WBA fact sheet

ENERGY RECOVERY FROM WASTE

SUMMARY

Waste management is a fast growing environmental business in the world today. One of the many solutions of dealing with the huge amount of waste is to create energy from it. Energy is recovered from the waste either in the form of electricity and/or heat, biogas and other transportation fuels after the primary treatment of waste. There are different methods to produce energy in a waste to energy plant (WtE) but it is dominated by combustion processes. The feedstock for WtE plants is mostly comprised of municipal solid waste (MSW) collected from the residential and commercial sector. The annual global waste generation accounts for 7-10 billion tonnes in total, out of which approximately 2 billion tonnes are categorized as MSW. Hence, there is a dire need to take care of this increasing problem. Advantages of using an energy recovery from waste system are:

- It reduces the volume of waste upto 96%.
- Production of heat and electricity along with solid waste management.
- Better sanitation, lower risk of contamination and diseases.
- WtE facilities are designed for high emission control
- It has climate change impact as producing energy from waste avoids potential emissions from landfilling

INTRODUCTION

The World Bank defines Municipal Solid Waste (MSW) as non-hazardous waste generated in households, commercial and business establishments, institutions, and non-hazardous industrial process wastes, agricultural wastes and sewage sludge. In practice, specific definitions vary across jurisdictions.

The world is facing a major global issue of municipal solid waste management. With the ever-growing amount of MSW generation globally, there comes a need to use MSW as a resource in a sustainable manner. The very need of a sound MSW management strategy in every country arises from the two biggest concerns undisposed waste brings along with it: health and environment.

Photo: Pixabay

Open dumping site.

Public Health

Solid waste has direct impact on the health of the community. If the solid waste is burned out in the open, it produces uncontrolled emissions of pollutants in the air and ruins the land, making it barren for a long time. More importantly, the emissions lead to various respiratory issues. If it is left out in the open, it becomes a breeding ground for various diseases, like cholera, dengue, malaria, etc. If it is dumped in an unsustainable manner, it can cause problems for the settlements near the dumpsites as well as for the rag pickers. Moreover, unsustainable dumping can pollute waterways or block waste water streams leading to spread of diseases.

Environmental Wellbeing

Open dumpsites are a major problem. They cause public health issues as well as environmental ones. The production of methane in such dumpsites makes it a source of greenhouse gas (GHG). If the dumpsite is near a water body, it makes the water body prone to pollution too. Exposure to open dumpsite has a greater ompact on population's life expectancy than malaria. In 2000, city of Payatas (Philippines) suffered from municipal dumpsite collapse on the slum in its vicinity after 10 days of rains. The landslide killed around 300 families and left many homeless. It happened because of high leachate levels, landfill gas pressures and unstable slopes of waste.

Though, a Waste Management strategy is a costly affair in low income and middle income countries, it stands as the largest employer too. A city which fails to provide this basic service to its citizens usually face many problems regarding health. In middle and low income countries, the costs due to the problems created are 5-10 times more than what it would require for solid waste management per capita. (UNEP, ISWA, 2015)

Waste generation globally

In 2012, the global MSW generation rates from cities were approximated at 1.3 billion tons MSW per year at a rate of 1.2 kg per person per day. They also estimated that this number would increase to 2.2 billion

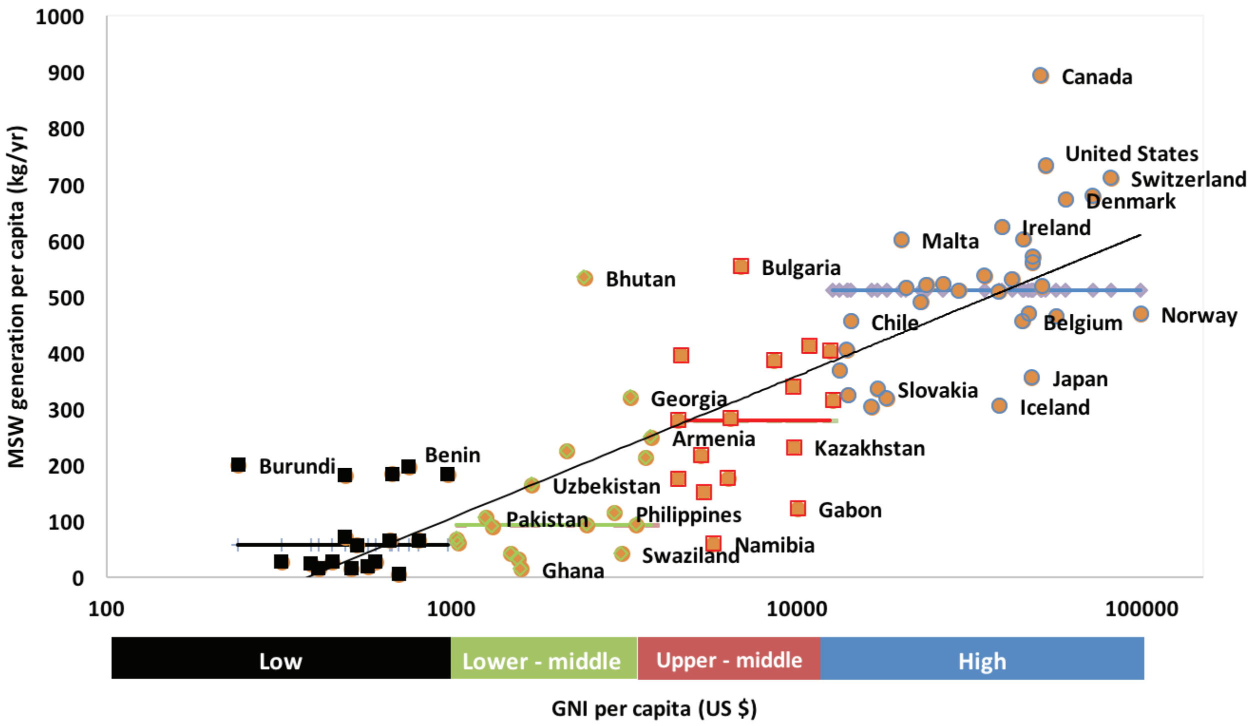

Figure 1: Waste generation versus the income level of the country. Source: (UNEP, ISWA, 2015)

tons of MSW per year by 2025. (Hoornweg D, 2012) This creates a need for a better waste management in the days to come. Even though, in the past decade, there was an increase in waste, waste management sector has changed a lot too. From being a sector which deals with primary treatment and management of waste streams to a sector which provides energy for the community.

The generation rates are highly dependent on the income level of the country. Other major influencing factors in MSW generation are rate of industrialization, urbanization, public habits and local climate. (UNEP, ISWA, 2015) There is a clear relation between the income level and MSW generation of a country as seen in the Figure 1.

Waste Heirarchy

According to the EU directive 2008/98/EC for waste management, the EU member state shall follow a waste hierarchy, where in, the state should strive to avoid creating waste at all. If waste is created, it should go through these stages, re-use, recycling, recovery and disposal as shown in the Figure 2. (European Union, 2008) It is also noted that, countries with high proportion of material recycling also resulted in high energy recovery. Hence, separation of waste at the source level, ultimately affects the energy recovery process too. Though, material recovery is better than energy recovery, the latter has found its niche when it comes to materials that are not recyclable, such as soiled or contaminated materials, composite materials and materials which have no value and are deteriorated after several recycling processes.

Waste Composition

The composition of the waste varies from country to country. MSW consists of organic materials, paper, plastics, glass, metals, textiles and other waste. The composition of MSW varies depending on the income level as discussed above. The low and middle income level countries have a higher organic material composition whereas the higher income countries have a lower percentage of organic material in their MSW. The reason for a higher organic content is that the other fractions have more values in low income countries and therefore enter informal re-use cycles without ending up in the MSW stream. The organic matter can be upto 88% and the paper content could be upto 46% as can be seen from Figure 3. (Hoornweg, 2012)

Waste recovery

The waste composition affects, treatment as well as collection of the waste. If the waste is wetter and denser, it has a low calorific value and hence the energy recovery process becomes more difficult. Also, the cost of waste transportation increases. The calorific value of MSW also changes around the world ranging from 4-12 MJ/kg. (ISWA, 2013)

Waste is managed based on its properties and hence the energy recovery methods vary accordingly. Different methods like material recovery, biological treatment and energy recovery must be used in the right mix to make the best use out of the waste. (Avfall Sverige, 2008)

Contrary to the conventional combustion technologies, energy recovery technologies' economic performance is positively affected by the input waste fuel prices. Waste has a negative price and is regulated often, forming the basis of major source of income for the WtE plant owners. Apart from this, generation of electricity and heat is another source of income. The major costs associated with these plants are the investment and maintenance

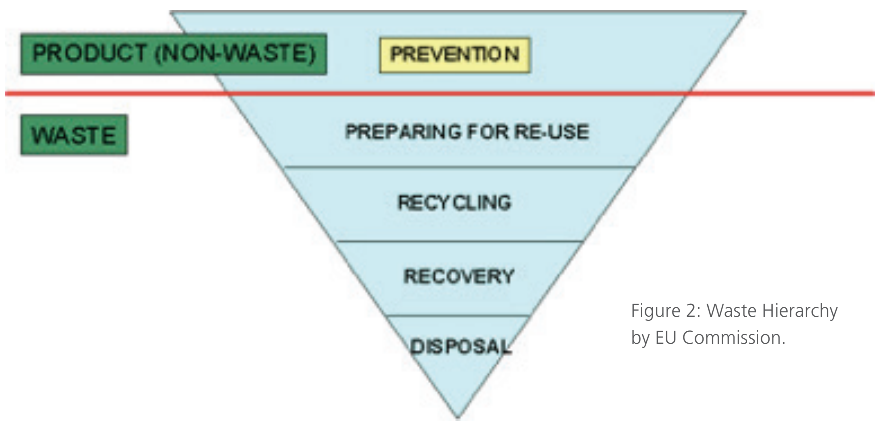

Figure 2: Waste Hierarchy by EU Commission.

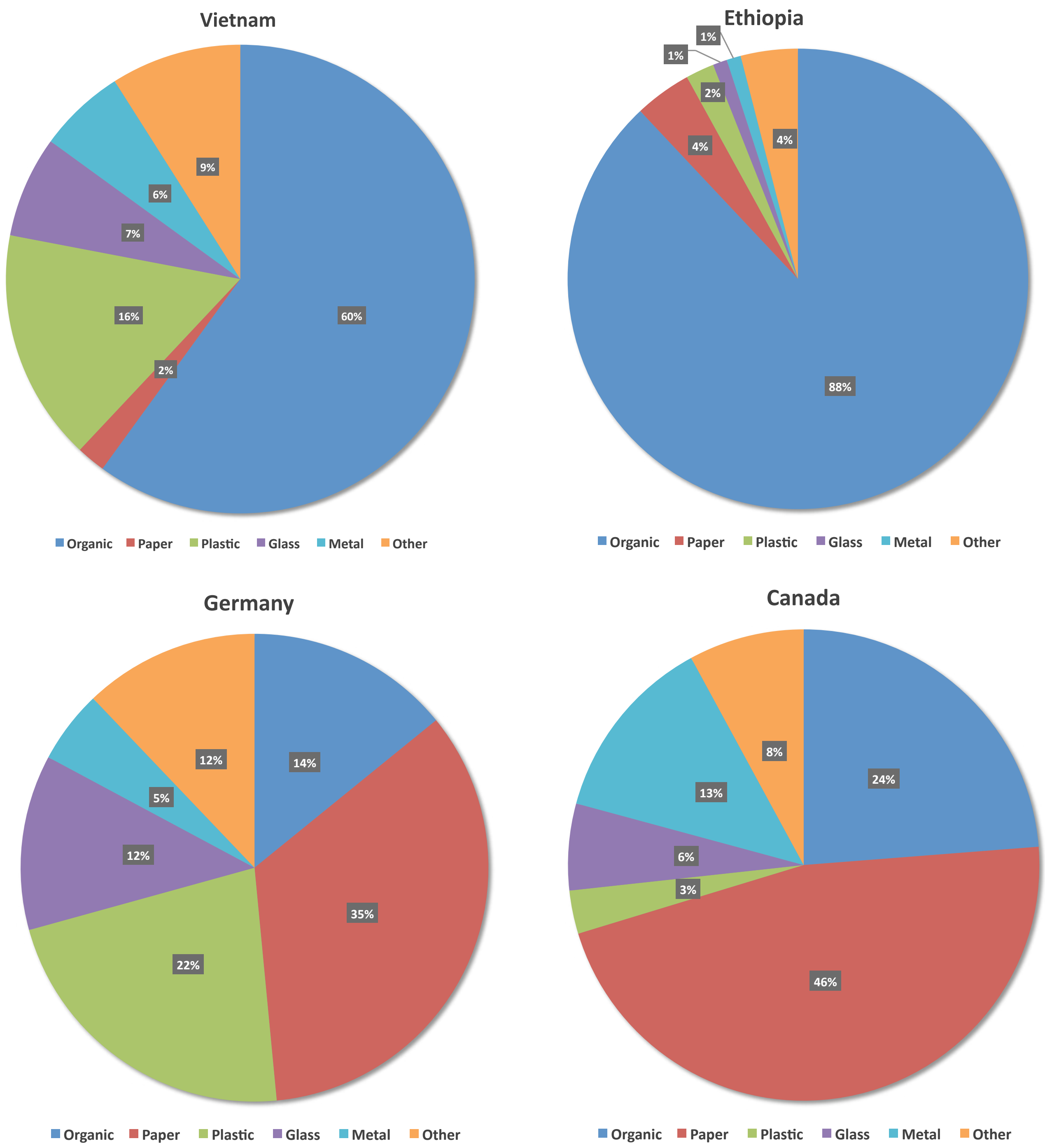

Figure 3: Comparison of MSW Composition of low income and high income countries. Data Source: What a Waste, The World Bank

costs. In general, the cost for WtE plant, depending on location, size and other factors is estimated at about $650 - $1000 per annual ton capacity (WTERT, Waste to Energy International 2015) . In low income countries this might cause unregulated dumping, which is seen a cheap solution.

The primary objective of any energy recovery facility is to treat the waste so as to avoid any possibility of spreading of disease and contamination due to it. The secondary objective is energy recovery from the waste. WtE plants are generally based on furnaces which have boiler for energy recovery and a flue gas cleaning system to ensure that minimum emissions are released and often also generates additional heat by flue gas condensation. WtE plants in Europe have the strictest environmental requirements. Though, incineration is the dominating technology in this sector, other technologies have also proven useful as discussed below.

Basics of a WtE incineration plant

Incineration is a widespread technology used in WtE plants all over the world. The process flow of incineration with energy recovery (WtE) is discussed below:

Input: The waste arrives in trucks which delivers and hurls the waste in the bunker. An overhead crane controls the grab bucket and the waste is released to the hopper, from where it is fed to the furnace. The overhead crane is also used to properly mix the waste so that a uniform incineration is achieved.

Combustion: The temperature in the furnace reaches around 1000 °C, using just the waste as a fuel. The waste burns in the presence of air and bottom ash falls on the bed whereas the hot flue gases rise upward. The ash is made of metals and a mineral part. The metals can be recycled and the mineral part can be recovered (e.g. in road constructions) after further treatment.

Energy recovery: The heat produced inside the boiler through the combustion is transferred to the process water that turns into steam. An optimization of the steam parameters as temperature and pressure is required in order to achieve a high efficiency from the process. The superheated steam is transferred to a turbine, which generates

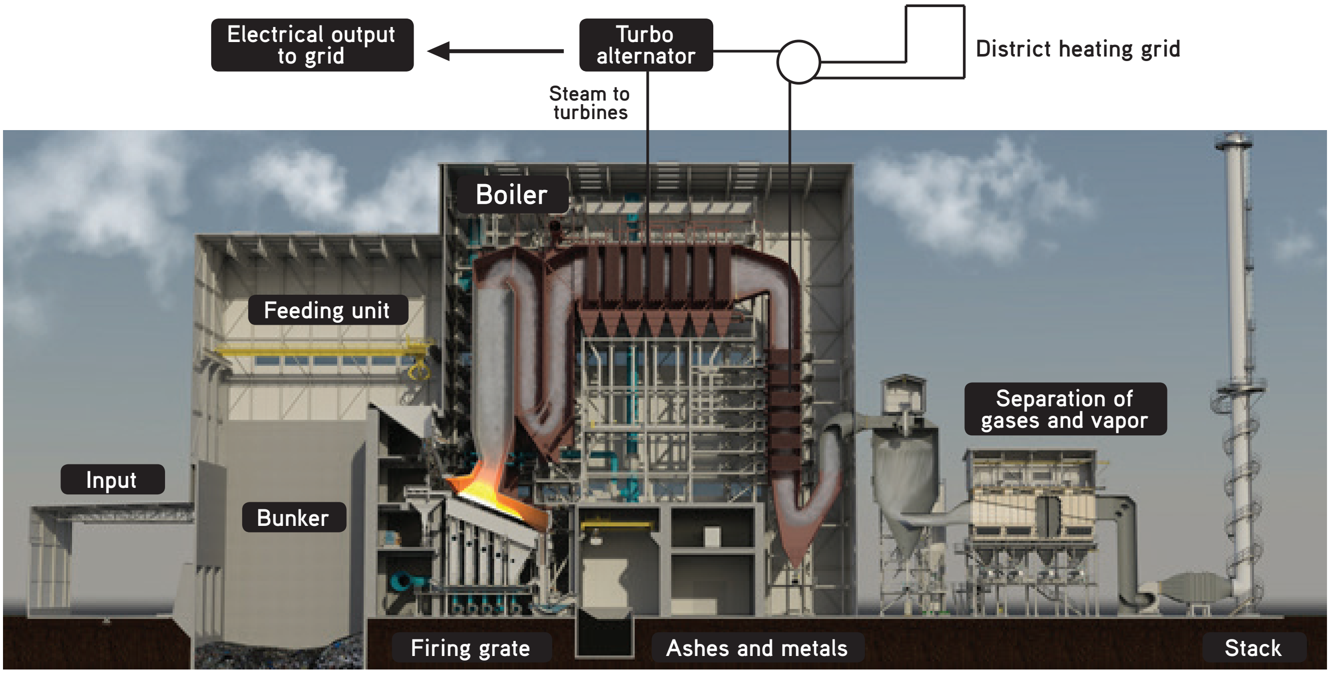

Figure 4: Schematic illustration of wate to energy incineration plant (with kind attention of Keppel Seghers)

electricity that is fed into the network.

Residual heat: The residual heat from this process can be used for feeding a district heating network with hot water, and then the steam is finally condensed and sent back to the boiler pipes through a pump.

Flue gas treatment: One vital part of such a WtE plant is the removal of toxic and acid gases released during the incineration of the waste. Different types of process such as wet, semi-dry or dry systems are used to clean the flue gases. The choice between them is depending on local constraints and technological advancements. All these systems are being used all over the world especially in Europe.

Wet treatment: In a wet process, initially, the flue gas passes through the electrostatic precipitator or bag house filter, removing all the dust. The dust is collected in an ash silo. Then, the flue gases pass through scrubbers which are basically washing down the flue gases in an acid stage before a second stage where water can be mixed with lime to clean the gas properly. The first scrubber cleans the heavy metals and acidic substances. The next scrubber removes the Sulphur dioxide. The last scrubber stage could condense most of the moisture in the gas and could deliver an additional 20% of energy as heat to a district heating net. By using a special packing material in the scrubber stages dioxins can also be taken out from the flue gases.

Dry treatment: Dry flue gas cleaning is also a common process. It is based on an injection of a very fine dry powder of lime or sodium bicarbonate downstream the boiler. This reactive agent captures the acid gases. A bag house filter collects downstream the dust, the reaction salts and the reactive agent in excess. Active carbon is also injected for an efficient capture of dioxins and gaseous heavy metals such as mercury. An electrostatic precipitator (ESP) could be added upstream between the boiler and the dry injection if fly ash has to be collected after the boiler, but it is optional. Some variants of dry process consist first in the flue gases temperature adjustment by cooling them in a heat exchanger or an evaporative tower and second in the recirculation of the dry mixture from bag house filter to reduce the excess of reactive agents with a lime reactivation by water or steam injection for example.

Semi dry treatment: Another possibility is the semi-dry process which is based on the injection of lime milk instead of the dry powder. This liquid is evaporated in a spray dryer absorption tower and this forms a fine "fog" of dry lime powder. The fabric filter is used to separate all reaction products, heavy metals and dust from the flue gases in one step.

Emissins cleaning: Another stage of cleaning is for reduction of nitrous oxides. One possibility is a selective catalytic converter installed downstream the main flue gas cleaning equipment. The flue gases pass through a fine, porous material and are brought in contact with ammonia water in the presence of a catalyst like titanium oxide. This converts Nitrous oxides into Nitrogen at low temperature with the help of the catalyst. The gas is finally clean enough to be released in the open air. This type of cleaning is called Selective Catalytic Reduction (SCR). The other possibility consists in Selective Non-Catalytic Reduction (SNCR). Reductants in the aqueous form (ammonia water or urea) or gaseous form (ammonia)are injected into hot flue gases in the furnace at high temperature which results in the formation of nitrogen in a non-catalytic way. SCR and SNCR are both used in Europe.

TECHNOLOGY

Uncontrolled dumping and landfilling used to be the solution for the MSW generation around the globe. The motivation to shift the regime from landfilling to different technologies was driven by the following concerns: potential water (groundwater, rivers and sea) pollution through leachate, scarcity of space, methane emissions from landfills and spread of pathogens. EU policy introduced a step by step approach to divert biodegradable waste from landfills. Many countries in Europe went beyond this and banned landfilling of waste that can be recycled or combusted. Some introduced high landfill taxes in Europe. Europe started investing and innovating in the energy from waste sector. Now, the waste to energy sector is dominated by the incineration technology in the EU with strict rules on emissions from the plants. USA and China also adopted the incineration technology to produce energy.

Thermal Technologies

Incineration is one of the initial technologies developed for the waste to energy system. Also known as direct combustion, it was originally designed to reduce the volume of the waste using combustion, but was later used to recover energy (electricity and heat). All the incineration WtE plants in the OECD

Facility in Shenzhen, China. Phase III Baoan WtE is built with Keppel Seghers technology. The plant will process waste equivalent to 46 truckloads every hour, or 9000 tonnes per day. The energy produced is enough for 3 million citizens or 13 million 40W light bulbs. This will replace the generating capacity of 700 000 tonnes of coal each year, with the effect of cutting CO_2 emissions by around 2 million tonnes per year.

countries have to meet strict emission standards after directive 2010/75/EU. The use of incineration in these countries has significantly reduced the usage of landfilling which used to emit a large amount of methane, that has a Global Warming Potential (GWP) 28 times bigger than carbon dioxide. Detailed explanation of the process is available in the previous section.

Though, incineration plants are benchmark in the energy recovery platform and still under development for example to rise steam temperatures to 500°C to further enhance the electricity efficiency, there are proven and emerging technologies being used to produce energy from waste without direct combustion. These technologies claim to increase the electrical efficiency of the whole system by removing the corrosive components from the converted fuel, hence better combustion temperatures are achieved.

One example of a the new plants built today with Keppel Seghers technoogy is the Phase III Baoan WtE as in the picture above.

This facility will be of its kind the biggest in the world with processing capacity of 3 million tonnes per year.

Gasification process converts carbon containing material into an energy relatively poor syngas by partial oxidation, mainly composed of a mixture of carbon monoxide and hydrogen with traces of water vapour, nitrogen and carbon dioxide. The technology is not developed in comparison to the incineration process for solid waste but this technology might hold potential. It might reach an overall higher efficiency with a better gas quality. Japan and Republic of Korea use this technology for the past 20 years. Syngas is directly burned downstream the gasifier, mainly for a purpose of direct melting of a part of residues taking in consideration the specific quality of MSW in these countries.

In Europe, developments were made, for e.g. Lahti Energy's Kymijärvi II power plant which was the first gasification power plant in the world to efficiently generate electricity and district heat from MSW. At the plant, MSW is gasified, the gas is cooled and cleaned before combustion. The plant produces 50 MW electricity and 90 MW district heat for the city of Lahti. Other regions in Europe are trying to develop it. It also has a potential in India because of increase in small gasifiers. For more information, refer the WBA Factsheet Thermo-chemical Gasification of Biomass.

Pyrolysis is a thermo-chemical conversion of organic material under the absence of oxygen at high temperatures. This results in irreversible changes of the fuel. The resultant product can be both syngas and biooil depending on the speed of pyrolysis. Because of the low quality of these products obtained from MSW, they are generally burned directly in a post combustion reactor. There is still research going on in this technology so as to operate it at large industrial size level.

Plasma Arc Gasification uses plasma arc with the help of carbon electrodes, copper, tungsten, hafnium or zirconium to reach gasification temperatures. The plasma temperature ranges from 2200-11000 °C which creates a high value syngas. This technology can be used to reduce waste, even hazardous and still generate energy. It produces lower NOx, SOx and CO2 emissions due to higher temperatures and it has no odour as for combustion. Currently, this technology is being used in Japan in around 10 plants (Cicero 2009), but only one is in commercial operation for MSW.

Non – Thermal Technologies

Anaerobic digestion is a biological conversion process which occurs under the absence of oxygen with anaerobic microorganisms. It can handle both wet and dry feedstock. It produces energy rich biogas composed of a mixture of methane and CO_2 and digested residue. The biogas can be used to generate electricity and heat or to produce biofuels. The residue can be used as a fertilizer for soil if it is produced according to the regulations with adapted feedstock. The major problem with this technology is that it needs a good process control due to the presence of microorganisms and hence any change in conditions can disrupt the process. Also, it requires a consistent input of homogenous waste and hence, organic part of MSW should be used. Small scale digesters are pre dominant in rural areas in developing countries.

In Europe and US, this technology is used to treat wet waste and sludge, but also to produce energy from biomass such as corn.. There were around 13800 plants in Europe and 2200 plants in US , mostly installed in farms and fed with biomass. In Asia, this technology is used in a widespread manner for the production of biogas with around 40 million plants in China, nearly 5 million in India and 300,000 in Nepal. (REN21, 2014)

Landfill process produces methane in a large quantity. An uncontrolled release of methane is harmful for the environment because it has a higher GWP (28 times bigger than carbon dioxide). The accumulation of the gas can lead to fire safety hazard. Hence, the gas should be safely collected in a controlled manner. The gas can either be used to generate electricity or it might be converted into a liquid fuel after cleaning. Energy recovery from landfill gas is prevalent in developing countries.

Photo: Pixabay

Garbage collection in cities.

POLICIES AND REGULATIONS

Most of the countries in the EU have a well established waste management system. The reason EU has such a strong focus towards material and energy recovery is because of the strict environmental rules and regulations revolving around the landfill dumping of waste. In US, it is cheaper to dump the waste in landfills. The landfill tipping fee in US is about 44 USD per ton in comparison to 193 USD per ton in Sweden (Gershman 2013).

European Union

In EU, the **Council Directive 1999/31/EC** on the landfilling of waste obliges Member States to minimize biodegradable waste to landfills to 75% by 2006, 50% by 2009 and 35% by 2016, and to treat it before disposal. The Directive also defines wastes which are not to be accepted in any landfill and sets up a system of operating permits for landfill sites.

According to the **Directive 2010/75/EU** on industrial emissions, the European Union imposes strict operating conditions and technical requirements on waste incineration plants in order to prevent or reduce air, water and soil pollution caused by the incineration of waste. The directive requires a permit based on best available techniques and emission limits are introduced for certain pollutants released to air or to water.

The **Waste Framework Directive 2008/98/EC** on waste provides for a general framework of waste management requirements and sets the basic waste management definitions for the EU. It laid down some important laws like "Polluter pays principal" where the producer has a significant sense of responsibility of the products being generated and the environmental pollution and waste along with the products and hence aim at the reduction of the waste. It also put down the waste hierarchy as discussed in the introduction. (European Union, 2008)

USA

The **Solid Waste Disposal Act** was the first attempt by US Federal government to improve the waste disposal technology. Due to the increase in waste generation, the act had to be amended and in 1970 it was changed to Resource Conservation and Recovery Act (RCRA).

RCRA gave Environmental Protection Agency (EPA) the authority to control haz-

DEFINITIONS OF MUNICIPAL SOLID WASTE

IEA

Municipal waste consists of wastes produced by households, industry, hospitals and the tertiary sector that are collected by local authorities.

European Commission

Municipal waste is mainly produced by households, though similar wastes from sources such as commerce, offices and public institutions are included. The amount of municipal waste generated consists of waste collected by or on behalf of municipal authorities and disposed of through the waste management system

OECD

Municipal waste is defined as waste collected and treated by or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, as well as yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste if managed as household waste. The definition excludes waste from municipal sewage networks and treatment, as well as waste from construction and demolition activities. This indicator is measured in thousand tons and in kilograms per capita.

ardous waste. This includes the generation, transportation, treatment, storage, and disposal of hazardous waste. RCRA also set forth a framework for the management of non-hazardous wastes. It also banned open dumping in US. Though, there are laws in US regarding waste disposal, the laws are not comprehensive enough as compared to the EU.

WASTE LOGISTICS

Waste collection is another important aspect. The collection system ensures that public health is maintained in a community. The method of collection depends on the country and the income level of the country. It can also vary widely within the country. In the global arena, the average waste collection coverage ranges from as low as 41% in low income countries to 98% in many high income countries. South Asia and Africa tend to have low collection rates with 65% and 46% respectively (Hoornweg D, 2012). This has a direct impact on the efficiency of the solid waste management system. Waste collection can be done in several ways (Hoornweg D, 2012):

1. Individual Household Collection: The waste is collected from each house individually. The user has to pay a fee for the services.
2. Community Trash Bins: The users bring their MSW at a single place in a neighborhood or locality and it is picked up by municipality services.
3. Curb – side pick up: Users keep their MSW in front of their houses according to the pick up service schedule.
4. Self Delivery: The users have to deliver the waste to the facility either themselves or using some 3rd party service.

Waste is typically collected in bins or containers. In some countries loose bags are collected where storage space is not enough to house bins or containers. Automated waste collection systems are used in some countries, predominantly in Europe and Asia, for denser urban developments. Waste and recyclables are stored underground and air transported from each house long distance underground to a collection station from where it is picked up in containers for recycling or WtE. Other collection systems include underground containers, with and without compactors that provide more waste storage than on ground bins and containers. Depending upon the regulations of the country, the collected MSW is either mixed or separated before treatment. The consumers are advised to separate waste at the source into organic fraction and non - organic fraction. This segregation eases the process of sorting for recycling. Though, in some developing countries, the recyclables are segregated manually by the waste pick-

TABLE 1: REGION WISE WASTE GENERATION

REGION	WASTE GENERATION (Kg/Capita/Day)
Sub – Saharan Africa	0.65
Eastern and Pacific Asia	0.95
Eastern and Central Asia	1.1
Latin America and Caribbean	1.1
Middle East and North Africa	1.1
OECD	2.2
South Asia	0.45

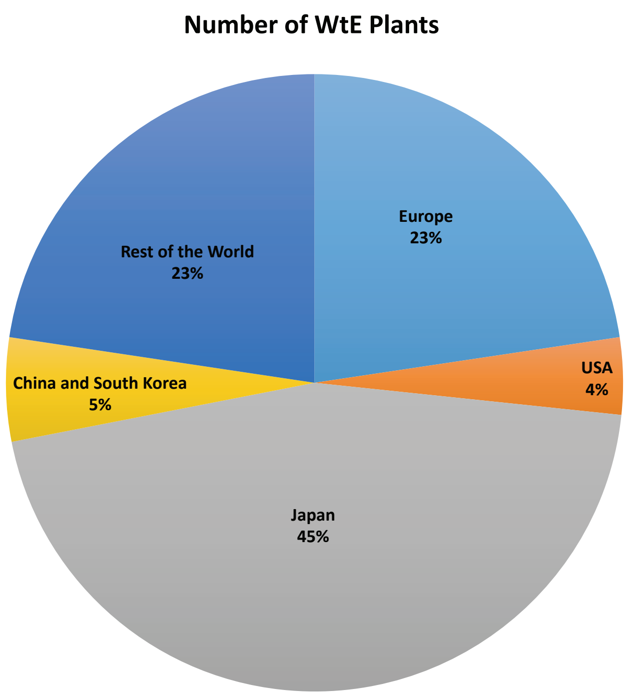

Figure 5: Waste to energy plants around the world. Data Source: (ISWA, 2013)

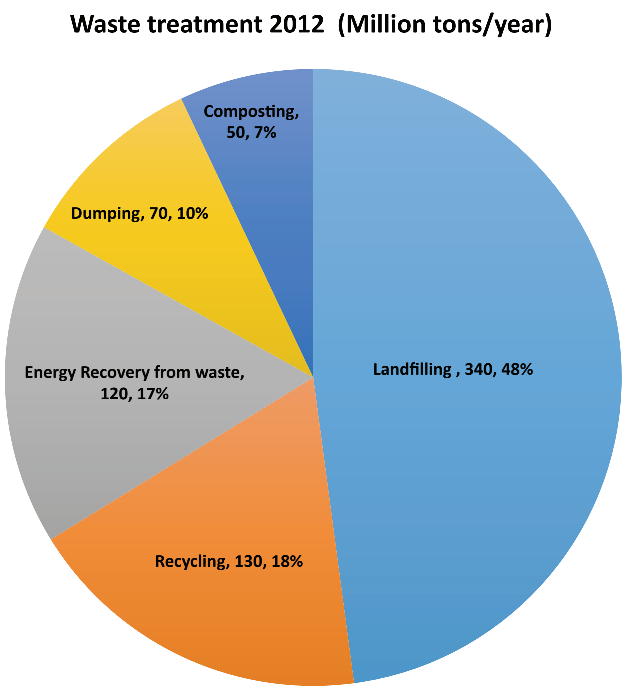

Figure 6: Worldwide waste treatment technologies (ISWA 2013)

ers and hence the process is inefficient. For example, in Buenos Aires, waste pickers remove the recyclables from the garbage and hence create scattered waste. Hence, there is an additional cost of removing the scattered waste. (Hoornweg D, 2012)

FEEDSTOCK

The composition and amount of the solid wastes from a municipality varies depending on the "level of economic development, cultural norms, geographical location, energy sources, and climate" (Hoornweg D, 2012).

Waste composition is a very important aspect because it affects the characteristics like density, moisture content and calorific value. These characteristics affect the choice of technology, the efficiency of the plant and the overall waste management system. With the increase in plastics, paper and packaging content in high income countries, the calorific value has also increased. Whereas the increased organic content in low income countries make the waste wetter, reducing the quality of MSW.

The renewability of the feedstock is a big debate. The energy produced from the biogenic part of the MSW is considered to be renewable in nature. Generally, more than 50% of MSW is biogenic with organic fraction, paper, cardboard etc. Hence, more than 50% of the energy generated from MSW can be considered renewable. (European Union, 2009) The percentage of renewable energy from waste can be increased if proper usage of resources is practiced by the consumers. The segregation of the waste during the source itself plays a major role in the increased efficiency of the plant as well as the renewability of the feedstock.

GLOBAL USAGE

In 2013, there were 2,200 waste to energy plants operating in the world as seen in figure 5. These plants utilized 255 million tons of waste per year. By 2017, another 180 plants with a capacity of 52 million tons will be added. Most of the waste to energy plants have been installed in areas like Europe, Japan, China and the USA because of higher investment opportunities. In US, there are 89 plants - about 12 % of waste is combusted for energy recovery mostly of the mass burn incineration type. Compared to the US, European Waste-to-Energy Plants can supply 38 TWh of electricity and 88 TWh of heat, from 88 million tons of residual household and similar waste that was treated in 2014 in Europe. Japan has incineration plants because of low landfill space. (Planning Commission of India, 2014)

Landfilling remained the major form of waste treatment as seen in figure 6 but the scenario is changing with major focus on recycling and energy recovery from waste around the world. Dumping has been reduced but the health impacts of landfilling remain very high, as do GHG emissions. Open dumping is responsible for 10% of global methane emission. The type of waste disposal treatment depends upon the income level of the country, higher the income, better the technology applied. (IEA Bioenergy, 2014)

The energy recovery sector has developed a lot in the past few years. It holds a lot of potential in the future. In an optimistic scenario, it can play a role in the energy security of a country and can be beneficial in reducing the energy poverty around the globe. The resources, if managed properly can become a source of energy rather than being a menace for a community.

POSITION OF WBA

Waste is a major problem in every nation around the world. Moreover, with increasing migration of population from rural to urban areas, the challenge of managing municipal solid waste will be immense in the coming years. Increasing amount of waste coupled with mismanagement means rising costs for governments and a bigger impact on the environment and public health. The most prominent and ineffective mode of disposal is via landfills.

WBA promotes that managing of waste should follow the heirarchy structure - reduce, reuse, recycle and recovery with the last option of disposal. Efficient utilization of resources is the first step followed by energy recovery. Countries in the Nordic region are already pioneers in resource efficiency and energy recovery so much so that some countries have to import waste to satisfy energy demand in the country.

Various technologies and pathways already exist in the conversion of waste to energy including incineration, gasification, pyrolysis, anaerobic digestion etc. Strict emission rules ensure that the waste is effectively utilized with lower impacts on the environment. The cost of conversion and feedstock logistics are some of the challenges which have to be addressed along with strong policies preventing dumping and incentivizing recycling and energy recovery should be promoted. Key is proper information dissemination among the general public. Good data on global waste production and utilization is also another key challenge to be addressed.

WBA believes that energy recovery from waste will be a major sector in the future enabling cities and regions to be energy secure, reduce dependency on fossil fuels and efficient utilization of resources.

SOURCES

1. Milan Brahmbhatt, A. D. (2008). *On SARS Type Economic Effects during Infectious Disease Outbreaks.* The World Bank. East Asia and Pacific Region: The World Bank.

2. UNEP, ISWA. (2015). *Global Waste Management Outlook.* UNEP.

3. Hoornweg D, B.-T. P. (2012). *WHAT A WASTE, A Global Review of Solid Waste Management.* The World Bank.

4. European Union. (2008). DIRECTIVE 2008/98/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 November 2008 on waste and repealing certain Directives. *Official Journal of the European Union.*

5. David C Wilson, L. R. (2012). *Comparative Analysis of SWM in 20 cities.*

6. Avfall Sverige. (2008). *Towards a greener future with Swedish Waste-to-energy, The world's best example avfall sverige.*

7. ISWA. (2015). *Circular Economy: Energy and Fuels.* ISWA.

8. Cicero, L. J. (n.d.). *California Energy Commission.* Retrieved from http://www.energy.ca.gov/: http://www.energy.ca.gov/proceedings/2008-ALT-1/documents/2009-02-17_workshop/presentations/Louis_Circeo-Georgia_Tech_Research_Institute.pdf

9. REN21. (2014). *RENEWABLES 2014 GLOBAL STATUS REPORT.* Paris: REN21.

10. IEA Bioenergy. (2014). *Waste to Energy, Summary and Conclusions from the IEA Bioenergy ExCo71 Workshop.*

11. Harvey Gershman (2013). *The US can Learn From Sweden.* Renewable Energy from Waste

12. European Union. (2009). *DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL* of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. Official Journal of the European Union.

13. ISWA. (2013). *Alternative Waste Conversion Technologies.*

14. IEA. (2013). *IEA Statistics.* Retrieved 07 08, 2016, from IEA: http://www.iea.org/statistics/statisticssearch/report/?year=2013&country=WORLD&product=RenewablesandWaste

15. Planning Commission of India. (2014). *Report of the Task Force on Waste to Energy (Volume I).*

16. WTERT, *The ABC of Sustainable Waste Management, http://www.seas.columbia.edu/earth/wtert/faq.html*

17. Waste to Energy International, *Cost of incineration plant, https://wteinternational.com/cost-of-incineration-plant/*

World Bioenergy Association, Holländargatan 17, SE 111 60 Stockholm, Sweden

Tel. + 46 (0)8 441 70 80, info@worldbioenergy.org, **www.worldbioenergy.org**