This publication provides the summary and conclusions from the workshop 'Waste to Energy' held in conjunction with the meeting of the Executive Committee of IEA Bioenergy in Cape Town, South Africa on 21 May 2013.

The purpose of the workshop was to provide the Executive Committee with an overview of waste to energy both at a global level and in the context of an emerging economy. The aim was to stimulate discussion between the Executive Committee, Task Leaders, invited experts, and various stakeholders and thereby to enhance the policy-oriented work within IEA Bioenergy.

Waste to Energy

Summary and Conclusions from the IEA Bioenergy ExCo71 Workshop

Spittelau Energy-from-Waste Plant, Vienna, Austria

IEA Bioenergy

IEA Bioenergy: ExCo:2014:03

INTRODUCTION

The IEA Bioenergy workshop on Waste to Energy (WtE) was held in conjunction with the IEA Bioenergy Executive Committee meeting ExCo71 in Cape Town, South Africa in May 2013. The workshop consisted of three sessions – *Waste Management, Technologies of Waste Treatment and Approach for Communities.*

WORKSHOP

IEA-Bioenergy chair Birger Kerckow welcomed the participants on behalf of IEA Bioenergy and highlighted the importance of proper waste treatment as part of bioenergy production and greenhouse gas (GHG) mitigation.

While the collection and upgrading of municipal solid waste (MSW) in Europe had reached a high standard, there were increasing problems in other parts of the world.

Currently, cities worldwide generate about 1.3 billion tonnes of solid waste per year.[1] This is expected to increase to 2.2 billion tonnes by 2025. Waste-generation rates will more than double over the next twenty years in lower-income countries. Cost increases will be most severe in low-income countries (more than fivefold increases) and lower-middle-income countries (more than fourfold). In lower-income-country cities, solid waste management is usually a city's single largest budgetary item.

The global impacts of solid waste are growing fast. Solid waste is a large source of methane, a powerful GHG that has particularly strong short-term impacts. Locally, uncollected solid waste contributes to flooding, air pollution and public-health impacts such as respiratory ailments, diarrhoea and dengue fever.

Meanwhile, the recycling industry is now a global business with international markets and extensive supply and transportation networks.

The host country South Africa, as an emerging economy, has made first steps into modern waste collection and treatment by introducing a White Paper on Integrated Pollution and Waste Management (IP&WM) and the National Waste Management Strategy (NWMS), published by the Department of Environmental Affairs and Tourism[2] in 1999 and 2000 respectively. South Africa now supports the waste hierarchy in its approach to waste management, by promoting cleaner production, waste minimisation, reuse, recycling and waste treatment, while disposal is seen as a last resort.

It will be interesting for South African representatives from government and communities as well as for ExCo members to compare actual activities in the host country with experiences from other emerging countries, as well as with the most developed technologies in Europe and elsewhere.

Session 1 – Waste Management

STATUS AND FUTURE OF WASTE TO ENERGY IN SOUTH AFRICA

Cristina Trois, Dean and Head, School of Engineering, University of KwaZulu-Natal, South Africa

Cristina Trois' overview was based on a year-long University of KwaZulu-Natal study on waste management and GHG emissions in African countries, which started in 2002. The focus of the study was on assisting local authorities in the design of waste management strategies. The aim was to provide a quantitative estimate of the potential for GHG reductions and landfill space savings that can be achieved through ad hoc zero waste strategies, assess their economic feasibility, and thus address knowledge gaps regarding the quantity and quality of the local MSW stream.

Solid-waste management in developing countries and emerging economies is generally characterised by highly inefficient waste-collection practices, variable and inadequate levels of service due to limited resources, lack of environmental control systems and appropriate legislation, limited know-how, indiscriminate dumping, littering and scavenging and, most of all, poor environmental and waste awareness among the general public.

It has been estimated that over 60 million cubic meters of waste was produced in South Africa in 2010; 90% of this was managed by local authorities and was disposed of in landfills, at an estimated total cost of over ZAR10 billion per annum (1ZAR=7US$). More recent figures from the DEA (2012)[3] indicated that 108 million tonnes total waste was generated, of which 98 million tonnes was landfilled and only about 10% recycled. This indicates huge potential for improvement.

In a project of the United Nations Centre for Regional Development (UNCRD) and the Province of KwaZulu-Natal's Department of Economic Development and Tourism (DEDT), KwaZulu University examined all of Africa's 62 political territories; only seven had potential for more advanced waste-to-energy projects. In South Africa only three municipalities – Johannesburg, Cape Town and Durban – had begun waste recycling towards the implementation of larger waste-to-energy projects. The focus of Trois and her team was on biogas from waste. In the DEDT project they also had the opportunity to study more deeply the possibility of gas recovery in the three largest landfills of Durban.

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1 World Bank (2012), What a Waste: A Global Review of Solid Waste Management, March 2012, No.15.

2 Now separated into the Department of Environmental Affairs (DEA) and the Department of Tourism.

3 DEA (2012), National Waste Management Strategy, Department of Environmental Affairs.

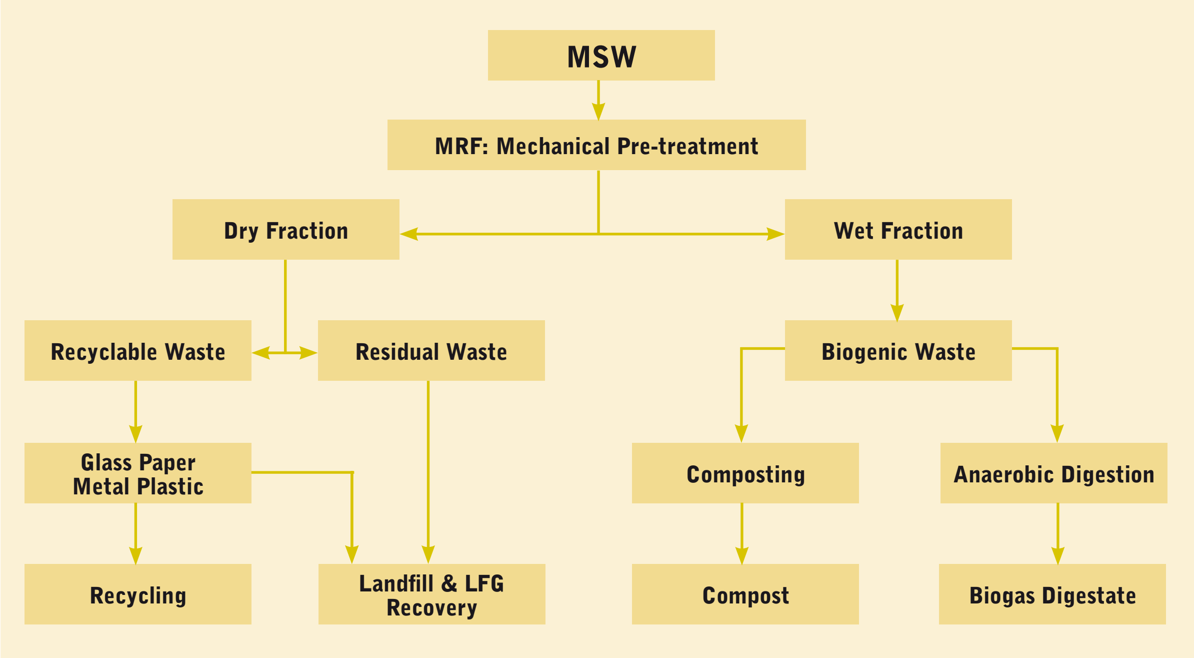

Figure 1: A typical dry-wet waste diversion model
MRF=Material Recovery Facility; LFG=Land Fill Gas

Zero waste model scenarios

A zero waste model was developed simulating various scenarios based on a dry-wet waste separation (wet means < 22% dry matter) that maximises diversion of recyclable fractions from disposal to landfill, as illustrated in Figure 1.

Five scenarios were evaluated[4] that were considered the most appropriate for the South African context in terms of the National Waste Management Strategy's implementation requirements, technical feasibility, and potential environmental impacts or benefits to municipal waste management systems:

- Scenario one: Landfill disposal of unsorted, untreated MSW (status quo, baseline)
- Scenario two: Landfill disposal of unsorted, untreated MSW with landfill gas recovery
- Scenario three: Mechanical pretreatment (MPT) of MSW, recovery of the recyclable fraction through a material recovery facility (MRF) with landfill gas recovery
- Scenario four: Mechanical-biological-treatment (MBT) with MPT, recovery of recyclables through a MRF, and anaerobic digestion of biogenic food waste with landfill gas recovery
- Scenario five: MBT with composting of all biogenic waste instead of AD and landfill gas recovery

The scenarios were tested based on data of real landfill sites located in two municipalities of KwaZulu Province: eThekwini (eTM) and uMgungundlovu (UMDM) municipalities. These municipalities were selected as representative of a typical South African population in terms of social profiling and socio-economic factors including waste streams in a medium to large municipality.

The eThekwini municipality is located on the eastern coastline. Sub-tropical climate conditions predominate in its coastal areas. The municipality has a population of around 3.16 million people. Waste generation rates for the formal sector range from 0.4 – 0.8 kg per capita per day, and 0.18 kg per capita for the informal sector. The total waste landfilled per annum is approximately 1.15 million tonnes. There are currently three engineered landfills, operated by Durban Solid Waste: Bisasar Road, Mariannhill and Buffelsdraai. Two of them are extracting landfill gas and producing electricity. Bisasar Road extracts about 350 m^3 per hour and produces 9 MWh of electricity per day. Mariannhill extracts about 160 m^3 per hour and produces 900 kWh_{el}.

uMgungundlovu municipality, situated in the KZN Midlands, has a total population of about one million people. Waste generation rates range between 0.35 and 0.61 kg/capita/day for urban areas and between 0.1 and 0.61 kg/capita/day for rural areas. The New England landfill, the largest, was opened in 1950 as an open dumpsite, and upgraded to an engineered landfill site in the 1980s, in accordance with the National Environment Act. The landfill receives an average of 183,531 tonnes of waste annually, equivalent to approx. 700 tonnes of waste per day.

[4] Trois C. & Jagath R. (2011), Sustained Carbon Emissions Reductions through Zero Waste Strategies for South African Municipalities. Waste Management, INTECH Publications. ISBN 978-953-307-179-4.

Table 1: Waste composition of New England landfill (UMDM) and Mariannhill (eThekwini)

Municipality	**eThekwini**	**UMDM**	**eThekwini**	**UMDM**
Waste Stream	**Household**	**Household**	**Commercial**	**Commercial**
Waste Fraction	**Waste fraction composition (%)**			
Biogenic	45.67	34.38	35.56	29.65
Other Waste	5.27	30.04	22.45	19.27
Recyclables	49.06	35.58	41.99	51.07
Paper & Cardboard	17.88	14.75	16.11	33.08
Plastic	19.01	8.65	6.08	11.43
Glass	6.83	7.00	14.86	3.87
Metals	5.34	5.18	4.947	2.70

The Mariannhill landfill was selected for the study, as a leachate treatment plant, landfill gas recovery and energy generation system and MRF are all located on-site. The landfill is therefore representative of an integrated waste management approach; however, none of the advanced strategies evaluated is applied in South Africa. They should serve as a guide for future development.

The study comprised four components to assess potential zero waste strategies: a waste stream analysis to determine the waste stream composition and quantities of specific fractions in the waste stream; a carbon emission/reduction assessment of each strategy; a landfill airspace assessment, and an evaluation of the costs and potential income and savings associated with each strategy.

Waste stream analysis

Waste stream analysis is completely lacking in most African countries. As a first step, a detailed waste analysis has been carried out on the New England landfill, the major landfill servicing the uMgungundlovu DM, and the Mariannhill landfill in the eThekwini municipality (Table 1).

The differences between the two landfill sites – including the content of biogenic waste and of recyclables – are astonishing.

GHG emission

To allow communities to calculate potential GHG-emission reduction, a simple calculation tool based on an Excel spreadsheet has been developed. The emission factors applied were derived from the United States Environmental Protection Agency (US EPA)[5] values for landfill disposal, landfill gas recovery, recycling and composting, using IPCC guidelines.

In all cases studied, full treatment with anaerobic digestion of the biogenic fraction yielded the highest GHG-emission reduction (Figure 2). Capturing and using the landfill gas in a combined heat and power (CHP) yielded values around zero emission, while composting was always second best. The high savings with electricity production from biogas are partially due to the high emissions of South African electricity, predominantly (> 90%) produced by coal.

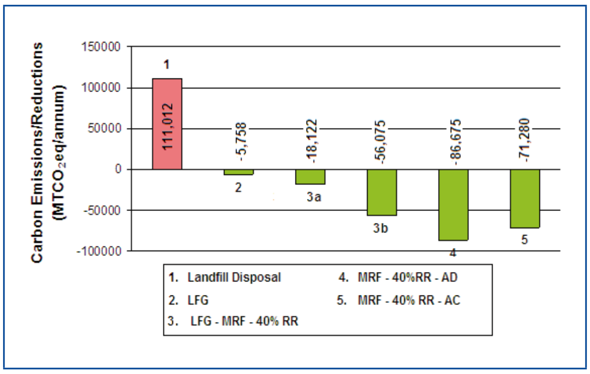

Figure 2: Assessment of Mariannhill landfill: calculated GHG emissions

Landfill space savings

The estimation of landfill space savings from waste diversion is largely an empirical calculation specifically defined by the compaction of waste into landfill cells. The density of the compacted MSW was assumed to be 1.2 tonnes/m^3. Landfill density factors of various waste fractions calculated by the US EPA (1995)[6] and the Department of Environment and Conservation of Western Australia were used to produce further estimates.

[5] US EPA (2006), Solid Waste Management and GHG: A Life-cycle Assessment of Emissions and Sinks: *www.nrcrecycle.org/Data/Sites/*

[6] US EPA (1995), Characterisation of MSW in the United States: *http://www.epa.gov/waste/nonhaz/municipal/pubs/msw95.pdf*

Economic analysis

As there are no advanced treatment plants in South Africa, both capital and operational costs had to be estimated based on research reports and journal publications. Major sources were studies by Chang et al. (2004)[7] and Tsilemou et al. (2006)[8] evaluating the capital and operating costs of 16 anaerobic digestion plants. The potential income derived from the sale of recyclables and electricity was sourced from local studies.

The strategy with gas recovery (today's best practice) based on 112,000 tonnes per year yielded a net income of ZAR3 million with a turnover of ZAR18 million. Best net gains were achieved with mechanical separation and recycling with ZAR18 million followed by anaerobic digestion with ZAR13.5 million and composting with ZAR10 million. However, a major hurdle for the two best economic systems was the high investment cost, at ZAR34 million and ZAR90 million respectively for the mechanical separation and recycling and anaerobic digestion. Composting at only ZAR2 million is comparably modest.

Conclusions

The greatest GHG reductions in both municipalities would be achieved by a MBT scenario with mechanical pretreatment and separation of the wet and dry fractions through a MRF; the consequent recycling of recyclable fractions; anaerobic digestion of biogenic waste with energy generation, and landfill disposal of all residual wastes. However, there are many challenges in implementing new technology and waste treatment methods. The capital costs of implementing waste diversion and zero waste strategies, in particular anaerobic digestion and MRF recycling, remain the greatest challenge in large-scale treatment of biogenic and recyclable fractions of MSW.

The study shows that source separation to remove dry recyclables, with door-to-door collection; composting of the remaining biogenic-carbon waste in windrows; using the maturated compost as a substitute fertiliser, and disposal of the remaining fossil-carbon waste to sanitary landfills will yield the best GHG-emission reductions at the lowest investment capital – yet still far higher than the current disposal or even dumping.

SUSTAINABLE WASTE MANAGEMENT WORLDWIDE

Jörgen Haukohl, Board ISWA, Managing Director Ramboll

The International Solid Waste Association has members all over the world, with exceptions in Eastern Europe and Africa (www.iswa.org). It is known for its commitment to continuing education and a strong know-how base. Ramboll, founded in 1945 in Denmark, has become a leading international engineering and consultancy company. It is Europe's fourth largest consultancy and has a significant presence in India and the Middle East. It has many dozens of references of WtE (incineration) plants throughout the world.

Europe is the most advanced continent when it comes to waste recycling and sustainable treatment. Apart from Eastern Europe, the density of anaerobic digestion (AD) and composting plants as well as incineration is extremely high. The driver is the European legislation that discourages disposal to landfills. In fact, landfilling of organic material is completely banned in countries such as Sweden, Switzerland, Austria and Germany. In the UK, landfill tax was increased every year by £8, reaching £72 per ton by 1st April 2013. This substantially reduces landfilling and increases separation and ultimately recycling, treatment of the organic fraction and incineration.

The remaining fraction after separation either at source or centrally is increasingly incinerated, combined with heat and power production. The number of WtE plants in Europe is steadily increasing (Figure 3), with the exception of seven member states in the east without any incineration. In Bulgaria and Romania almost all waste is landfilled, in Latvia and Lithuania over 90%. Valuable metals still go into incineration. However, with modern methods it is relatively easy to extract them from the bottom ash, including precious metals like gold, etc.

The trend in the USA is quite different. It is all market-driven. The USA does not ban landfill and dislikes taxes. A limiting factor is the space for new landfilling. For example, the scarcity of land around urbanised areas forced New York's Department of Sanitation to spend more than $300m a year on transporting waste, primarily by truck, to landfill and waste-disposal facilities outside the city. According to the US EPA, in 2010 the USA produced almost 250 million tons[9] of municipal solid waste (MSW), of which only 12% was diverted to waste-conversion facilities; of this, about 25 million tons is treated in incineration plants, especially in the east. This generated approximately 14 million MWh of electricity. In western USA, there is less development in waste management as land is still available. The largest single means of trash disposal in the USA is underground burial.

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[7] Chang, N.B. et al. (2005). Optimal design for Sustainable Development of a Material Recovery Facility in a fast growing urban setting. Waste Management. Volume 25, pp 833-846.

[8] Tsilemou, K. and Panagiotakopolous (2006). Approximate Cost Functions for Solid Waste Treatment Facilities. Waste Management & Research. Volume 24, pp 310-322.

[9] 1 ton is 2,000 lbs or 907 kg.

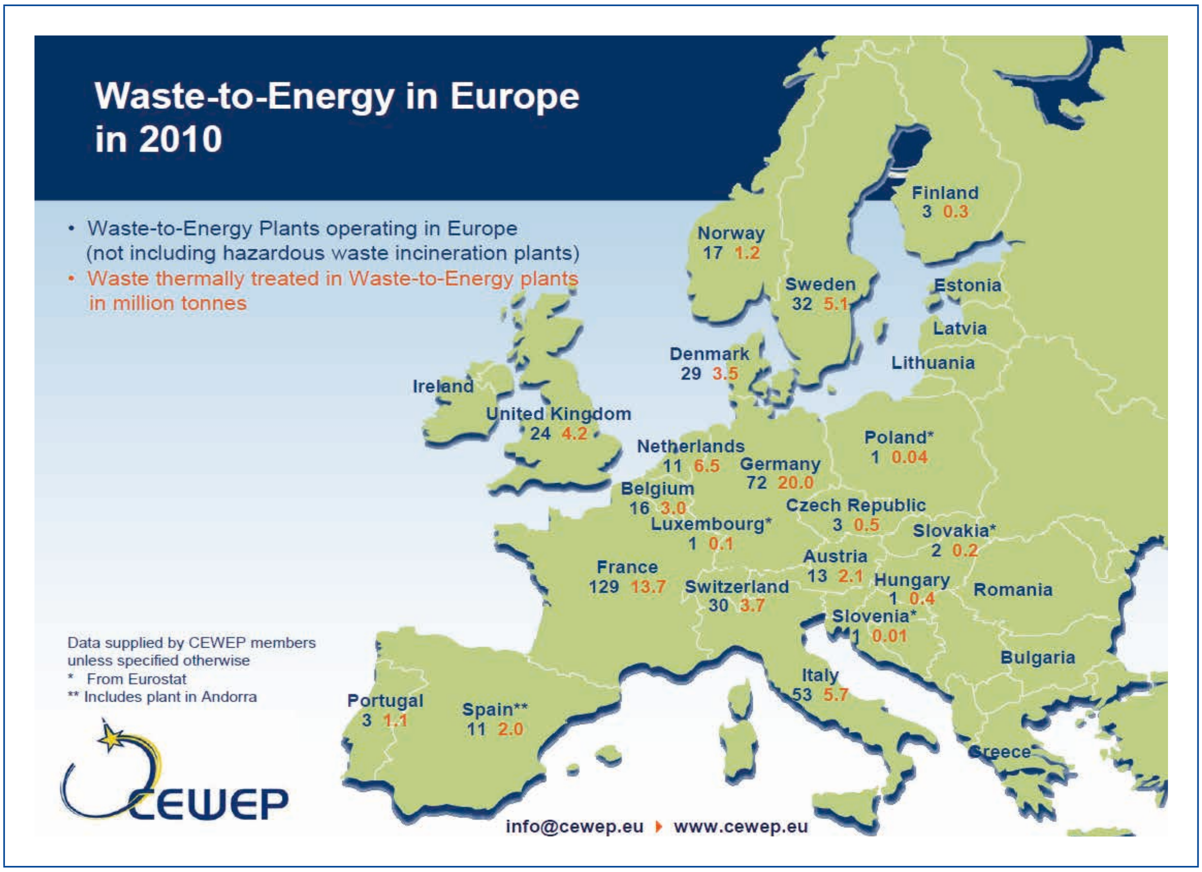

Figure 3: Status of WtE plants in Europe

Canada is similar to the USA. So far, it has built EtW plants in Vancouver, Ontario (2), Alberta (2) and Quebec only.

On the other hand Japan, Korea, Singapore and other densely populated Asian countries are very advanced when it comes to waste treatment. In Singapore, for example, 60% of solid waste is recycled, 37% is incinerated and only 3% goes to landfill.

Today's modern waste incineration plants do not have to be placed in remote areas anymore thanks to complete enclosure and stack gas treatment. A good example is Paris where the new Isseanne WtE plant is located in the city where the waste is produced (3.5 million tonnes a year) and the energy can be used. Two-thirds of the plant is below ground. Copenhagen has gone a similar way; a new plant is under construction only 4km from the city centre, to deal with 400,000 tonnes of waste from the city per year, generating 2 MWh of district heat and 0.7 MWh of electricity from each tonne of waste. An architectural competition resulted in a winning project for an above-ground plant. The building is 500m long and 100m high. Instead of a mountain of waste, there will be a "white mountain of snow" – an integrated ski slope using artificial snow with a 500m downhill track and a ski-lift (Figure 4).

Figure 4: Incineration plant in Copenhagen with integrated ski-slope

DRIVERS FOR OPTIMISED WASTE MANAGEMENT IN LOW AND MEDIUM-INCOME COUNTRIES

Herman Huisman, Ministry of the Environment,
The Netherlands

The amount of municipal solid waste (MSW), one of the most important by-products of an urban lifestyle, is growing even faster than the rate of urbanisation. Ten years ago, 2.9 billion urban residents generated about 0.64 kg of MSW per person per day (0.68 billion tonnes per year). A recent World Bank report (2012)[10] estimates that these amounts have increased to about 3 billion residents generating 1.2 kg per person per day (1.3 billion tonnes per year).

Waste production is a question of income and life-style. High-income countries produce the most waste per capita, while low-income countries produce the least. The highest production is found in Organisation for Economic Cooperation and Development (OECD) countries, with an average of 2.2 kg/capita/day.

Solid waste is usually the one service that falls completely within the local government's purview. A city that cannot effectively manage its waste is rarely able to manage more complex services such as health, education or transportation. Poorly managed waste has an enormous impact on health, the local and global environment, and the economy; improperly managed waste usually results in downstream costs higher than what it would have cost to manage the waste properly in the first place.

Waste treatment

Worldwide, landfilling is the most widespread technology (about 340 million tonnes per year), followed by recycling (130 million tonnes per year), WtE (120 million tonnes per year), dumping (70 million tonnes per year) and composting/digestion (50 million tonnes per year). 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 and variety of waste management methods used are also dependent on income: the higher the average income, the more advanced are the technologies applied (Figure 5).

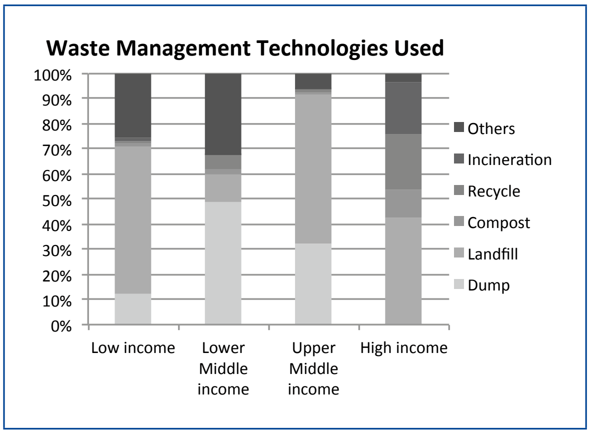

Figure 5: Waste management technologies related to income

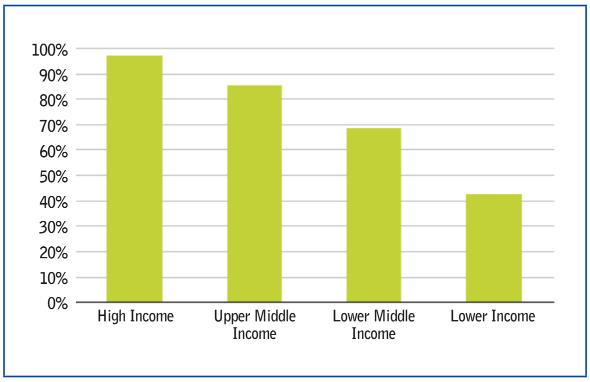

Figure 6: Waste collection rates by income

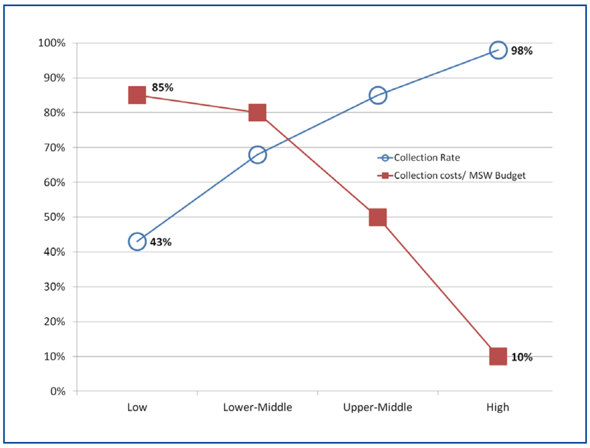

Figure 7: Collection rate as function of relative collection cost

[10] World Bank (2012), What a Waste: A Global Review of Solid Waste Management, March 2012, No.15.

Table 2: Collection and treatment standards as function of GDP

GDP (€ per capita)	Available (€ per capita)	Collection standard	Waste disposal standard
< 2,000	< 20	Limited collection	Open dumping
2,000–4,000	20–40	Improved collection	Controlled tipping
4,000–7,000	40–70	Good collection	Sanitary landfilling
7,000–10,000	70–100	Good collection	Separation, composting, sanitary landfilling
> 10,000	> 100	Separate collection	Prevention, recycling, composting, incineration, sanitary landfilling

Waste collection

As with the amount of waste produced per capita and the choice of treatment methods applied, the collection rate is directly related to gross domestic product (GDP). The higher a country's income, the more complete waste is collected. Industrialised countries collect up to 99% of all municipal waste produced (Figure 6) as compared to African countries, with an average of only 44%. The relative cost of collection as compared to the total budget available to collect and treat the waste defines the completeness of collection (Figure 7).

Low-income nations use a large fraction of the MSW budget for collection. As a rule of thumb, if the GDP per capita is less than a hundred times higher than the budget available for MSW, open dumping will occur (Table 2).

Frequency of collection is another important aspect readily under a municipality's control. From a health perspective, no more than weekly collection is needed. However, in some cities, largely because of culture and habituation, three-times per day residential collection is provided (e.g. Shanghai). Good waste collection programming requires an ongoing iterative approach between collection crews and generators (usually households). Therefore, waste producers should be aware of the true costs of collection, and ideally be charged for these directly.

To engage waste producers in waste management, awareness-raising is of crucial importance. Issues such as a healthier population, cleaner environment, attractiveness for tourism, job opportunities, etc., must be cited endlessly. Negative incentives (i.e. strong regulations and laws) usually do not improve proper collection.

Integration of informal waste collectors into the whole system is extremely important. They are doing an excellent job. However, they should be given an adequate working environment. China is a good example of how informal, private and public waste collectors can interlink. In Columbia and Brazil, instruments have been put in place to legally include producers as responsible bodies and integrate informal sectors in waste collection.

Waste composition

Waste composition has a direct influence on GHG emissions if waste is dumped or disposed of in an open landfill. The higher the organic content, the higher the emissions. Waste composition is dependent on social status, geographic region, food habits, etc. In general, low-income countries have higher organic (biogenic) fractions than high-income countries.

In regions where coal is used for heating, the ash content of waste in winter is far higher than in summer, so the organic fraction is correspondingly lower. In Ulan Bator, Mongolia, the ash content rises from 20% in summer to 60% in winter. In China the organic fraction in regions with coal is approx. 40% while in those with gas it is about 65% of total waste.

Slow development

Before getting concerned when considering the still serious waste problems in low-income countries, we should not forget that waste management in Europe took roughly 150 years to reach today's standard. Even then, countries like Romania and Bulgaria are still considered to be at a comparable level to South Africa. Not long ago, 75,000 containers of waste were being shipped from Rotterdam to China to 'solve' the waste problem.

Conclusions

The first priority for improved waste management is appropriate and efficient waste-collection systems. Once the waste is properly collected, the chances increase that it will also be adequately treated. Collected waste can be controlled by government, and should not end up in uncontrolled dump sites. The second priority is appropriate landfilling. Only after these two mandatory pre-conditions are fulfilled can further steps be taken.

Session 2: Technologies of Waste Treatment

ANAEROBIC DIGESTION OF THE ORGANIC FRACTION OF MSW – SYSTEM OVERVIEW FOR SOURCE AND CENTRAL SEPARATED WASTE

David Baxter and Teodorita al Seadi, Task 37

The development of human civilisation was based on consumption of world resources followed by production and disposal of wastes. The problems of waste management arose with the start of urbanisation, bringing people to live together in larger communities. Nowadays, the global quantities of waste, continuously increasing with the increasing world population, pose serious challenges to waste management, especially in urban areas. Efforts are made around the world to limit waste production and to reduce the costs of waste management. Nowadays the aim is to reduce the negative impact of waste on the environment and on human and animal health, and to preserve natural resources. Waste management is moving away from disposal towards recovery, reuse, recycling and reduction, demanding increased awareness among and active participation by citizens.

The role of anaerobic digestion (AD) in waste management

Poorly managed waste has an enormous impact on health, the local and global environment, and the economy. Improperly managed waste usually results in downstream costs higher than what it would have cost to manage the waste properly in the first place. Wherever in the world MSW is found, it contributes to GHG emissions, particularly through emission of methane from biodegradation of the organic fraction in poorly managed landfills.

In Europe a number of directives were introduced to incentivise the proper collection and treatment of the different waste fractions and to prevent potential health risks. These include:

- Limitation of landfilling of organic (biogenic) fractions (Waste Framework Directive)
- Production of renewable energy (Directive 2009/28/EC)
- Health protection (animal by-products regulation 1069/2009; EU Industrial Emissions Directive 2010/75/EC for air and water protection)

MSW comprises a biodegradable organic fraction, a combustible fraction and an inert fraction:

- The biodegradable organic fraction includes kitchen scraps, food residue from institutions, restaurants and households, and grass and plant residues.
- The combustible fraction includes slowly degrading ligno-cellulosic material like wood, paper and cardboard. (Lignin is not degraded under anaerobic conditions, so wood is not suited for AD and is more appropriate for other waste-to-energy processes.)
- The inert fraction contains stones, glass, sand, metal, etc. This fraction ideally should be removed, recycled or disposed of properly.

How much organic waste is available in cities worldwide? Assuming that the 3 billion urban residents are generating 1.2 kg household waste per person per day, this yields 1.3 billion tonnes of MSW per year. By 2025 this will likely increase to 2.2 billion tonnes per year, assuming an urban population of 4.3 billion, each generating about 1.4 kg of MSW per day.

Waste composition is influenced by factors such as culture, economic development, climate and energy sources; the composition of the waste influences how often waste is collected and how it is then treated. Low-income countries have the highest proportion of organic waste. Paper, plastics, and other inorganic materials make up the highest proportion of MSW in high-income countries.

By region, Eastern Asia and Pacific (EAP) has the highest proportion of organic waste, at 62%, while OECD countries have the least, at 27%, although the total amount of organic waste is still highest in OECD countries.

Food waste represents 23% to 67.5% of MSW (IPCC, 2000).

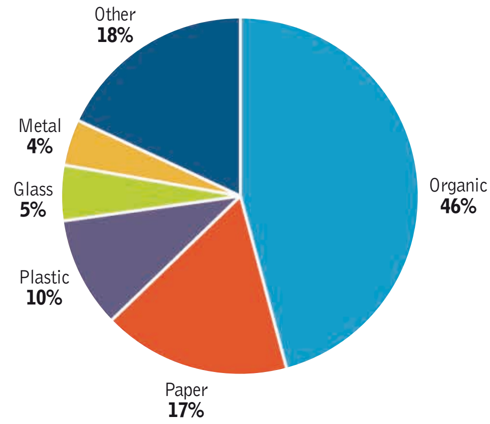

Figure 8: Average global MSW composition

Controlled anaerobic digestion in engineered digesters offers an optimum solution for the treatment of the biodegradable fraction of organic material to meet the challenges of today's management of environment, public health, energy and resources:

Climate change mitigation: Organic waste in landfills generates methane, a potent greenhouse gas. Diverting organics from landfills to AD treatment facilities allows renewable energy recovery as methane and decreasing methane emissions from landfills.

Public health: AD of organic MSW provides pathogen and disease control through sanitation, thus reducing the negative impact on human and animal health.

Table 3: Methane potential of organic wastes

Biomass type	DM	DM/VS	VS	Specific methane potential	Specific methane production
	(%)	(%)	(%)	$m^3CH_4/kgVS$	m^3CH_4/t
Cattle Slurry	8,00	80,0	6,40	0,200	12,8
Mixed fruit residues	15,00	85,0	12,75	0,370	42,1
Fats (Soy oil/margarine)	95,00	90,0	85,50	0,800	684,0
Household waste	30,00	85,0	25,50	0,400	102,0
Sewage sludge, concentrated	10,00	75,0	7,50	0,400	30,0

Recycling/recovery goals: AD of MSW (especially when combined with source segregation) helps divert the streams of organic materials from landfills toward recovery and recycling. Digestate (the material left over after digestion) is an excellent fertiliser.

Production of renewable energy: MSW and especially food waste has high methane potential (Table 3) from which renewable electricity can be generated or vehicle fuel produced.

AD technology

A large variety of AD methods, concepts and technologies are available for digesting the organic fraction of MSW. Basically, AD treatment of MSW can be classified according to content of total solids (TS) of the substrate to be digested in wet and dry digestion. Low solids (wet digestion) contain less than 12% TS, while high solids (dry digestion) range between 22% and 40% TS.

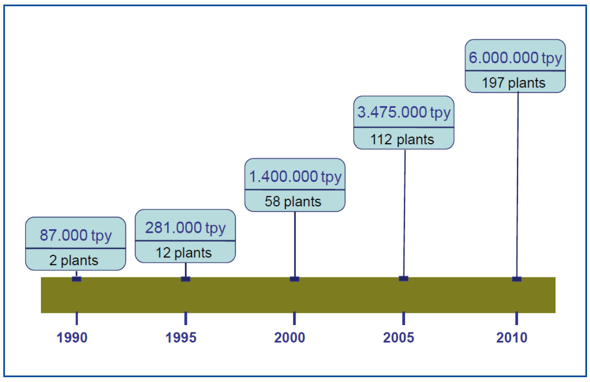

Figure 9: Development of AD plants for MSW digestion in Europe[11]

During the last decades, high-solids processes dominated the AD plants built in Europe. High-solids reactors are more robust, can handle high organic loading rates and require a smaller reactor volume per production unit, but are more expensive because of the high costs of the equipment (e.g. pumps).

Wet digestion

The industrial-scale MSW digestion plants established in Europe in the 1980s were predominantly low-solids systems. The main limitation of wet digestion is the large amount of water used, resulting in high reactor volume and expensive post-treatment technology, due to dewatering required at the end of the digestion process. Wet processes have been in operation for several decades for the treatment of wastewater sludge.

The oldest design is the Waasa process in Finland, taken into operation in 1989. Currently three Waasa plants are operated, ranging from 3,000 to 85,000 tonnes per annum, some operating at mesophilic (around 37° to 43°C) and others at thermophilic temperatures (52° to 57°C). The hydraulic retention time (HRT) in the mesophilic process is typically 20 days as compared to 10 days in the thermophilic range.

A newer and different design of wet AD of biowaste is the Komptech biogas plant at Markgrafneusiedl, Austria (Figure 10), where the waste is separated into a solid and a liquid fraction. Operation started in 2006 with a capacity of 15,000 tonnes waste per year at mesophilic temperatures. The digestate produced is used as liquid fertiliser in nearby agricultural areas.

[11] Mattheeuws (2012), Development of AD of OFMSW in Europe.

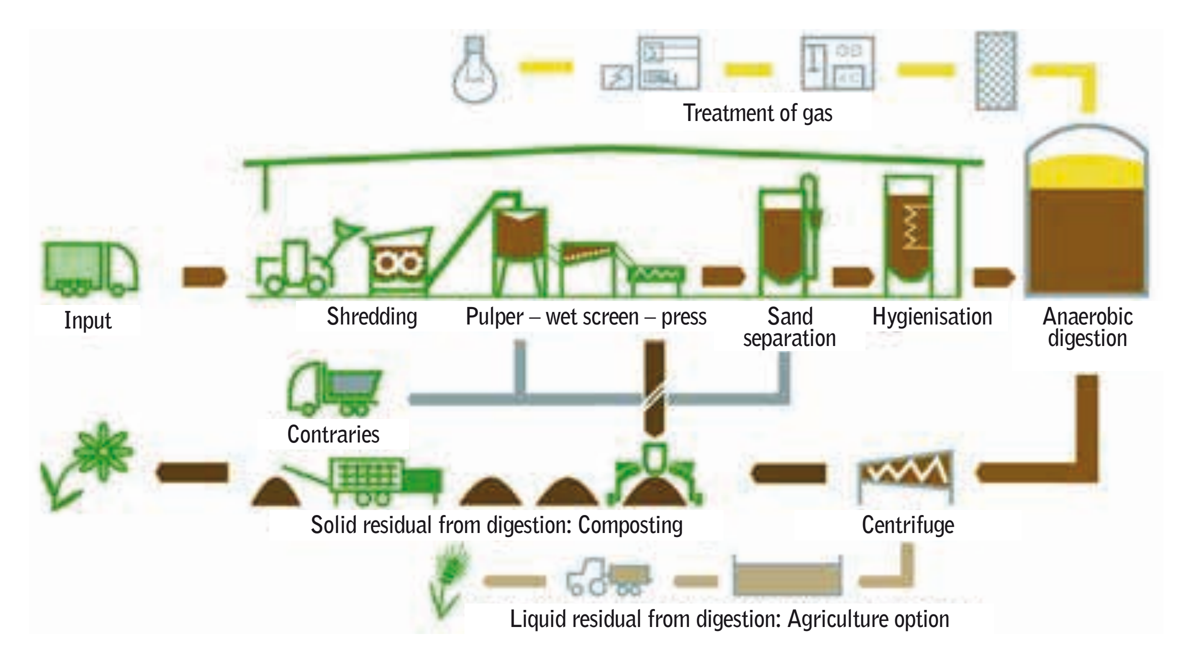

Figure 10: Process chain of a wet AD plant treating biowaste

The input material is first homogenised in a mixing unit using mixing screws. If necessary, a screening step can be taken prior to pressing to separate plastics and larger contaminants.

After homogenisation, a spiral press separates the material into a liquid and a solid phase. Between 30% and 50% (w/w) of the input material is liquid, with a dry-matter content of approximately 15% going into digestion. The remaining solid fraction (>30% TS) is processed in a composting facility.

Wet digesters are often operated as co-digestion plants, meaning that besides MSW other liquid or even solid material is digested at the same time. Most common is sewage sludge. A combination of biowaste and agricultural crops is applied in Västeras, Sweden. The company Svensk Växtkraft AB was formed between power company Mälarenergi and 17 farmers who own 20% of the company and the farmer's association. The farmers provide ley crops which are ensiled and added to the biowaste for digestion to produce a bio-fertiliser. The digestate is then used on the fields as fertiliser.

Dry digestion

Solid-waste (dry) digesters were developed in the 1980s. The oldest designs, and still the most applied, are the Dranco, Kompogas and Valorga processes. All three consist of a single-stage thermophilic or mesophilic reactor operated at retention times between 12 and 21 days.

In the Dranco reactor, the feedstock is pumped in at the top and the digestate withdrawn at the bottom. Instead of mechanical mixing the material is intensively recycled within about two days (Figure 11a).

The Kompogas process uses a horizontal plug flow. The digester is mixed with a longitudinal paddle stirrer (Figure 11b). The Valorga digester is also vertical but the substrate does not flow from top down, instead it enters at the bottom of a dividing wall positioned at 2/3 of the digester diameter and the digestate is removed after having turned around almost 360° at the other side of the wall (Figure 11c). The feedstock is mixed pneumatically using biogas, which is injected at the bottom of the digester.

All three digester types are so-called continuous systems, where an equal amount of substrate is removed from the digester as is added. In recent times, batch digesters were introduced for MSW digestion. Such digesters are often called 'garage systems' because loading and unloading is done with a front loader through a door at the front of the digester, giving it the look of a garage (Figure 12). The design is far simpler than that of continuous systems, but gas production is about 30% lower. Moreover, in a batch system the gas production is not constant. It gradually increases in the early stages and thereafter slowly decreases; consequently, at least three digesters are operated in parallel to maintain relatively steady gas production. While one 'garage' is being filled, one of the others is reaching highest gas production and the third is in its decreasing phase.

Quality of digestate

The best way to achieve high-quality digestate is to separate the organic fraction at the source, thereby minimising the risk of contaminants in the fertiliser. Of crucial importance is effective sorting of the waste. The discipline required can take years of education. In Europe a number of different separation and collection methods are applied. The most widespread is kerbside collection with plastic bins or bags – either paper bags, plastic bags (not recommended) or more recently biodegradable plastic bags (Figure 13).

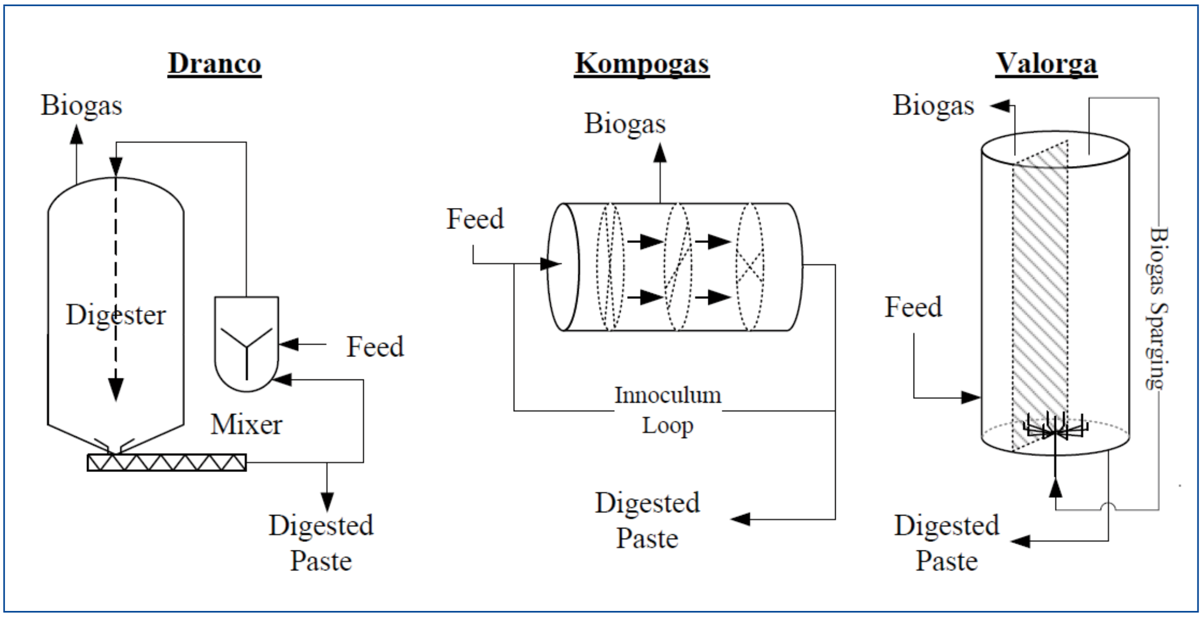

Figure 11: Solid-waste (dry) digester design: (a) Dranco, (b) Kompogas and (c) Valorga

Figure 12: Batch digesters in Thun, Switzerland

In large cities 'bring systems' are often used where road containers are available for citizens to drop off different types of waste (biogenic waste, paper, metals, plastic, etc).

Where people are not yet familiar with source segregation, the digestible organic fraction of the household waste can be recovered from the mixed municipal solid waste by central separation – that is, the organic fraction is removed from the total (or grey) waste in a central unit. This is usually referred to as 'mechanical treatment'. After separation, if the organic fraction is digested or composted, the whole process is called 'mechanical-biological-treatment' (MBT). MBT includes numerous separation steps, with sieving, crushing, metal removal, hand sorting, etc.

The digestate after MBT is always of lower quality than that from source-separated waste. There are always traces of impurities and higher heavy-metal concentrations. Only very extensive post-treatments can ensure reasonably good quality.[12]

Figure 13: Waste-collection systems for source separation: plastic bins, plastic bags for kerbside collection, and containers for bring systems

[12] Al Seadi, T. & Lukehurst, C. (2012), Quality management of digestate: *http://www.iea-biogas.net/files/daten-redaktion/download/publi-task37/digestate_quality_web_new.pdf*

TECHNOLOGY OVERVIEW OF INCINERATION TECHNOLOGIES

Jürgen Vehlow, Task 36

The primary goals of thermal waste treatment are inertisation and mass and volume reduction. Other conditions to be covered include: the process must in no way harm human health and has to be environmentally sustainable, i.e. strict stack gas cleaning procedures have to be followed, and increasingly resource recovery (energy and metals) is becoming important.

Currently thermal waste treatment is not implemented globally, mainly due to the high investment cost. There are two regions with significant application of incineration (Figure 14): Europe and Asia (Japan, Singapore, Korea, Taiwan).

In all these regions, space for landfilling is scarce. Waste management in the European Union is almost totally regulated by directives of the European Commission. Strategies in the main non-EU countries, Switzerland and Norway, follow the same fundamentals. The main focus is on preventing disposal of untreated waste, which is a strong driver for waste incineration.

In 2010 in the EU, more than 20% of waste was incinerated, most frequently with energy recovery.

Technologies

Basically, three technologies are applied for the thermal treatment of MSW: combustion, gasification and pyrolysis, the latter two in almost all cases being followed by a combustion process (two-step process).

Combustion: Grate furnaces, fluidised bed and rotary kiln are the three processes of combustion.

Grate combustion furnaces are by far the dominant technology, with a limited number of fluidised beds and rotary kilns, which are mainly used for hazardous waste treatment. Three types of grates are applied: roller grates, reciprocating grates and reverse-acting grates, often called Martin grates (Figure 15). The throughput of grate furnaces varies from approximately 4 to 40 tonnes per hour. Modern plants are mainly in the range of 20 to 25 tonnes per hour and per line.

The combustion chamber can be designed with counter, middle (mid-) or parallel (co-) flow configuration, meaning that the flue gas leaves the combustion chamber at its front end, in the middle or at its end. The counter-flow geometry is well suited to burn low-calorific waste and is often found in old plants. Parallel-flow combustion chambers were first installed in the early 1990s in roller-grate furnaces to achieve good bottom-ash burnout by the hot gases passing the backend of the grate. The preferred configuration in modern plants is middle flow.

Pyrolysis and gasification

Pyrolysis plants using a rotary drum as pyrolysis reactor are built primarily by the Japanese companies Mitsui Environmental Systems and Takuma. Twelve plants with a combined total of 24 lines are in operation, and a total treatment capacity of approximately 2,500 tonnes per day. A small rotary drum pyrolysis plant in Burgau, Germany, treating some 30,000 tonnes per year has been in operation since 1984.

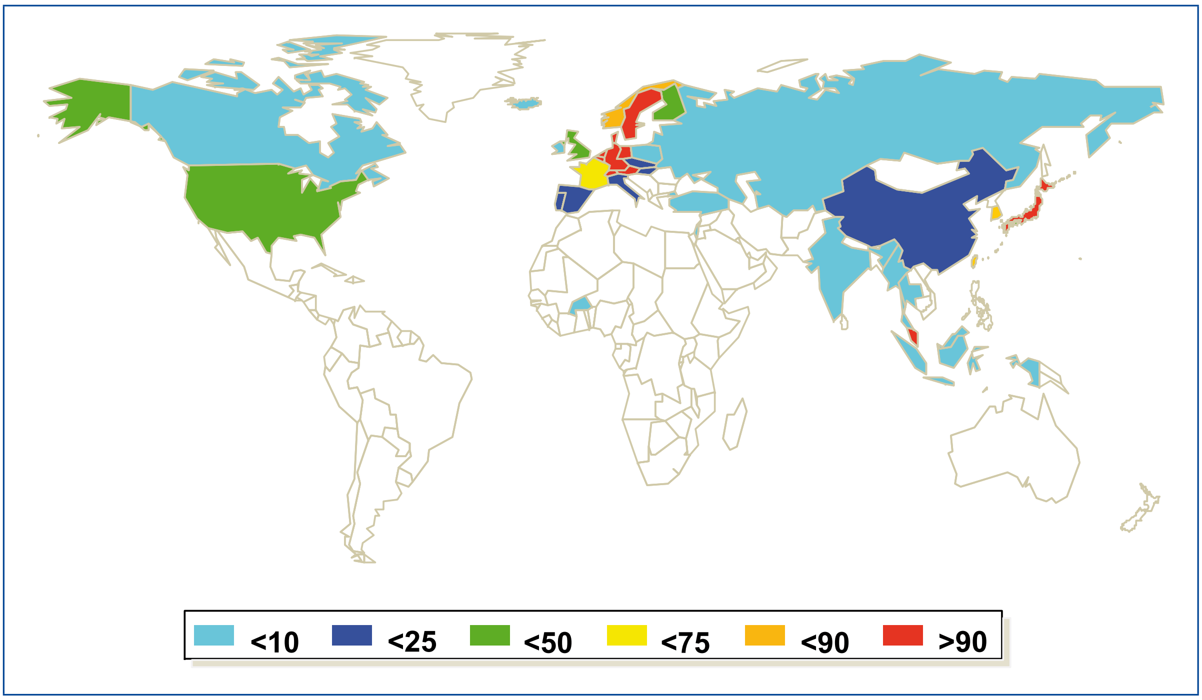

Figure 14: Distribution of waste incineration in percentage of residual waste after recycling

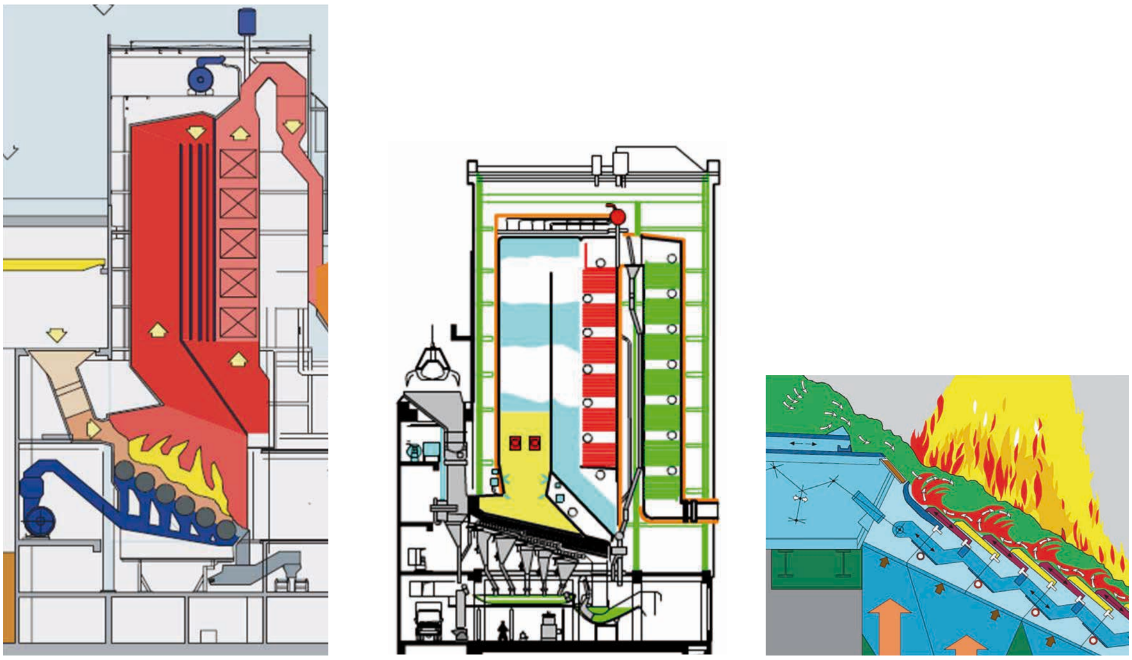

Figure 15: The three basic designs of grate furnaces: roller (left), reciprocating (central), reverse-acting grate (right)

Gasification of waste is performed either in shaft furnaces or in fluidised beds. Shaft furnaces resemble those used in steel production, and are brought to the market by Nippon Steel and JFE. In these plants 5% to 10% of coke is co-gasified. In total, 47 such gasification plants are in operation, treating some 8,400 tonnes per day.

Fluidised bed gasification plants have been built by two companies, Ebara and Kobelco. There are 30 plants, with a total capacity of approximately 6,000 tonnes per day, in operation. Gasification and pyrolysis technologies need waste pretreatment, such as size reduction. Their energy efficiency is typically lower than that of combustion plants and their operation costs are higher. That is why these technologies did not make it to the European market. They are well adapted for specific waste streams such as automotive shredding residues or waste from electrical and electronic equipment.

Energy recovery

The EU Waste Incineration Directive makes energy recovery mandatory. In fact, all modern waste incineration plants in Europe are equipped with a boiler and energy conversion system. The products are steam, heat, power, or combined heat and power (CHP). If steam can be used (e.g. in industrial processes) the efficiency might be as high as 75% to 90%. In CHP plants it is difficult to achieve higher electric efficiencies than 24%, with a corresponding heat production of 60% to 70%. The highest electric efficiency achieved is 30%, as in the Amsterdam plant where there is intermediate superheating of steam. However, the corresponding heat production is very low. Only a combination with a steam turbine allows efficiencies of up to 40%, as in the new incineration plants in Mainz, Germany and Bilbao, Spain.

There is an additional drive for energy recovery because of the increasing costs of oil and the political targets for renewable energy to address climate change. About 50% of the energy inventory of residential waste is of biogenic origin. Some European countries, such as the Netherlands, Finland and Switzerland, have acknowledged this, rewarding power generated from the biogenic part in waste incineration plants with feed-in tariffs, according to their national renewable energy programmes.

Air pollution control

All European combustion furnaces are equipped with air pollution control (APC) systems. In the 1970s, these were simple cyclones or electrostatic precipitators. Increasingly stringent air-emission standards required upgrading with chemical gas cleaning (neutralisation of acid gases, destruction of NOx and adsorption or destruction of organic micro-pollutants). The technology that still prevails in countries like Switzerland, Germany, the Netherlands and Denmark is wet scrubbing. Its advantage is that the operation is close to chemical stoichiometry. Many of these plants are not allowed to discharge liquid effluents, even after cleaning. Hence they are equipped with a spray dryer and a fabric filter to evaporate the water. A typical example is the new Amsterdam AEB incineration plant.

Dry scrubbing is another APC system that is becoming more popular. The typical neutralising agents are CaO (lime) or Ca(OH)2 (hydrated or slaked lime) which is sprayed into the hot flue gas. An alternative is NaHCO3, with the advantage of much better stoichiometry than calcium-based agents. An example of a plant with dry scrubbing is the Norrköping Solid Recovered Fuels (SRF) plant in Sweden, which is equipped with a circular fluidised bed (CFB) furnace. Lime is directly injected into the raw gas duct.

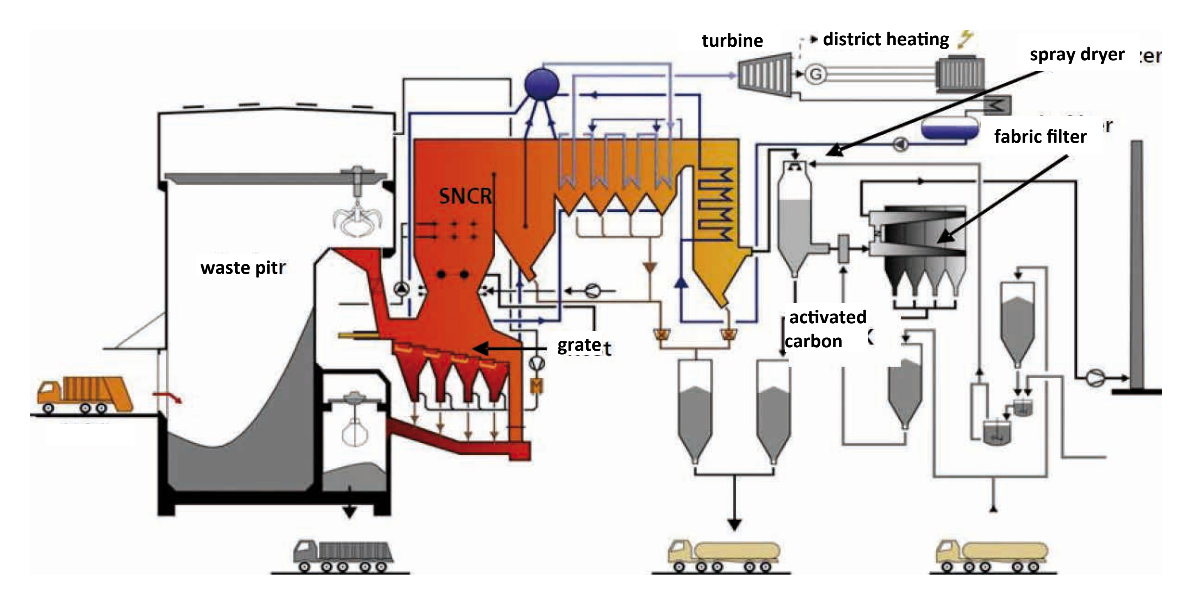

Figure 16: Stack gas treatment with SNCR, addition of activated carbon and fabric filter to remove NO_x, dioxins and fly ashes

Today's waste incineration plants are also equipped with abatement systems for NOx. This is often done by selective non-catalytic reduction (SNCR) where ammonia or urea is sprayed into the first flue gas draught at a temperature of 900 to 1,000 °C. Alternatively, a specific catalytic reduction (SCR) is applied at temperatures between 180 and 300 °C. The catalyst is generally located at the back-end of the APC system and requires reheating of the flue gas if wet scrubbing is used.

For dioxin removal, activated carbon or inorganic adsorbents like zeolites are common. In the 1980s fixed and moving bed filters were in use. Today entrained flow systems with a baghouse filter at the end of the APC system are preferred. These stages also remove Hg traces in the gas.

INTEGRATED WASTE MANAGEMENT IN AMSTERDAM

Erik Koldenhof, Waste and Energy Company, Amsterdam – AEB

The City of Amsterdam's Waste and Energy Company (Afval Energie Bedrijf, AEB) is a publicly owned WtE organisation, employing 400. It is located in the harbour area of Amsterdam. AEB processes waste from Amsterdam and 19 surrounding municipalities and companies.

Recoverable waste enters the recycling area through the waste points, the Hazardous Waste Depot and the Regional Sorting Centre, all of which are part of the AEB organisation. Residual waste that cannot be reused is converted into energy through incineration. Because the volume of combustible waste is decreasing in the Netherlands while the demand for sustainable energy is increasing, AEB now also accepts 700,000 tonnes per year of combustible waste from countries such as the United Kingdom (300,000 tonnes per year), Germany, Italy and Belgium.

AEB processes more than 1.4 million tonnes of household and industrial waste. This represents 20% to 25% of the total annual quantity of combustible waste in the Netherlands. A total of 4,400 tonnes of waste are delivered to AEB every day. In addition, AEB processes 100,000 tonnes of sewage sludge. A total of 53% of the MSW is of biological origin and is therefore considered as renewable.

WtE has a long tradition in Amsterdam. The first plant was built in 1917 and operated up to 1963. The second-generation plant was in operation until 1993 when it was replaced by the third-generation, still in operation today. In 2007 a fourth-generation plant (Waste Fired Power Plant, WFPP) was built (Figure 17).

The third-generation WtE plant has a capacity of 850,000 tonnes per year and an electrical efficiency of 24%, while the WFPP has a net efficiency of more than 30% and processes 530,000 tonnes per year. This electrical efficiency is made possible by an innovative system that taps steam from the turbine halfway through the process so it can be heated twice, thus producing even higher temperatures (Figure 18). The steam reheating is unique in world EtW plants.

In total, 1 TWh of electricity is provided per year to the electricity grid, enough to meet 1% of the electricity demand of the Netherlands or that of 285,000 households. In addition, 600 TJ of heat is fed to the district heating system, enough for 24,000 households. As a result, 700,000 tonnes of CO_2 is avoided, while 28,000 tonnes per year of ferrous and non-ferrous metals are recovered as a side-product.

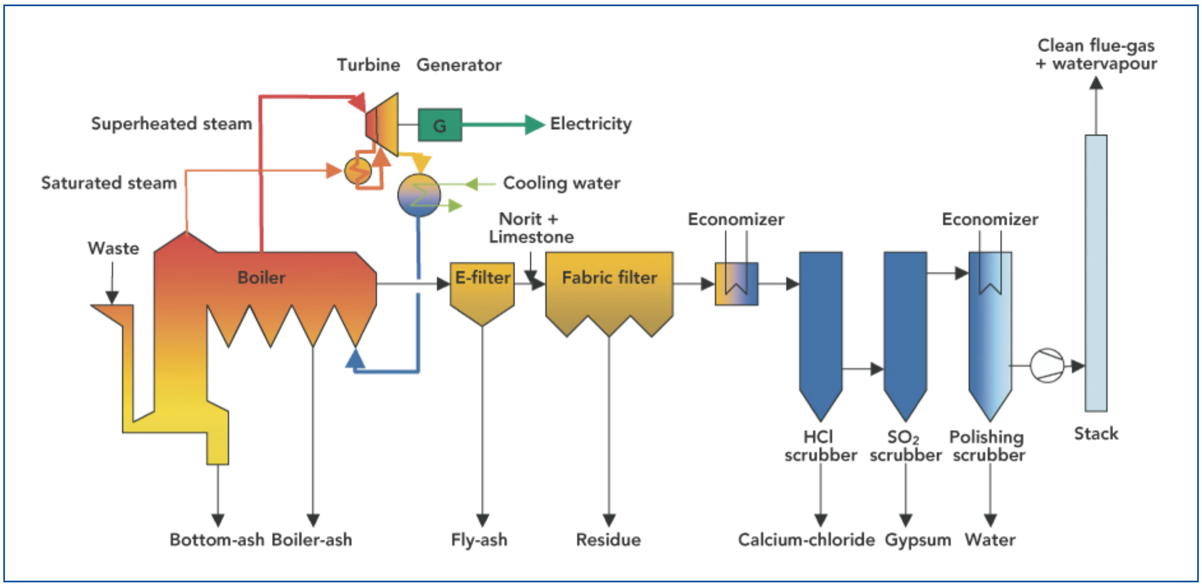

Figure 17: Layout of the high-efficiency WFPP scheme, Amsterdam

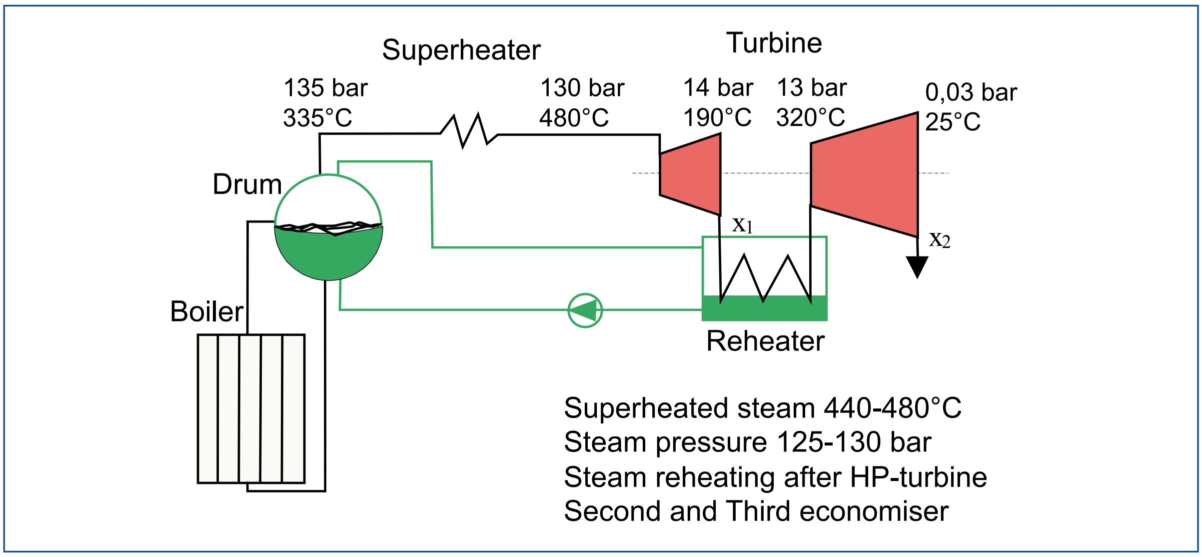

Figure 18: Intermediate steam reheating system

Chlorine corrosion is reduced by a nickel/chromium plating of the heat exchanger surfaces. After five years of operation none of the heat exchanger elements had to be replaced. The system was invented by AEB staff and is patented by AEB.

Flue-gas cleaning is as excellent as the energy production. The stack-gas purification is based on conventional technology, but the combination of different processes make it as efficient as it is.

Another strong point of the system is the almost total use of the by-products. From 1000 kg of waste only 0.5 kg goes into landfill, the rest being recycled. From the bottom ash, 16 kg of iron and 3 kg of other metals (copper, zinc and aluminium) are removed. During the flue-gas cleaning process, 4.5 kg of gypsum is extracted and then processed to produce a new gypsum product.

This strong recycling procedure also helps to avoid CO_2 that would otherwise have been emitted while producing new material (Figure 19).

Another feature of the AEB plant is the integration of the wastewater treatment plant (Figure 20), producing 25,000 m^3 per day of biogas and 100,000 tonnes of sewage sludge per year which goes to incineration. This was quite a challenge at first. The question was how to manage incineration of sludge without disturbing the main waste-burning process. Attempts were made with dried solid sludge, addition of sludge in big bags or dumping it into the main bunkers, without much success. The solution was found to be a closed injection system. This injects sludge with dry matter of 25% directly into the boiler.

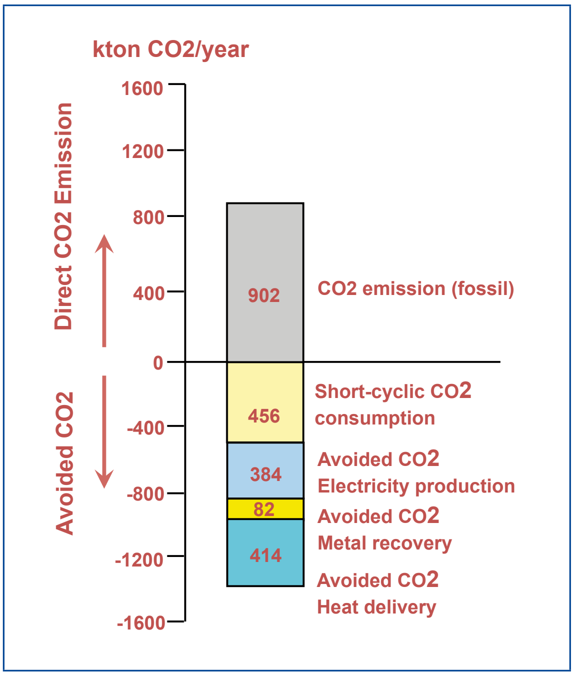

Figure 19: CO_2 emission of energy production vs CO_2 emission avoided through WtE and recycling

Figure 20: Integration of wastewater treatment plant adjacent to incinerator

The overall efficiency of the plant is excellent also for heat recovery; 15,000 households are connected to a district heating system, displacing natural gas. It is planned to connect as many as 60,000 households to the heat grid. A large number of projects are still in the pipeline, including an optimised bottom-ash treatment plant, a steam line in the harbour area, and energy production from green waste.

Session 3: Approach for Communities

INTEGRATED WASTE MANAGEMENT IN LOW- AND MEDIUM-INCOME COUNTRIES

Adam Read, Ricardo-AEA, UK

Adam Read, Practice Director at Ricardo-AEA in the UK, shared 18 years of experience and operational expertise in waste technology design, procurement and evaluation, including seven years in developing and transition economies.

Worldwide, the amount of waste is increasing every year. Current global MSW generation levels are approx. 1.3 billion tonnes per year, and are expected to increase to around 2.2 billion tonnes per year by 2025. This represents a large increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day within 15 years. However, global averages are broad estimates only as rates vary considerably by region, country, city, and even within cities.

Waste generation in sub-Saharan Africa spans a wide range, from 0.09 to 3.0 kg per person per day, with an average of 0.65 kg/capita/day. Per capita waste generation in East Asia and the Pacific Region ranges from 0.44 to 4.3 kg per person per day, with an average of 0.95 kg/capita/day.[13]

Waste generation and disposal is directly related to income: high incomes lead to more waste but also to improved disposal. The income level defines also the rate of recycling: at high income levels formal recycling is high, at lower levels it is low and mostly informal (Figure 21).

Income Level	Average %	Formal %	Informal %
High	54	54	0
Upper-middle	15	1	15
Lower-middle	27	11	16
Low	27	1	26

Figure 21: Recycling rates – formal vs informal[14]

The sustainable management of solid waste streams is imperative in order to minimise environmental and public health risks around the world. While the balance between the specific components of this system in delivering sustainable waste management is already well understood and established in most developed countries, this is not often the case for developing countries in the Middle East, Asia, Latin America

[13] World Bank (2012) What a Waste: A Global Review of Solid Waste Management, March 2012, No.15.

[14] Scheinberg A, Wilson D.C. & Rodic L. (2010), *Solid Waste Management in the World's Cities.* UN-Habitat by Earthscan Ltd. London/Washington DC.

and Africa. The literature concerning aspects of collection, transportation, treatment, reuse, recycling, recovery and disposal of waste is scarce and/or non-existent for these countries, making it difficult to evaluate and improve current situations or compare and contrast performance with other locations/nations.[15]

Uncollected and illegally or improperly disposed wastes pose serious risks to public health and the environment. The prevalence of parasites, tetanus, malaria, hookworm, cholera and diarrhoea in many African countries is attributed to unsanitary conditions caused by waste being simply strewn around cities, villages and other inhabited areas. In some African cities, incidents of flash floods, water pollution and littered landscapes have been attributed to poor waste management practices.

Uncontrolled dumping leads further to serious problems of environment, safety and land availability (Figure 22). It also harms global environment and economy; as has been stressed repeatedly, improperly managed waste usually results in downstream costs higher than what it would have cost to manage the waste properly in the first place. The global nature of MSW includes its contribution to GHG emissions (e.g. methane from the organic fraction of the waste stream) and the increasingly global linkages of products, urban practices and the recycling industry. GHG emissions from MSW have emerged as a major concern as post-consumer waste is estimated to account for almost 5% (1,460 million tonnesCO_2e) of total GHG emissions.

In conclusion, first priority in waste management goes to phasing out dumping.

Figure 22: Effects of uncontrolled dumping

A first step to better waste management is the collection of data on mass flows and costs, including cost of public health. Demographic and health surveys have directly shown an increased incidence of sickness among children living in households without a waste collection service by a factor of two or more for diarrhoea and a factor of six for acute respiratory infections. Indirect effects are induced by water-borne disease via blocked drains and flooding.

A key driver towards increased efficiency in solid waste management is the involvement of all stakeholders, including the waste generators, waste processors, formal and informal sectors and financial institutions, and private initiatives such as non-governmental and community-based organisations improving services and systems and ensuring more sustainable waste management services are developed and delivered. Usually, governments don't know the amount of waste that is produced, nor its composition. The key is to introduce an informal system into a formal organisation.

The World Bank has recommended five steps:

1. Need for Strategic Planning
2. Better Institutional Arrangements
3. More Efficient Operations
4. More Effective Financial Management
5. Environmentally Safe Disposal

It is not necessary to introduce Western waste systems in emerging or developing countries but dumping has to be avoided through structured waste collection and appropriate 'treatment'. The world is littered with failed technologies. But what is an appropriate solution? It has to be:

- Proven on a commercial scale
- Appropriate to local waste composition and climate
- Sustainable and affordable
- Manageable and maintainable locally

The rules are: start small, keep it simple and be cautious about magic solutions!

The hype of zero-waste systems is purely academic in the developing world, but there is an urgent need to start proper selection immediately. The best way is to develop a site-specific stepwise approach, rather than coming up with an imported complete system. Collection is of high relevance because:

- It has high public visibility
- Public health is a key driver
- It gets waste out 'from underfoot'
- It often accounts for the largest share of the municipal budget
- Typically only 30-70% of waste is collected in many developing economies
- Perhaps only 50% of people receive a service

[15] Manga V.E. et al. (2007), Waste management in Cameroon: A new perspective?, *Resources Conserv Recycl.*

However, collection is not everything – socially and culturally, well-adapted recycling is next in line in terms of sustainable waste management. Recycling can be increased when simple measures are taken into consideration, such as:

- Appreciating existing informal solutions
- Integrating waste management systems
- Improving feedstock by source separation
- Developing the livelihoods of pickers
- Building the capacity of micro-enterprises
- Focusing on markets (creating a business case)
- Selective collecting (market-oriented)

Unfortunately, there is no general recipe for establishing an integrated waste management system. But there is an excellent chance of improving waste management if a few guidelines are followed, such as:

- Phase out uncontrolled dumping – leading to huge health impacts!
- Good landfill is an essential part of any solution
- Focus also on reducing waste quantities at source
- Develop sustainable recycling – integrate the informal sector!
- Develop appropriate treatment for key materials
- Build local understanding and skills to manage the new system
- Underpin with sensible regulation and strategy

Discussion and Conclusions

The workshop provided a wide platform for exchanging information between ExCo members from industrialised countries and from developing or emerging economies. The presence of South African stakeholders from government, communities and industry as well as scientists expanded the range of views and added to a lively discussion. As much as the application of low- or high-end waste treatment methods might be different in the various regions of the world, proper, efficient and low-cost waste collection and transport is key to all economies.

QUALITY OF WASTE MANAGEMENT

The different contributions highlighted the vast differences in waste management between the various regions of the world. It was clearly demonstrated that the quality of waste management is a direct function of GDP per capita: the higher the GDP the more developed is waste separation, collection, recycling and treatment of waste fractions in dedicated plants.

In Europe the development of waste management took roughly 150 years to reach today's standard and, even then, countries like Romania and Bulgaria are still considered to be at a comparable level to South Africa. In the developing world, the large time-frame is not available, given the pressure of urbanisation. In fact the World Bank's Solid Waste study expects waste volumes to grow even faster than people moving into cities. Growth rates of MSW are fastest in China, other parts of East Asia, regions of Eastern Europe and the Middle East. To mitigate GHG emission, waste management planning is urgently needed.

INCENTIVES FOR WASTE MANAGEMENT

The incentives for reducing MSW dumping and uncontrolled landfilling were discussed in several instances. There are very limited possibilities in low-income countries to improve the situation in a short period of time. In a few places the outbreak of epidemics gave reason to introduce proper waste collection as a first step. In other countries such as China and India, growth of cities made it necessary to remove dump sites just outside of city limits and start organising proper waste collection and controlled landfilling away from residential areas. New solutions are only feasible when informal waste recycling is appreciated and integrated into the whole waste management system.

Above all, waste management is a question of social status and acceptance of the fact that proper treatment as a measure to prevent diseases and GHG emission saves money when compared to curing the problems at a later stage. However, this is difficult to promote, even though people don't like landfills in their neighbourhood. In some European countries a ban on landfilling of organic wastes was introduced, but there are still efforts to bypass the restriction. In other countries where a stringent landfill tax was introduced (in Denmark at €60 per tonne or the UK, where the progressively increased tax is now at £80 per tonne), alternatives are only now being introduced. In Europe only about 50% of waste is used for energy production, while in the USA the figure is even less, at 20%. This compares, for example, with Japan and Singapore where 100% goes into energy production.

WHERE TO START

All participants agreed about the need for proper collection, separation and adequate treatment of waste. However, the question was raised: who should take the initiative to start the process, at municipal or at national level? The question behind this is of course: who is going to take the primary financial responsibility? Obviously, it is not easy to provide a general answer. The key driver is the involvement of all stakeholders, including municipalities, waste generators, waste processors, formal and informal sectors, financial institutions and private initiatives. However, there is no doubt that government must take the first step, if only by introducing clear framework conditions. Afterwards the local partners are of crucial importance. Private public partnerships (PPPs) are often the solution of choice.

From the audience it was highlighted that institutional organisation hardly exists in South Africa. For example, in Cape Town there are over 900 dump sites because the municipality has increased gate fees for landfill sites. But there is also no incentive for private initiatives because administrative hurdles are often too high. For example, electricity feed into the grid is extremely difficult in South Africa, and the feed-in tariff is far lower than the electricity price for consumers. Waste is usually managed by municipalities; there is no private service provider. However, municipalities do not have the capacity and know-how, nor do they have the money. It is probable that nothing will change within the next ten years if government fails to take action and to provide seed money. Until very recently, too many departments were involved in the waste business and they competed against each other. Now a central department focused on sustainability has been created in order to avoid a silo mentality.

OUT OF SIGHT – OUT OF MIND

The industrialised world is not guiltless when it comes to problems of uncontrolled waste disposal. According to the Basel convention, trade of waste is not allowed anymore, but the USA still sends waste to Ghana and, until recently, to China (until China introduced a 'green fence' to avoid importation of waste). Over the years, 75,000 containers of waste have been shipped to China from Rotterdam.

However, inside Europe, waste transportation continues. Even the showcase WFPP in Amsterdam is importing waste from the UK. Economic considerations dominate. Because the gate fee is increasing in the UK while decreasing due to overcapacity in Germany and the Netherlands, the UK is keen on exporting while the target countries with overcapacity are actively acquiring waste. There is a competition for waste to keep the plants running at full capacity. But why is a brand-new plant – as in Amsterdam – overdesigned? The reason is the efficient recycling of waste – far higher than what was planned. The waste volume going to incineration in the Amsterdam plant was reduced by 30%. Because of European regulation, a public company like AEB is not allowed to compete with private industry. That is why it decided to start importing waste.

Other waste trades are occurring throughout Europe; e.g. the Netherlands still sends all batteries to Belgium and Switzerland. However, an advanced waste-disposal charge is being introduced based on good experience with cardboard; if producers do not cooperate, the government will introduce fees that are higher than the production cost of a battery.

THE CHOICE OF HIGH-END TECHNOLOGIES

In Europe, the most widespread options for upgrading waste treatment is incineration of grey waste in a WtE plant and anaerobic digestion (AD), often combined with composting of the separated fraction of organic waste. The question was raised: why is AD, as a relatively simple technology, not being used more often in developing countries such as South Africa? What is impeding the use of anaerobic digestion – heavy metals or price? The engineering company PDNA, in a study on behalf of the German development aid organisation GIZ, found that in different fractions of waste the heavy metals were very low. They did not believe this at first and had it double-checked by an Austrian laboratory. The result was the same: South Africa has far lower levels than any European standard. It has no legislation on heavy metals but it does have guidelines on the type of sludge that is allowed to be used as fertiliser. Even though the model developed by Cristina Trois and her group includes AD, there is no digester so far that is operated on source-separated MSW. The small number of AD plants are operated on agricultural waste. There is a lot of interest in waste treatment but communal legislation makes it almost impossible to develop.

When it comes to WtE plants there are regional preferences. For example, gasification is in favour in south Asian countries but, despite planning, all projects are cancelled. Fluidised beds are operated in a number of countries such as Spain (Madrid) and Sweden because of their capacity to accept other waste types, but in general Europe uses grate incineration.

Cost of thermal waste treatment is a crucial factor. The investment cost for pyrolysis and gasification is higher than for grate combustion. in addition, for pyrolysis the mandatory shredding of the waste increases operating cost.

CONCLUSIONS

There is no single recipe for waste management. However, there are a few golden rules: start small, keep it simple and advance step by step. It is better not to apply the most advanced technologies. There are too many redundant waste plants worldwide.

All stakeholders in the waste chain should be involved but it should be realised that PPPs might take a long time, up to five years. When assessing a waste project, the value of the number of jobs created should be included; this may be important to demonstrate economic viable. Likewise, environmental costs should be taken into consideration.

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