# Energy from Waste: A path to a sustainable development

## Introduction

Waste to Energy (WtE) is discussed often very technology-oriented, with incineration being the most prominent technique. There are, however, more aspects to be considered under a sustainable solid waste management (SWM) system, using resources more efficiently and enabling a future oriented local and regional development.

The world population is continuously increasing and so is the global economy. Besides population growth, waste production and energy consumption are influenced by a particularly fast growth of urban areas in lower (LIC) and middle income countries (MIC). These areas are demanding more electricity and producing more waste. In many cases, not/low industrialized countries give only subordinate importance to SWM in their political agendas and the infrastructure and organizational system of SWM and energy supply are insufficient. This results in a waste of resources and energy, social problems and environmental harm.

Meanwhile, the necessity of covering the energy demand in these countries often leads to strategically poor solutions that mostly contribute to climate change and non-sustainable use of resources. A change of paradigm is necessary: waste is to be considered a resource and not a problem because of its important amount of energetic value and potential for secondary resources. A long-term sustainable solution can only be achieved if the right conditions are created, well prepared and planned in advance. Specific solutions for LIC and MIC have to be designed, based on the existing framework conditions.

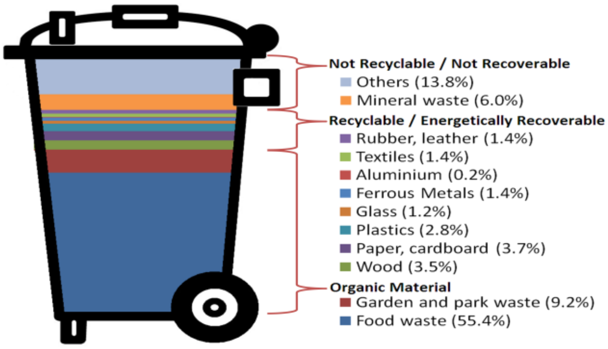
This topic sheet discusses the connections between waste and energy, focusing on the possibilities for development cooperation that arise from the idea of waste as a resource for energy saving and energy generation.

## Waste has a large potential as energy source

Typically, there is a high content of organic material in the residues of LIC and MIC. Biomass that is deposited on landfills or dumping sites degrades and releases methane and leachate. Integrated SWM prevents the contamination of air, soil and water. On one hand, the usage of biomass for compost reduces the energy needed for the production of chemical fertilizers and can bring comparable high-quality compost. On the other hand, biogas can be produced by the fermentation of biodegradable materials and can be used as fuel or in a heat engine to produce either mechanical or electrical power.

Furthermore, the content of recyclable material is important. Recycling focuses on re-purposing material and thus saving raw material and energy in the production processes, e.g. the production of Aluminium from recycled material needs 90% less energy than from raw material. And finally, material that cannot be recycled but has still high calorific value, such as plastic bags, can be used as alternative fuel. Figure 1 illustrates the typical waste composition in an average waste bin of LIC. More than 76% is organic or recyclable material.

**Figure 1. Typical waste composition in LIC**




Source: Own illustration with data from KfW (2008); supplemented by assessed shares of aluminium, nappies, wood and minerals and adjusting the "others" fraction

The **first priority** of a SWM system is to keep those areas clean where people live. This **reduces health risks** for the population by removing wastes from the residential areas. Especially LIC focus on public hygiene.

> AGRESU focused on this priority in **Mozambique**, where the municipality of Maputo and GIZ collaborated. 250 new jobs were created by establishing new small enterprises for primary waste collection. 450,000 inhabitants of sub-urban areas received SWM services.

The **second priority** is to prevent **environmental hazards** through an environmentally safe way of waste disposal of waste in to prevent contamination of soil and water sources. This is a typical measure in most of the MIC. These

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countries have mainly already solved the problem of reducing direct risks for the population. They have usually established a disposal site, where all the waste ends up. However, these dumpsites are often managed poorly and their contamination level is high. To prevent this, leachate and gas have to be collected and treated. Even though environmental pollution is prevented as far as possible, covering a landfill is only an "end of the pipe" solution that does not exploit all available resources.

An even **wider dimension** is characteristic when looking at **waste as a resource**. This comprises enhanced, efficient production processes, waste reduction strategies and recycling and/or valorisation activities. The energetic use of wastes can contribute to the power supply in LIC and MIC, if the different actors are involved in the preparation and implementation of the strategy step by step on middle to long term base. In order to identify options for recovering energy and raw materials from waste, it is important to analyse the composition of the waste stream and check on the potential of each fraction.

Figure 2 shows the different focuses of SWM of a country depending on its level of development.

**Figure 2. Strategy and Priorities of SWM with different stages depending on development**

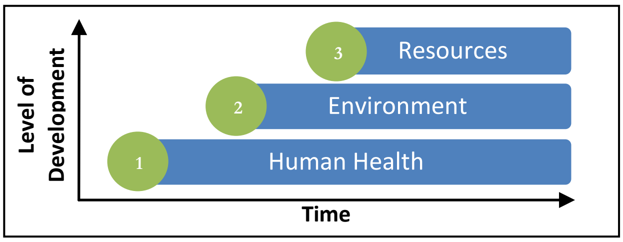
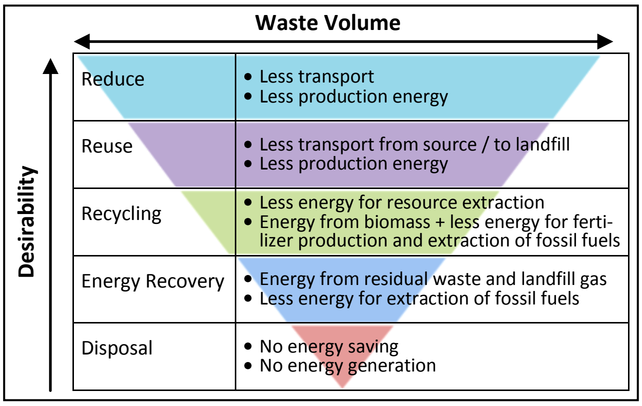



Figure 3 shows the preferable waste hierarchy and complements these three levels of priorities from a more technical point of view. This is based on the fact that the best waste is waste that is not being generated (**reduce**) and a large quantity of the nowadays wasted material can be **reused**. Depending on the technology and separation grade, different materials can be **recycled**. Energy recovery can occur in different stages. While thermal use of waste for energy production competes often with recycling concepts, biogas production from organic waste generates additional values without competing with other treatments. After applying these different steps, only little material is left for final disposal.

**Figure 3. Waste hierarchy and its relation to energy**




This 4 R strategy: **R**educe, **R**euse, **R**ecycle and **R**ecover energy reduces important quantities of resources, energy, greenhouse gases emissions (GHG) and reduces space requirement in landfills.

## How to implement a 4R strategy?

The implementation of these steps varies from one country to another. There is no unique solution; various factors influence on how to determine individual solutions. Copying high-income country's (HIC) solutions have often failed. Therefore the following aspects have to be considered:

- All technologies depend on the preconditions of the waste management system and will only work if they are synchronized as a system
- Thermal treatment competes with recycling of high calorific materials (mainly plastic)
- Recycling in MIC and LIC is mostly managed by waste pickers
- The capacity to pay for SWM is considerably lower
- Local governments are mostly responsible for providing SWM services and charging fees, but capacities are often scarce
- Include all relevant actors in the change process
- A solution needs to consider the local conditions

## Key elements of SWM

SWM can be divided into the steps of collection, transport, treatment and disposal.

All of these steps are to be considered in a sustainable waste management with optimized recovery of resources.

### • Collection and transport

Mixing up waste lowers its monetary value as all processes are more effective if the raw material has a good quality. Dirty paper gets a lower price than clean paper and contaminated biomass cannot be used as a high quality fertilizer. Therefore, separation is the key to a resource oriented SWM system. Energy recovery from a mixed waste stream is expensive and from a resource utilization point of view highly inefficient for many reasons. Mechanical separation and purification requires technology or a large amount of labour - under not very favourable conditions - while the results will always be suboptimal. The cheapest separation process is separation at the source. In LIC and MIC, almost no separation at the source is applied; but informal waste pickers recover and separate up to 20% of the materials and reintroduce them in the processing industry.

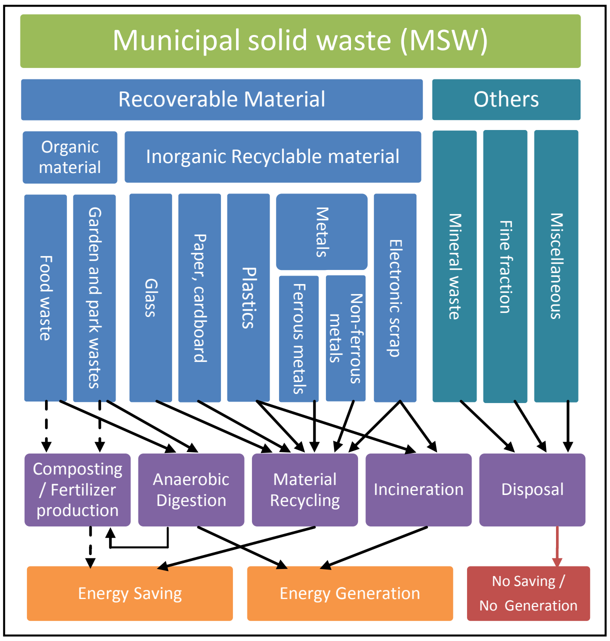
It is essential to count on the adequate SWM infrastructure for separate collection and transport systems which have to consider aspects such as waste volume, labour security, financial and legal aspects, personal, availability of resources and production capacity. Usually, collection and transport consumes most of the financial resources in SWM. Therefore transfer stations can help to reduce transportation costs. For waste to be treated in central plants, a flexible system of collection and transportation is needed which can support both source separation systems and conventional systems and deliver materials to the processing sites.

### • Treatment and disposal

Modern treatment technologies for the recovery of energy using wastes can be broadly classified as either biological, thermal, biochemical or chemical processes. For household and commercial waste, the mostly applied processes are biological and thermal treatments which will be briefly explained below.

Figure 4 shows the alternative treatment processes for each waste fraction.

**Figure 4. Scheme of municipal solid waste composition and treatment solutions**




## a) Biological Processes

In a biological process only organic wastes are treated, so that the output can be used as energy and/or fertilizer.

- **Composting**

Composting is a classical first step in a process of organized reuse of residual materials. Composting can be implemented on a centralized but also on decentralized scale and with comparably low technology demand. Quality and value of the produced compost depend highly on the input material. As the composting process requires mechanical treatment and does not generate energy, this process is considered as favourable to the climate by reducing methane emissions, but does not make use of the waste's energy content.

GIZ has accompanied a series of composting projects in its SWM activities, i.e. **Chile**, **Mexico** or **Thailand**.

- **Anaerobic Digestion**

During anaerobic digestion, organic material is decomposed in the absence of oxygen. A sub product of this process is methane gas which can be used for combustion. The main biogas production occurs in a digester, whose operating parameters have to be precisely controlled. The effluent can be used as a liquid or solid fertilizer with qualities also depending on the input material. If desired, a composting phase can be added to the digestion plant. This process is of interest in countries where energy has a high value because of high prices or undersupply and where large quantities of organic waste occur and availability of landfill space is low.

## b) Thermal Processes

The main objective of thermal processes for waste treatment is to reduce the volume and achieve an inert state and/or recover the embodied energy.

- **Incineration**

In many HIC, waste is incinerated in special facilities designed and built specifically for the purpose of disposing of municipal waste for producing energy. Like all other energy generation facilities, incinerators are to be designed in accordance to specific properties of the very heterogeneous material of solid waste. A critical aspect is emissions which have to be controlled. Therefore, modern plants count with sophisticated filter systems. The installation of incinerators in LIC is not recommended if environmentally critical emission factors cannot be guaranteed (e.g. because of missing legal frameworks or lack of enforcement of regulation).

As large state of the art incinerators require a comparably large minimum input amount per unit, competition with recycling concepts for high calorific material occur often also in industrialized countries. Especially promising recycling markets still to be established will suffer by competing with incineration.

- **Co-Processing in industrial plants**

Co-processing refers to the use of waste materials in industrial processes, such as cement, lime, steel production or any other large combustion plant. Primary fuel and raw materials are substituted by waste, recovering energy and secondary resources. Waste materials used for co-processing are referred to as alternative fuels and raw materials (AFR).

- **Gasification and Pyrolysis**

Gasification and pyrolysis are based on thermal decomposition at high temperatures, where combustible gases or energy rich 'pyrolytic oil' are burned in turbines or generators.

Large scale gasification and pyrolysis technologies for mixed wastes have not yet been proven to be economically viable for treatment of solid waste streams and should therefore not be considered in LDC and MIC.

## c) Disposal

Worldwide, the dominant methods of waste disposal are land filling or open dumping. Although these disposal methods have low initial costs, there are a number of serious side effects like local air and water pollution (open dumping), the production of bad odours and health problems for people living close to the disposal site. Further, the sites release the potent GHG methane.

- **Sanitary Landfill**

In comparison to dump sites, emissions from sanitary landfills are controlled and the filling technique is managed, which reduces the risks of slides, fire or contamination of the surrounding environment. The soil and underground water are protected by using a liner and a drainage system, while often the landfill gas (partly methane) is collected. In most of the landfills in LIC and MIC, the gas is being ventilated and in some cases flared in order to reduce its global warming potential (mainly motivated by CDM-credits). In very few cases energy from landfill gas is already used for electricity generation; as grids are in many cases not available at the landfill sites or feeding in tariffs do not exist.

Because of their disadvantages, to produce costs of collection and treatment of leachate and mainly not used landfill gas and the hereby resulting waste of usable resources, Sanitary Landfills should be considered as interims solutions on a way to a resource efficient waste treatment.

## Treatment costs

An important issue for deciding on the adequate SWM and treatment System is the cost aspect. Initial investment costs but also future treatment and operational costs can vary widely between low tech and high tech solutions (Table 1).

**Table 1. Cost comparison for investing in treatment systems**

| Costs (Euros/ t waste) | Min. | Max. |
|---|---|---|
| Controlled dump/landfill without gas collection | 3 | 5 |
| Sanitary landfill | 12 | 20 |
| Biological stabilization + landfill | 15 | 25 |
| Mechanical-biological treatment + landfill | 40 | 60 |
| Mechanical-biological / Mechanical-physical stabilization + co-processing in cement kiln | 50 | 80 |
| Incineration | 90 | 150 |
| Recycling of dry waste | 0 | 5 |
| Composting | 20 | 40 |
| Digestion | 60 | 90 |

Source: KfW estimates from "Manual SWM-GHG Calculator", BMZ, KfW, GTZ, 2010

Nevertheless, revenues for generated energy and recycling, emission reduction and fees for waste treatment have to be included in the total costs calculation. Considering all aspects higher investment for adequate technology often generates positive results and enables further development in the value chains of new energy and recycling markets.

A study of costs for waste management and possible technologies in different scenarios in **Morocco** showed that the recycling and energetic recovery option would generate more income, less environmental and better social effects than the pure capture of methane of the landfill. Despite of the higher investment costs of this option, the economic effects were more favorable.

## Conclusions

The link between waste and energy offers an interesting potential for win-win solutions. A deeper analysis can reveal options for new energy sources, better resource efficiency, mitigation of GHG and a reduction of other negative environmental impacts. Waste to Energy (WtE) is more than just technology; it requires a well structured SWM strategy, which needs to integrate environmental, social, and energetic aspects and the incorporation of relevant stakeholders into a strategic movement. There is no "one-fits-all solution" for SWM. Questions such as sound institutions and proactive policies, inclusivity and financial sustainability are key factors for a successful SWM system.

Nevertheless, end-of-pipe technologies like land filling are only short or medium term solutions. A strategy should also establish a vision on a long term base and consider this in framework conditions and instruments. Inhomogeneous and dirty waste fractions do always cause higher costs for treatment than separated materials which have a value depending on their characteristics (e.g. energy content).

Existing technologies need to be analyzed and adapted to local conditions in LIC and MIC. Separate collection in households requires a large effort of public awareness building and incentives to be implemented, but can be a benefit for different groups of actors. Therefore the process has to be developed stepwise.

## Recommendations

- The cheapest waste is waste that does not get produced; Therefore the cascade of priorities: Reduce, Reuse, Recycle with Recuperation of Energy (especially from organic material) shall be considered as an orientation.
- Waste is to be considered as a resource that can be used if adequate strategies and concepts are implemented. The energy potential has to be analyzed, based on the composition, distribution and volume of waste.
- Separation of waste at the source reduces treatment costs and optimizes quality and value of output material.
- A sustainable system requires long term planning in order to be able to react to market development for energy and resources.
- The informal sector can be an experienced partner for collection and sorting activities.
- To implement a sustainable waste to energy strategy, the following aspects have to be considered and aligned:
  - State of development of the SWM sector
  - Existing infrastructure for waste and energy
  - Availability of treatment technologies
  - Legal conditions, investment costs and income
  - Know-how in operation and management of plants
  - Capability of national/local government to control environmental impacts and implement new SWM structures.

## References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Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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