Title of Dissertation:

Waste Management in Ireland - the potential lessons to be learnt from Europe

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This dissertation is submitted as part fulfilment of the M.Sc. in Environmental Protection, Institute of Technology, Sligo.

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Abstract

The management of Municipal Solid Waste (MSW) in Ireland is currently in a transitional phase. It is possible that Ireland can capitalise on its late-mover status and emanate European examples. However as the literature review explores, there is deep disagreement in Ireland over the technological approach to waste disposal, particularly in relation to whether the country should progress Mechanical Biological Treatment (MBT) or Incineration.

Through the use of case studies, the waste treatment methods of various European countries are explored. The countries examined by case study are Sweden, Germany, The Netherland and Denmark.

The main treatment techniques utilised in these countries are incineration and biological treatment. Germany also has a strong MBT presence. Germany has been the principal developer of MBT technology in the world and has been utilising this technology since 2001. These countries have employed a variety of initiatives which Ireland can emanate.

It was recommended as a result of this paper's findings, that the Irish waste management system build on the established treatment methods. This includes expanding the biological treatment sector and utilising the SRF output from existing small MBT plants in Ireland. While incineration will come on line in summer 2011, it is necessary to adhere to the Waste Hierarchy. Accordingly MBT technology is preferred over Incineration. While incineration may be necessary in Ireland it must be strictly controlled. Taxes should be altered appropriately to reflect the waste hierarchy.

Due to the economic climate, the Irish government should also consider partial privatisation of the waste management industry. This would promote investment in technologies and research and development. Awareness regarding waste management should be entered into the primary curriculum to ensure that future generations are informed.

In conclusion it is necessary for Ireland to build on the technologies existing in the country whilst also integrating incineration. Strict controls and limits on volumes should be imposed on incineration facilities so as to adhere with the Waste Hierarchy. Privatisation should be considered to further expand the industry and develop the biological treatment market. Future study on this topic would be beneficial, such as examining in detail a recent late-mover in this field to aid in the development of the Irish waste sector.

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Glossary of Terms

BAT (Best Available Technologies) is the most effective and advance stage in the development of an activity and its methods of operation, which indicates the practical suitability of particular techniques for providing, in principle, the basis for emission limit values designed to prevent or eliminate or, where that is not practicable, generally to reduce an emission and its impact on the environment as a whole.

Biodegradable (in the context of waste) means waste that is capable of undergoing anaerobic or aerobic biological decomposition, such as food and garden waste, paper and cardboard etc.

Biowaste under the terms of the new Waste Framework Directive (2008/98/EC) means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.

c. (circa) - approximately.

CSO The Central Statistics Office.

DEHLG The Department of the Environment, Heritage and Local Government.

Disposal means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I of the new Waste Framework Directive (Directive 2008/98/EC) sets out a non-exhaustive list of disposal operations.

EPA the Environmental Protection Agency.

ESRI Economic and Social Research Institute.

EU European Union.

Leachate describes any liquid percolating through the deposited wastes and emitted from or contained within a landfill.

Mechanical-biological treatment (MBT) means the treatment of residual municipal waste (black bin) through a combination of manual and mechanical processing and biological stabilisation, in order to stabilise and reduce the mass of waste that requires disposal

Municipal solid waste (MSW) or **Municipal waste** means household waste as well as commercial and other waste that, because of its nature or composition, is similar to household waste. It excludes municipal sludge's and effluents. In the context of this report municipal waste consists of three main elements - household, commercial (including non-process industrial waste), and street cleansing waste (street sweepings, street bins and municipal parks and cemeteries maintenance waste, litter campaign material).

Organic waste is biodegradable food, garden and landscaping waste, and where the context permits, will also include industrial organic sludge's (e.g. from the food and drink production sector).

Packaging is used to contain, protect and present goods. Virtually all packaging eventually becomes waste. Packaging is made from such materials as cardboard, paper, glass, plastic, steel, aluminium, wood, and composite materials such as those used in milk and juice cartons.

Recovery means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.

Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Refuse derived fuels (RDF) are fuels produced from waste through processes such as mechanical separation, blending and compressing to increase the calorific value of the waste. Such waste derived fuels can be comprised of paper, plastic and other combustible wastes and can be combusted in a waste-to-energy plant or cement kiln.

Residual waste means the fraction of collected waste remaining after a treatment or diversion step, which generally requires further treatment or disposal.

Reuse means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.

Solid recovered fuels (SRF) are fuels refined from crude refuse derived fuels (RDF). To be defined as SRF a fuel must meet minimum standards for moisture content, particle size, metals, chloride and chlorine content and calorific value.

Treatment/pre-treatment includes, in relation to waste, any manual, thermal, physical, chemical or biological processes that change the characteristics of waste in order to reduce its mass, or hazardous nature or otherwise, to facilitate its handling, disposal or recovery.

Waste is defined as any substance or object which the holder discards, intends to discard or is required to discard, under the new Waste Framework Directive (WsFD) (Directive 2008/98/EC).

Waste Management means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker.

1. Introduction

1.1. Background

Waste Management is in a transitional stage in Ireland today. There are two main technologies currently being considered as possible treatment methods for municipal solid waste (MSW). Mechanical biological treatment (MBT) and Incineration are these two treatments. Both these methods have respective advantages and disadvantages which have been discussed thoroughly and exhaustively throughout the literature ranging from Government Reports, EPA Reports to a variety of Consultant Papers.

Up until recently landfill has been the sole waste disposal option for MSW generated, with excesses of 80% of MSW ending up in landfill, however the environmental and economical effects of landfill are no longer tenable. Landfilling has the potential to severely impact the environment in a variety of ways including polluting the groundwater with leachate, polluting the atmosphere with landfill gases and also effecting the local community through increased traffic, odours, generation of noise and increased animal behaviour, including birds and rats. All these can potentially damage the quality of life of local residents if adequate controls and measures are not implemented.

As a result of the Landfill Directive, targets diverting MSW from landfills were implemented. Failure to meet these targets would result in major fines for Ireland. It is for this reason that an alternative waste management option must be found and implemented in Ireland.

Figure 1. Treatment Methods for MSW in Europe 2008 *(International Solid Waste Association Conference, 2010).*

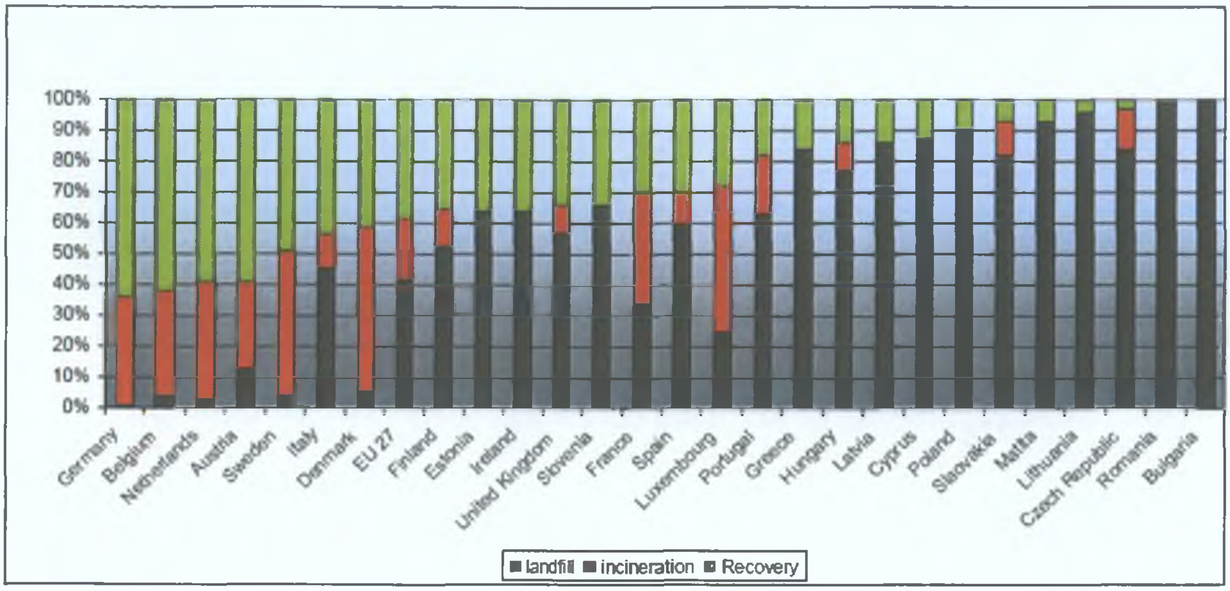


Figure 1 represents a breakdown of treatment methods currently utilised in the EU27 to manage MSW. The EU 27 averages that c40% of MSW is landfill; c20% is treated by incineration while the remainder c40% is recycled.

As is evident these treatment methods vary significantly across the member states. Germany recycles the most and landfills the least while the recently joined Bulgaria landfilled 100% of the MSW generated in the country. Ireland lies on par with Estonia in the middle of the above illustration neither with the best nor the worst recycling rate.

While Ireland has a strong uptake on recycling, the remainder is however landfilled. The volumes recycled are slightly below the EU27 average while the volumes going to landfill are way above the EU27 average. Ireland had no incineration capacity in the year outlined above.

As seen in figure 1, other European countries have diversified and incorporated incineration as a MSW treatment method. This is an alternative to landfilling waste and has been successfully adapted on the continent to deal with MSW.

Ireland has had a strong uptake to recycling but it is obvious from above that other methods of waste treatment have to be explored in order to keep up with our European counterparts. The Irish situation has not changed dramatically since the above data was presented at the International Solid Waste Association Conference in the Netherlands May 2010.

1.2. Research Focus

The literature has suggested that Ireland has the potential to capitalise on its "late-mover" status in the Waste Management Sector. It was seen that Ireland has the potential to "leap-frog" the leaders in this field in Europe. It can also be seen through the literature that both MBT and Incineration have been a success on mainland Europe as waste technologies for MSW and there is no reason why either or both of these methods would not be successful in Ireland today.

The overall focus of this dissertation is to explore the Waste Management System namely the approach and applications in selected European countries at the forefront of this industry and to ascertain how the underdeveloped Irish system can capitalise on their experiences. By studying the development of this sector in other countries it is likely that Ireland can capitalise on this knowledge in order to gain advantages in this field.

1.3. Overall Aim and Individual Objectives

The overall aim of this dissertation is to ascertain what Ireland can learn from the European experiences in developing their Waste Sectors. European countries are striding ahead in this field and learning from our peers is an obvious method of succeeding. It is the intention of this dissertation to explore, in the form of case studies, the waste management systems of carefully chosen European countries. It is by understanding how these countries have achieved their own efficient systems that can we replicate our own. The following objectives have been identified as paramount to achieving the aim as outlined above,

- Review Ireland's current waste management strategy and identify the preferred technology in Ireland.
- Identify European countries that have successful waste sectors Ireland could emanate.
- Explore the technologies utilised in the chosen countries.
- Identify any future objectives in these countries for waste management.
- Propose recommendations for the Irish waste sector upon improving the sector.

1.4. Value of research

This research is important for a number of reasons. Firstly the literature survey is a vital piece of information as it outlines the current methods of Waste Management in Ireland. The potential options and oppositions are debated through the various pieces of literature arguing which is the most appropriate waste management treatment method for MSW. It is here that a divide emerges and it creates the rationale for this dissertation.

Ireland's waste management sector is in a transitional stage where there is no consensus on the best possible outcome. By identifying the methods that are utilised successfully in Europe and adapting these to the Irish circumstances it provides the ideal platform for Ireland to emerge as a leader in this field.

Ultimately the information on how these nations are successful has the potential to save Ireland time and expense. By utilising the information gained, Ireland can take advantage of the late start and utilise our counterpart's experiences to influence our own agenda and eventually meet the Landfill targets fully.

By intending to leap frog these advanced countries we must first acknowledge their methods of Waste Management and try to replicate the successes of these countries.

The information gathered and evaluated and subsequently incorporated into our waste management sector has the potential to place Ireland at the forefront of Waste Management in Europe and the world.

2. Literature Survey

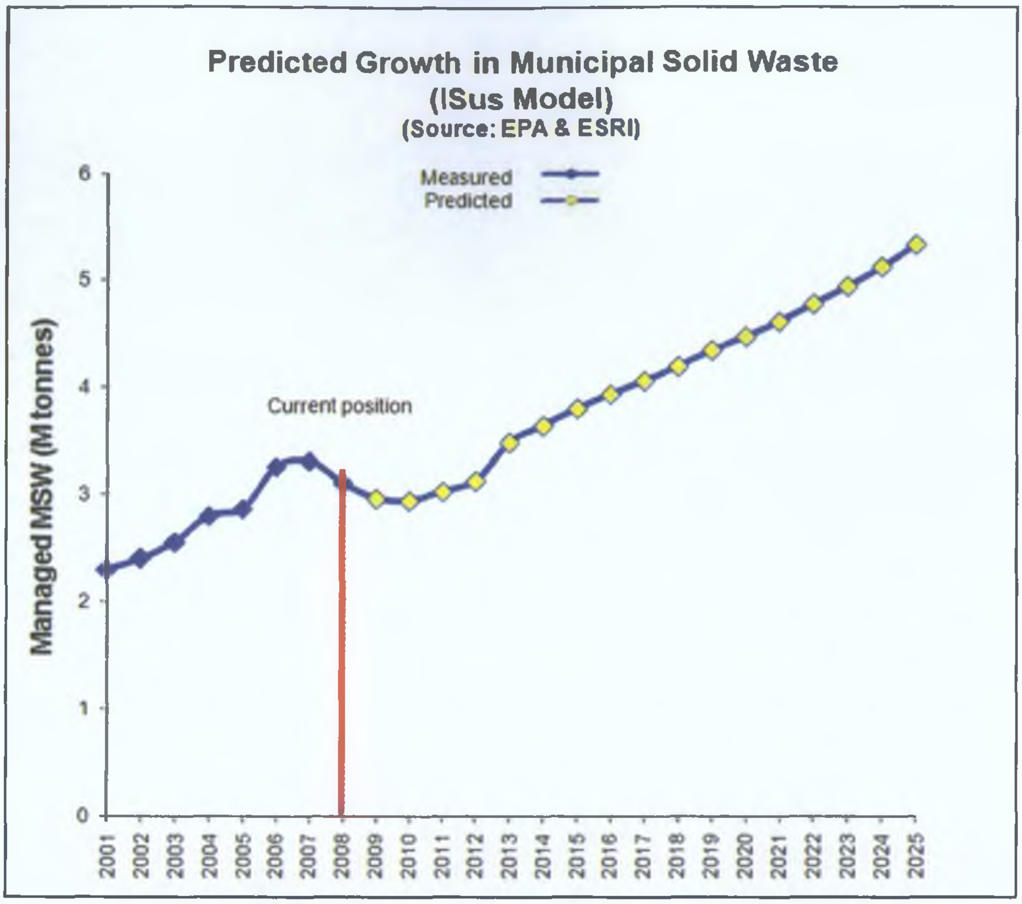
2.1. Introduction

Historically waste management in Ireland has received very little attention from central government and exchequer funding, as it was seen as a local authority function. The problems included little to no regulatory framework and no external regulation of local authority waste activities. This has resulted in Irelands waste management system being grossly inadequate for the 21st century and for our current population.

This sector has witnessed major changes since the introduction of the Waste Management Act 1998. Most notably the improvement in recycling rates are impressive, however this remains inadequate to substantially reduce the reliance on waste disposal.

The reliance on waste disposal represents a challenge, but some also believe that this is also an opportunity in relation to waste management in Ireland. It is believed that Ireland has the potential to make use of its 'late-mover' advantage in seeking to leap-frog in performance over the supposed 'leaders' in European waste management. It is also predicted that waste volumes are to increase gradually over the coming years as illustrated below, figure 2. However a slight downturn or dip is expected due to the economic conditions. Waste volumes are expected again to rebound with the improvement of the economy *(DOEHLG, 2006).*

Figure 2. The projected generation of Municipal Solid Waste *(EPA 2008 and ESRI website).*



Ultimately Ireland is being forced to find an alternative waste management technique as the EU Landfill Directive (1999) set down specific limits on the tonnage of biodegradable waste that can be accepted at landfills (Table 1 below). These targets are the most imminent of all waste policy targets in Ireland: by 1st January 2010, Ireland may only landfill a maximum 75% of the biodegradable waste generated in 1995, i.e. a maximum of 967,443 tonne can be sent to landfill. Failure to reach these targets will result in Ireland having to pay large fines to the EU.

Article 5 of the EU Landfill Directive 1999/31/EC sets out the targets for diversion of biodegradable municipal waste (BMW) from landfill as outlined below.

Table 1. Targets for biodegradable waste diversion from landfill *(Directive 1999/31/EC).*

Target Year	Landfill Directive Target (%)	Landfill Directive Target (tonnes)
2010	75% of quantity generated in 1995	967,433
2013	50% of quantity generated in 1995	644,956
2016	35% of quantity generated in 1995	451,469

These targets demand a modern, productive, robust and environmentally sound waste management system in order for the above targets to be met on time and in full. The National Biodegradable waste Strategy (2006) outlined that "*two broad options are currently available for residual waste treatment, namely Thermal Treatment and Mechanical Biological Treatment" (DOEHLG, 2006).*

These two treatment options are widely utilised on the continent in favour of landfilling and are tried and tested methods of treating waste *(Dublin City Council, 2010 and Greenstar, 2008).*

The German waste system has recognised that waste contains valuable raw materials which they intend to utilise in order to conserve natural resources. The land filling of untreated biodegradable matter and of organic waste has ceased. The Germans wish to eliminate the need for landfills by 2020 by the combined techniques of pre-treatment, recycling and energy recovery. The German Waste Management system endorses both the use of Incineration and of Mechanical Biological Treatment *(BMU, 2010).*

2.2. Background to Waste Management in Ireland

Prior to Ireland's membership into the European Community in 1973, Waste Management was provided for in the following pieces of legislation,

- Public Health (Ireland) Act, 1878
- The Public Acts Amendment Act, 1907
- Local Government (Sanitary Services) Acts 1978 – 1964
- Local Government (Planning and Development) Acts 1963 - 1993

These pieces of Legislation remained effective until the Waste Management Act, 1996, was imposed. The above Acts provided no guidance on waste management or the disposal of waste and also relevant definitions were not provided.

These pieces of legislation provided vague and indistinct information for example under section 52 of the Public Health Ireland Act, 1878 sanitary authorities were required to collect domestic refuse free of charge and under Section 55 they were obliged to provide suitable places for the deposit of such matter *(Public Health (Ireland) Act, 1878).*

As a result of this lack of guidance, 95% of municipal waste was land filled in some 300 relatively small and poorly operated dumps. The only recycling measures in place were a small number of glass and can "bring banks", scattered throughout the country, operated by a charity organisation, Rehab *(Rudden, 2005).*

It was the introduction of The Waste Management Act, 1996 that signalled the start of a new era in Waste Management. This Act overhauled the previous legislation. Definitions were provided and also waste prevention and minimisation techniques were outlined *(Waste Management Act, 1996).*

In this Act, "recovery", in relation to waste, means "*any activity carried on for the purposes of reclaiming, recycling or re-using, in whole or in part, the waste and any activities related to such reclamation, recycling or re-use, including any of the activities specified in the Fourth Schedule, and "waste recovery activity" shall be construed accordingly*".

National Policy evolved quickly after the Waste Management Act 1996, the Government reacted to the worsening crisis in the waste management area by compiling policy documents including the following.

- Changing Our Ways 1998
- Delivering Change – Preventing and Recycling Waste (2002)
- Waste Management – Taking Stock and Moving Forward (2004)

Changing Our Ways 1998, acknowledged the urgent need to modernise Waste Management Practices and secure the provision of environmentally efficient infrastructure. A number of targets were introduced in order to reduce the heavy reliance on land filling, including:

- A diversion of 50% of overall household waste away from landfill.
- A minimum 65% reduction in biodegradable municipal wastes consigned to landfill
- Materials recycling of 35% of municipal waste.

This report prefers the utilisation of composting or material recovery but states that Incineration is "*effective in diverting over 70% of municipal waste away from landfill and, if properly controlled, has a considerably lower environmental impact than landfill" (DOEHLG, 1998 and Environment Heritage and Local Government website 2011).*

Delivering Change – Preventing and Recycling Waste (2002) and Waste Management – Taking Stock and Moving Forward (2004) built on the principles outlined in the previous policy document, further enforcing the waste hierarchy. The waste hierarchy was seen as "*The most favoured option is waste prevention, followed by minimisation, reuse, recycling, energy recovery and the least favoured option of disposal to landfill" (DOEHLG 2002 and DOEHLG 2004).*

2.3. Waste Management Tools

The Irish Government has expressed agreement to MBT and Thermal treatment both in the National Biodegradable waste Strategy and the Agreed Programme of Government 2007-2012. In the National Biodegradable waste Strategy (2006) it is said that *"two broad options are currently available for residual waste treatment, namely Thermal Treatment and Mechanical Biological Treatment"(DOEHLG, 2006).*

Despite these it is clear that the development of MBT and Thermal treatment in Ireland is in the early stages of development as there are a lack of clear policy drivers, particularly in relation to MBT.

2.4. MBT as a Waste Management Tool

A clear indication to the commitment to MBT is evident in the the Agreed Programme of Government 2007-2012, where it states that *"we are also committed to meeting the targets to divert biogedrabable waste from landfill required under the 1999 EU landfill Directive. To achieve this, we are committed to the introduction of Mechanical Biological Treatment (MBT) facilities as one of a range of technologies".*

The National Development plan 2007 – 2013 also addresses the subject of Mechanical Biological Treatment in Ireland in a report published as part of the Science, Technology, Research and Innovation for the Environment (STRIVE) Programme 2007 – 2013 entitled *"Critical Analysis of the Potential of Mechanical Biological Treatment for Irish waste management"* This in-depth examination of MBT aimed to provide information on this topic that may influence future Government policy, identify issues that require addressing prior to the implementation of MBT and also make recommendations to solve these issues.

This report established that in order to implement MBT a variety of legislation has to be adhered to including planning, veterinary controls, renewable energy, thermal treatment, soil protection, and integrated environmental protection legislation. Also it is recommended that national standards be developed to govern the operation of MBT facilities in addition to EPA licensing.

This report emphasises the potential MBT has in ensuring Ireland meets the targets and objectives not only in relation to the Kyoto Agreement aimed at reducing greenhouse gas emissions but also in relation to landfill diversion targets.

Various Consulting Engineers have published reports in the aftermath of the above document outlining their own research into the viability of MBT as a waste management technique in the Irish context. The first, published in February 2008 is from one of the authors of the above STRIVE document - Bernie Guinan of Fehily Timoney & Co entitled *"Critical Analysis of the potential of Mechanical Biological Treatment"* This presentation has similar aims to the STRIVE document with the overall aim to examine if MBT can contribute to meeting landfill directive diversion targets in terms of treating MSW.

This report emphasised the proven technology of aerobic degradation, anaerobic degradation and bio drying and explored the potential of the emerging technologies available in this area, including autoclaving and ethanol production. It was acknowledged that MBT has its outputs that do require further treatment including recyclables, refuse derived fuel, solid recovered fuel, stabilised bio waste/compost and also biogas.

This Consultancy firm, Fehily Timoney & Co, has a keen interest in MBT as the same presentation is available as above for 2009 with updated data available. However the need for appropriate standards was the major argument, in order to control and monitor the following,

- The establishment of boundaries to achieve sector development
- In order to measure the facility's performance and standards
- To create an equitable operational market
- To aid future investment in the sector.

The desire for adequate standards is a theme throughout the literature of MBT technology in the Irish system.

Again in the 2008 report *"The Potential for MBT in an Irish context to play a role in delivering the necessary diversion targets"* by TOBIN Consulting Engineers the need for standards is reiterated. Here however unlike other reports this report claims that the most of the MBT developments to date have focussed on the Mechanical rather than the Biological.

This consultative paper emphasises that MBT does produce outputs in the form of recycled material, RDF and Stabilised Bio waste. The amount of reduction is very much dependant on the design and characteristics of each plant. However the following are the main outputs of any MBT *(Friends of the Earth, 2008).*

Table 2. MBT Outputs *(Friends of the Earth, 2008).*

Recyclables	**RDF / SRF**	**Biowaste (organic fraction)**	**Biogas**
Metals, hard plastics, glass	Combustible & high calorific portion of waste (paper)	Compost like output, is effectively the matured or composted organic fraction	biogas only produced if AD employed

Typical uses for this output, depending on contamination would be land reclamation of Brownfield sites, landfill restoration or merely deposited into landfill. While the RDF generated would be incinerated typically to generate power or as a fuel replacement.

The concern over these outputs generally is that the markets for these products are sensitive and fluctuating and often are worth a negative value. Also here in Ireland there is a limited market for these materials, the cement industries make use of a portion of these as a fuel replacement. However the majority is shipped abroad hence incurring costs. This highlights the fact that MBT is not a "disposal method" but merely a pre-treatment step prior to disposal, generally through landfill or incineration *(DEFRA 2007 and Assurre 2006).*

Despite this fact, MBT has a lot to offer the Irish Waste Industry as TOBIN Consulting Engineers and Eunomia Research, Assurre & Consulting Ltd have proven below *(Greenstar, 2007, Dublin City Council, 2010, TOBIN Consulting Engineers, 2008, Assurre 2006 and Finnveden, Bjorklund, Carlsson Reich, Eriksson, Sorbom, 2007).*

Table 3. Advantages and Disadvantages of MBT as a MSW Treatment option.

Advantages	Disadvantages
Proven Technology in Europe	Pre-treatment only NOT a method of Disposal.
Several designs are quite flexible in terms of their operation and technology	Additional Processing stages required before final disposal /thermal treatment
Variable sizes and quick to build due to their modular design	Operational costs are high as the complex & highly mechanised systems require constant maintenance
Reduction in Environmental Impact on landfill due to stabilization of waste	Lack of outlets for RDF processed from MBT plants, could be incinerated.
Reduction of the biodegradability of the waste thus reducing the emissions of gas, leachate, vermin, odour and onsite litter.	Reluctance of various industries to use this RDF as they would be required to upgrade pollution control equipment, as poor quality product is obtained.
High Calorific Value of Refuse Derived Fuel an output – Energy Generation possible	Stabilised Bio waste may contain high levels of heavy metals so is therefore a contamination risk to the environment
Biogas produced from anaerobic digestion can be utilised as natural gas substitute or converted into fuel	Recovery of recyclables is 3 – 15% depending on the input material and process.
MBT beneficial where segregated collection not viable i.e. in the country	Lifetime is expected to be 20 – 25 years
Increased recycling and recovery of mixed waste	Compost tends to be of lower quality then acceptable for land use
Less public opposition so time spent in planning process	No firm standards in place in Ireland for the management of outputs produced by the MBT process

A recent report entitled "*Meeting Irelands Waste Targets: The role of MBT*" assessed the performance of 6 commonly used waste management techniques against the Landfill Directive Targets and concluded that MBT can deliver much of what is required in order to reach these targets. The modelling here indicates that whether MBT operates in a stabilisation mode or a mode producing RDF/SRF, the major challenges can be met.

Larger MBT facilities in Ireland would require an animal by-product licence and a waste license or an IPPC license depending on the size of the facility. However there are currently no firm standards in place in Ireland for the management of outputs produced by the MBT process. In relation to a stabilised organic output, the *Working Document for the Treatment of Biowaste (2nd Draft)* (EC, 2001) suggests quality standards and limited land application uses for a stabilised organic material. Also proposed are biodegradability levels if landfilling the material. The Working Document has been abandoned yet remains the only guidance text on relevant standards produced at a European level.

The Environmental Protection Agency (EPA) has recently published *Municipal Solid Waste – Pre-treatment and Residuals Management Technical Guidance Document, Consultant Draft (EPA, 2008)*. This document proposes a standard that may be adopted by the industry in the near future.

2.5. Incineration as a Waste Management Tool

Reiterating the National Biogradable waste Strategy (2006) it is said that *"two broad options are currently available for residual waste treatment, namely Thermal Treatment and Mechanical Biological Treatment"*

Incineration is globally believed to be one of the best disposal technologies for municipal solid waste, since it has the potential to reduce the waste volume significantly and reduce toxicity. In addition, the heat energy produced during incineration can be recovered for electric power generation. For example, c60% of Danish households source their heating and hot water from district heating plants, many of which are fuelled by waste *(Greenstar, 2007).*

However, inadequate design or operation can result in the emission of pollutants. It is these pollutants that result in fierce opposition to this technology. The Friends of the Earth believe that incineration will destroy natural resources, undermine recycling by demanding a steady stream of waste, will add to climate change and it causes pollution from air emissions and toxic ash *(Friends of the Earth, 2008, Ming-Yen Wey, Wen-Yu Ou, Zhen-ShuLiu, Hui-Hsin Tseng, Wen-Yi Yang, Bo-Chin Chiang, 2001).*

Despite this opinion by the Friends of the Earth in Ireland, the majority of local and regional waste management plans, 7 out of the 10, have included incineration with energy recovery as an integral component of their future waste management strategies, including Dublin and the Limerick/Clare and Kerry region. In order to protect the environment and set a minimum technical standard in relation to incineration, the Waste Incineration Directive (2000/76/EC) has been transposed into Irish law. This has introduced new stringent operating conditions and aims to limit any negative environmental effects of emissions into air, soil, surface and ground water, and reduce the risks to human health *(EPA, 2004 and EPA, 2008).*

In 2001 Forfas issued a report on waste management in Ireland representing a strong case for thermal treatment. It cites studies which suggest no increases in dioxin levels above the background levels around incineration plants and argues that emission standards are now much tighter than in the past. This report argues that Ireland is "*critically lacking in thermal facilities*".

According to this report,
"Thermal treatment is regarded as being more environmentally desirable from the perspective of human health, and a more environmentally sustainable waste management option than landfill. The energy by-product of incineration can be recovered, displacing the need to burn fossil fuels, and consequently reducing greenhouse gas emissions".

In November 2006, the EPA granted two licenses for two commercial incinerators operated by Indavar Ireland at Carranstown, Co Meath and Ringaskiddy, Co Cork. While in December 2008, the EPA also granted a license for a third municipal waste incinerator at Ringsend in Dublin. As of the end of 2008 only one of these had commenced construction. Carranstown is due to accept waste in 2011.

It is the Ringsend, Poolbeg Incinerator development which is shrouded in controversy over whether there will be sufficient volumes of waste to operate the plant. The ESRI has stated that there will be sufficient volumes, a statement which the former Minister John Gormley rejected. A foreshore license is still being processed by this Department and is currently delaying the €350 million project. This controversial incinerator is due to be opened by 2013 *(Indavar Ireland).*

As with MBT it is the outputs from this process that are of concern to people. A recent EPA report entitled *"Municipal Solid Waste Incineration as part of Ireland's Integrated Waste Management Strategy"* details the outputs generated from the incineration process. Firstly it can be noted that Incineration involves the controlled burning of wastes at high temperatures for a sustained period. The outputs are the ash generated, both bottom ash and fly ash, and the emissions generated.

Table 4. Emissions generated from Incineration *(Institute for prospective Technological Studies, Seville 1999).*

Emission	**Examples**
Gases	$CO, CO_2, NOx, SOx, HCl, HF$
Mineral Dust	Fly Ash
Heavy Metals	Pb, Cu, Hg, Cd, Ni, As.
Organic Molecules	Soot, PAH, hydrocarbons, Dioxin/Furans, VOCs

The above gases mostly generated by the combustion phase may contribute to global warming, acidification, ozone depletion and to smog in the troposphere. Similarly these gases would affect the human population in the form of irritation to the lungs and cancer is also linked to dioxins.

However all these gases can be avoided and/or contained. Complete oxidation is essential to prevent the production of the undesirable organic pollutants, so a well maintained unit is essential. In response to the environmental and health concerns raised in relation to incineration, the European and national environmental regulations have set emission limit standards. Specifically in response to the flue gas and the combustion gases produces vast arrays of treatment methods have been made a mandatory requirement to these incinerators.

These include Electrostatic precipitators, Fabric filters, Scrubbers and Moving-bed adsorbers to name a few.

These are designed to capture all gases and particulates before they are released into the atmosphere. It is these controls that can reduce the dioxin emissions by more than 99% *(McKay 2002).*

Incineration in Ireland requires an IPPC license to be obtained; this is issued by the EPA. The EPA has also published the BAT Guidance Note for The Waste Sector; this provides guidance for industries applying for an IPPC license and also provides emission limit values for outputs using BAT, 'the best available technology'. It also describes the existing, or possible, measures for reduction and control of emissions in relation to incineration. These range from relatively simple containment measures to sophisticated recovery and end-of-pipe technologies.

The IPPC license of the facility stipulates that emissions must be continuously monitored for compliance with the strict emissions emission limit values. The temperature is also measured to ensure efficiency and effective even burning.

Table 5. Emission limit values – Incineration *(EPA 2008).*

	Hazardous & Clinical Waste Incineration		**Animal Carcass Incineration**	**Other Incineration**
Averaging Period	**30 min.**	**Daily**	**Hourly**	**Hourly**
Volatile organic compounds (excluding particulate matter) expressed as total organic carbon	20 mg/m^3	10 mg/m^3	-	20mg/m^3
Total particulate matter	30 mg/m^3	10 mg/m^3	100 mg/m^3	30 mg/m^3
Hydrogen chloride	60 mg/m^3	10 mg/m^3	30 mg/m^3	30 mg/m^3
Hydrogen fluoride	4 mg/m^3	1 mg/m^3	-	2 mg/m^3
Sulphur dioxide	200 mg/m^3	50 mg/m^3	300 mg/m^3	300 mg/m^3
Dioxins* (6-8 hours samples)	-	0.1 ng/m^3	0.1 ng/m^3	0.1 ng/m^3

Note: Achievement of ELV concentration by the introduction of dilution air is not permitted

A recent article on the "Pros and Cons of Incineration for Landfill Relief" outlines the potential advantages of Incineration and why it is taking a prominent role for municipal authorities all over the world *(Dublin City Council, 2010, Ming-Yen Wey, Wen-Yu Ou, Zhen-ShuLiu, Hui-Hsin Tseng, Wen-Yi Yang, Bo-Chin Chiang, 2001, Institute for prospective Technological Studies, Seville 1999, Gordon. 2002 and Row 2010).*

Table 6. Advantages and Disadvantages of incineration as a treatment method for MSW

Advantages	Disadvantages
Cost savings on transport to out of the way landfills	Capital and operating costs are high
Volume MSW is reduced to a fraction of the original (85–90%)	Large volumes of waste required for sustainment
This energy can be sold to generate a profit	Outputs have potential to damage environment and human health therefore Constant vigilance required to ensure complete and even burning
Reduction in environmental impacts of landfills (gases and leachate)	Require highly skilled operators
Toxicity reduction and Outputs are sterile	Inadequate design or operation can result in the emission of pollutants
Flexible in the sense can accommodate a variety of waste streams	Can be difficult to find an output for the heat energy during the Summer
Improving Technologies include, Thermolysis, Gasification and Pyrolysis	Ashes slag and flue residues generally have to be disposed of to landfill, although cement production plants may take these also.
All emissions are controlled under the IPPC license and strict ELVS in place.	Some materials should not be incinerated because they are more valuable for recycling.
	Supplementary fuels may be required to achieve the high combustion temperatures.

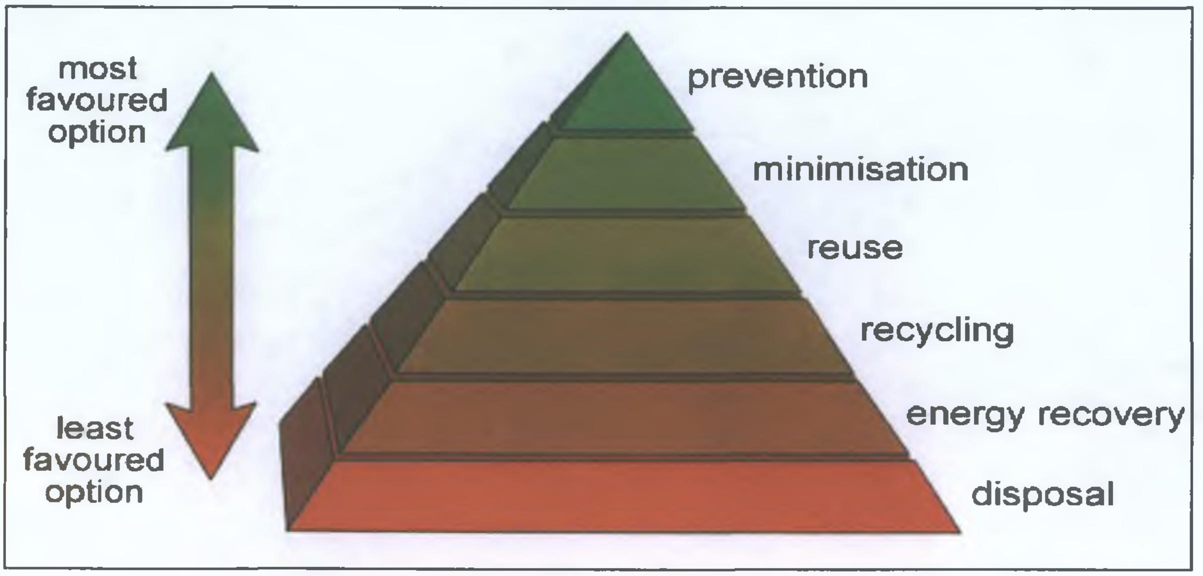
It seems that the foundations for incineration as a waste management option are already in place in Ireland in terms of legislation dictated by the EU. This is despite the fact that there are no facilities currently accepting municipal solid waste at this time.

The legislation and relevant regulatory framework is in place for incineration to be introduced immediately as a waste management treatment option. While there is currently no specific legislation governing MBT, there is a vast array of legislation that must be adhered to. Due to the framework surrounding incineration, there are strict limitations and guidelines in place to influence and monitor the incineration process, ultimately ensuring that emissions do not reach the atmosphere.

2.6. Adhering to the Waste Hierarchy

The waste hierarchy is an internationally accepted approach both in law and in practice as the key determinant in influencing the approach to waste policy. These guiding principles have been adopted in the Waste Framework Directive and therefore must be respected when deciding on an appropriate waste management tool. The top of the pyramid is the favoured approach to waste management while but the bottom is the least favoured option. It is obvious from figure 3, below that disposal is least favoured and recycling is favoured over energy recovery *(CEWEP 2010).*

Figure 3. The Waste Hierarchy *(European Commission).*



3. Methodology

3.1. Strategy and Justification

The strategy that best fits this study was for the use of case studies. This seemed the logical and most appropriate choice. Case studies as a form of methodology have been popular for years as an accurate and reliable form of gathering information. Case study research has been described as having the ability to excel at bringing us to an understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research *(Soy, 1997).*

In this situation it was determined that case studies would best methodology to convey the possibilities that are open to Ireland. The casestudies would explore adequate techniques that would best fit the Irish Waste Management system based on real experience. Principally countries in Europe are sending less MSW to landfill and are prime examples of modern effective and efficient waste management systems. It is from their examples that Ireland will learn and improve and modernise waste management in Ireland. Therefore by exploring these chosen countries waste management systems through the medium of case studies Ireland can fully understand and comprehend the choices and the rationale behind these techniques. There is a massive potential to adapt these techniques into Irish society and hence become on par with the leaders in this field throughout Europe.

3.2. Which Countries and Why?

Sweden and Germany are the main countries of interest, while the Netherlands and Denmark will be looked at in a secondary capacity. Like Ireland, these countries are all in the EU and hence are governed by common laws, directives and practices imposed by the EU. A major endeavour of the EU is the diversion of waste from landfills and implementation and practice of the waste hierarchy system.

These four countries are at the forefront of Waste Management technology in Europe and each have been recognised for their achievements by being considered for the honour of the European Green Capital Awards. Stockholm was the European Green Capital for 2010 while Hamburg took the honours in 2011. This award propels the chosen countries to act as role models to inspire other cities and countries to promote best practices to all other European cities and countries.

It is also acknowledged that these four countries, Germany, Sweden, The Netherlands and Denmark, as seen from the figure 1 above, have attained extremely low landfill rates. All with significantly less than 10% of MSW diverted to landfill facilities. These countries have successfully sourced alternative methods to treat municipal solid waste. It is this that Ireland is intending to emanate. Ireland has to divert MSW away from landfills and similarly find a suitable manner to treat this diverted waste. The methods that these European countries have employed can be replicated to aid Ireland achieving this.

3.3. Data Collection Techniques

The techniques utilised in order to collect the data required to complete these case studies will come from books, journal articles and government and consultant reports. The Journal articles were collated and accessed on the internet through online libraries such as Science Direct, accessible through the Sligo IT library directory. Government Reports were accessed through the EPA and Government websites of the respective countries and will therefore be the most up to date and accurate data available. Statistics were accessed through the respective countries national collection agency while European statistics were accessed through Eurostat.

3.4. Framework for data analysis

It is expected that data on the four countries of choice be collated and compared. Germany and Sweden will be explored in depth while The Netherlands and Denmark will be examined in a secondary capacity. The information obtained will be assessed and determined if viable for implementation within the Irish situation. Recommendations will be proposed and validated and presented below.

3.5. Limitations of this study

There are varying opinions on the methodology of case studies. Some critics of the case study method believe that the study of a small number of cases can offer no grounds for establishing reliability or generality of findings. Others feel that the intense exposure to study of the case biases the findings. Some dismiss case study research as useful only as an exploratory tool. Yet researchers continue to use the case study research method with success in carefully planned and crafted studies of real-life situations, issues, and problems. Reports on case studies from many disciplines are widely available in the literature. It is the intention of this dissertation to prove that case studies are the most appropriate methodology for achieving the chosen aims and objectives; however it is acknowledged that some critics hold no value in this methodology *(Khairul Baharein Mohd Noor 2008).*

It is also predicted that a major limitation will be time constraints due to the nature of this study and the volume of information required. Following on from this it is not expected that detailed 2010 data will be accessible as this data will not be available on Government websites as this data has not been analysed upon time of writing. The 2010 data represented will be highlighted below.

It should also be noted that information and situations in the Irish and European contexts are continuously in motion and that legislation and political agendas are likely to have been altered from the time of writing to the time of reading. This is particularly relevant in the Irish situation with the change of Government in 2011.

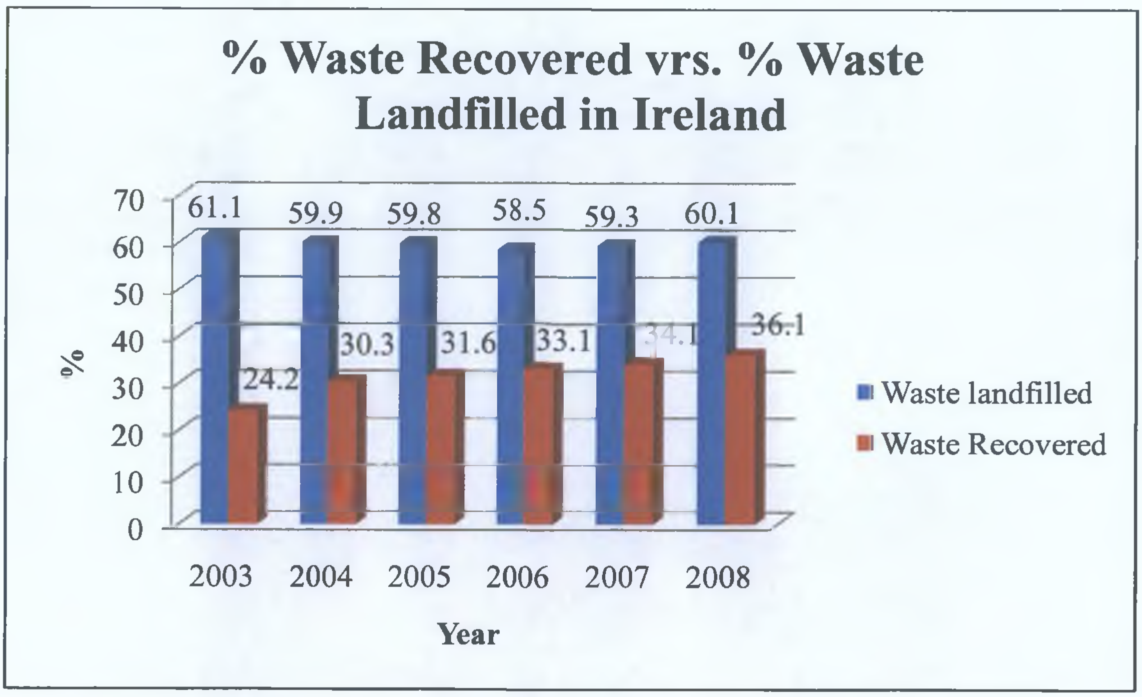
4. Case studies

Sweden and Germany will be examined in detail under the headings, background, current statistics, technologies used, targets and initiatives. While the Netherlands and Denmark will be examined under introduction and current statistics and initiatives only. The information obtained in these sectors will provide for the discussion and comparison with the Irish situation. Ireland must build upon the experiences of these leaders in the field of waste management in order to be able to compete with them in the future.

4.1. Brief Country Comparison

The most recent data regarding the direction of Municipal Solid Waste in Ireland through the period of 2003 to 2008 is outlined below.

Figure 4. Current trends in the Irish Waste Management sector *(CSO, EPA National Waste report Series).*



It is obvious that a clear increasing trend has immersed in the rates recovered, over the 5 year period documented above, the recovery rate has increased by nearly 12%. This increase is a clear sign of intention of the Irish people towards the commitment to recycling and also to diversifying from landfill. This figure would also include the volumes recovered in the emerging MBT facilities throughout the country. To date the biological fraction remains of poor quality while the refuse derived fuel is utilised as a fuel in the cement industry *(EPA, 2011).*

However in contrast, landfill rates remain consistently high at an average of 60% over this period. This can be explained by the lack of other well developed and established outlets for MSW in the Irish system. Landfilling, as the waste hierarchy stipulates is the last option that should be considered for the flow of MSW.

Table 7. A Brief Comparison of Countries Examined *(Eurostat, 2010).*

	Ireland	**Germany**	**Sweden**	**Netherlands**	**Denmark**
Population	4.5million	82million	9.2million	16.4million	5.5million
Area	70,000km^2	356,854 km^2	449,964 km^2	41,526 km^2	43,094 km^2
Ban on organics to Landfill	2010	2005	2005	1996	1997
Ban on combustibles to landfill	n/a	2005	2002	1996	1997
Funding	74%Public: 26%Private	35%public: 65%private	25%public: 75% private	N/E	N/E
# Incinerators*	0	67	30	17	29
# Bio Treatment facilities **	30	980	125	N/E	N/E
Number of MBT facilities	2	78	0	N/E	N/E
No of bin collections	2 bins - 95% 3 bins - 21%	4	At least 3	N/E	N/E

N/E = Not Examined

* Information obtained from CEWEP website *(http://www.cewep.eu/index.html)*

**These include both composting/digestion facilities. *(compostnetwork.info)*

The above data illustrates how inherently different the chosen countries are to each other. The populations range from Ireland's 4.5 million to 82 million in Germany while the Netherlands is the smallest in area but holds the second largest population. The largest in area is Sweden which does not possess the largest or the smallest population.

These countries have, most notably progressed their waste management systems at a quicker pace than Irelands; this is evident in the years in which they have banned both combustibles and organics entering landfills. Ireland is 13 years behind Denmark in its organic waste outlaw to landfill but merely 5 years behind Germany and Sweden.

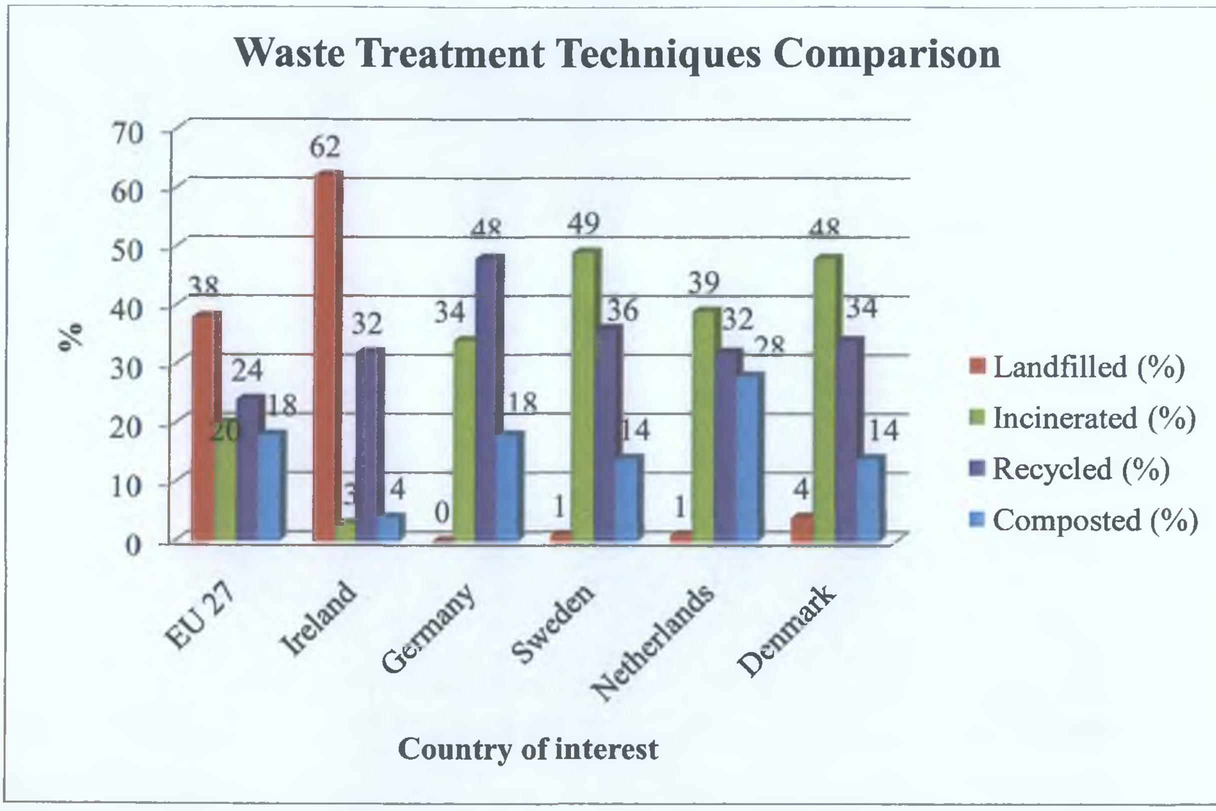
Of the countries examined in depth, Ireland is the only country which has a majority public share in its waste management sector. Both Germany and Sweden have mostly privatised the service.

Also evident from the above table is that despite the range in areas and populations there is ample investment in Incineration as a MSW treatment option in all the countries explored. Notably though there are even more biological treatment centres in Germany and Sweden than incineration facilities.

Also of the countries examined Ireland has the least amount of bin collections. The EPA has supplied the information that the majority of Irish people 95% have 2 bin collections while a mere 21% have a third brown (organic) bin. In Germany there are 4 bin collections as standard. While in Sweden, separate multi-compartments bins are used to separate household wastes and varying coloured bags are also used to signify the contents.

Figure 5 below outlines the direction of MSW in the chosen countries and the EU27 countries. This data was obtained from the Eurostat website and is the most current available, 2009; the raw data is available in the appendix.

Figure 5. Waste Treatment Techniques in Europe, 2009 *(Eurostat, 2010).*



The most striking piece of information from the above figure is that Ireland has by far landfilled the most compared to the countries of interest and also exceeds the EU27 by 24%. The closest country following the EU27 is Denmark, which remains 58% behind Ireland.

Following on from this in the EU 27 Sweden had the highest % of MSW incinerated followed closely by Denmark, while Germany had the highest % of MSW recycled.

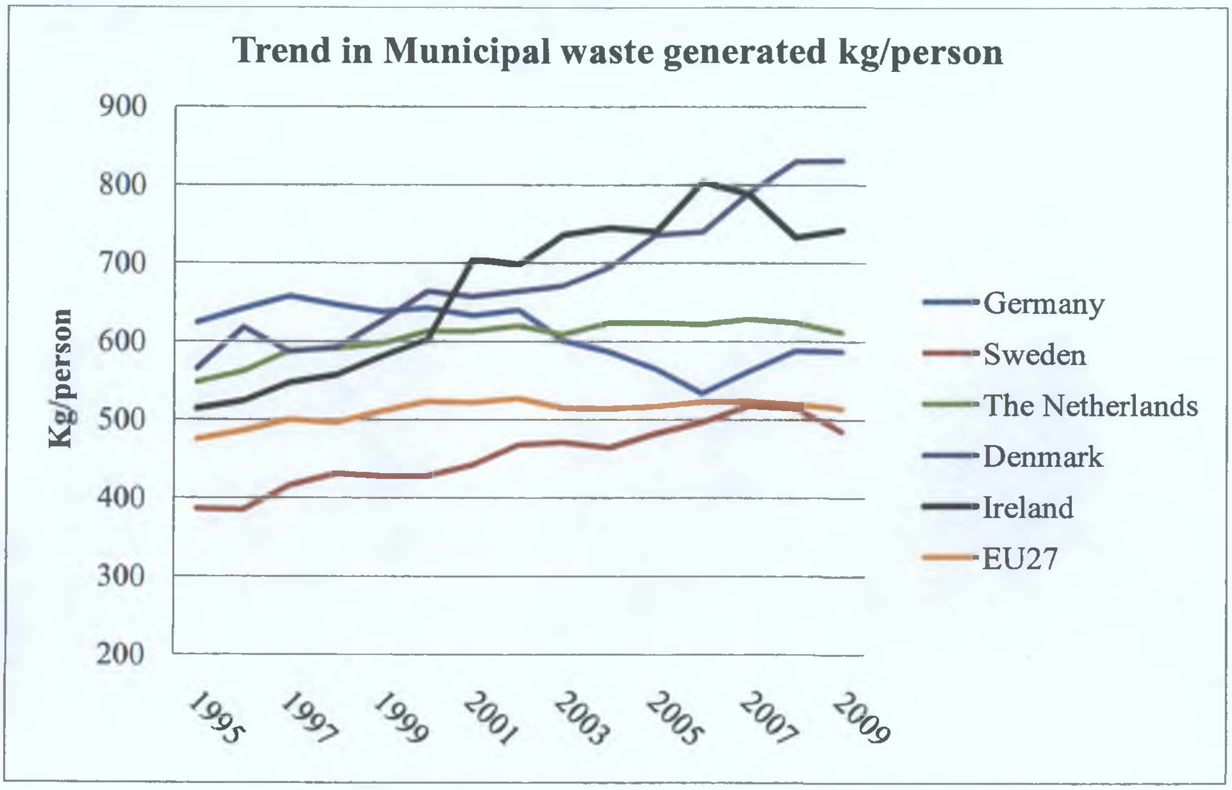
It can be observed that all of the countries being investigated are above the EU 27 average for both incineration and recycling and below average for landfilling. Composting is about average in these countries but notably 10% higher in the Netherlands.

On a positive note Ireland has achieved a higher recycling rate than the EU 27.

Figure 6 below demonstrates the volumes generated per person in each of the countries identified, also available is EU27 data.

Denmark is obviously the highest in 2009 followed by Ireland. The figures below illustrate the 2009 figures. Denmark is 317kg/person over the EU27 data while Ireland is 228kg/person over the EU27. Germany is over the average also, but to a lesser extent, 73kg/person. Sweden is comfortably under this average by 29kg/person.

***Figure* 6.** Trends in the volume MSW generated per person *(Eurostat 2010).*



The above trend shows that both Ireland and Denmark have been on a steady trend upwards until 2007 where Ireland declined suddenly. This can be assigned to the economic climate; however the Danes continued to climb. Sweden is the only country to remain under the EU27 average consistently over the period illustrated. Germany is on a downwards decline while since 1999 the Netherlands have remained constant just above 600kg/person.

4.2. Sweden

4.2.1. Background

Sweden joined the EU in 1995 but decades previous to this the country had been concerned and working actively on waste management technologies. The first incinerator in Sweden was set up outside of Stockholm in 1901. However the aim of this facility was solely to reduce the volume of waste. Energy recovery was not considered at this stage. It was the oil crises in 1973 and 1979 which refocused the objective of these incinerators and marked the turning point in Sweden in relation to waste management *(RVF, 2003).*

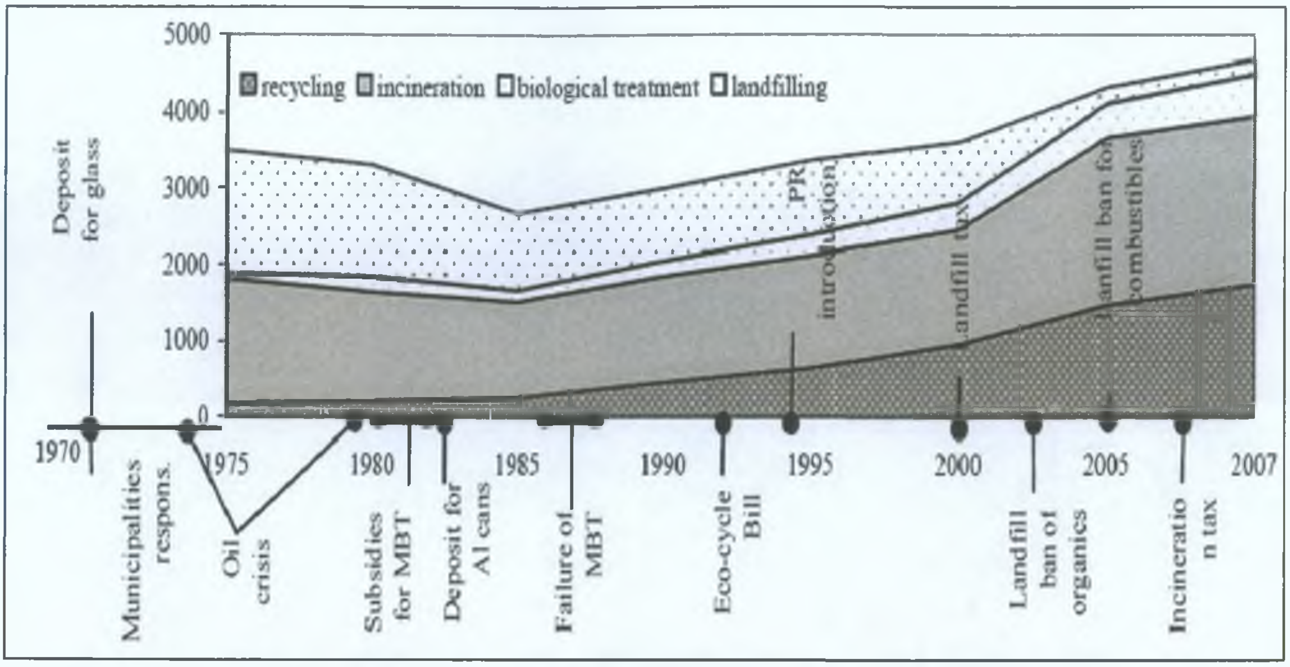
In 1974 a governmental study concluded: *"waste is resource that should be used".* It resulted in thirteen new incinerators with energy recovery built by the end of the 1970s. The municipalities aimed to be less dependent on external factors influencing energy prices and hence invested heavily in both new and older facilities, upgrading these with the newest Combined Heat and Power technology, (CHP). These were utilised by the already established central district heating system, (CDH) *(Smith, 2006, SEPA 2005).*

Simultaneously over this period there was an emphasis placed on pre treatment and the concept of MBT technology was introduced and the government invested in these projects. This technology was deemed not appropriate for Sweden and abandoned in the 1980s.

Again during the 1990s, there was a renewed effort to combat waste generation with the introduction of The Eco-Cycle Bill (1992/93:180) which put focus on prevention of waste generation amongst other items. The principle of *extended producer responsibility* (PR) was proposed and it made producers responsible for treating their waste. *(Miliute & Plepys, 2009).*

Figure 7 below illustrates the journey of Waste Management in Sweden from 1970 – 2007. This diagram illustrates that incineration remains the main techniques for treating household waste. But interestingly a steady increase in recycling is evident; conversely a decline in household waste going to landfill is also evident. Biological treatment continues to increase steadily albeit at slower rate.

***Figure** 7.* Swedish household Waste Management history 1970-2007 *(Eurostat, 2006).*



By the time Sweden was granted membership into the EU in 1995, WM standards, both proposed and actual, were higher than those required in the EU legislation. All data was collaborated by Avfall Sverige a Swedish Waste Management Association.

Table 8. Swedish Household waste recycling targets and situation in 2007 *(Avfall Sverige, 2008).*

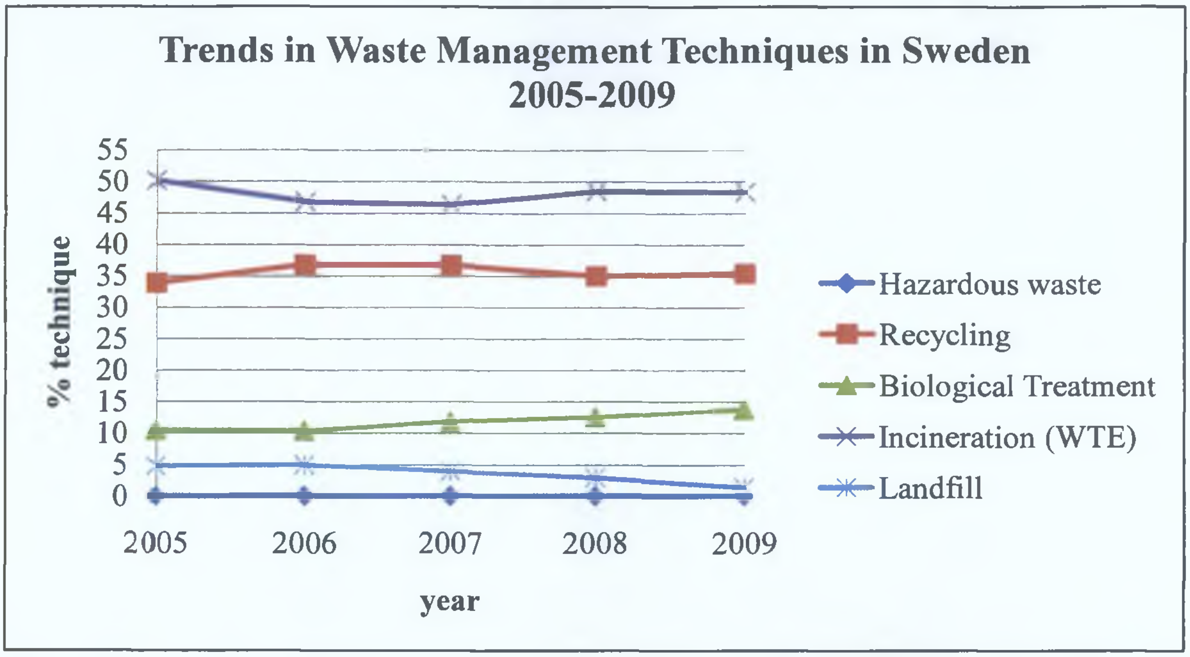
	EU target (for Sweden) %	Swedish national targets 2007, %	Actual situation in Sweden, 2007, %
Newsprint	-	75	85.0
Office paper	-	50	61.5
Cardboard packaging	60	65	72.6
Metal packaging	50	70	67.0
Plastic packaging	22.5	30	30.1
Glass packaging	60	70	95.0

Table 8 above illustrates the EU and Swedish targets for certain recyclables. Also present is the actual % recycled rate for these products. The largest difference is in glass packaging, where Sweden had already exceeded the EU target by 35%. At this time there were no target rates for newsprint and office paper in the EU, however these were documented in the Swedish system.

4.2.2. Current Statistics

Statistics given in this section were sourced from *"Swedish Waste Management 2010"* and was collected from the web based statistics system Avfall Web launched by Avfall Sverige. *(Avfall Sverige, 2010).*

Figure 8. Trends in the waste management techniques used in Sweden from 2005 – 2009.



It can be seen from figure 8 above that Incineration or Waste to Energy is by far the most popular means of waste disposal in Sweden through the period examined 2005 to 2009. Slight dips in the year 2006 and 2007 are evident but this is counteracted by higher recycling rates for these two years.

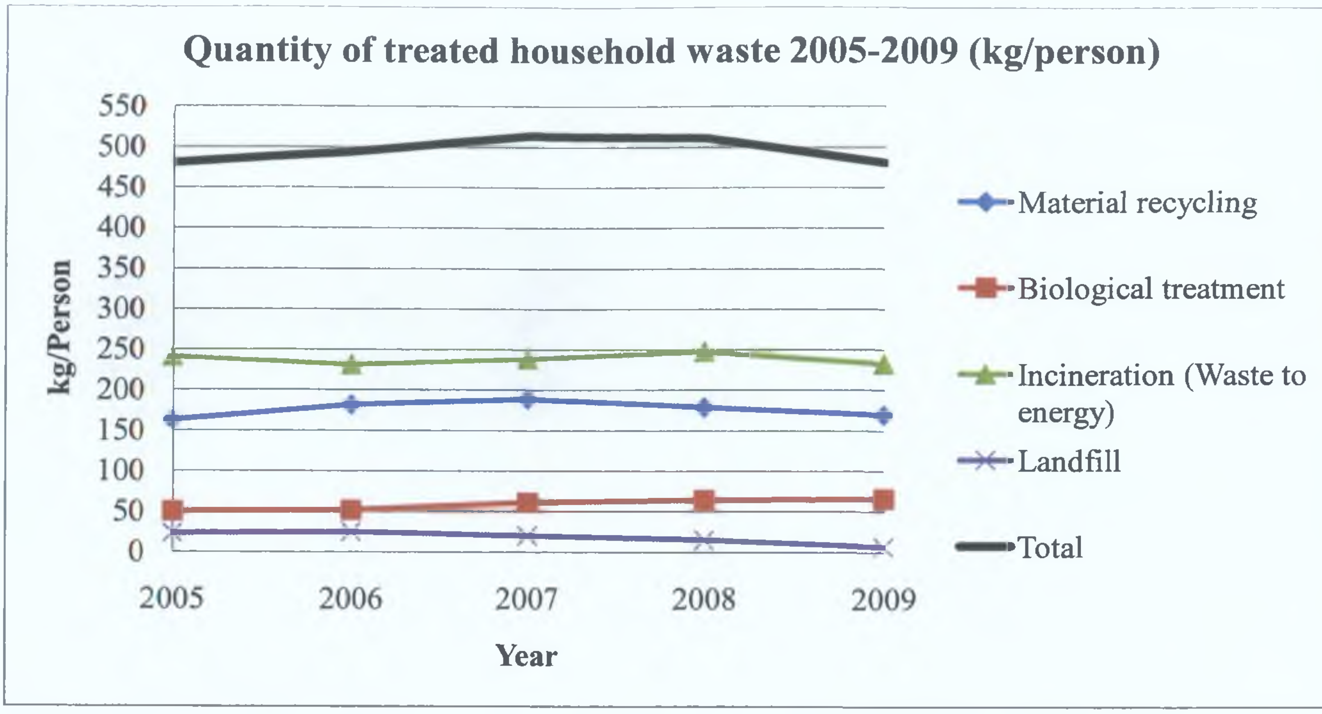
WTE treated nearly 50% of the household waste generated in Sweden, over this period.

After WTE, recycling also has a high uptake. The % household waste treated by recycling appears consistent at c35%. Biological treatment has been increasing in popularity since 2006; conversely land filling of waste has been decreasing since this date.

So in general, WTE and recycling has remained consistently high over these 4 years, while biological treatment has made impressive gains at the cost of land filling. Landfilling of waste is dwindling and is obviously no longer recognised as a viable method of disposal.

Overall waste volumes generated remain consistently high over the years examined, averaging at c500kg/person/year.

Figure 9. Quantities of treated household waste from 2005 – 2009 in Sweden.



Similar to the Irish situation the economy has affected waste volumes produced in 2009. Taking this into account however, it is predicted that the volumes of waste generated are to increase steadily in the coming years as the economy improves (*Swedish Waste Management 2010).*

4.2.3. Technologies Used and advances

Incineration with energy recovery

As discussed previously Sweden has a long history of incineration. Firstly it was a method of reducing the volume of waste and after the oil crisis it was looked upon as a technology which could reduce the dependence on the oil industry. In the 1980s incineration plants were shrouded in controversy as the public were concerned about the volumes of pollutants emitted from these facilities. At this time there were reports of dioxins found in fat tissues and mother's milk. The Swedish government acted quickly and effectively on this matter, imposing strict regulations on the emissions produced and even went so far as to close non performing facilities. Changes were also implemented to the operating conditions and processes were modified in order to reduce pollutants. Licences are required for all incineration plants from the mid 1980s.

Waste incineration is classified as a recovery operation in Sweden as opposed to waste disposal. It is through integration of the district heating scheme and also the electricity schemes that the energy produced is utilised and exploited. However in contrast to recovery facilities in similar countries, waste incinerators in Sweden are generally run by a private or municipal energy company and not a waste management company.

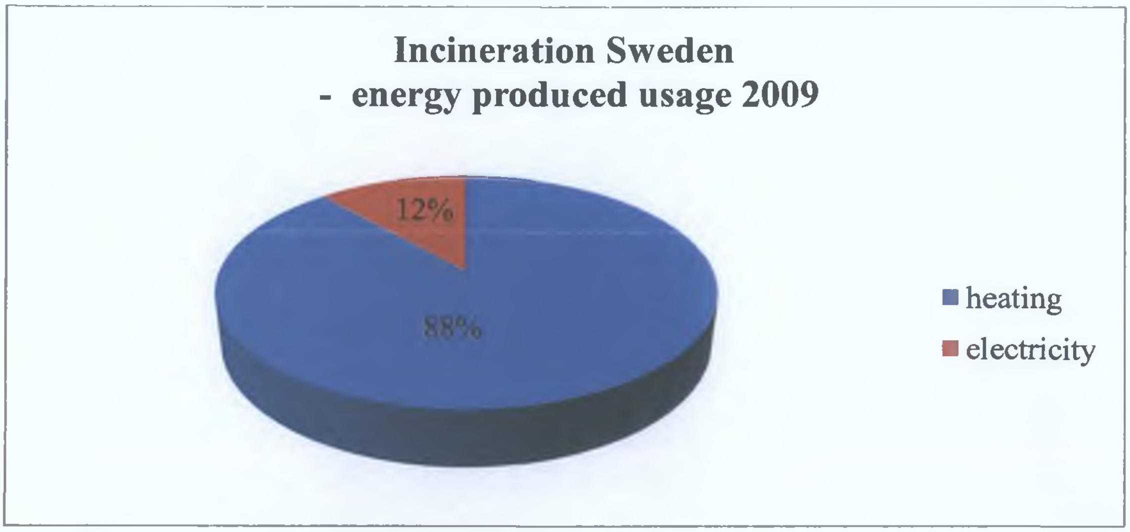
Large investments were made in the 1980s with the aim to overhaul and reduce toxic emissions from incineration facilities. At this time there was a moratorium on the construction of new plants. Significant Research and Development determined that reductions were possible and this led to the eventual overhaul in the standards and operation of these plants. Emission limit values were implemented and strict conditions were imposed to reflect this research and development.

Sweden has adapted and developed their Waste Management system through this process of Research and development. This industry has continued to strive because of this essential adaption and flexibility. Since the mid-1980s, incineration capacity has trebled and energy production has increased five-fold, while emissions have fallen by almost 99 per cent.

In the year 2009, 13.9 TWh of energy was produced through this method of waste disposal/energy recovery, of which 12.3 TWh was used for heating and 1.6 TWh for electricity. As seen in figure 10, below this equates to 88% of the energy produced contributing towards heating while 12% supplemented the electricity board.

This value corresponds to electricity for 275,000 normal sized homes, and heating for 820,000 homes. This is an increase on the 12.2 TWh of energy produced in 2008, despite the interest in biological waste treatment measures being introduced *(Swedish Waste Management 2010).*

Figure 10. Breakdown of the energy usage of energy produced by incineration (WTE)



In Sweden alone, waste incineration generates as much energy as 1.1 million cubic metres (m^3) of oil, which reduces carbon dioxide (CO_2) emissions by 2.2 million tons per year. This CO_2 emission equates to 680,000 petrol-powered cars emit in a year *(Avfall Sverige, 2006).*

Recycling

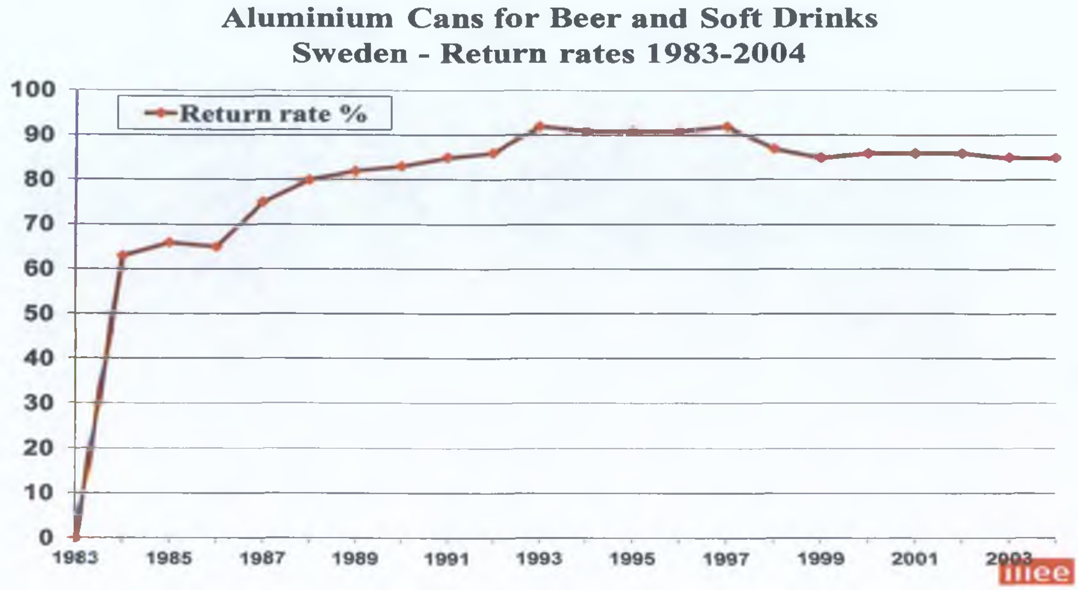
Traditionally energy recovery through waste incineration has been the primary method of waste disposal in Sweden. However Recycling has also emerged through this process. By-products of the process in the form of ash and dust are recycled and reused in the construction of roads and also used to close mines in Sweden.

Also the introduction of the deposit system to aluminium cans, in 1984, secured high collection rates. During the 1980's the economy was poor and uptake was generally high to reflect the economic circumstances. Energy was saved in the production costs of generating new aluminium cans and likewise energy was saved disposing of these.

This deposit system remains today and has since expanded to include all containers for consumption ready beverages including, PET bottles in 1994. Recent reports claim to have a 91% and 84% return rate on aluminium and PET bottles respectively. The return rates for the two glass bottle types are 99% and 90% respectively *(Swedish Glass Recycling, 2011).*

The international institute for Industry environment economics at Lund University provides the following information on return rates for aluminium cans between 1983 and 2004.

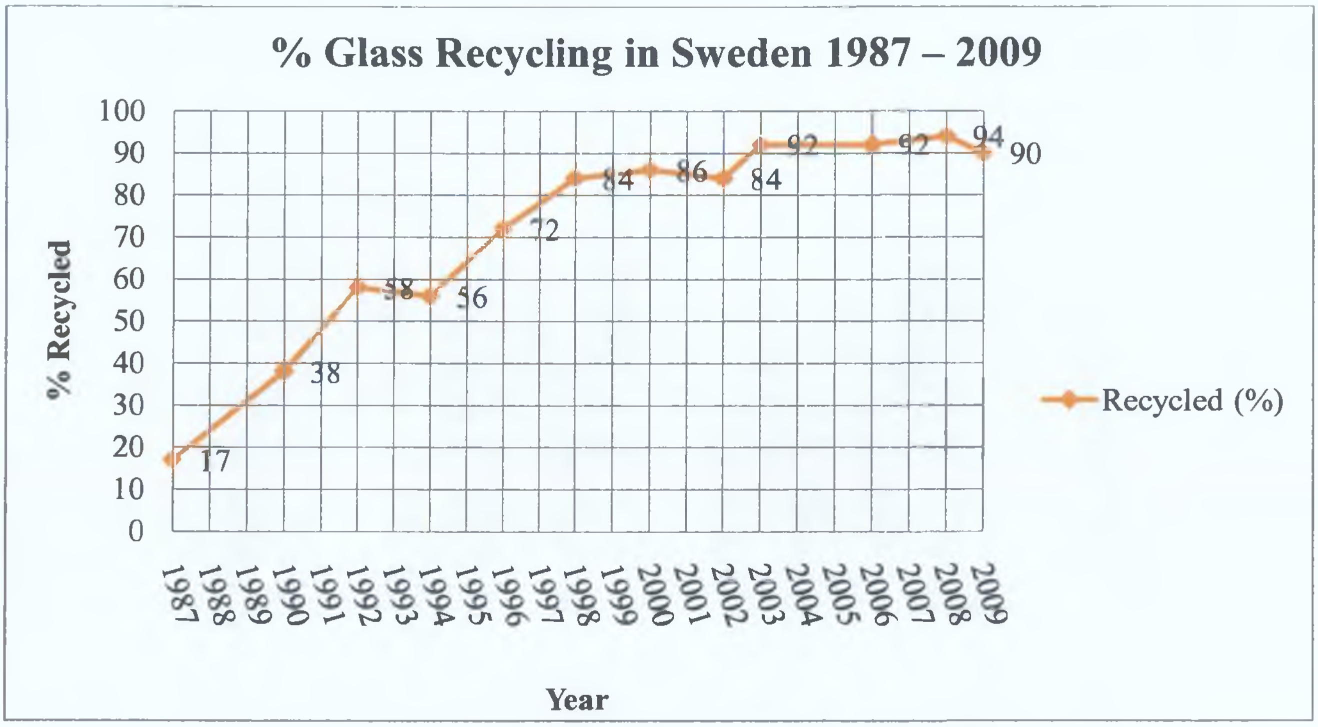
Figure 11. Return rates of drinks containers in Sweden from 1983 – 2004



Svensk Glas Återvinning AB is responsible for the deposit system of glass bottles. This company was founded in 1986 for the collection and recycling of used and graded glass containers. In 1994, the Swedish Parliament passed a law on producer liability for packaging. The law required a recycling target of 70% for glass containers. This target was reached in 1996. Today, the recovery rate is more than 90%.

From the outset, SGÅ's recycling of glass containers has developed considerably since 1987, as the figure 12 illustrates below *(Swedish Glass Recycling, 2011)*.

Figure 12. The % Glass Recycling in Sweden from 1987 – 2009



The legislation regarding container deposit systems was updated so that from January 1, 2006 containers from other plastics and metals, e.g. steel cans, can be included in the deposit systems.

Mechanical Biological Treatment

Sweden explored the possibility of incorporating the technology of MBT into their Waste Management system in the 70s and 80s. Large investments were made by the Swedish government as an incentive for this technology and using these funds large scale mechanical sorting facilities for mixed household waste were built. These facilities where intended to reduce the pressure on landfill and promote recycling simultaneously. However this technology failed, primarily as the by-products produced were of low than acceptable quality. These by-products proved to be worthless on the open market. The Compost which was generated was deemed to be of substandard quality, rather than contaminating agricultural land by using it as a fertilizer this was finally landfilled *(Lindhqvist, 2000).*

The mechanical aspect of MBT failed to materialise in Sweden but the biological treatment of waste has flourished, see figure 13. Many reports suggest that MBT was disregarded as not to impede on the development of the growing composting and waste to energy industry within the country. The development of Incineration within the country has greatly benefitted from this decision. There is less competition within the market and as the latest statistics illustrate Incineration dominates the waste sector in Sweden as a result *(Compost Network Website).*

Biological treatment

Biological treatment of organic waste is an age-old practise which has made a revival in recent times. The diversion of waste from landfill and a requirement to improve recycling rates has contributed to this revival in Sweden.

As anywhere, biological treatment can be carried out principally applying two methods, anaerobic digestion or aerobic digestion. These treatments can be manipulated to yield the desired product, whether it is heat, electricity, fertilizer or soil improving composts.

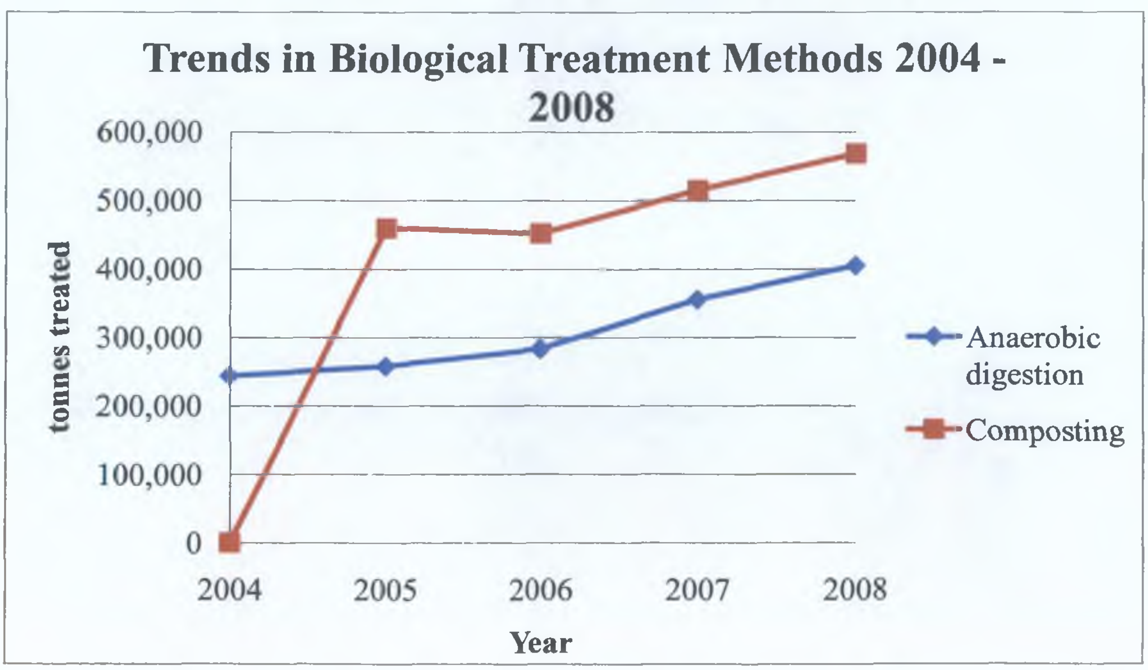
It has been noted globally that Sweden is at the forefront at converting bio waste into usable biogas. Biogas is methane produced from natural micro-organisms using renewable raw materials. This gas is then utilised to yield electricity, residential heating, or as car fuel. This gas is widely used as a fuel for cars in Sweden; more than 8,000 vehicles in Sweden currently are powered by a combination of natural gas and biogas. These include transit buses, refuse trucks, and cars. The gas used to power these vehicles has been produced at one of 25 biogas facilities in Sweden and bought at one of the 65 filling stations providing this fuel source.

According to the Swedish Gas Association, more than 50 percent of the methane used to power Sweden's natural gas vehicles now comes from biological sources, up from 45% last year. Natural gas vehicle sales in Sweden are increasing at the rate of 25% per annum *(Renewable Energy Institute).*

Svensk Biogas is an example of a biogas production facility with numorous plants. Apart from producing biogas for vehicle use, the plants also recycles the remaining by-products to produce a bio manure that can substitute artificial fertilisers.

According to the Swedish EPA website, Just over 10 per cent of household waste underwent biological treatment in 2004, i.e. about 430,000 tonnes of waste. Half of the waste treated in 2004 was waste from parks and gardens, and one third was food waste. Four years later around 13 percent of household waste, or 522,300 tonnes, went to biological treatment. Food waste accounted for 135,000 tonnes of this quantity, the remainder being park and garden waste. Biological treatment capacity is planned to increase in the immediate future *(Swedish EPA).*

Figure 13. Trends in Biological Treatment Methods 2004 - 2008



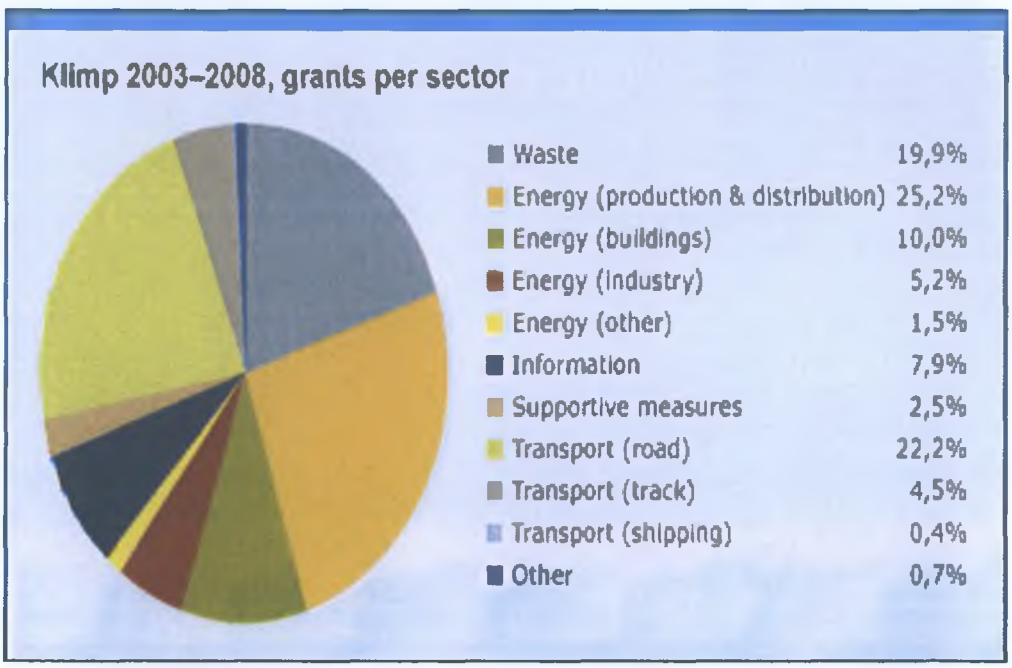
4.2.4. Initiatives

State Grants

The Swedish Government's support to Climate Investment Programmes, "Klimp", is a tool for reaching the Swedish climate objective as formulated in the Swedish climate strategy in 2002. Klimp has enabled municipalities and other local organisations to receive grants for long-term investments that reduce greenhouse gas emissions.

The government estimated that the landfill of waste was reduced by 370 000 tonnes as a result of investment subsidies to waste management tasks. Similarly the construction of biogas plants benefitted from grants worth up to 30% in cases. Figure 14 below illustrates that the waste sector received nearly 20% of the total grants through the period from 2003 to 2008 *(Swedish EPA, 2005).*

Figure 14. Grants per sector 2004 – 2008 under the Klimp programme *(Swedish EPA 2009).*



Deposit/Refund Scheme

Sweden has attempted to increase recycling rates by the use of a deposit/refund system. The aluminium can recycling rate in 1995 was 92%. This can be credited to the deposit system *(Container Recycling Institute).*

Returpack is responsible for the functioning of the deposit system for metal cans and recyclable PET-bottles for ready-to-drink beverages in Sweden. They currently use reverse vending machines for recycling in order to collect these spent bottles. This Swedish model developed by Returpack has served as an example for other European countries and the systems operates today in Norway, Finland, Denmark, Estonia, Holland and Iceland.

The circulation begins in the store when you buy your drink. You also pay then a small sum as deposit. You will later recover that sum when you return the empty containers to the Reverse Vending Machine and the machine identifies the barcode that can be found on every can or plastic bottle. These vending machines are widely accessible in order to be more convenient for the public *(Returpack Sweden).*

Figure 15. *Reverse Vending Machines (Cool Things 2011).*

Vacuum systems

Vacuum systems transports waste at high speed through underground tunnels to a collection station where it is compacted and sealed in containers. Ideally these would be installed at the construction stages of the build. Halmstad has one of the vacuum waste collection systems built into urban development projects by Envac, with 1,500 units at present.

The pneumatic system is monitored and controlled remotely from several hundred kilometres away. A discrete building provides this service. Here the waste is packed and sucked away through 40cm pipes into a 15 tonne container, usually emptied twice weekly. This is then transported to the incineration plant.

This system eliminates the need for a waste collection and offers the user ease and convenience, while also reducing fuel emissions and energy usage in the traditional waste collection.

Bring Centres

In Sweden there are 2,000,000 collection points for household waste, 13,000 drop off centres for batteries, 7,000 drop off centres for packaging waste and waste paper and 1,000 recycling centres for bulky and garden waste. The large number of these bring centres makes it easier for the public to recycle items.

Taxes

A Tax on land filling was introduced in 2000, which stipulated a specific tax to be added in addition to the landfill gate fees for each tonne of waste. This tax had almost the same effect as prohibiting land filling of combustible and organic waste in so far as there was an increase in the volumes going to be incinerated. The final ban on land filling of combustible waste followed in 2002 and finally organic waste was prohibited from landfills in 2005.

An incineration tax was introduced in 2006 to encourage recycling; this rate remained lower than the landfill rate in order to discourage landfilling. However this incineration tax has since been removed, October 2010.

Producer Responsibility Pays

The purpose of producer responsibilities is to reduce the amount of waste, increase recycling and achieve a more environmentally friendly product design. The producer responsibility was introduced for tyres and waste paper in 1994 and packaging in 1997.

Public Involvement / Information campaigns

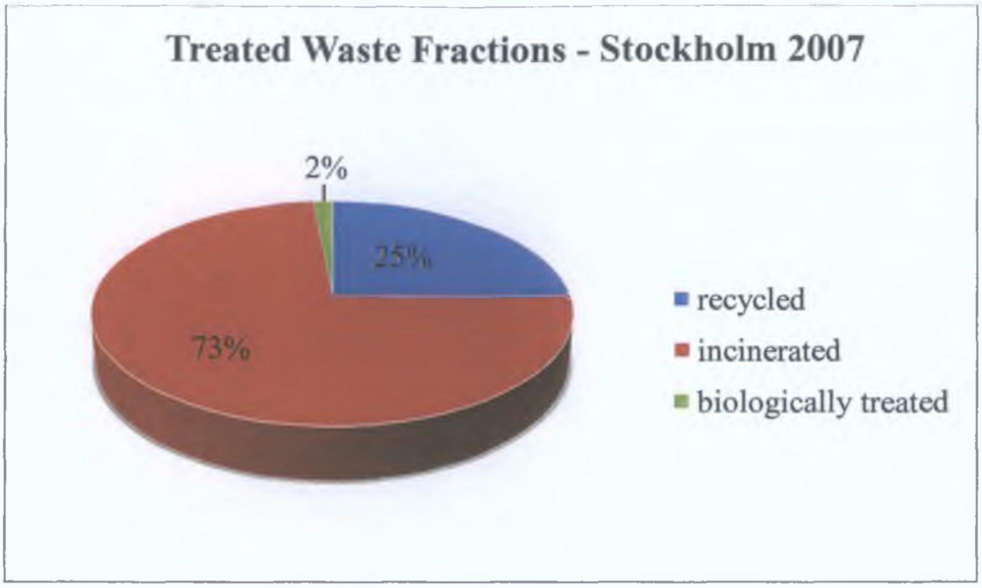
The experience of Swedish municipalities shows that although there is a connection between the costs of information campaigns and the quality of waste sorting by households, even the stronger dependency seems to fall on the length of such campaigns. For example, a municipal regional waste management company in Eslöv (Sweden) dedicated 5-15% of its budget to information campaigns for private households, but the signs of the first desired results in terms of sorting quality appeared only 5-10 years later *(Miliute & Plepys, 2009).*

International Recognition Green Capital

According to a "Sustainable Households, Attitudes, Resources and Policy" (SHARP) programme a questionnaire to 4,000 Swedes that it is primarily the feeling of being a good citizen and pride in their community that gives the individual the motivation and incentive to sort their own household garage. This motivation and desire to improve the community largely contributed to Stockholm being awarded the Green capital of Europe for 2010 *(Economics Unit Luleå University of Technology, 2007).*

In Stockholm, in 2007 the diagram below illustrates that no waste was committed to landfill. It is through such dedication to Waste Management and other sustainable designs that Stockholm was awarded the Green Capital in 2010 *(City of Stockholm Website).*

Figure 16. Stockholm Waste Fractions 2007



Research

Numerous projects are currently ongoing at the Swedish Environmental Research Institute regarding waste management. Towards Sustainable Waste Management, TOSUWAMA, is an inter-disciplinary research programme funded by the Swedish EPA and run by researchers in Sweden. It focuses both on how to manage waste in a more sustainable way and to prevent that waste arising in the first place. These projects target the less functioning areas of waste management and are working on devising plans on how to improve these areas.

Some project include examining the potential for reuse and recycling of plastics and organic waste, determining what policy measures may be necessary in order to establish well-functioning markets for recycled materials *(Towards Sustainable Waste Management).*

Laws

The law also makes it illegal in Sweden to sell consumption-ready beverages in containers that are not part of an authorised Swedish container deposit system, with the exception of beverages that mainly consist of dairy products or vegetable, fruit, or berry juice.

4.3. Germany

4.3.1. Background

Similar to Sweden, Germany has a rich history of waste incineration. The first incinerator was built in 1894/95 following a major cholera outbreak in Hamburg. It opened on January 1st 1896 disposing of the waste of the city's 300,000 inhabitants.

West Germany was a founding member of the European Union in 1957; however it wasn't until the early 1970s that the first Waste legislation was implemented in Germany. Also following the reunification of Germany in 1990, substantial work was undertaken to improve the Waste Management system of the entire country. Prior to this legislation, West Germany exported much of its waste to East Germany and other European countries.

Waste management in Germany has evolved since then and developed substantially since the early 1970s. The first independent Waste Management Act was adopted in Germany in 1972 and its primary aim was to shut down uncontrolled refuse dumps and replace them with central, regulated and supervised landfill sites. Following the introduction of this legislation there was a marked decrease in the amount of landfill available for use. Instead of creating new landfill sites and incineration plants, the new Waste Avoidance and Management Act of 1986 was introduced. This act stipulated that avoidance and recycling of waste were to be given precedence over waste disposal; this was the first introduction of the waste hierarchy. It was this rationale that influenced all subsequent legislation including:

- German Packaging Ordinance (1991).
- Technical Instructions on the Storage, Chemical, Physical and Biological Treatment, Incineration and Storage of Waste Requiring Particular Supervision (1991).
- Technical Instructions on Waste from Human Settlement (1993).
- Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal
- Closed Substance Cycle and Waste Management Act (1996).
- Waste Storage Ordinance (2001).

The two pivotal pieces of legislation are Closed Substance Cycle and Waste Management Act (1996) and also the Waste Storage Ordinance (2001).

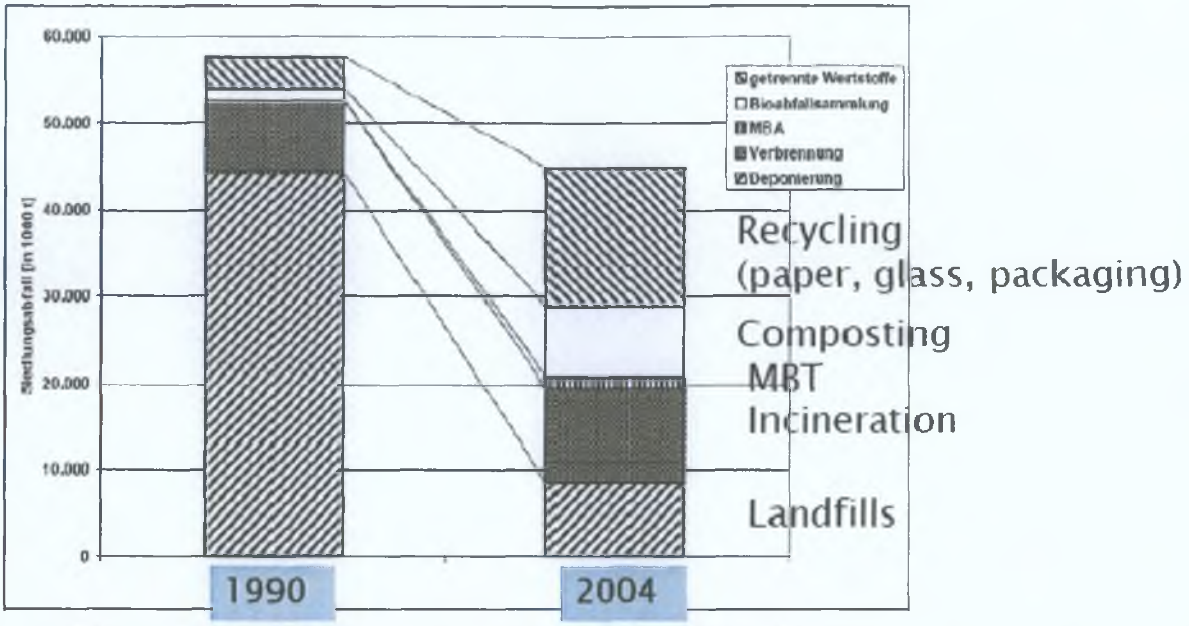
The provisions of The German Closed Substance Cycle and Waste Management Act (1996) introduced the ''polluter pays" principle. This reduces the onus on public authorities and making private sector generators of waste, not just municipalities, responsible for dealing with waste. The provisions for the polluter pays are further detailed in statutory ordinances. Also contained in this legislation is a reinforcement of the waste hierarchy, emphasising that avoidance takes precedence over recovery, which in turn is favoured over disposal.

The Waste Storage Ordinance (2001) agreed that land filling of untreated biodegradable matter and of municipal solid waste containing organics be ceased on 1 June 2005 in Germany. Simultaneously 200 landfills were closed as a result of non compliance to the new standards. This was hailed as the end of the era of burying and forgetting waste in Germany *(Zhang, Keat, Gersberg, 2010).*

As an effect of the banning of untreated household waste from landfills in 2005, incineration plants were built all over the country. The advantages of cheap fuel alternative to gas and oil, which were soaring in price at this time was viewed as a good investment.

As with Ireland and Sweden, Germany has integrated European Directives into its waste legislation. Similar to Sweden however Germany have established and imposed stricter targets than required by the EU. Germany intends to divert all MSW away from landfill by 2020. As a result, disposal will not be practiced and only recycling and recovery will be allowed *(BMU, 2009).*

Figure 17. Changes in Treatment methods for MSW 1990 – 2004 *(Maue,2007).*



[Municipal waste [in thousands of tonnes]; Separated recyclable materials; Collection of biological waste; Mechanical-biological treatment (MBA); Incineration; Landfilling]

Since the before mentioned pieces of legislation were introduced, dramatic changes in the treatment techniques are evident. As illustrated below the volumes going to landfill have dramatically decreased while all other techniques have increased. Most notably is the dramatic decrease in the volumes going to landfill, all other fractions have increased because of this reduction.

Figure 18. German MSW Management System *(Mühlea, Balsamb, Cheesemana, 2010).*

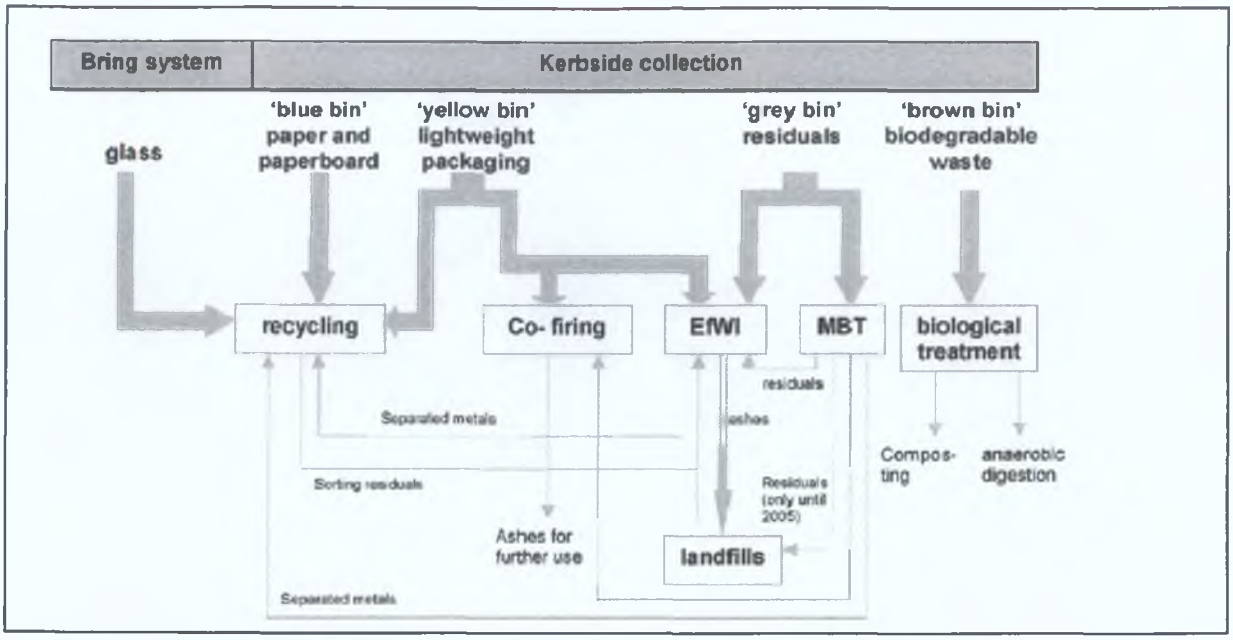


Table 9. Bin Collections in Germany *(Mühlea, Balsamb, Cheesemana, 2010).*

Blue Bin	Yellow Bin	Brown Bin	Grey Bin
Paper	Recyclable	Biowaste	Residuals

As seen in figure18, the majority of Germans have 4 bins in which waste is placed and these are collected periodically from the kerb side. As from the diagram it can be noted that the use of landfill is used as a secondary treatment and not a primary treatment.

4.3.2. Current Statistics

Statistics given in this section have been sourced from the German EPA (UBA) website, from the German Federal Ministry for the Environment Nature Conservation and Nuclear Safety website (BMU) and also the Statisches Bundesamt Deutschland website.

The BMU states that the German waste management sector has become an extensive and powerful economic sector in recent decades. This industry boasts employment of 200,000 people and a turnover of around 50 billion euro *(Data as of 2011, UBA website).*

The data in figure 19 represents Municipal solid waste generated in Germany over the period 2003 – 2008. MSW generated decreased from 2004 to 2006 but increased again in 2008, at just less than 5,000,000 tonnes. The gap widened between waste recovered and disposed of in 2005. Disposal was decreasing while recovery increasing.

Figure 19. Trends in MSW in Germany 2003-2008 *(Statisches Bundesamt Germany, 2011).*

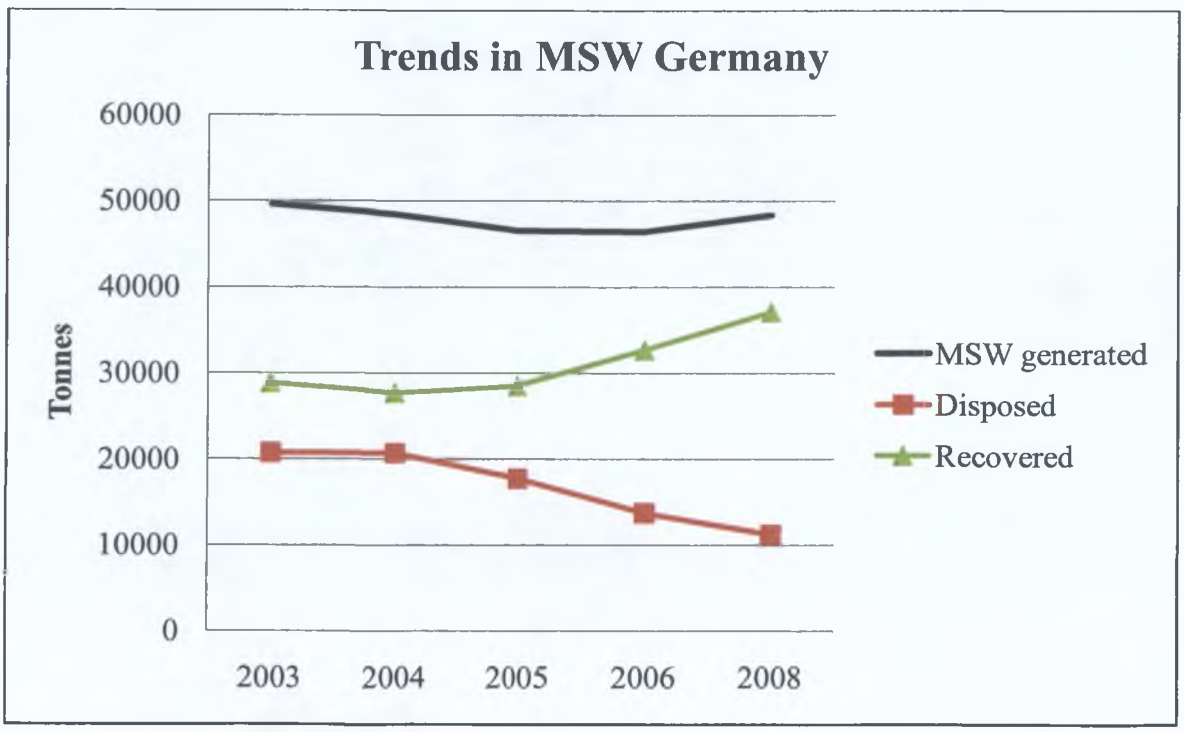
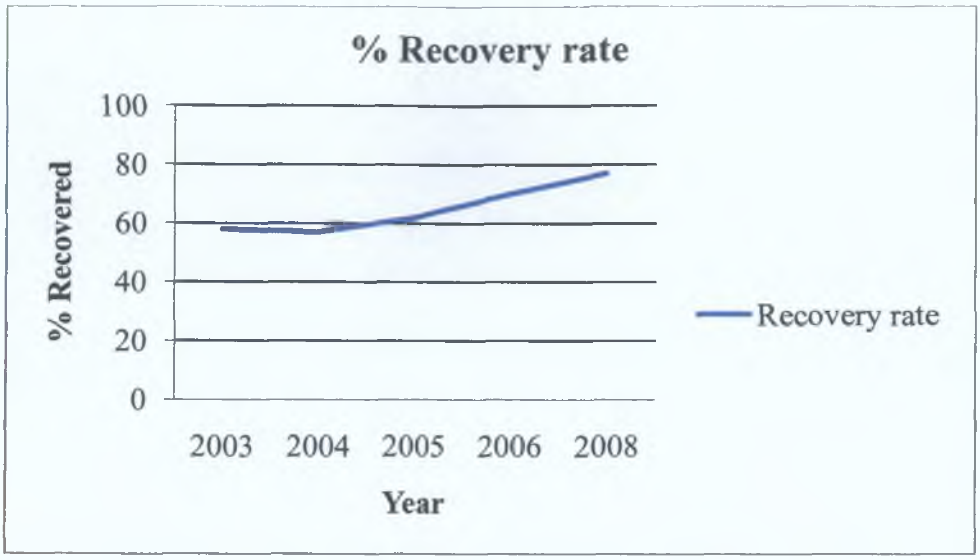


Figure 20 reiterates the previous point above, which is that since 2003 there has been significant improvement in the rate of recovery.

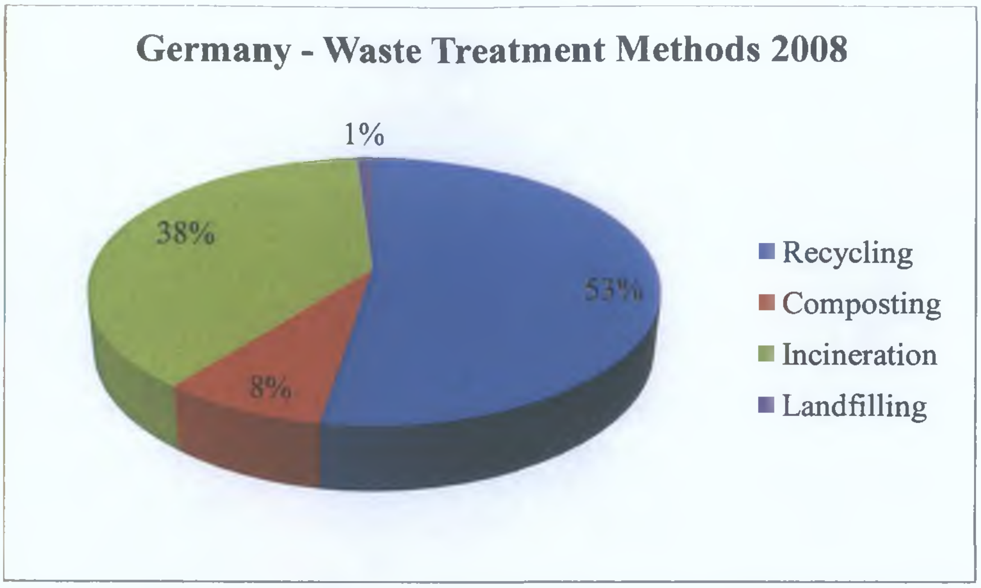
Figure 20. % Recovery Rate of MSW



In 2008 the recovery rate was nearly 80%; it is hoped in Germany that this figure will continue to rise further.

The treatment methods employed to recover MSW are outlined below, the data corresponding to the treatment method is the % volume treated by the corresponding method for the year 2008.

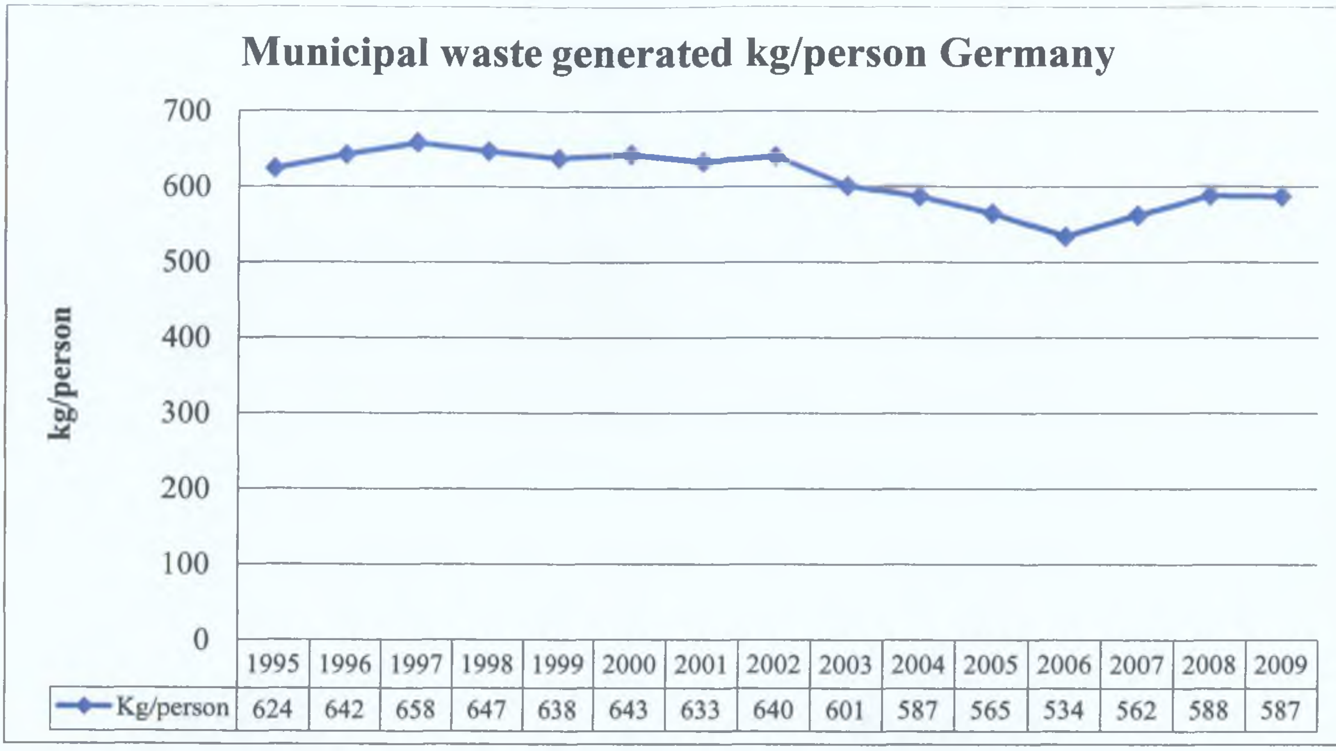
Figure 21. Treatment methods in Germany 2008 *(CEWEP Country Report, 2010).*



As evident from figure 21, recycling is the most popular recovery method at 53% followed by Incineration at 38%. Landfilling is at 1% which is close to the 0% required by the German Government in 2020, still 12 years remaining on this target. Composting represents 8% of the recovery of MSW.

As the rate of MSW landfilled decreased, so too did the volume of waste generated per person. This rate has been steadily decreasing since 1997 and hit an all time low in 2006. The 2006 rate has bounced back to stabilise at 587kg/person in 2009.

Figure 22. Waste Generated per person from 1995 - 2009 *(CEWEP Country Report, 2010).*



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Kg/person	624	642	658	647	638	643	633	640	601	587	565	534	562	588	587

4.3.3. Technologies Used and Advances

Incineration with energy recovery

Thermal waste treatment is one of the main pillars of waste management in Germany. The BMU in Berlin says there are so far 69 fully licensed thermal treatment facilities in Germany with an annual capacity of nearly 18 million tons. These facilities use the energy generated to produce electricity, heat and/or process steam *(ITAD, 2011)*.

The Germans have addressed the agrument whether there is room for thermal treatment and recycling in one society. Waste incineration does not oppose waste prevention, states a new background paper issued by the Federal Environment Agency (UBA). "The prevention principle continues to take priority over recycling and disposal of waste", said UBA President Prof. Dr. Andreas Troge.

The report outlines that waste is naturally incurred and it is necessary to thermally treat waste and eventually reap the product of this treatment. The above reports argues about comparing European countries with progressive waste management systems. Here it is not unusual to see both a high proportion of waste incineration as well as high rates of materials recycling. For example in Denmark and the Netherlands, where waste incineration does not impede high rates of recycling.

Figure 23. Volume MSW Thermally treated from 1999 – 2009, in Germany *(Eurostat 2010)*.

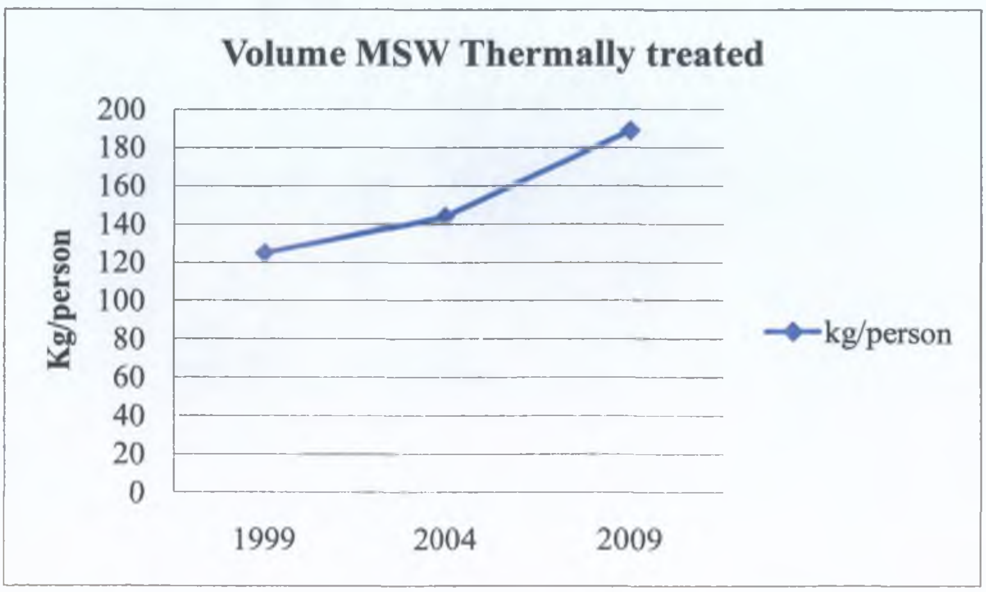
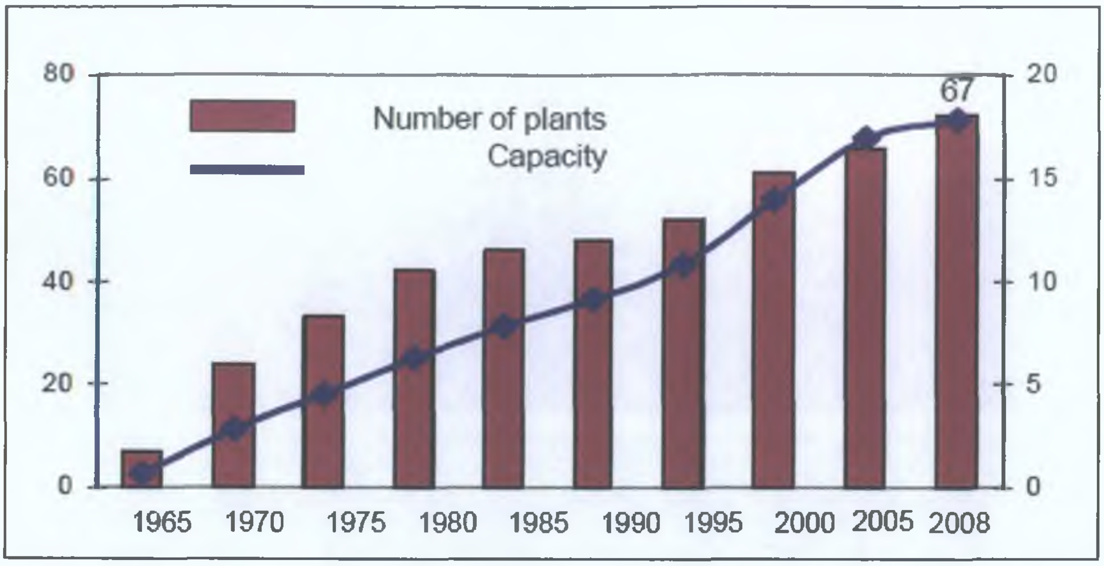


Figure 24. The number of Thermal treatment plants in Germany *(ITAD, 2011)*.



The above figures illustrate both that thermal treatment facilities have been steadily developed since the 60s and also that there is an increase in the volume of waste per person going for thermal treatment.

The legislation governing incineration facilities in Germany is the Waste Incinerator Ordinance passed in 1990. This sets down strict emission limit values for the emissions from municipal waste incinerators. These are most notably for carcinogenic and toxic substances such as dioxins and heavy metals. Also outlined in this piece of legislation to ensure complete destruction of pollutants are minimum temperatures and residence times for the combustion products in the combustion zone. It also dictates that all pollutant emissions must be continuously monitored. This legislation was updated in 2003 in order to acknowledge the EU waste Directive 200/76/EEC; this imposed even stricter emission limits.

The majority of incineration facilities sell the surplus energy generated to third parties in the form of both electricity and heat (district heat or district steam). The facilities in Germany have the capability to produce 18,870,000 tonnes of energy annually for heat and electricity usage. Or in other terms the substitution of fossil fuels with this form of energy has aided to Germany avoiding some 9.75 million terapascals of CO_2 emissions.

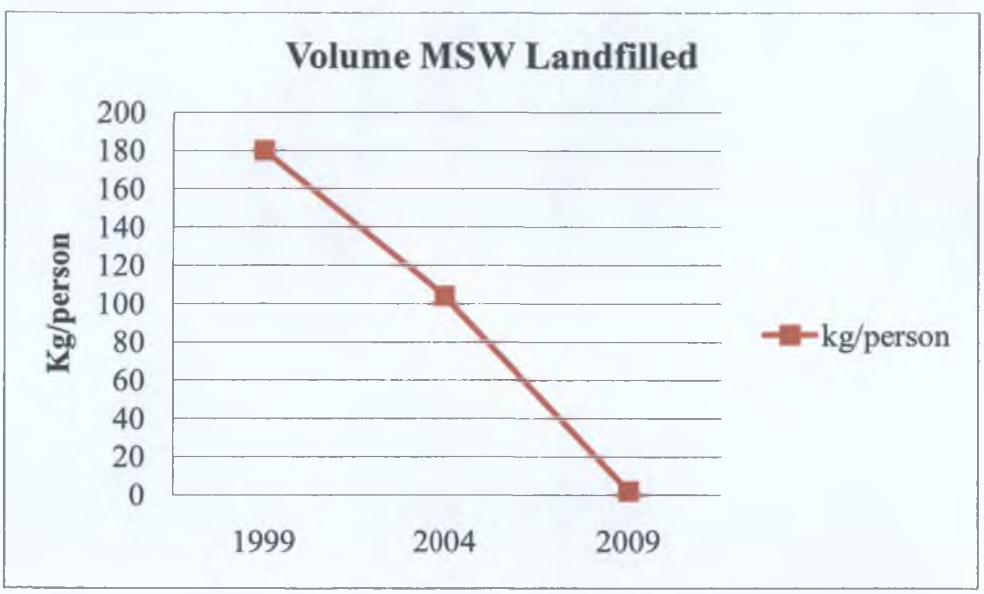
The overall level of average utilisation is in the order of 50% for all the plants. It is acknowledged however that there is further scope for improvement and an increase in the volumes of surplus energy generated with further investment *(German EPA, Oct 2008 and European Environment Agency Country Assessments, 2010)*.

Landfilling

Similar to other European countries Germany is moving away from land filling as it lies at the bottom of the waste hierarchy pyramid. A ban on land filling waste containing organic chemicals on municipal waste landfills without pre-treatment, which came into force on May 2005. This has resulted in a large number of landfill closures and changes in landfill capacities.

In the 1970s there were c50,000 landfills in Germany, however in 2000 the number of landfills had been reduced significantly to 333, as of 2010 there are believed to be 160 landfill sites still active. *(Zhang Dongqing., Keat Tan Soon., Gersberg Richard M., 2010)* Figure 25 also illustrates this point, as of 1999 180kg/person was going to landfill compared with 2kg/person in 2009. If this trend continues Germany will be on course to achieve the target of all MSW diverted from landfill by 2020.

Figure 25. Volume MSW Landfilled from 1999 – 2009 in Germany *(Eurostat 2010).*

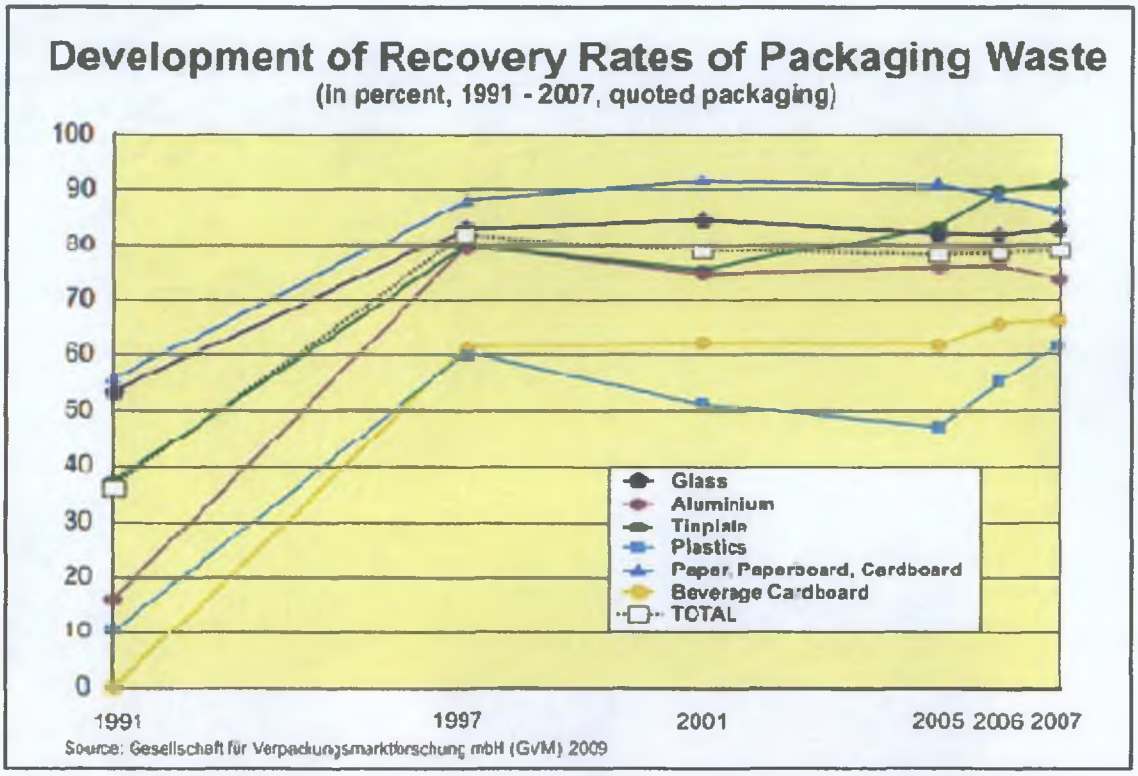


Recycling

The Packaging Ordinance was the first piece of legislation that dealt with the material cycle and was introduced in order to counteract the increasing volume of packaging being produced. This legislation places emphasis on the extended producer responsibility, this transfers responsibility for recycling packaging waste to the producers or distributors. It encourages producers/distributors to use packaging only where it is really indispensable.

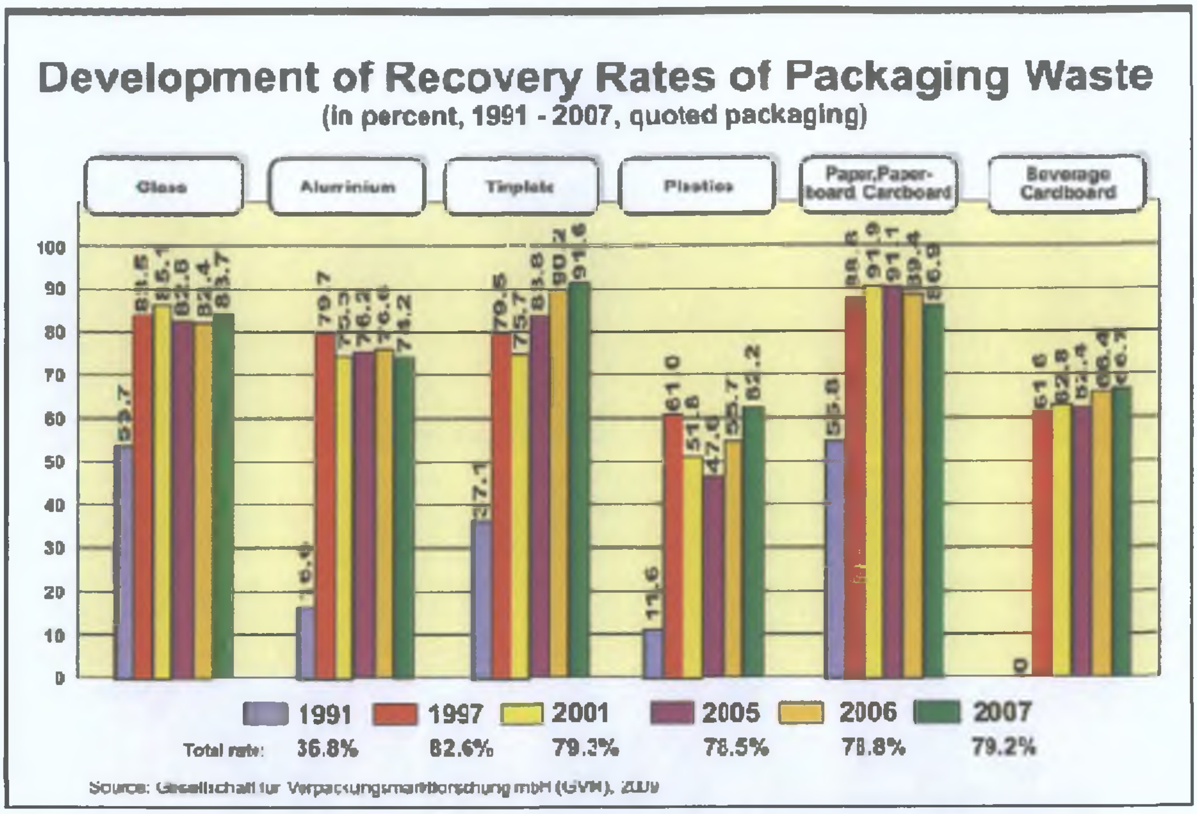
The Packaging Ordinance has proved to be an effective instrument, as evident from the figure below. Recovery of all packaging wastes increased dramatically since 1991.

Figure 26. Packaging trends (*Reporting by Germany on Waste Management, Funakoshi).*



The average total packaging rate recovered is c80%. Plastics are the lowest while tin and paper, paperboard and cardboard are the highest. Similarly the figure below also illustrates this trend. It is obvious from the figure below that the recovery rates are consistently high or trending upwards.

Figure 27. Recovery Rates 1991-2007 *(BMU,2009).*



According to the BMU 2009, the recycling rates for the separately collected MSW materials were: glass 100%, paper and paperboard 99%, biodegradable waste 100% and lightweight packaging 78.5% in 2009.

MBT

In Germany MBT is recognised in two different forms, mechanical-biological treatment (MBT) and mechanical-biological stabilisation (MBS). There is essentially very little difference, in stabilisation the entire waste is subject to biological treatment with subsequent splitting of the stabilised material into recyclables, refuse derived fuel (RDF) and residuals for land filling. While in MBT, separation occurs initially, the biological fractions are treated by anaerobic digestion or composting or elements of both. When anaerobic digestion is used, the process is usually configured to optimise bio-gas production. When composting is the core technology to biologically treat the derived waste material, no biogas is produced and the mix can be utilised on land depending on its quality. These methods are discussed below.

The following two pieces of legislation were instrumental in providing framework for the introduction of MBT/MBS technology into Germany.

- Ordinance on Landfill of Municipal Waste (Abfallablagerungsverordnung)
- 30th Federal Immission Control Ordinance

These came into force on 1 March 2001, providing the regulatory framework for licensing these facilities and also imposed strict requirements for the mechanical-biological treatment/stabilisation of residual waste in Germany. The Thirtieth Federal Immission Control Ordinance specified that these MBT facilities must be enclosed and operate below the emission limits at which regenerative thermal oxidation (RTO) technology is needed to clean the exhaust gases. Also older facilities must be retrofitted to comply or be decommissioned by 1 March 2006.

Unlike thermal waste treatment, mechanical-biological waste treatment is not an independent waste management method, but separates the residual waste into different fractions and processes them for disposal or recycling. MBT concepts therefore have to include additional methods for managing the waste fractions created *(German EPA, 2010).*

The total capacity of mechanical/biological waste treatment facilities is currently between 5 - 6 million tonnes per annum depending on size. In 2006, 66 MBT plants with a capacity of approximately 7.1 million tonnes per annum were available. Recent data puts the number of MBT facilities at 78, these ranging in capacity.

Biological Treatment

The Waste Deposit Ordinance was the piece of legislation in Germany that banned untreated biodegradable or municipal waste rich in organic substances going to landfill with effect from 1 June 2005. Approximately 8 million tonnes of biowaste is currently collected separately in Germany and 50% of the population of Germany can currently collect biowaste separately.

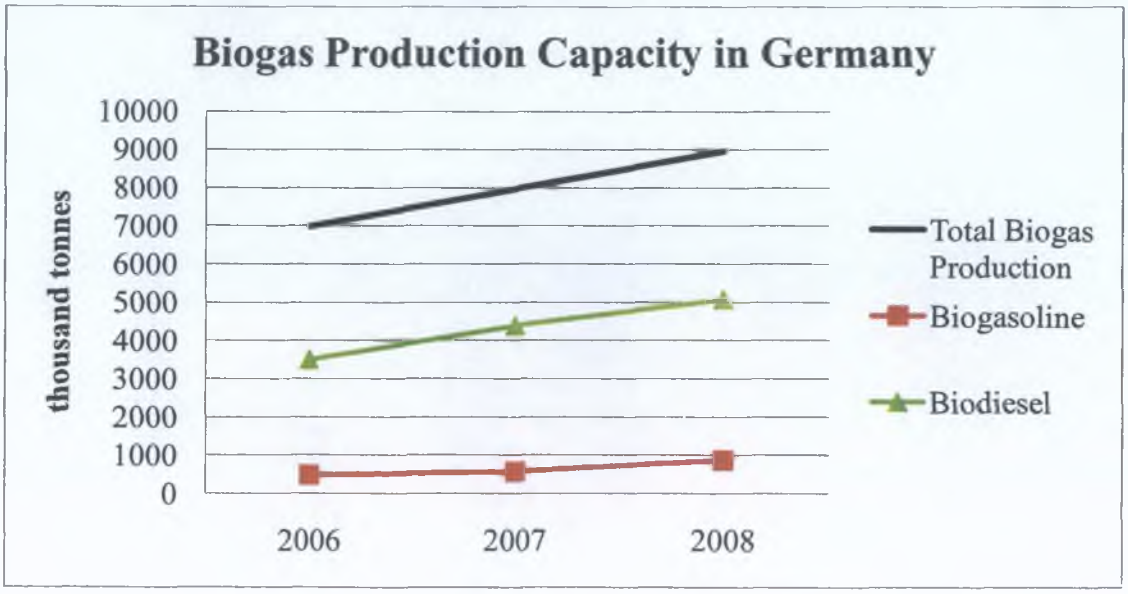
The two most popular outlets for this form of waste in Germany is production of Biogas through anaerobic digestion or composting.

Bio-energy Production

According to a Eurostat pocketbook, Germany is the largest generator of electricity from renewables in the EU-27 with 19% of the total EU-27 capacity. The renewable resources in question include municipal solid waste and biogas. Biogas itself presented a six fold increase from 1998 to 2008. Its share of the total grew from 3 % in 1998 to 10 % in 2008, 7% over a ten year period.

In absolute terms, the Member States with the highest electricity generation from biological sources were Germany (95 TWh), Sweden (82TWh) and France (76 TWh).

Figure 28. Biogas Capacity in Germany



The above figure illustrates the increasing trend in the capacity and subsequent generation of biofuels.

A recent report by the BMU, "National Biomass Action Plan for Germany Biomass and Sustainable Energy Supply" states that in 2007, bioenergy (relative to overall energy consumption) provided 3.9 percent of the electricity used in Germany, 6.1 percent of total heat and 7.3 percent of total fuel consumption. It can be deduced then that bio-energy provided 4.9% of overall primary energy consumption in 2007.

Composting

Since the mid eighties, composting has grown significantly over Europe. The first separate collection schemes in Germany were established in 1983. However even before this, composting had been adopted as a disposal route for municipal solid waste, through the attempt to sort the organic fraction mechanically.

According to the Federal Statistical Office, about 12.2 million tonnes of biogenic waste were composted or fermented in biogas plants in 2002 in Germany and then used on the land. This volume includes biowaste from households, garden and park waste and waste from the food processing industry, from restaurants and commercial kitchens and some residues from agriculture that have been sent to composting or fermentation facilities.

In 2002, the Federal Statistical Office recorded over 1,500 composting and fermentation facilities nationwide treating biogenic waste. This figure includes many agricultural biogas plants and special composting plants. These do not use biowaste or green waste as defined in the Closed Substance Cycle and Waste Management Act or the Biowaste Ordinance. But ferment, for example, slurry, dung and energy crops or compost sewage sludge. The Compost Quality Assurance Organisation (Bundesgütegemeinschaft Kompost - BGK) estimates that there are 813 composting plants and 85 fermentation plants using biowaste from households and commerce, along with garden and park waste.

4.3.4. Initiatives

Education

There are ample locations across Germany which specialise in the education and research of all topics involving waste management. These centres have benefited from an initiative by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety *(RETech, 2011)*.

Figure 29. Map of institution's which provide waste management education in Germany.

An example includes the Institute for Waste Management and Contaminated Sites in Dresden, Saxony. Here the primary focus of education is waste management planning, waste processing and treatment and also emissions and emission limiting technologies e.g. scrubbers and biofilters.

While the University of Applied Sciences Ostwestfalen-Lippe, Höxter in the North Rhine Westphalia district has developed a department which specialises in Waste Management and

Landfill Technology. The main focus here is the waste process and treatment, namely biological treatment and MBT.

All these institutes are researching and developing new, more modern technology for dealing with Germany's waste streams.

International Recognition Green City

This award represents a city which has a consistently high record in environmental standards and one which should be emanated. Hamburg was named the 2011 Green City of Europe. This was granted partly based on the city's waste management achievements.

One of the city's waste incinerator Stellinger Moor was adapted and introduced measures and resulted in 20 -30 tonnes of CO_2 avoidance per year.

This was recorded on the application form for the Green City of the year, in 2007 Hamburg commissioned a report on "Optimisation of waste management in Hamburg. This report took into account the specific aspect of climate protection". The report focuses on the quantity streams and recycling flows of the waste categories bio-waste, green waste, waste paper, plastics and metals On the basis of the report measures to further reduce the amount of municipal waste and optimise recycling flows will be implemented within the scope of a "recycling offensive" project.

Other measures include the city's utilization of bio-waste and its subsequent use to provide energy and heat to the city. In 2007 Hamburg had a recycling rate of 62% of MSW compared to 46% in 1997.

Nürenberg was also a runner up in this competition for 2012/13. This is a reflection on the high standards and commitment the German population strive to achieve in environmental matters, which includes the waste management sector.

Producer Responsibility

The piece of legislation which introduced the polluter pays principle was the "German Closed Substance Cycle and Waste Management Act (1996)". This principle states that the cost of the waste management shall be borne by the original producer. It is intended that the consistent implementation of this principle will promote a less wasteful and over packaged society. This legislation promotes environmental friendly design, manufacture and packaging. The overall objective with this legislation is to prevent unnecessary waste generation.

Deposit/Refund Scheme

The introduction of the Deposit-return system for drinks containers was due to the fact in 2002 only 50% packaging was being recycled.

In 2003 to combat this figure, Germany introduced a compulsory deposit on non-recyclable drinks packaging for mineral water, beer and carbonated soft drinks. The aim of this scheme was to stabilise the proportion of recyclable drinks packaging going to landfill and put an end to the throw-away mentality. This scheme excelled and was expanded to include all non-ecologically favourable non-recyclable drinks packaging and non-carbonated soft drinks and alcoholic mixed drinks. The compulsory charge is 25 cents for all containers and recycling rates have improved considerable.

Taxes

The Germans have operated a ban on land filling since 2005 and it is for that reason that they have not imposed a tax on landfill. Germany intends to reach 0% of MSW landfilled by 2020.

They also have no incineration tax and also these are exempt from VAT. This is because it is believed that waste to energy facilities are not affecting a high recycling rate being achieved.

Funding/grants

Germany supports a vast number of environmental project which capture waste management techniques. A small number of these projects are listed below.

- In 2005, industry, the government, and privatized public enterprises combined to invest c34.1 billion euro on environmental protection. More than half of this investment was directed into the public water and waste industries *(German EPA 2009).*
- The Federal Environment Ministry introduced the initiative "Recycling and Efficiency Technologies" *(RETech, 2011)* in 2006 in order to develop the transfer of German recycling and waste disposal technologies abroad. The initiative aims at providing long-term support for German enterprises regarding the export of recycling and efficiency technologies. This is an ongoing project but the aim of spreading German technologies in Waste Management globally.
- In February 2008, the German government opened the German Biomass Research Centre *(DBFZ)* which will be developed into a centre of excellence for bioenergy research. Research activities will range from conditioning, to biomass conversion to electricity, heat and fuel. The DBFZ receives its basic funding in the amount of €4 million from the Federal Ministry of Food, Agriculture and Consumer Protection *(BMELV).*
- Since 2008, funds accrued from the sale of emissions trading certificates have been used to finance a climate change mitigation initiative. €400 million was available in 2008. These funds are utilised for climate change projects, whose aim is to increase energy efficiency and optimise biomass use in energy, heat and fuel production. This involves projects and facilities for biogenic waste, system studies and international cooperation activities, biomass-to-gas technologies, bio-methane imports and sustainable bio-energy sources.

Awareness

The use of waste awareness campaigns are used in Germany as a vital component of Waste Management Plans. The following are campaigns used,

- ***"Overdose - An anti-returnable cans campaign"*** (aimed at young people).
- ***"Eco Top Ten"*** (funded by the BMBF, to inform consumers about environmentally friendly products)
- ***"Publication of educational materials on waste prevention, waste management and recycling"*** (Teaching materials, published by the BMU, for teachers at primary schools)
- ***"Low-waste Christmas"*** (Advice on environmentally friendly and long-lasting Christmas presents)

4.4. The Netherlands

4.4.1. Introduction and Current Statistics

The Netherlands have a long history of waste management stretching back to the installation of the first public municipal waste bins in 1475. Amsterdam established a Municipal Sanitation Department in 1877 and began researching the complexities of incineration with energy recovery in 1902. This relationship with waste management is evident from todays figures on the subject *(World Congress of the International Solid Waste Management Association Speech, 2011).*

The most important piece of legislation in the Netherlands concerning waste management is The Environmental Management Act (1993). This piece of legislation was introduced as an integrated approach to environmental issues. The main feature of this legislation was the establishment of a hierarchy of management options based on Lansink's Ladder. This made separate collection of organic household waste compulsory. Also included were taxes on the landfilling of waste and a ban on landfilling 35 categories of combustible or recyclable wastes *(Eunomia Research & Consulting 2010).*

Figure 30 illustrates the treatment methods used for municipal solid waste in the Netherlands in 2009. As is evident, between composting and recycling, 60% of municipal solid waste is recovered under the umbrella of recycling. The other primary technique for municipal waste treatment is incineration with energy recovery. The final remaining proportion is landfilled, 1% in total in 2009.

Figure 30. Municipal Waste treatment methods in the Netherlands 2009 *(Eurostat, 2011).*

The Dutch Environmental Agency *(RIVM)* and the Waste Management Council *(AOO)* credit the high recycling rates in the country to a combination of high landfill tax, landfill bans and limitations on incineration capacity. These institutions claim this combination of instruments was crucial in achieving these high recycling rates.

One policy advisor comments, "*The cost of landfilling went up, which raised financial incentives for recycling. At the same time, landfill bans were introduced on combustible waste, but there is insufficient incineration capacity for them all, which stimulates recycling*".

In the Netherlands Lansinks Ladder, imposed in the Environmental Management Act, outlines the preference for waste management in the Netherlands. The Lansinks Ladder system, like the Waste Hierarchy, categories the waste flows, with product recycling being the most desirable outcome and landfilling it the least *(Ministry of Housing, Spatial Planning and the Environment, 2006).*

4.4.2. Initiatives

Public ownership

The Dutch Government controls ten out of the eleven incineration plants in the country. This ultimately allows the government to place constraints on incineration capacity in order to prevent incineration from competing with recycling. This also prevents competition between Incineration facilities for waste in the country.

Taxes

The Netherlands implemented a landfill ban in 1996 as well as introducing a landfill tax. The aim of this was to deter landfill activities and make this option more expensive hence favouring the more desired alternatives, recycling, fermentation and incineration. This landfill tax has since steadily increased, the average charge for landfill is now c115euro per ton. However if the waste to be landfilled consists of combustibles, this figure will rise dramatically. It is preferred that combustibles are recycled or incinerated to yield energy.

There is also a product tax on non-refillable plastic beverage containers to deter their use.

Waste to energy plants do not have a tax associated with them as the Government doesn't deem incineration to be interfering with the recycling rate in the Netherlands *(Senternovem, 2006).*

Awareness Campaigns

- **Less waste - It's in your hand**
- **Plastic Hero's** In 2009 in the Netherlands, the collection of all plastic become mandatory. This led Nedvangb to launch the orange 'plastic heroes' campaign. This campaign is aimed at children and adults alike. An online computer game was developed in conjunction with Nickelodeon where the more plastic recycled equates to points. While the plastic hero's campaign also stretches to festival goers in conjunction with Heineken in order to recycles plastic beverage holders. This is an enormously successful campaign *(Nedvangb, 2011).*
- **Impulse Programme (2007-2009).**
- **National Waste Hotline**

- **Food Waste, Value of food in the Chain**
- **Mass Media Campaign on Food Waste 2010-2011** commissioned by The Ministry of Agriculture, Nature and Food Quality

(Waste Management Council, (AOO), 2000)

Producer responsibility

Producers have their own responsibility with regard to the management of the products they market when they reach the waste stage. This responsibility means that some or all of the waste management costs must be included in the price of the product.

Producer Responsibility extends to PVC products, white and brown goods, packaging waste and fluorescent lights to name a few *(Waste Management Authority- Senternovem, 2006).*

Deposit/Refund Scheme

Similar to Germany and Sweden, the Netherlands operate a Deposit/Refund Scheme on large plastic and glass bottles. PET bottles carry a 25-cent deposit, this yields a 95% return rate compared to non-deposited PET bottles. While glass bottles carry a 10-cent deposit and the subsequent return rate is 90%.

The Netherlands also has a voluntary deposit refund scheme on batteries with a high content of cadmium and mercury

Convenience

There are five curb side collections of MSW in The Netherlands each of varying frequency they are as follows;

- The GFT box or Green box.
- Red box - household chemicals, batteries.
- Paper collection.
- White bag - clothing.
- Blue box - plastics.

Grants

The NL Agency is a department of the Dutch Ministry of Economic Affairs, Agriculture and Innovation which implements government policy for sustainability, innovation, and international business and cooperation. This agency has a dedicated Waste Management Department which offers expertise, information and financial support for new innovative Research and Development projects.

Within this agency, Municipalities can also avail of grants for waste management improvements. The grant budget for the scheme in 2007 was € 1.5 million.

The applicant is obliged to utilise these funds to increase the level of waste separation and waste prevention of MSW by raising awareness. The overall aim was to minimize waste volumes *(Senter Novem website – Financial Aid, 2011).*

Research

There is a plethora of research undertaken in the Netherlands to improve the Waste Management system. Listed below are a few examples of the type of research underway, these projects were entitled to avail of the grants above.

- The Delft University of Technology is currently home developing a Magnetic Density Separator which can be used to recover the various components from mixed material streams with a high degree of purity. The streams can be anything from a mix of aluminium and copper to a mix of plastics or a stream of shreds of polyethylene terephthalate (PET) contaminated with pebbles and metal and glass particles (*The Open Waste Management Journal, 2010, 3, 117-126).*
- Research into limiting food waste is also plentiful in the Netherlands, the following are two projects listed by The Ministry of Agriculture, Nature and Food Quality *(Food waste in the Netherlands, Fact sheet, 2010).*
- Title Study 'Food waste, Value of Food in the Agrochain', study by LEI Wageningen UR. Gives a comprehensive picture of the many aspects of food waste in the Netherlands (including a research agenda to support the education agenda). Commissioning body: Green Knowledge Cooperative (Groene Kennis Coöperatie) and Ministry of Agriculture, Nature and Food Quality.

- Title Project 'Bread of Tomorrow / 'Fast return': Project to study whether it is possible to recover leavening agent from day-old bread to make new bread. Collaboration between: European Bakery Innovation Centre (EBIC) and Ministry of Agriculture, Nature and Food Quality

4.5. Denmark

4.5.1. Introduction and Current Statistics

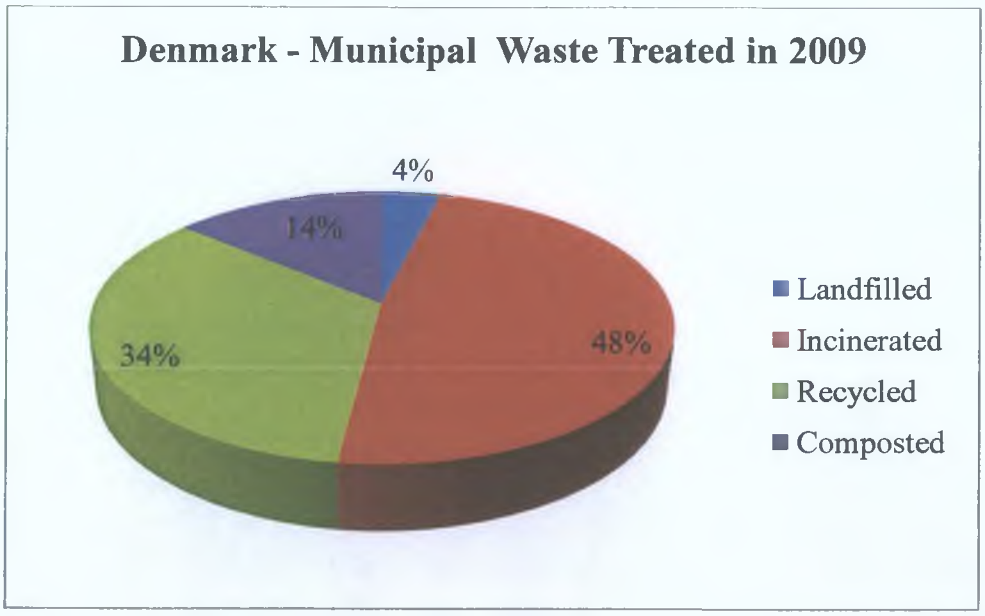
Similar to Sweden it was the oil crisis in the 1970s which prompted Denmark to take action in becoming self sufficient. It is the philosophy of the country that "waste is not just waste" but a valuable resource. However Denmark has a long history of waste incineration with the first waste incinerator being built in 1903.

Denmark was the first country in Europe to introduce a ban on landfilling of waste suitable for incineration. This encouraged both recycling and incineration to flourish. The 31 waste-to-energy facilities in Denmark are operated by non-profit companies, based on a cost coverage principle. The companies operate so that any profit gained from selling waste heat is used to off-set the costs of operating the plant. The remaining income is generated from gate fees charged by the plants. Gate fees are amongst the lowest in Europe, despite the existence of incineration taxes.

The extensive district heating systems that are in place in the country already purchase heat on the open market, however, there are price ceilings placed on the sale of heat from EfW plants so as to protect the heat consumers, and to ensure the heat is generally the lowest regional price so as to encourage its use *(Eunomia Research & Consulting, 2010 and RenoSam and Rambøll, 2006).*

As is evident from the figure 31, the incineration tax has not deterred the public from choosing incineration as a viable method of Municipal Solid waste disposal. It can be seen that equal volumes of municipal solid waste is recycled, in the form of composting and recyclables, as is incinerated. These two have equal share of the market, while landfilling is at 4%.

Figure 31. MSW Treatment methods 2009 *(Eurostat, 2011).*



4.5.2. Initiatives

Taxes

Denmark imposes a general state tax on waste. The tax to landfill waste is the highest. While it is less expensive to incinerate this waste but it is tax exempt to recycle waste in Denmark. The landfill tax is an effective deterrent from diverting waste to landfill, as is illustrated from the graph above, with only 4% of waste generated going to landfill *(Eurostat, 2010).*

The incineration tax is highly controversial in Denmark; however like above it is achieving its desired effect, in this case to encourage recycling. The recycling rate in Denmark is high at 48% in 2009 so this would seem adequate. However the gate fees for incineration facilities are the lowest in Europe.

Also, a green tax is enforced for a number of items, including packaging, plastic bags, disposable tableware and nickel-cadmium batteries.

Tax Incentives

The government provide tax breaks to companies who take the option to use CHP or district heating over electricity. These tax breaks could reach 50%. Annual costs per household are half that of oil heated homes *(International District Energy Association, 2009).*

Producer Responsibility

There is no Producer Responsibility scheme in Denmark. It is the only member state that has opted for the internalisation of packaging waste management costs rather than setting up an industry run funding system. However the most current Waste Strategy is identifying whether advantages can be achieved by introducing producer responsibility in relevant product areas. This matter is currently being evaluated as a possibility

Deposit/return scheme

The deposit-return system for beverage containers has been in force in Denmark since 1984 but has expanded since as outlined below,

- **1984-2002:** only refillable beverage containers covered.
- **In 2002:** extended to include non-refillable, reusable and disposable beverage containers (such as metal cans).
- **In 2005:** ready-to-drink beverages (alcopops & energy drinks)
- **Since 2008:** the system also covers mineral water bottles.

The Danish deposit and return system operates at more than 9,000 sales locations throughout the country which except returns. Also there are c2, 900 reverse vending machines throughout the country. In 2008, Danish consumers returned around 446 million empty items of packaging on which deposits were payable: c57 million glass bottles, c99 million plastic bottles, and c290 million cans *(Danish Return System, Statistics, 2011).*

Awareness Campaigns

- **Making Waste Work**
- **Waste Disposal Message in Denmark,** companies such as McDonalds have been involved with this visual campaign *(Advert to Log, 2011).*
- **LA21 Projects** supported by the Green Fund

Research

Various research and development is being undertaken in Denmark to improve waste management technologies and facilities.

- The Technical University of Denmark is leading the field in Denmark with research in areas such as biofuels, materials technology and recycling. This university actively collaborates with companies to provide technologic advancements. The university has currently over 200 patents on emerging advancements many of which are within the Residual Resources Engineering Department. These collaborations are active and the most recent networks are looking at the potential of biological waste.
  Also here one out of four staff members in this university, actively assist the government in providing research-based consulting reports on technical and scientific matters *(Technical University of Denmark, 2011)*.

- Clean waste research alliance is a combination of research resources in Denmark investigating the potential benefits of organic matter. The groups aim is to research and develop environmentally friendly and cost-effective technologies for the treatment of organic waste *(The Clean Waste Alliance)*.

- 3R (Residual Resources Research), Graduate school on integrated resources and waste management specialises in waste management research, this graduate school was established in 2005. The research undertaken is to PhD standard in various aspects of waste management. Residual Resources Research is a partnership between nine Danish universities, research institutions, private companies and utility companies while the Danish Research Agency provides one third of the funding. Course opportunities include, "Advanced environmental assessment of waste-to energy systems" and "Life Cycle Assessment modelling of solid waste systems" This school also offers various seminars both in Denmark and across the world online on various topics of Waste Management.

5. Findings and Discussion

Referring back to the overall aims and objectives of this dissertation contained in Section 1.3, it was foremost the intention of this paper to review Ireland's current stance on Waste Management and identify the preferred technologies. This information was established and outlined in the form of the literature survey, Section 2. The literature survey simplified that the current trend of diverting MSW to landfill was no longer tenable and that Ireland is exploring both MBT and Incineration as methods of treatment for MSW. However the literature survey highlighted the deep division in the Ireland regarding the preferred method of MSW treatment. While both MBT and incineration both have advantages and disadvantages, no one technology has the consensus of the industry in Ireland.

It was this conclusion that lead to the remaining objectives. As there is such deep division and varying opinions in Ireland over the direction of the Irish Waste Management system, naturally it would prove beneficial to look to the thriving European examples in this field. The countries examined in depth where Sweden and Germany while in a secondary capacity The Netherlands and Denmark where also examined.

The chosen countries, each of which are subject to the same EU directives and laws as Ireland, have established thriving waste management sectors, achieved in a variety of ways, by a variety of means. It was deemed appropriate to investigate these countries due to their successes in advancing the industry in both the technology and initiatives employed. The countries employed are a range of varying populations and land area and offer solutions to waste management issues in diverse conditions. These countries strive towards a 0% landfill rate, while Ireland struggles to decrease the volumes going to landfill. The potential to scrutinize these leading systems have provided valuable insight for the future of waste management in Ireland.

The main technologies established in these countries proved to be mainly incineration and recovery through both biological and dry recyclables, with Germany also employing MBT technology.

All of the countries explored have a deep history of mass incineration, firstly in Germany; this technology was initially developed to combat a cholera outbreak in 1894. While in Sweden, incineration was employed firstly as a method of reducing the volume of waste in 1901. The Netherlands and Denmark also developed incinerators in the early 1900s. The natural progression into energy recovery emerged later. Technologies advanced and also the oil crisis in 1973 emerged as a key event. Governments began to recognise the potential for energy generation.

While MBT is a relatively new technology, Germany is at the forefront of research and development of this form of treatment. The German system has diversified to incorporate this technology into the reunified state. Legislation to control and develop MBT was put in place in 2001 in Germany.

Both these technologies have resulted in the statistics that are outlined extensively through this paper and are summarised below, in table 10.

Table 10. Waste Treatment Techniques in Europe 2010 (Eurostat available at http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/8-08032011-AP/EN/8-08032011-AP-EN.PDF).

	Sweden	Germany	Netherlands	Denmark
Incinerated	49	34	39	48
Recovered	50	66	60	48
Land filled	1	0	1	4

As is evident from table 10, recovery is maintained in varying degrees over incineration with exception to Denmark where these are identical. Most notably, Germany recovers nearly double the volume which the country incinerates while similarly, the Netherlands also recover more than incinerate. It can be noted that Germany recovers the most due to the combined use of recycling and Mechanical Biological Treatment (MBT); this is the only country which employs both measures. This has proved very successful in this case. All the above figures are evident of the strong relationship and adherence to the values of the waste hierarchy. Recovery is preferred over energy recovery which is preferred over landfill.

Waste technologies are far advanced in these countries examined due to a rich history of waste management. These technologies have been adapted and developed to incorporate changing regulations, policy needs and also advancements in technology. It is because of this rich history of waste management that the ambitious target of a 0% landfill rate is attainable to these countries within the near future.

Table 11 outlines the main instruments that have attributed to the successful Waste Management Systems in the countries identified in this study.

Table 11. **Table of Findings**

Regions	Instruments	
	Measures in Place	**Regulatory**
Sweden	- Deposit/refund system - Improving Technology - Ease of Access to facilities - Numerous info campaigns - Green Capital Award - Research ongoing	- Extended producer responsibility - Strict national targets recycling - Financial support - Landfill taxes - Legal requirements - Tax exemptions - Financial Support
Germany	- Deposit/refund system - Research ongoing - Educational centres offering Waste Management courses - Green capital award - Numerous info campaigns	- Polluter pays principal - Strict national targets recycling - Legal requirements - Tax/VAT exemptions - Financial Support
The Netherlands	- Deposit/refund system - Research ongoing - Educational centres offering Waste Management courses - Ease of Access to facilities - Numerous info campaigns	- Environmental based taxes - Producer Responsibility - Landfill Taxes - Financial Support - Tax Exemptions
Denmark	- Deposit/refund system - Research ongoing - Numerous info campaigns	- Green taxes and charges including - Financial Support - Tax Exemptions

A number of measures have materialised due to this research and upon implementation in Ireland have the potential to improve the current waste management system. These are outlined below in the form of recommendations. However it is appropriate to stress that Ireland has implemented Producer Responsibility in relation to a large number of items in full accordance with European directives. Also Ireland has established a thriving recycling system so despite a deposit/refund scheme being in place in all of the above countries, this exercise would be futile in Ireland and lead to negligible increases in the recycling rate.

6. Recommendations for Ireland

Being a member of the EU, Ireland is obliged to fulfil all the provisions of the European legislation on waste, including strict adherence to the waste hierarchy. The hierarchy endorses prevention measures foremost while recovery and energy recovery follows, while disposal is the least favourable option available. Listed below are recommendations which, if implemented, could result in an Irish waste management sector on par with the countries explored above.

- Building on the established – Biological Treatment

As the current economic climate continues it would be foolish and naive of this paper to suggest that Ireland would be best to start afresh in terms of waste management. This would be unattainable and unrealistic. Instead this paper recommends that work be invested in the measures currently in place. The diversion of large quantities of food waste is a priority which requires more attention. Although legislation has been implemented to ensure the diversion of biodegradable from landfill, the basic foundations have not been implemented. There is hence no legislation in place ensuring that every home in Ireland to have and maintain a 3rd brown bin. This not only would accelerate the biodegradable municipal waste (BMW) landfill diversion targets but in turn decrease significant volumes to landfill. Currently in Ireland MBT technology is emerging and the implementation of a brown bin service would greatly support this industry in the stabilisation and utilisation of this fraction of waste. This fraction has the potential to produce biogas, which combined with natural gas could be utilised as a fuel as is done in Sweden to great success. Bio-manure is also a natural product of biological treatment which could be utilised on farm land as a substitute for artificial fertilisers.

- Building on the established – SRF

As mentioned above MBT is an emerging technology in Ireland and contributes towards the volumes recovered and diverted from landfill. SRF is a by product of the mechanical fraction of this process which when produced, currently either is shipped abroad for use as a fuel or alternatively utilised as a co-fuel in Irelands many cement factories. This fraction has the potential to substitute fossil fuels in cement kilns, power plants and incinerators entirely. These industries have the potential to exploit this alternative fuel source but instead the facilities, which do take this fuel, charge hefty figures to do so. This paper recommends that further incentives be applied to facilities which accept SRF as a fossil fuel substitute. This practice could potentially be made a requirement of the license of the facility and be an automatic requirement.

This option also has a benefit to the industry which utilises the waste also, as the carbon emissions of the plant would decrease as a result of substituting fossil fuels with SRF.

In Germany RDF is utilised as a co-fuel in incineration facilities as well as cement factories.

- Regulatory Controls

Although the majority of countries examined above did not have a cap on incineration volumes it would be advisable in Ireland to place strict controls on the incoming incineration facilities. The Netherlands do impose a cap on incineration and this is one of the factors responsible for the high recycling rate within the country, 60% between recycling and composting. These caps on incineration would ensure that the waste hierarchy is adhered to and recovery would be considered prior to this option being sought.

It is advised that the correct regulatory controls are in place prior to the implementation of incineration as not to result in a monopoly forming within the waste management sector. Instead the emphasis should remain on recycling and recovery through the already established means with incineration in an inferior role.

- Privatisation

It can be seen above in table 7, section 4.1, that in Ireland unlike in Germany and Sweden, the waste sector is a majority public affair. In Ireland 74% of this sector is publically owned and managed compared to 35% in Germany and 25% in Sweden. An ideal situation for Ireland to control the waste management sector would be to mimic the Dutch situation where the government controls ten of the eleven incineration plants. However this situation is not an option as the proposed incineration facilities in Ireland will be privately owned. Therefore it would be a recommendation to privatise this industry while remaining a minority stake holder. This would allow competition to flourish and also provide funding for emerging technologies and advances. It would be imperative however that the waste hierarchy be maintained through this system through regulatory controls.

- Taxes

Denmark is the best example of the countries examined of the tax system of waste, which Ireland should try to emanate. Denmark imposes a general state tax on waste. The tax to landfill waste is the highest. While it is less expensive to incinerate and finally it is tax exempt to recycle waste in Denmark. The incineration tax is highly controversial in Denmark; however like it is achieving its desired effect, in this case encouraging recycling. This system of taxation follows the waste hierarchy and is effective in the case of Denmark.

Since the change of Government in 2011, the new Minister concerned with the area of Waste Management, Phil Hogan has indicated that diverting waste from landfill is a priority. He intends to introduce measures to support this including raising the landfill levy, from €30 per tonne to €50 per tonne from 1 September 2011, €65 per tonne from July 2012 and €75 per tonne from July 2013. It is his belief that these increases will result in changes in the treatment of waste in Ireland *(DOEHLG 2011)*.

The minister has not yet indicated his position on a levy on incineration, but this is expected in the near future. Although the minister has pledged to modernise and improve the waste management system he has remained silent to date on the methods he intends to employ. If he chooses to implement the recommendations of the Forfas 2010, *Benchmarking Analysis and Policy Priorities*, there would be no cap put on incineration and no levy on waste to energy treatment facilities. These recommendations from Forfas are not in line with the measures proposed in this paper.

- Awareness

Further expansion of the *"race against waste campaign"* and the *"reduce, reuse and recycle campaign"* is required. It is advised that waste management be entered into the primary curriculum as to grow awareness to this issue at a young age.

This would be relatively easy in Ireland as the majority of primary schools are state run. Further funding for this initiative could come from the Environmental fund.

- Further Study

This study has provided valuable information on the leaders in the field of Waste Management within Europe and the initiative they employ. However Ireland is not the only "late-mover" in this field. It may be beneficial to explore the direction and options that other late movers have employed in this sector. Britain is a prime example which could provide Ireland with insight into improving the waste sector.

7. Conclusion

Waste management in Ireland today is in a transitional stage. There are two technologies vying for the main treatment of municipal solid waste. These are Mechanical Biological Treatment and Incineration. Traditionally Ireland disposed of MSW to landfill but this option is no longer tenable due to environmental impacts and also the introduction of the waste hierarchy from the EU. This waste hierarchy promotes prevention of waste followed by minimisation, reuse, recycling, energy recovery and finally disposal in this order. Tough new targets diverting MSW from landfills have also been put in place by the EU; therefore it is now necessary to decide on an alternative method of treatment for MSW.

The overall aim of this research was to ascertain what Ireland can learn from the European experiences in developing their Waste Sectors. This has been achieved through the addressing of specific objectives, listed below,

- Review Irelands current waste management strategy and identify the preferred technology in Ireland
- Identify European Countries that have successful Waste sectors Ireland could emanate
- Explore the technologies utilised in the chosen countries
- Identify any future objectives in these countries for Waste Management
- Propose recommendations for the Irish Waste Sector upon improving the sector

The review of Ireland's current waste management strategy was outlined in the literature review. As found in the Literature review there were large disagreements in the direction of the Irish waste Management system going forward with two options regarded in the framework, MBT and Incineration. These two technologies are acknowledged to offer a variety of advantages and disadvantages aimed at reducing the volumes going to landfill. However there are major disagreements on which is the preferred option, this has resulted in confusion. MBT is established currently in Ireland on a small scale while incineration is due to come online summer 2011. It is imperative that this confusion be addressed immediately by the new Minister for the Environment, Phil Hogan.

The European countries examined were Sweden and Germany while the Netherlands and Denmark were examined in a secondary capacity. These countries were initially identified as all possessing low landfill rates and high recovery rates, which Ireland strives towards. These countries with their unique stances on waste management can provide Ireland with insight into a functioning system which could be replicated or adapted to improve the current state.

The technology most widely exploited is incineration with energy recovery while biological treatment is common also in all these countries, also MBT is utilised in Germany. All the countries identified have long histories of waste incineration, so this technology is widely employed. This technology was developed initially for hygiene and volume reduction, however later this technology was exploited to recover energy. Biological treatment is emerging as a viable method of waste recovery also in these nations which supplements recycling. MBT technology is only utilised in Germany since 2001 and the full capabilities of this technology has not yet been realised. The Germans are at the forefront of developing this technology and hence has the largest uptake of it.

The main objective of these countries for the future is to achieve a 0% landfill rate by diverting all their MSW away from landfill entirely. Germany has succeeded in doing this in 2010, according to the Eurostat statistics throughout this paper.

The potential lessons learnt from these countries that have been realised in this paper and are outlined below

- Building on the established – Biological Treatment / SRF

It would be impractical for Ireland to ignore the established waste treatment methods already in place in Ireland. So it is recommended that these already established technologies be built on rather than starting afresh. A 3rd biological bin system should be established nationwide while incentives should be offered to industries for accepting RDF over the burning of fossil fuels.

- Regulatory Controls

Regulatory controls should be placed on the volumes going to the future Incineration facilities in Ireland. A control of this nature would encourage the treatment methods which are higher up the waste hierarchy to be favoured.

- Privatisation

Privatisation of the waste sector should be considered as this would increase competition and investments in education and research and development. The government should retain a % stake as Sweden and Germany have on the continent.

- Taxes

Taxes on waste treatment should ideally follow the waste hierarchy, landfilling should have the highest tax while incineration should be less expensive. Then it is recommended that recycling be tax exempt. This would ensure a high recycling rate for future years.

- Awareness

As the majority of primary schools are state run, it would be beneficial if waste management be introduced on the primary curriculum. This would ensure that the future generations are aware of the importance of recycling.

- Further Study

Ireland is not the only late-mover in Europe concerning waste management. It would prove beneficial for more study to be undertaken on other late-movers, such as Britain. The methods employed and future undertakings could be compared with a nation on par to Ireland.

The final conclusion of this paper, deduced from the European lessons, is that both MBT and incineration are viable treatment options for the future of waste management in Ireland. While MBT is already established and is preferred over Incineration, according to the waste hierarchy, it would be wise to continue investment and improvements in this technology. While Incineration will also be a useful tool in diverting MSW away from landfills in Ireland, it must not be given a monopoly in the market. Various regulatory measures need to be established to both prevent this and also encourage the uptake of more preferred methods of waste treatment. Further incentives are required to ensure the uptake and development of biological treatment and SRF usage in Ireland. This could be done by regulations, privatisation or through taxes. Further study on this topic would prove beneficial in order to compare Ireland's opinions to a similar late-mover in this field, for example Britain.

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9. Appendices

9.1. Raw Data

Figure 4 raw data. Current trends in the Irish Waste Management sector *(Information from the CSO accessed on 10-3-11, EPA National Waste report Series).*

			000 tonnes	*% of waste generated*	
Year	Waste Generated	Waste Recovered	Waste Landfilled	Waste Recovered	Waste landfilled
2003	3,001.0	726.8	1,832.6	24.2	61.1
2004	3034.6	919.0	1,818.5	30.3	59.9
2005	3050.1	964.4	1,824.1	31.6	59.8
2006	3,384.6	1,119.7	1,980.6	33.1	58.5
2007	3,397.7	1,159.8	2,014.8	34.1	59.3
2008	3,224.3	1,165.1	1,938.7	36.1	60.1

Figure 5 Raw Data. Waste Treatment Techniques in Europe, 2010 *(Eurostat available at http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/8-08032011-AP/EN/8-08032011-AP-EN.PDF).*

	MSW, generated. kg/ person	**Total MSW, treated. kg/ person**	**Landfilled (%)**	**Incinerated (%)**	**Recycled (%)**	**Composted (%)**
EU 27	***513***	***504***	***38***	***20***	***24***	***18***
Ireland	742	730	62	3	32	4
Germany	587	564	0	34	48	18
Sweden	485	480	1	49	36	14
Netherlands	611	520	1	39	32	28
Denmark	831	831	4	48	34	14

***Figure* 6.** Trends in the volume MSW generated per person, *(Eurostat, 2010 available at http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/sectors/municipal_waste).*

Year	Germany	Sweden	The Netherlands	Denmark	Ireland	EU27
1995	624	386	548	565	514	475
1996	642	385	562	618	524	486
1997	658	416	588	587	547	500
1998	647	431	591	592	557	496
1999	638	428	597	626	581	511
2000	643	428	613	664	603	523
2001	633	442	613	657	705	522
2002	640	468	620	664	698	527
2003	601	471	609	671	736	515
2004	587	464	624	695	745	514
2005	565	482	624	736	740	517
2006	534	497	622	740	804	523
2007	562	518	629	790	788	524
2008	588	515	624	830	733	520
2009	587	485	611	831	742	514

Figure 8 Raw Data. Trends in the waste management techniques used in Sweden from 2005 – 2009.

	2005	2006	2007	2008	2009
Hazardous waste	26,400 *(0.6%)*	38,960 *(0.9%)*	40,880 *(0.9%)*	43,320 *(0.9%)*	45,380 *(1.0%)*
Material recycling	1,474,280 *(33.9%)*	1,657,520 (36.8%)	1,737,720 *(36.8%)*	1,657,840 *(35.0%)*	1,586,600 *(35.4%)*
Biological treatment	454,450 *(10.5%)*	469,880 (10.4%)	561,300 *(11.9%)*	597,280 *(12.6%)*	617,680 *(13.8%)*
Waste to energy	2,181,890 *(50.2%)*	2,107,860 (46.8%)	2,190,980 *(46.4%)*	2,292,970 *(48.5%)*	2,173,000 *(48.4%)*
Landfill	210,110 (4.8%)	226,000 (5.0%)	186,490 *(4.0%)*	140,250 *(3.0%)*	63,000 *(1.4%)*
Total	**4,347,130**	**4,500,220**	**4,717,370**	**4,731,660**	**4,485,660**

Figure 9 Raw Data. Quantities of treated household waste, Sweden, 2005-2009 (kg/person)

	2005	**2006**	**2007**	**2008**	**2009**
Hazardous waste	2.9	4.3	4.5	4.7	4.9
Material recycling	162.9	181.9	189.2	179.1	169.9
Biological treatment	50.2	51.6	61.1	64.5	66.1
Incineration (WTE)	241.2	231.3	238.6	247.7	232.6
Landfill	23.2	24.8	20.3	15.2	6.7
Total	**480.5**	**493.8**	**513.7**	**511.2**	**480.2**

Figure 12 Raw Data. Sweden Glass Recycling 1987 – 2009, *(Svensk Glas Återvinning AB).*

Year	Collected (tonnes)	Recycled (%)
1987	22,000	17
1990	49,800	38
1992	75,700	58
1994	94,200	56
1996	119,600	72
1998	143,100	84
2000	143,800	86
2002	149,000	84
2003	151,200	92
2006	158,700	92
2008	174,100	94
2009	178,100	90

Figure 13 Raw Data. Volumes which undergoing Biological Waste treatment from 2004 – 2008, all values are in tonnes.

	2004	**2005**	**2006**	**2007**	**2008**
Anaerobic digestion	244,374	258,071	283,729	356,087	405,580
Composting	389,384	459,827	452,388	515,294	568,700
Total biological treatment	**633,758**	**717,710**	**736,117**	**871,380**	**974,280**

Figure 19 Raw Data. Recovery Rates of MSW 2003-2008 *(Statisches Bundesamt Germany).*

	2003	2004	2005	2006	2008
Recovery Rate	58	57	62	70	77

Figure 21 Raw Data. Treatment methods in Germany 2008.

Treatment type	Volume (%)
Recycling	53
Composting	8
Incineration	38
Landfilling	1

Figure 20 Raw Data. % Recovery Rate of MSW

	2003	2004	2005	2006	2008
MSW generated*	49622	48434	46555	46426	48367
Disposed*	20769	20723	17758	13729	11268
Recovered*	28854	27710	28520	32697	37099

*All data in tonnes and in 1000

Figure 28 Raw Data. Biogas Capacity in Germany (thousand tonnes per year)

	Total			Biogasoline			Biodiesel		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
EU 27	22503	24998	21000	1411	1823	3322	6992	10131	14629
Germany	6984	7966	8955	484	576	875	3500	4390	5080
% Share	31.0%	31.9%	42.6%	34.3%	31.6%	26.3%	50.1%	43.3%	34.7%