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Wrong Tracks in Waste Management

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Waste Management is ubiquitous in our everyday life. Economic prosperity and the abundance of materialistic goods imply the generation of waste. In parallel the public awareness for environmentally sound solutions in the field of waste management is raising. This context imposes challenging conditions for political leaders. Often politicians are confronted to take decisions about concepts or investments in waste management without independent expertise. They are approached by vendors of waste treatment technologies or concepts, claiming high environmental and energetic performance, combined with profitable cost – benefit rates.

The truth is, in the last half century many thousands of millions have been invested in failed disposal concepts and technologies. Grave experiences have been made with immature and alternative waste management concepts. Their promises have often turned out to be exaggerated or completely wrong with considerable damage and financial loss to society. In this paper alternative concepts and technologies are lighted in a critical way. It is shown why very often alternative concepts and technologies turn out to be wrong tracks in waste management.

For a century, the goal of diverting non-recyclable waste from landfill and producing energy from this waste has been fulfilled by predominantly grate-based Energy from Waste combustion technologies in addition to fluidized-bed applications (*waste incineration*). It is true, incineration of waste, which is the state of the art technology of today, has already been developed half a century ago. On the first sight the core principle has not changed. But this is only true when the large developments surrounding the incineration process are ignored:

- Modern waste to energy plants have extensive flue gas treatment systems in place which are very often far better than any other industrial process involving combustion.

- The energy from the combustion, contained in the flue gas, is used to generate electricity and district heat or process steam. The efficiency of the system is only limited to the possibility of supplying the process steam or district heat to an appropriate user, which has to be not too far away.
- The main residues from the incineration process, the bottom ashes, contain inert materials which can be gained by a downstream treatment. The revenues of the gained metals like iron, aluminium and copper justify the investment in the current available technologies and are paid off within a few years.

1. Underrated obstacles of waste treatment projects

Project risks can be caused by external events, or any other circumstances, which hamper the project's overall success. The risk can affect the budget of the project, the timeline or the functioning of the scope.

The focus in this chapter is to list the most common risks, which threaten the success of a big infrastructure project in the field of waste management. This chapter is a summary of the lessons learned from many successful and unsuccessful waste to energy projects. It focuses on the relevant risks, which the project owner has to take care for. The project owner is the entity which initiates a project, finances it and profits from its outputs. In the field of waste management, the project owner is typically a city or a larger group of municipalities.

- **No ownership of land**
  It must be one of the first actions of the project owner to secure the land, where he intends to build the project. As soon as details of the project are spread it is easy for opposition to delay or inhibit the transfer of the land to the project owner.
- **Early contract signing with one turn-key supplier**
  Turn-key equipment suppliers are strong in technological aspects. Of course they claim to provide the cheapest solution, when they can solve all technical issues in-house. The truth is, that a contract at an early stage of the project with one supplier is a big risk for the success of the project. The reason is, that non-technical aspects are easily overseen or even ignored. Communication, involvement of all stakeholders, changes in boundary conditions,… these are all aspects which make it probable to change the scope during the course of the project. With a signed contract it can be very difficult to do so, or involve high costs.
- **Secure the waste stream**
  The financial success in operation of the project depends on the revenues the project can generate. In waste management the revenues are mainly dependent on the amount of waste which can be treated and the tipping fee or gate fee which is paid with the waste. If a large fraction of the waste stream is diverted to another facility, the entire project is at risk, as profitability can never be reached. It is very important that the project owner secures at an early stage the waste stream with signed contracts.

- **Underestimating permitting procedures**
  The special legal framework of waste management and the public perception of waste as a problematic issue make the permitting process very time consuming and often cumbersome. It is absolutely necessary to avoid any formal mistakes and be as transparent as possible. The execution of the project can only start when the permitting is concluded. To have impatient business partners, in the worst case with signed contracts and deadlines complicate the project.

2. The limits of separate collection of waste

It looks like a very attractive goal to access valuable fractions in household waste before they are mixed with other waste and collected separately right at the waste producer level. Many problems of household waste start when waste is mixed with various types of material streams. Especially the exposure, even over shorts time, to biodegradable waste fractions make waste sticky, stinky and finally painful to deal with.

The advantage of separate collection are: No contamination from other waste fractions like the biodegradable waste, purer or higher quality waste streams, less or no separation efforts, avoidance of technically complicated handling issues which come with wet conditions of waste.

Separate collection can work under certain conditions and be economically and environmentally viable, like the separate collection of glass bottles. But the reality proves that the path to successful separate collection is long and arduous. Many examples show that goals have been too optimistic and initial results don't last.

In the following the most critical challenges and issues are listed, which show that separate collection is very often a wrong track in waste management.

Challenges and unsolved issues in separate collection

- Psychological aspects: Traditionally all waste is treated in the same way and ends in one garbage bag, which is also the easiest way for the waste producers. Often waste is a topic where people are not willing to spend much attention on. Waste should get out of our way quickly. In order to gain waste fractions right at the waste-producer level, the behaviour of the people has to change.
- Unclear definition for waste producer: The separate collection system must be as easy as possible as it shall be understood by everybody. Especially different plastic fractions are very similar to each other and are easily mistaken. If the waste producers do not understand the exact definitions of the separate collection system, they are also not able to handle the waste in the designed manner. This point is especially complex as the waste market is so wide and under continuous change. There are potentially more waste materials or waste streams existent than designers of a separate collection system think about.

- Economic aspects: Separate collection needs additional infrastructure for the specific waste stream. The infrastructure must be built at large scale in addition to the existing infrastructure. Someone has to be in charge to build and maintain the infrastructure. All these costs need to be covered by the revenues generated from the sale of the separately collected waste stream. Often separate collections systems are only maintained because they are subsidised or have a sponsor.
- Entry barriers and economy of scale: In order to achieve low treatment cost for the separately collected materials, potential treatment facilities shall be as big as possible. However, the large volume must first be gathered on the waste market. This means the collection infrastructure must be rolled out and implemented over a large area. Which imposes high investment costs and big financial risks in case of failure. If the separate collection project is only started in a limited area, the gained material is possibly too little to justify further processing or the resulting treatment cost becomes very high.
- Logistic aspects and transport distance: The separately collected waste must be gathered and transported to the treatment facility. With longer transport distances the economic outlook deteriorates. Compared to municipal solid waste, separately collected waste is always only a fraction and hence a much smaller volume. So for the same size of treatment facility the waste must be transported further. This is not so critical for densely populated areas and cities but becomes more important in rural areas.
- Handling costs due to impurities: Very often the waste stream gained in separate collection is far away from being pure. Many foreign bodies or other waste streams are mixed to it and impose the necessity to have an additional sorting or pre-treatment. The cost of additional sorting or pre-treatment is often underestimated at early phases and question the later viability of the separate collection project.

3. Technologies for thermal treatment of waste

During the last decades, alternative technologies have started to emerge with visions of improved recycling options for the residues remaining after incineration, higher energy efficiencies and even lower emissions. Three classes of alternative thermal waste treatment technology are proposed to the market: pyrolysis, gasification and (as a special group) plasma gasification. This chapter reviews the challenges in these technologies and shows why very often these alternative technologies turn out to be wrong tracks in waste management.

Comparison of the different technologies in the field of waste to energy is difficult, as the field is very wide and new concepts are still emerging. There is a large number of technologies on the market, with a very different level of maturity. Some of the technologies only appear on paper and never make it to a prototype. Some technologies overcome the status of a prototype and reach the status of a small scale demonstration plant. A few large scale plants are actually built, but often struggle with long term operational stability. Only in Japan approximately 20 gasification plants made it to existence, but at much higher treatment costs and under quite different operational conditions than in Europe. This chapter tries to give an answer on the question why the alternative waste to energy technologies often lead to a dead end and cause large costs for the society.

3.1. Chemical processes

In a very broad sense, energy from waste is the process of creating energy in the form of electricity or heat from the thermal breakdown of waste through any thermal conversion technology or combination of conversion technologies. The definitions are not always clearly distinguished and often different meanings are associated under the same keyword. This list explains the technical meaning of the most important steps in thermal conversion of waste, which are at the same time names for alternative concepts used in the field of energy from waste.

- Pyrolysis is the thermal breakdown of waste in the absence of air, to produce char, pyrolysis oil and syngas – e.g. the conversion of wood into charcoal.
- Gasification is the thermal breakdown of waste under oxygen starved conditions (oxygen content in the conversion gas stream is lower than needed for combustion), thus creating a syngas – e.g. the conversion of coal into city gas.
- Combustion/incineration is the thermal breakdown of waste supplying an excess of air, producing a flue gas, mainly containing nitrogen, water vapour, carbon dioxide, oxygen and heat.
- Plasma gasification is the treatment of waste through a very high intensity electron arc, leading to temperatures of > 2,000 °C. Within such a plasma, gasifying conditions break the waste down into a syngas and vetrified slag.

Complete thermal conversion of waste consists of a sequence of pyrolysis, gasification and/or combustion steps. Within a conventional combustion system, these three steps are integrated, whereas in the case of alternative conversion systems, an intermediate product is generated and the combustion step is carried through later. Any thermal treatment begins with a pyrolysis process. If heat and steam or in limited amounts air is added then gasification occurs. If excess amount of air is admitted then complete combustion takes place.

3.2. Motivation for alternative technologies

The motivation for innovation and new technologies shall be to improve the value created for the society. In energy to waste technologies different claims are made, which involve very often the following aspects: reduced overall emissions, no residues, gaining of valuable products from the treatment which can be sold to a high price, generation of higher amounts of electrical energy or thermal energy such as process steam or district heating. In the following the most common claims of some alternative technologies are listed.

Claims for pyrolysis

The claims by providers are the following: Pyrolysis oil and syngas can be utilized as high value fuels in more efficient conversion cycles – such as gas turbines or gas motors – from the char, metals and carbon black streams can be easily recycled with a high product value. Through the pyrolysis route, lower emissions will be generated.

Claims for gasification

The claims by providers are the following: Syngas can be utilized as a high value fuel in more energy efficient conversion cycles – such as gas turbines or gas motors. Through the gasification route, lower emissions will be generated. A number of gasification technologies provide high temperature (> 1,500 °C) vitrification of the ashes, thus improving the recycling of the ashes – however also significantly reducing energy efficiency.

Claims for plasma gasification

The claims by providers are the following: After plasma treatment syngas can be utilized as high value fuels in more energy efficient conversion cycles – such as gas turbines or gas motors. Through the plasma route, zero emissions will be generated. Inert residues are vitrified and recycled.

3.3. Overview of risks of alternative technologies

Every technology has its own working conditions and its specialized equipment which is designed to cope with the unique aspects of the technology. However there are groups of risks which are applicable to all alternative treatment technologies and are therefore listed in the following:

- Project risks:
  - Find adequate equipment suppliers with sufficient experience. The experience must also be related to the size of the project or treated volume.
  - Scaling up of prototype always brings surprises. There is no guarantee that the operation conditions of working demonstration plant can be transferred directly to a large scale waste treatment plant.
  - No or very little long-term experience available on the technology.
- Engineering risks:
  - A new technology needs several years of development. For waste treatment, a plant capacity for at least 100'000 tons per year is needed. Hence, scale up from lab to a technical size needs several engineering steps.
- Operation risks:
  - Process control: The control system is not able to achieve long term stability in operation.

  * Pyrolysis gases contain high amounts of tars, that lead to malfunction of the power generation cycle behind the pyrolysis installation, reducing income,
  * Energy requirement may be higher than considered – for instance for the pre-treatment (shredder) or in view of the production of oxygen that is needed for the process,
  * Hidden operation costs, which have not been accounted for in the budgeting, like premature degradation of refractory material or additional pre-treatment,
- Risk: Maintenance cost and requirements are very high.
  A new technology has new and specialized equipment or uses existing equipment in a new way. Often the new technology exposes equipment to more challenging conditions in terms of higher temperatures, higher pressures or higher vibrations. All these aspects cause wear at the equipment. Sometimes the wear has been anticipated and the parts can be replaced easily, sometimes the wear occurs at a position in the process where replacement or repair is very difficult. Higher maintenance cost and probably higher downtime of the plant are the result. In some cases the wear is so excessive, that a continuous operation of the entire plant is not possible.
- Input material risk:
  * Only very specific input material is suited for the technology. Little changes in composition of the incoming waste have large effects on the stability of the process and its maintenance costs. There is no robustness or flexibility in the technology to cope with the typical variations in solid municipal waste.
  * High requirement for pre-treatment of the waste input, leading to extra costs, like sorting out of foreign bodies or shredding for size reduction.
  * A system of separate collection must first be implemented in order to gain the needed waste and avoid contamination with harmful substances to the technology.
- Output material risks:
  * Calorific value, quality and quantity of produced gases may be lower than designed, thus lowering income streams,
  * Claims of high quality carbon black production (the char) cannot be met, lowering income streams,
  * There is a remaining fraction which needs further treatment in order to be legally disposed or landfilled.

4. Mechanical biological waste treatment

The mechanical biological treatment (MBT) was developed in Germany already in the 1990 when it became obvious that landfilling is not anymore a viable option, but incineration appeared to be too expensive and had strong popular opposition.

The goals of MBT can be summarized as:

- Reduce the volume of waste to be disposed, in order to use the available space in landfills more efficiently,
- Reduce the biological activity of the waste, in order to keep the methane production in landfills at an acceptable limit,
- Reduce the amount of pollutants in the waste, which are potentially transferred to ground water at landfills.

It can be stated that MBT was from its beginning strongly connected with landfilling, so it was never the goal to avoid it but rather to optimize large scale landfilling and to lower its negative impacts on the environment, which have already been well acknowledged at that time.

From 1990 to 2010 various MBT technologies and treatment procedures have been developed and combined under these premises, such as industrialized composting (rotting), anerobic digestion, biological stabilization (Herhoff). All MBT technologies have two main features in common:

- Mechanical treatment of waste, which combines different stages of shredding, sieving and sorting to separate the waste in different streams.
- Biological treatment of waste, which uses microorganisms and chemical reactions for further degradation of the waste.

From 2010 onwards it became obvious that large-scale landfilling was politically no longer accepted and also EU legislation moved towards a general ban on landfills, with less and less exceptions.

These changes in vital boundary conditions, forced the MBT operators to look for new paths for the output materials. Thereby most of the MBT plants, adapted their layout and became so called SRF (solid recovered fuel) or RDF (refuse derived fuel) producers, which describes a high caloric fraction of the waste, containing mainly plastics, cardboards and papers. SRF or RDF can be used in cement plants and power plants as substitutes for traditional fuels such as coal and gas, and have therefore a certain economic value.

However the goal of waste management is not only to offer a solution for the valuable fractions and reduce the rest of it, but to offer a sustainable solution for all fractions in the waste. And this is where MBT plants started to suffer, when legislation became stricter.

Challenges and unsolved issues in MBT plants

The following list gives an overview of the challenges in mechanical biological waste treatment like it has been developed in Germany and Austria in the late nineties:

- Operational issues in mechanical stage:
    * The mechanical stage which comprises typically of shredding, sieving and separation is subject to high wear. The wear is the more aggressive as more sand-like materials are present. Shredder knives need to be replaced regularly, the entire mechanical chain of equipment is worn out after 10 years and needs to be replaced.

 * High electric cost of mechanical equipment. The most energy intensive steps are shredding and ballistic separation with air separators.
 * All air exposed over longer time to waste is polluted and cannot be released to ambiance due to odour issues and sometimes VOC emission limits. Air collection systems and air treatment with bio filters is needed. If the legislation is more strict the bio filters are not sufficient and RTO treatment is necessary, which comes along with high fuel costs.

- Leachate problem:
 * Organic matter in waste decomposes with time. Rain water percolates through waste materials and mobilizes all kind of organic and also inorganic substances. This liquid mixture, with high organic content and a variety of other elements, is referred to as leachate.
 * Leachate is potentially hazardous due to pathogenic microorganisms and toxic substances dependent on the involved waste materials – batteries, solvents, heavy metals etc.
 * Leachate typically has a high ammonia concentrate and can be very aggressive to mechanical equipment, where it causes excessive wear and boosts maintenance efforts.
 * Leachate is ubiquitous where raw waste, with high organic content is stored, handled or manipulated in any way. The proper dealing with leachate, in particular its collection, storage, and treatment, makes municipal solid waste management challenging and needs to be addressed specifically.

- Issues with biological treatment:
 * In the beginning the residues of composting could be put on the landfill, then they were promoted as compost, containing a high content of nutrients as phosphor and nitrogen. But a closer look revealed that all organic fraction which has been exposed to raw municipal waste is contaminated with heavy metals and can therefore not be used as fertilizer. The residues must be treated specifically.
 * Biological treatment depends on continuous activity of microorganisms. The microorganism adapt to the available waste mix over time and need stable operation conditions. Changes in waste composition, in amount of waste feed or climate conditions can hamper the activity of the microorganism to the extent that no degradation of waste is achieved and the system fails to function.
 * Aerobic biological treatment needs fresh oxygen and therefor controlled air exchange. The waste air from the biological stage is highly polluted and has typically a bad smell, it needs to be further treated and causes operational costs.

- Challenges with the production of (SRF):
 * Secondary fuels can be co-fired in cement kilns or power plants, but only if they fulfil certain quality requirements. The most important criterion is the chlorine content. If there is too much chlorine in the SRF huge operational problem in the cement kiln or power plant occur, due to build-ups or corrosion.

* As the chlorine content in raw waste without organics is already too high for SRF, the mechanical treatment needs to lower the chlorine content, enriching another fraction of waste with more chlorine. This fraction needs disposal.
* Only a little fraction of the waste can be recycled or used as SRF. The treatment technology is applied to all the incoming raw waste, resulting in a very low efficiency in terms of energy-effort or entire investment.
* There is always a fraction with no value at the end of the MBT treatment, which cannot be used as resource. Sometimes it is more than half of the incoming waste, which can neither be recycled or transformed to a fuel. Although it is the final output for the mechanical treatment, it is not yet stabilized chemically or physically. It therefore needs further treatment in another type of technology, which again has some treatment cost. Often the residues from MBT end up in a waste incineration plant.

5. Conclusion

There have been many waste treatment technologies invented in the last years and surely more ideas will be developed and tested. But the fact that over the last twenty years the waste incineration embedded in a waste to energy plant has become the state of the art technology in most northern European countries shows a deeper truth about waste.

Waste becomes waste because it is not used anymore and people want to get rid of it. Only when it is collected and concentrated people recognise the value of it. It is the power of economics which pushes for obtaining the valuables of waste. Different efforts are made to gain what is wanted out of the waste, very often subject to national laws and regulations.

However there will always be a fraction of waste which no-one is interested in. May it be a direct fraction from the raw waste or an indirect fraction from a recycling treatment residue. The processing or handling of the last fraction needs an ambassador, because all economically driven interests are exhausted. The best solution for the disposal of this fraction is incineration in waste to energy plants. State of the art waste to energy plants are highly flexible to cope with a wide variety of waste types. The technology is simple in its core and transforms waste into energy and mineralized material, while the emissions are controlled by the best available technologies today:

Every society which wants to abandon landfilling in the long run, has to envisage incineration to some extent. Alternative ways are very risky and can cause great economic damages.

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