Swiss Engineering for Thermal Waste Treatment
Overall planning – everything under one roof

- Project development
- Site and process selection
- System concepts
- Planning, Approval planning
- Tenders
- Supervision of the realisation
- Operation optimisation
- Operation, fault and risk analysis
- Environmental impact studies
- Complete plants
- Process engineering
- Process control and electrical engineering
- Civil construction including logistics

www.tbf.ch

tbfpartner
Consulting Engineers

Development of Waste-to-Energy Projects

Trimurti Irzan, Lukas Schwank and Martina de Giovanni

1. Introduction

1.1. Goals of waste disposal

The first objective of waste management must always be to protect society and the health of individuals from harmful substances contained in the waste. Along the various methods around the globe with which waste has been treated the waste pyramid or waste management hierarchy has become widely accepted as the governing principle for waste management in modern societies. These principles have also been integrated in the European waste framework directive 2008/98/EC.

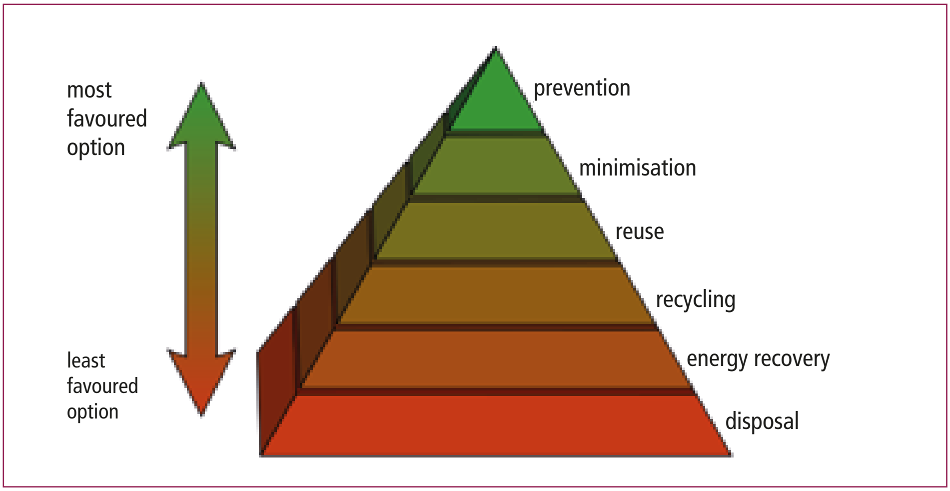

Figure 1: Waste management hierarchy shows more and less favoured options

Source: Wikipedia, The Free Encyclopedia: Waste hierarchy. Retrieved June 27, 2016, from https://en.wikipedia.org/w/index.php?title=Waste_hierarchy&oldid=731743243

At the bottom of the pyramid lays disposal of waste, meaning it is the least favourable option to treat a primary waste. However this does not mean implementing the waste pyramid prohibits disposal. It merely means that before disposal all other meaningful options are exhausted, and the quantity has been minimized.

It is important to note, that all waste-treatment methods by today have a certain fraction, which needs disposal. The goal can only be to minimize this fraction by reasonable and acceptable efforts of the entire society. In order not to violate the first objective – no harm to people – the waste or fraction of the waste, which goes to disposal must be stabilized physically and chemically. In Switzerland the waste management plan requires all waste, which shall be disposed, to be earth-crust like. It turned out that the best way to achieve this demanding goal is when waste is afore treated by an incineration plant.

1.2. Waste management strategy on national level

Waste management in modern society is embedded in a tight net of laws and regulations. The legislation process is a national or even transnational process, which takes often years for changes. For any waste management project this net of laws and regulations defines the most fundamental boundary conditions such as the allowed input materials, the required output materials and its impacts to the environment.

1.3. Waste-to-Energy is best available technology today

Incineration of waste was regarded over a long time with suspicion due to emission problems. Even today concerns are sometimes raised. However the arguments of critics are often outdated and are not anymore applicable for state of the art waste-to-energy projects with modern waste gas treatment systems.

Waste-to-energy is the best available technology in waste management as it has been proven in many projects over the last decade [2], [3]. It offers society an efficient and reliable solution for the increasing amount of waste by producing electricity and district heating out of it.

1.4. Input material: Properties of municipal solid waste

The composition of municipal solid waste varies strongly around the world, as it reflects the lifestyle of individuals, the level of technology used and society as a whole. It can be observed that waste composition changes along with economic development of a country, wherefore the GDP (Gross Domestic Product) is a good indicator for the quantity of the typical waste fractions. The classification into waste categories around the world brings some insecurities with it, such as different definitions or different sampling procedures. Therefor the below numbers shall only be seen as tendencies.

Table 1: Comparison of waste properties from high and low GDP countries

Material	Fraction in high GDP-Country*	Fraction in low GDP Country**	Calorific value	Comment
	%	%		
Organics	34	58		High humidity, bad smell
Plastics	32	14	+++	High calorific value, often contaminated with food, which makes recycling cumbersome
Paper and cardboard	17	10	++	Medium calorific value, paper often very humid
Glass and Minerals	10	4	Inert	Potential resource for construction material
Metals	2	3	Inert	Fe and non Fe-metals, valuable resource, effort needed to gain them from waste.
Other	5	11	often high emissions	Electronics, batteries, undefined waste

Sources:

* BAFU Bundesamt für Umwelt: Abfallmengen und Recycling 2011 im Überblick. Bern, Schweiz, 2012

** Pop, I.N.; Baciu, C.; et al: Survey on household waste composition generated in Cluj-Napoca, Romania during the summer season. In: Environmental Engineering and Management Journal, Vol 14, No.11, Technical University of Iasi, Romania, 2015

The table above shows that the fraction of organics which is still everywhere in the world the biggest fraction in municipal solid waste, shrinks with the economic development of a country, whereas the burnable fractions of plastics and of paper and cardboard increase with the economic development. This means that the overall calorific value of municipal solid waste will increase with GDP. It can be concluded that incineration of waste and the construction of waste-to-energy plants become the more attractive the better developed the region is. This is also true within a country, meaning that the waste from cities and urbanized areas brings a higher potential for incineration than the waste from rural areas, where agriculture is dominant.

2. Non-technical aspects during project definition phase

In the following chapter important aspects of a Waste-to-energy (abbreviated as WtE) project are discussed which are referred to as non-technical. This means they have to be considered or solved before the technical aspects as choice of technology, division into sub-projects, choice of equipment supplier, etc can be addressed.

2.1. Funding body and steering committee of project

The funding body is the legal institution which organises the financing of the project. The funding body has a vital interest in the success of the project, as it gives the security for the financing. Therefore the funding body is typically also present in the steering committee of the project, which provides guidance and control of key issues of the project. The funding body may be a big city or the union of several municipalities. The formation of the union of several independent municipalities may be time consuming, as the roles and responsibilities have to be agreed on by everyone.

2.2. Coherent waste management planning on regional level

Local waste management planning, which is defined by the local authorities, is embedded in the national waste legislation framework. The task of the local authorities is to work out a more detailed plan how waste management shall be approached and implemented in a given region or city.

For the benefit of all stakeholders, society and waste management industry, the waste management planning shall be as coherent and transparent as possible. Large projects which involve large investment need security for the entire lifetime of operation. The costs of the construction project need to be amortized over a long period of time, up to 25 years. A basic change in waste management planning may make the entire investment obsolete and worthless. This risk must be considered by the regional authorities, when setting a new waste treatment project on track.

2.3. Site selection and ownership

Prior to any serious technical discussion the ownership of the land foreseen for the WtE plant should be clarified. If the land and its access is not secured for the WtE project, the cost for buying it at a later stage might become extremely expensive or impossible.

Finding a good location for the plant is a crucial step in the pre-project phase. It must be done before a technical consortium is invited for tender. It is fatal to a project to lose the site during the course of the project. The proper evaluation of a suited site is of great importance to the success of the project and has to consider the following aspects:

- Logistics/transport of waste/transport of ash,
- Neighbourhood/acceptance,
- Revenues from district heat or process steam.

2.4. Permitting

To build and operate a WtE plant different permits from authorities need to be obtained. To list all relevant permits and establish contacts to authorities in an early stage may help avoiding delays and prevent formal mistakes. Receiving a permit which is subject to political decision making or democratic process can be long lasting.

2.5. Public relation and transparent communication

The kind of information and the moment in time when it reaches the public might have a critical impact on the project. An open, transparent and proactive approach by the project team with all affected stakeholders remains the best way of overcoming the genuinely-held concerns of a sceptical public.

Realizing a project successfully therefore requires a high degree of stakeholder's management. Not only have the needs of the builders to be met, but also those of various other stakeholders, such as:

- Project investors,
- Government, local authorities and environmental offices,
- NGO's engaged in environmental protection,
- Local residents and small businesses,
- Industry and large waste producers.

2.6. Supply of waste

Waste may appear to be abundant, but the continuous supply of waste is an important success factor of the WtE project. The waste supply regarding quantity and quality to the WtE-project must be assured. The waste which can be treated in a WtE plant can have different origins, typically household waste and industrial waste from small and medium sized companies is distinguished. Bigger industrial companies have often own solutions for their highly specific waste. Some of these waste streams have become a resource attributed with a value and there is a competitive market for them.

A modern WtE-project involves electricity or steam generation, the calorific value and not only the quantity of waste become an important aspect. The more complex the waste treatment technology is, the more profound waste analysis have to be made in advance, and the more detailed contracts on waste supply have to be signed.

No investment should be done without a binding contract for waste delivery with the planned quantity and quality over the scheduled lifetime of the plant.

2.7. Financial aspects

Today no large investment project is approved if the profitability is not evaluated in detail. The cost efficient operation during lifetime is important to bring the WtE project to success. Costs and revenues have to be balanced. It can be complex to estimate the exact costs and revenues at an early stage.

Costs

The costs during operation of a WtE plant can be divided into four cost blocks, which typically amount all to twenty to thirty percent of the total costs. A detailed estimation of them, based on the local conditions, assures healthy financial status for operation.

Cost block	Description
Direct operating costs	Energy cost, operating media, maintenance material, spare parts
Capital cost	Interest rate for financing credit
Personnel cost	Salaries for workers and staff
Disposal cost for residues	Examples: ash from incineration, sludge from wet scrubber

Table 2: Main cost blocks of WtE plant in opertion

Revenues

Revenues of a WtE plant are generated at the incoming and the outgoing side of the material flow. This is a unique aspect of business in for waste management, where money is paid to take over a waste and with it its liabilities.

To generate revenues from electrical or thermal energy special technical installations are needed, which have to be considered in the project definition phase. The electricity market has a major influence on the profitability of selling electricity. It is important to notice that the market is volatile and changes faster than the legal situation. The period from planning to start-up of a WtE plant can be very long. There is a risk that assumptions made during the planning phase turn out to be wrong.

Table 3: Main revenue streams of WtE plant in operation

Main revenues	Description
Gate fee	All waste delivered to the WtE plant has to be paid for. The operator of the WtE plant receives a gate fee or tipping fees for every ton of waste. There might be different waste categories with different prices according to the environmental risk imposed by the waste.
Sale of electrical energy	Electricity generation with steam turbine
Sale of thermal heat	• District heating, high temperature level • Heating for agriculture greenhouses, low temperature level
Sale of recovered materials	• Mechanical processing and sorting of ash to recover metals (Au, Ag, Cu, Al, Fe, ect.) • Clean inert fraction in some countries accepted as construction material

2.8. Time axis for Waste-to-Energy project

Experience shows that the timeframe for a WtE project from the first idea to the final start-up of the plant is in the order of eight to twelve years. Elaborated planning at an early stage may help to save some time, but very often external factors, which are not under direct control of the project team have a decisive influence on the overall timeframe. Especially legal clarifications, ownership of the land and permitting require a lot of time. The construction of the plant itself including the installation of all equipment takes only two to three years, from the moment that all detail engineering is done.

This relatively short period might be misleading and entice project teams to underestimate the entire timeframe.

The planning sequence comprises of the following steps:

- First idea,
- Project definition/strategic planning,
- Project marketing,
- Permitting,
- Funding and Financing,
- Feasibility study,
- Basic engineering,
- Procurement and construction – including detail engineering,
- Commissioning,
- Final acceptance test and handing over to operator.

2.9. Procurement procedure

There are different ways to carry out a large infrastructure project such as a WtE project. The main questions is: *who is in charge* for the different phases of the project, such as feasibility study, basic, engineering, detail engineering and plant operation.

Depending on the knowledge available or accessible to the project client, a different approach for the procurement of the WtE plant is chosen. Typically the more control and responsibility is kept with the project owner, the cheaper the project becomes in terms of investment but the higher are the efforts in project coordination and control.

- Conventional
- General contractor
- Total contractor
- Concession

Table 4: Overview of responsabilities for different procurement procedures

Description	Conventional	General Contractor	Total Contractor	Concession
Feasibility study	Owner	Owner	Owner	(Concessionaire)
Basic Engineering	Owner	Owner	Total contractor	Concessionaire
Tender to contractor	Owner	General contractor	Total contractor	Concessionaire
Tender to subcontractor	Contractor	General contractor	Total contractor	Concessionaire
Detail engineering construction/commissioning	Contractor	General contractor	Total contractor	Concessionaire
Plant operation	Owner	Owner	Owner	Concessionaire

From the perspective of the owner of the WtE plant the different procurement methods offer the following pros and cons:

Table 5: Pros and cons for different procurement procedures

	Pros	Contras
Conventional	Owner has maximum technical and cost control, including permitting procedures Tapping of market forces brings cost advantage (higher number of suppliers)	Early planning and investment (consultant fee cost) Demanding coordination and project management as many contracts need to be administered
General Contractor	Owner has technical and cost control including permitting Simplicity of the project, only one contract Little coordination needed	Limited bidder market Demanding quality management
Total Contractor	Moderate start investment Simplicity of the project, only one contract No coordination required	Limited bidder market Higher investment costs as risk premium of total contractor has to be paid
Concession	No investment costs One contract No coordination required	No transparency about costs No influence on plant design and operation Risk of penalties if supply of waste is not achieved

2.10. Size of the Waste-to-Energy plant

For reasons of technological efficiency and material handling aspects there is a minimum size for a WtE plant. If the waste amount is smaller, the merger of waste generating regions or the increase of the region must be considered. On the other hand there is a cost advantage during operation for larger plants which is known as economies of scale and is characteristic for any industrial process. This imposes that the WtE project should be as big as possible.

The limit for the maximum plant size is mainly given by the logistic cost to transport the waste to the site of the WtE-plant. In order to gather sufficient waste for a very big WtE plant, more waste has to be transported from remote areas to one central point. The definition of the appropriate waste collection region has logistic constraints but is very often also subject to political discussions.

Typical suppliers deliver incineration lines for 50,000 – 150,000 tons of waste per year. If the waste volume is bigger, the WtE plant is designed with several lines. In operation of the WtE plant it can be attractive to have several smaller lines instead of only one big line, as this gives more flexibility regarding maintenance and unplanned breakdown. However this will cause an increase in initial investment, as it is more complex to build two lines instead of one line.

So there are the following drivers to be balanced:

- Economy of scale tends towards larger and fewer plants,
- Efficient transport of waste to WtE site,
- Numbers of lines for waste quantity,
- Redundancy/operating reliability/flexibility/incoming waste storage.

3. Conclusions

The focus of this paper is the description of the most important non-technical aspects of a waste to energy project. Very often these aspects are underrated at the cost of technical aspects. Ignoring the non-technical aspects can hamper the overall success of the waste to energy project.

The biggest risks of the project have to be dealt with by the project owner himself. They cannot be delegated to an equipment supplier. The most critical non-technical steps in the development of a waste to energy project are:

- Obtain ownership of the land,
- Acquire all relevant permits,
- Secure the waste stream.

If these risks are not adequately tackled at an early stage in the project, the potential damage to the project in terms of cost or lost time can be very grave .Professional assistance from independent experts, which accompany the waste to energy project from an early stage, can help to overcome the biggest risks.

4. References

[1] BAFU Bundesamt für Umwelt: Abfallmengen und Recycling 2011 im Überblick. Bern, Schweiz, 2012

[2] Irzan, T.; Pelloni, L.; Vollmeier, T.; Wieduwilt, M.; Dietschweiler, D.; da Silva, D.; De Giovanni, M.: Waste Incineration Plants – State of the Art. In: Thomé-Kozmiensky, K. J.; Thiel, S. (eds.): Waste Management, Volume 5. Neuruppin: TK Verlag Karl Thomé Kozmiensky, 2015, pp. 109-127

[3] Pelloni, L.: Incineration – an Indispensable Element of a Responsible Waste Management. In: Thomé-Kozmiensky, K. J.; Thiel, S. (eds.): Waste Management, Volume 4. Neuruppin: TK Verlag Karl Thomé Kozmiensky, 2014, pp. 41-47

[4] Pop, I.N.; Baciu, C.; et al: Survey on household waste composition generated in Cluj-Napoca, Romania during the summer season. In: Environmental Engineering and Management Journal, Vol 14, No.11, Technical University of Iasi, Romania, 2015

[5] Wikipedia, The Free Encyclopedia: Waste hierarchy. Retrieved June 27, 2016, from https://en.wikipedia.org/w/index.php?title=Waste_hierarchy&oldid=731743243

IRF

International
Recovery
Foundation

Bibliografische Information der Deutschen Nationalbibliothek

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.dnb.de abrufbar

Thomé-Kozmiensky, K. J.; Thiel, S. (Eds.): **Waste Management, Volume 6**
– Waste-to-Energy –

ISBN 978-3-944310-29-9 TK Verlag Karl Thomé-Kozmiensky

Publisher: TK Verlag Karl Thomé-Kozmiensky • Neuruppin 2016
Editorial office: Professor Dr.-Ing. habil. Dr. h. c. Karl J. Thomé-Kozmiensky, Dr.-Ing. Stephanie Thiel, M. Sc. Elisabeth Thomé-Kozmiensky, Janin Burbott-Seidel und Claudia Naumann-Deppe
Layout: Sandra Peters, Anne Kuhlo, Janin Burbott-Seidel, Claudia Naumann-Deppe, Ginette Teske, Gabi Spiegel und Cordula Müller
Printing: Universal Medien GmbH, Munich