In the world economy, the waste market plays a considerable role, this by the very fact that the yearly turnover in the industrialised countries of Europe adds up to over 30,000 million EUR. This attracts serious and less serious stakeholders to splash around. Utopians and charlatans promoted concepts and technologies, which lead to numerous wrong decisions. For Europe, total losses of about 37,000 million EUR are estimated. With the instrument of a simple but clear system analysis, wrong conclusions could be avoided. It is possible to identify utopian concepts as such, and supposed so called innovative technologies can be examined if they fulfil the goals really.

1. Introduction

Waste management is regulated mainly by environmental laws, what means by ecological criteria. Regulations bear the concept that waste material shall be either disposed or landfilled. Landfilled materials must have no harmful impact on soil, water and air. They must be converted into a state like the crust of earth, free form organic bioactive substances.

The way of avoidance of waste or its direct disposal occurs quasi by itself, as the driving force is of economic nature.

Appropriate regulations and concepts should base on these simple basic findings. Unfortunately, this is not always the case, as it will be shown in this paper.

Note: For statements and examples in this paper, waste is generally considered as domestic waste.
2. What is waste?

A simple definition would be: Waste is a material with a value of less than zero, or mathematical:

\[ w = \sum_{n=1}^{t} m(n) \times p(n) < 0 \]  

(1)

whereas \( w \) = specific value of waste related to mass with \( t \) components, \( m \) = mass fraction of waste component \( n \), \( p \) = specific value related to mass of component \( n \). \( p \) includes the expenditures for treatment to a marketable product or to make it feasible for landfilling.

An example:

Kitchen slops consists of about 80 percent water, 15 percent solid organic waste and five percent solid inorganic waste [5]. With the organic part, it is possible to generate energy. For this, the organic substance must be largely dewatered, for allowing a burning process. The costs for dewatering, drying and incineration are higher than the benefits from energy production, even considering the sale of the residuals from incineration as fertilizer.

\[ w = 0.8 \times 0 + 0.15 \times (A+B) + 0.05 \times 0 \]

\[ A = \text{benefit from energy recovery} = 20 \text{ MJ/kg} \times \text{Yield: 0.3} = 6 \text{ MJ/kg @ 0.15 EUR/kWh} = 0.26 \text{ EUR/kg} \]

\[ B = \text{dewatering + drying costs} = -0.350 \text{ EUR/kg} \text{ (mean costs for larger sewage treatment plants)} \]

\[ w = -0.09 \text{ EUR/kg} \]

This is the reason why there is always a fee for the disposal of sewage sludge which has a similar composition as kitchen slop. Referring to the above-mentioned definition, it must be classified as waste.

*Note: if wet fermentation is applied for energy recovery, only a part of the organic material is eliminated. The goals of disposal are not yet achieved (see chapter 4.2.)*

3. The zero-waste society and recycling rates

The emergence of waste correlates strongly with the gross domestic product (GDP) or wealth. History shows that governmental regulations for reducing waste production – like taxes or fees – may help to minimize the increase rate. The goal of a waste free society is quite far away and will remain a utopia. Why?

The civil society lives in a cycle of goods which is given by demand, consumption and production. Today, a billion-population must be supplied with food, commodities and investment goods. This implies a corresponding infrastructure and logistics, whereas packaging plays a dominant role. A society aiming to live without today’s amenities and health standard needed to go back to middle ages (Figure 1).
Avoiding waste makes sense for example where functional properties are optimized accordingly. The prevalence of tools of everyday life with complex material composition disables a direct re-use.

An excrescence of the zero-waste ideology is the specification of recycling rates. Such a regulation finally leads to a recycling at any costs. This requirement corresponds to a planned economy and its failure is well known.

In earlier times, rag and bone man went through the streets, and they picked up for free material which was not anymore useful for the people. Apparently, the collected material had for them a value > 0. Their successors today are waste disposal companies which collect for free some pre-selected material, such as paper, cardboard, glass or metals. The remaining material is waste. Its disposal is – or should be – regulated by the public authorities.

Time and again, this well-tried concept is put into question.

With the help of a system analysis, a meaningful assignment of tasks between political goals and economy shall be shown. Figure 2 depicts these interactions: the goals and boundary conditions are set by policy, namely laws and regulations. The processes within the system must be optimized to fulfil these requirements. This is clearly an issue for the economy. Included in these economic tasks are eventual recycling processes and corresponding sub-goals.

Figure 1: Zero Waste Society: Pieter Bruegel the Elder, Everyday Life in the Middle Ages
Countries with successful economies apply this concept. In analogy, this fact is also valid for a successful waste management.

It can be concluded that pre-setting of a recycling rate is not meaningful. It would disturb the already optimized elements and interactions within the system. Is there a limit for recycling?

A qualitative approach related to entropy and value of material in the waste treatment path is illustrated in Figure 3.

This diagram illustrates, that there is a residue with a value of < 0 after each treatment step. In practice, this is always the case. Ideally, the residue with negative value (and high entropy) has inert properties, that means earth crust alike and can be landfilled or used as filling material.
Figure 4 shows the diagram with a semi-quantitative classification by assigning values to different classes of valuable material. For material above the 45°-line, a recovery can be profitable (price base 2017). Below the 45°-line, earnings are less than treatment costs and a separate recovery makes no sense. The costs for recovery must include:

- appropriate logistics for collection,
- quality control,
- pre-treatment, including purification,
- processing costs to marketable product,
- marketing costs,
- disposal costs for residues.

Currently, there is a political dispute related to recycling of plastics. The essential question is about benefits and costs. In practice, the balance is in general negative, so long as no subventions flow (for example anticipated fees for disposal), as shown in a study from the Swiss Federal Office for the Environment [1]. Treatment costs for recycled PET (polyethylene) sum up to 400 to 600 EUR per tonne [3]. The question arises whether it is convenient to recycle, considering that the treatment costs for thermal recovery are lower by 200 to 400 EUR per tonne.

Today, about 6 to 7 percent of crude oil consumption is used for plastics production [8]. So long as fossil fuels are available at today’s price range, the production of new and pure plastic base material will remain the favoured choice. Re-use of recycled plastic would also threat the quality of the raw material and its derived products.
Considering that a thermal recovery is possible, after all the energetic content can be recovered. Furthermore, plastic parts bound or doped with metals like computer chips, circuit boards, micro drives, etc. cannot be extracted by mechanical means. The plastic matrix must be mineralized. This process enables to recover the precious metals which mostly are present in trace concentration, like gold, silver, tin or niobium. The best feasible technology was proven to be incineration with subsequent metal extraction from the residues. The latter process was developed and is today state of the art [8].

4. **Innovative** and biological processes for waste treatment

Waste has a negative image, due to its nature or as stated above, its negative value. Nobody would steel waste. One wants to have it out of sight and get rid of it. For doing this, one pays for this service – just to remind: exportation of waste is in effect importation of a service.

The market for this service is considerable: In a developed country about 500 kg of waste per year per person is produced and the disposal costs are about 75 EUR per tonne. Europe with its 400 million inhabitants generate a market volume of about 30,000 million EUR per year, with a growing potential, despite prevention and recycling. This is a treasured market, and it attracts serious and less serious participants.

Waste management became a task for the public authorities. Politicians, as representatives of the sponsorship, bear responsibility for the implementation of the rules and regulations. Danger lurks for them to fall for charlatan’s line. In the last fifty years, this happened numerous times. These cases were failed projects, mostly connected to so called **innovative** technologies and were praised to be modern and economically and environmentally feasible.

The debacles have one common cause: The decision makers were bedazzled by sexy attributes, with **innovative** and **biological** on the charts. The propagation of these catchwords follows the dynamics of the spread of memes [2]. Sexy memes infiltrate the receiver through the emotional way. A rational judgement is missed.

In Europe, at least fifty projects were realized with **innovative** technology [4]. All of them failed. With an assumed mean investment of 100 million EUR per project it results a total of 5,000 million EUR. Furthermore, between 330 and 450 plants with mechanical and biological waste treatment were built in Europe what corresponds to a capacity between 33 and 46 million tonnes per year [6]. Assuming mean investments of about 50 million EUR per plant, 2,000 million EUR are resulting. The total of false investments sums up to 7,000 million EUR.

Not included are the extra costs for unnecessary treatment. Assuming 50 EUR/t for unnecessary mechanical and biological pre-treatment, an operating time of twenty years and an interest rate of 3 %, about capitalized 30,000 million EUR are resulting.

Why did these projects fail?
4.1. **Innovative** technologies

The common basic concept of these technologies is a thermal treatment in a reductive atmosphere. This leads to a pyrolytic reaction which produces gas. This gas can be used as fuel.

In practice, however there are many obstacles which only can be overcome with very high expenses. One handicap is the composition of the pyrolysis gas, which gets homogenous only at a reactor temperature of above 1,800 °C. At these conditions, very high requirements for material and plant operation are needed. With lower reactor temperatures, unwanted by-products are generated like soot or tar. An operating time of 7,500 hours per year – a standard for modern incineration plants – cannot be achieved. In best cases, about 4,000 hours per year were reached. Applying this technology for waste treatment would be the same as using a Ferrari for tilling a field.

Nevertheless, it is proposed consistently by newcomers from outside the waste treatment sector, with a new name. The basic concept is still the same [4].

What are well-tried solutions?

Waste has heterogenous structure and composition. This demanding property requires to a waste treatment plant much higher standards than for example conventional fossil fired power plants. The suppliers and operators of feasible plants with high availability are representatives from a highly specialized industry. The core knowledge cannot be gained at universities. It is acquired during decades with operating plants. Today, more than 2,000 waste incineration plants are in operation worldwide. They mineralize waste to physically and chemically stable material which today is further processed, to extract precious metals as mentioned in chapter 3.

Plants with state-of-the-art technology recover energy and valuable material from waste. This ultimately corresponds to a recycling process. This successful solution is a result of an evolution over more than a hundred years, during which would be revolutionary technologies dropped out.

4.2. Biological treatment processes

The first waste incineration plants were not equipped for energy recovery, not to mention with a flue gas treatment. At the beginning of the 1980s, thanks to environmental standards, such equipment was installed. In the following years, environmental regulations became tightened. Today, incineration plants can be operated even in rural areas without any hazard. However, the old image remained inherent in public opinion.

The temptation became obvious to choose a *green* technology for waste disposal. The biological treatment was propagated in the 1990s, mainly in Germany. It was regarded as an environmentally friendly solution for waste treatment. Numerous mechanical biological plants (*MBA*) were built. The product from these plants were mainly biogas and waste with a moderately lower content of organic matter.
This process fails by its concept. The main output corresponds more-or-less to the input, which is usually shredded due to the required pre-treatment. In Germany, this shredded waste is classified as refuse derived fuel (RDF). It must be treated in appropriate plants, which basically are identical to waste incineration plants.

It can be concluded from these facts that biological waste treatment makes no sense, even not as pre-treatment. There are no advantages. In contrary, the total disposal costs are at least fifty percent higher than the direct way without mechanical and biological treatment.

Earnings from sale of biogas are by far not sufficient to compensate these extra costs. The energetic recovery is limited. In the best case, about thirty percent of the organic biogenic part of the waste is converted into biogas. The total organic part of domestic waste is about seventy to eighty percent.

Production of compost with the rest of the organic part is not feasible because of harmful substances present in the waste, such as heavy metals. These cannot be extracted by mechanical means.

Biological treatment does therefore not fulfil the goal of up-to-date standards for waste disposal.

Figure 5 shows a comparison of the basic performance properties between biotreatment and incineration.

![Biotreatment vs. Incineration](image)

Figure 5: Basic performance properties of biotreatment and incineration

Despite this fact, some national and regional waste management plans still specify mechanical biological treatment plants. The possible causes for this policy are:

- Biological treatment sounds of soft technology, there is no risk for public opposition
- The lobbies of suppliers of such plants and landfill owners are active on all levels from politics and authorities, using the sexy attributes like *soft technology* or *biofuel*. 
5. Conclusion

How can these wrong ways and decisions in waste management be avoided?

- Identify the utopia

A feasible instrument for this aim is a thorough system analysis. The essential elements are the superordinate goals and boundary conditions. With this, the proposed concept can be examined for answering the question about fulfilling the set goals what utopia don’t. Mainly they follow an ideology and focus only on elements of the system which are of their interest.

- Avoiding charlatans

Charlatans apply sexy attributes like innovative or biological. Their concepts are at most in a status of development. The prove of practical application in a technical scale is missing. Technically and economically feasible operation over a reasonable time frame (at least two years) is missing.

Rely on companies or consultants with a proof of experience in practice. Given the complexity and the character of a specialist field, they should exhibit an expert knowledge from at least twenty years, with the appropriate references of success.

6. References

Several plants in Germany have been provided with this technology. Figure 8 shows a plant, realised with a dry hydrator for a Ca(OH)₂ production capacity of approximately 3 t/h.

As an alternative, there is the possibility to install the dry hydrator close to the additive can now be injected directly into the reactor without temporary storage in a silo. Figure 9 shows such a dry hydrator as well as the corresponding WtE plant.

Figure 8: RDF incineration plant EEW Premnitz / Germany

Figure 9: Dry hydrator and corresponding WtE plant.