may be able to combust wet MSW with a calorific value of about 7 MJ/kg. But drying technologies should be assessed before starting a WtE project.
- If the calorific value is < 7 MJ/kg due to mineral waste, overall waste management should be improved first before starting with WtE options[17].

Especially for Lebanon, as the calorific value of waste is not high enough to sustain incineration, Ramboll suggests to prepare the MSW for incineration by maintaining sorting of the very wet organic waste (removing at least 15 % of the organic fraction), in order to enhance the incineration process and increase the calorific value to approximately 8 MJ/kg[18].

Pyrolysis/gasification is unsuitable for most MSW and has not been commercially applied to MSW on a city scale outside of dealing with specialist waste streams[19] (Annex 3.3).

[16] CWG, Collaborative Working Group on Solid Waste Management in Low and Middle Income Countries, "CWG Rapid Technology Assessment Tool," 2016.
[17] Waste Management Association of Australia, Sustainability Guide for EfW Projects and Proposals Page 1 Edition 1b – 24/01/05
[18] CDR, SWM in Lebanon, Phase 1 Report, Paragraph 2.4, prepared by Ramboll, December 2012
[19] Advanced Thermal Treatment of Waste https://www.gov.uk/government/uploads/system/uploads/attachment_data/le/221035/ pb13888-thermal-treatment-waste.pdf

4.3. Feedstock quantities

WtE incineration should not been discussed with less than 50,000 tonnes of waste per annum.

From experience, including a review of case studies on smaller incinerators, MSWI can operate efficiently at > 150,000 tonnes of available waste per year. For waste quantities between 50,000 and 150,000 metric tonnes per year the cost-effectiveness of incineration should be assessed carefully. Below 50,000 metric tonnes waste-to-energy incineration is too expensive and it is recommended to be avoided[20].

Incinerators handling smaller volumes have been commonly used for mass-burn only for municipal, medical and other wastes, often for batch rather than continuous feed burning. Where not fitted with pollution control equipment and subject to strict environmental regulation, such systems present high environmental and health risks (Section 4.4) as well as, in the case of MSW, being an expensive option[21] which does not align with effective waste management.

4.4. Environmental and health risks

Incineration generates highly toxic substances which are harmful to human health and the environment unless managed by emissions control technology, skilled incinerator operation monitoring and maintenance and safe disposal of hazardous ashes.

Small, unregulated incinerators pose a high environmental and public health risk

A major disadvantage of incineration is the creation of combustion by-products that may be released into the atmosphere and the generation of hazardous ash. Of special concern is the generation of persistent organic pollutants (POPs), especially dioxins which are highly toxic, readily dispersed and bioaccumulated into the environment, including the food chain, and long lasting. Dioxins are especially produced by burning plastics, particularly PVC[22].

Incinerators have been recognised by UNEP[23] as one of the major sources of dioxins and other substances catalogued under the Stockholm Convention on Persistent Organic Pollutants. Incinerators are also recognized as a major source of mercury emissions under the Minimata

[20] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, May 2017 *Waste-to-Energy Options in Municipal Solid Waste Management. A Guide for Decision Makers in Developing and Emerging Countries.*
[21] Claudine Ellyin, Small Scale Waste to Energy Technologies, Columbia University 2012
[22] Sharma et al, The impact of incinerators on human health and environment, Rev Environ Health. 2013;28(1):67-72. doi: 10.1515/reveh-2012-0035.
[23] United Nations Environment Programme (UNEP) Secretariat of the Stockholm Convention on Persistent Organic Pollutants, October 2008, *Guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants.*

Convention. Dioxins may cause cancer and neurological damage, and disrupt reproductive systems, thyroid systems and respiratory systems. Not only incinerator workers but local populations may be affected - even people some way away, as pollutants may be widely dispersed. Environmental and health issues are further summarised in Annex 4.

Advanced MSW incinerators concentrate airborne dioxin emissions and other toxic substance in fly ash after application of filters and scrubbing and other technology (Annex 2)[24]. Fly ash must be regarded as a hazardous waste and safely disposed of on a special hazardous waste landfill, not a municipal landfill. Furnace bottom ash, filters and other equipment, as well as waste water may also contain toxins and should be treated accordingly[25]. Disposal as hazardous waste is recommended.

Because of the environmental and health risks, incinerators are subject to strict permitting, emissions limits and other controls in countries with established regulatory systems. Annex 4 shows limits for the European Union. These require best available technology (BAT) pollution control equipment, safe disposal of wastes, monitoring of emissions and emissions control equipment, and operation and maintenance by trained personnel[26]. In the absence of these conditions (which significantly add to costs), incineration presents a high risk to health and the environment. This is especially the case for small incinerators operated without such controls in place, and typically without proper or malfunctioning pollution control equipment, irregular, sub-optimal (smoky) operation and feeding, operation by untrained personnel, dispersal of emissions to the environment and unsafe disposal of ash.

Finally, Lebanon has no infrastructure to manage hazardous waste. This means that:

- Hazardous waste components are found in the MSW stream, creating additional health and environmental risks during the incineration process, and
- There is no local solution for the fly ash, thus it must be exported in proper facilities with a very high cost, at the order of at least 600-800 Us $/ton.

[24] Silva & Lopes, Environnemental Aspects and Impacts of a Waste Incineration Plant, 4th International Conference on Energy and Environment Research, ICEER 2017, 17-20 July 2017, Porto, Portugal, EnergyProcceedia10306 (2017) 020309–020404
[25] Solid Waste Technology & Management Edited by Thomas H. Christensen © 2011 Blackwell Publishing Ltd. ISBN: 978-1-405-17517-3, Chapter 8.2, 8.4
[26] By Products and Residues of Incineration Technologies
http://web.mit.edu/urbanupgrading/urbanenvironment/resources/references/pdfs/MunicipalSWIncin.pdf

4.5. Operational efficiency

Achievement of operational efficiency requires plant operation and maintenance by appropriately qualified personnel.

Waste management facilities can be operated by the public sector, the private sector or in cooperation-. For foreign MSWI technologies long term support from technology suppliers should be contractually ensured. Learning from past failed waste management projects, it is clear that MSWI requires experienced management and well-trained technical staff. Good communication between the public and private actors is an essential precondition. Most actors require capacity building for MSWI.

4.6. Environmental and other legal framework

A specific regulatory framework needs to be in place and enforced.

Some of the issues are summarized in Table 5.

Table 5: Legal framework and environmental requirements

- Because of the various environmental emissions and risks (see Annex 4) an existing comprehensive legal framework for waste management is a precondition for MSWI success.
- Legislation needs to include high environmental standards for emissions to air, water and soils, odors and noise as well as health and safety requirements.
- It also should define the role of WtE within an integrated waste management system. Legislation should be tailored for the national circumstances.
- Effective enforcement mechanisms should minimize illegal waste management practices to ensure-functioning waste supply chain to MSWI facilities. However, legislation should aim for cooperation with the informal sector for collection logistics rather than to further marginalize them.
- International standards on emissions limits, monitoring and enforcement must be guaranteed. Public authorities must be sufficiently trained and equipped for ensuring adherence to environmental standards.

The lack of relevant laboratories to undertake the monitoring of dioxins and furans in Lebanon is something that should be addressed immediately, in case incinerators will finally be constructed – without them Lebanon will be fully dependent on foreign laboratories that will provide the relevant services in very high cost and maybe questionable transparency.

In addition, there is a serious concern about the enforcement capacity of the Lebanese state and its realistic ability to monitor and enforce high environmental standards not only in incinerators but also in landfills and the existing MBTs.

4.7. Economics

Incineration is a high capital and operating cost option for waste disposal and constitutes a substantial financial risk. Energy sales can partly cover operating costs but not capital costs.

Small incinerators are not cost-effective, either for producing energy or for volume reduction only.

An independent assessment of costs and a profound understanding on financial implications are crucial for decision making.

MSWI requires a major capital investment and must be supported by long term financial planning and sufficient resources to secure continuous operation and maintenance of the plant[27]. Initial investment funds may often be available; however, financial resources for the operation phase are often not adequately considered. To compare and assess the full financial viability of operating a MSWI, initial investment costs and expected operational costs have to be annualized. For a net cost calculation, any annual revenues from energy and material sales can be subtracted from the annualized capital investment and operational costs to derive an overall cost per tonne of waste based on the annually treated waste. Such an estimate is shown in Table 6[28] for a MSWI with a capacity to treat 150,000 metric tons of waste annually. The table shows that the market revenues from energy and material sales alone will not cover the full annual costs of the plant, and the expected net costs of 40 to 80 EUR per metric ton of waste must be covered by other financing means. Additional revenues from gate fees, public subsidies or other funds are required to ensure these full costs are met and that operations can be financed sustainably in the long term. Whilst the cost estimates are relatively well established for industrialized countries, it is difficult to provide representative costing information for other countries. The investment and operation costs listed in Table 6 provide indicative figures derived from international sources.

[27] DEFRA, Economies of Scale in Waste Management, 2009
[28] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, May 2017 *Waste-to-Energy Options in Municipal Solid Waste Management. A Guide for Decision Makers in Developing and Emerging Countries.*

Table 6: Cost estimate of MSWI in industrialized and emerging countries (indicative costs only)[28]

Incineration Capacity: 150'000 t/a	Initial Investment	Capital costs per ton of waste input	O&M costs per ton	Total cost per ton	Revenues from energy sales per ton	Cost to be covered per ton waste input
Cost Basis in the EU (advanced technical set-up2 furnace lines)	135 - 185 million EUR	80 - 115 EUR/t	180 EUR/t	260 - 295 EUR/t	60 EUR/t heat and (electricity) 27 EUR/t (electricity)	200 - 235 EUR/t
Emerging country cost basis (basic technical set-up, 1 furnace line, no advanced antipollution systems)	30 - 75 million EUR	22 - 55 EUR/t	20 - 35 EUR/t	42 - 90 EUR/t	2 - 10 EUR/t (electricity)	40 - 80 EUR/t

Data collected from ISWA's members shows that investment cost have in general been seen in the magnitude of 300-500 USD/yearly tonnage capacity in low income countries with a low calorific value, a low need for structural protection of the equipment and a general low labor cost[29]. For middle income countries with some requirements for structural protection of the plant, with slightly higher calorific value and higher labor cost, a typical capital cost per yearly tonne capacity is found to be around 400-600 USD. This should be compared to an investment cost typically in the range of 600-900 USD or even higher per yearly tonne capacity in European countries and in North America. The higher cost is mainly due to more stringent demands to the equipment and to the building. Often the buildings are requested to have a high architectural standard to become outstanding icons for the city.

For Lebanon, it can be considered that the real costs for a successful and environmental sage operation of incinerators will be probably higher because of the following reasons:

- The projects will be constructed through PPPs, which usually drive the gate fees much higher due to the bank loans and the interest rates, but also due to the relatively high risks of the projects in Lebanon.
- The flying ash should be exported, as it has already been mentioned, with a high cost.
- The cost of environmental monitoring will be very high if it is based on foreign laboratories. As an example a sample for stack emissions is costing more than 10,000 USD in Lebanon (figure based on data from existing cement plants).

[29] International Solid Waste Association (ISWA), August 2013. ISWA Guidelines: Waste to Energy in Low and Middle Income Countries.

Table 7 summarizes the major economic considerations

Table 7 Summary of economic considerations

Capital cost

The actual capital investment for a new MSWI facility has to be based on an actual budget for the specific plant and comparison between plants are difficult as many factors will influence the cost.

- The annual capital costs are calculated based on the initial investments, the required interest rate for such an investment (e.g. 6% per year) and the expected life span of the facility (e.g. 15-20 years).
- Large plants require higher absolute initial investments compared to smaller plants but have lower specific annual costs per ton of treated waste due to economies of scale. This cost development does not follow a linear relationship to the amount of waste treated. A second furnace line leads to only about 35% higher investments compared to a single furnace. If the MSWI provides power and heat, e.g. steam for industry, a second furnace increases the supply safety and reduces time.
- The investments also depend on the applied incineration and flue-gas treatment technology, the number of technical backup systems, the housing of the facility and buildings etc.
- Process heating or district cooling require additional investments but also increase the overall energy efficiency of the MSWI plant. In many cases, land costs are not addressed as it is assumed that municipalities provide land for free. This could lead to legal issues and financial bottlenecks if not properly considered from the beginning.
- An additional factor to capital expenditure is the desired form of energy output. Utilizing heat only (steam for industry or district heating), has a high degree of total efficiency and the least degree of complexity. Generating power requires the need for a steam cycle and make much more complex. The most complex energy recovery system, but also the one with highest energy yield, is combined heat and power production. As the complexity of the plant increases, so do the capital expenditures and operating expenditures.
- However, it also results in higher income as energy recovery sale is one of the most important sources of revenue for the plant and may often pay for the higher investment.
- Due to the economy of scale it is in general more financially viable to build large WtE units. Mass burn units are in general built with a capacity from approx. 3 t/h up to approx. 40 t/h. For power producing facilities the minimum capacity should be around 10 tonnes of waste throughput per hour to make the investment in the turbine/generator equipment financially viable, however the break-even will be based on the actual income for sale of electricity and the cost for the equipment in the country in question.
- If the hourly capacity exceeds the maximum capacity for one unit or if there is a need to have more lines to ensure treatment of waste also in the period where the WtE unit is off for the yearly maintenance more units need to be established.

Annual operational costs:

- The operational costs include mainly the personnel costs, auxiliary materials (e.g. chemicals for flue gas treatment), spare parts and maintenance, insurance and taxes, electricity, and the costs for the disposal of the residues such as slag or fly ash (in some cases slag can be used in road construction).
- Possible additional costs for extra waste handling (e.g. segregation of unwanted waste fraction such as inert material) should also be considered. The collection of the waste is not addressed here, but is crucial to be organized and financed properly to achieve high rates of utilization.

- The specific investment and operation costs per ton of waste decrease as the capacity of the plant and the utilization rate increases. Therefore, the plant capacity should be preferably higher than 100,000 tons per year to achieve optimal economies of scale together with average collection distances.

Revenues:

- The derived revenues from energy sales depend on the prices for electricity and process heat, the efficiency of the plant and the LCV of the waste.
- Other incomes from recovered materials can in general be neglected. As these market revenues alone will not be sufficient, additional gate fees or subsidies are required to cover the full costs.
- The disposal fee, commonly called tipping fee is an important source of income. Usually, a disposal fee is also charged by landfills. The landfill tipping fee is usually cheaper compared to the tipping fee at the MSW incineration facility. This can be justified by MSW incineration being considered a long term sustainable solution. However, if the tipping fee is considerably higher than what is being charged at the landfills, waste producers may choose to seek alternative ways of disposing their waste, such as illegal dumping of waste.
- It is recommended to conduct a survey among the waste producers, determining the capability to pay increased disposal fees and if the gap between the actual cost and the capability to pay it is too large, it should be considered if the waste management system is sufficiently mature for setting up the MSWI facility, or other incentives should be considered to direct the waste to the facility. In some countries tax on waste to landfills has been an instrument to direct waste from landfill to energy recovery.
- Alternatively, increased tipping fees can be partly or fully subsidized by the government/local municipality and thereby part of the state/city budget.
- Other possible revenues for a WtE facility include carbon credits, from selling of recyclable ferrous and non-ferrous metals recovered from the bottom ash, and they can also come from ash used as construction material.

Small scale incinerators

As noted above, similar issues apply to smaller incinerators but some specific considerations apply (Table 8).

Table 8: Economics of small scale v larger incinerators[30]

- As noted above large plants require higher absolute initial investments compared to smaller plants but have lower specific annual costs per ton of treated waste due to economies of scale. This cost development does not follow a linear relationship to the amount of waste treated.
- The specific investment and operation costs per ton of waste decrease as the capacity of the plant and the utilization rate increases. Therefore, the plant capacity should be preferably higher than 100,000 tons per year to achieve optimal economies of scale together with average collection distances.
- There are economies of scale that mean that per tonne of waste costs decrease with size of EfW plant. For example, more efficient use of land, reduced unit costs, higher energy efficiency of some elements of the plant, and the fact that some costs such as access roads, weighbridges, development costs and engineering design do not necessarily increase in line with plant capacity.
- Some of the operational costs are also higher for a smaller plant, such as the costs for periodic measurements of emissions stipulated by the IED in Europe (and emissions legislation in other countries around the world) and the need for quality assurance and control of the instruments used in emission monitoring are examples that are not linear with size of plant, but rather on number of instruments and/or number of production lines in the plant.
- Not being able to benefit from the economies of scale of a larger facility is a well- documented disadvantage when developing a small-scale incineration. In most cases, operating costs are understood to be much higher per tonne for smaller scale facilities.
- High investment costs have led to attempts to bring low cost incinerators to the market. There is little experience of successful implementation to fully assess these. However, there is a high risk of failure where these omit critical equipment, especially environmental controls or use sub-standard components.

There is little data for small plants. Table 9 provides 2014 data for some case studies produced by IEA[31].

[30] Stein W., Tobiasen L., "Review of small scale waste to energy conversion systems", IEA Bioenergy – Task 36. March 2004
[31] IEA Bioenergy, 2015. *Small Scale Energy-from-Waste: Drivers and barriers*

Table 9 Economic comparison for small plants[31]

Economics	Exeter (UK)	Pontenex (France)	Skövde (Norway)
Investment cost in the year of delivery	£41.2 M (€51 M)	€16 M (would be approx. € 40M in 2014)	320 MSEK (€34.5 M)
Capacity(tonnes per year)	60,000	43,000	60,000
Gate fee MSW (€/tonne)	>141	81-100	41-60
Gate fee C&I (€/tonne)	>141	101-120	41-60
Average price electricity (€/MWh)	61.7	40 (feed-in tariff)	33.5 (average spot price)
Average price for heat (€/MWh)	-	31	55 (price to end consumer, including costs for distribution)

It should be noted that pollution control is a significant part of the total costs of safe incineration[32], whether in capital cost of equipment, or operating costs, or the safe disposal of hazardous waste. In the absence of local hazardous waste landfill, ash needs to be transported to a suitable disposal site.

Where small incinerator investors and operators attempt to avoid these costs, there is an environmental and health price to pay[33].

Small mass-burn only incinerators are still expensive (depending on size, small 5000t/year units can cost 0.5- 1 million USD, very small units less) and are not an economic way of managing waste. Pyrolysis/gasification applied to just part of the waste stream is prohibitively expensive[34] (Annex 3.3).

[32] Avfall Sverige, "Swedish waste management 2014", June 2014 http://www.avfallsverige.se/fileadmin/uploads/Rapporter/sah_2014_Eng_141001.pdf
[33] Batterman, S. "Findings on an assessment of Small-scale Incinerators for Health-care Waste", WHO/SDE/WSH/04.07, World Health organisation, Geneva, 2004
[34] Lombardi L., Carnevale E., Corti A., "A review of technologies and performances of thermal treatment systems for energy recovery of waste", Waste management 37 (2015) 26-44, 2015

4.8. Availability of finance

Consistent availability of finance, including foreign currency, is essential.

Some of the issues are summarized in Table 10.

Table 10: Considerations in availability of finance

- The consistent availability of financial means is crucial for long term application of MSWI technologies.
- Before considering MSWI as an opportunity, municipalities must be able to fully cover the costs for MSW collection and disposal in a controlled landfill; further financial means to cover additional costs should be easily accessible.
- In the long-term a fee for waste generators based on the polluter pays principle is desirable, whereas current management costs may be primarily covered from the municipality budget[35]. In particular, increasing the fee for landfilling can make other waste management options more feasible.
- If increasing the waste fee is not enforceable or municipalities do not want to or cannot increase budget, a detailed cost assessment by independent experts and/or the search for alternative long-term funding through alternative financing instruments is essential before initiating an MSWI project[36].
- Where long-term financing options are not established, municipalities are likely to be left with the bill – resulting in either operational shutdown or unwanted additional costs for the municipality
- Access to foreign currency is essential for all spare parts which are not locally available, as part failure will otherwise lead to shut down of operations – or failure to meet operating standards.
- When most of the spare parts can be purchased locally and sales offices are locally available for spare parts to be imported, the expected cost and access to foreign currency should be assessed before initiating an MSWI project.
- If key technology of the WtE plant must be imported or delays in getting access to purchases in foreign currency can be expected, incineration should not be chosen.

4.9. Access to energy end-users

WTE benefits from access to demand for heat as well as power

The choice of a location for a MSWI facility depends amongst other things on the access to end-users for the energy. The choice of the location and the incomes should be reviewed before starting the project. Industrial areas can benefit from the generated power and heat. If the project is in areas with no or only moderate heat demand, revenues from energy sales will be lower. The transformation of all the heat into electricity is an option but not the most economical, as the efficiency rate is much lower than a direct use of steam. Locations with a poor connection to energy end-users are substantially disadvantaged for MSWI as this implies limited use of recovered energy and increased net operating costs. Especially in Lebanon, as there is no known solution about the utilization of heat, there is a need to study carefully what will be the financial

[35] Nixon, JD et al, November 2013, *A comparative assessment of waste incinerators in the UK* (Waste Management Journal Vol 33 Issue 11)
[36] World Bank, Technical Guidance Report, Municipal Waste Incineration, Chapter 5, 1999

impact to the plant's operations and what potential alternatives exist in order to make the system viable.

4.10. Incentives for low carbon power generation

MSWI benefits from access to incentives for low carbon energy

The sale of energy from waste is subject to being competitively priced out of the market by fluctuations in price of conventional fossil fuels such as oil, coal and gas. When this happens the economic feasibility of the plant is endangered, making a secure income for energy from MSWI plants necessary to ensure stable long-term income for waste management. Regulatory incentives (such as feed in tariffs) for low carbon energy generation will not only support WtE but can also contribute to national targets defined in NDCs (Nationally Determined Contributions) of the Paris Agreement on Climate Change. An already successful application of incentives for low carbon energy indicates good potential for MSWI.

4.11. Decision-making matrix

Based on the above considerations a decision-making matrix has been derived from a matrix developed by GIZ. This is presented in Table 11[37]. The application of the matrix allows users to build a first transparent assessment of realistic MSWI options for the near future. It gives an overview of the preconditions that require fulfilment in the targeted region for an MSWI project and of the information gap for a more comprehensive evaluation

For each of the twelve parameters listed above, the user should assess their local conditions according to the options given horizontally from left (highly advanced) to right (very underdeveloped) in the matrix. The potential suitability of incineration against each measure is shown by a different color for each of the horizontally given local conditions.

GIZ suggests that with nine or more green fields in principal MSWI seems applicable. With less than nine conditions do not yet favor its implementation and more assessment is needed. One or more red field is a knock out criteria. All red highlighted conditions must be improved before initiating a project. It should be considered that most green conditions do not yet apply in Lebanon.

[37] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, May 2017 *Waste-to-Energy Options in Municipal Solid Waste Management. A Guide for Decision Makers in Developing and Emerging Countries.*

Table 11: Decision matrix[35]

GREEN: MSWI is probably suitable **YELLOW:** More information and improvement to local conditions may be required **RED** MSWI is not suitable without changing the conditions

1 Overall level of waste management			
Advanced waste management system which is based on waste streams (e.g. biomass, hazardous waste, recyclables) exists.	Systematic waste collection in place. Some waste fractions (e.g. tyres, recyclables, biomass) are directed towards recycling and composting.	Systematic waste collection and disposal to landfill exist. Recycling is not organized systematically.	Absence of systematic waste collection, recycling and disposal.
2 Composition of waste			
Organic and non-organic fractions are collected separately. Hazardous and bulky mineral waste is treated separately	MSW or separate collected waste fractions are some-times mixed with small fractions of mineral and hazardous waste	MSW is regularly mixed with fractions of minerals or hazardous waste	MSW is mixed with large amounts of mineral and hazardous waste
3 Calorific value of MSW			
The calorific value of MSW is on average > 8 MJ/kg.	The calorific value of MSW is on average between 7 and 8 MJ/kg.	The calorific value of MSW is < 7 MJ/kg. High biomass content with high average humidity.	The calorific value of MSW is < 7 MJ/kg. High content of inorganic fractions .
4 Suitable waste quantities for MSWI			
> 150,000 metric tonnes of suitable waste fractions are available per year	50,000 to 150,000 metric tonnes of suitable waste fractions per year	10,000 to 50,000 metric tonnes of suitable waste fractions per year	< 10,000 metric tonnes of suitable waste fractions per year
5 Efficient operation of waste facilities			
Public and private actors are experienced in efficient running of waste management facilities, also in cooperation	Public or private actors are experienced but require capacity building to manage WtE facilities efficiently	Public actors have limited experience with WtE and recruitment of qualified national staff is difficult for public and private sector	Neither public nor private actors have experience with the operation of WtE systems.
6 Additional transport time and distance for MSW to incineration plant			
Distance or transport time will hardly change compared to the current situation.	Transport time will -increase < 1 hour, additional distance <50 km.	Transport time will increase >1 hour. Additional transport distance > 100 km.	Additional transport distance > 200 km and rail transport is not available.
7 Marketing and/or final disposal of process residues			
A market for process residues exists. Hazardous residues can be disposed - of safely at a controlled landfill close to MSWI plant.	No market for process residues. All process residues can be disposed of safely at a controlled landfill close to the plant.	No market for process residues. Safe disposal requires large transport distances	No market for process residues and safe disposal of process residues cannot be made available
8 Legal framework			
A comprehensive legal framework which considers all types of MSWI exists. Laws are enforced and a national waste management strategy also covers MSWI	A national legal framework for WtE exists. Any deficiencies on the level of enforcement, ordinances and by-laws are being addressed.	National legal framework for WtE is non- or only partially existent. It cannot be ensured that international standards are respected in specific projects.	The existing legal framework forbids thermal WtE or there are indications that sufficient emissions standards cannot be enforced.
9 Financing the management of MSW			
Collection and disposal costs of MSW are always fully covered. Financial means to cover additional costs of MSWI are accessible.	Collection and disposal costs of MSW are always fully covered. Additional costs for MSWI might be difficult to cover.	The costs for collection and disposal of MSW cannot be covered on a regular basis.	There is frequently a lack of financial means to cover operating costs of MSW services.
10 Access to foreign currency			
Spare parts can be purchased locally. No restriction on purchasing spare parts in foreign currency.	Most spare parts can be purchased locally. Sales offices for spare parts to be imported are locally available.	Key technology of the MSWI plant must be imported.Delays in access to purchases in foreign currency	No access to foreign currency
11 Access to energy end-users			
MSWI facilities are located close to an industrial area with power and heat demand. Good transport and energy infrastructure exists.	MSWI facilities are located in an area with moderate heat demand. Good transport and energy infrastructure exists.	MSWI facilities are located close to a large power transmission network. No heat demand in the area.	MSWI facilities are located in an area which is poorly connected to energy consumers.
12 Incentives for low carbon energy generation			
Economic incentives for low carbon heat and power are already successfully applied	Economic incentives for low carbon electricity from waste are regulated by law but not yet applied	Introduction of economic incentives is most likely within one year	No economics incentives exist

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

Based on extensive experience the guidelines stress that MSW incineration is generally only considered suitable in mature waste management systems, where waste collection is working properly, where the calorific value has a certain minimum level and where the required tipping fees are affordable and the necessary regulatory, financial and other arrangements are in place. These considerations apply to small as well as larger plant. In summary, incineration should generally only be considered as an option if:

- A mature and well operated waste management system already exists.
- MSW is already being disposed in controlled and well-operated landfills.
- The supply of combustible MSW should at least amount to 100,000 t / year. (Can be smaller in isolated areas).
- The lower calorific value must be, on average, at least 7 MJ/kg and never fall below 6 MJ/kg.
- The community is able and willing to pay for the increased treatment cost for example via management charges, tipping fees, tax based subsidies or high electricity feed-in tariffs.
- Skilled staff can be hired and maintained, including for regulation and management as well as operation.
- The community planning system is stable and able to make appropriate long term planning

When considering the introduction of WtE technologies, decision makers need to consider the following aspects:

- The development of MSWM systems should follow the waste hierarchy based on careful quantification and evaluation of the waste stream and building on an efficient MSWM systems
- MSWI must fulfil high emission standards with a comprehensive legal framework applying internationally recognized standards
- MSWI requires careful analysis of costs and revenues and significant financial resources which must be secured, as well as legal security for private sector investors

Based on the review, some initial conclusions can be drawn on the readiness of Lebanon for MSW incineration in general and on proposals for small and very small incinerators.

- The required conditions are not presently in place for the effective and safe implementation of MSW incineration. The main reason is that incinerators are effective only when they are working in a proper supportive ecosystem that ensures the quality and the quantity of the feedstock, addresses the institutional, financial and environmental challenges and integrates them in the waste supply chain. This supportive ecosystem does not exist in Lebanon.
- Accordingly, the construction of incinerators without the proper supporting ecosystem might present environmental, health and economic risks as well potentially undermining the implementation of an effective waste management strategy.
- Small plants are not viable for energy production (the lower limit is 50,000 t/year; above 150,000 t/year is more economical). Very small plants (e.g. 5,000t/year) are an expensive option for volume reduction, and in the absence of high levels of environmental control, present a high risk to the environment and public health.

A review of pyrolysis and gasification confirmed that it is not suitable for mixed MSW and is not commercially viable.

5.2. Recommendations

The following recommendations are made:

- In the light of the above, proposals for incinerators, large or small, should be shelved until a detailed, independent assessment is made of their longer-term role, if any, in the national waste management strategy, including conformance to the waste hierarchy. Standalone interim proposals should not be approved.
- No incinerator projects should be approved until appropriate environmental regulatory and management controls and conditions are in place; this includes establishing a specific regulatory framework and subjecting all proposals to environmental assessment as well as permitting.
- Having implemented legal, regulatory and related institutional changes, all proposals should be subject to independent and detailed economic and financial evaluation, including examination of suppliers' claims on costs and performance, training and maintenance obligations.

ANNEX 1: SUGGESTED READINGS

- Advanced Thermal Treatment of Waste
  https://www.gov.uk/government/uploads/system/uploads/attachment_data/le/221035/ pb13888-thermal-treatment-waste.pdf
- CWG, Collaborative Working Group on Solid Waste Management in Low and Middle Income Countries, "CWG Rapid Technology Assessment Tool," 2016.
- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Eschborn, May 2017 *Waste-to-Energy Options in Municipal Solid Waste Management. A Guide for Decision Makers in Developing and Emerging Countries.*
- EU Waste Incineration Directive:
  http://europa.eu/legislation_summaries/environment/waste_management/l28072_en.htm
- IEA Bioenergy, 2015. *Small Scale Energy-from-Waste: Drivers and barriers*
- International Solid Waste Association (ISWA), August 2013. ISWA Guidelines: Waste to Energy in Low and Middle Income Countries.
- Nixon, JD et al, November 2013, A comparative assessment of waste incinerators in the UK (Waste Management Journal Vol 33 Issue 11)
- Waste Management Association of Australia, Sustainability Guide for EfW Projects and Proposals Page 1 Edition 1b – 24/01/05
- World Bank, Technical Guidance Report, Municipal Waste Incineration, 1999

ANNEX 2: WASTE AS FUEL

The viability of any MSW incineration facility depends highly on the quantity and calorific value of the waste. Issues to consider are tabulated here[38]:

- The economic state of the country/area is highly correlated to the calorific value of the waste. Countries with high degree of consumerism tend to have higher calorific waste composition due to plastics and cardboard for packaging of consumer goods etc.
- In low to middle income countries the content of plastics and cardboard waste is lower and the content of organic waste is higher. In some locations, a large part of the wet kitchen waste ends up in the waste bin resulting in high water content.
- In some locations, the waste management system is often based on open waste containers and the collection is often carried out in open vehicles. During heavy rainfall, this further adds to moisture content.
- Scavengers may influence the waste stream, making a living by picking and sorting recyclable fractions for recycling. The scavengers may pick out waste from the waste collection points or from the landfill sites. Scavenging relates to great health risks as no procedures are done to protect the scavengers from diseases. There is also a great risk of incidents when the trucks are unloading the waste as well as a risk of injuries from sharp objects.
- Implementing MSW incineration will significantly affect the lives of the scavengers as they will lose a source of income. A change in scavenging activity might change the composition and thus the calorific value of waste.
- Thus, the impact from scavenging must be carefully considered when assessing the suitability of waste as a fuel. It is important that the waste authority or the governmental body assist in the transformation from informal scavenging to organized and protected waste recyclers.
- For these reasons, the overall calorific value (lower heating value) may be too low for combustion without the constant supply of auxiliary fuel, putting the viability of an MSW incineration facility at risk.
- It may be that the MSW is of poor calorific value and unsuitable, whereas the industrial solid waste is of higher calorific value and very well suited. A mix of MSW and industrial solid waste may then also be suitable for incineration. However, this requires a well-managed waste management system to ensure that the industrial waste stream will not contain hazardous components.
- Seasonal changes should also be taken into consideration as well as religious traditions which may have implications to the calorific value of the waste.
- In general, the average lower calorific value of waste should be at least 7 MJ/kg and must never fall below 6 MJ/kg.
- Other factors, such as water content and ash content, also affect the calorific value of the waste. A thorough investigation of the average calorific value and the annual quantity is necessary in order to commence a comprehensive feasibility study. As these factors are highly dependent on socio-economic state and waste management system, data from countries alike can only be projected with a high degree of uncertainty.

[38] International Solid Waste Association (ISWA), August 2013. ISWA Guidelines: Waste to Energy in Low and Middle Income Countries

Figure A1 shows the typical waste composition from four different income level countries.

Figure A1

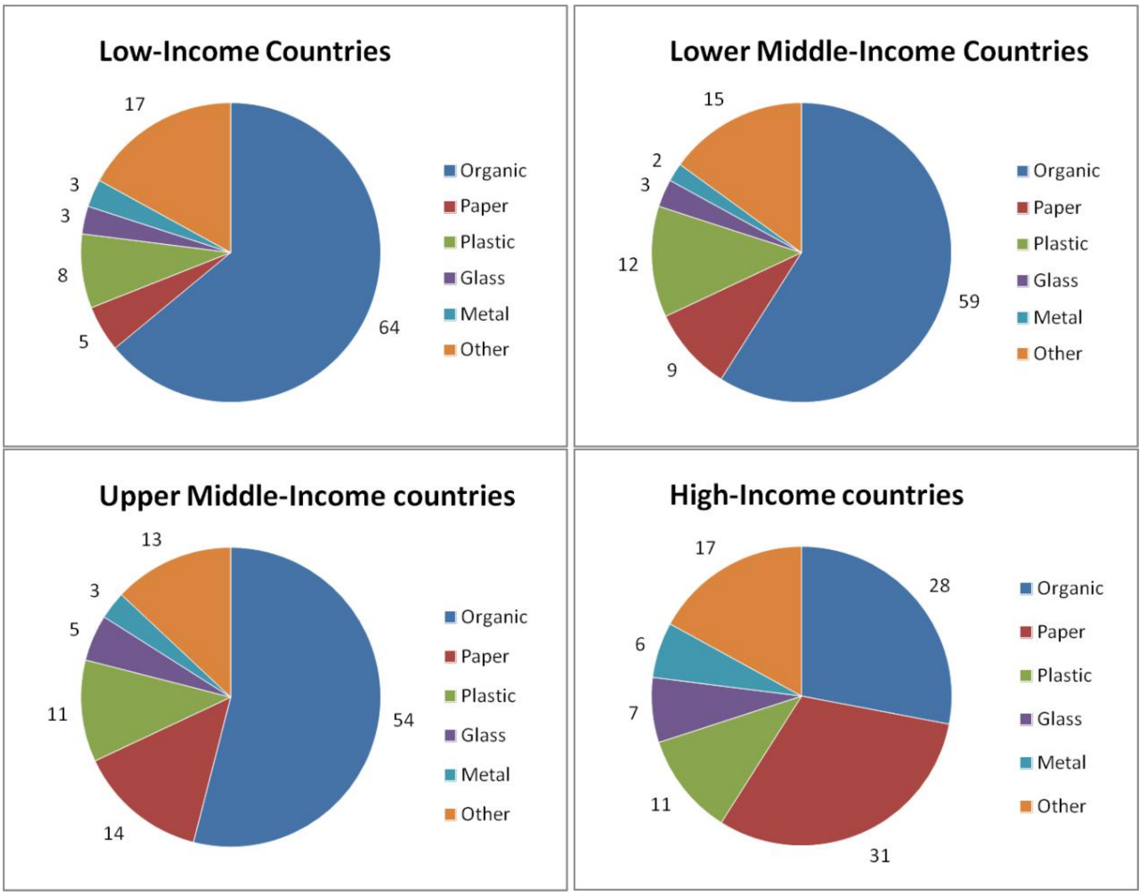

Figure 1 - Typical waste composition for different income level countries[2].

ANNEX 3: WASTE INCINERATION TECHNOLOGY

A3.1 Overview of technology

Municipal solid waste incineration (MSWI) is the burning of waste in a controlled process within a specific facility that has been built for this purpose. The primary goal of MSWI is to reduce MSW volume and mass and make it chemically inert in a combustion process without the need of additional fuel (autothermic combustion). As a side effect, it also enables recovery of energy, minerals and metals from the waste stream. There are always about 20% residues from incineration in the form of slag (bottom ash) and fly ash. Bottom ash is made up of fine particulates that fall to the bottom of the incinerator during combustion, whilst fly ash refers to fine particulates in exhaust gases which must be removed in flue gas treatment. These residues need further attention and, in the case of the hazardous fly ash, a secure place for final disposal.

The combustible materials in waste burn when they reach the necessary ignition temperature and come into contact with oxygen, undergoing an oxidation reaction. The reaction temperature is between 850 and 1450ºC, and the combustion process takes place in the gas and solid phase, simultaneously releasing heat energy. A minimum calorific value of the waste is required to enable a thermal chain reaction and self-supporting combustion (so-called autothermic combustion), i.e. there is no need for addition of other fuels. During incineration, exhaust gases are created which, after cleaning, exit to the atmosphere via a pipe or channel called a flue. These flue-gases contain the majority of the available fuel energy as heat, as well as dust and gaseous air pollutants which must be removed via a flue-gas purification process. Excess heat from combustion can be used to make steam for electricity generation, district heating/cooling or steam supply for nearby process industry. Plants that utilize cogeneration of thermal power (heating and cooling) together with electricity generation can reach optimum efficiencies of 80%, whereas electricity generation alone will only reach maximum efficiencies of about 20%.

A3.2 Components of a MSWI

This section describes the concepts and major components of an MSW incineration facility following the flow of the process shown in the diagram below.

Furnace/boiler

The tipping hall is where the MSW is unloaded from collecting trucks. In order to determine the amount of waste delivered, a weighing station is installed prior to the tipping hall. To avoid unpleasant odors to the local community, the tipping hall and building shall be kept at pressure slightly under atmospheric conditions.

Waste bunker

The size of the bunker depends on the planned capacity of the plant. The bunker should be able to hold about a week of MSW for the plant to cope with maintenance, or any other halt in operation.

Waste feeding

The waste crane serves multiple purposes. Firstly, it can pick up waste that is too large to enter the waste feeder directly such as a large mattress.

Secondly, it mixes the incoming waste to ensure the waste fed to the combustion unit is as uniform as possible as it gives the most stable combustion and hereby the highest energy efficiency.

Lastly, the crane distributes the waste evenly in the waste hopper. The waste is led to the combustion zone through a chute which also functions as an air seal to avoid uncontrolled air leaks to the combustion chamber. Generally, the chute should be designed to handle objects with a length of up to 1 metre.

Grate

The grate serves two purposes:

- Transportation, agitation, stirring, mixing, distribution and levelling of the waste on the grate
- Distribution of primary combustion air to the waste layer

Various grate designs and makes are available, usually characterised by their respective principles of movement. These principles include an inclined or horizontal grate with forward or backwards moving grate sections. The average residence time of the waste on the grate is about one hour.

Furnace

The furnace, where primary combustion occurs, is cooled by water walls with steam later used for energy recovery. The steam runs through gas-tight membrane tube walls forming the walls and ceiling of the furnace. This part of the furnace must be highly resistant to corrosion as the very high temperature of the flue gas makes acidic and alkaline components extremely aggressive.

Through an arrangement of nozzles above the waste, secondary air is supplied to complete the reactions of combustion. An additional function of supplying secondary air is to mix the combustion gasses and ensure a uniform temperature of the flue gas. Typically, 40% of the total combustion air is supplied as secondary air and 60% as primary air.

The furnace should be equipped with at least two auxiliary burners to be used during start-up and shut-down of the plant and for maintaining the temperature should sudden temperature drops occur.

The combination of high temperature and alkaline in the flue gas makes the flue gas aggressive. The tube walls of the furnace and the boiler tubes must therefore be coated with the corrosive and temperature resistant alloy Inconel, or with a refractory lining to avoid direct contact between the flue gas and the boiler tubes. Typically, the corrosion protection must be applied until a point in the boiler where the flue gas temperature is approx. 850-900°.

Boiler

The overall efficiency of the boiler is highly dependent on the temperature and the pressure of the steam. Optimal steam parameters depend on a balance of two adverse design criteria:

- The higher the temperature and pressure the more electricity production
- The higher the temperature and pressure the higher risk of corrosion and thus increase in maintenance costs.

Most WtE facilities operate with a steam pressure between 40-60 bar and a steam temperature between 400-425 C.

Principally two basic boiler designs exist, vertical and horizontal design. The vertical boiler design has vertical passes in both the radiation and the convection part (incl. the economizer). The horizontal boiler design has vertical radiation passes followed by a horizontal convection pass with pre-evaporator, super heater, evaporator and economizer sections.

Energy recovery

Energy can be recovered to produce power and/or steam. The choice of energy recovery system depends on the local energy infrastructure, the end-use consumption of the region and prices of energy alternatives.

For combined heat and power plants, one tonne of waste with a lower calorific value of 10 MJ/kg can be converted to approximately 2 MWh heat and 2/3 MWh electricity. If only electricity is produced, the energy output can be expected to rise to approximately 0.70-0.75 MWh per tonne of waste with a lower calorific value of 10 MJ/kg.

The energy production per tonne of waste varies proportionally with the calorific value.

Flue gas treatment

Flue gas contains the pollutants from the waste and requires treatment before being emitted to the atmosphere. Various treatment methods exist – from the dry solutions to the more complicated wet solutions.

Principally all processes are based on a reaction between lime injected in a reactor and the acidic components in the flue gas converting them to solid compounds. These compounds are removed – together with the dust (fly ash) – in a downstream bag house filter. By adding activated carbon between the reactor and the bag-house filter it is possible also to remove dioxins and mercury (Hg).

All combustion processes produce NOx. The amounts are affected by temperature and molecular composition of the air supply. Partly, the NOx content can be controlled by the control of the combustion process, however in order to achieve emissions standards (see Annex 4), active NOx removal is necessary.

The two most common systems are SNCR (selective non-catalytic reduction) and SCR (selective catalytic reduction). Both systems reduce NOx to N_2 by supplying ammonia to the raw flue gas.

In the SNCR process, ammonia is injected into the raw flue gas in the furnace at a location where the temperature is around 850-900^{o}C.

In the SCR process, the reaction between ammonia and the flue gas occurs on a catalytic surface normally situated downstream of the APC. SCR is normally used only for plants which are under tight NOx regulatory limits or if a financial incentive to reduce NOx emissions exists.

Ash handling/residue

The volume of the MSW after combustion is reduced to about 10% of its original volume and about 20% based on weight. This is a combination of bottom ash, fly ash and residues after the flue gas treatment process.

The bottom ash quality, i.e. remaining organic content, is measured in order to evaluate the combustion process and should be lower than 3%.

Bottom ash is sometimes used in for construction purposes instead of gravels after metals are sorted out for recycling, but this depends on analysis for the presence of heavy metals and the presence of persistent organic pollutants. If these are present it should be disposed of to a hazardous waste landfill. Fly ash and flue gas residues are considered hazardous waste and must be treated accordingly. Environmental issues are considered in Annex 4.

Figure A2 shows a cross-section of a WtE facility with a semi-dry flue gas treatment system.

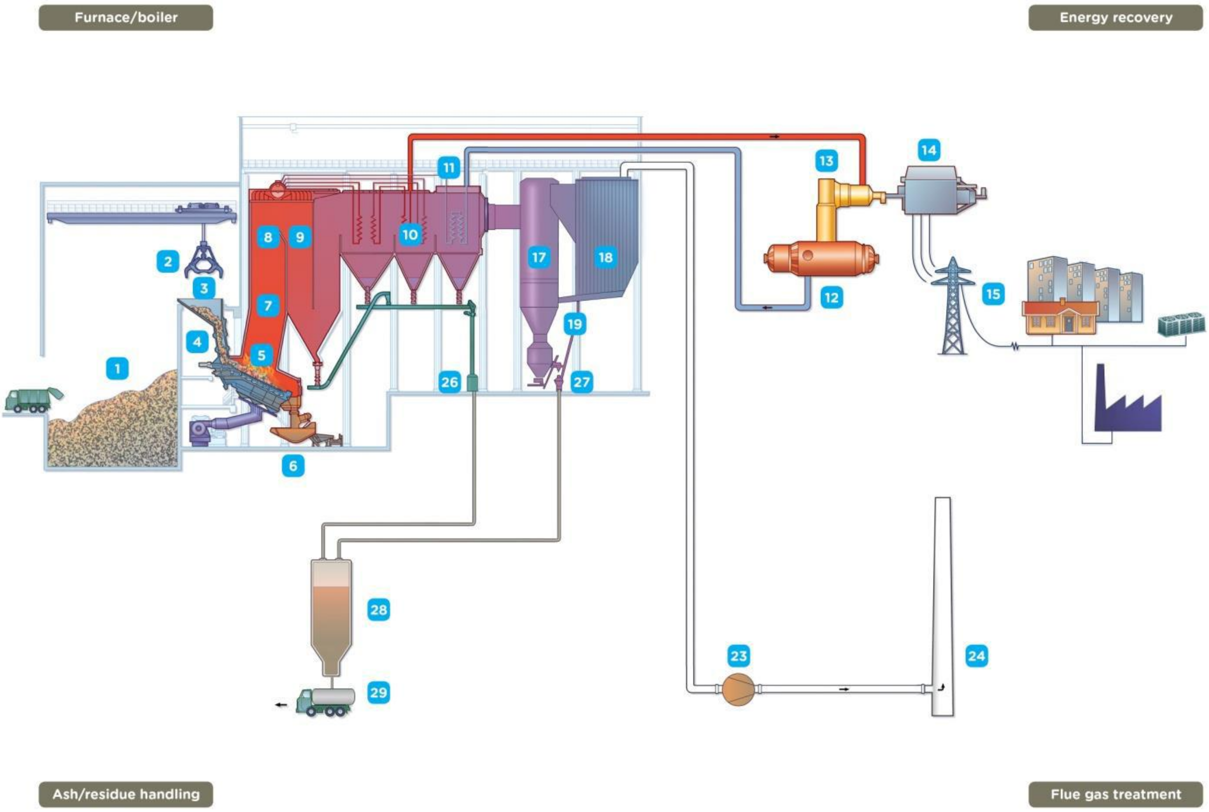

Figure 11 Cross-section of a dry/semi-dry WtE facility (Power production only).

Legend:
Furnace/boiler:
1. Bunker 2. Waste Crane 3. Hopper/feed chute 4. Feeder ram 5. Grate 6. Bottom ash discharger 7. Furnace 8. Afterburning chamber 9. Radiation part 10. Convection part 11. Economiser

Energy recovery:
12. Condenser 13. Turbine 14. Generator 15. Electrical output

Flue gas treatment:
17. Reactor for acid gas absorption 18. Bag house filter 19. Residue recirculation 23. ID fan 24. Stack **Ash/residue handling:**

26. Boiler ash conveying system 27. Flue gas cleaning residue transport system 28. Ash/residue silo 29. Ash/residue discharge.

A3.3 PYROLYSIS AND GASIFICATION

Technology description

Pyrolysis/gasification of waste is the gasification[39] of waste under oxygen controlled conditions, during which pyrolysis gas and a solid coke are formed. The heat values of pyrolysis gas typically lie between 5 and 15 MJ/m³ based on municipal waste[40]. In a broader sense, pyrolysis is a generic term including a number of different technology combinations that constitute, in general, the following technological steps:

- **Smouldering process**: Formation of gas from volatile waste particles at temperatures between 400 and 600°C
- **Pyrolysis**: Thermal decomposition of the organic molecules of the waste between 500 and 800°C resulting in formation of gas and a solid fraction
- **Gasification**: Conversion of the carbon share remaining in the pyrolysis coke at 800 to 1000°C with the help of a gasification substance (e.g. air or steam)
- **Incineration**: Depending on the technology combination, the gas and coke are combusted in an incineration chamber.

Other processes have been developed that are based on the de-coupling of the phases which also take place in an incinerator: drying, volatilization, pyrolysis, carbonization and oxidation of the waste. Some of these developments have met technical and economic problems when they were scaled-up to commercial sizes, and are therefore no longer pursued. Some are used on a commercial basis (e.g. in Japan) and others are being tested in demonstration plants throughout Europe, but still have only a small share of the overall treatment capacity when compared to incineration and are applied for selected waste only.

Application

Like waste incineration, the objective is to treat waste to reduce its volume and hazards, whilst capturing (and thus concentrating) or destroying potentially harmful substances. The process also provides a means to enable recovery of energy, mineral and/or chemical content from waste in the form of useful "recycling" products such as syngas, oil, char or coke

At present, no plant for the treatment of MSW is in operation on a larger scale in Europe, Africa or Latin America and the few plants in Asia (mainly Japan) and the USA are operating as an integrated element of a more complex MSWM system or for specific waste streams only. The advanced technology and operating requirements, highly specific waste input needs and high upfront capital costs make this technology difficult to apply at scale.

Suitable waste

There are no successful experiences with the treatment of bigger volumes of mixed MSW due to its heterogeneous composition. For this reason, pyrolysis might be an option for the final treatment of specific waste streams such as organic fraction from MBT plants, contaminated soil,

[39] Process and technological aspects of municipal solid waste gasi cation – A review by Umberto Arena http://www.ncbi.nlm.nih.gov/pubmed/22035903

[40] Advanced Thermal Treatment of Waste https://www.gov.uk/government/uploads/system/uploads/attachment_data/le/221035/ pb13888-thermal-treatment-waste.pdf

clinical waste or mono hazardous industrial / commercial waste. It is not recommended for either mixed municipal waste, or for an environment in which robust and proven technologies are needed.

Operational aspects

Pyrolysis or gasification is not considered easy to handle stand-alone technologies but must be a component within an overall waste management system. Operation requires good understanding of the composition of the incoming waste and process knowledge. Experience has shown that trouble free operation of a pyrolysis plant requires highly skilled technicians

Environmental aspects

The potential benefits of pyrolysis processes may include:

- Recovering the material value of the organic fraction e.g. as methanol;
- Increased electrical generation using gas engines or gas turbines;
- Reduced flue-gas volumes after combustion;
- Production of char or coke which can be used as fuel in power or cement plants.

Legal aspects

Where existing environmental legislation does not deal with the application of pyrolysis and gasification as combustion (or WtE) technology, the process of impact assessment and operation licensing is complicated and time consuming.

Economic aspects

Due to high operation and maintenance costs the economics of pyrolysis/gasification can only be considered as acceptable if the process products (gas, coke) have a good market value.

This depends very much on market conditions and the - need for an end consumer (e.g. cement plant) close to the AT plant. Experiences from the last 40 years show that - in addition to the technical challenges, pyrolysis and gasification companies often have to deal with economic challenges which has led in many cases to shut downs in operation, since no adequate revenues could be obtained for the additional costs of product preparation. Compared to all other WtE technologies, pyrolysis and gasification are the most expensive. The following table gives an indication on the costs for a plant with an annual input of 150,000 – 200,000 tons.

Cost estimates of a pyrolysis/gasification plant (source GIZ)

Initial Investment	**Capital costs per ton & year of waste input**	**O&M costs per ton**	**Total cost per ton**	**Revenues per ton**	**Cost per ton waste input**	**Remark**
80 – 120 million EUR	35 – 45 EUR/t	30 – 40 EUR/t	65 – 85 EUR/t	2 – 5 EUR/t	63 – 80 EUR/t	Capacity 250,000 t/a, 20y operation, 6% p.a. IR

ANNEX 4. ENVIRONMENTAL AND HEALTH CONSIDERATIONS

Environmental concerns

A major disadvantage of incineration is the creation of combustion by-products that may be released into the atmosphere and the generation of hazardous ash. The combustion of municipal waste produces gaseous emissions, including steam, carbon dioxide, nitrogen oxides and a range of volatile substances (e.g. metals, halogenic acids, products of incomplete combustion) and particulate matter, plus solid residues in the form of ashes. Of special concern is the generation of persistent organic pollutants (POPs), especially dioxins which are highly toxic, readily dispersed and bioaccumulated into the environment, including the food chain, and long lasting. Incinerators have been recognised by UNEP as one of the major sources of dioxins and other substances catalogued under the Stockholm Convention on Persistent Organic Pollutants. Incinerators are also recognized as a major source of mercury emissions under the Minamata Convention. Dioxins are highly toxic and which may cause cancer and neurological damage, and disrupt reproductive systems, thyroid systems and respiratory systems.

Dioxins are transported in the atmosphere and are capable of being transported thousands of kilometers away across national boundaries. Dioxins are removed from the atmosphere via wet or dry deposition onto surface water, soil or vegetation. Dioxins in soil tend to adsorb strongly to organic matter. Estimates of the environmental half-life of dioxins on soil range from 9 to 15 years on the soil surface, and 25 to 100 years in subsurface soil. The half-live of dioxins in sediment depends on many factors including aerobic biodegradation and the extent to which sediment is re-suspended in the water.

Because of the extreme environmental and health concerns, incineration is heavily regulated in all countries with well-developed environmental control and enforcement systems and subject to emissions limits for flue gas discharges.Table A2 shows the European limits and the BAT (Best Available Techniques) operational levels for flue gas emissions from WtE facilities measured in half hour and daily average

Table A2 European flue gas emission limit values (ELV) and BAT operational levels.

	Half hour average in mg/Nm^3		**Daily average in mg/Nm^3**	
	Limits in 2000/76/EC	BAT	Limits in 2000/76/EC	Bat
Total dust	20	1-20	10	1-5
Hydrogen Chloride (HCl)	60	1-50	10	1-8
Hydrogen Fluoride (HF)	4	<2	1	<1
Sulphur dioxide (SO_2)	200	1-150	50	1-40
NO_x using SNCR	400	30-350	200	120-180
Gaseous and vaporous organic substances, expressed as TOC	20	1- 20	10	1-10
Carbon monoxide (CO)	100	5-100	50	5-30
Mercury and its compounds (as Hg)	n/a	0,001-0,03	0,05	0,001-0,02
Total cadmium and thallium	n/a	0,005-0,05 [1]	0,05	0,005-0,05 [1]
Sum of other metals	n/a	0,005-0,5[1]	0,5	0,005-0,5 [1]
Dioxins and Furans (in ng TEQ/Nm^3)	n/a	0,01-0,1 [1]	0,1	0,01-0,1[1]
Ammonia	n/a	1-10	n/a	<10

[1] from Non-continuous samples

Key environmental issues to note are as follows:

- Dioxins are produced during incineration of wastes through de novo synthesis, whereby carbon, hydrogen, oxygen, and chlorine recombine and react to form dioxins as the exhaust gases cool in a critical temperature range from between 250 to 450 ^{o} C.
- Dioxins are also formed through a precursor route, involving surface-catalyzed reactions of chlorinated precursors such as chlorobenzenes and chlorophenols. These precursors are byproducts of incomplete combustion typically at temperatures of around 750 ^{o} C.
- The reactions are catalyzed by elements in the fly ash. Both organic and inorganic chlorine in the waste provide the chlorine source for dioxin formation.
- When released from incinerator stacks, dioxins are primarily adsorbed on airborne particulates.
- The incineration process produces two types of ash. Bottom ash comes from the furnace and is mixed with slag, while fly ash comes from the stack and contains components that are more hazardous. In small incinerators without proper combustion and flue gas treatment, white ash is also produced as smoke.
- In municipal waste incinerators, bottom ash is approximately 10% by volume and approximately 20%by weight of the solid waste input. Fly ash quantities are much lower, generally only a few percent of input.
- Emissions from incinerators can include heavy metals, dioxins and furans, which may be present in the waste gases, water or ash. Plastics are the major source of the calorific value of the waste. The combustion of plastics, especially polyvinyl chloride (PVC) gives rise to these highly toxic pollutants.
- Toxic pollutants are created at various stages of such thermal technologies, and not only at the end of the stack. These can be created during the combustion process, in the stack pipes, as residues in ash, scrubber water and filters, and in air plumes which leave the stack.
- Fly ash concentrates harmful substance and so is treated as hazardous waste and must be disposed of to a hazardous waste landfill (not to a municipal waste landfill) to prevent leaching into the environment, especially the aquatic environment. Pollutants may be present in bottom ash and so this is often also regarded as hazardous waste.
- If flue gases are quenched or subject to wet scrubbing dioxins may also be present in waste waters, also regarded as hazardous waste.
- Pollution control equipment is essential to reduce emissions to permitted levels: The first component of the pollution control equipment is the stage at which ammonia is injected into the gases produced from the burning process which assists in the removal of NOx.
- The removal of mercury is achieved by the injection of activated carbon. Lime is then injected in the dry scrubber stage whereby the acid gases are removed. Further, most incinerators have a bag-house or electrostatic precipitator to facilitate the capture of particulate and toxics.
- Because of the risks from a breakdown of controls, emissions must be continuously monitored and pollution control equipment maintained and tested as part of environmental permitting conditions.

Human health concerns

Despite controls, waste incineration remains controversial, even in developed countries because of the evidence of harm from long term exposure to POPs, even at small levels. This includes evidence of higher levels of health impacts among people living near to incinerators, even those with environmental controls.

There has been extensive research into the health impacts of incinerators in developed countries and increasing research in developing countries. Not surprisingly the health impacts are much greater in developing countries where use of small incinerators without pollution control or skilled operation is common.

Because of health and environmental concerns, the World Health Organisation, UNEP and other agencies have produced guidelines on the use of small incinerators, including use for medical waste.

Key health issues for all incinerators, large or small, are (see UNEP references):

- Dioxins, polyaromatic hydrocarbons (PAHs), POPs and heavy metals have been classified as carcinogenic by the International Agency for the Research of Cancer.
- Dioxins have been linked to chronic lymphocytic leukemia, soft-tissue sarcoma, non-Hodgkin's lymphoma, and Hodgkin's disease.39 There is limited or suggestive evidence of a possible association with respiratory cancer, prostate cancer, type 2 diabetes, spina bifida in children of exposed persons, and other disorders.
- Other possible health effects associated with chronic dioxin exposures include reproductive disorders such as reduced sperm count and decreased fertility, as well as developmental and immune system impacts.
- Various studies in Japan, Spain, and Germany show that incinerator workers or children and other residents living near incinerators have significantly higher blood or urine levels of dioxins, furans, polychlorinated biphenyls, hexachlorobenzene, 2,4/2,5-dichlorophenols, 2,4,5-trichlorophenols, hydroxypyrene, toluene, and tetrachlorophenols compared to control groups or to national averages.
- The affected population includes those living near the incinerator as well as those living in the broader region. People are exposed to dioxins and other toxics compounds in several ways:

  - By breathing the air which affects both workers in the plant and people who live nearby;
  - By eating locally produced foods or water that have been contaminated by air pollutants from the incinerator;
  - By eating fish or wildlife that have been contaminated by the air emissions.

Annex 4: Policy note on the use of compost-like outputs (CLO) from mechanical-biological treatment plant (MBT)

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

This report is part of the EU funded project *"Technical support to upgrading the solid waste management capacities in Lebanon – ENPI/2017/389-095".*

One option for managing the organic fraction of municipal solid waste (MSW) is mechanical-biological treatment (MBT) and use of compost-like outputs (CLO) for soil improvement. This Policy Note has been prepared to inform decision-making on this subject. It provides an overview of CLO from MBT and how it differs from compost from organic separation-at-source. It reviews use of CLO in the EU, potential use in Lebanon, and, if pursued, the necessary regulatory framework to ensure safe use and a market for the product.

Main findings

The main findings are as follows:

- The terms compost, MBT and CLO are subject to a high level of inconsistency in definition in the EU and internationally. MBT describes a range of processes and each country has its own regulations and standards relating to compost and CLO.
- There are drivers and potential benefits, environmental and economic for MBT, including the potential production of biogas, refuse derived fuel (RDF) and CLO and digestate. However, the main technology driver in the EU has been the production of stabilized organic material to meet obligations under the Landfill Directive to reduce biodegradable waste going to landfill.
- Most northern European countries operate source-separation of organic waste and landfill the stabilized outputs; use of CLO on agricultural land is prohibited and use for other purposes is subject to strict control.
- Wider use for agricultural soil improvement is permitted in some southern European countries, especially in Spain to combat desertification; also in Portugal and some parts of Italy where incentives have been given to farmers to use CLO from MSW e.g. in vineyards.
- Standards vary between countries on classes and application of compost. All, to varying degrees, specify limits on heavy metals and other substances and, in some cases, application rates.
- It is generally accepted that compost from source-separation is higher quality than CLO because of heavy metal and other characteristics due to the nature and variability of the mixed waste input.

- There is also variation on classification as waste or product, an issue in market acceptability. CLO in general is more likely to remain classified as a waste.
- MBT plants designed for sorting and composting form an important part of current MSW management but the quality of the CLO outputs is a serious challenge.
- Lebanon has an existing Compost Ordinance which provides a basis for regulating the use of CLO. However, the production and use of CLO faces very serious barriers.

Conclusions

Based on this review it is concluded that the use of CLO from MBT in Lebanon is a serious challenge that should be addressed:

- There are several MBT plants and the volumes of CLO produced are high enough to require a specific policy to address its use. As currently MBT is the only treatment method in Lebanon, addressing the use of CLO is a major requirement to maximize the MBT benefits and minimize the residual stream.
- Because of the environmental and health risks, the currently produced CLO is unsuitable for sale as a product and use in agriculture for food production. The current mixing of special waste with municipal waste makes it even more unsuitable.
- However, its potential use as a low value soil improver in forestry, landscaping or brownfield land restoration should be examined in detail and, if successful, it will provide a substantial improvement to the current waste treatment operations.
- Source-separation of organic waste is a much better option for MSW, being more efficient and economical and producing potentially better quality and marketable compost.

Recommendations

The following recommendations are made:

- Preference should be given to source-separation of organic MSW, as well as recyclables wherever possible.
- CLO or stabilized outputs from MBT should be used wherever possible for soil improvement for restricted purposes as permitted.
- MBT should focus more on the production of high quality RDF that involves the organic fraction, as a measure to reduce the quantities of CLO produced and make easier their management.

- Appropriate regulatory and institutional, including financial arrangements should be established depending on selected applications e.g. on forest restoration.
- Other processes and products from MBT should be considered such as biodrying and biochar.

2. INTRODUCTION

2.1. Background

Recognizing the growing volumes and problems of municipal solid waste in Lebanon, and the need for better management now and in the future, several Waste Management Master Plans are presently being developed with EU assistance. The Master Plans propose a strategic approach to waste management at national and local levels based on the well-established hierarchy of waste management: reduce, reuse, recycle and, where no other options are available, disposal to landfill. The Master Plans propose waste management options as part of a transition to a more sustainable, circular economy, where materials are recovered as valuable resources rather than part of a linear flow to waste.

Biodegradable (organic) waste forms a major proportion of total mass of MSW - 60-70% in most countries. Recovery and use of this material where possible is justified by resource efficiency, return to the land for soil improvement and avoidance of greenhouse gas emissions when disposed of to landfill.

One option is to segregate organic MSW material at source and produce compost. Another option is to process unsorted MSW or source-separated in mechanical-biological treatment (MBT) plants. Here inorganic materials are removed for recycling or disposal and organic materials are treated to produce ‘compost-like outputs’ (CLO), biogas or refuse-derived fuel (RDF). Although practiced in several EU countries, the use of CLO for soil improvement raises environmental, health, economic, regulatory, market and other issues that should be successfully addressed. Specifically, CLO has several disadvantages with respect to quality and the presence of contaminants compared to compost from source-separated organic material. This Policy Note has been prepared to inform decision-making about the use of CLO.

2.2. Purpose and scope

This Policy Note provides an overview of the issues which would need to be considered in producing and using CLO from MBT plants in Lebanon. It provides:

- An overview of terminology in order to clarify what MBT/CLO is and how it differs from compost from source-segregated compost.

- A summary of the drivers and benefits of MBT and the barriers to production and use of CLO, including environmental and health risks, regulatory, quality, economic and market issues.
- A review of uses of CLO in the EU and applicable standards, which vary widely between countries.
- Potential uses of CLO in Lebanon and the necessary conditions for its future use, including a regulatory framework to ensure safe use and facilitate a local market. The main problems with CLO have been material quality (contamination), restrictions on their use and market acceptance. A key issue in using any waste material as a saleable product is when it ceases to be waste.
- Alternatives to CLO production: RDF through biodrying and biochar.

This document has been prepared from a review of decision-making guidelines, technical notes and other literature in this area. This literature is based on extensive international experiences. It does not constitute a detailed feasibility study forr the production and use of CLO nationally in Lebanon or for any specific locality but provides some guidance and recommendations on the potential role of CLO in the current and the future waste management systems.

3. TERMINOLOGY

There has been much inconsistency and sometimes confusion in definitions in this area. This section provides and overview of terms and processes which are set out in Table 1.

The objective of composting is to produce compost as soil conditioner. Many countries have established separate regulations and standards for the production, content and use of compost. In the EU these are generally statutory, sometimes voluntary (see Section 4). Lebanon itself established an Ordinance on the quality assurance and utilization of compost.

Many countries have well-established processes for producing commercial scale compost from organic material, although there is variation in source and use. e.g. in the UK compost can only be produced from green waste while many countries permit the use of kitchen waste in composting. In Europe, a few countries, Germany followed by Italy and the Netherlands, dominate the compost market[12].

There has been particular inconsistency in the definitions of MBT and CLO since MBT encompasses a range of processes and has different objectives between countries.

Depending on the final purpose of the biodegradable fraction, MBT installations are designed differently[12]. MBT installations either aim to produce:

a) a stabilized landfillable or combustible fraction with a minimum of unstable biodegradable material, NOT destined for agriculture, in which case the wording CLO/digestate is not used; or

b) a composted/digested organic fraction that can be recycled in e.g. agriculture with an acceptable maximum level of pollutants and physical impurities (only allowed in certain EU Member States), often denominated as MBT CLO/digestate or (mixed) MSW CLO/digestate.

Other processes and outputs can include anaerobic digestion (producing biogas and digestate) and the production of refuse-derived fuel.

Table 1: Terms and definitions

Anaerobic digestion (AD)

- Anaerobic digestion, employed in many MBT systems, is a process of controlled decomposition of biodegradable materials under managed conditions, predominantly anaerobic (absence of oxygen) and at temperatures suitable for mesophilic or thermophilic bacteria to produce a mixture of carbon dioxide and methane.
- There are various types of digester, including continuous and discontinuous, wet and dry. The outputs are biogas and digestate (see below).

Biochar (BC)

- A charcoal-like material produced by the thermochemical pyrolysis of biomass materials. when biomass, such as wood, manure, waste or leaves, is heated in a closed container with little or no available air (see Annex 3 for further description).

Biodegradable waste

- Defined in the EU Landfill Directive as "any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and green waste, and paper and paperboard". Sometimes termed biowaste.

Biological treatment

- Different forms of (biological) treatment exist for bio-waste and biodegradable waste, but composting and digestion represent the vast majority of the processes used (see below).

Composting and compost[12 and 15]

- Composting is the aerobic degradation of organic waste to produce compost, solid particulate material which has been sanitized and stabilized by a controlled biological treatment process which is predominantly aerobic and which allow the development of temperatures suitable for thermophilic bacteria as a result of biologically produced heat.
- Composting may occur in an in-vessel composting system (various types) or a windrow. There are various types of windrow system including open and closed, with and without forced aeration.
- It should be noted that mere aerobic storage or maturation of anaerobically digested materials is not

considered to be a composting step.

- Material classified and sold as compost is normally produced from source-separated organic waste but also composted material from MBTs (CLO) is called compost in some countries.
- Many countries have established regulations, standards and guidelines for the classification, content and use of compost, including limits on contaminants and use in horticulture and agriculture
- It should be noted that the function of compost is soil improvement to provide structure and organic material. Although compost contains fertilizing nutrients, and is often controlled under fertiliser regulations, it is not primarily a fertilizer. Also, some materials sold as compost, such as peat, are not compost.
- Compost can provide water-holding capacity, soil aeration, organic matter, soil stability, aggregate, bulk density, erosion prevention, pH balance and cation exchange.

Compost-like outputs (CLO)

- Broadly refers to the organic outputs of processes in mechanical-biological treatment (MBT) plants where intended for restricted land application; where residue is intended for landfill it is called stabilized MBT output, or pre-treated waste, or other terms, not CLO

Digestate

- The output of anaerobic digestion: the semisolid or liquid product that has been sanitized and stabilized by a biological treatment process of which the last step is anaerobic digestion

Mechanical-biological treatment (MBT)[5 and 10]

- A generic term to describe the processing of a mixed MSW waste stream by mechanical sorting and separation of waste into distinct fractions of biodegradable and non-biodegradable materials.
- There are many types and designs and they can be flexible, configured to the waste systems, inputs and required outputs of the user. Plants can be large or small.
- Inputs can be MSW residue (after removal of recyclables), ʽblack binʼ (unsorted) MSW, and source-separated organic waste (direct to biological treatment)
- Mechanical separation can employ various levels of automation. The outputs from the mechanical separation generally include recyclables, residues and an organic fraction. This organic fraction may be treated by several different biological stabilization processes, depending upon the intended end use for the output, and may include anaerobic digestion (AD) or composting (see below).
- Composting of biodegradable material in an MBT plant MBTs can include biological drying where the heat from aerobic decomposition is used to dry the treated waste.
- The final outputs from an MBT can include recyclables, refuse derived fuel (RDF or SRF), renewable energy from AD, CLO (see below) and/or stabilized material for landfill.
- MBT systems can be a modular design which means they can be switched from processing mixed MSW to processing source separated organic waste, which may need to occur if the collection system is changed from a mixed waste collection system to a source segregated collection. Sites processing both mixed/residual MSW and to an increasing extent separately collected biowaste are often known as "double duty" sites. These sites are found diffused across Europe and provide a flexible answer to the need to tackle changes in schemes and of local strategy.

Refuse-derived fuel (RDF)

- The product from processing municipal solid waste to separate the noncombustible from the combustible portion, and preparing the combustible portion into a form that can be effectively fired in an existing or new boiler (see Annex 2 for further description).

4. MBT/CLO: DRIVERS, BENEFITS AND BARRIERS

In the EU (and elsewhere), the drivers and benefits for MBT and, in some cases, the production of CLO have been mainly environmental (Table 2):

Table 2: MBT/CLO drivers and benefits

- Development and application of MBT has been especially driven by countries' needs to comply with the Landfill Directive which has set targets for reducing biodegradable waste to landfill and subsequent release of greenhouse gases and leachate. In northern European countries e.g. Germany, MBT treatment is mainly aimed at biological stabilization of organic material in MSW residue as a pre-treatment before landfill or incineration (organics are mostly source-segregated)[5].
- Besides compliance with the Land Directive, use of CLO for soil improvement has been a driver in southern European countries where arid conditions and soils with poor structure and low organic nutrient content are often common. Spain has been the leading country in MBT/CLO application because of desertification concerns where the benefits of soil improvement have been seen as outweighing the risks from contamination.
- There have been some economic benefits: Saleable biogas and RDF outputs help support MBT/CLO through direct sales and renewable energy credits, and even where the CLO is of low or negative value (e.g. if farmers are paid to take it) landfill disposal costs are avoided.
- MBT supports sustainable development and waste hierarchy principles by helping to optimizing resource recovery.
- MBT is flexible if collection systems and/or material composition changes over time and can be scalable to local circumstances and volumes (plants can be large or small and they can shift easily from miced to source separated waste).

The barriers to use the CLO from MBT have been environmental and health risks, regulatory, quality, economic and marketing issues (Table 3):

Table 3: Barriers to use of CLO from MBT

Environmental and health

- The main barrier to use of CLO in soil improvement is the environmental/health risk from accumulation of heavy metals, plastics and other materials (including persistent organic pollutants) in soils used for food production and potential impacts on the wider environment and human health.
- Some countries permit use of CLO on agricultural land subject to restrictions (see Section 5); others (e.g. UK) prohibit the use of CLO on agricultural land. The long-term health effects of the use of CLO are still subject of research programs.
- Modern MBT plant can reduce contaminants but, from extensive testing, CLO pollutants' levels are generally higher than in compost from source-segregated waste[12].
- Pathogens, posing a health risk, may be present in CLO and treatment must reduce these to safe levels (this risk of course applies to all compost products).
- Composting/digestion processes in MBT plants can produce odours which are a potential nuisance to neighbours, as well as ammonia, dust and other air emissions and wastewater discharges. They need

to be publicly acceptable and located, designed, permitted and operated to minimize impacts.

Regulatory

- Regulations must first permit the use of CLO in specific cases, and the conditions and limits; as noted above, often they do not.
- Regulations must state when a material ceases to be waste if it is marketed and sold as a product, otherwise it remains a waste. CLOs typically are still classified as waste, which restricts their use and market acceptability (the EU has been developing End of Waste Criteria for CLO).

Quality standards[11]

- Quality standards for compost, including sampling and testing, must permit the marketing and sale of a CLO. These do not generally apply e.g. CLO is excluded from PAS 1000, the UK standard for compost.
- The ad hoc and piecemeal standards for applying compost to farmlands make the use of MBT CLO difficult for this purpose.
- Besides the presence of contaminants (sometimes visible), CLO is typically a low-grade soil improver compared to source-separated compost.
- The physical, chemical and biological characteristics of mechanically segregated MSW are variable from plant to plant, with residual Inerts and metal content remaining in the refined compost to differing degrees.

Economics

- CLO has an uncertain market. Marketability is affected by the presence of contaminants.
- CLO is generally a low value material.
- Higher quality CLO requires more complex and costly plants as well as refining.
- Higher quality compost can be produced more economically from source-separated material.
- Sale as a product requires quality control and certification, an additional cost to producers.
- Customers (especially farmers) may be unwilling to pay for a perceived inferior material.
- Advanced MBT plants, with high standards of environmental control are costly. They may be justified by sales of biogas, RDF or landfill/other costs avoided, or soil improvement benefits, but not sales of CLO.

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5. CLO: USE AND STANDARDS IN THE EU

5.1. Use

CLO are treated differently across EU Member States. MBT technology was developed, especially in Germany and Austria, for the primary purpose of stabilization of the biodegradable fraction of MSW as a pre-treatment before landfill. In these and other 'northern' Member States, production and use of CLO on land for soil improvement has little or no role (Table 4). Countries where these conditions apply include Austria, Belgium, Denmark, Luxembourg, Netherlands, Germany and the UK.

In certain other countries, the use of CLO on agricultural land has been permitted subject to controls. Compost-orientated MBT has been practiced on significant scale in France, Spain, Portugal, Poland, and parts of Italy (Table 5).

Table 4: Conditions where CLO has no significant role[5 and 12]

- The majority of Member States report a historical market rejection of the separated organic fraction obtained from MBT for use as compost on (agricultural) land, especially from early MBT plants.
- Biodegradable MSW is often source-segregated for the production of compost in composters or digesters; only MSW residue goes to the MBT for treatment e.g. in the Netherlands, a major compost producer, segregation of fruit and vegetable waste is mandatory.
- The treated solid output from MBTs mainly goes to landfill or is used as landfill cover and restoration (its compact mass is beneficial for this). e.g. the Austrian Ordinance on Composting (2001) includes a set of quality standards for MBT outputs so they can be used in landfill remediation projects or biofilters.
- in these countries, the primary outputs of MBT, besides stabilized material, are biogas and/or RDF, not CLO.
- Because of heavy metal and other contaminants, the application of CLO to agricultural land used for food production is prohibited. Limits under the Sewage Sludge Directive have been generally adopted in the EU.
- Use for brownfield applications may be permitted e.g. restoration of contaminated land, but only under strict and controlled conditions.
- The legal classification of the status of CLO is often unclear, but CLO generally remains a waste and subject to controls as such.
- CLO does not satisfy standards for sale and use as a horticultural compost e.g. in the UK CLO does not qualify for certification under PAS 100.

Table 5: Countries and conditions where CLO has had a role[5 and 12]

- While the general opinion is that composts from source-segregated materials are likely to make higher quality composts, there still remains interest in composting mechanically segregated MSW feedstocks in some countries as part of a MBT process.
- Desertification is a key driver for compost -based solutions in many parts of Spain, such that the government has adopted a national Action Plan under the UN Convention to Combat Desertification (UN-CCD). As a result, the use of material derived from mixed, i.e. non -source - separated, wastes on agricultural land receives far greater acceptance than in other Member States. Spain is by far the biggest user of CLO with a treatment capacity of over 3 million tonnes per annum
- In Portugal, low-end 'compost' from mixed MSW was permitted for use in agriculture only until 2008 but now may only be used for re-cultivation purposes.
- In Italy, MSW is mainly source segregated for composting but in some regions financial incentives are given to farmers to use mixed-waste derived compost on land e.g. in vineyards.
- In France, there are 70 plants processing over 2 million tonnes per annum of MSW with CLO outputs used on land.
- Outside of the EU, in Turkey one MBT plant located in Istanbul and with a capacity of 150,000 Tpa uses the produced CLO as a soil improver[11].

5.2 Standards

Content and limits

There are currently no EU-wide standards for the assessment of CLO[12]. National regulatory frameworks for CLO use and associated product standards, generally statutory (voluntary for the UK and Sweden), are highly variable. Some of these standards are taken directly from existing regimes, especially for sewage sludge, while others have been derived for use with general composts. Very few have been derived specifically for CLO. Generally, the standards always include limits for physical contaminants, microbial pathogens and metals.

The standards can differ quite significantly from one country to another. While the seven most common metals are typically covered by the standards, the limit values vary and some countries apply limit values for additional substances. For example, Denmark, Germany and Sweden have limit values for dioxins, Polychlorinated biphenyls (PCBs), Polycyclic aromatic hydrocarbons (PAHs) and other substances. Few, if any, national limits or standards for composts contain values for many organic micro-pollutants. This situation is especially relevant for CLO, as with sewage sludge, in that recent evidence suggests that little effort has been invested in assessing risks from xenobiotic organic compounds, such as pharmaceuticals, fragrances, surfactants, and ingredients in household cleaning products, likely to be found in waste streams destined for land[5].

Most countries differentiate between two compost classes, but a few such as Austria and the Netherlands apply three standards. Very few standards consider non-source-segregated MSW outputs. The classes of compost/digestate from source-separated materials are generally considered suitable for use on land growing food crops. However, CLO or stabilized biowaste is generally considered unsuitable for use on pasture or food crops, but suitable for daily and final landfill cover, improvement of contaminated land, landscape restoration, forestry, road construction, golf courses, ski slopes, football pitches etc.

Table 6 provides a summary of the metal concentration limits set by various countries for different classes of compost outputs

Table 6 Metal concentration limits for compost classes in EU countries[5].

	Metal concentration limits (mg kg^{-1} dry matter)								
	Cd	**Cr (total)**	**Cr(VI)**	**Cu**	**Hg**	**Ni**	**Pb**	**Zn**	**As**
Austria (Class A)	1	70	-	150	0.7	60	120	500	-
Austria (Class B)	3	250	-	500	3	100	200	1800	-
Belgium	1.5	70	-	90	1	20	120	300	-
Denmark+	0.4	-	-	1000	0.8	30	120	4000	25
France (NF U44-051)	3	120	-	300	2	60	180	600	18
Germany (Class II)	1.5	70	-	100	1	50	150	400	-
Greece				500		200	500	2000	
Italy (Class I)	1.5	-	0.5	150	1.5	50	140	500	-
Italy (Class II)	10	500	10	600	10	200	500	2500	10
Netherlands	1	50	-	60	0.3	20	100	200	15
Spain (Class A)	0.7	70		70	0.4	25	45	200	
Spain (Class B)	22	250		300	1.5	90	150	500	
Spain (Class C)	3	300	-	400	2.5	100	200	1000	-
UK (PAS 100)	1.5	100	-	200	1	50	200	400	-
Organic farming+	0.7	70	-	70	0.4	60	120	500	-

+ Metal limits not regulated for green waste

Standards for compost relate to application rates as well as content e.g. based on restriction in sewage sludge use, a general requirement is that stabilized biowaste materials should not be used on the same area within a 10-year period and that applications should not exceed 200 tonnes of dry matter per hectare.

It should be noted that most regulations in this area are precautionary since the long-term effects on the environment and health of contaminants in compost and applying CLO to land are unknown.

Waste or product

There is similarly no consistency on when a material ceases to be a waste. In general CLO remains classified as a waste and subject to permitting in its use. Labelling a material as waste, and even if safe, as a material sourced from waste, is affecting its marketability and sale, as well as the willingness of potential users to use it.

A material is considered a product if complying with the corresponding national standards as it is the case in Spain and Austria. However, in Austria there are tight restrictions on use (e.g. it cannot be used on soil for feed or feed production). In several countries, including Italy and France, this type of compost may be used on soil as waste requiring special permits[11].

6. CLO: POTENTIAL USE IN LEBANON

6.1. Existing and planned MBTs and production of CLO

MBT plants have become an important part of MSW management in Lebanon, financed by the Lebanese Government and a variety of donors. Most of those installed are small sorting and composting plants but some have been larger. A number have had several operational and environmental problems, somehow typical for developing countries that adopt MBT technologies. However, despite the problems involved, MBTs in Lebanon are the central pillar of current waste management system and they:

Divert significant amounts of waste from dumpsites and landfills

Recover recyclables

Pre-treat and stabilize organic fraction, mitigating its environmental impacts

However, the quality of CLO outputs has been poor and the material is stockpiled, dumped or The quantity of the existing CLO outputs is uncertain, however it is clear that if CLO production continues to be pursued, the quantities of CLO produced will increase commensurately. This is not a sustainable situation given the existing problems in producing and using CLO.

Alternative configurations to reducing the production of CLO and improve the production of useful outputs from MBT are considered in Section 7. Specifically, these are source-segregation of organic waste to produce better quality compost, the production of RDF and potential production of biochar.

Under these configurations, the production of CLO is limited to the treatment of residues and quantities needing disposal greatly reduced.

It should be noted that a further limitation to the quality and use of CLO from existing MBT is the widespread mixing of special waste with MSW (exhausted ois, WEEE tires, etc) resulting in even higher levels of contaminants in outputs than from household waste alone. The Master Plans propose the collection and diversion of these special waste from the municipal waste stream.

6.2. The Compost Ordinance

The Lebanon Government has developed an Ordinance for compost: *Ordinance on the quality assurance and utilization of compost in agriculture, horticulture and landscaping* (Compost Ordinance)[3]. The main objective of this ordinance is to create a legal framework for the production and utilization of compost and to improve the long-term recycling quota of organic material from waste.

In the context of CLO, the Compost Ordinance regulates the application of treated and untreated bio-wastes and mixtures on land used in agriculture, horticulture, viticulture or forestry; also the use of low quality compost in landscaping and in landfill operation. It covers suitable raw materials, quality and hygiene requirements, and treatment and investigation of bio-wastes and mixtures. It regulates from a precautionary perspective, in particular the presence of heavy metals in application.

The Compost Ordinance defines four different types of compost by quality criteria presented in Table 8. These range from Grade A compost, being a high-quality compost and most appropriate for any agricultural utilization, to Grade D compost which must only be used on controlled landfills as intermediate cover or as landscaping material. The product of a composting process which does not correspond to the specifications of Grade D compost cannot be considered as an organic recycling-product and must be categorized as waste.

Table 8: Lebanon Compost Ordinance: Definition of compost types (overview)[3]

Type of compost	Characteristics	Main Fields of Utilization
Grade A	Main characteristics are: • Native organic raw material, generated by source-separation; • Mature compost (maturation degree V); hygienised, biologically stable; • Corresponds to European Eco-label for composts	Food production in • Agriculture • Horticulture • Viticulture
Grade B	Main characteristics are: • Organic raw material, generated by mechanical treatment of household waste; • Mature compost (maturation grade IV or V); • hygienised, biologically stable; • Corresponds to European Eco-label for composts;	Food production in • Agriculture • Horticulture • Viticulture
Grade C	Main characteristics are: • Organic raw material, generated by mechanical treatment of household waste or appropriate waste from industrial sources (e.g. residues from the food and animal feed industry • Semi-mature compost (maturation grade III); hygienised material, • Limits given for heavy metals correspond to doubled values of European Eco-label for composts;	Utilized only if any risks to humans and any contamination of food or agricultural soil can be excluded; e.g. in • Landscaping • Recultivation of abandoned quarries • Soil for green space along traffic roads
Grade D	Main characteristics are: • Organic raw material, generated by mechanical treatment of household waste or appropriate waste from industrial sources (e.g. residues from the food and	Only to be used as re-cultivation material on controlled landfills and as intermediate layer of deposited waste. No to be utilized as top layer of re-

	animal feed industry) after appropriate treatment • Immature compost (maturation grade II); hygienised material, • Limits given for heavy metals correspond to fivefold values of European Eco-label for composts;	cultivated landfill sites in order to prevent contamination of humans, fauna and flora as well as spreading of pollutants.

The Ordinance contains other tables relating to compost specifications and quality. However, no quality assurance and certification scheme has been established, including processes and facilities for testing and control of use.

6.3. Potential uses

The potential future use of any CLO in any particular situation will depend on its quality and conformance to the requirements of the Compost Ordinance; also on compliance with any other relevant regulations for application in any specific situation and location. These may include regulations for soil and water protection, agriculture, food safety, human health and others as applicable. All use should be subject to risk assessment and, if Class D, permitting and monitoring.

The general potential for use will depend on demand. Some demand is continuous, e.g. daily landfill cover, but most use of CLO is likely to be one-off or infrequent in order to avoid accumulation of contaminants e.g. in restoring contaminated or degraded land, where use is subject to similar restrictions as sewage sludge. Use for landscaping in construction projects is similarly one-off for a particular project. In such cases, there could be continuing demand from agricultural or construction agencies or companies who could afford testing and other controls.

The potential for use would also depend on supply and the ability of MBT plants to meet demand if the material was wanted. Any larger quantities required might be met by larger plants, but probably not smaller plants unless materials were consolidated at CLO stockpiles.

It is likely that in most cases the quality of CLO from mixed MSW inputs or MBT residue will preclude use in agriculture because of the environmental and health risks - also the economic risks to producers from food contamination. Use would be restricted to non-agricultural application and subject to controls to minimise risks.

Potential uses in Lebanon are listed in Table 9. Suitability for any use would depend on more detailed evaluation of the potential demand in relation to supply and the costs, benefits and risks, transport and operational logistics and user acceptability. Given the low value of the material it may be that users would not want to pay for it and might even want a financial incentive.

The economic benefits will include avoiding landfill costs as well as benefits from land improvement. Where use of CLO displaced imported compost and fertilizer there would be an additional economic benefit.

The most promising use would be in forest restoration, already operating as a funded assistance project and needing compost and fertilizer.

Table 9: CLO: Potential uses in Lebanon

- Forestry
- Improvement of soil structure and water retention in arid areas where there is no food production.
- Daily and final landfill capping.
- Remediation of contaminated land.
- Landscaping and verges in road building and other civil engineering works
- Non-food agricultural land e.g. energy, textile -related crops.
- Quarry restoration

6.4. Development of regulations, market and institutional conditions for use

The potential use will depend on the development and implementation of regulations and standards, market, institutional and other changes for the use of CLO.

If sold as a product this would need to be defined in regulations and the material subject to quality assurance testing. If it remains a waste it will need to subject to permitting and control.

If, as is more likely, CLO use is restricted to non-agricultural use, and is of little or no sales value, then appropriate financial incentives and institutional arrangements will be necessary. This will require negotiation with potential interested parties in the forestry, construction and non-food agricultural sectors.

Of particular importance will be the establishment of independent quality assurance, including in situ and laboratory testing as well as monitoring to ensure safe use and a market for the product. This requirement also applies to the production and sale of compost from source-segregation of organic MSW, proposed as a much better option compared to treatment of mixed MSW in MBT and subsequent recovery of all organics as CLO.

7. ALTERNATIVE MBT CONFIGURATIONS AND OUTPUTS

7.1. Strategies for managing biowaste

According to best practices for managing biodegradable waste (biowaste) from MSW, and proposals within the Master Plans, the management objectives should be

- No MSW waste is landfilled without prior treatment: Treatment before landfilling should become mandatory for all the waste that is not recovered (formally and informally).
- Organic waste and recyclables are source-segregated wherever possible so that treatment plant only process residue.
- Waste treatment plants should deliver useful and valuable products wherever possible to maximize their benefits.
- Where feasible and economic, treatment plants should focus on the production of good quality RDF capable of use as a fuel substitute.
- The remaining residue should be used where possible (e.g. 50% w/w) for the production of CLO of acceptable quality for use in non-food land application.

The production and use of RDF is well-established and successful internationally. It is further considered in Section 7.2 and Annex 2. Anaerobic digestion is another option for the treatment of some organic wastes, producing biogas and digestate. While smaller plants are an option for specialized wastes, they are costly and have other limitations for large scale application to MSW.

Emerging technologies should also be considered. The most promising is the use of pyrolysis to produce biochar (Section 7.3 and Annex 3)

7.2. RDF

Refuse-derived fuel (RDF) is the product of processing municipal solid waste to separate the noncombustible from the combustible portion, and preparing the combustible portion into a form that can be effectively fired in an existing or new boiler. Options for using RDF may be:

- Use as an additional source of energy in a cement kiln (the most common use) or other industrial process.
- Combustion to generate energy in a waste-to-energy plant.

- A dedicated RDF incinerator near to a power plants receiving the high calorific fraction from all the MBT plants and utilizing them to produce electricity.

The benefits include the production of electricity and displacing the equivalent quantities and costs of imported fossil fuel (Annex 2.2).

Production and sale of RDF depends on the production meeting specifications and optimizing processes to achieve these (see Annex 2). Biodrying is an important process for reducing water content (see Annex 2). Production and use especially depends on finding or generating markets at a suitable price.

In principle cement plants in Lebanon have expressed a willingness to use RDF under the following conditions:

- RDF will be available with a certain stable quality (minimum calorific value of at least 4,500 Kcal/kg, less than 1% Cl and less than 1% sulphur) and in guaranteed quantities. This requires identifying proper outlets and deliver an RDF according the required specifications. A suitable national policy framework should be developed to support further standardization of the RDF and boost its energy utilization.
- RDF transport will be arranged in accordance with the detailed plan of logistics and the transportation cost.
- The investments required to re-configure the cement plants' fuel reception should be a shared cost.
- According the first round of discussions that was completed with the cement plans, the cement plants can absorb something between 200-230,000 tons of RDF per year.

Such arrangements require a regulatory update by the MoE and a proper licensing process that will stimulate the use of RDF under certain terms and conditions and will support the creation of a national RDF market.

7.3. Biochar

Biochar (BC) is a charcoal-like material produced by the pyrolysis of biomass materials. when biomass, is heated in a closed container with little or no available air.

It differs from charcoal by the fact that biochar is produced with the intent to be applied to soil as a means of improving soil productivity, carbon (C) storage, or filtration of percolating soil water.

Besides its proven soil improvement and soil treatment properties there has been high international interest in biochar as a potentially significant means of storing carbon for long periods to mitigate greenhouse gases. Time limits for the sequestration of carbon in BC extend to 1000years. Therefore, biochar can be considered a tool to inhibit global warming.

The many benefits of biochar are set out in Annex 3.

Production of biochar is also an option for the treatment of MSW in producing beneficial outputs. Further, compared to combustion, production of CLO and landfilling, emissions of toxic substances is much reduced since pyrolysis can treat persistent organic pollutants such as dioxins

Conversely, lack of consumer awareness and higher cost of biochar as opposed to chemical alternatives are a few challenges faced by the global biochar market.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

Based on this review, it is concluded that the use of CLO from MBT in Lebanon is a serious challenge that should be addressed:

- There are several MBT plants and the volumes of CLO produced are high enough to require a specific policy to address its use. As currently MBT is the only treatment method in Lebanon, addressing the use of CLO is a major requirement to maximize the MBT benefits and minimize the residual stream.
- Because of the environmental and health risks, the currently produced CLO is unsuitable for sale as a product and use in agriculture for food production. The current mixing of special waste with municipal waste makes it even more unsuitable.
- However, its potential use as a low value soil improver in forestry, landscaping or brownfield land restoration should be examined in detail and, if successful, it will provide a substantial improvement to the current waste treatment operations.

8.2. Recommendations

The following recommendations are made:

- Preference should be given to source-separation of organic MSW, as well as recyclables wherever possible.
- CLO or stabilized outputs from MBT should be used where possible for soil improvement for restricted purposes as permitted. A relevant detailed is study is required to identify and map out potential uses, prioritize them and propose the terms and conditions required for its different use.
- MBT should focus more on the production of high quality RDF that involves the organic fraction, as a measure to reduce the quantities of CLO produced and make easier their management.
- Appropriate regulatory and institutional, including financial arrangements should be established depending on selected applications e.g. on forest restoration.
- Other processes and products from MBT should be considered including biodrying and biochar.

ANNEX 1: REFERENCES

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ANNEX 2: REFUSE DERIVED FUEL AND BIODRYING

A2.1. Refuse derived fuel

Refuse-derived fuel (RDF) is the product of processing municipal solid waste to separate the noncombustible from the combustible portion, and preparing the combustible portion into a form that can be effectively fired in an existing or new boiler. RDF may be combusted to generate energy in a waste-to-energy plant or as an additional source of energy in a cement kiln (the most common use) or other industrial process. Currently available data indicate that approximately 13.5 Mt of RDF are used in the EU, 12 Mt of which are used in cement plants and dedicated WtE plants and 1.5 Mt in other applications.

A2.2 Benefits and risks

In the EU, more than 5,000 million m3 of Russian gas per year is replaced with RDF. Besides energy production a major benefit is reducing waste to landfill and associated greenhouse gas emissions, leachate leakage and other environmental impacts.

To asses a potential price, 1.5-1.8 tons of RDF can substitute 1 ton of coal – the exact equivalent depends on the RDF specifications and the potential price on the long-term price of coal. However, currently in the EU there few long-term contracts with cement plants, either in low prices or with the arrangement that cement plants cover the transportation cost plus the investments required to utilize RDF. The reasons for that are the following:

- There is overcapacity in the EU RDF markets, in several countries it is already produced more RDF that the local market can absorb.
- For the waste management authorities, even when they give the RDF for free to the cement plants, this means that they save the transport to WtE or landfill and the relevant gate fees (which sometimes can be up to 100 $/ton, including landfill tax).

A2.3. Unit operations

The choice of unit operations and the sequence in which these are used in a plant determine the yield and the quality of the RDF product (Table A1).

Table A1: Unit Operations for RDF production

Unit operation	Purpose of operation	Change of characteristics
Biodrying, Physical drying	Reduction of the water content	Stop of degradation processes, better storage properties, increase of net calorific value (NCV)
Screening	Removal of a fine fraction Removal of a coarse fraction	Increase of net calorific value (NCV), reduction of the heavy metal content
Magnetic separation Eddy current separation	Removal of ferrous metals Removal of nonferrous metals	Recovery of a recyclable fraction, removal of inert materials, removal of metallic aluminum as an oxidative substance
Ballistic separation	Removal of a heavy fraction	Increase of net calorific value (NCV), removal of heavy metals
Air classification	Separation of plastic films	Recovery of high caloric fraction (> 18 MJ/kg), reduction of the ash content
Aeroherds	Removal of mineral and inert	Increase of net calorific value (NCV),

	fractions	reduction of the ash content
Automatic picking with NIR identification	Removal of PVC (negative sorting) Removal of PVC-free fuel (positive sorting)	Decrease of the organic chlorine content
Size reduction, palletizing	Liberation of composite material Achieving required dimension and other mechanical characteristics	Change of grain size, bulk density, thermal and mechanical stability

A2.2 Biodrying

Biodrying and conventional RDF production method are different processes as follows:

- Conventional RDF is based on separation which seeks to split the waste into 'biodegradable' (that may be composted and afterwards landfilled) and 'high calorific' fractions.
- RDF with biodrying is based on dry stabilization which is less concerned with the splitting into fractions, and more focuses on the use of heat from a 'composting' process to dry the waste (biodrying) and increase its calorific value, thereby making it suitable for use as a fuel as well as facilitating the separation of fractions. As alternative to the biodrying, drying with natural gas, landfill gas or biogas can be used (physical drying).
- In both cases, there are some common objectives e.g.
- Removal of water and inert components to improve calorific value.
- Removal of chlorine, aluminum and zinc to avoid corrosion and other fuel-related technical difficulties in furnace and boiler.
- Reduction of volatile substances that have a negative environmental impact when combusted
- Reduction of substances that have a negative impact on the quality of byproducts such as ashes and gypsum from flue gas desulfurization

Figure A1 illustrates the differences between the two methods.

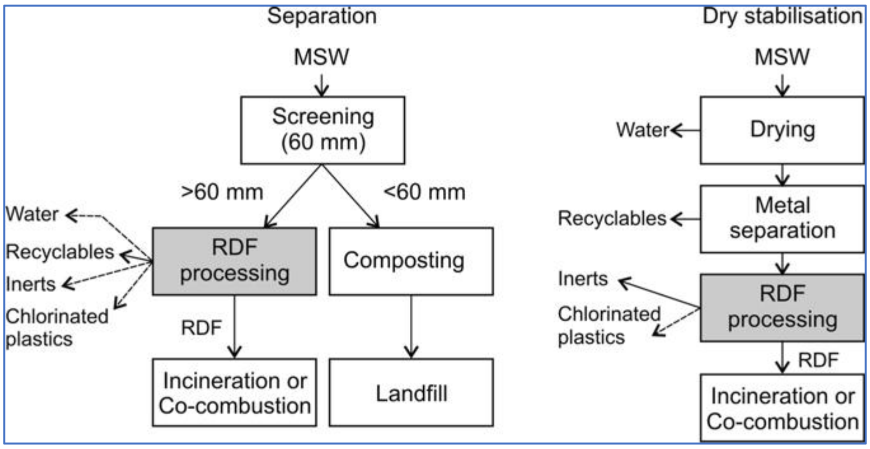


Figure A1: Two ways to produce secondary fuel from waste

RDF production with biodrying and Mechanical Separation of inert and non-combustible waste streams results in a fuel that includes plastics, papers, leather, wood and other combustible parts of the waste streams plus the dried organic fraction.

Hand and automatic picking combined with near-infrared (NIR) spectroscopy detection is often applied for the selective removal of polyvinylchloride (PVC). NIR spectroscopy can also be used in RDF processing for selectively sorting out suitable fuel components such as paper, plastics (polyethylene, polypropylene, polystyrene), wood and textiles. The final configuration for RDF production through biodrying depends on the end-user fuel specifications and requirements.

A2.4 Specifications and standards

Fuel standardization is an important part of developing a market for RDF and aims at[1]:

- Describing the fuels.
- Establishing a common language.
- Distinguishing between different fuels.
- Helping to develop the RDF markets

To meet these aims, a series of standards have been issued so far by CEN/TC343, a technical body working on secondary fuel standards publishing several technical documents so far, comprising five working groups, each of which is working on different issues of standardization (terminology and quality assurance, fuel specifications and classes, sampling and supplementary test methods, physical/mechanical tests and chemical tests).

However, standardization in isolation cannot guarantee increased market share of secondary fuels, since their marketability depends largely on their quality and the existing outlets. Therefore, the implementation of a comprehensive Quality Management System (QMS), including appropriate QA/QC procedures, especially in the light of the wider technical, financial, policy and legal challenges involved, is imperative, especially in the light of the wider technical, financial, policy and legal challenges involved.
RDF outcome specifications, based on the EU standards, are as follows:

- Lower Heating Value: 14-15 MJ/kg
- Chlorine content: Less than 1% w/w (dry)
- Mercury: Only classes 1 and 2 as described at CEN TC/343
- Moisture: Less than 15% w/w

ANNEX 3: BIOCHAR

A3.1 Definition

Biochar (BC) is a charcoal-like material produced by the thermochemical pyrolysis of biomass materials. when biomass, such as wood, manure, waste or leaves, is heated in a closed container with little or no available air. In more technical terms, biochar is produced by so-called thermal decomposition of organic material under limited supply of oxygen (O_2), and at relatively low temperatures (<700°C). This process often mirrors the production of charcoal However, it distinguishes itself from charcoal by the fact that biochar is produced with the intent to be applied to soil as a means of improving soil productivity, carbon (C) storage, or filtration of percolating soil water.

"Char" means any carbonaceous solid material processed under thermal decomposition without or under starved O_2 conditions.

A3.2 Uses and benefits

Uses and benefits of biochar include:

- In soil improvement for improved productivity as well as reduced pollution; include reduction of nitrate leaching, adsorption of contaminants, such as arsenic and copper from soils and reduction of trace-gas emissions from soils (nitrous oxide and methane
- As potentially significant means of storing carbon for long periods to mitigate greenhouse gases. Time limits for the sequestration of carbon in BC extend to 1000years; Therefore, it can be considered a tool to inhibit global warming.
- Use of the organic fraction from MSW for transformation into BC has double benefits: namely, the reduction of emissions from landfills and reduction of the waste mass.
- Compared to combustion and gasification of MSW, emission of toxic substances from pyrolysis is minor . It has been reported that the pyrolysis of MSW can control and limit the emission of polychlorinated dibenzo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCD), and polychlorinated biphenyl (PCB).
- Potential benefits for bioenergy production (e.g., syngas, bio-oil and heat), Biochar is also useful to the waste-processing industry in allowing the recovery of waste as a potentially useful by-product.
- A closed sustainable system of energy with a variable material flow and variable output according to the process cycle ensures the desirable cost-effectiveness.
- As an adsorbent: chemically activated BC may provide an efficient, simple, and low-cost approach to removing environmental contaminants from land. As an adsorbent: chemically activated BC may provide an efficient, simple, and low-cost approach to removing environmental contaminants from land.
- The use of BC as a landfill cover has many different aspects, such as LFG control, leachate and contaminant control, plant growth enhancement, soil ecology improvement, and soil property alteration

Conversely, lack of consumer awareness and higher cost as opposed to chemical alternatives are a few challenges faced by the global biochar market.

A3.3 Production from MSW

The technological aspects of BC preparation involve three major steps: feedstock selection, preparation of the feedstock, and selection of the thermal pathway and reactor. The first step, the energy requirement, is a factor to be considered for BC production. Regulation of the feedstock moisture content is considered an important parameter. Food and organic waste has a high moisture content so that additional vaporization takes place during decomposition.

The complex behavior and composition of MSW contribute to a more diversified array for the desired output.
Lignocellulose and moisture content are the main factors to consider when producing biochar using MSW. Research have been carried out to study the parent material composition and ash content during pyrolysis of MSW. Proximate and ultimate analysis of different types of MSW has shown high variation in results from different studies. Therefore, for the MSW-BC derivation process, more feedstock properties should be studied than for other BC derivation processes.

The characteristics of the MSW-BC product depend on the thermal pathway and the MSW feedstock composition. The slow pyrolysis process for MSW-BC derivation can be considered sound compared with other methods, and this process has been reported on by several MSW-BC studies. The fibrous fraction of the MSW contributes more sorbent properties to the MSW-BC product with minimized environmental drawbacks.

Concerning the slow pyrolysis process, constituents of three different fiber materials (lignin, cellulose, and hemicellulose) contained within the fibrous fraction and their elongated phase-by-phase degradation pattern are distinguished by several thermogravimetric studies. The superimposed degradation patterns were also observed via different MSW-BC studies. Therefore, the characteristics of MSW-BC can be compared with those of BC, which has an elemental composition near that of lignin.

As noted above, biochars prepared from MSW can greatly benefit the carbon content of soil. Additionally, biochar may interact with fertilizers to deliver indirect improvements in plant growth and reduce the emission of greenhouse gases from native organic matter. Biochars can also be custom-designed to increase/decrease native soil pH to bring it closer to the op mum range for microbial and plant growth. These applications give solid organic municipal wastes promising potential as precursors for value- added biochars with varied physicochemical characteristics allowing them to be used not only as an alternative to bio-waste management and greenhouse gas mitigation but also as means to improve depleted soil.

Annex 5: Site selection criteria and process

Identification of the suitability of potential landfill sites, and modifications to existing facilities, requires a comprehensive assessment of site conditions and potential impacts on the environment. This includes consideration of topography, surface water, drainage, hydrogeology (groundwater), geology, climate (including air quality and odour modelling) and flora and fauna, access and distance from the community the landfill will service.

The following landfill site selection criteria detail the key issues that need to be considered when identifying potential landfill sites and planning site investigations and assessing the suitability of a site for landfilling.

It is unlikely that the majority of sites will meet all necessary criteria, in which case the assessment of the suitability of a site for a landfill needs to consider and appropriately manage and justify the selection of a site that does not meet all the necessary criteria. Consideration needs to be given to the:

- Comparison of site characteristics with alternative locations;
- Potential for engineered systems to overcome site deficiencies;
- Methods of operation proposed for the site; and
- Social and cultural issues associated with the site.

In order to minimise future risk to the environment from landfill activities, primary consideration should be given to key issues and potential fatal flaws with respect to geology, hydrogeology, surface hydrology and site stability.

1. Geology

Suitable geology is important to ensure containment of leachate in the long term, or in the event of engineered containment systems failing. Geology should be assessed with regards to the movement of leachate and landfill gas.

Engineered liner systems have a finite lifetime, the ability of the underlying strata to minimise the potential for liquids to migrate out of the landfill into the environment should the liner either degrade, tear, or crack needs careful consideration. Due to risk of off-site movement of leachate and landfill gas, landfills (in principle and if alternatives exist) should not be sited in areas with the following characteristics:

- High permeability soils, sands, gravels, or substrata;
- High permeability seams or faults; and/or
- Karst geology — regions with highly soluble rocks, sinks and caverns.

An assessment of geology and site soils should consider:

- The availability of on-site materials for lining, cover and capping. Soils with a high percentage of clay particles are generally the preferred soil type;
- The suitability of on-site materials for the construction of dams and drainage systems;
- Potential sediment management problems, with highly erodible soils;
- Existing site contamination and discharges, if present;
- Suitability for on-site disposal of leachate by surface or subsurface irrigation; and
- The potential effects of failure of leachate containment and collection systems.

Geological factors also influence stormwater, silt and groundwater controls, the containment and control of leachate and gas, as well as the availability of final cover materials.

2. Site Stability

Site stability should be considered from both short and long-term perspectives, including the effects of settlement. Landfills, in principle, should not be sited in the following areas:

- Areas subject to instability, except where the instability is of a shallow or surface nature that can be overcome, in perpetuity, by engineering works;
- Areas susceptible to ground movements that may adversely impact on the integrity of the landfill and engineered systems such as liners, leachate collection and final cover;
- Within 1km of a major tertiary (first order) fault line that presents risk of seismic activity (e.g. fault lines displaced in the Holocene period);
- Areas of geothermal activity; and/or
- Karst terrain — regions with highly soluble rocks, sinks and caverns.

In assessing the suitability of a site for a landfill the local soils need to be considered with respect to the following:

- Localised subsidence areas. Differential movement could render a landfill unusable due to rupture of liners, leachate drains or other structures.
- Landslide prone areas. The future weight could, through a wide variety of mass movement, destabilise the landfill. Instability may also be triggered by earthquakes, rain and seepage.
- Local/onsite soil conditions that may result in significant differential settlement, for example compressible (peat) or expansive soil, or sensitive clays or silts.

3. Hydrogeology

A suitable hydrogeological location is important to protect groundwater resources and understand the likely fate and rate of discharge of contaminants which may enter groundwater. Landfills, in principle, must not be located in the following areas:

- areas overlying drinking water aquifers; and/or
- areas where, after taking into account specific design proposals, there could be a risk of causing unacceptable deterioration of the groundwater quality in the locality.

All new landfills require a hydrogeological assessment. Existing landfills will require a hydrogeological assessment if the facility has no current monitoring program or the current monitoring program is not adequate to determine whether the landfill is having an impact on the environment. The purpose of a hydrogeological assessment is to determine the relationship between the landfill and surrounding hydrogeology in order to ascertain the potential risk the landfill facility will have on the environment. In assessing the suitability of a site for a landfill with respect to hydrogeology, the following need to be considered:

- Depth to water table and seasonal water table fluctuations;
- Location of aquifer recharge areas, seeps or springs;

- Distance to water users;
- Sensitivity of water users;
- Dispersion characteristics of aquifers;
- Variations in groundwater levels;
- Rate and direction of groundwater flow;
- Existence of groundwater divides;
- Baseline water quality; and
- The potential effects of failure of leachate containment and collection systems.

A hydrogeologiocal assessment report should be prepared by a suitably qualified and experienced person. This report should contain plans, specifications, and descriptions of the hydro-geologic conditions of the site, adjacent and nearby properties, and the regional area in which the site is located, including at a minimum, the following:

- A general description of the regional geologic and hydro-geologic conditions occurring within 5 km of the site. This description should identify any unstable soils or bedrock, indicate the location and nature of any boundaries to groundwater movement, and characterize the significance of groundwater resources and the use made of these resources;
- A description of local hydro-geologic conditions occurring at the site, adjacent to the site and other properties within 500 m of the site. The description shall indicate how local conditions relate to regional conditions;
- A detailed hydro-geologic investigation of the site which establishes soil, rock, and groundwater conditions;
- An interpretation of the results of the detailed hydro-geologic investigation of the site, including plans, specifications, and descriptions;
- An assessment of the suitability of the site for waste disposal purposes considering the regional, local, and site specific hydro-geologic conditions, the design of the site, and the contingency plans for the control of leachate and landfill gas;
- A conceptual model of the hydrogeological setting of the landfill and its surrounds. The model will indicate the risk that the landfill and its associated operations may pose to the groundwater.

A regular groundwater monitoring program for the site should be developed in line with the conceptual model. The recommended minimum separation distances from the base of the landfill to the groundwater level is 2 meters for a lined facility. This separation distance is to be measured from the underside of the landfill liner to the highest seasonal groundwater level. Separation distances to the water table for unlined sites will be assessed on a case by case basis and will generally be greater than 2 meters.

4. Hydrology

The pollution of surface water by leachate is one of the principal concerns in relation to landfill location. If landfills are located in close proximity to waterways there is an increased risk of water pollution. The potential impact of water pollution is greater in waterways that are used for drinking water or aquaculture.

It is generally undesirable to site a landfill in the following areas:

- Flood plains — these are generally areas which could be affected by a major (1 in 100 year) flood event;
- Land that is designated as a water supply catchment or reserves for public water supply;
  Areas with significant water ingress, except where this can be controlled by engineering works without risk to the integrity of the landfill;
  Water courses and locations requiring culverts through the site and beneath the landfill; or
- Estuaries, marshes and wetlands.

When assessing the suitability of a site for a landfill, the local surface hydrology needs to be considered in regards to the sensitivity of the receiving environment, including the following:

- The proximity of water bodies or wetlands;
- The risks of pollution of water bodies used for drinking water or aquaculture;
- Sensitive aquatic ecosystems; and
- Potential for impact from cyclones and tsunamis.

An assessment of the stormwater catchment above the site should be made to identify the extent of any drainage diversion requirements that may need to be addressed.

An assessment report of the local hydrology needs to be undertaken prior to the establishment or expansion of a landfill site. The report should contain plans, specifications, and descriptions of the surface water conditions of the site, adjacent and nearby properties, and the regional area in which the site is located, including, at a minimum:

- A general description of the surface water features occurring within 5 km of the site that is based on the contributing/receiving drainage area, catchment, sub-watershed or watershed that is sufficiently large to assess the range and extent of potential effects.
- A description of the local surface water features occurring at the site, and adjacent and other properties within 500 m of the site, and the description should include how local features relate to regional features;
- A detailed surface water investigation of the site to assess water quality, quantity, and habitat conditions of the surface water features identified on site;
- An assessment of the suitability of the site for waste disposal purposes considering the regional, local, and site specific surface water conditions, the design of the site, and the contingency plan for the control of leachate.

Landfills should be sited and designed to prevent surface water from contacting waste. This should be achieved by siting landfills so that they will not be inundated by either natural or artificial water courses or water bodies.

5. Topography

Careful consideration needs to be given to the landforms in the vicinity of the disposal site as they may influence:

- The type of disposal method that can be utilised;
- The suitability of the site for construction of service facilities; o Surface water drainage management;
- Groundwater conditions;
- Soil erosion risk;
- Access to the site;
- Ability to screen the site from view; and
- The impact of winds on the site.

Ideally the slope of the site should not be greater than 15% (1 vertical to 7 horizontal), particularly where the trench method of disposal is used. Modest slopes enable easier stormwater control, leachate control and site stability measures, as well as facilitating the operation of the site. When considering potential landfill sites an assessment of the potential for existing topographical features to assist in minimising impacts should be made.

6. Flora and fauna

The development of landfills may impact on the flora and fauna of the local area. The potential impacts on flora and fauna are:

- Clearing of vegetation;
- Loss of habitat and displacement of fauna;
- Loss of biodiversity by impacts on rare or endangered flora and fauna;
- Potential for spreading plant diseases and noxious weeds;
- Litter from the landfill detrimentally impacting on flora and fauna;
- Contamination of sensitive ecosystems, such as wetlands, by leachate;
- Creation of new habitats for scavenger and predatory species;
- Erosion; and
- Alteration of water courses

A survey of the site and collection of comprehensive baseline environmental data are essential steps in the assessment of potential impacts from proposed landfilling operations. The nature and extent of this data should be site-specific, taking into account the size of the proposed operation and the risks posed to adjacent sensitive areas. This includes potential impacts from scavenger birds on aircraft safety and water supplies, as well as impacts from predatory animals, such as feral cats, on surrounding native fauna. Sites that contain protected or endangered fauna and/or flora, or sensitive ecosystems are unsuitable for landfill facilities.

An assessment of the local flora and fauna needs to be undertaken prior to the establishment or expansion of a site. An assessment report is to be prepared by a suitably qualified and experienced person. This report should contain maps, specifications, and descriptions of the flora and fauna of the site, adjacent and nearby properties, and the regional area in which the site is located.

7. Climate

Consideration should be given to the local climatic conditions when siting a waste disposal facility. Heavy rainfall situations can cause severe erosion and stormwater drainage issues if landfills are not sited and designed in an appropriate manner. Hot, dry windy conditions can cause dust and windblown waste issues.

8. Environmental Sensitive Areas

Landfills are not to be located in areas of high environmental value, or in areas subject to considerable environmental constraints and high environmental risks (see next table). Such areas should be excluded from further consideration. Next table provides and indicative but not exhaustive list regarding the environmental sensitive areas, not including local legislation issues.

Table 1: Indicative list of environmentally sensitive areas

A site within 250 metres of an area of significant environmental or conservation value identified under relevant legislation including: o national parks, marine national parks; o historic and heritage areas, buildings or sites protected under the Heritage Conservation Act; o sites of conservation significance; o world heritage areas; o wetlands protected under RAMSAR treaties.
Sites within an identified sensitive location within a drinking water catchment, including: o potable groundwater o groundwater recharge areas;
Sites within 250 metres of a: o Residential zone; o Dwelling, school or hospital not associated with the facility.
Sites located: o In or within 500 metres of a permanent or intermittent water body (including rivers, lakes, bays or wetlands) and the 100 year flood plain; o Below the regional water table;

o Within 3 metres of the highest seasonal groundwater.
Sites located: o Within a karst region; o Within 1km of a holocene fault; o With substrata which are prone to land slip or subsidence.
Sites within a floodway which may be subject to washout during a major flood event. A major flood event is considered to be a 1 in 100 year event.

9. Infrastructure

Local infrastructure must be able to sustain the operation of a landfill. Landfilling requires the transportation of waste. The capacity of the road network to cope safely and with a minimum of disturbance to the local community, with any increased traffic load should be examined.

The preferred transportation route should minimise the transport of waste through residential and other sensitive areas. This consideration may influence the placement of the entrance to the landfill.

A transportation study may reveal the need for additional road infrastructure, such as highway interchanges, turning lanes or signals. The availability of services such as reticulated water, sewerage and power will influence the facilities provided for staff at the landfill and perhaps indicate a need to provide additional services, such as water storage for fire-fighting purposes.

10. Access

A landfill facility must have all weather access. Access roads should be located to minimise erosion and the alteration of drainage systems.

Landfill development and operations can generate significant flows of heavy vehicle traffic. The following need to be considered when locating and determining access to landfills

- type and number of vehicles accessing the site;
- types of traffic using roads adjoining landfill access road;
- the standard and capacity of the road network, with respect to accommodation of traffic generated by the landfill;
- whether the traffic can avoid residential areas;
- road safety considerations in regards to the landfill entrance (vehicles using the landfill should not be required to queue on a main road).

11. Land Uses

Adjacent existing and future land uses should be investigated to identify sensitive areas and other protected areas that are likely to be adversely impacted by landfill operations. Long term planning projections need to be considered when assessing the suitability of a site.

In order to protect sensitive areas from impacts associated with landfill operations, such as odours, noise, litter and dust, an adequate separation (buffer zone) distance needs to be maintained between the landfill and adjacent land uses. The requirement for and extent of buffer areas should be determined on a site- specific basis. Where possible, the buffer area should be controlled by the landfill operator.

An assessment of the suitability of a site for a landfill, and/or appropriate buffer zone, in regards to reducing the potential for adverse effects on surrounding land use should consider:

- existing property boundaries and ownership;
- statutory planning constraints including;
- zoning (the protection of amenity associated with residential, commercial or rural zones from nuisances associated with odour, vermin, birds and flies, noise, litter, dust and visual effects, or failure of containment, leachate collection or landfill gas systems)
- land designated for a special purpose (e.g. hospitals and schools) o airport safety; and
- proximity to sites with cultural or historical significance.

A buffer zone is not an alternative to adopting the management practices detailed in this guideline, but an adjunct to support these management practices.

12. Operational requirements

<u>Leachate</u>

Landfill site selection should consider the potential methods of leachate treatment and disposal and its effect on site neighbours. Methods of leachate treatment and/or disposal could include the following:

- Discharge to land by spray or subsurface irrigation, with or without treatment – the effects of runoff, odour from leachate storage ponds, odour and spray drift from irrigation systems and effects on soil structure need to be assessed.
- Discharge to natural water after treatment and consideration of any cultural constraints.
- Treatment by recirculation within the landfill – the effects of increased landfill gas production, odour and potential for differential settlement, leachate build-up on the base of the landfill, decreased stability of the refuse mass and leachate breakout on surface slopes needs to be considered.
- Evaporation using heat generated from the combustion of landfill gas.

<u>Landfill Gas Management</u>

Inappropriate landfill gas management can result in adverse environmental and safety impacts such as:

- odour nuisance;
- degradation of the ozone layer;
- migration of landfill gas in the surrounding sub-strata;
- vegetation die off within or on the completed landfill surface and adjacent areas;
- explosions or fires due to gas release through cracks and fissures at the surface, or in confined spaces such as manholes, chambers and poorly-ventilated areas of buildings on or adjacent to the site; and
- asphyxiation of personnel entering trenches, manholes or buildings on or near the landfill site.

The potential for landfill gas migration in surrounding sub-strata needs to be considered with respect to containment proposals. Landfill site selection should consider the various potential methods of landfill gas treatment and disposal and its effect on site neighbours. Methods of landfill gas treatment and/or disposal could include:

- Venting of landfill gas - effects of odour and non-methane organic compounds on site neighbours need to be assessed along with greenhouse gas emissions.
- Flaring of landfill gas – the visual and noise effects of landfill gas flares need to be considered.
- On-site power generation - the effects of generator noise and backup flares need to be considered.
- On-site treatment or gas stripping prior to off-site use - the potential effects of odour and backup flares needs to be considered.

Site Capacity

The life of the landfill and the demand for future landfill space should be considered during the site selection process. Proponents should consider the type and quantities of waste generated within the area being serviced by the landfill, the current disposal pathways for these wastes, projected quantities and types of waste requiring disposal and the remaining landfill capacity at existing landfills sites which service the area. Landfills should be designed to ensure that sufficient capacity exists for the current and future waste management needs of the community into the foreseeable future.

13. Land Ownership

Land ownership will influence the siting of landfills. It is preferable to construct landfills and waste management infrastructure on public land, but in cases where public health emergencies or other public interest priorities are valid, private land should seriously be considered.

Selection process

The selection procedure can be based on graphical representation of the region or on numerical schemes ranking potential sites. The two approaches address the same criteria and combinations of them can be applied.

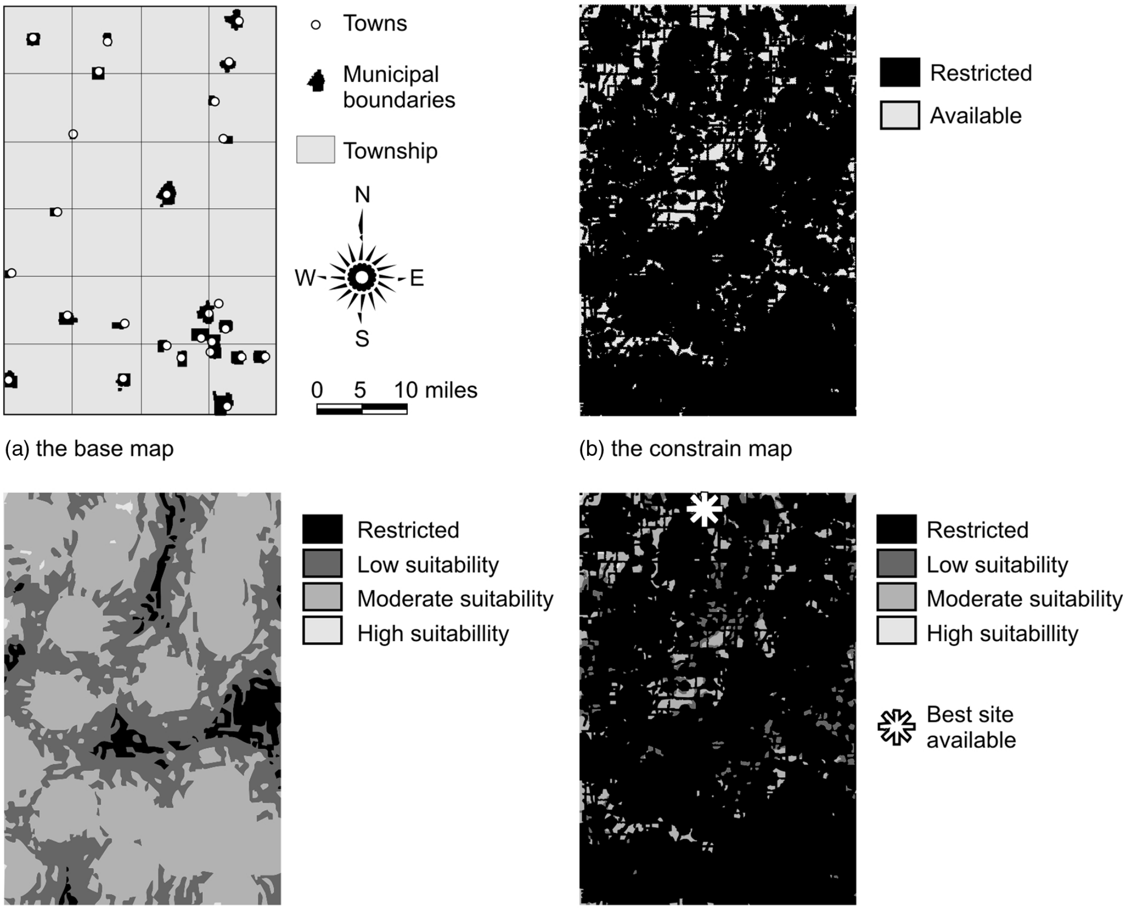
Graphical procedures

Graphical procedures are based on illustration of the main features and criteria on a map of the region. This may be geographical and geological features as well as human-activity related features such as urban areas, recreational areas and roads. Probably, the first and most famous of these approaches is the 'land suitability analysis', a technique otherwise named 'overlay maps', where each feature (criterion) is plotted on a map of the region by means of colours; different colour intensities across the map denote variation in fulfilling the criterion. By superimposing all the thematic maps, it is possible to identify the most suitable areas for landfilling and those that should be avoided.

The geographic information system (GIS), originating directly from the 'overlay maps', is widely used in computer- aided decision support tool for site selection. These tools combine large amounts of georeferenced data with other statistical information to assist in evaluating siting locations. Basically, complex sources of information, such as national survey maps, aerial or satellite images are dismantled into files of homogeneous elements that could be easily classified and stored in a database. Classification can relate to land cover, land use, topography, population density, waste generation, etc. Querying the database can generate thematic maps.

These maps are then combined by means of Boolean functions that 'add' or 'subtract' these thematic features, or search for particular patterns. Again, the main output of this procedure is an image of region (digitized map, usually) showing areas that are suitable for landfill siting and those unsuited. This is also the technique that is used in this project. Next figure provides an example of the process.

Figure 1 Example of a GIS suitability analysis using thematic maps



(a) the base map
(b) the constrain map
(c) the suitability map
(d) the final suitability map

Ranking procedures

Ranking procedures basically use similar criteria as the graphical procedures, but are most often used on a limited number of alternative siting locations subject to many criteria. Multicriteria ranking procedures are based on the simple idea that complex problems can be divided into more manageable parts to be analysed and then reassembled into the final result.

The most important advantages of these models are:

A. The decision maker does not need specific theoretical knowledge about the procedure. The procedure is direct and transparent and does not require sophisticated computer facilities. The results are particularly clear and simple making them suitable for communication with the public.

B. The procedure involves a two-dimensional matrix, named the 'performance matrix': the rows represent the alternatives, and the columns are the factors (called 'criteria') by which the alternatives are judged. The elements of the matrix represent a standardized measurement of the decision maker's satisfaction with each alternative, in relation to the criteria. The relative priority of each criterion is also determined by means of 'weights' (e.g. numbers used to rank the criteria) that are associated to every factor. The various methodologies differ from each other in the way they compute the ‘satisfaction values’ and the ‘weights,’ and the method for combining them into the final score. The most common approaches are based on direct assignation of weights; these weights multiply the satisfaction values of a specific alternative with respect to every criterion. Data are then aggregated by using simple calculations (such as addition, subtraction, etc.). As most of these models are based upon the ‘utility theory,’ if the criteria have positive value, the more the score, the most suitable is the site.

Thus, site selection is performed by:

- Assessing the relative importance of each regulatory constraint and that of each siting criterion.
- Assessing the performance of each area with respect to every regulatory constraint and site criterion.
- Combining all these values in final ‘suitability’ scores.
- Ranking the sites with respect to these scores.

Annex 6: Practicing Public Involvement

Local residents should be asked to take a more active role in the decision-making process and should be given the opportunity to affect the ultimate decision by contributing local insights and suggestions. Frustration results when all parties involved are not as open as they can be or as informed as possible regarding details of the process. The community may see their role as protecting the home turf. The landfill developers may see their role as providing a service for the general public. The regulators may see the process as a means of getting a job done in accordance with the law. Motivations may differ, but the development of informed consent may solve the problem.

Distributing a publication such as a fact sheet or pamphlet is one way to introduce a proposed landfill, but perhaps more effective is a full-page presentation in a local newspaper. Here the major players can be introduced, the concept outlined, the reasons for the landfill explained and then the community can be offered a clip-out response form that will allow them to give their own opinions about the project. Two-way communication is often more effective than an informative lecture.

In planning a meeting, traditional seating, traditional evening scheduling and traditional confrontations may be avoided by using an open house concept. Where authorities consider it necessary, a defined public hearing should come after an informal "open house" session. As a result, the formal hearing may be shorter and less confrontational. The public awareness session or community involvement session would be considered less formal methods of obtaining public participation.

When a community seems sharply divided on an issue, such as a landfill siting, it may be effective to bring those strong feelings to a "planning workshop." Such activity will usually encourage the building of partnerships while the issues are being addressed. At this stage, an impartial facilitator may play a key role in the development of constructive communication. Participants can represent all concerned parties, but the focus is on local interests. Developers and regulators participate as resource people.

The first step in arranging for public participation is to determine the level of public interest in the proposed landfill siting. This can be accomplished by talking to people who have experience working with members of the affected community or conducting personal or phone interviews with community leaders or others who have expressed an interest in the project.

Since the process of landfill siting may last for several years, it is suggested a mailing list be developed early and maintained to involve new stakeholders and changes in community and local government leadership.

Preparing a public notice is a key element in the public participation process. Coordinate publication and meeting dates so weekly publications get the notice in time to be useful. Public notices should never substitute for other activities that involve direct communication with the public. Fact sheets are an important tool to be used in mailings, for community assessments or at meetings. It is suggested they be considered for use as a written statement or to provide "bullet" facts. These documents allow the agency/applicant to communicate a consistent message to the public and the media. They also serve to educate the public about the process and technical issues and can aid in creating a general community understanding of the project. Fact sheets are a one-way communication tool so it is suggested that they always provide a name, an e-mail and telephone number of a contact person to encourage public reaction, comments and questions.

Public Meetings

The traditional public meeting or town hall - type meeting may encourage a confrontational environment and presents a formal appearance that may discourage communication. However, the traditionally defined public meeting may also suggest stability and attention to community expectations in some cases. This type of meeting may be correct in some cases. It is important to know that there are alternatives.

The first alternative suggested is the informal meeting. This type of meeting can take two to three days to plan and conduct - three hours for scheduling and set up, five hours for preparation, four hours to conduct the meeting and four hours to follow up on issues raised during the meeting. Informal meetings offer both citizens and officials a chance to increase their familiarity with how the process works, increase awareness of each other's point of view and actively promote public participation. Informal meetings also may diffuse any tension between the community and the authorities involved.

Some opposition groups may perceive efforts to restrict the number of persons attending as a 'divide and conquer' tactic designed to limit the influence of large groups or exclude certain individuals or groups from participation. To prevent this, provide the opportunity for additional informal meetings with those who express a concern about being left out.

Irate groups or individuals may accuse staff of telling different stories to different people at these small meetings. Avoid this by inviting a cross-section of interest groups to each small meeting or wind up the series with a large public meeting. Staff can also keep detailed notes of the meeting proceedings and make these available to the public.

A Citizen Advisory Panel (CAP) is a style of informal meeting that has emerged for public participation during regulatory negotiation and the permitting process. CAPs (also called Citizen Advisory Groups) are designed to provide community leaders with regular access to the process. Either the permit applicant or the involved authority department may organize a CAP. Suggested CAP members are representatives of local government, business and civic organizations, environmental action groups and staff from a variety of government agencies or departments with a stake in the process.

The CAP can be used to gauge community reactions and monitor developments early in the planning process. Later, the CAP can direct specific concerns to study groups or technical panels. They can become an ongoing oversight group working with both the permit applicant and the department to reflect community concerns regarding a landfill site. It is suggested if a CAP is used, it be organized early and meets regularly. How often the meetings occur is likely to depend on the stage of a project's development.

Another popular meeting type is the availability session/open house. This format allows presenters to erect displays, posters or slide shows to illustrate their message. In turn, it allows the public to meet one-on-one with the agency or business representatives best prepared to answer their specific questions. Late afternoon and early evening hours are suggested for the availability session because this allows the public to come in for information at their convenience. There should be plenty of advance notice and planning to make sure the session meets public expectations.

A list of potential Frequently Asked Questions is suggested to be distributed. A signup sheet will allow contact between the presenters and public members at a later date. Fact sheets are helpful to the public as they form their questions and to have for later reference.

If public interest is considerable and the community is willing, a workshop may be effective. The workshop, or seminar, is a gathering of 20 to 50 people who are guided by a small group of specialists or technicians that can address specific concerns. Workshops can be conducted before formal public hearings or during public comment periods to assist citizens in developing and presenting testimony. Fact sheets and exhibits can also be used at workshops.

Workshops have proven successful in familiarizing citizens with key technical terms and concepts before a formal public meeting. Workshops also allow two-way communication, making them particularly good for reaching opinion leaders, interest group leaders, and the affected public.

In addition to the various types of meetings to encourage public participation, it is important to keep in mind the communication between the local government officials, government agencies, legal teams and others involved in the business of landfill siting. For this purpose, briefings and presentations can be developed to make sure everyone is still moving towards the same goal as the landfill permit process moves along.

Ten steps for successful siting

In Lebanon, there is a long history of unsuccessful interventions in waste management and a strong network of NGOs and other civil society organizations that prioritise waste management in their activities. This combination sets the scene for the emergence of NIMBY syndromes in any case where a new facility must be allocated. Thus, it is important to follow the best practices, as they have been discussed and defined by many different stakeholders in different countries.

The following steps are most useful for a publicly owned facility. Although privately owned facilities may not follow these same steps, they must meet state public involvement requirements such as holding public hearings. Siting is always complex and multi-dimensional; approaches will differ from area to area. Of course, no single successful siting process exists and several steps may occur simultaneously. Adjust the steps according to regional circumstances and variations in state requirements.

Step Zero: Set the scene

Set the baseline for decision-making. Explain in details the health and environmental impacts from dumpsites, discuss the hidden costs in ignoring them, highlight the long-term consequences for the food-chain and the local population. This is very important because this will create the basis to understand the benefits of the proposed facilities and the new waste management system. Without this step, all the next ones will be an undocumented effort to present a new system, without establishing the need for that in a concrete way.

Step One: Speak about the new system not just the facility

Present the proposed waste management system as a whole and put the new proposed facility in this framework. One of the most usual mistakes is to present and discuss any new facility as an isolated infrastructure, without the linkages to the whole system. Identify the facility need and purpose clearly, establish the gravity of the region's solid waste situation, the need for an integrated municipal solid waste (MSW) management approach and the rest of the required facilities (type and size). The public may not be alarmed by limited landfill capacity until the site nears closure or until some other crisis occurs. Consequently, facility need must be clearly established at the outset or continuing opposition may significantly lengthen the siting process.

Step Two: Involve Public as early as possible

Public involvement must go beyond required formal public hearings. Lack of meaningful public involvement can cause costly delays or can completely halt solid waste facility construction. Early and continuous public involvement is necessary for a credible siting process and to inform local officials of residents' perceived risks. Often, citizens mistrust government - especially if past solid waste management decisions were made by a few people behind closed doors. A completely open process that maximizes public participation has the best chance for success.

Public involvement for siting should involve two-way communication between all interested parties and those responsible for carrying out the siting process. Public involvement should serve two main purposes: first, to determine the most suitable facility site and, second, to ensure that the public completely understands the process, any possible problems and all potential solutions.

Step Three: Use an independent consultant

An independent consultant can serve as a technical advisor and a neutral participant in the siting process. He or she can research environmental constraints, legal requirements, costs and other relevant siting details. A consultant also can conduct the waste characterization study, a waste centroid analysis (to identify potential sites in broad geographic terms) and a cost/finance analysis. Use this information to outline the advantages and disadvantages of each proposed site. All consultant recommendations must be clearly presented to the public.

Step Four: Set and Communicate Clear Siting Criteria

A siting committee can prepare a list of exclusionary siting factors based on government's and local laws. Apply the exclusionary criteria as a starting point for defining unsuitable and suitable land areas. Exclusionary siting factors include airports, floodplains, wetlands, fault areas, seismic impact zones and unstable areas. Other exclusionary siting factors include current and anticipated incompatible land uses, local zoning restrictions or lack of transportation access.

The siting committee also should develop a list of siting criteria for evaluating and ranking potential sites. Sites that meet the most criteria should receive the highest ranking. Siting criteria should include environmental and political impacts as well as social and economic factors.

Visually portray the most promising areas by mapping pertinent features on separate overlays and then combining them. A Geographic Information System (GIS), a computerized mapping system, is ideal. If a GIS is not available, use a series of overlay maps made of translucent mylar material. A GIS and/or mylar maps allow officials to visualize in layers constraints such as natural and man-made features, population location and density and protected areas, and then to combine them to portray overall impacts.

Step Five: Rank and Exclude transparently

Sites Applying the exclusionary factors and selection criteria to the study area will reveal several potential sites. Choose a manageable number for ranking and further evaluation by staff, the committee or a consultant.

Not all criteria are equally important. Therefore, the criteria should be weighted based on the importance to each participant. Scoring the criteria is a subjective process, depending on each participant's understanding. However, because the final ranking totals all the opinions, the process is democratic and unswayed by one or more individuals.

Apply the selected criteria and their weighted ranking to each potential site. Numerically rate how well each site matches each criterion. Submit the best rated sites to further environmental, cost and other technical analyses.

Step Six: Select the Best Site

The siting committee, all participating jurisdictions and the public should be involved in selecting the preferred final site. Soils, water, slope, wetlands and other environmental considerations should be reviewed for each potential site. The consultant, staff and other participants should visit each of the top sites.

Compare the analyses for the potential sites and determine a final site based on environmental acceptability and other pertinent factors. For landfills, certified geologists or engineers must next conduct a site suitability analysis. This analysis involves testing the site's soil type and characteristics, water table depth, wetlands delineation, depth to bed-rock and aquifers, and conducting other highly technical subsurface analyses. This study's cost will vary depending upon state requirements and the site's environmental condition.

Step Seven: Discuss Host Community Benefits

A host community should receive certain benefits, amenities or services in exchange for locating a MSW facility within its geographic boundaries. Before permitting begins, the siting committee, residents and elected officials should be involved in determining the benefits.

Appropriate timing is essential when discussing acceptable, feasible benefits. Discussions and negotiations held too late may lead people to believe they are being "bought off." The most common host benefit is a substantial reduction on the fees for the facility use plus other direct benefits like annual support for social or recreational activities, investments in the area etc.

Step Eight: Secure proper financing

Funding for solid waste facilities can be public, private or both. The financing method will depend upon the facility type, ownership, size, area served and current financial resources available. A regional MSW entity or the jurisdictions served by the facility should determine the financing methods for a publicly financed project. In any case, what is really important is to secure that the financial resources will be enough to construct and operate the proposed project in a proper way that will ensure health and environmental protection. One of the most usual mistakes is that the projects are not realised as they are planned and designed, and as they are discussed during the consultation period due to budget restrictions.

Step Nine: Continue Public Involvement

Public Involvement and Siting committee meetings should continue after final site selection to discuss design and construction, permit status and ways to implement non-permit requirements such as host community benefits, local traffic controls and aesthetic buffers. The committee can comment on the overall facility design as well as the daily operations plan.

Annex 7 : Options for Regionalization

Regionalisation requires an appropriate institutional form in order to bring those who intend to use the regional facilities under one umbrella. Within a region, it is vital to establish an organisational structure that will facilitate cooperation and the development of regional infrastructure. In particular, mechanisms must be identified that will enable the necessary shared capital expenditure and the shared recovery of capital and operating costs. The main challenge is to bring tariffs, operational costs, available waste collection equipment and the daily routine of enterprises within a sound integrated system functioning under universal conditions over the entire area.

Institutional models of regionalisation may take the following forms:

- Municipalities retain their own service responsibility and/or company.
- One regional entity is responsible for the entire collection system.
- Municipalities remain responsible for internal collection systems within settlements, while haulage between settlements and the central facility is carried out by a different service company (linked to the management of the facility).
- A combination of the above.

We will briefly discuss those options below.

<u>Municipalities retain their own services.</u>

Municipalities are responsible for waste management services, thus each municipality has a service organisation. After the commissioning of the regional facility, municipal service providers may remain in place. As local dumps are closed after the central facility is commissioned, municipalities (except the host municipality) will have to transport their waste over much longer distances to the central facility. This is the “least-change” model of regionalisation: the change is that municipalities transport waste to a regional facility, incurring significant additional costs for the local service providers.

This is what is actually happening today in Tyr, resulting in complains by municipalities for the long distances they have to travel (although in reality they are not long, they are definitely longer than the previous ones where every municipality had its own dump – in addition the restrictions and difficulties of the road network in some rural areas made the transport really problematic). This approach results in higher unit costs for collection and leaves the development of recycling programs on the municipality level, which makes recycling a big challenge, especially for the small municipalities in rural areas.

A plausible investment scenario under this alternative is the wholesale replacement of the local vehicle fleets with larger- capacity compactor vehicles, which will transport waste directly to the central facility. At the same time, in the longer term municipalities can be expected to utilise economies of scale in organising the collection by merging services with neighbouring municipalities, or jointly contracting private companies to carry out the service. This process implies radical changes in the performance of local utilities towards enabling the further merger, or closing down, of weak service providers.

<u>Regional Entity organizes the whole collection system</u>

This model is frequently propounded as the most efficient, in terms of economies of scale. Certainly, overheads will be much lower than for a dozen or more independent municipal service providers; repair and maintenance facilities can be merged etc. Such a system could emerge from a merger of the municipal service providers, but this is rare in reality. More frequently, sub-regional service providers operate in conjunction with a partnership with a private investor. For example, a group of municipalities forms a joint venture and subsequently this company in turn forms a joint venture with a strategic investor (the latter normally being the majority shareholder). Alternatively, such regional companies emerge gradually when a service company in a larger town enters into service contracts or joint ventures with adjoining municipalities. This practice is very usual in many Balkn countries and SE Europe.

Municipalities retain collection, transfer is done by a central service provider

In this model, municipalities remain responsible for their internal collection system (presumably with their existing service organisations). Waste is brought to transfer stations, from where long-distance haulage is carried out by a separate transport fleet associated with the central facility. The incremental vehicle requirement in this model essentially consists of the vehicles that transport waste from the transfer stations to the facility. In this model, there is significant investment in transfer stations (and in "collection points" in rural areas). Since the regional operation is superimposed over the local service suffering protracted problems, the implementation of regional projects suggests a variety of risks in terms of financial sustainability (fee collection efficiency and the ability of municipal service organisations to pay for increased transfer/transportation and disposal costs) and monitoring/enforcement measures in relation to the illegal dumping of waste within the municipalities.

Hybrid models

In reality, arrangements are more complex and variegated than the patterns discussed above. A project area of about 50 independent municipalities, with the intention to create a regional waste management body, would bring about significant changes in the inherited institutional set-up.

Waste collection and transportation, for example, may be carried out by a private operator in several municipalities, using a non-compliant dumpsite. Some public utilities may provide services to neighbouring rural municipalities. In certain rural municipalities a small private operator may be engaged to carry out the service.

Given such a diversity of operators, in order to create conditions for initiating an integrated municipal waste management system at regional level, it may be necessary to form either a regional waste management company, jointly funded by the cooperating municipalities (in some way in proportion to the population to be served by the regional system); or a regional contracting agency, again jointly funded and responsible for contracting out waste collection, transportation, treatment and disposal. The institutional concept, under any regional context, envisages the distribution of the ownership of the new regional facilities (including landfills) to joint inter-municipal public utilities. The owner of all the facilities to be acquired in the course of project implementation and financed by grants/loans would become the regional enterprise, to be founded by interested municipalities in the operation areas. It would be either a publicly owned communal enterprise or a joint stock company owned jointly by all the municipalities participating in the region. Examples of inter-municipal associations being formed with a similar purpose exist in many EU member states.

The municipalities participating in the region need tailor-made technical assistance on the collection of solid waste, waste reduction/recycling and the collection of waste fees. The scope of expertise required by the individual recipients in the region ranges from landfill operation and waste logistics to collection technology and public awareness/relations, as well as commercial management issues and tariff calculation.

Expertise is also needed for the establishment of a joint waste monitoring and control system for the operational area. The facility operation entity also needs appropriate operational know-how, which can be provided by a private partner and/or technical assistance in the initial period.

Annexing this pool of know-how to the regional body in the initial operational period by an international training facility may contribute to achieving economic and political independence from specific interest groups (such as political parties), important for its technical and supervisory functions.

Annex 8: Financial Tools for improvement

Budget and Accounting

Adequate budgeting, cost accounting, financial monitoring and financial evaluation are essential to the effective management of solid waste systems. In most municipalities, however, officials responsible for MSWM do not have accurate information concerning the real costs of operations. This is often the result of unfamiliarity and/or lack of capacity to use available financial tools and methods; it is sometimes exacerbated by a lack of incentive or even reluctance in the bureaucratic culture of many local administrations to achieve transparency regarding costs and expenditures.

Introduction of improved cost accounting and financial analysis should thus be associated with broader efforts to increase the accountability, efficiency and commercial orientation of municipal infrastructure management. Where accounting expertise is lacking, it may be brought in from the private sector.

As things are now, solid waste service revenues flow into a general municipal account, where they tend to be absorbed by overall expenditures instead of being applied to the intended purpose of waste management. The danger of such misallocation of funds is even greater when locally collected fees and revenues are transferred to the central government before being redistributed to the local level. Besides the simple fact of reducing funding for waste management, the absence of linkage between revenues and the actual levels of service provision tends to undermine the accountability of local waste management institutions and remove their incentive to improve and/or extend services. Resolution of this problem calls for clear political decisions and autonomous accounting procedures which ensure that the collected revenues are actually applied to solid waste management.

A separate budget line with proper analysis for waste management activities is a minimum condition to improve the accountability of the sector.

Capital Investments

The main options available to local governments for financing capital investment in the solid waste sector are local budget resources, loans from financial intermediaries and/or special loans or grants from the central government. A further option, private sector financing, has attracted increasing interest in recent years. The central government is and will continue to be the principal source of funding for major infrastructure investments in solid waste and other sectors. It is important, however, that full responsibility for the functions of planning and investment programming remain with the local government, which must subsequently operate and maintain the acquired facilities and equipment. Procedures which facilitate central financing while devolving investment authority and responsibility to the local government (e.g. infrastructure development funds or banks) should therefore be promoted.

To ensure the appropriateness of investment decisions and avoid “white elephants”, adequate financial analysis procedures are needed at the local government level at the strategic planning phase.

Financing operations

There are three main options for financing the substantial recurrent costs of MSWM: user charges, local taxes and intergovernmental transfers. To promote the responsiveness of the supplying agency to user needs and ensure that collected funds are actually applied to waste management it is usually preferable to finance operations through user charges rather than general tax revenues. Since property tax coverage is universal and the municipal government is responsible for its collection, an itemised line on the tax bill may be appropriate.

User charges should be based on the actual costs of solid waste management, and related, as far as possible, to the volume of collection service actually provided. Among larger waste generators, variable fees may be used to manage the demand for waste services by providing added incentive for waste minimization. While the economic demand for waste collection services may cover primary collection costs, it seldom covers full transfer, treatment and disposal costs, especially among low-income groups. To achieve equity of waste service access, some cross-subsidisation and/or financing out of general revenues will be required. Large scale waste generators should pay the full cost of disposal services on the polluter pays principle, however.

In practice, municipal government performance in the collection of waste service fees is often quite poor. People are reluctant to pay for municipal waste collection services which are perceived to be unsatisfactory; at the same time, poor payment performance leads to a further deterioration of service quality, and a vicious circle may arise. Improved fee collection can usually be achieved by attaching waste collection charges to the billing of another service such as water supply or electricity. Such systems may be made progressive, in the sense that large users would pay a higher rate per volume of collected waste than small users. In the case of large single point producers such as industrial or commercial enterprises, volume or weight-based charges may be more appropriate; this has the advantage of linking waste revenues to the actual volume of services provided.

Cost reduction and control

To ensure the long-term economic sustainability of MSWM systems, investments in system development should correspond to the level of resources which the society can make available for waste management. The potential for increasing revenues from solid waste operations is usually quite limited, though, and the most effective way to ensure financial sustainability is through cost reduction doing more with less . There are almost always opportunities to significantly reduce the operational costs of MSWM services.

In principle, the most straightforward way to lower the variable cost component of waste management is to reduce the waste load at source, i.e. to minimise the generation of waste. In the low-income residential areas, the potential for waste reduction is usually quite limited, however.

Public waste collection costs may be reduced through the participation of residential communities in local solid waste management. In most cases, this involves hiring of small scale enterprises or informal waste collection workers. Besides lower cost collection service, informal waste recovery and/or scavenging also contributes to cost savings by reducing the volume of waste which needs to be transferred and disposed.

Important cost reductions may be achieved by introducing competition through public-private partnerships for waste management. Private enterprises are highly motivated to lower costs and may introduce innovations and efficiency-raising measures to this end. The outcome may be useful for defining realistic performance standards which are also applicable to the public segment of the waste management system.

At the most fundamental level, cost reduction implies a better utilisation of available manpower and equipment, improved maintenance of equipment, introduction of appropriate technologies and the elimination of inefficient bureaucratic procedures. Authorities concerned at local and central government levels should have access to information on the actual cost of MSWM services and relevant performance standards to better judge the potential for cost reduction. The collection and dissemination of cost data, efficiency indicators, performance standards and the like may serve to focus managers attention on those areas of operations which require improvement.

Annex 9: Governance, users' and providers' Inclusivity

Waste Governance

Waste governance starts from strategic goals and guiding principles. It addresses policy instruments, institutional arrangements and capacities and stakeholder interactions.

It requires formulating explicit and clear goals, and plan how to achieve them. It' important to formulate the goals carefully – the goals express the very purpose of the system, and thus determine its elements and the way they interact. Waste prevention is an important goal, not only for developed countries but also and particularly for developing countries.

It is of major importance to communicate, facilitate involvement, engage in exchange with the actors in the system. Spending time on building citizen and stakeholder engagement into policy-making processes and making sure that those who are key to the success of the system are on board, is the only way to achieve long-term sustainability.

Good governance requires consistency in decision-making applied to all levels and all dimensions of the system. You have to make sure that the strategic goals are reflected in choices made throughout the waste system, not only those related to policies and institutions but also, and particularly, technology selection and financing structure. Three points must be carefully addressed:

- Take charge of the technology selection process at the level of governance, not at the level of technical management. Understand the function and purpose of technological options, rather than just their features, and study their performance and real costs before making a selection.

- Aim for financial sustainability of the system. As a part of it, aspire to cost recovery in relation to services with directly visible benefits to the users, such as waste collection. In developing countries, the capital needed for the construction of processing or disposal facilities will require other sources of financing such as the central government, while operation and maintenance could be financed locally.
- In cases where waste collection systems or facilities were developed through donor-financed projects, make sure to establish appropriate cost-recovery mechanisms for their operation for the period after the project – and donor funding – end.

Experience suggests that an effective waste system calls for a continuous use of three categories of policy instruments in a coherent mix: (a) 'direct regulation', comprising legislation accompanied by its keen enforcement, (b) economic instruments, providing incentives and disincentives for specific waste practices and (c) 'social' instruments, based on communication and interaction with stakeholders.

While policy instruments had previously focused on waste generators and the waste sector, they are increasingly focusing on producers, including manufacturers, brand owners and importers, in consideration of the entire life cycle of materials and products. This is part of a broader societal trend toward sustainable consumption and production.

Direct regulation serves to protect common interests in a society, such as public health and the environment. A combination of legislation (laws and derived regulations) and its credible and consistent enforcement has resulted in the waste industry as we currently know it – otherwise waste would be dumped at the lowest cost.

Laws and regulations define basic concepts such as waste and hazardous waste, clearly allocate responsibilities, set standards of environmental performance of facilities and operations, and state sanctions in cases of non-compliance and violation. A 'direct regulation' approach is based on information and monitoring; therefore, a commitment to reporting and inspection in combination with good and continuous data management are essential.

A relatively recent addition to waste legislation addresses waste reduction and recovery of resources from waste, in terms of materials, nutrients and energy. These laws and regulations are as much a response to the increasing costs of waste management as to the value of the resources recovered.

While monitoring, inspection and enforcement tend to be costly in terms of institutional capacities required, 'direct regulation' will remain a preferred policy instrument in situations involving high risks to society and serious consequences of non-compliance, such as the handling of hazardous waste.

In order for businesses – both waste generators and the waste management industry – to plan their operations and investments into the future, they need 'regulatory certainty'. This entails the passing of coherent and clear legislation (laws and derived regulations, including incentive and sanction measures) and fair and consistent enforcement.

Economic instruments serve to steer stakeholders' behaviours and practices towards strategic goals through market-based incentives and disincentives. For example, a pay-as-you-throw (PAYT) charging system for residual (mixed) waste will reward people for segregating their waste; taxes on landfilling or incineration will discourage opting for these methods; scale benefits will encourage private companies' investment in SWM. When in doubt whether or not such instruments are appropriate, look at the system as a whole.

- If one of the main goals is to get disposal under some level of control, then taxes on disposal are certainly out of place. In contrast, PAYT may turn out to be beneficial to raise awareness and help segregation at source.
- In developing countries, subsidies may simply not be affordable for the government to finance, in the face of various other claims in the society.
- Extended producer responsibility (EPR) will hold producers and importers accountable for the products they place on the local market.

Finally, 'Social' instruments rely on communication, awareness raising and interaction between the government institutions and the public and other stakeholders. It takes more than just providing information to change people's attitudes and behaviours. Encouraging people, engaging with communities, and leading by example are at least as important.

Waste governance will also depend on the institutional framework in place and capacities of institutions to prepare legislation and particularly to enforce it, to collaborate among them and with the private sector, and to engage with the public. For the effectiveness and credibility of enforcement, it is better to keep the two roles – that of legislator and that of regulator (enforcer) – separate.

User Inclusivity

In general, the need for a basic waste collection service is essentially undisputed. If a service is not provided, or is (perceived to be) unaffordable, then people will take steps to deal with their waste on their own – often by illegal dumping, burying or burning. When a SWM system is being designed and developed, either for the very first time or in a renewed form, waste generators – householders, businesses and others alike – usually have a lot to say about their preferences and concerns. For example, people living in densely populated neighborhoods, in houses without yards, will be less likely to segregate their waste, whether in Lyon, France or Tyr, Lebanon. Therefore, instead of insisting on one or the other technical 'solution', experience shows that new or revised service provisions have a higher chance of success if they are discussed, negotiated and agreed with those whose needs they are to address. This means that citizens participate in decision- making on the SWM system if they wish to do so. The instruments include an array of possibilities, from various platforms for public consultation in planning the SWM system and siting the facilities, to feedback mechanisms through which the service provider can learn about system performance.

In the special case of siting new waste facilities, if timely and appropriate communication and transparency from the authorities are lacking, members of the local community are very likely to respond with NIMBY attitudes, which may precipitate fierce protests and opposition. This is particularly likely to result if people have been 'burned' by bad experiences with poor waste management practices in the past (as it is the case in Lebanon), such as indiscriminate dumping of hazardous waste that affected their residential areas and water wells or soot from early incineration plants with inadequate emission controls. Reassurances that experts will address possible risks, or explanations that modern engineering practices are much better, will not suffice; people will be reluctant to believe that the governance factors required to make that happen will actually be delivered. This was typical of the dire situation with facility siting in Europe in the 1980s, where in some cases waste had to be temporarily stored until a permanent disposal solution was found. Under such circumstances, it is important to engage in dialogue with the community on the possible sites that are selected based on sound environmental and technical criteria, as demonstrated by a high-quality environmental impact assessment (EIA), rather than settling for an unsuitable site simply because there are no objections there from the local community. Such processes may involve negotiations of compensation to the community as well as more fundamental discussions about the need for the waste facility in the first place.

In an operational system, the transparent sharing of information and the existence of an effective complaint (grievances) mechanism are means of 'downward accountability' toward service users. Complaints provide direct and valuable feedback about the service performance and the quality of services provided. Furthermore, if the complaints are timely and adequately addressed, this helps develop trust and goodwill with customers, which is a good starting point for collaboration (which can be built upon) concerning, for example, good habits of placing appropriate waste at appropriate places at appropriate times, and waste segregation at source.

While participatory processes hold the promise of broader societal support for the policies or legislation at hand, in order for a constructive dialogue to take place, a genuine interest in each other's views is key, guided by clear and agreed goals, and supported by the right setting. Otherwise, there is a danger that the exchange becomes an exercise of 'going through the motions' without any real substance to it, resulting in 'participation fatigue' and a deepened divide between the authorities and the citizens.

While a participatory process may not guarantee collaboration, consensus and agreement, i.e. while it may not result in pragmatic benefits for the decision-making process at hand, it has normative benefits for the society in a broader sense. Hence, stakeholder participation is generally promoted as a process of social learning and a means of not only enhancing procedural fairness but also challenging what is in the public interest in the first place; it also contributes to the integration of social values into technical decisions, and quality assurance into expert-centred decision-making. Moreover, it helps increase institutional legitimacy and contributes to public trust and confidence in decisions and decision-makers, and ultimately helps advance democracy. Any one of these enhancements would of itself be a valuable outcome in its own right.

Provider Inclusivity

Generally, municipal (or other comparable local level) authorities have a legal responsibility to ensure that an adequate waste service is provided to citizens. The law may prescribe or allow various operator models. In many places, the law obliges the public entity (either a municipal department or publicly owned waste company) to actually provide the service in the city; in others, the public service provider is obliged – and is the only service provider allowed – to serve households, while commercial waste generators may choose whether they contract with them or with a private service provider; in yet others, contracted private companies may be engaged throughout the city. In addition or instead, the service provider is a local community-based organization or enterprise, or informal sector workers. (This service typically pertains to primary collection, i.e. collection of waste from a residential house or commercial premises and transport to a collection point in the neighborhood. In such cases, the formal service provider then takes over and transports the waste to the final destination.) Inclusivity of service providers represents the degree to which service providers from both municipal and non-municipal (including the formal private, community or informal sectors) are included in the planning and implementation of solid waste and recycling services and activities.

In some cases, where local authorities are overwhelmed by the daunting task of addressing ever-growing amounts of waste, citizens may help both in the preparation of strategic plans. Such situations, where the system shows a remarkable capacity of self-organization, require an attitude of openness and willingness to collaborate on the part of institutions. This also concerns interest in and support for grass-roots initiatives.