



Technical support to upgrading the solid waste management capacities in Lebanon

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Policy Note on small scale incinerators

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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 will be used¹.

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 practices².

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-treatment³.
- 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

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



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 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 facilities⁴. 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

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



all the levels 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 applied⁵.

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 effort⁶. 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 MacDonald.

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

Table 1: MSWI benefits

- | |
|--|
| <ul style="list-style-type: none">▪ 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 landfills⁷. |
|--|

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 regulation⁸. Small scale incinerators are not uncommon, where small scale is generally defined as < 100,000 tonnes a year⁹. 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 levels¹⁰.

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 incineration¹¹. 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 failure¹². 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 inexperienced salesmen unaware of different conditions outside of developing countries, sometimes the result of dishonest, even fraudulent, claims to make a sale¹³. 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 rates of equipment failure as well as poor performance, technically, environmentally and

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.



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 development¹⁴ and waste management principles¹⁵, 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 incineration¹⁶. 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 options¹⁷.

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/kg¹⁸.

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 streams¹⁹ (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/file/221035/pb13888-thermal-treatment-waste.pdf



4.3. Feedstock quantities

WtE incineration should not be 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 avoided²⁰.

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 option²¹ 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 PVC²².

Incinerators have been recognised by UNEP²³ 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

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 accordingly²⁵. 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 personnel²⁶. 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, Environmental Aspects and Impacts of a Waste Incineration Plant, 4th International Conference on Energy and Environment Research, ICEER 2017, 17-20 July 2017, Porto, Portugal, EnergyProceedia10306 (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/MunicipalSWInciner.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

- | |
|--|
| <ul style="list-style-type: none">▪ 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 plant²⁷. 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 6²⁸ 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 anti-pollution 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 cost²⁹. 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 safe 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 incinerators³⁰

- 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 IEA³¹.

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 plants³¹

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 incineration³², 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 pay³³.

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 expensive³⁴ (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 budget³⁵. 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 project³⁶.
- 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 shutdown 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

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



there is no known solution about the utilization of heat, there is a need to study carefully what will be the financial 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 11³⁷. 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 matrix³⁵

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 economic 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/file/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 here³⁸:

- 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

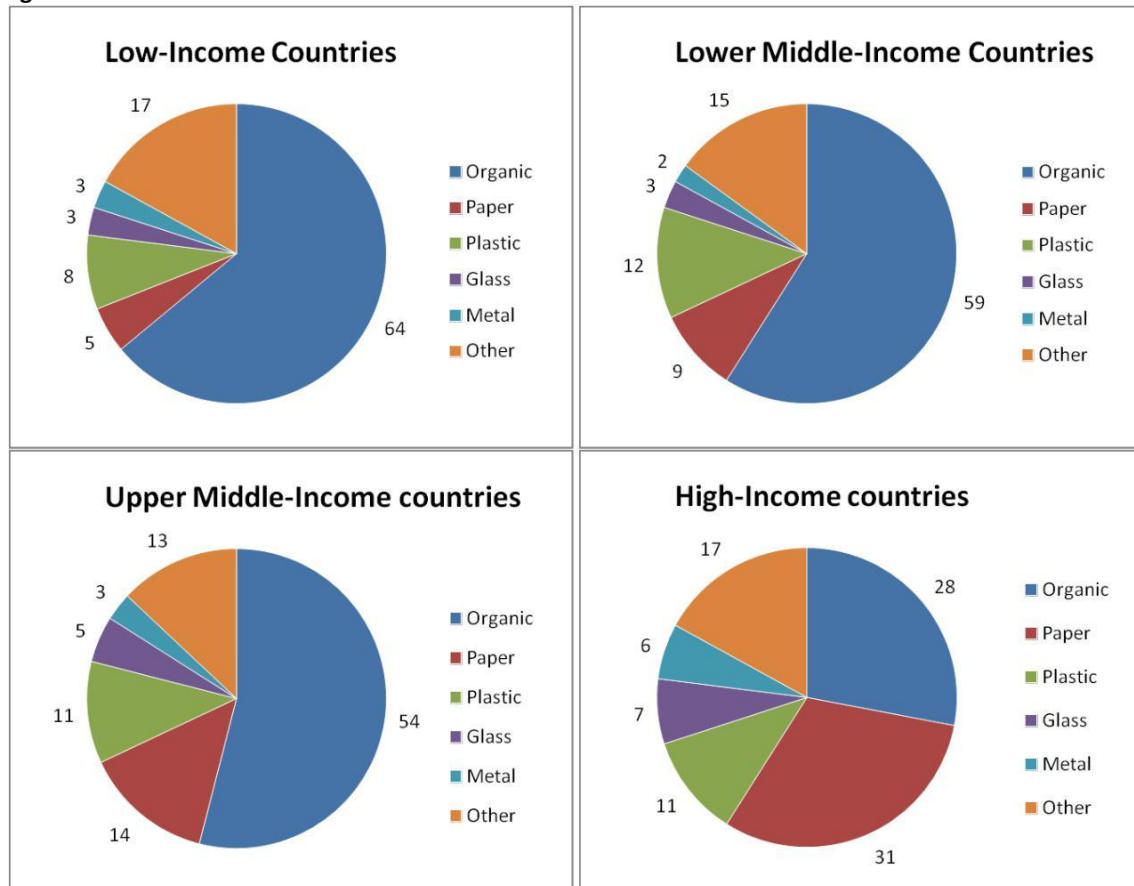


Figure 1 - Typical waste composition for different income level countries.



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 1450°C, 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 NO_x. The amounts are affected by temperature and molecular composition of the air supply. Partly, the NO_x content can be controlled by the control of the combustion process, however in order to achieve emissions standards (see Annex 4), active NO_x removal is necessary.

The two most common systems are SNCR (selective non-catalytic reduction) and SCR (selective catalytic reduction). Both systems reduce NO_x to N₂ 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°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 NO_x regulatory limits or if a financial incentive to reduce NO_x 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.

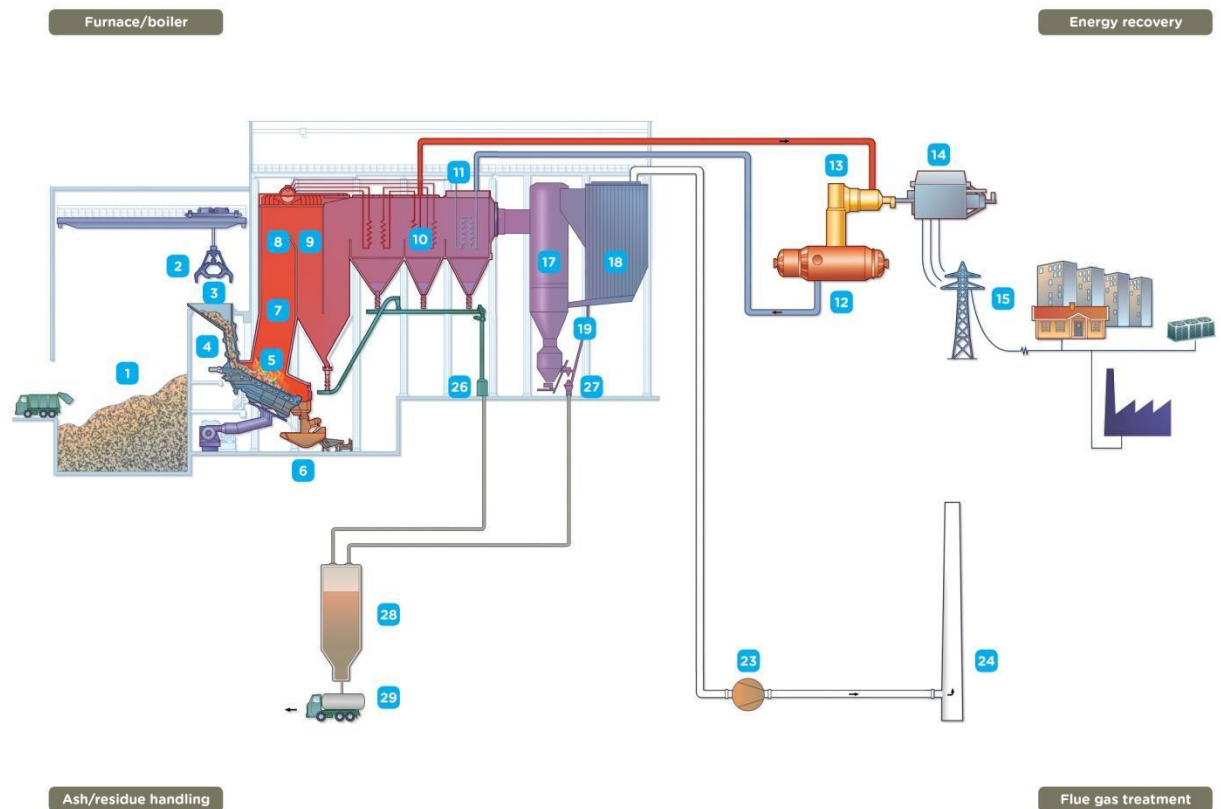


Figure 11 Cross-section of a dry/semi-dry WtE facility (Power production only).

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 gasification³⁹ 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 waste⁴⁰. 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

³⁹ Process and technological aspects of municipal solid waste gasification – 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/file/221035/pb13888-thermal-treatment-waste.pdf



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, 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	35 – 45	30 – 40	65 – 85	2 – 5	63 – 80	Capacity 250,000 t/a, 20y operation
million EUR	EUR/t	EUR/t	EUR/t	EUR/t	EUR/t	,



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-life 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 2000/76/EC	in BAT	Limits 2000/76/EC	in 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 °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 °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 toxic 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.

